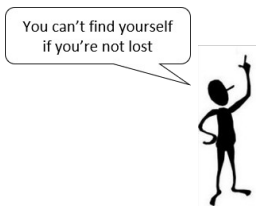
PLS Lost Corner Methods

2026 Western Regional Survey Conference
Wed 18 Mar 2026

Jerry Mahun, PLS jerry.mahun@gmail.com
715-896-3178
jerry.mahun.com

Table of Contents



I. Overview

A. Introduction

Most, if not all, PLS States have statutes or code that instruct the surveyor subdividing a Section or re-establishing a government corner to follow the instructions of the BLM. These are encapsulated in the *Manual of Surveying Instructions (Manual)* which is currently the 2009 edition. Except for some corner condition definition refinement, re-establishment and Section subdivision has not changed substantially between the 1973 and 2009 editions.

The *Manual,* while the definitive publication on Public Land Survey System (PLS) and corner re-establishment, cannot address all possible lost corner situations. While the original instructions laid out a systematic survey plan and described how to deal with some potential problem areas, corner locations depended on what individual surveyors actually did. Some followed the instructions as closely as possible while others used more creative approaches. There were many issues having impact an impact on how corners were set: terrain, weather, material shortages, disease, and so on. Life on the frontier, particularly for those first setting foot into it, was not easy. Regardless how or where corners were set, that is where they legally belong and are the positions we strive to re-establish today.

B. Will-Be-Was

1. The PLS Corner Rule-of-Three

In surveying, we have quite a few *rules-of-three*s *(R3)*[1] principles. An R3 principle is one that has three conditions or recognized possibilities. For example, we know for a monument to control it has to be (1) called for, (2) identifiable, and (3) undisturbed. Likewise a valid oral boundary agreement requires that: (1) the true line be unknown, (2) parties agreement to fix a boundary, and (3) they act with respect to agreement. The more you think about it, the more R3s you will find.

Whether re-establishing a lost or obliterated corner, we should first understand the instructions under which it was placed. A PLS corner location also conforms to the R3. There are three possible locations for a PLS corner: where the surveyor

(1) was *supposed* to place it (Instructions, *Manuals*)
(2) *said* he placed it (notes, plat)
(3) actually *did* place it (original physical evidence)

The order of re-establishment importance is the R3 reversed. If the original corner monument (or accepted replacement) or its accessories cannot be found (#3), then we use the notes and plat (#2) together with secondary and parol evidence treating it as an obliterated corner. Should that evidence be lacking then we resort

[1]You won't find this in any textbooks, it's just a pattern I've noticed.

to lost corner methods described by the *Manual* trying to give effect to original measurements which in many cases are nominal (ie, 40 ch, 80 ch) (#1).

2. Applicable Instructions

Instructions identified proscribed procedures, monumentation and marking, note forms, accuracies, etc. These were in the normally issued Instructions as well as *Special Instructions,* getting more sophisticated as the PLS matured.

The 1851 *Manual of Surveying Instructions to the Surveyor General of Oregon* was the technically the first PLS manual. However, the *Manual of Surveying Instructions, 1855*, is widely considered the official first *Manual* since it was not written for a specific territory. Individual *Manuals of Instruction* from 1851 through 2009 editions are online in pdf form at:

- BLM Knowledge Resource Center: https://www.ntc.blm.gov/krc/legacy/course/538
- Arizona BLM Library: https://www.az.blm.gov/surveys/index.php?dir=Library/&sort=size&order=asc
- CLSA Education Foundation Library: https://keithwspencer.net/Library/BLMbooks.shtml

Earlier instructions are at the National Archives. An excellent source of the major aspects of all PLS instructions in a single volume is C.A. White's c1985 book *A History of the Rectangular Survey System*. Its nearly 800 pages contain excerpts from Instructions along with sample notes, diagrams, and summaries up through the *1973 Manual*. It also covers the colonial land tenure systems that lead to the development of the PLS, gives a detailed explanation of the actual Seven Ranges surveys, and describes the nature of the individuals who drove the PLS evolution. Out of print and expensive if you can find it, a downloadable digital version is available at the BLM Knowledge Resource Center.

3. Original Notes and Plats

Notes are important because they include information on original accessories as well as other evidence for a corner location.

Similarly, plats depict the information in graphic form. Because plats are derived from notes, information on a plat would yield if in conflict with the notes. Plats can also depict information in the Section interiors such as meandered waterways, existing claims, tree cover, wetlands, etc.

There are three copies of notes and plats[1]:

Original: turned over to the States
Duplicates: retained by the GLO/BLM
Triplicates: in the National Archive

Duplicates and Triplicates are handmade copies of the Originals. As such, there can be scribing differences

[1]Another R3? Hmmm...

between them. Originals are considered the highest form and held if conflicting with either of the others. However, because the others are copies made (usually) under more favorable conditions, they are often easier to read (some plats even using colors). It's a good idea to have both since the cleaner GLO copy may help interpret the original.

In some states, the original records are held by a specific agency. In others, such as Oregon and Washington, they are held at a regional BLM office. Due to their age and delicate nature, original records are usually housed in climate controlled environs with strict handling limitations. Some states have scanned their original notes and plats and made them available online.

Records were not always protected like they are today. In the 1880s, a large portion of Washington's original PLS records were destroyed by a fire caused by a smoldering cigar. Copies were made of the GLO secondary notes of the destroyed records and transmitted to the state. This means some records in Washington are copy of a copy. Many "original" notes in Iowa are typewritten, often indecipherable and filled with spelling errors. Iowa also experienced a records room fire in the early 1930s, but unlike Washington's case, it was suppressed ... with water. The Depression Era Works Progress Administration hired people to recover and reproduce what they could of the notes. Needless to say, having non-surveyors with rudimentary typing skills interpret and document water-soaked field notes did not faithfully reproduce original records.

BLM/GLO copies generally can be accessed at the *GLO Records* website: https://glorecords.blm.gov/default.aspx. Records at the GLO site also include omitted lands and completion surveys as well as dependent and independent resurveys (prior to private ownership), and patents. .

Figure 1 is a copy of original notes for running the line north between Sections 28 & 27, then random-and-true between Sections 27 and 22 in T25N R40E Wilamette Meridian. The type of monument set is indicated as are the witness marks (a treeless area at the time?). Accessories set by the surveyor at corner establishment are considered part of the original monument.

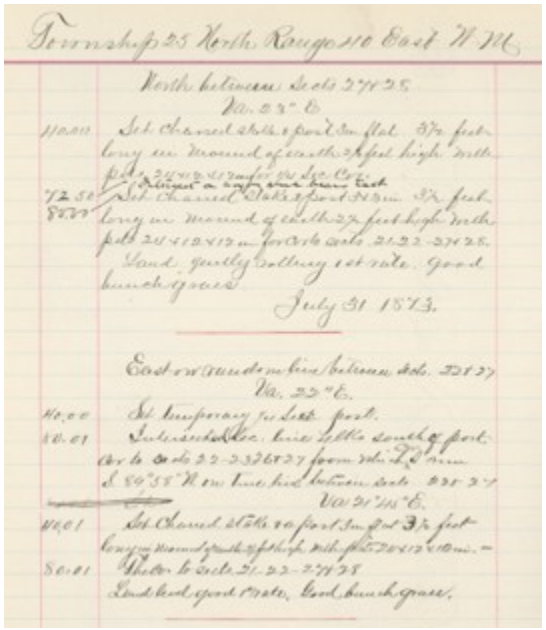

Township 25 North, Range 40 East W.M.
North between Secs 27 & 28
Va. 22° E.
July 31 1873.
East on random line between Secs. 22 & 27
Va. 22° E.

Figure 1: Section Line Field Notes

4. A Package Deal

Why bother getting notes for something that was done over 150 years ago? Everything has changed and we have more accurate equipment so what's the relevancy?

The contemporary resurvey tries to recreate that 150+ year old survey. The notes give insight into what was done to create the cadastral framework on which all subsequent surveys are based. Although Instructions were issued, a number of requirements, such as monument marking, closing corner placement, etc, changed over sometimes short periods of time. Extraordinary circumstances may have required separate *Special*

Instructions which deviated from the norm. Terrain conditions, particularly in water infused areas, may have required the surveyor devise ways that still met the spirit of the PLS by using a variation of standard procedures.

The notes and plat are written records of what the surveyor did and how. Some lost corner re-establishment methods are predicated on the original surveyor following the Instructions as issued. Procedural deviation may necessitate a different methodology which better reflects original intent. After all, our charge is not to place a corner where it should have been but to recreate its position as defined by the original surveyor.

Even with copies of the notes, plats, and Instructions, it may not be readily apparent how the surveyor actually performed the fieldwork. How did he know when his northbound line intersected a Correction Line? How did he run a true line of latitude? At best, resorting to lost corner methods is only a compromise with no guarantee the re-established and original positions coincide.

5. Monument Records

We may not be the first surveyor determining a particular PLS corner location. Previous surveyors may have re-established the corner and filed or recorded a Monument Record at a public office. In some states a surveyor is required to file a record at the County Surveyor's Office. A record is required when a corner is re-established for the first time, a different position for an existing corner is accepted, or additional information is added (witness marks, replacement monument, etc). Generally, all records are retained and not replaced as new ones are created. This serves as the written history of a corner's position over time and must also be considered when re-establishing or using a corner.

6. Other Resources

These are some useful publications:

- *Guide to the Identification of Bearing Tree Remains*, Drain and Stefan, U.S. Forest Service. Detailed analysis of tree remains including color illustrations. Based on 25 years of retracements in the Ottawa National Forest.
- *Durability of Bearing Trees* is a training manual written by the BLM Cadastral Survey Training Staff. Narrative description of distribution, appearance, and durability of typical tree used as accessories.
- *BLM Glossary*: The PLS is a unique system and has specific terminology as well as some unique ones. While a bit dated, it does cover quite a few terms
- *Legal Reference Library*: *Word* .doc of a collection of case law excerpts on various aspects of the PLS.
- *BLM Casebook, 1975*: Originally published in large (24"x36") format, it has been converted to .pdf. The Casebook contains a collection of actual interesting and unique resurvey situations used for Cadastral Training. (The *2001 Revision Version* only has the first part of the *Casebook*.)

The publications can be found in the online libraries previously identified.

C. Corner Types

1. Regular

Section and quarter Section corners are usually referred to as *regular* corners. Since the earliest PLS Instructions, the intent was to create one mile square parcels and either monument, or provide for subsequent monumentation of, their corners and, later, intermediate corners. On the ground, where the world wasn't flat and clear of obstacles, other corners were needed to delineate and perpetuate the system. Some have a direct effect on lost corner re-establishment whiles others do not. It depends on the reasons the corners were placed and their relationship to regular corners and lines.

2. Special Corners

a. Closing

(1) What and Where

Closing Corners were so named because a PLS line was to close on a previously established line.

Lines running to the north from a Standard Parallel[1] would start at a Township or Section corner placed when the Standard Parallel was run. Theses are called Standard Corners (SC). Lines from the south would intersect the Standard Parallel at a Closing Corner (CC), Figure 2.

Due to meridian convergence the CC should be on the Principal Meridian (PM) side of the SC. Under most Instructions, the surveyor was to record the distance to the corresponding SC. The combination of CC and SC on a correction line is referred to as double-corner situation.

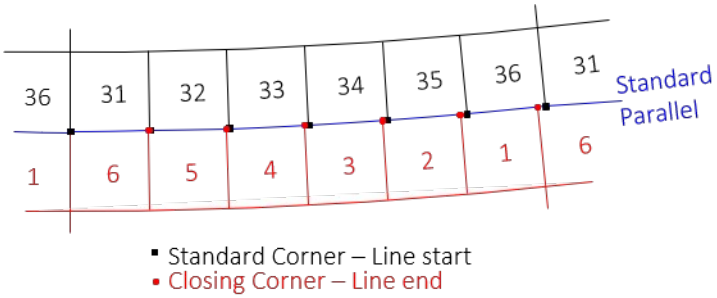


Figure 2: Closing and Standard Corners

Although a CC would be theoretically to the PM side of its corresponding SC, its actual location was also affected by survey errors in the Township and Section line surveys. As a consequence, the CC could fall long or short of the respective correction line and east or west of the SC. If a CC did not intersect at an SC then the direction and distance between them would be recorded. Early in PLS development the principle that a CC would control line direction, not termination was adopted. This was done to avoid gaps and overlaps with adjacent Townships. Consider Township lines as senior to interior Section lines: an exterior Section must end on and not cross its

[1]Also called a Correction Line.

Township boundary(ies).

(2) Closing Corners Evolution

CC placement went through an evolutionary change during the surveys. Tiffin's *1815 Instructions* required double corners on north and west Township lines, Figure 3[1]. If the CC matched the existing SC then it became the Section corner. The *1833 Instructions* required CC only on the north Township boundary. Figure 4.

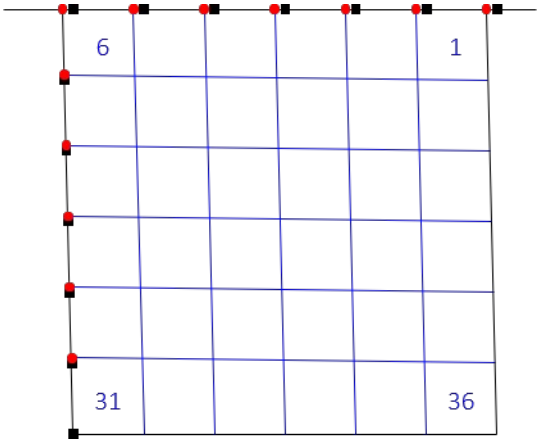


Figure 3: Double Corners Pre-1851

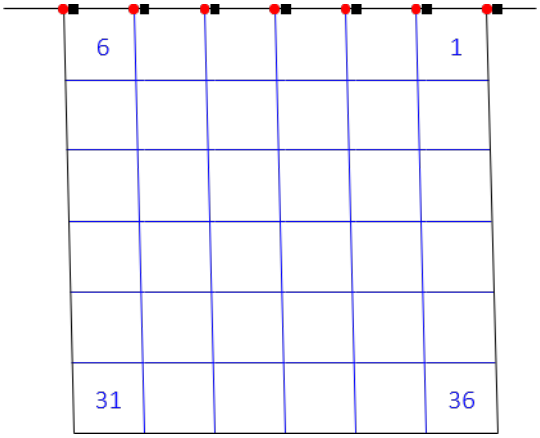


Figure 4: Double Corners Post-1851

The 1840 Instructions required CC placement only on a Standard Parallel. For north and west Township boundaries, Section lines closed on the existing corners.

b. Witness Corner

A witness corner (WC) was set in situations where it was not possible to set a regular corner except when a navigable water body was involved. Generally only one WC was used and it was placed on a line into the regular corner location. Their marking and accessories requirements were the same as for a regular corner.

There are two kinds of WC based on where they were placed:

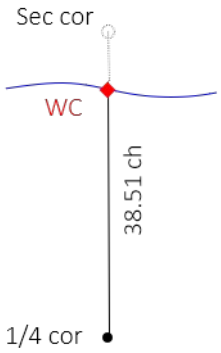


Figure 5: On Section Line

On a line leading into the regular corner, Figure 5. The distance from the previous set regular corner is recorded.

A WC off to the side of the line, Figure 6. This WC type serves as an accessory to the original corner.

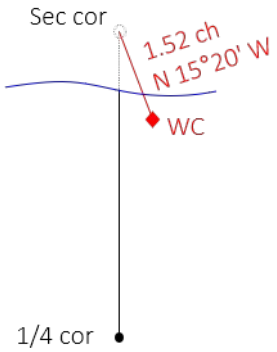


Figure 6: Off Section Line

[1] The terms *Closing* and *Standard Corner* were not used until the *1851 Manual of Instructions*.

c. Meander Corners

Two types of Meander Corners (MC) were set, Figure 7:

- where a PLS line intersected, or a regular corner fell in, a meanderable body of water,
- to map meanderable bodies of water.

Our interest for corner re-establishment is the former.

As with an online WC, distance to a MC along the line was recorded; marking and accessories requirements were the same as those for a regular corner.

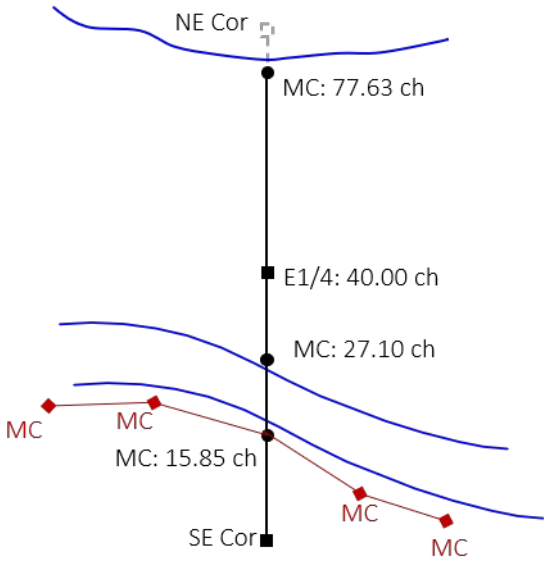


Figure 7: Types of Meander Corners

II. Principles of Corner Re-Establishment

A. Corner Disposition

The amount and quality of evidence determine a corner's disposition: it may be existent, obliterated, or lost[1].
According to the *1973 Manual* the three corner conditions are defined as:

> 5-5. An existent corner is one whose position can be identified by verifying the evidence of the monument or its accessories, by reference to the description in the field notes, or located by an acceptable supplemental survey record, some physical evidence, or testimony.
> Even though its physical evidence may have entirely disappeared, a corner will not be regarded as lost if its position can be recovered through the testimony of one or more witnesses who have a dependable knowledge of the original location.
>
> 5-9. An obliterated corner is one at whose point there are no remaining traces of the monument or its accessories, but whose location has been perpetuated, or the point for which may be recovered beyond reasonable doubt by the acts and testimony of the interested landowners, competent surveyors, other qualified local authorities, or witnesses, or by some acceptable record evidence.
> A position that depends upon the use of collateral evidence can be accepted only as duly supported, generally through proper relation to known corners, and agreement with the field notes regarding distances to natural objects, stream crossings, line trees, and off-line tree blazes, etc., or unquestionable testimony.
>
> 5-20. A lost corner is a point of a survey whose position cannot be determined, beyond reasonable doubt, either from traces of the original marks or from acceptable evidence or testimony that bears upon the original position, and whose location can be restored only by reference to one or more interdependent

[1]See? R3.

corners.

The *2009 Manual* definitions are:

> 6-11. An existent corner is one whose original position can be identified by substantial evidence of the monument or its accessories, by reference to the description in the field notes, or located by an acceptable supplemental survey record, some physical evidence, or reliable testimony.
> A corner is existent (or found) if such conclusion is supported by substantial evidence. The substantial evidence standard of proof is such relevant evidence as a reasonable mind might accept as adequate to support a conclusion. Substantial evidence is more than a scintilla of evidence but less than a preponderance of the evidence.
>
> 6-17. An obliterated corner is an existent corner where, at the corner's original position, there are no remaining traces of the monument or its accessories but whose position has been perpetuated, or the point for which may be recovered, by substantial evidence from the acts or reliable testimony of the interested landowners, competent surveyors, other qualified local authorities, or witnesses, or by some acceptable record evidence.
>
> 7-2. A lost corner is one whose original position cannot be determined by substantial evidence, either from traces of the original marks or from acceptable evidence or reliable testimony that bears upon the original position, and whose location can be restored only by reference to one or more interdependent corners.

The surveyor will notice that the 2009 version expressly states that an obliterated corner is an existent corner. A more subtle difference is the 2009 versions do not include "beyond a reasonable doubt" in either obliterated or lost corner definitions.

These corner conditions sound simple enough, but in practice they may be hard to distinguish with quite a bit of gray area in between. The difference between existent or obliterated, and obliterated or lost may be the degree of evidence discovered. Is soil discoloration, Figure 8, remains of the original corner post or one of its witnesses? If so, then it might be an existent corner, if not it may be obliterated or lost depending on other evidence. Had the surveyor stopped digging six inches earlier may have affected the corner type decision.

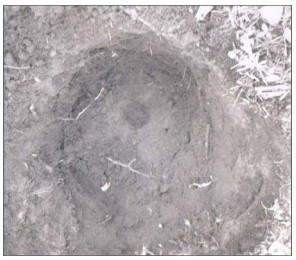


Figure 8
Soil Discoloration

The role of evidence in re-establishing PLS corners is no different from that in re-establishing any other legal corner. We still collect evidence, evaluate it using the Rules of Construction as a framework, and look for a "preponderance" indicating the most likely location of the original corner.

A single corner cannot be existent for one surveyor and lost for a second. Those are opinions based on the evidence each surveyor considers. Either both are not considering the same evidence or they evaluate the same evidence differently. Corner disposition is independent of the surveyor; disposition is defined by evidence. At any

given time, a corner's disposition is only one of the three conditions. It's the surveyor's challenge to collect all pertinent evidence and weigh it accordingly in order to discover the true corner disposition.

B. Lost Corner Restoration Methods

The *2009 Manual* divides restoration methods into *Primary* and *Secondary Methods*. Because of corner dependencies, order of establishment, etc, there can be overlap between the methods and even require using combinations of them.

1. Primary Methods

Double Proportionate Measurement (DPM)	Sec 7-8
Single Proportionate Measurement (SPM)	Sec 7-16
3 Point Control (3PC)	Sec 7-13
2 Point Control (2PC)	Sec 7-14
Modified SPM (MSPM)	Sec 7-44

2. Secondary Methods

Irregular Boundary Adjustment (IRR)	Sec 7-51
Grant Boundary (GB)	Sec 7-54
One Point Control (1PC)	Sec 7.58
Mixed & Miscellaneous	Sec 7-58 & 59

In addition to the restoration methods an *Index Correction* may need to be considered.

C. PLS Direction

1. Original

PLS Instructions required original surveyors lay out lines referenced to True North, despite surveyors measuring with magnetic compasses for a good part of the first surveys. Astronomic observations, Solar and Polaris, were made to determine the True Meridian which could then be measured with a compass to determine the magnetic variation[1].

Prior to the *1864 Instructions to the Surveyors General*, east-west random and true lines did not show true directions in the notes nor on the plat. That changed with the 1864 instructions:

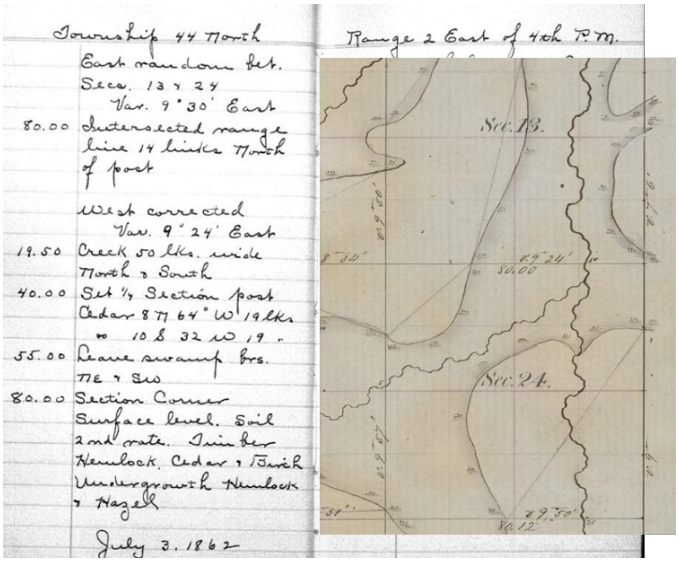
> VVIII.- Mode of Correcting Back Random Lines
>
> The manner of running random and true lines illustrated in the specimen notes, marked "B," in the Manual, is hereby modified so as to conform to the directions on page 23; that is, the deputy, having run a

[1] *Declination* is the contemporary term for the angle from True to Magnetic North and *variation* is its rate of change. The PLS Instructions use *variation* instead of *declination*. We'll use the PLS term.

random line, will correct back “by calculating a course that will run in a true line back to the corner post from which the random started.” For instance: instead of saying “west on a true line,” &c., with an *altered* variation, say “north 89°47’ west on a true line,” &c., with *same* variation.

For pre-1864 surveys, if bearings are not indicated on the plat but are needed, the notes should be examined. Without additional information, the presumption is that east and west Section lines are in cardinal directions. For random and true east-west lines, the surveyor should have recorded how far north or south the random line missed the closed upon corner. The bearing of the true line can be computed from that information.

Figure 9 shows the notes and partial plat for the line between Sections 13 and 24 of T44N R02E 4th PM. The survey was performed in July 1862 using the *1855 Instructions* which did not require line bearings. The surveyor’s random line intersected the Township boundary 14 links north of the corner. That information creates the geometry shown in Figure 10,


Township 44 North Range 2 East of 4th P.M.
East random bet.
Secs. 13 & 24
Var. 9° 30' East
80.00 Intersected range line 14 links North of post
West corrected
Var. 9° 24' East
19.50 Creek 50 lks. wide North & South
40.00 Set ¼ Section post Cedar 8 Tr 64° W 19 lks to 10 & 32 10 19
55.00 Leave swamp Brs. NE & SW
80.00 Section Corner Surface level. Soil 2nd rate. Timber Hemlock, Cedar & Birch Undergrowth Hemlock & Hazel
July 3. 1862
Sec. 13.
Sec. 24.
Figure 9: Random and True

To solve the bearing angle:

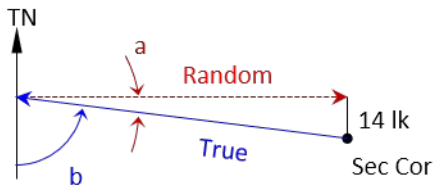


Figure 10: Random and True

$$a = \tan^{-1}\left[\frac{0.14}{80.00}\right] = 0°06'01''$$

$$b = 90°00'00'' - 0°06'01'' = 89°53'59''$$

Since he finished north of the corner, the true line must be corrected south at its east end making it run south-east. The record bearing is S89°54’E, rounded to the nearest minute to keep it consistent with the original surveyor’s dimensions.

2. Cardinal Equivalents

Many, but not all, corner re-establishment procedures requires converting a line’s distance and direction into its N-S and E-W components. These are its *cardinal equivalents*, Figure 11.

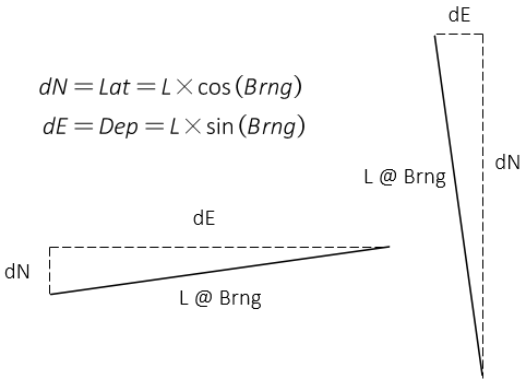


Figure 11: Cardinal Equivalents

Cardinal equivalents are used to proportion record and contemporary measurements and must be computed with respect to True North.

3. Grid Systems

Surveyors tend to work in a coordinate system whether an assumed one for small projects or a formal one for large projects. Many states have multiple formal coordinate systems form locally defined ones to State Plane Coordinates (SPC) and Universal Transverse Mercator (UTM). The most common system used in all is SPC, although the principles described here are similar for all systems.

Manual Section 7-9:

> Distortion encountered while using grid bearings on a coordinate system could introduce errors and thus incorrect results if factors of geodesy are not accounted for. In State plane coordinate systems, the grid scale factor varies across the project. Datum differences could introduce errors into the computations. Error can also be introduced if the lines are at dramatically different elevations, since the Public Land Survey datum is based upon measurements at actual average ground elevation along the line.

Section 7-9 identifies two potential distortions: Grid vs True direction and Grid vs Ground distance.

a. Directions

In a grid system, meridians do not converge. A grid system is fit to an ellipsoid whose meridians converge to the geodetic poles. The relationship between Grid and Geodetic North, Figure 12, is the following equation:

$$Geodetic\ Az = Grid\ Az + \gamma$$

γ: convergence

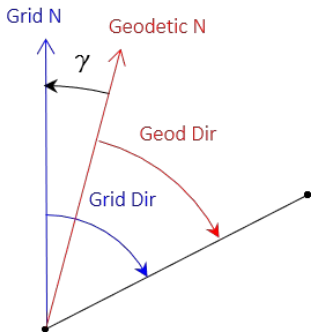


Figure 12: Grid & Geodetic Relationship

Geodetic and True North, as defined by the *2009 Manual*, are not the same but can be very close. In many cases, the two can be considered the same reference meridian, which was the case up through the *1973 Manual*. There is a slight difference between them, although it may not be significant. This is explained more fully in Appendix A. If Geodetic and True North can be considered the same then:

$$True\ Az = Grid\ Az + \gamma$$.

Convergence is zero at the Central Meridian (CM) of a grid system; its size increases moving East (+) and West (-) from the CM. SPC (and UTM) convergence can be computed using NGS' online *NCAT*[1] software.

Many states have created Low Distortion Projections (LDP): coordinate systems covering smaller areas and closer to the Earth's surface. These reduces distance distortions to the point that ground and grid can be considered the same. Convergence, however, may still be large enough to be accounted for.

NCAT does not currently support local Low Distortion Projections so determination of convergence depends on locally available software tools. Many states have successfully submitted their LDPs for inclusion in the upcoming *State Plane Coordinate Systems of 2022* (SPCS2022). That means they will be supported in future versions of *NCAT.*

How significant is convergence? Except for states that have gone to a single state-wide SPC zone, convergence generally does not exceed 2.5°. Not compensating a 2.5° convergence offsets the end of an east-west half mile line 115 ft. Even at 0°30' the offset is 23 ft, pretty substantial.

b. Distances

If using grid distances, they must be converted to ground level where original measurements were made. This requires dividing the grid distance by the grid scale factor (k) and elevation factor (EF). The former is a function of location in the grid system, the latter based on terrain elevation and geoid height. The grid scale factor can be computed using *NCAT,* geoid height (N) using *GEOID18* in the NGS *Geodetic Tool Kit*[2]. Elevations can be interpolated from USGS topoquads[3].

$$Ground = \frac{Grid}{k \times EF}$$

$$EF = \frac{R}{R + H + N}$$

k: Grid scale factor
R: Mean Earth radius; 20,906,000 ft
H: Average endpoint elevation
N: Geoid height

An LDP is specifically designed to minimize distance distortions allowing Grid and Ground distances to be treated as the same. In most LDPs distortion is no more than 1/40,000 to 1/50,000 with many being much better. At the 1/40,000 distortion level, a half-mile line would be affected by 0.07 ft if Grid distance is treated as Ground distance.

4. What About An Assumed System?

Do not use an assumed direction system for any re-establishment where cardinal equivalents are required: an assumed north has no connection to the True Meridian.

[1]https://www.ngs.noaa.gov/NCAT/
[2]https://geodesy.noaa.gov/TOOLS/
[3]USGS TopoView: https://ngmdb.usgs.gov/topoview/viewer/

III. Lost Corner Re-Establishment

A. When All is Lost

1. The Island of Lost Corners

The basic rules for lost PLS corners re-establishment are the same as those used for a subdivision lot resurvey[4]:

- One or more accepted original corner locations are needed to re-establish a lost corner.
- Original corners cannot be disturbed.
- Any discrepancies between original corner positions must be managed between those positions and cannot extend beyond them.

The primary difference between PLS and other lost corner corner re-establishment methods is that PLS methods are defined in the *Manual* so are consistent (for the most part) across jurisdictions. Non-PLS restoration uses the Rules of Construction for guidance and relies heavily on common law which can vary state-by-state.

It is important to understand that a lost corner means there is *no credible evidence* of an original corner location. Or if there is evidence, it is so weak or contradictory that the original position cannot be located with any degree of certainty. A lost corner must be re-established by relating contemporary measurements to record values between surrounding existent, or otherwise re-established, original corner locations. The resulting position is dependent on the disposition quality of surrounding corners and the original surveyor's records.

Corner re-establishment attempts to set a monument in the same location as did the original surveyor. Although the intent of the PLS was to introduce consistency in procedures and effect, that was nearly impossible from the onset. Across terrain that varied from flat and treeless to rugged and nearly impassible, heavily forested to pockmarked with water bodies, let alone the conditions they labored under, surveyors encountered unique situations requiring deviation from the Instructions and/or creative implementation of them. Over time, lost corner restoration methods evolved to better address those conditions while attempting to stay true to PLS intent.

2. Line Hierarchy

The PLS framework was built in parts, although not in the prefect order described in the *Instructions*. The order of line establishment defines their senior standing or higher relative weight where they intersect other lines.

The general order is:

- Principal Meridian and Base Line
- Correction Lines (aka Standard Parallels) and Guide Meridians
- Township Lines
- Section Lines

The theoretic order built the legal control framework inwards with the first run lines controlling subsequent lines. For example: A Township boundary contained the corners at which its Section lines began and ended; Quarter

[4] *Three* rules, hmmm....

corners controlled a Section's aliquot part subdivision. Line hierarchy affects how a lost corner is re-established.

3. Corner Dependency

There must be a dependency between the lost corner and the adjacent corner(s) from which it will be re-established. As with any corner re-establishment, the contemporary surveyor attempts to recreate the original situation using as much original evidence as possible. The corner(s) controlling re-establishment must be of the same standing, or higher, than the lost corner, defined by line hierarchy.

4. It's a Guess at Best

There is no guarantee that a lost corner re-established by any method will be in the original location. It is the best location we can arrive at based solely on record and contemporary measurements. You can be pretty sure that a lost corner re-established by proportionate measurement *is not* in the original position.

Although lost corner methods are considered a last resort they can be used as another piece of evidence to support an obliterated corner location. In that case they serve strictly in a secondary role.

B. A Matter of Proportions

1. Distance Based

Some lost corner restoration methods depend on proportionate measurement. Proportionate measurement relates current and record measurements in a ratio between accepted original or re-established corners. There must be a dependency between the lost corner and the adjacent corner(s) between which the proportion will be applied. That's because, as with any corner re-establishment, the contemporary surveyor attempts to recreate the original situation.

The original surveyor had specific distance and direction criteria to follow; proportionate measurement, however, may favor distance over direction or vice versa depending on the corner. Lost corners are re-established using original distance intent which can substantially alter line directions from what the original surveyor was instructed to use. Because PLS lines were intended to run N-S and E/S, proportioning follows the same pattern using cardinal equivalents.

Technology has made proportionate measurement, a previously arduous process requiring hours of measurements, a relatively easy and quick process. It is also less labor-intensive than evidence research making it an even more tempting corner solution. Fight the temptation. It can be used to help determine a potential search area but not substitute for the search itself.

Using proportionate measurement instead of evidence is almost as bad as applying it incorrectly when it is the proper method to employ. Although the presentation emphasis is on methods other than Single- and Double-Proportionate Measurement (SPM & DPM), they are both used in most of the other procedures so we will briefly review them.

2. Single Proportionate Measurement (SPM)

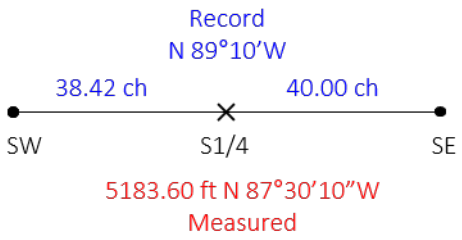
SPM is probably the most often used, and misused, lost corner method. It used to re-establish one or more corners along a single line. Where a corner falls at the intersection of two unequal lines, SPM is used along the higher weighted line.

Since the lost corner must fall on the line between the two controlling corners, there is no need to reduce record or contemporary distances to cardinal equivalents. There's no harm if you do, you will wind up withe the same result but do more computations in the process.

Once the controlling corners are recovered and measurements made between them, the SPM process to re-establish the lost corner is simple:

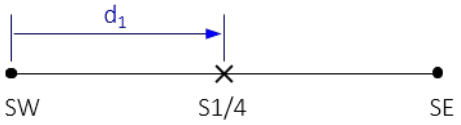
Step 1. Set up the proportion between record and contemporary distances.

$$\frac{5183.60\ ft}{(38.42\ ch + 40.00\ ch)} = \frac{5183.60\ ft}{78.42\ ch}$$



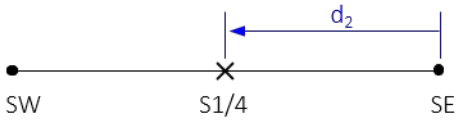
Step 2. Compute the distance to lost corner from either control point.

From SW



$$d_1 = 38.42\ ch \times \frac{5183.60\ ft}{78.42\ ch} = 2539.581\ ft$$

Math check: From SE



$$d_2 = 40.00\ ch \times \frac{5183.60\ ft}{78.42\ ch} = 2644.019\ ft$$

$$2539.581\ ft\ +\ 2644.019\ ft = 5183.600\ ft$$

Step 3. Re-set the lost corner

Measure 2539.58 ft from SW in direction of SE

or

Measure 2644.02 ft from SE in direction of SW

3. Double Proportionate Measurement (DPM)

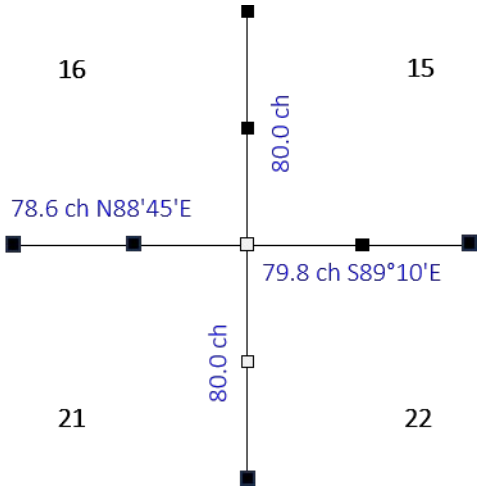
DPM is used to re-establish a lost corner located at the intersection of two equal weight lines. The location is not biased in one direction over the other. When using DPM, the record and contemporary distances must be reduced to their cardinal equivalents before proportioning.

Lost Corner Re-establishment

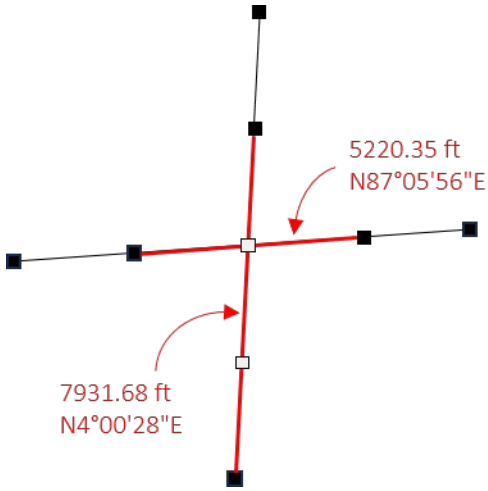
The DPM process is:

Step 1. Compute cardinal equivalents

Record Dimensions



Resurvey Measurements



N-S

$80.0\ ch\ +\ 40.0\ ch = 120.0\ ch$

E-W

$\left(78.6\ ch/2\right) \times \sin(88°45') = 39.29\ ch$

$\left(79.8\ ch/2\right) \times \sin(89°10') = 39.90\ ch$

$39.29\ ch + 39.90\ ch = 79.19\ ch$

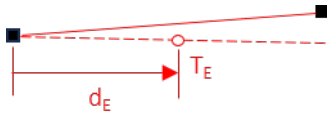
N-S

$7931.68\ ft \times \cos(4°00'28'') = 7912.284\ ft$

E-W

$5220.35\ ft \times \sin(87°05'56'') = 5213.659\ ft$

Step 2. SPM E-W and set temporary point, T_E

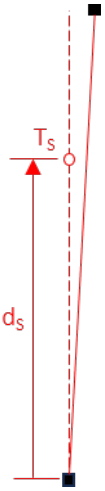


$$\frac{d_E}{39.29\ ch} = \frac{5213.659\ ft}{79.19\ ch}$$

$$d_E = 39.29\ ch \times \frac{5213.659\ ft}{79.19\ ch}$$

$$d_E = 2586.764\ ft$$

Step 3. SPM N-S and set temporary point T_S

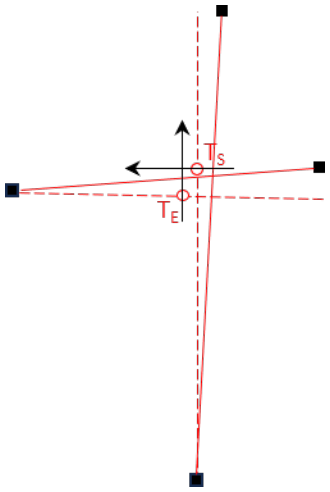


$$\frac{d_S}{40.0\ ch} = \frac{7912.284\ ft}{120.0\ ch}$$

$$d_E = 80.0\ ch \times \frac{7912.284\ ft}{120.0\ ch}$$

$$d_E = 5274.856\ ft$$

Step 4. Re-establish the lost corner at the intersection of cardinal lines through the temporary points.



DPM prioritizes distance over direction to re-establish the lost corner. As a result, Figure 13:

there is no guarantee the corner will be online in either N-S or E-W directions as was originally intended.

the final distances are no longer in the original proportions.

A point that may have originally been online and halfway between the two controlling points may be no longer meet those conditions. This is one reason lost corner methods are used as a last resort.

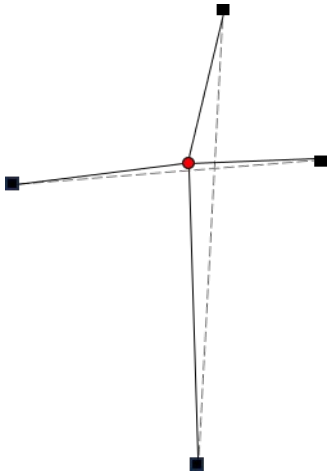


Figure 13: DPM Result

4. Which Way When?

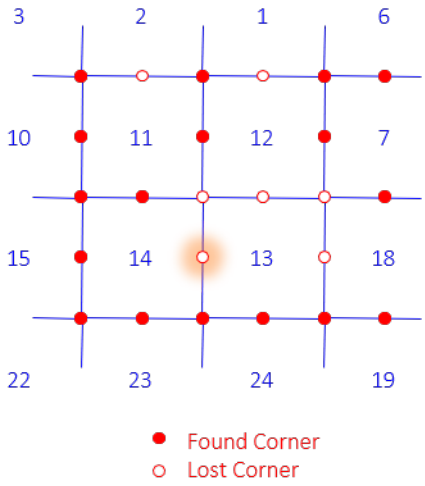


Figure 14: Re-Establishing W1/4 Sec 13

Which to apply, SPM or DPM, depends on the intersecting lines and controlling corners available. Based on the situation, re-establishing a specific corner may require re-establishing others first. The overall process could consist of multiple SPM and DPM operations.

For example, what is the process for re-establishing the W1/4 cor of Sec 13, Figure 14? Assume the corners indicated as lost truly are.

A 1/4 cor is located by SPM. The SW cor of Sec 13 can be one control point. The W1/4 cor of Sec 12 cannot be used as the other because there is a lost intermediate Sec cor. It must be re-established first.

Because it is a cor interior to the Township at the intersection of two equal weight lines, the NW cor of Sec 13 must be re-established by DPM. The W1/4 cor of Sec 12 and the SW cor of Sec 13 can be used for the

north and south control points. The S1/4 cor of Sec 11 can be used as the west control point, but the S1/4 of Sec 7 cannot be used for the east control point because it is in a different township.

The SE cor of Sec 12 can be used as the east control point, but it must re-established first. Because it is on a Township boundary, it would be located by SPM between the SE cor of Sec 13 and the E1/4 cor of Sec 12.

Starting with the last step, work backwards through the rest, Figure 15. By the time the W1/4 cor of Sec 13 has been re-established, so have two others: SE cor of Sec 12 and the NW cor of Sec 13 (as long as you are at it, might as well set the S1/4 cor of Sec 12, maybe even the E1/4 cor of Sec 13).

This example shows that corner dependency and line hierarchy must be considered when re-establishing a lost corner. What may seem like a simple situation can quickly grow into a much larger process.

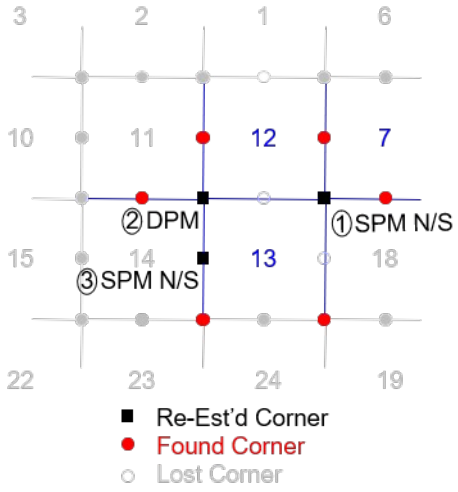


Figure 15: Re-Establishment Procedure

5. Modified SPM (MSPM)

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Figure 16: Township Divided by Two Surveyors

In some cases a Section line was intentionally bent at an intermediate corner so the line between bounding Section corners was not a constant bearing.

Original surveys did not start at an Initial Point and progressively survey north systematically creating Sections. Where industry expanded or populations settled created the highest surveys priority. Surveys sometimes had to "meet in the middle" which could cause Section line mismatching.

One possible situation was in the interior of a Township, Figure 16, partially divided by two different surveyors. In normal Township subdivision, random lines were run to the east or west to close on an existing Section corner setting a temporary quarter corner. If the closure was acceptable, the temporary quarter corner would be corrected back to the true line. Random lines were not typically run to the north so a second surveyor might bend the line at the quarter corner to meet the first surveyor's Section corner.

How often would one encounter an MSPM lost corner situation? A line can deflect at a witness or meander corner. It could also happen on a line that, although shown as straight on the plat, in reality isn't. From Section 7-34 of the *2009 Manual*:

> There may be persuasive proof of a deflection in the alinement of the exterior, though the record shows the line to be straight...This condition, when supported by substantial evidence, would warrant an exception to the straight-line or two-way adjustment because under the rules for the acceptance of

evidence, the evidence out-weighs the record.

This could happen where a navigable water body was so large causing the surveyor traverse around it to continue the line. An error in the traverse could cause a bend in the Section line although it would be shown on the plat as the same bearing.

The MSPM procedure attempts to recreate the bent aspect of the line segments. That means unlike SPM where the corner is re-established online between controlling corners, the lost corner is re-established the same side of the line between controlling corners.

Figure 17(a) shows the record dimensions for the east line of Section 15[1].

Section 15's NE and SE corners are found while its E1/4 corner is lost. Figure 17(b) shows the contemporary measurements between the found corners.

The cardinal equivalents for both sets of values are shown in Figure 18.

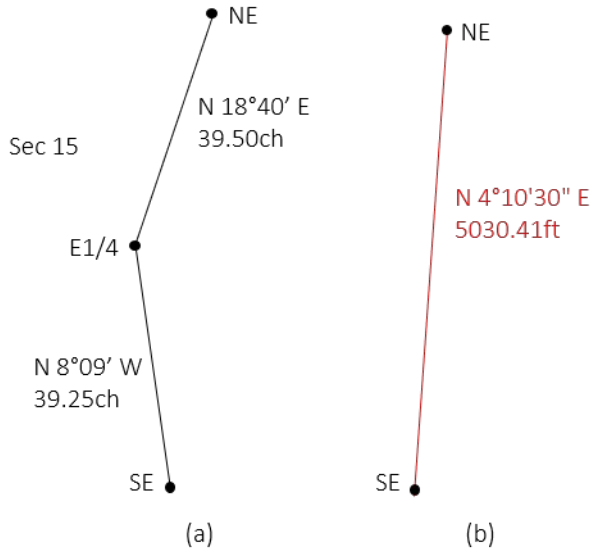


Figure 17: MSPM Record and Contemporary Values

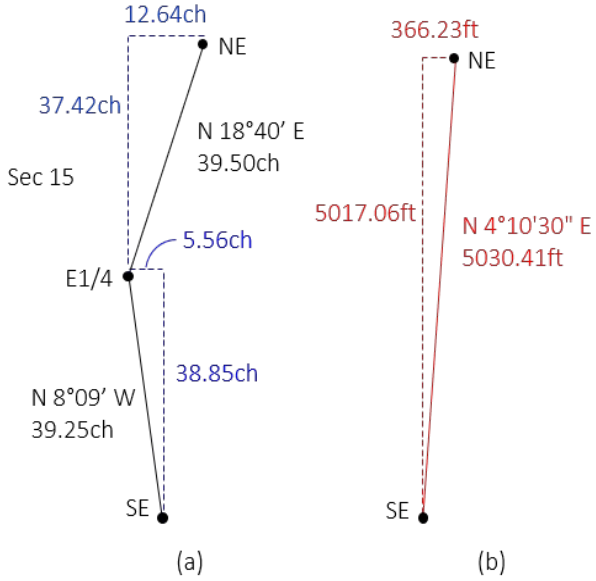


Figure 18: MSPM Cardinal Equivalents

[1]The directions deviate considerably from North in this example to better illustrate the MSPM calculations.

To determine the lost corner's location:

Compute the proportioned distance north of the SE corner, Figure 19.

$$\frac{n}{5017.06ft} = \frac{38.85ch}{(38.85ch + 37.42ch)}$$

$$\Rightarrow n = 5017.06 \times \left[\frac{38.85ch}{(38.85ch + 37.42ch)}\right]$$

$$n = 2555.56ft$$

Set a temporary point 2555.56 ft north of the SE corner.

The lost corner must be offset west from the line connecting the SE and NE corners, Figure 20

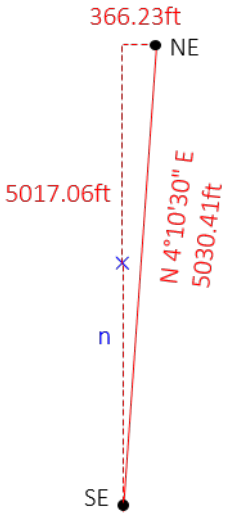


Figure 19: MSPM N-S Proportion

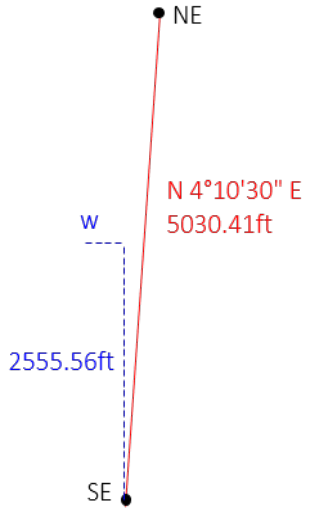


Figure 20: MSPM E-W Offset

Compute the offset

$$\frac{w}{2555.56ft} = \frac{5.56ch}{38.85ch}$$

$$\Rightarrow w = 2555.56ft \times \left[\frac{5.56ch}{38.85ch}\right]$$

$$w = 365.74ft$$

The lost corner is set 365.74 ft west on a cardinal line through the temporary point, Figure 21.

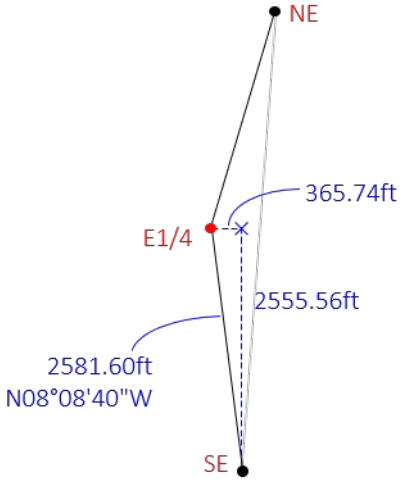


Figure 21: MSPM Corner

6. Index Correction

The *2009 Manual* describes an *Index Correction* in Sections 7-5 and 7-57 with the latter providing a clearer definition:

> In cases where a retracement has been made of many miles of the original lines, between identified original corners, and there has been developed a definite and consistent surplus or deficiency in distance, or a definite and consistent angle from cardinal that characterizes the original survey, it is proper to make allowance for the average difference(s). Such adjustment will be incorporated automatically in all cases where there exists a suitable basis for proportional measurement.

An index correction is used to compensate an original surveyor's systematic error. This does not affect the original corner locations only the measurements connecting them. Early surveyors were required to have at least two chains- one would be used only for calibration, the other for the actual measurements. Chains links would wear affecting distances and the surveyor was supposed to check the working chain and adjust it as needed. If he

didn't, his corners would be placed too far apart, Figure 22.

A systematic error could also exist if the surveyor used the incorrect magnetic variation. This could be caused by errors in astronomic observations to establish direction.

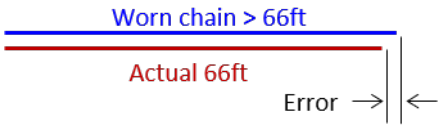


Figure 22: Chaining Error

When using proportional restoration methods, an index error is generally automatically compensated. They may need to be addressed in other restoration methods where there are insufficient controlling corners. Dealing with them is relatively simple, determining if they exist may not be.

C. Control Corners

Regular Section and quarter corners control when used in correct hierarchical order as shown in Figure 15.

Closing, Witness, and Meander corners also control corner re-establishment, but depending may require slight variation of the methods based on their locations And, just like a regular corner, a special corner could be lost and also need-re-establishment.

1. Closing Corner

An existing or restored Closing Corner (CC) location, whether on, past, or short of a Township boundary, controls both distance and direction for proportioning purposes.

Figure 23 shows some Closing and lost corner situations. CC A and C are long and short of the Township line, respectively.

The NW corner of Sec 5 is located where the line from SW cor Sec 5 through CC A intersects the Township line.

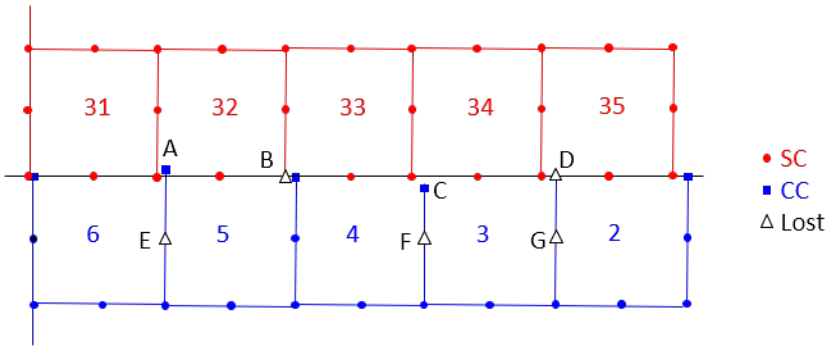


Figure 23: Closing and Lost Corners

The W1/4 corner of Sec 5 (E) is re-established by SPM between the SW corner of Sec 5 and CC A.

Why use the CC instead of the NW Cor Sec 5?

Dependency: the W1/4 cor and CC were set in same survey.

The SE corner Sec 32 (B) is a standard corner. It is re-established by SPM between the S 1/4 corners of Secs 32 and 33. The CC at the NW corner Sec 4 cannot be used to re-establish B because it came after the corners on the north Township line.

The NW corner of Sec 3 is at the intersection of the line from the SW corner Sec 3 through CC C with the Township line.

The W1/4 corner Sec 3 (F) is re-established by SPM between the CC at C and the SW corner Sec 3.

When a CC was set, the surveyor was to record the distance to the nearest corresponding standard corner. The lost CC at D would be set by SPM using the surveyor's recorded distance and the SW and S1/4 corners of Sec 35.

The W1/4 Sec 2 is set by SPM between the SW corner Sec 2 and the re-established NE corner Sec 2 (D).

2. Witness Corner

Section 6.17 *2009 Manual of Instructions*:

> "...Where the witness corner was placed on a line of the survey, if no complications arise, the witness corner will be used as control in determining the true point for the corner....
>
> ....For corners reestablished by double proportionate measurement, the true point for the corner will be determined by extending the line through the witness corner at record distance. For corners reestablished by single proportionate measurement, the true point for the corner will be determined by single proportionate measurement between the witness corner and the opposite controlling corner. Thus, in single proportionate measurement, the record bearing and distance is modified, and the witness corner becomes an angle point of the line...."

For a Witness Corner (WC) to contribute to corner re-establishment it must be on the Section line, not an accessory WC. A found accessory WC is part of the original monument making the associated corner existent.

Since ian online WC's distance is measured from the previous corner it can be used for proportioning. For DPM situations, the regular corner is determined from the WC position and used as a control for one direction of DPM.

Figure 24 shows some lost corners involving an WC.

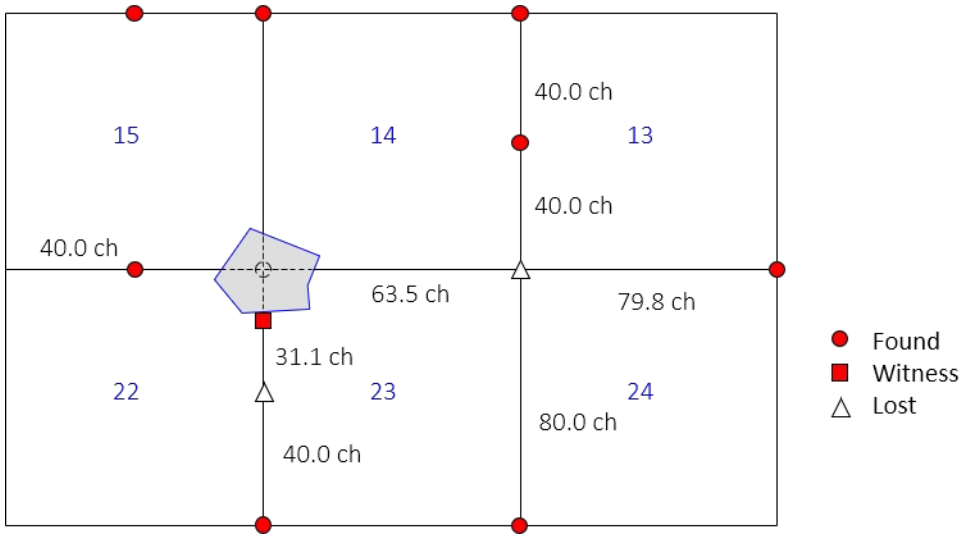


Figure 24: Witness and Lost Corners

Corner	Description
W1/4 Sec 23	The WC can be used to re-establish the lost corner by SPM between it and the SW Sec 23. The E1/4 cor would be set at the distance from the SE cor toward the WC.
NE Sec 23	The position of NW cor Sec 23 is computed continuing 8.9 ch N past the WC along the Sec line. Re-est the NE Sec 23 by DPM using NW Sec 23 to NE Sec 24 E-W SE Sec 23 to E1/4 Sec 14 N-S

A lost WC would be re-established the same as a regular corner, either by DPM or SPM depending on the corner it represents.

3. Meander Corner

Section 3-173 of the *2009 Manual*:

> "Meander corners are a controlling monument on the surveyed line and shall be treated similarly to other regularly established monuments such as Section or quarter-Section corners and tract corners for dependent resurvey purposes"

Section 6-30 of the *2009 Manual*:

> "When recovered, meander corners normally control both alinement and proportionate measurement along the line, as any corner of first order. Meander corners not recovered will normally be reestablished (see Section 7-37). Resurvey and retracement records must be examined carefully because meander corners, by instructions, have been used differently for restorations and establishments."

According to the *Manual*, a Meander Corner (MC) is considered the same as a regular corner and controls both distance and direction just like any other Section or quarter corner[1]. Unlike a regular corner, however, it is not the terminal point of a line. The line terminates at the waterbody- the MC controls the line direction. It is similar to a Closing Corner, except it ends at the water instead of a Correction Line.

Figure 25(a) shows the record information for a Section line crossing a river. MCs were set on both sides of the river. Directions were not given so distances are used as record cardinal equivalents.

Figure 25(b) shows the found corners and line segments connecting them. The E1/4 corner is lost and must be re-established using SPM. Individual segment lengths and directions are measured.

Figure 25(c) shows the SPM distances to the E1/4 cor from the NE Cor and MC.

[1]In Wisconsin, there is case law and Attorney General Opinions which say a meander corner can be used only for direction control, not distance. They are treated similar to Closing Corners.

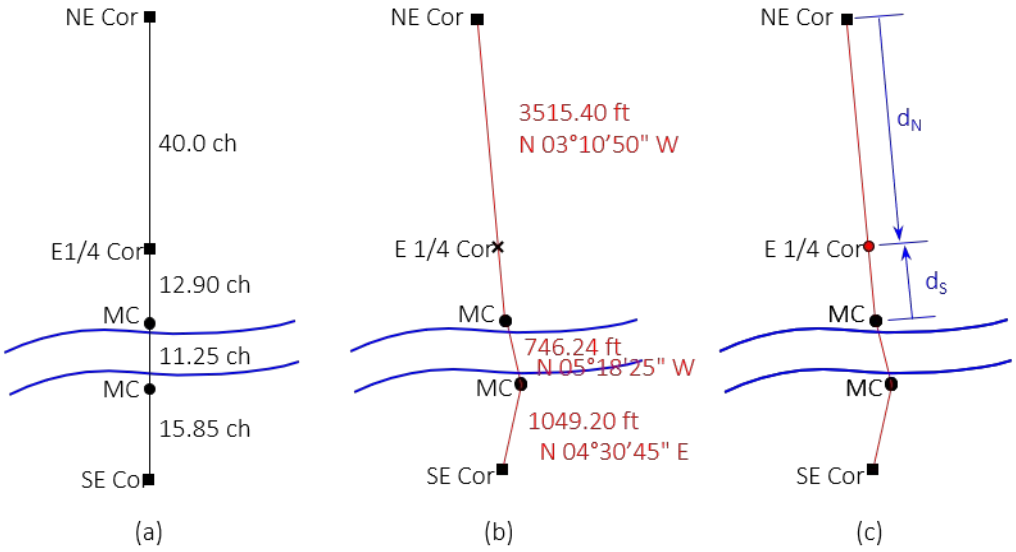


Figure 25: Meander Corner Example

$$\frac{d_N}{40.0\ ch} = \frac{3515.40\ ft}{(40.0\ ch + 12.90\ ch)}$$

$$d_N = 40.0\ ch \times \frac{3515.40\ ft}{52.90\ ch}$$

$$= 2658.147 ft$$

$$\frac{d_S}{12.9\ ch} = \frac{3515.40\ ft}{(40.0\ ch + 12.90\ ch)}$$

$$d_N = 12.9\ ch \times \frac{3515.40\ ft}{52.90\ ch}$$

$$= 857.253 ft$$

Math check:

$$2658.147\ ft + 857.253\ ft = 3515.400\ ft \hookleftarrow$$

Re-establish the lost corner 2658.15 ft from the NE Cor toward the north MC.

or

Re-establish the lost corner 857.25 ft from the north MC toward the NE Cor.

D. Limited Control

Limited control means a lost corner was originally tied to fewer corners than are needed to re-establish it by SPM or DPM. Or, all the corners needed for control on one are also lost and cannot be re-established so there is nothing to proportion against.

When lacking sufficient control for proportioning, we must resort to record dimensions for lost corner re-establishment. Although not optimal, because it is based on record and contemporary measurements being in partial or full agreement, record dimensions are the only evidence available.

There are three conditions[1]: Three-Point Control, Two-Point Control, and One-Point Control. The *Manual* classifies Two- and Three-Point as Primary Methods, One-Point as Secondary. In all three cases, at least one controlling point was never established, or cannot be re-established, so a proportion cannot be performed in that direction. Record information must used to help re-create the lost corner location.

1. Three-Point Control

Three-Point Control (3PC) is used when a controlling point doesn't exist on one side of a DPM situation, Figure 26(a).

SPM is done in the direction of bounding control and a temporary point is set.

In the direction where only a single control point exists, a second temporary point is set at the cardinal record distance, Figure 26(b).

As with DPM, True E-W and N-S lines are run through the temporary points. The lost corner is re-established at their intersection, Figure 26(c).

The new lines connect the three control points with the newly re-established corner, Figure 26(d).

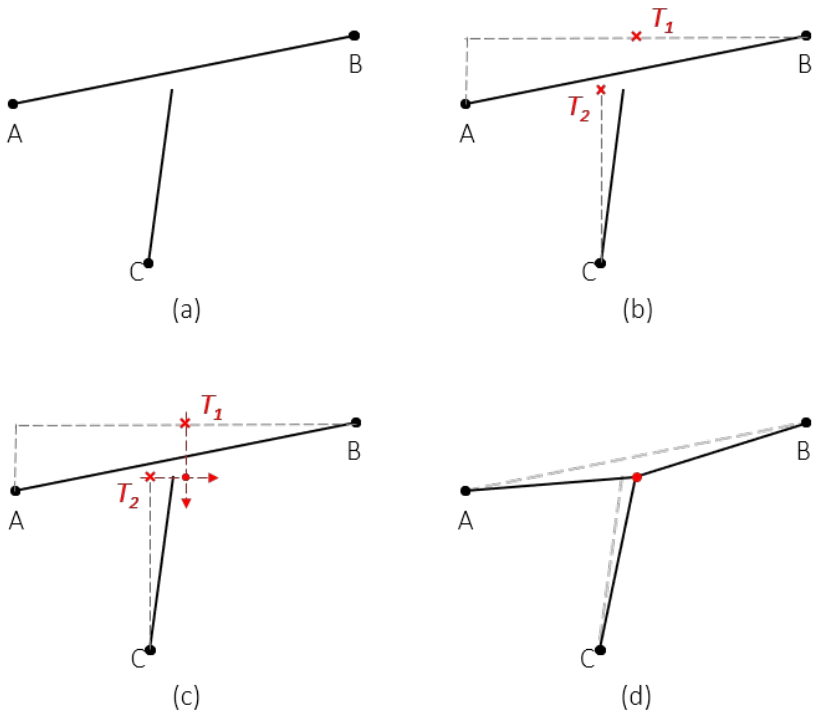


Figure 26: Three-Point Control

2. Two-point Control

Two-Point Control (2PC) is used when there is only a single controlling point in both directions of a DPM situation, Figure 27(a).

Place temporary points at the cardinal equivalents of the record measurements, Figure 27(b).

[1]Wait, is that three again?

Extend cardinal lines through each temporary point and re-establish the lost corner at their intersection, Figure 27(c).

The new lines connect the two control points with the newly re-established corner, Figure 27(d).

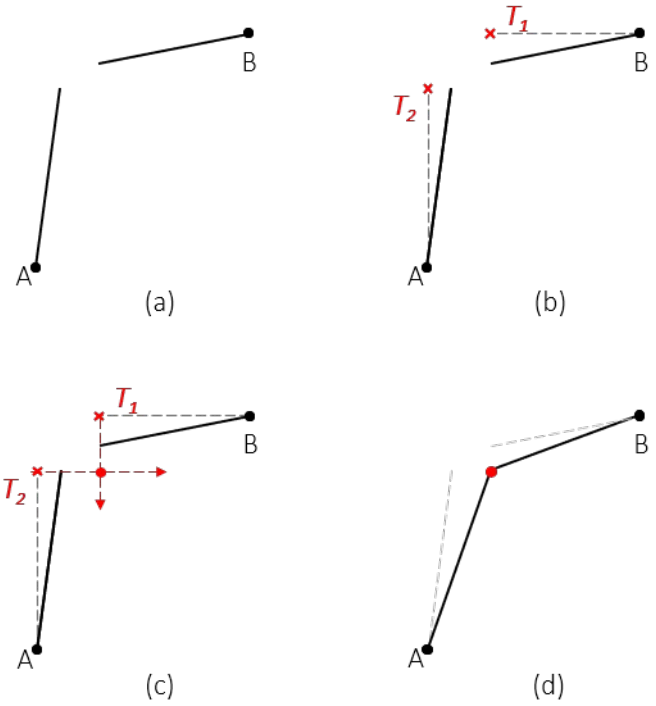


Figure 27: Two-Point Control

3. One-Point Control

The lost corner is connected to a single record corner, Figure 28(a), and is restored at the record distance and direction, Figure 28(b). Cardinal equivalents are not used.

Figure 28: One-Point Control

4. Examples

Figure 29 is part of a fractional Township that extends into a large lake. The following lost corners are to be re-established:

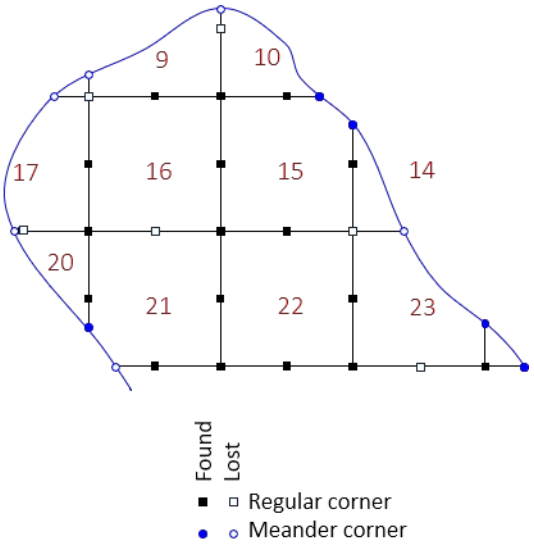


Figure 29: Fractional Township

a. E1/4 cor Sec 9

A quarter corner is established by SPM between the Section corners on each side of it. In this case, however, there is only one existing control corner, the SE cor Sec 9. This corner must be re-established using 1PC.

Record data:

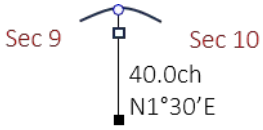


Figure 30: Record Data to E12/4 cor Sec 9

The E1/4 corner would be located 40.0 ch, N1°30'E from the SE cor Sec 9.

b. SE cor Sec 15

This corner would normally be re-established using DPM, bit there is only a single control point in the E-W direction. There are two in the N-S direction so use 3PC.

Record data are shown in Figure 31.

(1) SPM between the E1/4 cor Sec 15 and E1/4 cor Sec 22.

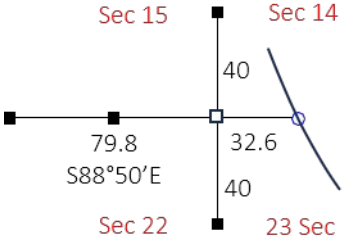


Figure 31: Record Data to SE cor Sec 15

Field measurement from the E1/4 cor Sec 22 to the E 1/4 cor Sec 15 is N3°10'20"W and 5212.36 feet. Since the record distamces are 40 ch on both sides, set a temporary corner, T_N, 2606.18 ft from the E 1/4 cor Sec 22 in the direction of the E 1/4 cor Sec 15.

(2) Compute E-W record cardinal distance:

$$Dep = (79.8ch/2) \times sin(88°50') = 39.89ch$$

Set a temporary point, TE, 39.89 ch East of the S1/4 cor Sec 15.

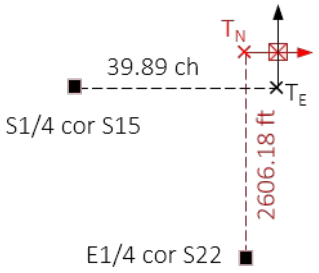


Figure 32: 3PC Re-establishment

(3) Set SE cor Sec 15 at intersection of cardinal N-S line through T_E with cardinal E-W line through T_N, Figure 32

c. NW cor Sec 16

Cannot use DPM to re-establish the lost corner because there is only a single control corner in N-S and E-W directions. Must use 2PC with record cardinal distances from the N1/4 and W1/4 corners of Sec 16.

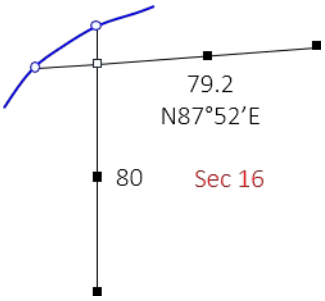


Figure 33: Record Data For NE Coe Sec 16

There was no bearing given for the west line of Sec 16 so presume it is cardinal.

Compute record cardinal distance from N1/4 cor to NW cor.

$$Dep = \left(79.2ch/2\right) \times sin\left(87°52'\right) = 39.57ch$$

Measure 40 ch north from the W1/4 cor Sec 16 and set temporary point T_N.

Measure 39.57 ch west from N1/4 cor Sec 16 and set temporary point T_E.

Set NW cor Sec 16 at intersection of E-W line through T_N and N-S line through T_E.

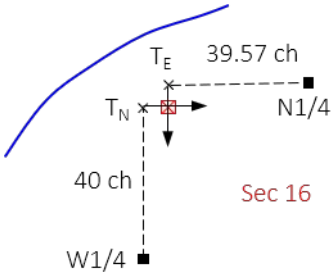


Figure 34: 2CP Re-establishment

E. Other Methods

1. Irregular Boundary Adjustment

The irregular boundary adjustment method is applicable to Townships whose exteriors are not straight due to multiple partial surveys, modifications of prescribed methods, or erroneous procedures.

A retracement is run using record dimensions between accepted positions. The misclosure is determined by measuring the distance between the existing corner and the corresponding record surveyed position.

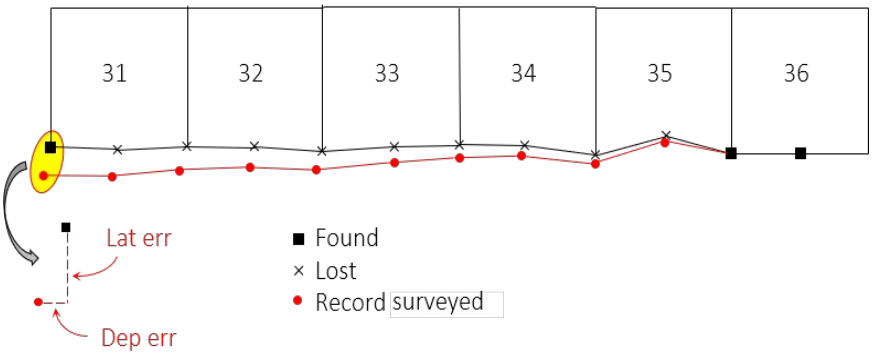


Figure 35: Irregular Boundary Adjustment

Figure 35 shows a record traverse run from SW cor Sec 36 to SW cor Sec 31. The inset shows the misclosure reduced to cardinal equivalents. The E-W line position of each lost corner is determined by SPM; The N-S offset is determined using the Compass Rule.

On N-S lines, SPM determines the N-S location and Compass Rule the E-W offset.

The corner positions are located by the SPM and Compass Rule position shifts. These can serve as search areas for corner evidence; if none exits then can be used for lost corner reestablishment.

Manual computations can be lengthy so rather than show it here, a worked example is included in Appendix B.

2. Grant Boundary

Existing grants and reservation boundaries had to be respected when encountered by an original PLS survey. PLS surveys were to close on these boundaries much like a correction line, Figure 36. Found corners long or short of the boundary control line direction only, not termination.

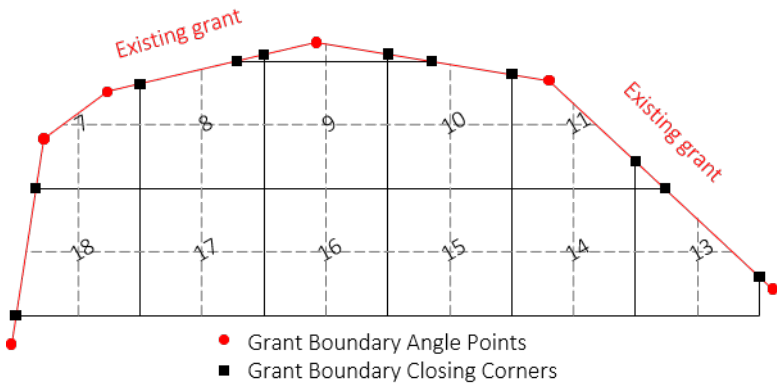


Figure 36: Grant or Reservation Boundaries

The grant boundary must be located first because it is a senior line. These were typically described by metes and bounds and often used topographic calls.

Nominal PLS lines typically run in near cardinal directions, making proportioning between existent or re-established corners relatively simple. Grant boundaries, on the other hand, are not similarly restricted and require a different proportioning method to preserve their shape.

The general process is:

Step 1. Two existent or re-established grant boundary corners are located, Figure 37.

Step 2. Using record information, the angle point locations of the boundary are computed

Step 3. The length and direction of the line (AB') between found corners is computed from the record information

Step 4. The length and direction of the line (AB) between found corners is measured.

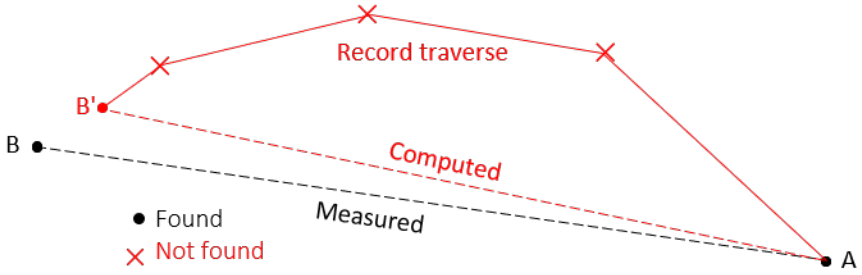


Figure 37: Found Corners and Record Traverse

Step 5. The record traverse is rotated into the measured line between found corners, Figure 38. The rotation angle is computed from the directions in Steps 3 and 4. Each grant boundary line segment

bearing will change by the rotation angle. Some will increase others decrease depending on quadrant location.

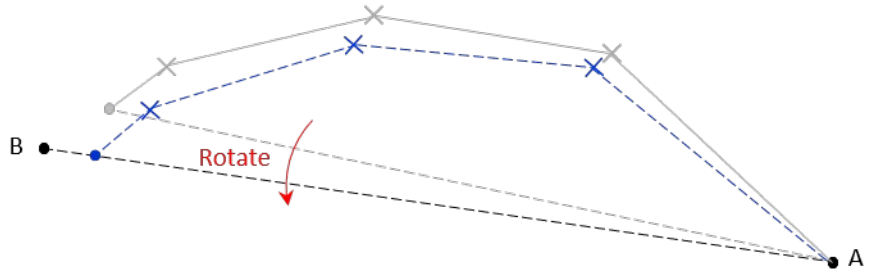


Figure 38: Rotating Record Traverse

Step 6. The rotated record traverse is scaled so its endpoints match the measured found corners, Figure 39. The scale is computed from the distances in Steps 3 and 4. Each distance changes by the scale.

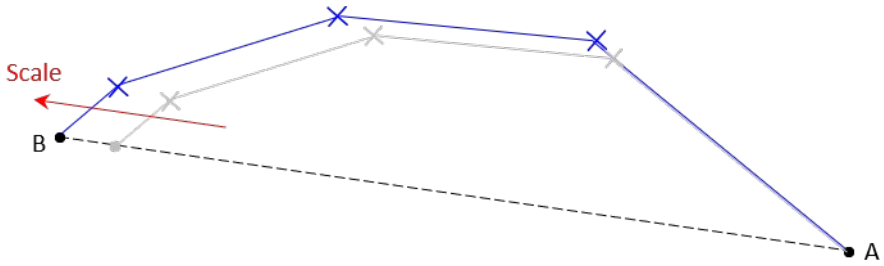


Figure 39: Scaling Rotated Record Traverse

Step 7. The new bearings and distances are used to locate the angle points in the field. These serve as search areas for original corner evidence. If sufficient evidence is not found to consider the corner existent or obliterated, it is deemed lost and re-established at the traverse point location.

Once the grant boundary is re-established, Section lines are forced to close on it, similar to a correction line. The rules of closing corners and correction lines apply. Any existing corners which fall short or long of the grant boundary are only used to fix direction, not termination.

Basically, it is a two-dimensional transformation: rotate and scale. Most software, including CAD, includes some basic transformation capabilities. A manually computed example is included in Appendix C.

3. Mixed and Miscellaneous

The final method defined in the *Manual* is, basically, at the surveyor's discretion. Because of local conditions, now and at original survey time, as well original survey(or) quality, other methods may not provide a *reasonable* result or one that reflects how a corner was originally set. Combining two (or more) methods may yield a location better reflecting original intent. It's a judgment call an a corner-by-corner basis.

F. Curved Lines

A lost corner re-established by SPM on any line originally run as a true line of latitude should be offset to the south to maintain line curvature. The *1973 Manual* explained how to determine the offset using the *Standard Field Tables and Trigonometric Formulas* publication. The *2009 Manual* briefly discusses it, and even gives the offset at the middle of a one mile line at 45° latitude, but doesn't explain how to compute it.

How large is an offset? It depends on:

- latitude of the line
- distance between the control corners used for SPM
- distance the lost corner is along the line between the control corners

For example, the north line of T25N R42E Willamette Meridian is at approximately 47°42' Lat. Offsets for Section corners re-established by SPM between two Township corners, Figure 40, are in Table 1.

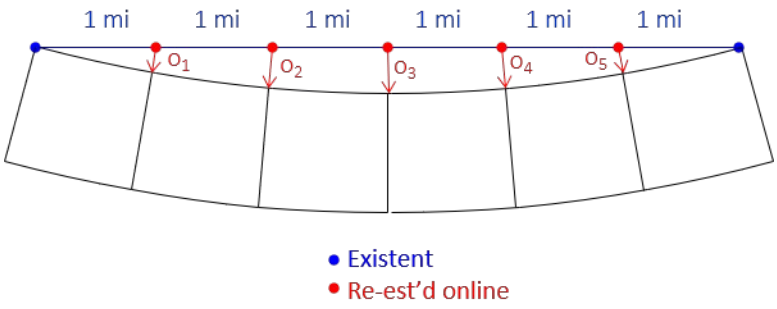


Figure 40: Township Line Offsets

Table 1: Township Line Offsets

Offset	Dist, ft	Ang err
o_1	3.7	0°02'24"
o_2	5.9	0°01'55'
o_3	6.6	0°01'26"
o_4	5.9	0°00'58"
o_5	3.7	0°00'29"

Note that the offsets are symmetric about the chord dle.

In one mile, a 3.7 ft offset is pretty significant, if the only control corners are at the Township corners.

A lost quarter corner between two found Section corners would be offset only 0.2 ft. Should it be applied? Some *Manual* requirements and a method to compute offsets are covered in Appendix D.

IV. Perpetuation

Once a position is determined (or verified) it must be perpetuated in physical and written form. Besides appropriate restoration methods, the *Manual* is silent on private land corner perpetuation requirements. Because restoration is performed by private surveyors, regulation regarding perpetuation are generally dictated by state law or administrative code, possibly down to local county, parish, or municipal level.

A. Monumentation

2009 Manual Chapter IV Monumentation discusses monument materials, markings, accessories and memorials. These are requirements for official surveys by BLM Cadastral personnel on public and Federal lands. They are not binding on private surveyors unless adopted by state or local regulations.

State and local regulations may have some basic monumentation requirements (material, minimum length, diameter, weight per lineal foot, etc) but often leave it to the surveyor to exercise appropriate judgment.

States may have minimum monumentation criteria in statute or administrative code. In many states, the PLS network maintenance is managed at the local level - County, Parish, or Municipality. These may have their own specific monumentation, marking, and reference marks criteria.

B. Documentation

This can be the most important part of the corner perpetuation process, but is sometimes an afterthought or done with less rigor than the corner re-establishment. Documentation must contain sufficient information allowing subsequent surveyors to understand the rationale for the corner location.

Under the *Rules of Construction*, a monument can only control if it is called for, identifiable, and undisturbed. Chances are good that today we won't find the wooden post and dirt pile set by the original surveyor at a Section corner but possibly a 1-1/2 inch iron pipe instead. Does the pipe meet the identification requirement for monument control? How do we know it represents the original corner location? How was the position determined?

The Record provides the lineage and authority for a perpetuated position. Whether to accept an existing replacement monument at a PLS corner depends on the evidence used to place it and the connection it has to those before it. Without that information on the PLS Monument Record, the character of the monument is suspect.

States have varying degrees of content requirement for a Monument Record and many have suggested forms created by their Licensing Board and/or professional association.

Some common required elements include:

> A drawing depicting the relevant monuments and reference ties with sufficient detail to enable accurate location of the corner monument if it is disturbed.
>
> A description of any record evidence, monument evidence, occupational evidence, testimonial evidence or any other material evidence considered by the surveyor, and whether the monument was found, placed, or re-placed. This includes other already existing monuments in the corner vicinity.
>
> If the corner was re-established through lost-corner-proportionate methods, which other public land survey corners which were used as evidence or used for proportioning. The type of proportioning applied should also be identified. Merely stating "Re-established using proportionate measurement." is neither sufficient nor an indication why it was assumed lost.
>
> A description of any material discrepancy between the location of the corner as restored or re-established and the location of that corner as previously restored or re-established.

Other requirements may include unique corner identification codes, coordinates, panel review, accessory ties, etc. These can be state- or local-level dictates.

What about parol evidence used to determine a position? It should also be memorialized since the source will not be available in the future, yet the information will still be important..

Monument Records are usually filed or recorded in a public office. Older records are generally not removed as new ones are added. Over time monuments get replaced, physical evidence lost or gained, and even the accepted corner position changed. The temporal documentation can be important when retracing an older survey which uses a particular corner or quarter-Section line. We must be able to determine which monument at what physical location was used for a description beginning “Commencing at the northeast corner of said Section 16; thence....” Was it the same one that represents the corner today? Or a plat whose basis of bearings is “based on the East line of the southeast quarter of said Section 16.” with minimal monument information.

V. Summary

Corner restoration by one of the methods covered in this paper presumes the corner position is lost. LOST. L-O-S-T. That means there is no evidence sufficient to establish its position with even an inkling level of certainty. Considering a corner lost is no light decision. Any patented lands that have been occupied and used will usually exhibit some physical evidence except for possibly the most remote areas. Monuments were placed to help patentees find their land, patentees used those monument to define the extent of their activities. Secondary evidence owes its existence to corner locations. The older the evidence, the closer it is to the corners’ original placement. Research is critical in determining a corner’s disposition. Only until all investigative paths have been exhausted should a corner be considered lost.

Equally important, once a corner is deemed lost, is to use the correct method to re-establish it. The *Manual* describes the acceptable methods depending on line hierarchy, corner dependence, and protecting existing rights, but it does leave it to the surveyor to consider alternative approaches in unique circumstances.

What if a monument is found in the vicinity of a corner, but there no physical or parol evidence nor monument record to explain its existence? Nada. Applying a lost corner method gives a position very close to the monument. Very close. Accept or place a new monument? Dilemma.

Understand that measurements, regardless technology used, are subject to error. Distances involved in PLS corner re-establishment are much longer than those of a typical lot survey. Errors accumulate and interact affecting the accuracy of our final location. Does the situation in Figure 41 reflect differences in degree of evidence collection and evaluation or is it the result of the cumulative uncertainty of all three “correct locations”?

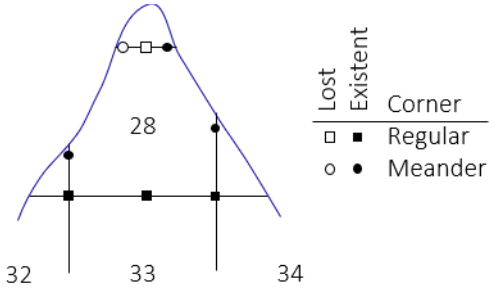
Figure 41: Which is Right?

Research, re-establish, document.

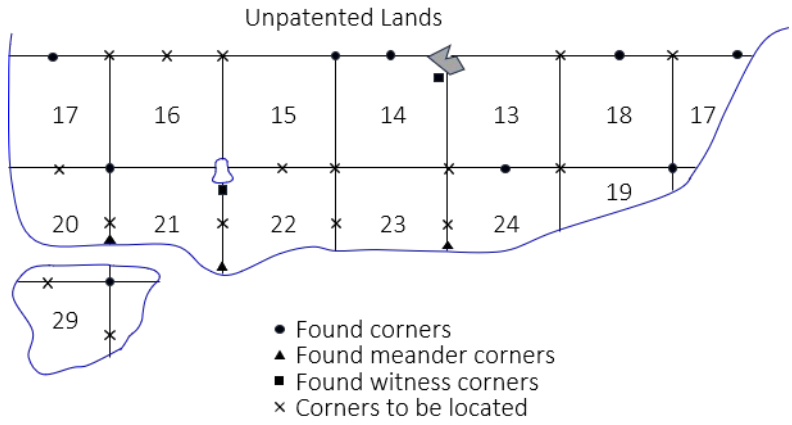
VI. Exercises

Exercise 1

How would you re-establish the lost N1/4 of Sec 28?



Exercise 2



From original notes:

The witness corner near the NE cor Sec 21 was on the Section line.

The witness corner near the NE cor Sec 14 was not on the Section line.

Distance and direction was measured from each witness corner to the respective regular corner

Explain the procedure to re-establish the indicated corner.

(a) N1/4 Sec 20

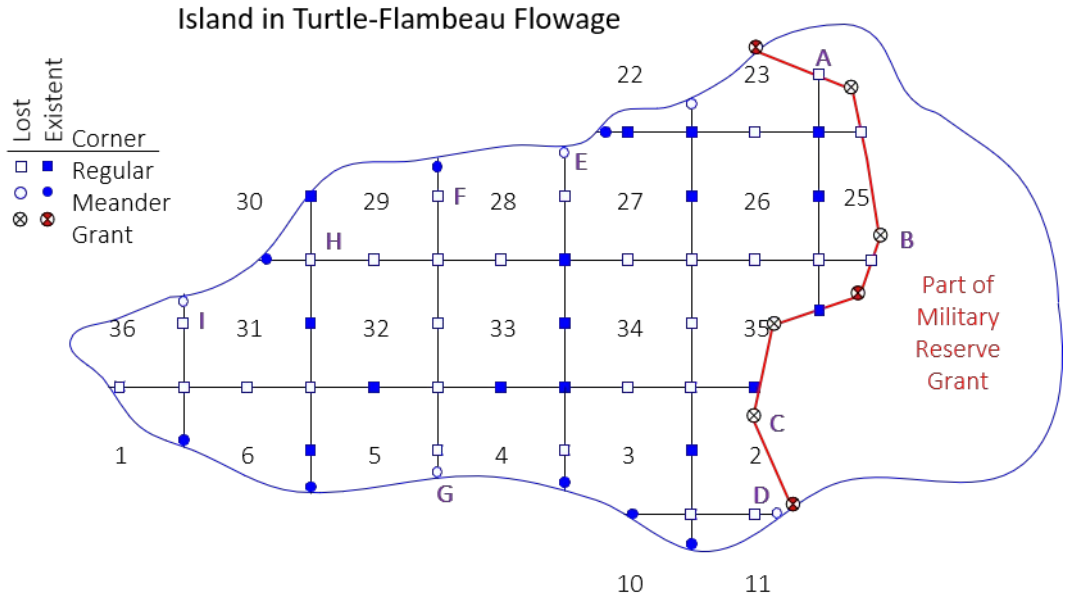
(b) NE Sec 16

(c) W1/4 Sec 13

(d) E1/4 Sec 24

(e) N1/4 Sec 22

Exercise 3



Explain procedure to re-establish the point labeled:

A.

B.

C.

D.

E.

F.

G.

H.

I.

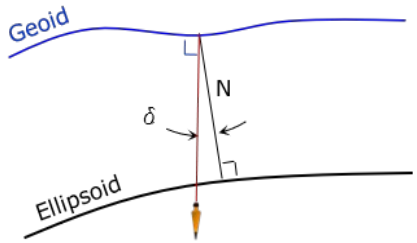
Appendix A: LaPlace Correction

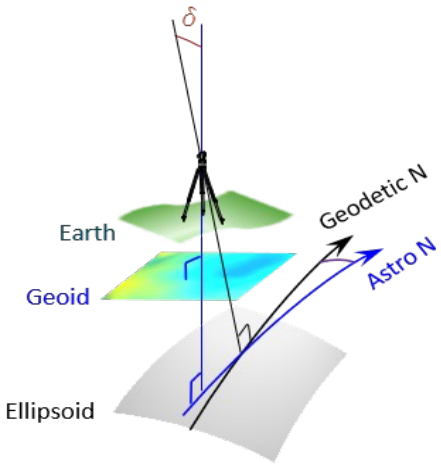
Manual of Surveying Instructions 2009

> 2-3 The direction of each line of the public land surveys is determined with reference to the true meridian as defined by the axis of the earth's rotation. The true meridian is a line along a meridian of longitude. Historically, determination of the true meridian has been based upon direct astronomic observation at the point of record and, thus, an astronomic meridian. The value of the angular difference between the astronomic and geodetic direction, caused by the deflection of the vertical, relates the astronomic meridian to the geodetic meridian, as properly aligned with the axis of the earth's rotation.

The *Manual* equates Astronomic and True Norths. Astronomic and Geodetic North are related by the "deflection of the vertical." This is the angle, δ, between the Normal (N, the line perpendicular to the ellipsoid) and the direction of gravity at a point. It is an indication of the skewness of the two surfaces.

Astronomically determined True North is referenced to the geoid, Geodetic North is referenced to the ellipsoid. There is a slight angular separation between the two called the *LaPlace Correction* cause by the deflection of the vertical.





Generally small in most areas, the LaPlace Correction can be over 20" in some areas of greater mass anomalies affecting gravity.

Astronomic and Geodetic directions are related by:

$$Astro\ Az = Geodetic\ Az + (\eta \times \tan(Lat))$$

$\eta \times \tan(Lat)$: LaPlace Correction

The LaPlace Correction can be computed using *DEFLEC18*[1] in NGS' *Geodetic Toolkit*[2] or obtained from a datasheet of a nearby control point.

If the LaPlace Correction is small enough, Geodetic and True North can be considered the same:

$$Grid\ Az = True\ Az - \gamma$$

[1] *DEFLEC18* was the model when this paper was written.

[2] https://geodesy.noaa.gov/TOOLS/

Appendix B: Irregular Boundary Adjustment

Procedure

An irregular boundary adjustment consist of four distinct steps, although some step contain some degree of computations.

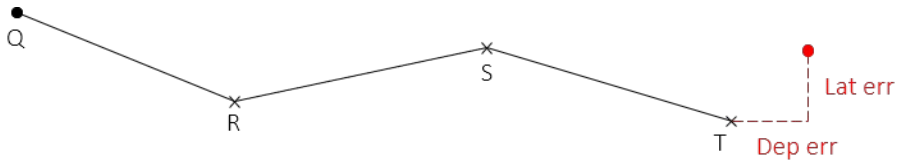
When performing computations with traverses, cardinal components are Latitudes (Lat; N-S) and Departures (Dep; E-W).

$$\text{Lat} = \text{L} \times \cos(\text{Dir})$$
$$\text{Dep} = \text{L} \times \sin(\text{Dir})$$

Step (1)

Starting at one existent monument, run a survey using record distances and directions, staking each point, toward the second existent monument.

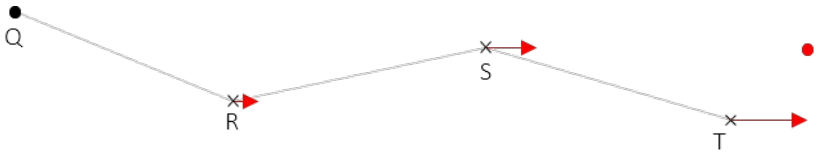
At survey completion, measure E-W and N-S components from the last surveyed point to the second existent monument. These are the Dep err and Lat err, respectively.



Dep and Lat errors are expressed as from the traverse point to the known point. In the diagram above, the Dep err is positive and the Lat err is positive.

Step (2)

Single Proportionate Measurement (SPM) in the direction of survey.



This traverse uses Deps as cardinal components for proportioning.

Step (3)

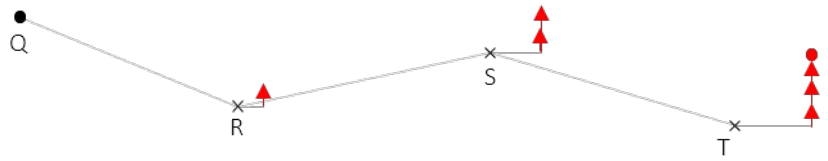
Compass Rule adjustment in the other cardinal direction.

The position shift at each point is cumulative. For example:

The position shift at R is the Lat correction for line QR.
The shift at R affects the line R to S, so the shift at S is the Lat correction for line QR plus the Lat

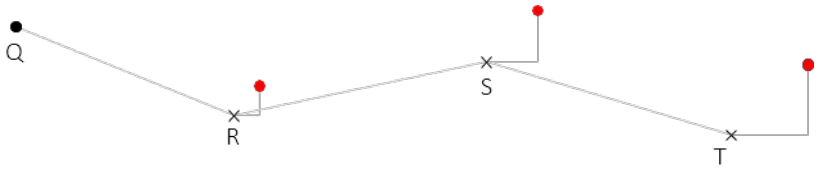
correction for line RS

and so on.



Step (4)

Using the corrections computed in Steps (2) and (3), re-establish the lost corners from the corresponding traverse points.



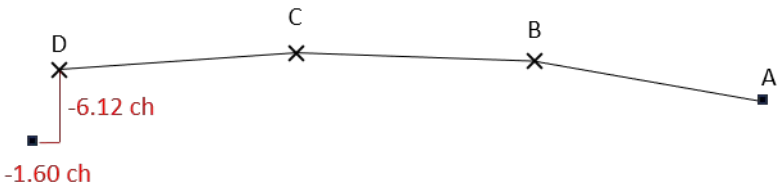
These positions can also serve as corner search areas. If insufficient evidence is found to identify as an otherwise existent or obliterated corner, the position is accepted as a lost re-establishment.

Example

Record data

Line	Bearing	Len (ch)
A-B	N80°00'W	39.82
B-C	N88°00'W	40.00
C-D	S86°00'W	40.00

Step (1) Record Survey



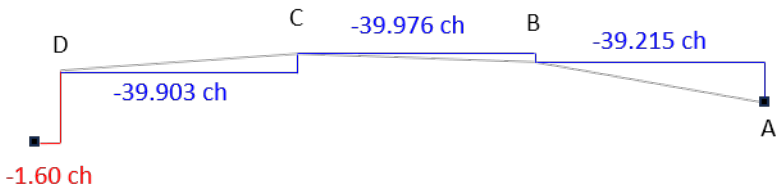
The Lat and Dep errs are intentionally large to better demonstrate the procedure and computations.

Step (2) SPM in direction of boundary

Compute Latitudes and Departures to obtain cardinal equivalents for each line

Line	*Bearing*	*Len (ch)*	*Lat*	*Dep*
A-B	N80°00'W	39.82	+6.915	-39.215
B-C	N88°00'W	40.00	+1.396	-39.976
C-D	S86°00'W	40.00	-2.790	-39.903
	sums:	119.82	+5.521	-119.093

Appendices



Total record E-W distance is the sum of the record Deps.:-119.093

The total measured E-W distance is the sum of the record Deps *plus* the Dep Err:

-119.093-(-1.60) =-120.694

Proportions – Distances to each point from A:

$$d_B = -39.215 \times \frac{-120.694}{-119.093} = -39.742$$

$$d_C = (-39.215 - 39.976) \times \frac{-120.694}{-119.093} = -80.256$$

$$d_D = (-39.903 - 39.215 - 39.976) \times \frac{-120.694}{-119.093} = -120.694$$

E-W Shift at each point:

Pt	*E-W Shift*
B	-39.742- (-39.215) =-0.527
C	-80.256- (-39.215-39.976) =-1.065
D	-120.694- (-39.215-39.976-39.903) =-1.600

Step (3) Compass Rule adjustment – N-S

$$(\text{Lat corr'n})_{i-j} = L_{i-j} \times \left[\frac{-6.12}{119.82}\right]$$

Line	*Len*	*Lat*	*Lat corr'n*	*Point*	*N-S shift*
A-B	39.82	+6.915	-2.034	B	-2.034
B-C	40.00	+1.396	-2.043	C	-2.034-2.043 =-4.077
C-D	40.00	-2.790	-2.043	D	-4.077-2.043 =-6.120

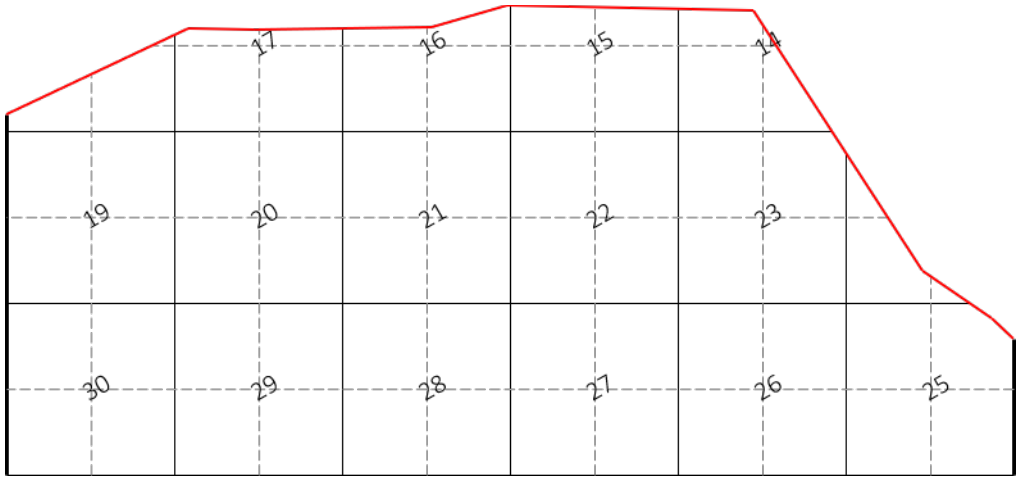
Step (4) Re-establish Lost Corners

Use the point shifts from Steps (2) and (3) as cardinal distance measurements from traverse points to respective lost corners

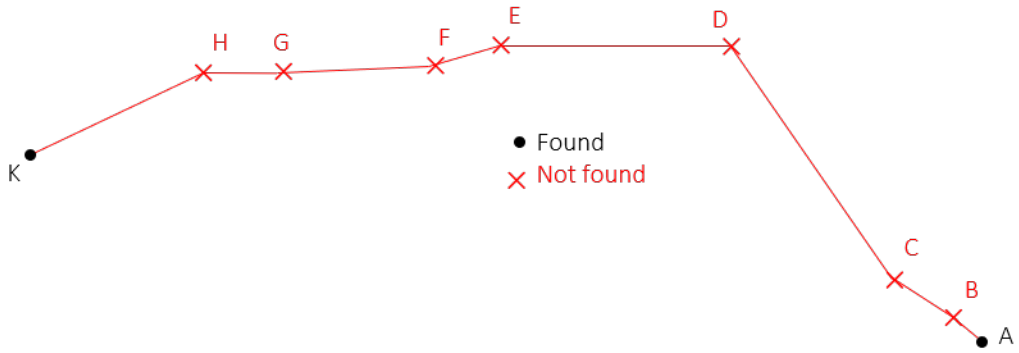
	Measure	
From	*E-W*	*N-S*
B	-0.527	-2.034
C	-1.065	-4.077
D	-1.600	-6.120

Appendix C: Grant Boundary

A Township and its Sections intersect a grant boundary from the south

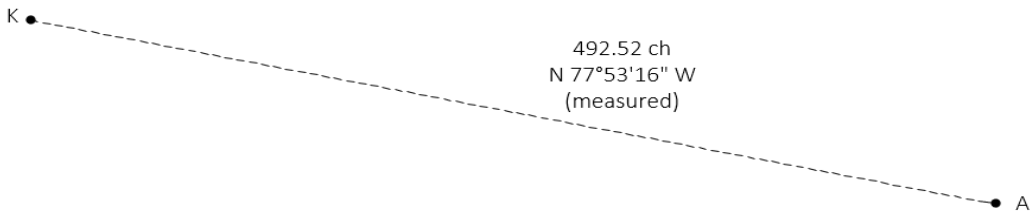


Two existent grant boundary corners are found where the boundary intersects the east and west Township lines. There are seven intermediate angle points which have not been located.



The angle points must be found or restored to re-create the grant boundary

Step (1) Measure Between the Found Corners



Step (2)

Use the record dimensions to compute a preliminary grant boundary between the found corners.

$$Lat = Dist \times \cos(dir) \qquad \text{N(+); S(-)}$$
$$Dep = Dist \times \sin(dir) \qquad \text{E(+); W(-)}$$

	Record			
Line	Bearing	Dist (ch)	Lat	Dep
A-B	N50°W	13.03	8.376	-9.982
B-C	N57°W	35.77	19.482	-29.999
C-D	N35°W	132.57	108.595	-76.039
D-E	West	107.32	0.000	-107.320
E-F	S73°W	34.09	-9.967	-32.600
F-G	S88°W	77.10	-2.691	-77.053
G-H	West	28.30	0.000	-28.300
H-K	S64°W	88.84	-38.945	-79.849

Step (3) Determine rotation and scale.

The grant boundary must be fit to the two existing corners.

From the data in Step (2), compute the record length and direction between the two found corners.

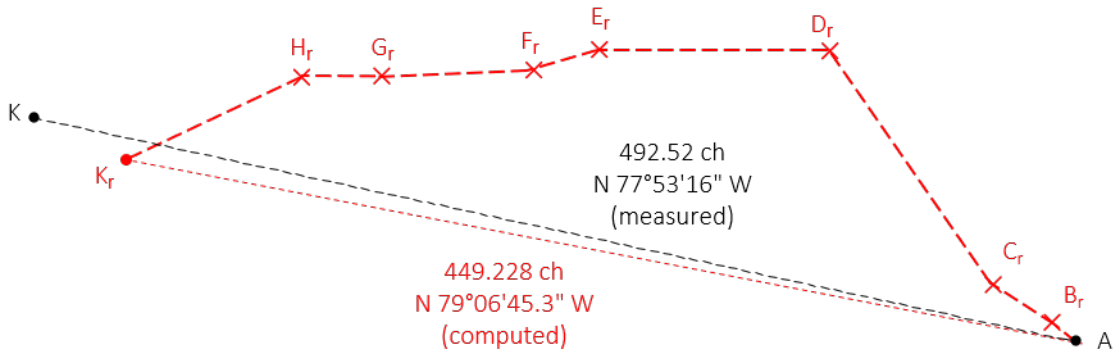
$$\sum Lat = +84.850$$

$$\sum Dep = -441.142$$

$$Dist = \sqrt{(+84.850)^2 + (-441.142)^2} = 449.228$$

$$\theta = \tan^{-1}\left[\frac{-441.142}{+84.850}\right]_{N}^{W} = -79°06'45.3''$$

$$Brng = N79°06'45.3''W$$



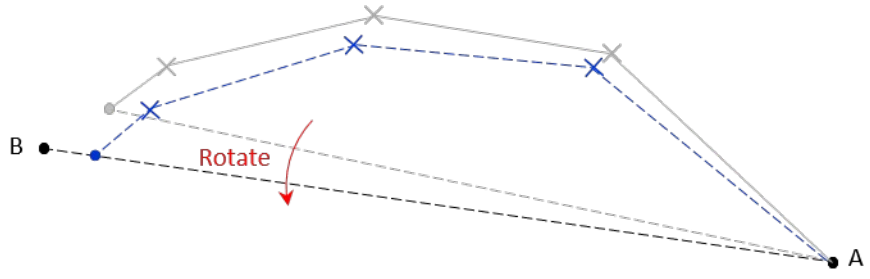
Using line bearings, compute the rotation angle at A: $\rho = 79°06'45.3'' - 77°53'16'' = 1°13'29.3''$

Using the lengths of lines AK_r and AK, determine how much the record traverse must be scaled:

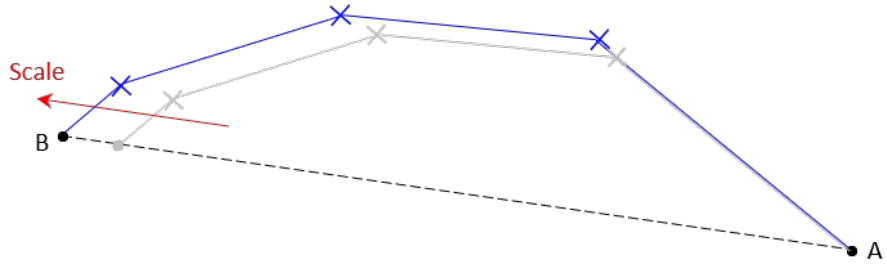
$$s = \frac{AK}{AK_r} = \frac{492.52}{449.228} = 1.096370$$

Step (4) Create the Retracement Traverse

Rotate the record traverse 1°13'29.3" clockwise at point A so the closing line (AK_r) coincides with the line between found corners (AK). This changes each bearing 1°13'29.3". Some get numerically larger, other smaller. It depends on their quadrant.



Multiply each record distance by the scale, 1.096370.



This creates a retracement traverse with new bearings and distances. The shape and configuration of the original grant boundary is preserved by the retracement traverse.

	Retracement Traverse	
Line	Bearing	Dist (ch)
A-B	N48°46’30”W	14.29
B-C	N55°46’30”W	39.22
C-D	N33°46’30”W	145.34
D-E	N88°46’30”W	117.66
E-F	S74°13’30”W	37.37
F-G	S89°13’30”W	84.53
G-H	N88°46’30”W	31.03
H-K	S65°13’30”W	97.40

Step (5) Stake the Retracement Traverse

The retracement traverse points are search areas for the original angle points. If they cannot be found or recreated as obliterated corners, they are re-established as lost corners using the retracement points locations.

Step (6) Close Section Lines on the Grant Boundary

The grant boundary is a senior line; Section lines must terminate on the grant boundary. Re-establishing corners on the boundary is done similar to re-establishing corners on a correction line. Existing corners short or long of the grant boundary are used to control closing line directions. This is true for east-west as well as north-south lines.

Appendix D: Latitudinal Lines

A. Introduction

Specific east-west PLS lines were run as true lines of latitude making them curved. Single Proportionate Measurement (SPM) re-establishes a corner on a straight line between the controlling points. To maintain the latitudinal curve, the corner must be offset to the south.

2009 Manual Section 7-17.

> In order to restore a lost corner on a line by single proportionate measurement, a retracement is made connecting the nearest identified corners on the line. These corners control the position of the lost corner. The lost corner is then reestablished at proportionate distance on the line connecting the recovered corners. Proper adjustment is made on an east and west line to secure the latitudinal curve. Any number of intermediate lost corners may be located on the same plan.

Under the *1973 Manual*, offsets were computed using the *Standard Field Tables and Trigonometric Formulas* publication. Besides chord-to-arc offsets, the *1973 Manual* also explained how to run parallels of latitude by the Secant and Tangent offset methods.

From Section 2-18 of the *2009 Manual*:

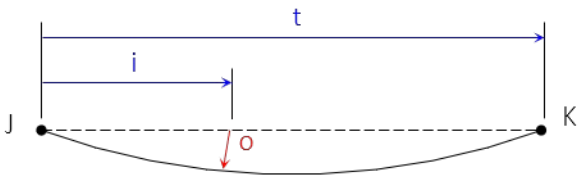
> Often referred to as the correction or adjustment for curvature, the effect can be very large at higher latitudes.
>
> For example:
>
> > At latitude 45° N., it is 52" (seconds) per mile of departure. The adjustment for curvature, at the midpoint of a parallel of latitude line 1 mile in length, at latitude 45° is 0.3 lks. dist.
> >
> > For latitude 70° N., it is 2' (minutes) 23" (seconds) per mile of departure. The adjustment for curvature, at the midpoint of a parallel of latitude line 1 mile in length, at latitude 70° is 0.7 lks. dist.

Despite Sections 2-18 and 7-17, the *2099 Manual* doesn't explain *how* to compute offsets. This appendix briefly describes the geometry and equations to compute chord-to-arc offsets.

B. Geometry

The size of a chord-to-arc offset is a function of three things:

latitude
chord distance between control points; t
distance along the chord to offset point; i



The offset is True S so it is perpendicular to the chord only at its midpoint.

The radius, which is constant for a latitude, is determined using the geometry of the GRS80 ellipsoid[1].

The latitudinal radius, R_P, is computed from this set of equations[2]:

$$e = \sqrt{1 - \frac{b^2}{a^2}}$$

$$R_p = \frac{a}{\tan(\phi)\sqrt{1 - e^2 \sin^2(\phi)}}$$

a Semi-major axis = 6,378,206.4 m
b Semi-minor axis = 6,356,583.8 m
ϕ Latitude
R_P Radius

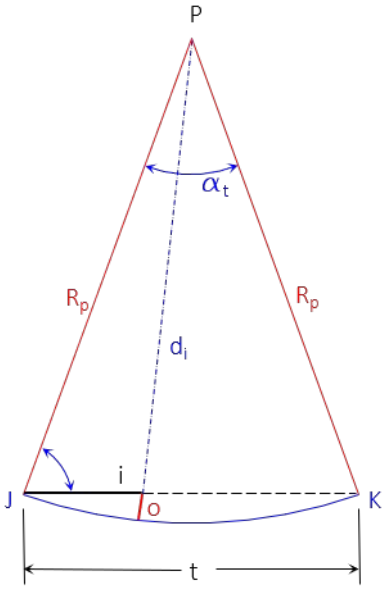
The offset is computed from these equations:

$$\alpha_t = 2 \times \sin^{-1}\left[\frac{t}{2 \times R_p}\right]$$

$$J = 90° - \frac{\alpha_t}{2}$$

$$d_i = \sqrt{i^2 + R_p^2 - 2(i)(R_p) \times \cos(J)}$$

$$o = R_p - d_i$$



t Length of latitude chord
i Distance along latitude chord
o Chord-arc offset at distance i

For SPM, points J and K are the control points; corners in between are lost

[1]The examples in Section 2-19 of the *2009 Manual* are based on the Clarke 1866 ellipsoid used for NAD27. NAD27 has been replaced with NAD83 which uses the GRS80 ellipsoid. Because their semi-major and-minor axes are within a few hundred meters of each other, either can be used with the same offset results.

[2]An *Excel* spreadsheet, *Latitude_Offset.xlsx*, to perform the calculations is available in the *Seminars* section at jerrymahun.com.

C. Example

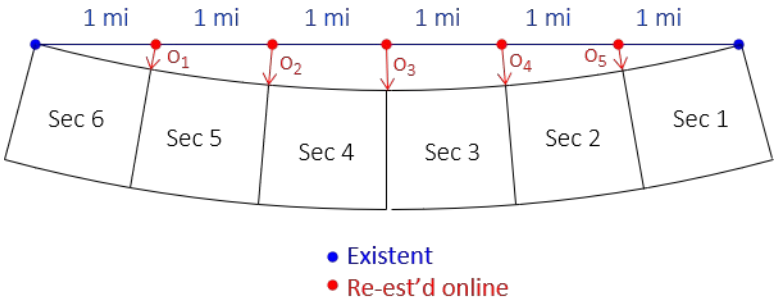
To demonstrate the offset magnitudes, two examples at two different latitudes are computed.

The two latitudes are of Wisconsin's Base Line at the south and the last full Township boundary at the north

1. Township lines offsets

Using Township corners for control; Section corners between them are lost.

(Quarter corners not included in this example)



Latitude \ Dist	*1 mi*	*2 mi*	*3 mi*	*4 mi*	*5 mi*
46°50'57"	3.6	5.7	6.4	5.7	3.6
42°30'23"	3.1	4.9	5.5	4.9	3.1

Dist is the distance from the east end of the Township line.

Note the offsets are symmetric about the chord middle.

2. Section line offset

The offset at a quarter corner between two found Section corners is 0.2 ft at both latitudes.

D. Summary

The arc-to-chord offset can be significant depending on a number of factors. Should it be applied? It depends on the particular situation and offset amount. If it is applied, it should be documented in the monument as it constitutes part of the lost corner re-establishment procedure.