ELEMENTS OF SURVEYING

FOR CADASTRAL MAPPING

Chapter 4

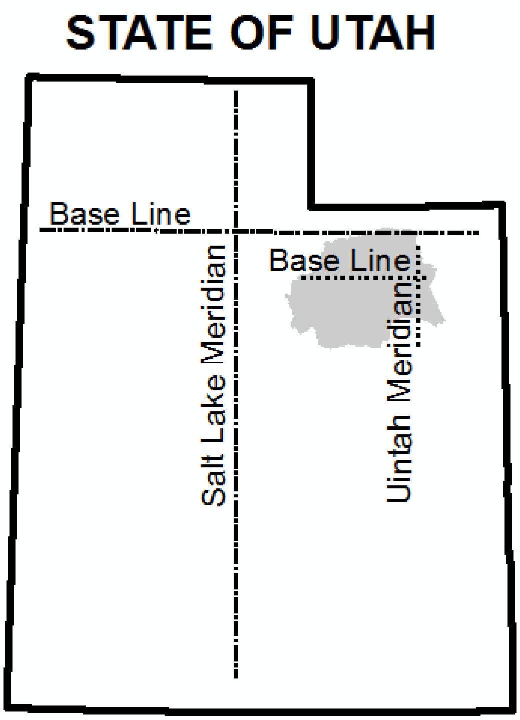
2015 Cadastral Mapping Manual

Elements of Surveying and Mapping

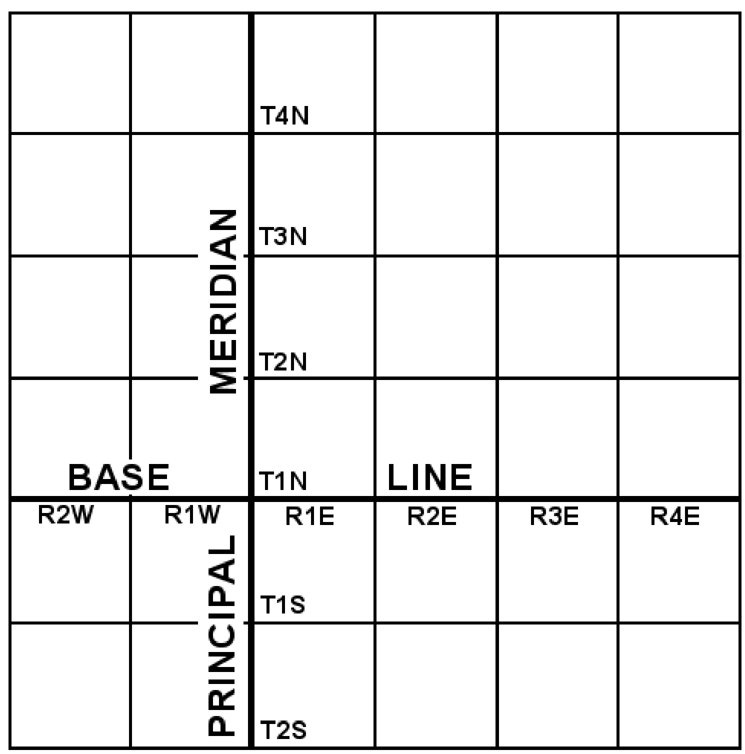
Utah's system of land surveying is the rectangular survey system as set forth on May 20, 1785 by the Continental Congress. Subsequent legislation and regulations have added refinements.

Under the rectangular survey system the State of Utah is plotted into a grid of squares, six miles to each side, called "Townships".

These Townships are determined from an initial point of intersection of a north-south line and an east-west line. The north-south line is called a Principal meridian and is identified by a name - The Salt Lake Meridian, for example. The east-west line becomes the base line for that Meridian. The State of Utah has two (2) principal meridians, the Salt Lake Meridian and the Uintah Special Meridian (shown in grey).

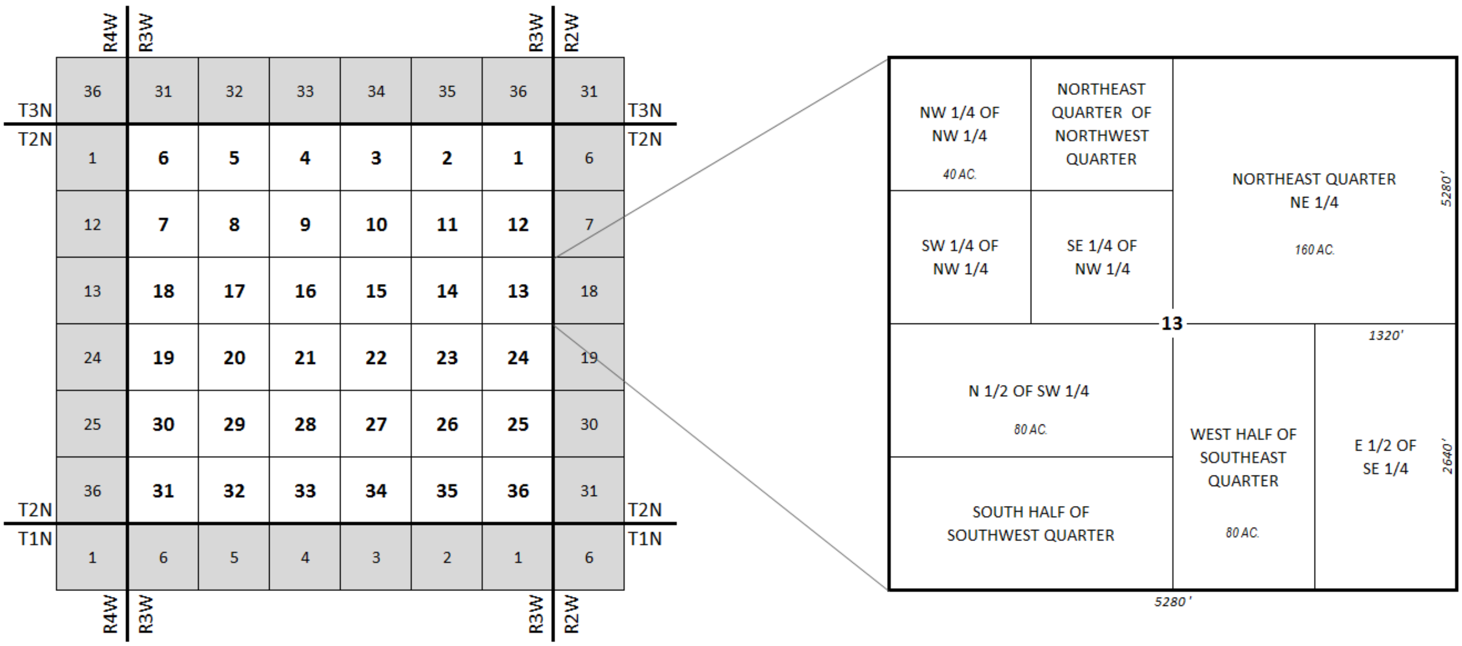


Working along the principal meridian and base line, the townships are set at six (6) mile intervals, and then by extension, the townships are marked off into a grid. Each of the six (6) mile squares is a township of 36 square miles or approximately 23,040 acres. Any specific township can then be located according to its relationship to the appropriate meridian and the base line.



See the end of this chapter for or more information on the Public Land Survey system and Section Township and Range

The township is further divided into sections of 1 mile squares containing 640 acres. Individual sections are identified by a numbering system that starts with section 1 in the northeast corner of the township and ends with section 36 in the southeast corner.

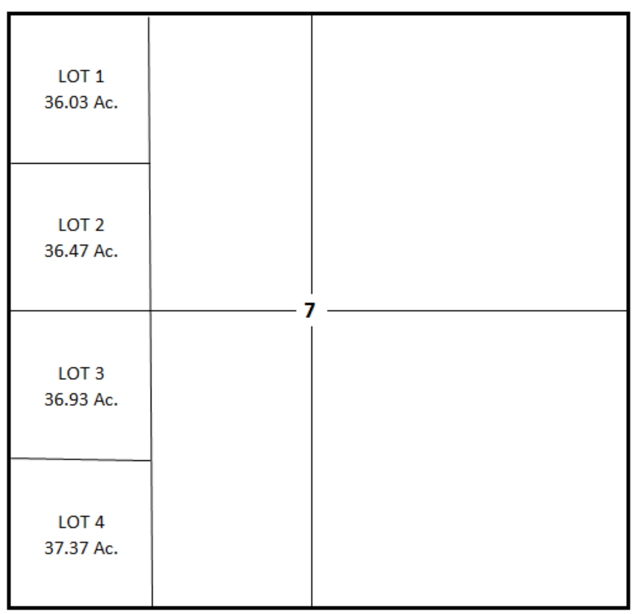


T 2 N, R 3 W S.L.B. & M.

The sections can be further subdivided into quarter sections of 160 acres. Quarter sections can be divided into half quarters of 80 acres or into quarter-quarter sections of 40 acres, etc.

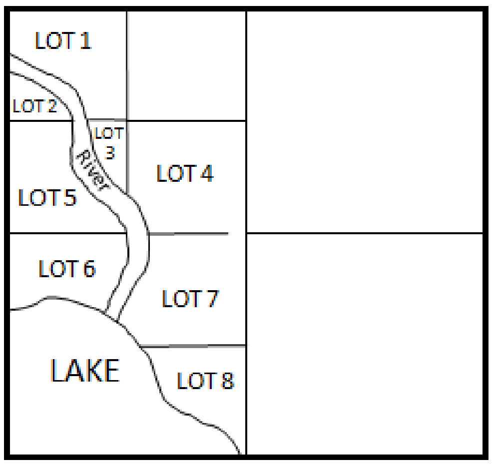
These portions of sections can easily be described in short form with the name of the base and principal meridian “NE1/4 NW1/4 Sec. 13, T 2 N, R 3 W. S. L. B. & M.

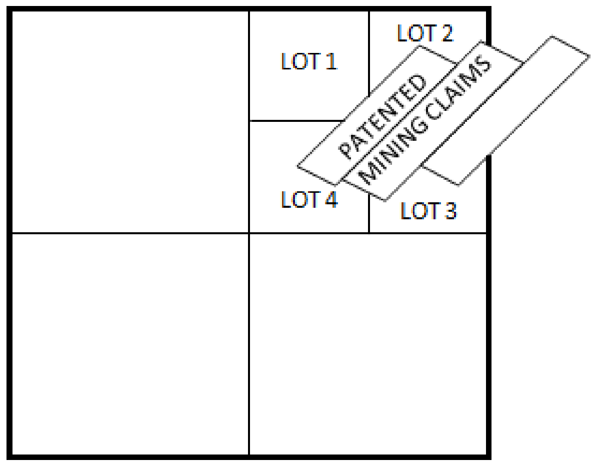
Fractional or aliquot parts of sections can be legally and correctly described as lots to make up for surpluses and shortages. These types of lots are frequently used on the west and north edges of townships to take up surpluses and shortages as shown below.



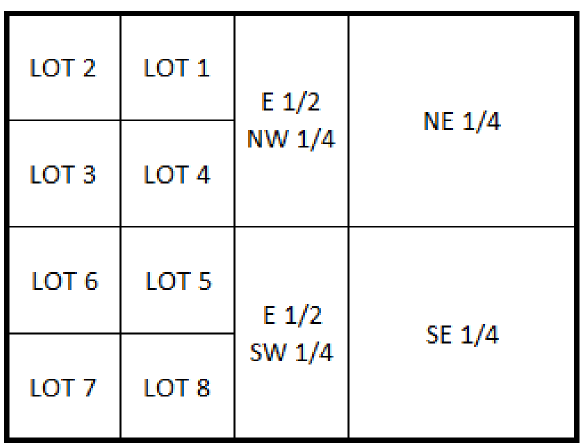
Special surveys may involve areas of land that are not aliquot parts of sections but are designated as lots or tracts. In common usage the term "tract" is applied to an expanse of land of no particular size, often irregular in form. In modern public land surveys the term is used specifically to mean a parcel of land that lies in more than one section or that cannot be identified in whole as a part of a particular section. It is properly described by tract number and township. Tracts within a township are numbered beginning with 37 or the next highest unused numerical designation to avoid confusion with section numbers.

Section lots are also used to describe parts of fractional sections remaining after portions are removed to lakes, navigable rivers, patented mining claims, farm lots, reservations, etc. The following are examples:

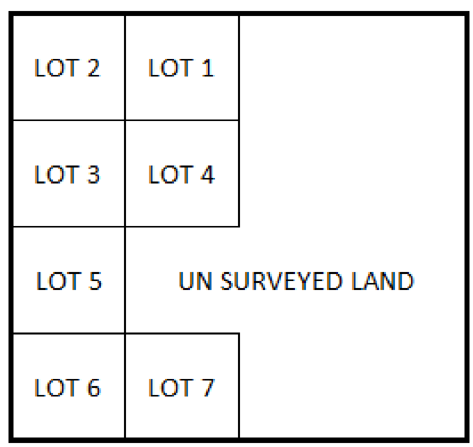




Sectional lots are used to fill out excessively oversized sections (or sections that are only partially surveyed). The following are examples:



AN OVER SIZED SECTION



A PARTIALLY SURVEYED SECTION

In a legal description, a section lot can be described as follows: Lot 2, Section 16, T.6 S. R.13 W. S.L. B. & M.

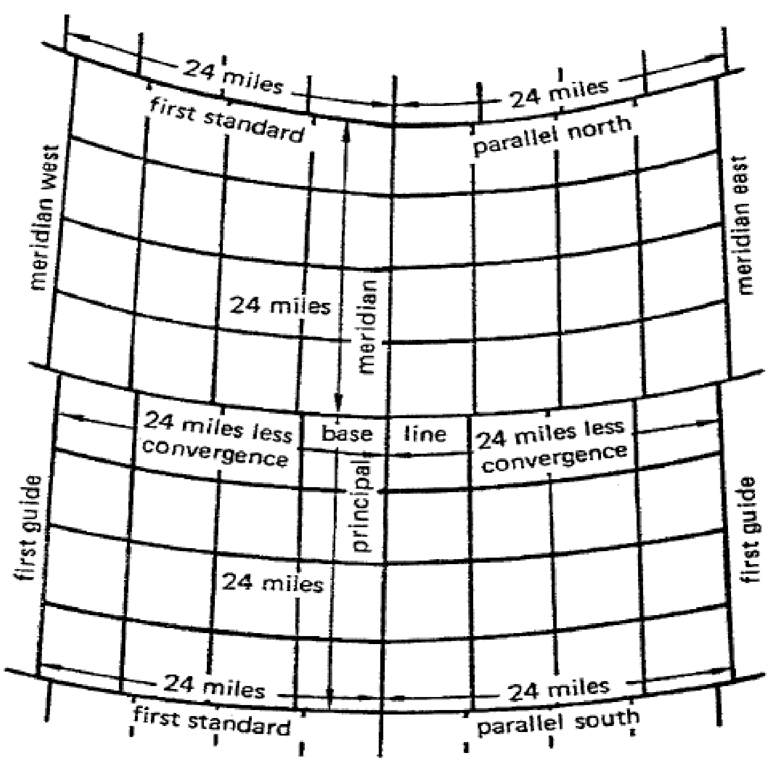
Adjustments for Earth's Curvature

All north-south township lines are true meridians (ie. They are longitude lines). All east-west township lines are latitude lines. Because of the shape of the Earth and the fact that townships lines point toward the north pole, the north end of a township is more narrow than the south end. This difference is compensated by establishing section lots (irregularly sized fractions of sections) along the west side of the township. Compensation is also made along the north side of the township.

Changing error compensated

Chaining and convergence compensated

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



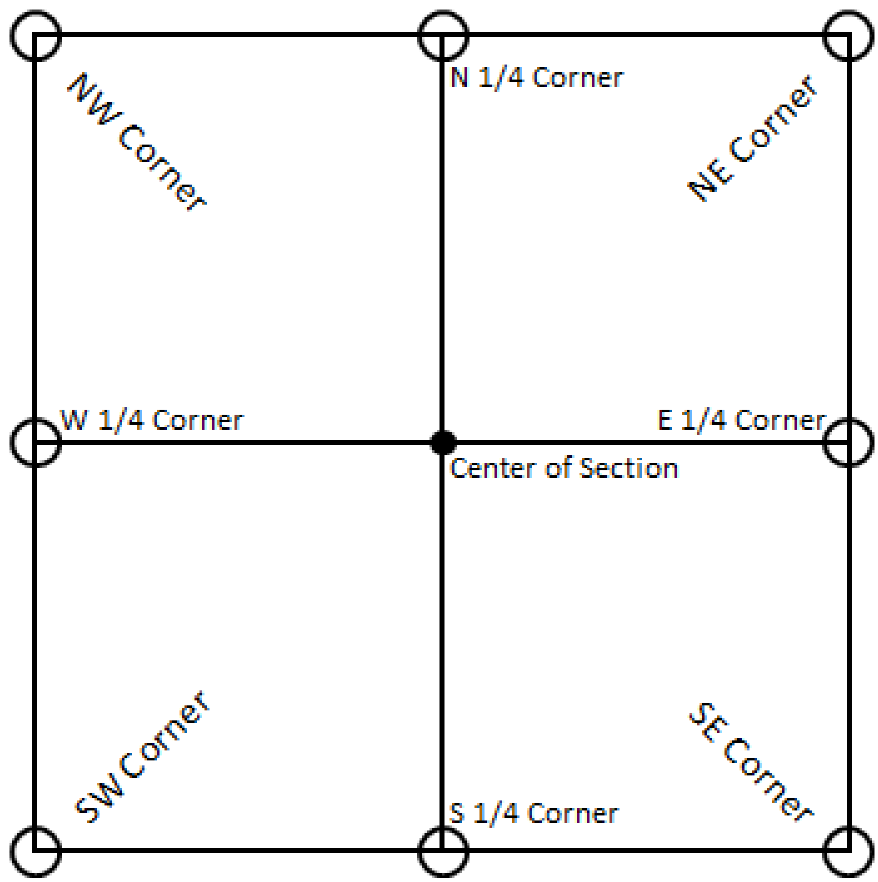
A quadrangle is twenty-four (24) miles square and consists of 16 townships. Because of the convergence of meridians, quadrangle corners do not coincide except along the principal meridian. Adjustments for the Earth's curvatures are made between quadrangles, but, normally within each quadrangle the township corners coincide.

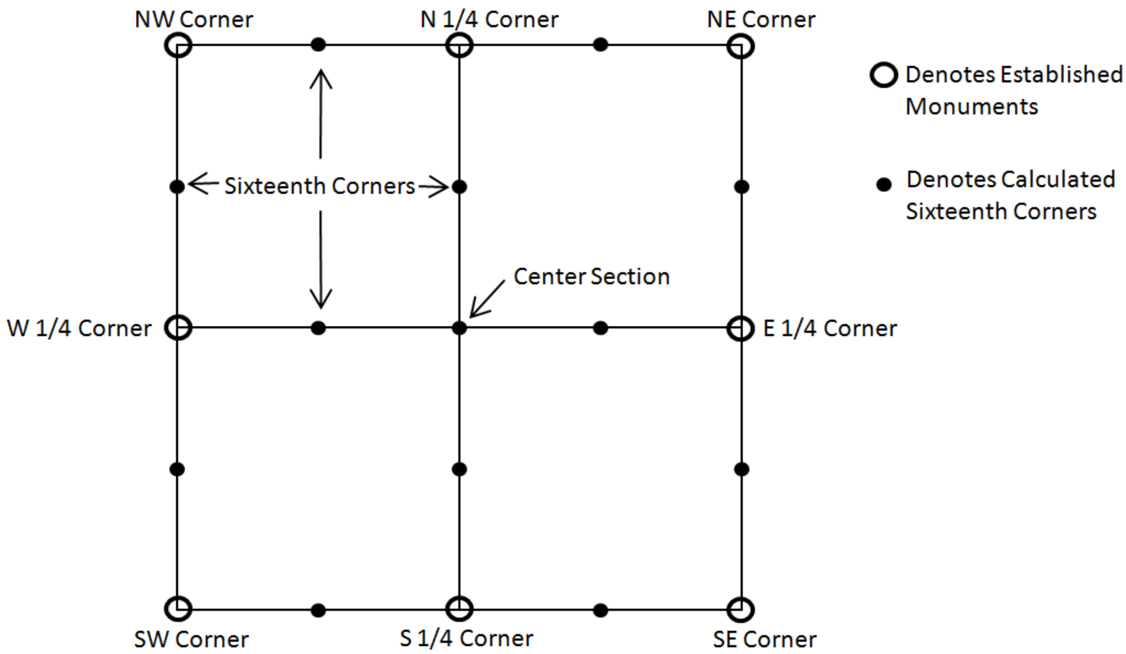
Fractional Division of a Section

For a regular section containing no sectional lots, the process of subdividing the section into quarter and quarter - quarters is as follows:

1. The section to be divided must have all section corner monuments and quarter corner monuments in place. There must be bearings and distances between the monuments around the perimeter of the section. You must be provided with or be able to calculate relative coordinates at each quarter corner.

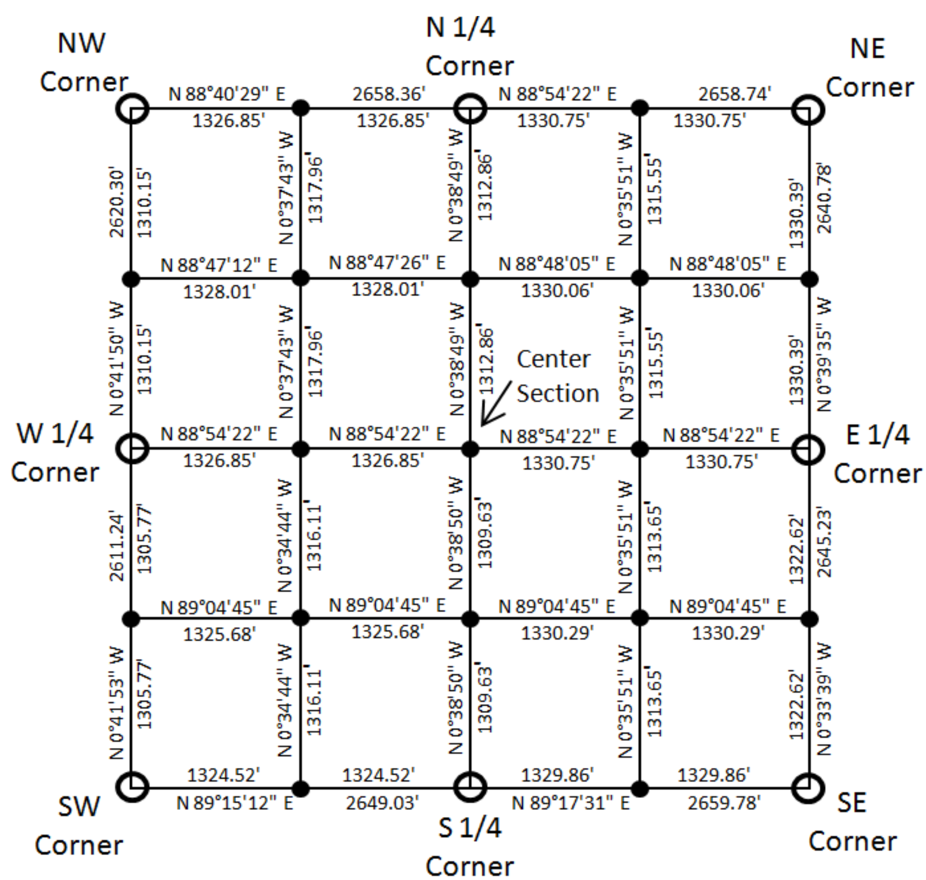
2. To subdivide a section into quarter sections, run straight lines from the established quarter section corners to the opposite quarter section corners. The point of intersection of the lines thus run will be the corner common to the several quarter sections, or the legal center of the section.





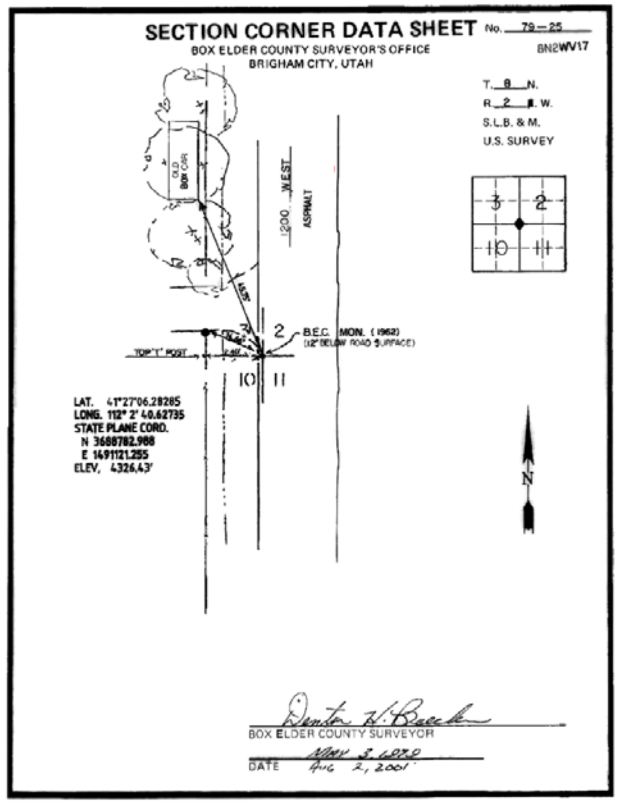
Sixteenth corners are located at mid-point along section and quarter section lines.

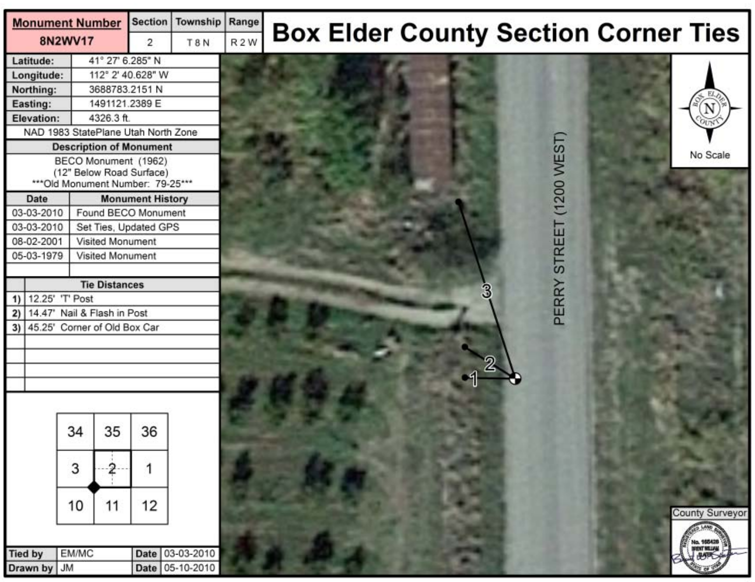
3. Preliminary to the subdivision of quarter sections into sixteenths, the sixteenth - section corners will be established at points midway between the section and quarter - section corners and between the quarter – section corners and the center of the section (As shown below). The lines connecting the sixteenth corners bisect each other. The following is a section divided into sixteenths.

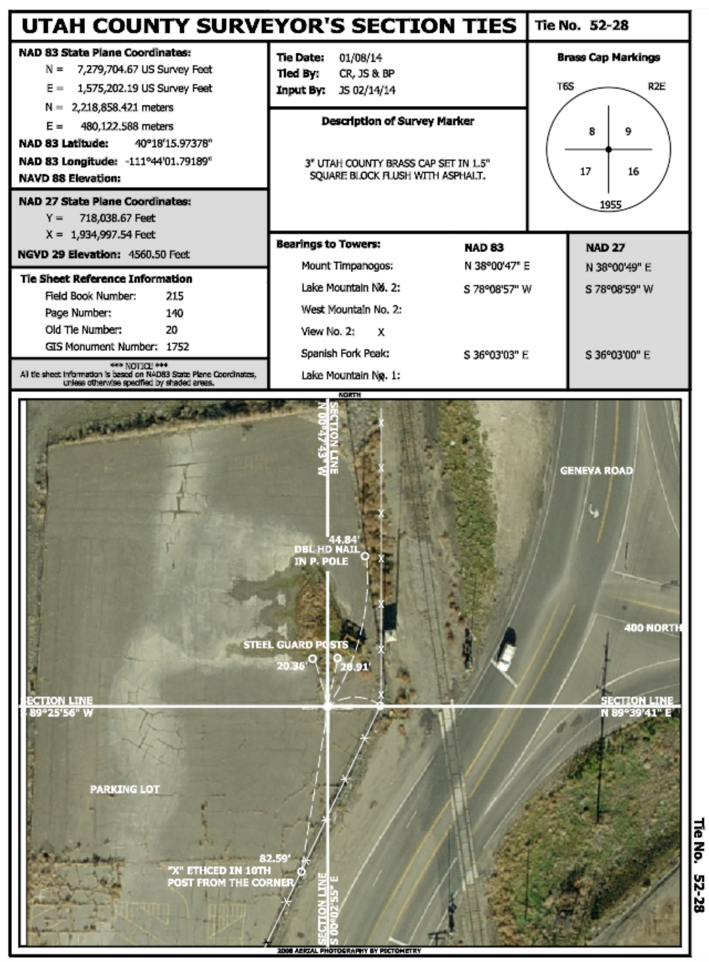


Any irregular sections, that is, those containing section lots or missing section corners or quarter corner monuments, should probably be deferred to the county surveyor for subdivision into fractional sections. If the burden for this type of subdivision falls on the Recorder, she/he should follow the principles outlined in chapter 3 of the manual of surveying instructions published by the U.S. department of the Interior, Bureau of Land Management or defer to the County Surveyor.

All section corners and quarter corners should be monumented on the ground with a corner monument, with the corner information stamped on the top. These monuments are used for measurement purposes to locate properties on the ground. The location of these corners is normally on file with the county surveyor of each county on section corner data sheets as shown.







Most government surveys show quarter sections and sections that measure exactly 2640 feet and 5280 feet on a side with interior angles of 90° and 180°. Unfortunately most sections vary greatly from these values and this causes many artificial overlaps and gaps to exist in the county recorder's maps. These problems can often be overcome by accurate surveys of existing sections corners by the county surveyor.

Re-surveys of this type have always been necessary to properly locate existing corners and to restore obliterated or lost original monuments. However, no resurvey can impair the bona fide land rights of affected claimants. Corners established in original surveys are forever fixed in position even though they may not fall precisely at a stated bearing and distance from a previous point. Many counties in the state of Utah are employing the State Plane Coordinate System. The major advantages of this system are:

1. There exists a consistent basis of bearing throughout the entire state coordinate system within a zone.

2. All of the monuments within the system are related to each other mathematically.

3. The use of state coordinates and state coordinate monumentation helps to eliminate the accumulation of error in long traverses.

4. A monument or a station with a state plane coordinate becomes a permanent monument in that it can be reestablished, if needed, from any other known monument having a state plane coordinate.

5. We are not limited in the position we select for a particular station or monument under the state coordinate system. The monument may be located anywhere. This makes it possible to locate monuments in convenient positions such as within roadways or sidewalks where they can be used without interference by buildings, structures, farming or other activities.

6. Once a station has been given a state coordinate it is not necessary to ever use that particular station again as long as it can be related to another station of known state coordinate in the same area.

7. A state plane coordinate system can be established and overlapped on the already existing sectional system.

Most of the disadvantages of the sectional system are overcome by utilization of the state coordinate system and the sectional system combined.

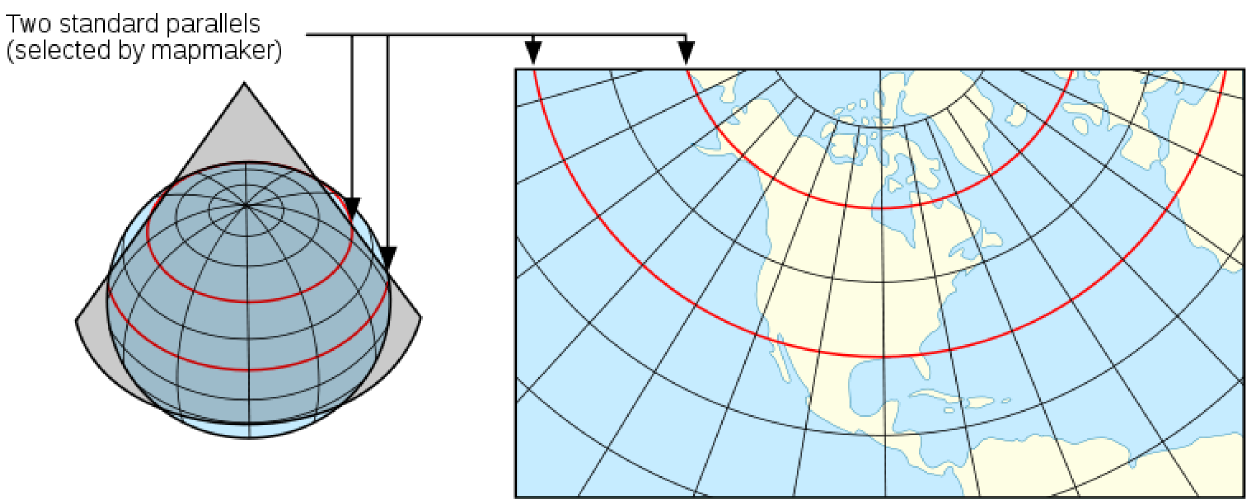
Basic Facts About the Utah State Coordinate System

Many people are under the impression that the use of the Utah State Coordinate System is difficult. This is not true. State coordinates are established for Utah by the coast and Geodetic Survey in such a manner that their utilization is simple and straightforward.

Some of the important facts that must be understood about the state coordinate system are as follows:

1. The Lambert Conformal Projection located on the sea level plane is used as the basis for establishing the Utah State Coordinate System.

LAMBERT PROJECTION CONE



2. All state coordinate meridians (north-south lines) are parallel to each other. All bearing are based on a central astronomic meridian bearing North. In Utah, the central meridian, where the astronomic bearing of North was established, is located at a longitude of 111° 30'. All bearings are based on right angles measured from this meridian.

3. X coordinates in the Utah State Coordinate System are East coordinates measured East from an X equals 0 base line located west of the state of Utah. The central meridian (longitude = 111° 30') is located at an X coordinate of 2,000,000.00 feet.

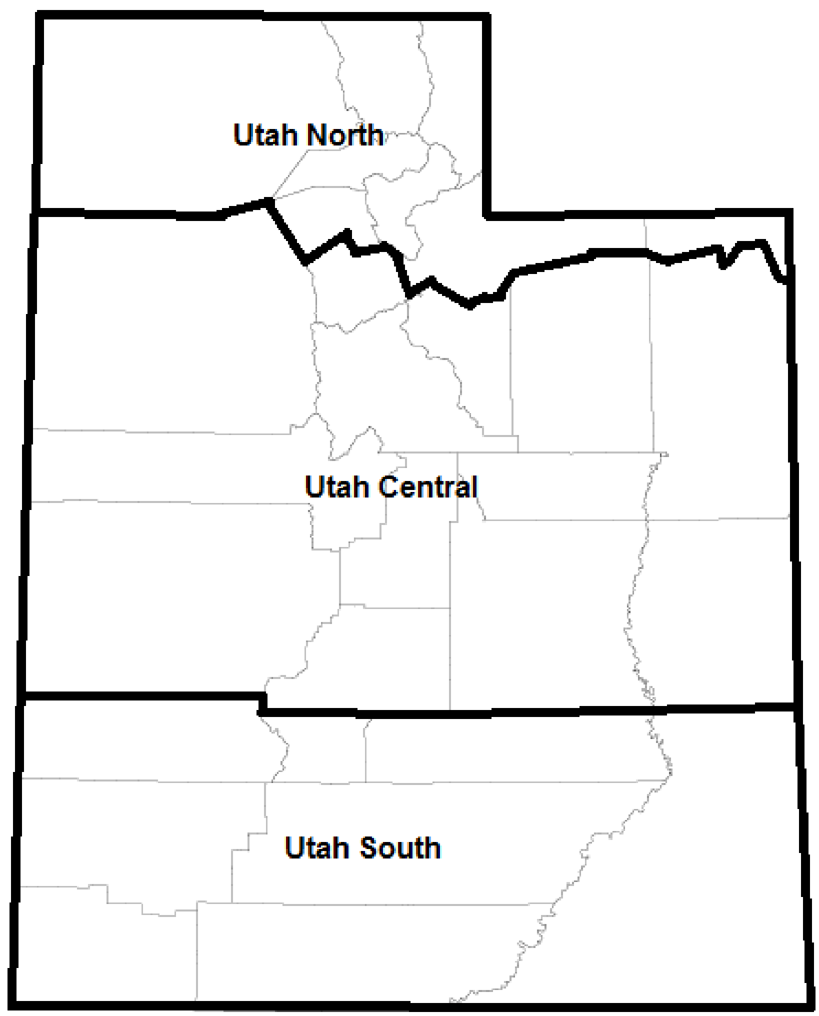
4. Y coordinates in the Utah State coordinate System are-North coordinates measured North from a Y equals 0 base line located south of any zone in the state of Utah. For better accuracy within the state of Utah there are three state coordinates zones in the North-South direction. These are the North, Central and South zones. In these zones, Y coordinates vary from about 70,000.00 feet to about 1, 000, 000.00 feet.

5. As a person travels north within a state coordinate zone, his state coordinate increases. If the travel is south the state coordinate decreases within the state.

6. As a person travels east within a state, his state coordinate increases. If the direction of travel is west within the state, the state coordinate decreases.

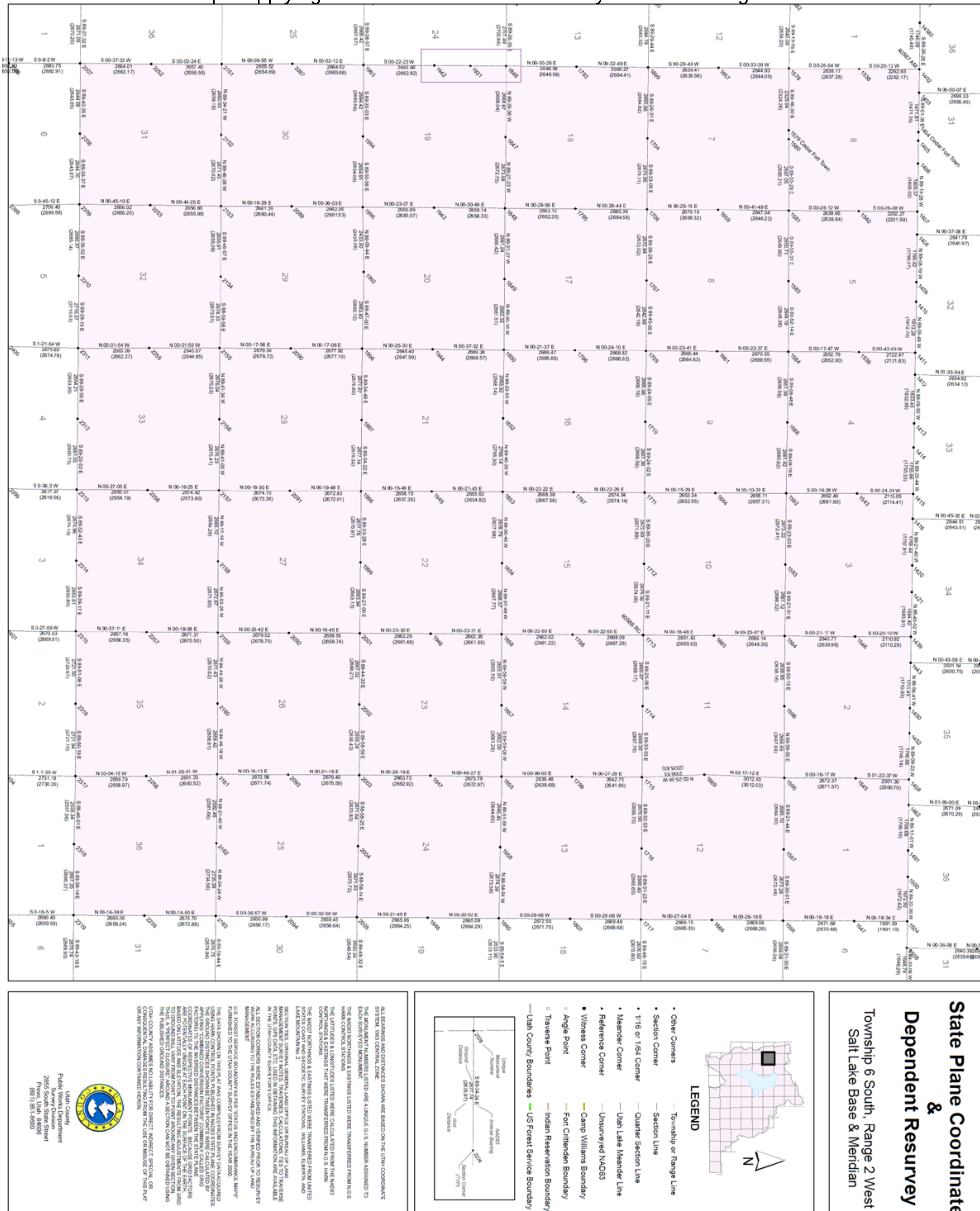
The accompanying illustration is a sketch of a state coordinate zone map which shows the location of the zones within the state of Utah with respect to the county boundaries. Some of the more important features of the basic coordinates system appear on the sketch shown.

STATE COORDINATE ZONE MAP FOR UTAH



See Title 57, Chapter 10 for Nad 83 definition and update on the Utah Coordinate System-statute.

Below is a sample applying the State Plane Coordinate System to existing monuments.



Survey Accuracy

The use of coordinate geometry in mapping allows the drawing of extremely accurate maps. If, however the deed's legal descriptions are inaccurate or the section monument's mathematical framework is not right, the resulting maps can be very confusing. Gaps or overlaps which may not exist will cloud the map. It may also prevent the mapper from being able to write accurate remnant descriptions when a parcel split occurs.

The legal description on deeds that we use in mapping to make up the taxing descriptions and construct our maps generally comes from land surveys performed by licensed land surveyors. To measure the bearings and distances between property corners, the survey instruments used are either:

1. A theodolite (for measuring bearings) and a chain, tape or an electronic distance meter.
2. A total station (an electronic distance meter which includes a theodolite).
3. G. P. S. (Global Positioning System).

The technologies in items 1 and 2 above are currently used by most land surveyors. Where it is practical, many surveyors are migrating to G. P. S. (item 3). To meet today's requirements for a higher degree of accuracy the whole field of surveying has improved.

1. Instrumentation has improved. The application of GPS into surveying equipment has improved accuracy a great deal.
2. The use of computers has allowed surveyors to use better survey techniques and adjust for error.
3. Stricter surveyor license requirements and periodic renewal of the licenses have helped produce much better surveyors.

Excluding GPS, standards of accuracy have been established and are as follows:

1. <u>First Order Accuracy</u> - one part in 25,000 parts or better. This order of accuracy is used in the accurate placement of survey control monuments (ie., section corners, street control monuments, etc...) or surveying valuable commercial property.
2. <u>Second Order Accuracy</u> - one part in 10,000 parts or better. This is the level of accuracy currently used for most private property surveys.
3. <u>Third Order Accuracy</u> - below one part in 10,000 parts. Many of the older surveys fall into this category.

It is not unusual for a surveyor to traverse from a section corner to a property corner and cover 5,000 feet in the process. If the level of accuracy is barely second order (one part in 10,000 parts) that point could be 0.50 feet off from the absolute location.

Mappers can locate points and lines on the computer or through calculations to within 0.01 feet or closer. In order to map this accurately, mappers do not have the constraints and challenges that a surveyor has surveying the real world. To expect two adjoining properties surveyed by two different surveyors to match up exactly mathematically is ludicrous. On the other hand if the difference is much more than 0.50 - 1.0 feet, there may be a problem with one or both of the surveys.

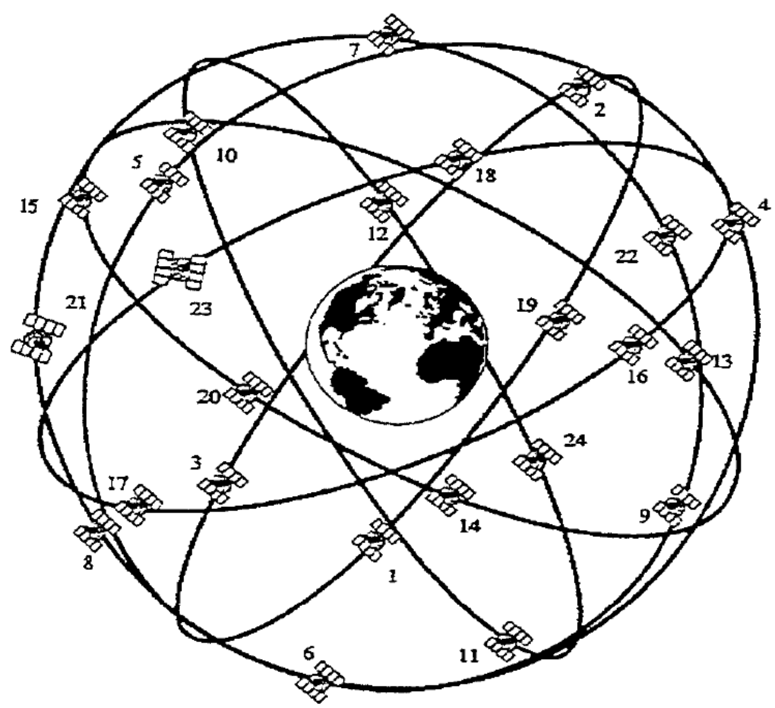
When comparing adjacent parcels which are surveyed from different section monuments (or city block corners), the results are only going to _bp.as accurate as the measured distances (and bearings) between the monuments. GLO (Government Land Office) published distances for sections are often 20 - 50 feet off from the accurately measured distances. In conclusion, a map can only represent property as correctly as the accuracy of the legal descriptions on the conveying documents and the mathematical accuracy of the framework of the section monuments or city blocks.

A computer is required to do coordinate geometry mapping precisely. If the data (deed descriptions and survey monument grid) to be mapped are accurate then the maps drawn up from it can represent the owner's title very precisely. The map becomes a valuable tool to surveyors, title companies, attorneys and land owners. If the data are inaccurate then, mapping that data precisely would give questionable results. Gaps or overlaps between properties would be suspect and the map could only be used as rough reference tool.

GPS

(Global Positioning System)

When people talk about "a GPS," they usually mean a GPS receiver. The Global Positioning System (GPS) is actually a constellation of Earth-orbiting satellites with originally 27 satellites. 24 were in operation with three extras in case one failed. The U.S. military developed and implemented this satellite network as a military navigation system, but soon opened it up to everybody else. In 1994 the U.S. Defense Department launched the last of the original 24 high orbiting satellites that make up the base of GPS Each of these solar-powered satellites circles the globe at about 12,000 miles per hour, making two complete rotations every day. The orbits are arranged in 6 orbits around the earth so that at anytime, anywhere on Earth, there are at least four satellites "visible" in the sky. With this full complement of satellites it is possible with the aid of receivers to locate specific positions anywhere in the world 24 hours a day.

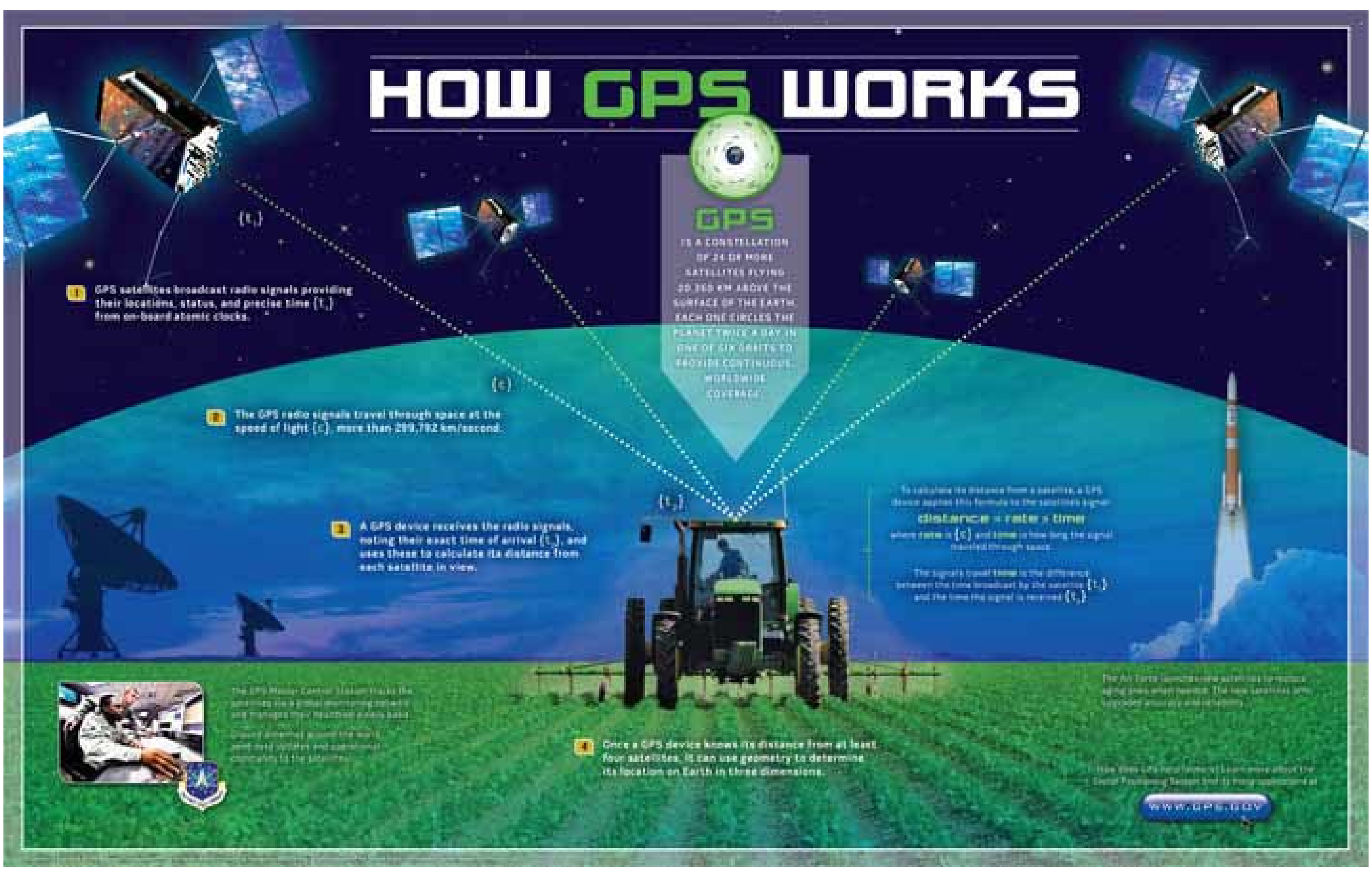


Since 1994 GPS has become more common place and more devices have GPS receivers. Additional newer satellites have been launched into orbit replacing most the original 27 and the GPS constellation is now a mix of old and new satellites. As of December 11, 2015, there were 31 operational satellites in the GPS constellation. This does not include the decommissioned GPS satellites ("residuals") kept in orbit in case there is a need to reactivate them.

Though GPS was originally created as a device for accurate navigation for the military, use for it outside the military is mushrooming. GPS receivers are becoming small enough and cheap enough to be carried by just about anyone and applications are almost limitless. Currently, a unit the size of a cellular phone can help guide outdoors men back to their vehicle. Some new automobiles have a GPS unit built in which can help guide emergency vehicles to it in case of an accident or emergency. Since the system can locate a point in three dimensions it could work as a traffic control device for aircraft as well. Almost all new Cellular phones have a GPS receiver enabling most

The GPS space segment consists of a constellation of satellites transmitting radio signals to users. The United States is committed to maintaining the availability of at least 24 operational GPS satellites, 95% of the time. To ensure this commitment, the Air Force has been flying 31 operational GPS satellites for the past few years.

For Official U.S. Government information about the Global Positioning System (GPS) and related topics visit **http://www.gps.gov/**

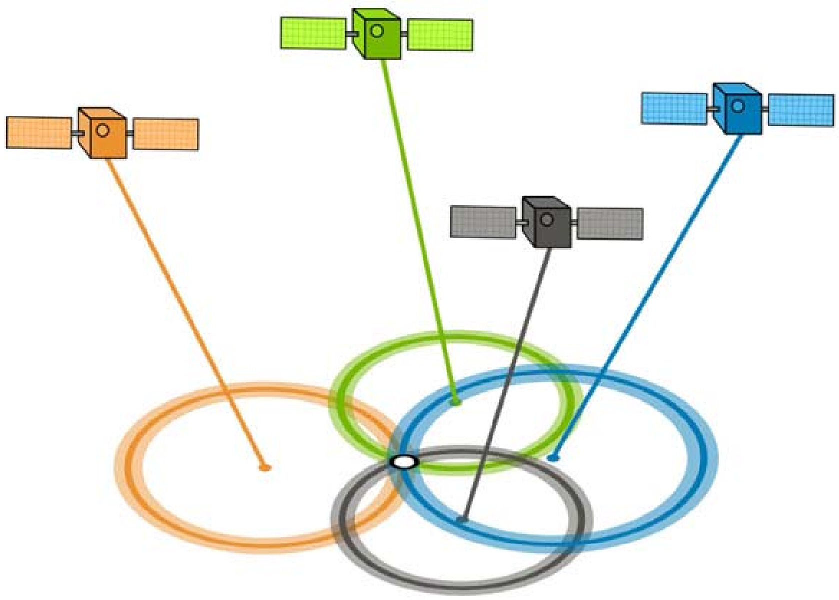


How GPS Works

GPS uses receivers on the earth's surface and orbiting satellites to exchange information and uses this information to deduce its own location.

If the receiver can receive signals, in an un-obstructed direct line between a satellite and the receiver from at least 4 satellites, the point or location of the receiver can be determined through triangulation. Receivers generally look to connect to more than 4 satellites to improve location accuracy and provide precise altitude information.

In order to make the simple location calculation the GPS receiver has to know two things; the location of at least four satellites in the sky and the distance between the GPS receiver and each of those satellites.

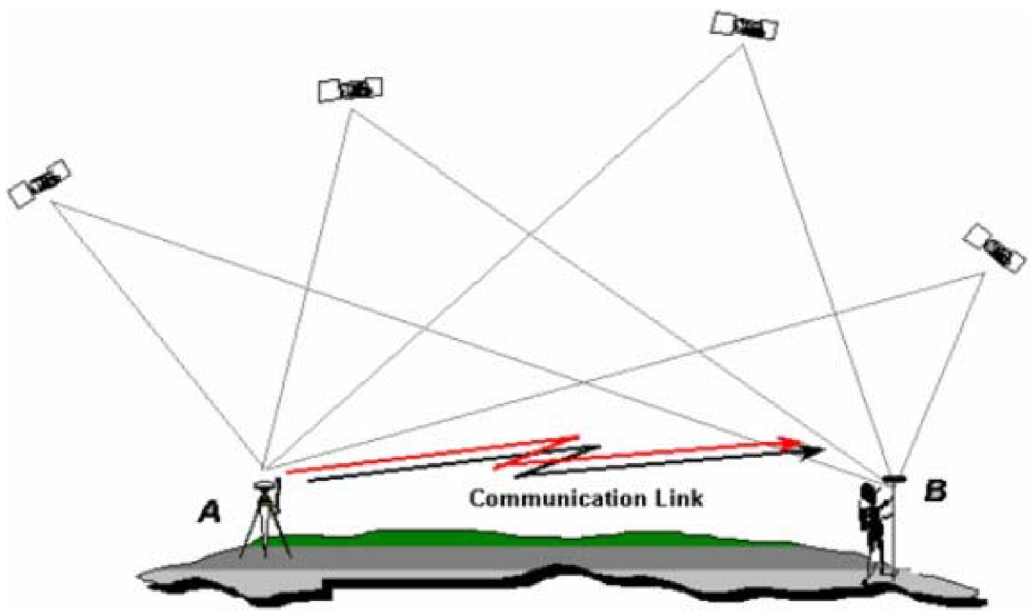


The GPS receiver figures both of these things out by analyzing high-frequency, low-power radio signals from the GPS satellites. Better units have multiple receivers, so they can pick up signals from several satellites simultaneously.

Surveying Using GPS

GPS Receivers that are more precise and accurate are now available to land surveyors. County Surveyors are using GPS to locate section corners and control monuments with a high degree of accuracy. Private land surveyors are using GPS to do property surveys. Unless you are surveying next to a building or steep mountain it is not a problem to receive signals from at least 4 satellites. In fact there are normally 6-7 or as many as 9 satellites accessible at any given time.

Because of changes in the atmosphere and ionosphere, radio waves from the satellites do not maintain a constant speed. The interferences make it difficult to get an exact distance. To adjust for these interferences, surveyors have two receivers. One is a stationary receiver called a base station. That stationary base station is set up on a known point, such as a survey monument, to act as a standard, and the other is a roving receiver used to locate the coordinates of the property corners.



A= Stationary Base Station Receiver B= Roving Receiver

The stationary receiver can make adjustments for the atmosphere interference to reflect the known coordinates on its monument. The stationary base station receiver then transmits those adjustments to the roving receiver so it can make those same adjustments and get a true reading of the coordinates for the property corners.

↑ Survey Controller

↑ GPS Base Station Receiver and radio transmitter

↑ GPS Rover Receiver

Some of the advantages to GPS surveying are:

1. One person survey crew. Only one person is required to locate the receiver over the survey monument or property corner to get a coordinate reading.

2. You do not have to be in line of sight view of a survey monument (nor do you need to traverse into the property from the survey monument).

3. You can survey in stormy or foggy weather or at night.

4. High degree of accuracy. Accuracy for most GPS surveys would be equivalent to first order survey accuracy obtained through the older survey technology. GPS actually establishes a new standard of accuracy in surveying. For a long traverse using the older technology, the amount of error can accumulate and become greater the more corners in the survey and the longer the traverse. Using GPS, each point of a survey is independent of every other point, and point locations are within one centimeter of the absolute location. So whether the survey is a small subdivision lot or a large parcel with many corners the accuracy of the location for each corner in each parcel is the same.

5. Completing a survey is much faster.

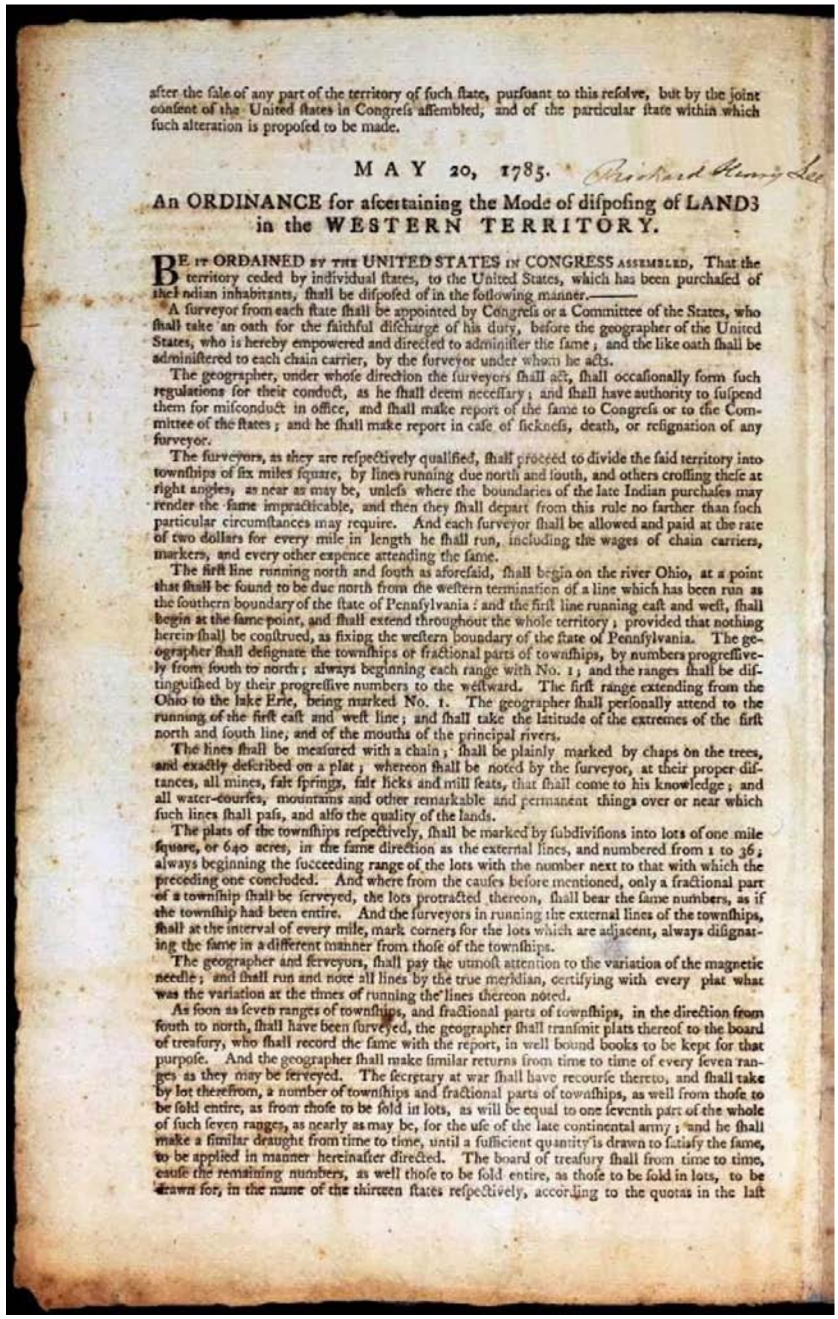
6. The result will give elevations (Z coordinates) as well as X (East and West), Y (North and South) coordinates.

Though surveyors at present must go through a considerable learning curve to operate GPS equipment, it is becoming easier to operate as the new equipment evolves. GPS surveying equipment is also getting less expensive all the time.

Interesting information about the history of the Public Land Survey System (PLSS)

Utah's system of land surveying is the rectangular survey system as set forth in 1785 by the Continental Congress.

The Land Ordinance of 1785 was adopted by the United States Congress of the Confederation on May 20, 1785. It set up a standardized system whereby settlers could purchase title to farmland in the undeveloped west. Congress at the time did not have the power to raise revenue by direct taxation, so land sales provided an important revenue stream. The Ordinance set up a survey system that eventually covered over three-fourths of the area of the continental United States.



after the ſale of any part of the territory of ſuch ſtate, purſuant to this reſolve, but by the joint conſent of the United ſtates in Congreſs aſſembled, and of the particular ſtate within which ſuch alteration is propoſed to be made.

MAY 20, 1785. Richard Henry Lee

An ORDINANCE for aſcertaining the Mode of diſpoſing of LANDS in the WESTERN TERRITORY.

BE IT ORDAINED BY THE UNITED STATES IN CONGRESS ASSEMBLED, That the territory ceded by individual ſtates, to the United States, which has been purchaſed of the Indian inhabitants, ſhall be diſpoſed of in the following manner.——

A ſurveyor from each ſtate ſhall be appointed by Congreſs or a Committee of the States, who ſhall take an oath for the faithful diſcharge of his duty, before the geographer of the United States, who is hereby empowered and directed to adminiſter the ſame; and the like oath ſhall be adminiſtered to each chain carrier, by the ſurveyor under whom he acts.

The geographer, under whoſe direction the ſurveyors ſhall act, ſhall occaſionally form ſuch regulations for their conduct, as he ſhall deem neceſſary; and ſhall have authority to ſuſpend them for miſconduct in office, and ſhall make report of the ſame to Congreſs or to the Committee of the ſtates; and he ſhall make report in caſe of ſickneſs, death, or reſignation of any ſurveyor.

The ſurveyors, as they are reſpectively qualified, ſhall proceed to divide the ſaid territory into townſhips of ſix miles ſquare, by lines running due north and ſouth, and others croſſing theſe at right angles, as near as may be, unleſs where the boundaries of the late Indian purchaſes may render the ſame impracticable, and then they ſhall depart from this rule no farther than ſuch particular circumſtances may require. And each ſurveyor ſhall be allowed and paid at the rate of two dollars for every mile in length he ſhall run, including the wages of chain carriers, markers, and every other expence attending the ſame.

The firſt line running north and ſouth as aforeſaid, ſhall begin on the river Ohio, at a point that ſhall be found to be due north from the weſtern termination of a line which has been run as the ſouthern boundary of the ſtate of Pennſylvania; and the firſt line running eaſt and weſt, ſhall begin at the ſame point, and ſhall extend throughout the whole territory; provided that nothing herein ſhall be conſtrued, as fixing the weſtern boundary of the ſtate of Pennſylvania. The geographer ſhall deſignate the townſhips or fractional parts of townſhips, by numbers progreſſively from ſouth to north; always beginning each range with No. 1; and the ranges ſhall be diſtinguiſhed by their progreſſive numbers to the weſtward. The firſt range extending from the Ohio to the lake Erie, being marked No. 1. The geographer ſhall perſonally attend to the running of the firſt eaſt and weſt line; and ſhall take the latitude of the extremes of the firſt north and ſouth line, and of the mouths of the principal rivers.

The lines ſhall be meaſured with a chain; ſhall be plainly marked by chaps on the trees, and exactly deſcribed on a plat; whereon ſhall be noted by the ſurveyor, at their proper diſtances, all mines, ſalt ſprings, ſalt licks and mill ſeats, that ſhall come to his knowledge; and all water-courſes, mountains and other remarkable and permanent things over or near which ſuch lines ſhall paſs, and alſo the quality of the lands.

The plats of the townſhips reſpectively, ſhall be marked by ſubdiviſions into lots of one mile ſquare, or 640 acres, in the ſame direction as the external lines, and numbered from 1 to 36; always beginning the ſucceeding range of the lots with the number next to that with which the preceding one concluded. And where from the cauſes before mentioned, only a fractional part of a townſhip ſhall be ſerveyed, the lots protracted thereon, ſhall bear the ſame numbers, as if the townſhip had been entire. And the ſurveyors in running the external lines of the townſhips, ſhall at the interval of every mile, mark corners for the lots which are adjacent, always diſignating the ſame in a different manner from thoſe of the townſhips.

The geographer and ſerveyors, ſhall pay the utmoſt attention to the variation of the magnetic needle; and ſhall run and note all lines by the true meridian, certifying with every plat what was the variation at the times of running the lines thereon noted.

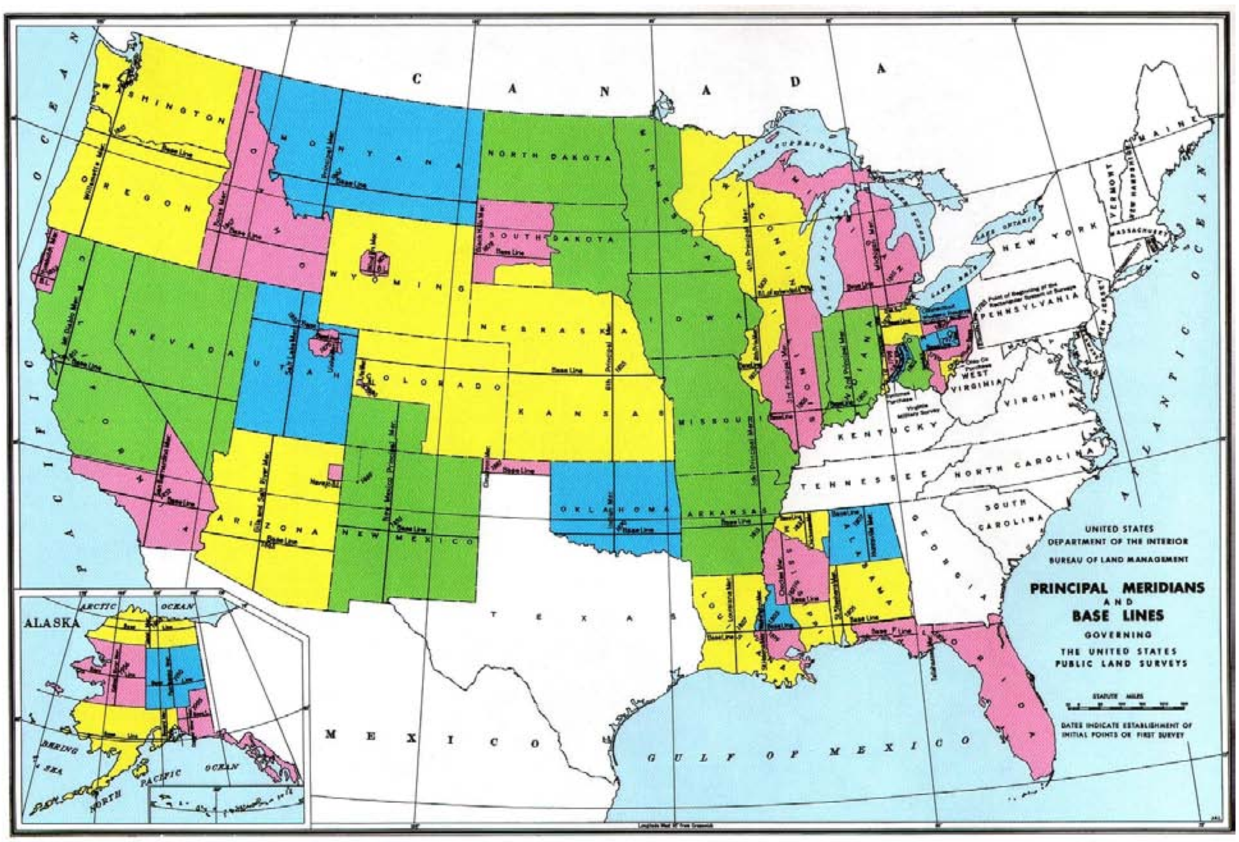
As ſoon as ſeven ranges of townſhips, and fractional parts of townſhips, in the direction from ſouth to north, ſhall have been ſurveyed, the geographer ſhall tranſmit plats thereof to the board of treaſury, who ſhall record the ſame with the report, in well bound books to be kept for that purpoſe. And the geographer ſhall make ſimilar returns from time to time of every ſeven ranges as they may be ſerveyed. The ſecretary at war ſhall have recourſe thereto, and ſhall take by lot therefrom, a number of townſhips and fractional parts of townſhips, as well from thoſe to be ſold entire, as from thoſe to be ſold in lots, as will be equal to one ſeventh part of the whole of ſuch ſeven ranges, as nearly as may be, for the uſe of the late continental army; and he ſhall make a ſimilar draught from time to time, until a ſufficient quantity is drawn to ſatisfy the ſame, to be applied in manner hereinafter directed. The board of treaſury ſhall from time to time, cauſe the remaining numbers, as well thoſe to be ſold entire, as thoſe to be ſold in lots, to be drawn for, in the name of the thirteen ſtates reſpectively, according to the quotas in the laſt

Land was systematically surveyed into square townships, six miles on each side. Each of these townships were subdivided into thirty six sections of one square mile or 640 acres. These sections could then be further subdivided for re-sale by settlers and land speculators.

The intent of the system was to survey and monument the western lands prior to patenting the lands to private citizens. The surveyed sections provided standard sized and shaped parcels of land, interrelated by reference to townships and initial points. Simple aliquot part descriptions, dividing sections into halves and fourths etc, were all that were necessary to describe with certainty a parcel of land.

The basic framework of PLSS lines consists of principal meridians, base lines, standard parallels, guide meridians, township lines and section lines. The corners established by the original surveys include standard, township, section, quarter-section, closing, and witness corners.

The early surveying, particularly in Ohio, was performed with more speed than care, with the result that many of the oldest townships and sections vary considerably from their prescribed shape and area. Proceeding westward, accuracy became more of a consideration than rapid sale, and the system was simplified by establishing one major north-south line (principal meridian) and one east-west (base) line that control descriptions for an entire state or more. For example, a single Willamette Meridian serves both Oregon and Washington. County lines frequently follow the survey, so there are many rectangular counties in the Midwest and the West.



INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1988

The ordinance was also significant for establishing a mechanism for funding public education. Section 16 in each township was reserved for the maintenance of public schools and later sections 2, 32 and 36 of each township were also designated as "school sections".

The use of surveyors to precisely chart out the new townships in the westward expansion was directly influenced by the New England land system, which similarly relied on surveyors and local committees to clearly delineate property boundaries. Defined property boundary lines and an established land title system, provided colonials with a sense of security in their land ownership, by minimizing the likelihood of ownership or boundary disputes.

Utah's system of land surveying that was set up as a result of the Land Ordinance of 1785 and established the basis for the Public Land Survey System that we use today. The State of Utah is plotted into a grid of squares, six miles by six miles, called "Townships".