

L E O

CONVERSION BETWEEN LEGAL AND GEOGRAPHIC
REFERENCE SYSTEMS IN KANSAS

By:

Charles G. Ross

Automated Cartography
Technical Information Services
KANSAS GEOLOGICAL SURVEY
April 1989

Kansas Geological Survey Open File Report # 89-10

Kansas Geological Survey
Open-file Report

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The LEO System

The existence of geologic and geographic data in differing reference systems (geographic coordinates or longitude-latitude, cartesian/**projected** coordinates or (x,y), and legal coordinates or township, range, and section) makes it necessary to provide conversions between these systems to fully utilize the data and to perform functions which are available only within a given system or are more efficient within that system.

In particular, much data (both digital and non-digital) exists in which locations are specified in the legal reference system whose spatial nature inhibits (if not prohibits) its use in mapping, graphics, and spatial analysis. This problem has not been overcome in the past because it has not been possible until recently to convert from legal to geographic coordinates with acceptable accuracy. LEO provides this function, resulting in geographic coordinates which can then be projected (using the **GIMMAP.PROJCT** system) into Cartesian coordinates suitable for the above functions.

The LEO conversion system (LEgal \Leftrightarrow gEOgraphic), consists of a FORTRAN77 subroutine called LEOCVT and an associated spatial database, GIMMAP.LEOBASE. It functions to perform conversions between the geographic and legal reference systems for the state of Kansas. Given a legal location including township, range, section and subdivisions of the section, LEOCVT will produce the most accurate (see below) longitude and latitude, (the geographic location), available for the center of the selected sub-area.

Conversely, given a geographic location in the form of a longitude and latitude, LEOCVT will produce the legal description including the township, range, section and four successive levels of subdivision of the section. The smallest area specified will contain the original point given in longitude and latitude.

These conversions have been made possible by construction of the GIMMAP.LEOBASE database, essentially the collection of all township and section corners, spatially-ordered and represented as geographic locations. This information was originally extracted from the digitized (and edited) data contained in the Kansas Cartographic Database (KCD).

The KCD has been compiled by use of the **GIMMAP** (Geodata Interactive Management Map Analysis and Production) system in the Automated Cartography section at the Kansas Geological Survey from 1980 to the present, Nearly all the data in the KCD was digitized from the series of 7.5' quadrangle maps produced by the U.S. Geological Survey.

The Legal Reference System

The legal (township-range-section) system is based on a set of surveyed grid corners and lines with an arbitrary origin at the intersection of the **base line** (at 40 degrees north latitude), and the **principal meridian** (the "6th", at 97 degrees, 23 minutes west longitude). The legal system of reference comprises a grid of (theoretically) equal-sized townships (six by six miles) whose locations are described as some number of rows south of the base line ("township 14 south"), and columns east or west of the principal meridian, ("range 4 east" or "range 22 west").

In Kansas, there are 35 rows of townships and 25 columns (range designations) east and 43 columns west of the principal meridian. Each township is divided into 36 sections, and each section is approximately one mile square. Sections are referred to by unique section numbers, 1-36. Within the township, section numbers are assigned in a snakelike pattern. Section 1 is in the northeast corner of the township. Sections 2-6 proceed to the west, with section 6 in the northwest corner. Section 7 lies immediately below section 6, and sections 8-12 lie eastward from section 7. Numbering ends with section 36 in the southeastern corner of the township:

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

Specification of locations within this system apply only within the state of Kansas. They are composed of a township specification, a section specification, and various, optional forms of further specification (called subdivision) within the section. Township specification is by township and range (east or west) numbers, such as township 5 south and range 12 west (written as T5S and R12W). The section number (1-36) fixes the unique section within the township.

Specification of a legal location within the section may be performed in several ways. LEO supports four options of point specification within the selected section:

The first option is to make no further specification and use the center of the section (average of four corners).

The second option allows selection of one of the township corners by use of the appropriate letters for subdivision into quarter-areas (as shown below) in the first subdivision of the section. The CORNER = 1 option must be used, and the location of the selected township or section corner is returned.

The third option is to subdivide the section successively into smaller and smaller half parts for a maximum of four levels of subdivision. The subdivided areas may be 1/2, 1/4, 1/8 or 1/16 of the section. Each subdivision is specified by a letter (see below), and the selected point is the averaged center of the smallest specified sub-area. The specification of subdivisions is made by setting the subdivision values at each successive level using the following letters:

Specifying Half-Area Subdivisions

N	=>	North half of area
S	=>	South half
E	=>	Eastern half
W	=>	Western half

The fourth option for subdivision of sections is to divide by quarter-areas. As with half-areas, a maximum of four levels of subdividing is allowed. Thus, sub-areas of one-quarter, one-sixteenth, one-sixty-fourth and one-two hundred and fifty-sixth (1/4, 1/16, 1/64, 1/256) the original area may be generated. The averaged center of the smallest subdivision is the point used to perform the conversion. Selection of quarter-areas is made by either of two methods of letter assignment:

Specifying Quarter-Area Subdivisions

NE	or	A	=>	Northeast
NW	or	B	=>	Northwest
SW	or	C	=>	Southwest
SE	or	D	=>	Southeast

Another method for subdivision, not directly supported by the LEO system, is that of specifying location by distances or "footages" on the ground, as measured from section or township corners or lines. This method may be approximated with LEO by a technique described later.

Using the LEOCVT Routine

Legal descriptions may include up to 4 levels of quarter- or half-areas for subdivision of a section into an area as small as 1/256th of the original section. The location produced is that of the center of the smallest subdivided area specified (unless the CORNER = 1 option is used to select the exact corner of a section). Conversion from a geographic location to a legal one results in specification of all four levels of subdivision, any part of which may be used to define the area containing the original point.

LINK

To use the LEOCVT routine, the user must LINK the calling program to the LEOCVT object file:

```
:UTIL:GIMMAP.LEOCVT.OB
```

OPEN

Prior to using the LEOCVT routine for conversions, the user must open the database as follows:

```
OPEN(LEOFC,FILE=':UTIL:GIMMAP.LEOBASE',ACCESS='DIRECT',  
+     FORM='UNFORMATTED',RECL=400,IOINTENT='INPUT')
```

where the unit number for the GIMMAP.LEOBASE database, LEOFC, is also passed as the unit number to the LEOCVT routine (see below).

CONVERSION

Conversion between reference systems is then performed by:

```
CHARACTER EW*1, SUBD*2(4)
INTEGER*2 CORNER, LEOFC, LORG, RANGE, SECT, SUCCESS, TSHIP
REAL PLAT, PLON
```

:

```
(set values for TSHIP, RANGE, EW, SECT, CORNER, SUBD,
LEOFC and LORG=1 for legal -> geographic)
```

OR

```
(set PLON, PLAT, LEOFC and LORG=2 for geographic -> legal)
```

:

```
CALL LEOCVT(TSHIP, RANGE, EW, SECT, CORNER, SUBD,
+          PLON, PLAT, LEOFC, SUCCESS, LORG)
```

:

```
(check the value of SUCCESS for successful conversion)
```

where

```
TSHIP   = Township number (integer, 1-35)
RANGE   = Range number (integer, 1-25E, 1-43W)
EW       = Range Indicator, 'E' = East, 'W' = West
SECT     = Section number (integer, 1-36)
CORNER   = 0 for center of smallest subdivision
          = 1 for section corner specified in SUBD(1)
SUBD(4)  = Specification for section subdivisions
```

Each subdivision is applied to the area specified at the previous level, beginning at (1) as the largest to (4) as the smallest. If a subdivision is blank, subdivision stops. The specification of subdivision may be made as quarter or half- area designations.

For quarter-area designations:

'NE' or 'A ' => Northeast
'NW' or 'B ' => Northwest
'SW' or 'C ' => Southwest
'SE' or 'D ' => Southeast

For half-area designations:

'N ' => North
'S ' => South
'E ' => East
'W ' => West

Note: The smallest subdivision used is the last non-blank subdivision. All others must be blank:

SUBD(unused) = ' '

Note: When the CORNER = 1 option is used, the value of SUBD(1) is used to specify the section or township corner whose coordinates are desired.

PLON = Longitude in decimal degrees, positive or negative as input, positive on output

PLAT = Latitude in decimal degrees

LEOFC = Unit number of (OPENed) GIMMAP.LEOBASE

SUCCESS = 1 => **Successful Conversion**
= -1 => Township number out of range
= -2 => Range number out of range
= -3 => Illegal EW indicator value
= -4 => Section number out of range
= -5 => Illegal Subdivision #1
= -6 => Illegal Subdivision #2
= -7 => Illegal Subdivision #3
= -8 => Illegal Subdivision #4
= -9 => Illegal LORG indicator
= -10 => Invalid longitude for LEO/Kansas
= -11 => Invalid latitude for LEO/Kansas
= -12 => Insufficient information in LEOBASE
= -13 => Error in LEOBASE data
= -14 => Thrashing error at township level
= -15 => Thrashing error at section level

LORG = 1 => conversion from Legal to Geographic
(township/range/section to long/lat)
= 2 => conversion from Geographic to Legal

Note on LEO System Errors

The LEOBASE database of section and township corners has been constructed from the Kansas Cartographic Database (KCD), a state-wide cartographic database for the state of Kansas. The features in the KCD were generally digitized from the USGS 7.5' quadrangle series of topographic maps covering the state at a scale of 1:24000. Errors certainly exist in the representation of features on these maps, and errors have occurred in creating the KCD from the maps. Therefore, some section/township corner locations may be in error beyond normal tolerances. All users of the LEO system are requested to report any such errors so that the database may be corrected for future use.

LEO has been tested minimally, and errors may yet be found. The value of SUCCESS should be checked after every call to the LEOCVT routine. SUCCESS values from -11 to -1 indicate user errors (in the specification of parameters). SUCCESS values below -11 indicate LEO system errors or lack of information.

Please report any unresolved errors (SUCCESS = 0) you may encounter. Such errors may be the result of problems in the database which could be fixed for future use. Also, report all errors in the range -12 to -15. When reporting errors, note the error number and if possible the exact conversion values which failed. Complete specification of the parameters passed to the LEOCVT routine and any values returned will be helpful. There are no guarantees for the accuracy of locations in the database or for the LEO conversion system, but in general both seem to be fairly good. Correction of GIMMAP.LEOBASE and LEO system errors will improve the system for the future use for everyone.

Exceptions to the Legal System in Kansas

One area of Kansas does not follow the structure for the legal system which is used in the rest of the state. This is the column of townships in Range 8 east, in which the western half of the western column of sections (6, 7, 18, 19, 30 and 31) are exceptionally wide due to the poorly planned meeting of two separate surveys. The problem was resolved at the county level, resulting in further subdivision into lots which are arranged and numbered in ways defined by each county.

The LEO system at present does not incorporate these county solutions, but instead assumes these townships are the same as all others. Any points lying in the westernmost sections of this range should first be converted to an appropriate quarter- or half-area location description before conversion by LEOCVT is performed. Furthermore, other areas around the Missouri river and elsewhere along the state boundary may fail in conversion due to a lack of complete data.

Approximation of Footages by Subdivision

Legal descriptions which use footages or distances from section or township corners or lines to describe locations within specified sections are not (**yet**) directly convertible in the LEO system. However, these locations may be converted approximately by using either of the following procedures.

First, convert the footages to fractions of the width/height of the section, assuming a constant size of 1 mile on a side (more accurate measures may be gained by projection of section corners obtained by LEO). Convert the fractions into appropriate subdivision notations and use LEO to convert the points.

Alternatively, the CORNER = 1 option may be used to obtain the locations of the four corners of the section. The fractions may then be applied directly to these values to produce the locations of the desired points.

A Note on Accuracy

There are many sources of potential error in the locations of the section and township corners. The process of surveying of the locations may introduce some error. Original construction of the USGS 7.5' maps may introduce additional error. Shrinking and stretching of paper maps may introduce non-linear distortions of a magnitude which can not be completely corrected. Digitization may add errors of hardware, software and operator.

Once in the computer, the accuracy of the locations may be affected by any mathematical operations or by any input or output operations. The basic objective in the GIMMAP handling of this information is to maintain the level of accuracy and to prevent any loss in that level. Storage of this data in single precision is believed to comply with this objective.