The Universal Transverse Mercator Grid

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Abstract

Recent developments in land-use planning require a complete description of the incidence, distribution and relationship of phenomena. To solve problems it is necessary to determine what exists and where it exists.

To provide an accurate base for coding data and a compatible format the Universal Transverse Mercator grid (UTM) and the Transverse Mercator projection (TM) should be used to code data needed for planning. This paper examined the advantages of the UTM as the proper grid system for coding compatible data for local or national land-use surveys.

Introduction

The first step in land-use planning is a descriptive categorization and recording of the extent, density and dynamic relationships of phenomena. An inventory of land-uses for planning purposes presents a major problem due to the large amounts of data that are collected. Such data must be compatible not only to the procedures used in collection and recording but also to computer software application for manipulation, storage and retrieval. Intelligent land-use planning requires the selection of a method by which large amounts of data can be identified, recorded and made available for immediate retrieval.

The best method for identifying and recording data is the Transverse Mercator projection (TM) used in combination with the Universal Transverse Mercator grid (UTM). The UTM is a combination of rectangular coordinates and graticule that has a number of desirable characteristics for inventorying large amounts of data.

The purpose of this paper is to reintroduce the UTM system and to promote its acceptance as the proper method for encoding data for land-use planning.

Discussion

The UTM system as presently used has been designed to represent the earth's surface between 84° N latitude and 80° S latitude.

Transverse Mercator Projection

One major part of the UTM system is the Transverse Mercator projection (TM). This projection is the transverse case of the Mercator projection (Fig. 1). Dashed lines on Figure 1 indicate the Mercator projection while the solid lines indicate the superposition of the Transverse Mercator. It can be seen that a great circle of longitude of the Transverse Mercator occupies the parallel of 0° latitude of the Mercator thus a rotation of 90°. Hence the poles of the transverse case are located along the equator of the Mercator. Consequently, the equator of the transverse case (shown thrice) is coincident with a meridian of the Mercator.

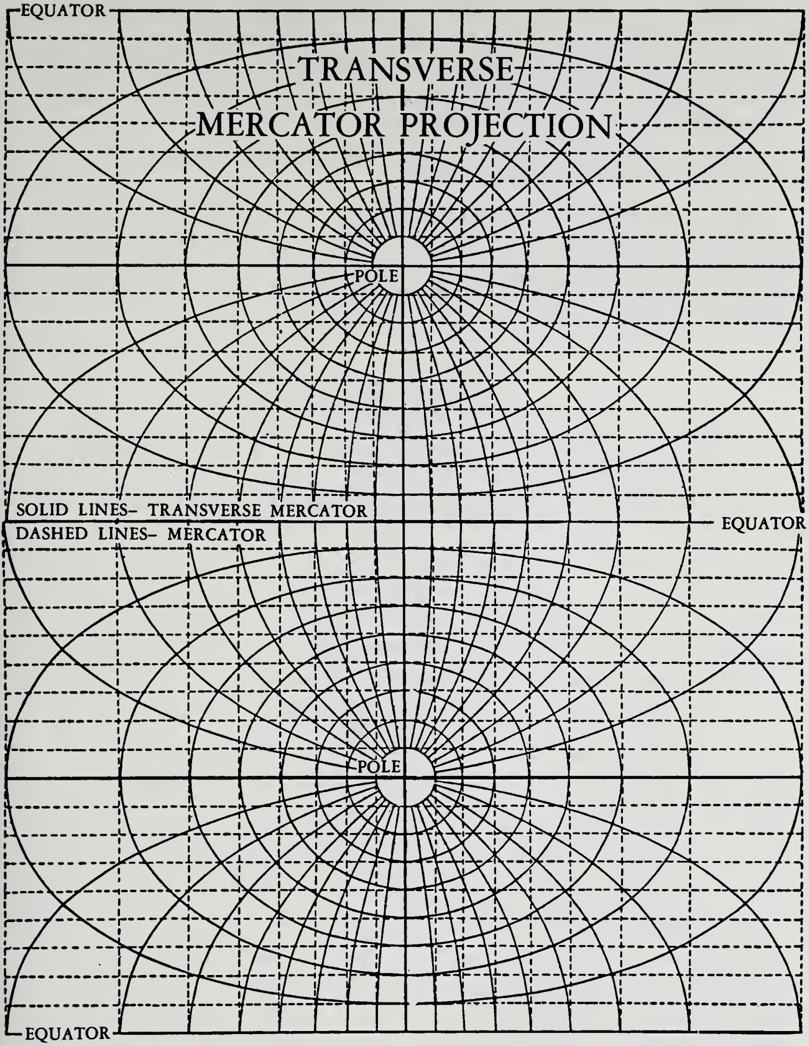

FIGURE 1. *The Transverse Mercator Projection (solid lines) as it appears relative to the Mercator projection (dashed lines). Adapted from Elements of Map Projection, page 123*

A modification in using the Transverse Mercator increases its usefulness. Again reference to Figure 1 indicates that along the central meridian of the TM exact scale is held. Modification of this situation occurs as scale is held exact "along two small circles formed by planes parallel to the plane of the central meridian" (3). In reality therefore, the projection is derived from the secant position. This situation allows true scale along parallel lines located equidistant from the central meridian of the projection. The surface distance referenced between lines of true scale is 360 km (360,000 m).

Only a narrow extent of 3°.5 on either side of the central meridian is actually used in conjunction with the UTM grid. Logically the total system is not used for large-scale mapping purposes. The meridians and parallels of the projection to be used are identified according to that portion of the earth to be mapped.

Universal Transverse Mercator Grid

The Universal Transverse Mercator grid (UTM) is a system of intersecting parallel lines forming a series of rectangles (Fig. 2). The dimensions of each rectangle can be determined according to the degree of complexity required as subdividing each square results in setting off smaller areas.

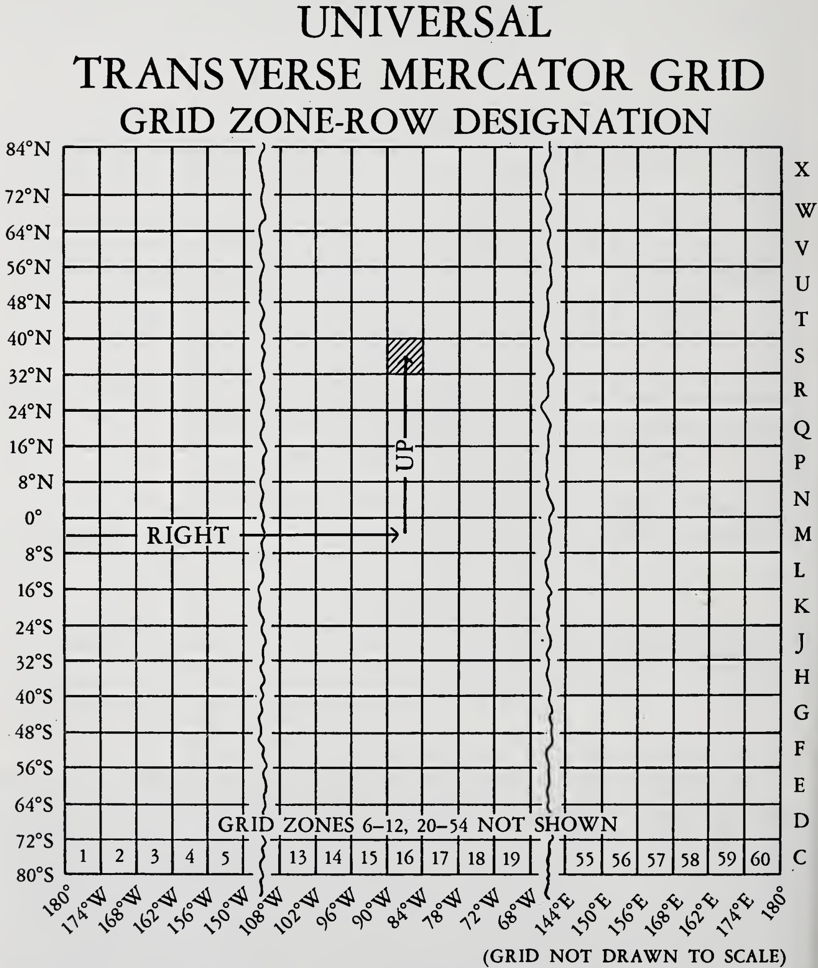

FIGURE 2. *Grid zone identification of the Universal Transverse Mercator grid.*

The grid is located on the earth's surface such that a vertical zone is centered on a chosen central meridian of longitude and rows are centered on the equator. Each vertical zone at the equator is 6° of longitude in width and extends from 84° N to 80° S (as presently used). Figure 2 indicates how each zone is set off and identified. Sixty zones are numbered consecutively eastward through 360° with Zone 1 at 180°.

With one exception the vertical zones are delimited into rows 8° wide. Again, Figure 2 locates the rows and the method of identification. Successive rows are lettered C to X (omitting I and O) beginning at 80° S and extending to 84° N. The resultant grid consists of rectangles bounded by parallel lines equally spaced with a peculiar location.

The identification of each rectangle at various levels is simple and straightforward. All 6° by 8° rectangles are identified by zone-row designation. Figure 2 indicates the location of one such area as 16S. Further subdivisions are based upon a method of "false eastings" and "false northings" (Fig. 3). Using the intersection of the central meridian of each vertical zone and the equator an origin is established so that each area subsequently located always has a positive listing. The central meridian is identified as 500,000 m east while the equator of even-numbered zones is begun at 500,000 m north. Odd-numbered zones begin at 0 m north. Proceeding in the southern hemisphere is such that the equator is enumerated as 10,000,000 m north (4).

Figure 3 shows how each zone and row is further subdivided into 100,000 m squares. The alphabet is used to subdivide the 6° column into 100,000 m columns. Beginning at 180° longitude and proceeding eastward each 100,000 m column is identified A-Z (excluding I and O). For each 18° of longitude the alphabet is repeated. Similarly rows are created using the alphabet A-V (again excluding I and O) south to north and is repeated at 2,000,000 m intervals. Each 100,000-m square is thus identified by two letters. Further subdivision to the 10,000 m, the 1,000 m and the 100-m square is accomplished by equal divisions of each square. Thus 10,000-m squares are designated by two 1 digit numbers derived from the false eastings and northings. Subsequent divisions to the 1,000 m (km) uses two 2 digit numbers and the 100-m square (hectare) uses two 3 digit numbers.

An example is as follows (Fig. 4):

16S	locates a 6° by 8° area in Indiana and Illinois
16SDD	locates the 100,000-m square in which Terre Haute is located
16SDD66	locates the 10,000-m square in which the Vigo County courthouse is located
16SDD6363	locates the 1,000-m square in which the Vigo County courthouse is more precisely located
16SDD633635	locates a 100-m square within the area occupied by the Vigo County courthouse

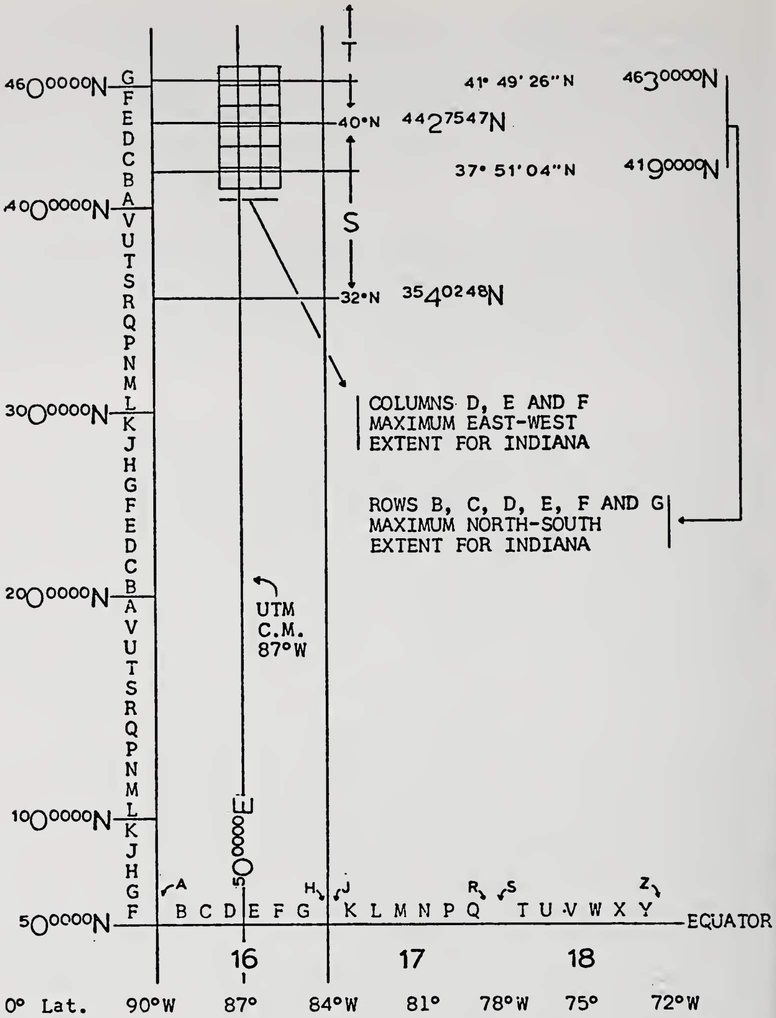

FIGURE 3. *The location of 100,000-m squares within the Universal Transverse Mercator grid system.*

A Reference System

The case for using the UTM as the reference system encoding land-use data is based upon a number of important considerations. These considerations are derived from a) the nature of the system, and b) the requirements of data encoding.

Nature of the UTM System

The basic reference form for the earth's surface is the ellipsoid of revolution although with "the use of spherical harmonics, far more complicated mathematical figures can be defined to better approach the real earth figure, but to be of practical use the ellipsoid of revolution appears to be as complicated a figure as is warranted" (2). Since much of the mapping on the earth's surface is large-scale mapping there is an advantage to reducing the sea-level arc to a plane surface. This changes spherical coordinates to rectangular coordinates thus

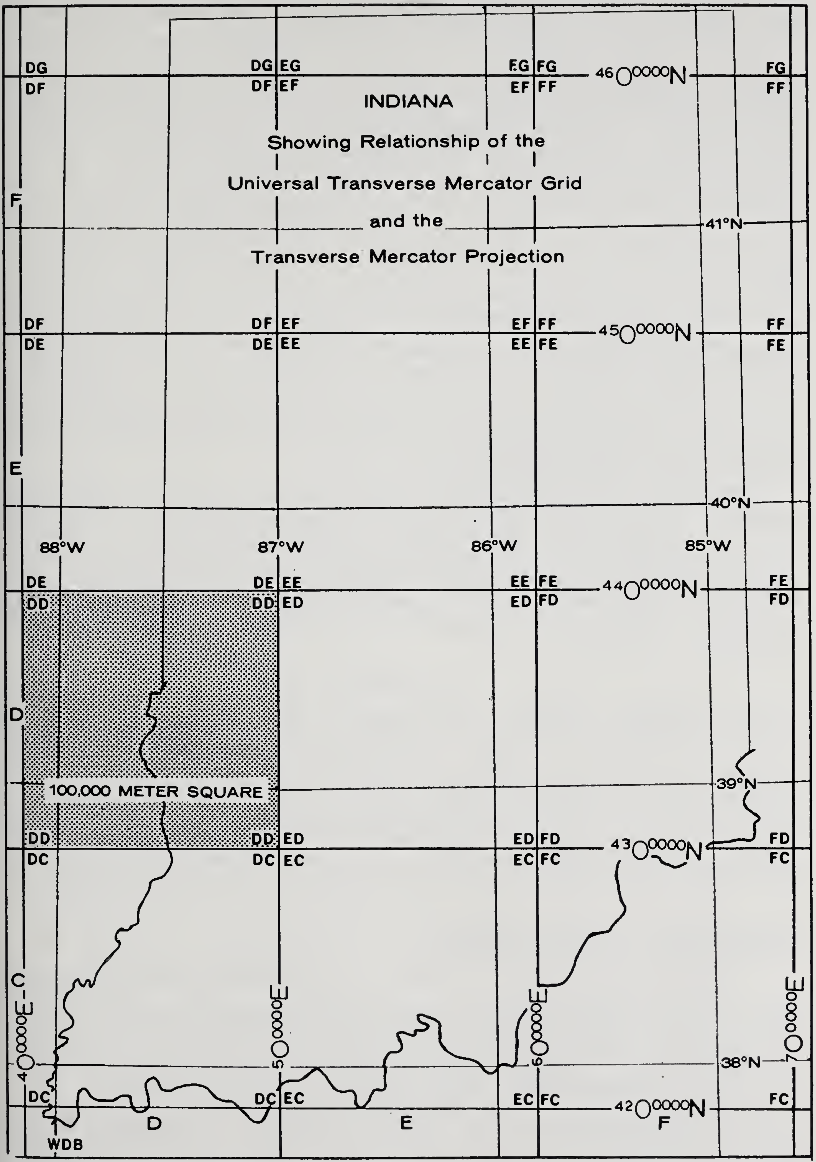

FIGURE 4. *Indiana showing relationship of the Universal Transverse Mercator grid and the Transverse Mercator projection.*

reducing to a minimum alteration from true scale representation. Furthermore, the transformation promotes ease in determining distance and azimuth and it also will allow all present maps to be recast to a compatible identification format.

The transformation from spherical coordinates to rectangular coordinates allows for a minimum scale alteration. Large-scale mapping and surveying involves the use of rectangular coordinates and it is the "consensus of those who have seriously considered the fundamental mapping problem (that) . . . a series of cylinders transverse to the equator are the best surfaces to be used and that the projection should be conformal" (1). The Transverse Mercator is conformal on a transverse cylinder. Conformality as a property requires that all angular relations be preserved and also scale in all directions from a point be true. More importantly with the Transverse Mercator the scale factor resulting from points on the sea level arc being projected to the plane surface would range from 0.99960000 through unity to 1.0016504. The angle from the central meridian in each grid zone is 3° 40′ for the latter figure. Furthermore, the elevation of the datum would range from a minus 2,548 m at the C.M. through O to a plus 10,516 m at the edges of the grid zone. These figures are for a 6° width zone and it is obvious that 4° or 2° width zone would reduce scale alteration even more. These scale factors represent tolerable error for most mapping and surveying projects.

Calculation for distance and azimuth between points is reasonably simple with the UTM grid. Since the coordinate system is based on a known projection the relationship or scale distortion can be correctly established for all points. These factors can be readily applied as to bring all computations within geodetic accuracy (3). Measured angles originally referred to the spheroid can be reduced to the plane surface by the (t-T) correction.

A reference system based on the UTM would allow compatible mapping projects between discontinuous areas. If selected the UTM could be related to a single earth-centered-reference-system. All calculations from ground inventory reduced first to sea level and then to the reference datum would insure not only compatible mapping between locales, even on a world-wide basis, but also insure compatible mapping between projects initiated by various agencies. Geodetic control on ground location would be the same for all mapping projects.

Requirements of Data Encoding

Requirements of data encoding and subsequent computer application produces constraints on any data encoding system which must be compromised. The UTM grid system offers a method to permit data to be recorded on a common base, provides for maximum data content and allows for up-to-date base maps on a continued basis.

The effectiveness of any inventory system is enhanced if all data can be recorded on a common base. The UTM grid system provides through intersecting parallel lines either the 1,000-m square or the 100-m square as the basic unit within which all categories of data can be referenced in the metric system. Using proper computer software many categorically different data can be assigned the same location coordinates. It is standard procedure in computer mapping for grids to overlay source maps from which x, y, z coordinates can be easily digitized. A common grid would permit interagency compatible data banks and reduce the considerable amount of duplicate effort. The identification of a proper landscape unit from which to inventory data is a key point in an approach to land-use planning (5).

The selection of a common base coupled with appropriate computer software provides for maximum data bank content. A proper land-use inventory must be so organized that collected data can be used to provide maximum interpretation of land-uses although maximum interpretive ability can occur only if software allows a selectivity in informational detail retrieval.

Recent events in Congress portend the advent of federal level mandates regarding land-uses and land-use planning. Because of this it is imperative that any attempt at inventory should be done so that data banks are available on an interagency basis. This capability will be achieved only if all data are collected in a compatible format. The United States Geological Survey has for many years produced topographic sheets with the UTM grid ticks and presently are producing sheets with a fine line UTM grid superimposed. But some state, regional and federal agencies are compiling detailed data bases "independently and without coordination, with resultant duplication of effort and establishment of information systems that are not compatible" (5). The need for standardized collection of data that is compatible between locales, agencies and even other countries can begin with the acceptance of the UTM grid system.

Conclusions

The UTM is a system retaining the necessary requisites for a proper reference system. They include:

1) The system is conformal allowing true scale and preservation of all angular relationships about a point.

2) With a superpositioning of a grid small scale alterations are maintained.

3) With the superpositioning of a grid a common base for data diversity categorization is provided at either a square kilometer or hectare size.

4) The use of the UTM grid would allow compatible data banks as they would be based on the same measurement system.

5) Referencing in the metric system would simplify data encoding and would permit interface with extracontinental mapping.

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