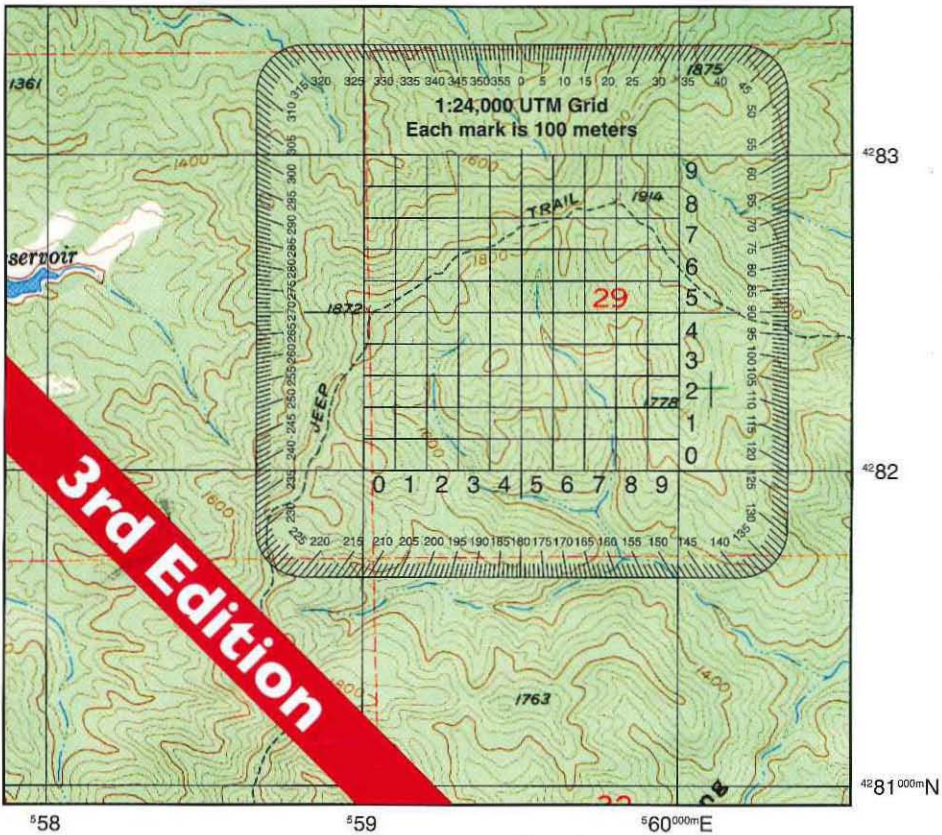


# UTM

## Using your GPS with the Universal Transverse Mercator Map Coordinate System



John Carnes



# UTM

Using your GPS with the  
Universal Transverse Mercator  
Map Coordinate System

by

John Carnes

Third Edition

v3.1

©2007-2009 MapTools

MapTools  
1755 La Honda Rd #95  
Woodside, CA 94062  
[www.MapTools.com](http://www.MapTools.com)

ISBN: 0-9710901-1-4

# Table of Contents

Introduction.....	1
A Quick Start for Using UTM Coordinates.....	2
Why Use UTM Coordinates .....	6
Setting Up Your GPS to Use UTM .....	8
Using Your GPS .....	11
Locating Coordinate Grid Information on USGS Maps .....	14
Tools to Measure Within the Grid.....	16
Drawing the UTM Grid Lines .....	21
UTM Practice Map .....	23
Adding UTM Grid Information .....	27
More Details About the UTM Coordinate System .....	32
MGRS and USNG Coordinates.....	36
North Reference .....	44
UPS .....	46
Scale Reference .....	48

# Introduction



I firmly believe that, aside from your brain, a good map is the most useful navigation tool you can use.

Two forces have led me to develop the material in the pages of this book. The first is the progress that has been made in GPS receivers. The second is the ready availability of specialized maps, aerial photography, and satellite images.

An outdoors adventurer can now purchase a lightweight, rugged, and reliable GPS receiver for less than \$100. An abundance of features is not necessary, as the most common use of a GPS receiver is to get coordinates that allow you to locate yourself on your map. But to utilize the GPS for this purpose requires an understanding of coordinate systems, map scales, and map datums. Most of which, are new skills even for seasoned backcountry navigators.

Long past are the days when the only maps you would likely be using were the topographic map series published by the USGS. Maps and imagery are now readily available for download on the internet, and in CD-ROM and DVD based computer programs. Many wilderness users are printing their own maps right from their computers. But again, for this to be successful, it is necessary to have a good understanding of coordinate systems, map scale, and map datums.

In this guide I introduce the user to UTM coordinates using two different units of measure, meters and kilometers. I find the kilometer units to be intuitive, and very easy for a beginner to grasp. Most users are working with a one kilometer map grid, and then measuring a fractional distance within the grid. Some folks have named this "kUTM". Some folks like it, others hate it. I've made a point of always including the unit of measure with coordinates in this booklet both because it is always good practice to write the unit of measure along with a measurement, and to help prevent any confusion on the part of the reader between the two formats. Hopefully you will understand both notations and then be able to work with whichever one works best for your circumstances.

# Quick Start Using UTM Coordinates

# 1

## Setup Your GPS to Use UTM Coordinates

Using the setup menus for your GPS, set the position display format to UTM or UTM/UPS.

While you are in the setup menus, you should also set the map datum to match the datum of the map you are using. In the Continental United States there are only three datums you are likely to encounter. They are, WGS84, NAD83, and NAD27 CONUS.

Most topographic maps published by the USGS for the Continental United States use NAD27 CONUS for their datum. Other map series may use one of the other datums, check the "fine print" for a datum listing.

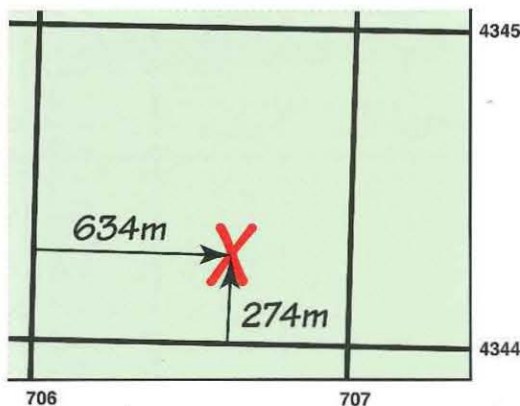
## Locate the UTM Grid on Your Map

On a 1:24,000 scale map, a UTM grid consists of a square grid with grid lines spaced 1 kilometer apart. The coordinate values for these grid lines will be printed along the edges of the map. Many maps do not have grid lines printed on the map. They only have tic marks (usually light blue in color) along the edges and you will need to connect the tics to draw the grid. Other map scales may have different spacing between their grid lines.

Refer to the *Locating Coordinate Grid Information* section of this guide for more information.

## A UTM Coordinate Consists of an East-West Position and a North-South Position

UTM coordinates are simply an east-west position and a north-south position measured using metric distance units of either meters or kilometers. By convention the east-west distance is always first, and is referred to as the easting. The easting increases from left to right (west to east). Next, is the north-south position, called a northing. Northings increase from bottom to top (south to north). A complete UTM coordinate also includes a zone. The zone is an important part of the UTM coordinate when it is used on a global scale. But, since it has little impact when working in a localized area, we will postpone discussing it until later in this guide.



The UTM coordinates of the red X are 706.634km E 4344.274km N.

With a one kilometer grid square it is convenient to write the easting and northing values in kilometers. The portion of the coordinate to the left of the decimal point represents full kilometers and corresponds to the UTM value for the grid line found along the edge of the map. The digits to the right of the decimal point represent fractions of a kilometer, and are measured within the one kilometer grid square on the map.

One kilometer is equivalent to 1000 meters. Thus it is easy to convert between UTM coordinates written in either kilometers or meters.

These two coordinates are equivalent:

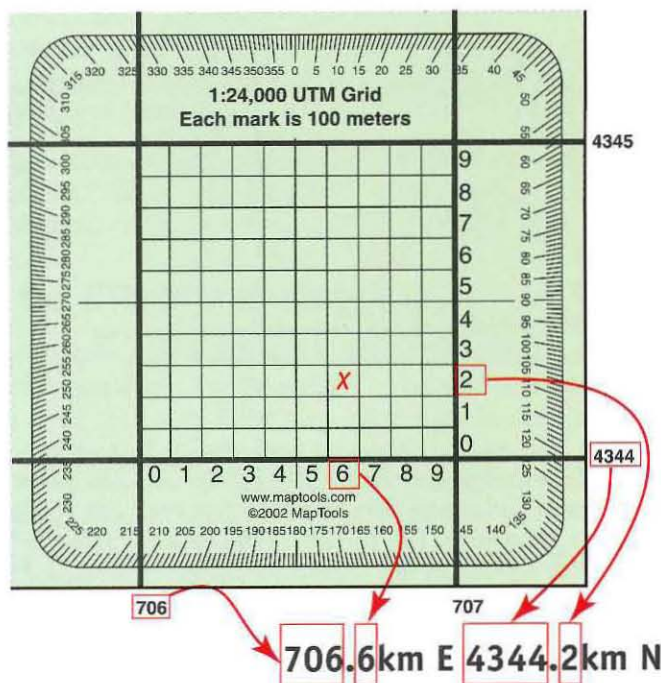
706.634km E                      and                      706634m E  
4344.274km N                      4344274m N

On a 1:24,000 scale map it is nearly impossible to measure with more than a 10m accuracy. Thus it is common to drop the 1m digit in a UTM coordinate written in kilometers. Our example would become 706.63km E 4344.27km N.

## A Tool to Measure Within the Grid Square

To determine coordinates with more precision than the grid square on the map, you will need a small measuring tool that matches the scale of your map, and that is marked in metric distance units. Use this tool to measure position within the grid square. Refer to the *Tools to Measure within the Grid* section of this guide for more information.

The grid tool in the back of this guide is an example of such a tool. It is designed to work with a 1km grid on a 1:24,000 scale map. The tool divides the 1km grid into 100 smaller grid squares, each a tenth of a kilometer on a side.



Since the tool measures with 0.1km (100m) accuracy, it is common to write the coordinates with the same level of precision. In this case, 706.6km E 4344.2km N. A 100m grid square is about the size of two football fields placed side by side. While this is sufficient for many applications, some demand greater accuracy. Other tools with finer markings can measure position within the grid with 10m accuracy. It is not practical to measure with more than 10m accuracy on a 1:24,000 scale map.

## UTM Coordinates on Your GPS

GPS receivers typically display UTM coordinates in meters. Standing at the red X, your GPS would display the coordinates like this

### UTM Coordinates displayed on a typical GPS receiver

East-West coordinate in meters.  
The "Easting"

The  
UTM → 10 S 0706634  
Zone → 4344274

North-South coordinate in meters.  
The "Northing"

To convert from meters to kilometers add a decimal point three digits in from the right, between the 1000m and 100m digits. Now it is easy to separate the digits we use to locate the 1km grid square from the distance we measure within the grid square.

Our example becomes:

**0706.634km E**  
**4344.274km N**

To plot this on the map we need to locate the 706km E 4344km N grid square. Then we need to measure, within the grid, an additional 0.63km to the east and 0.27km to the north.

Try out your skills with the practice map and problems located later in this guide.

# Why Use UTM Coordinates

## 2

### Benefits Offered by UTM Coordinates

#### A square grid

UTM provides a constant distance scale anywhere on the map. In the angular coordinate system of latitude and longitude, the distance covered by a degree of longitude differs as you move towards the poles and only equals the distance covered by a degree of latitude at the equator. With UTM coordinates the north - south and east - west measurements are the same.

#### No negative numbers

#### No east-west or north-south designators

#### Grid values increase from left to right and bottom to top

This is just like the X Y Cartesian coordinate system you learned in high school math class. Simple Cartesian coordinate mathematics can be used. No spherical trigonometry is required!

#### Coordinates are decimal based

Ones, tens, hundreds and so on. No more minutes and seconds to convert.

#### Coordinates are measured in metric units

All UTM coordinates are measured in metric distance units of meters or kilometers. The UTM system allows the coordinate numbering system and the distance measuring system to be identical. Most of the world has already adopted the metric system. Now you won't need to remember how many feet are in a mile. And what's that in yards?

## **A Few Reasons Not to Use UTM**

### **No UTM Coordinate information on the map**

While every USGS map produced since the 1940's has UTM coordinate information, this is not true for every map you may encounter. The coordinate markings on your map will be a factor in choosing the coordinate system you use. It is possible to add a UTM grid to a map. Refer to the section on that topic later in this guide for more information.

### **User community has standardized on another coordinate system**

Most aviation and marine users have standardized on using latitude longitude coordinates. GPS receivers that are designed specifically for aircraft or marine use, may not support UTM, and their users are unlikely to be familiar with UTM coordinates. While this may make it necessary to use lat/lon coordinates when you communicate with these resources, you may find it is easier to convert the coordinates to UTM in order to plot them on your map. Your GPS will display a stored position in whatever position format you specify. Thus you can use your GPS to convert between coordinate systems, by storing a position, changing the position display format, and then recalling the stored position.

### **Don't become a coordinate Nazi**

Be flexible in your choice of coordinate system. Though UTM is often easier to plot on a map, lat/lon is still a very common format. If you learn to work with both, and to use your GPS to convert from one format to another, you will be able to work with many different map users, different types of maps, and the various computer systems, and publications that have chosen one coordinate system over the other. Don't get stuck thinking that there is "only one proper coordinate system" and that everyone should be made to use your chosen format.

# Setting Up Your GPS to Use UTM

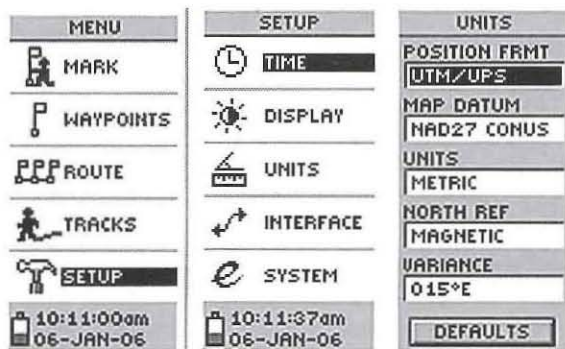
## 3

Almost every GPS receiver currently available for land based recreational users supports the UTM coordinate system. However, GPS receivers that are designed as car navigation systems, or that are built into cellular phones, typically will not display UTM coordinates. Some may not even provide coordinates for your current position in any format.

Your GPS receiver probably came from the factory configured to display your position in lat/lon coordinates. You will need to change the settings for your GPS in order to display your position using UTM coordinates

The examples on the following pages show screens from a Garmin eTrex. Your GPS receiver's menus and screens will likely be different, but similarly named menus and selections should be available. You may wish to refer to the manual that came with your GPS for specific details.

The first step is to page between the various screens until you find the screen with the setup menu items.



The two most important settings are the Position Format and the Map Datum. It is also useful to set the North Reference and the Distance and Elevation Units.

## Position Format

This is where you will select UTM/UPS to instruct the GPS to display coordinates in UTM format. You will see many different formats to choose from. The most common choices include:

UTM/UPS  
MGRS  
hddd° mm.mmm'  
hddd° mm' ss.s"  
hddd.dddd°

MGRS is a specialized form of UTM discussed in a later section. The last three are latitude/longitude formats.

## Map Datum

Setting the map datum is essential when you are using the GPS coordinates with a map. **The map datum setting on the GPS must match the datum of the map you are using.** Failure to set the correct datum is a common error, resulting in positions that are consistently several hundred meters off. The most common choices for map datum include:

NAD27 CONUS  
NAD83  
WGS84

NAD27 CONUS is shorthand for the North American Datum of 1927 – Continental United States.

NAD27 CONUS is the datum used on most topographic maps printed by the USGS.

WGS84 is the default datum for most GPS receivers, and is commonly used on most modern navigation charts. More information on Map Datums can be found in a later section of this guide.

NAD83 is essentially the same datum as WGS84. It was established as a North American datum just prior to its adoption as a world wide datum.

## Distance and Elevation Units

Your choice of distance and elevation units is mostly based on your personal preference. Some GPS receivers will let you select distance and elevation units separately, others combine the selection. The two most common choices are, Metric or Statute Miles and Feet.

Since you are using UTM coordinates, which use metric based units, it makes sense to select metric distance units. Your map is gridded in 1km grids and

you probably have some tool that you can use to measure within the 1km grid. Thus it is easy to measure metric distances on your map.

If you have the option of setting elevation units separately, it is sensible to set them to the same units as the contour lines and elevation markings on your map.

## North Reference

Your choice of North Reference will determine the  $0^\circ$  or North reference for headings and bearings displayed by your GPS. This will impact how you plot bearings from the GPS on your map and how you use your compass with these values. The most common choices include:

True  
Magnetic  
Grid

Choosing True, will result in directions that are referenced to True North. On most maps, the left and right edges of the map are lines of longitude, which also represent a True North reference.

Choosing Magnetic, will result in directions that are referenced to Magnetic North. These directions will match up with compass readings taken with a compass that has not been adjusted to compensate for the local declination. Some GPS receivers split this option into two choices one of which will automatically calculate the declination for your current location, and the other that will let you manually enter the declination you wish to use. If your desire is to have the GPS values match readings on your compass, choose the automatic option.

Choosing Grid, will result in directions that are referenced to Grid North. Grid North is referenced to the UTM grid lines on your map. Grid North is a convenient north reference to use when plotting bearings on the map, since the map has lots of grid lines on it that make handy north reference lines.

Additional information can be found in the *North Reference* section later in this book.

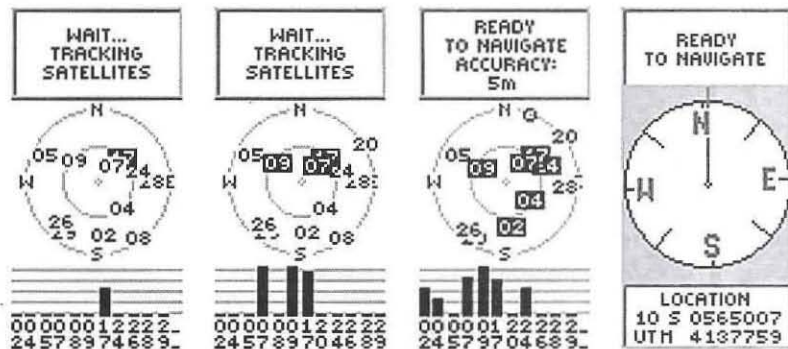
# Using Your GPS

## 4

### Basic GPS Operation

Before your GPS can calculate your position it needs to receive and synchronize with the signals from at least four different satellites. Typically you will see a screen that shows the progress of this synchronization. The time required to acquire the signals will vary. If it has been many days since you last turned the unit on, or you have moved several hundred miles or more from the location where you last turned it on, it will have a poor model of the positions of the satellites in the sky and will thus take longer to synchronize.

On a Garmin eTrex the start up sequence looks like this:

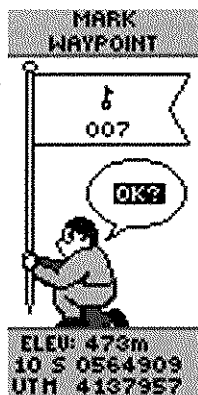


Once its position has been calculated, many GPS receivers will automatically switch to a display of your current position. Others require you to select the position display yourself.

You should develop the habit of checking the estimated accuracy of the position computed by your GPS. This is especially important when you are determining the coordinates of a small item that you wish to return to using these coordinates. Most GPS units will provide this accuracy information on the screen that displays the satellite status. You will want to see small numbers. Less than 20m (60ft.) is common. With good conditions, values less than 10m are likely. A few GPS units display the estimated position error on the same screen that the coordinates are displayed. In the author's opinion this is the right place for it to be displayed! Extra points if it also displays the datum on this screen as well.

## To Save Your Current Position

Many GPS units have a button that, when pressed and held for a second or two, will save your current location into memory. Garmin calls these saved locations waypoints. Magellan calls them landmarks. By default, most GPS units label the saved locations with sequential numbers. You can change the name of the waypoint to something more meaningful. Or, since entering text is often tedious, you may decide to just make note of the waypoint number and what it corresponds to.



## To Store Known Coordinates

To store coordinates for a location other than your current position, you will want to first store your current position and then edit it to match the value of the desired coordinates. If you have many locations to store, the process can be quite tedious. You may find that using the computer interface, a data cable, and compatible software will be much quicker and easier.



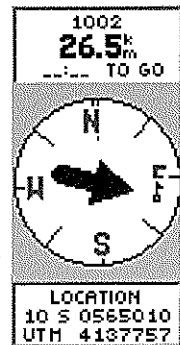
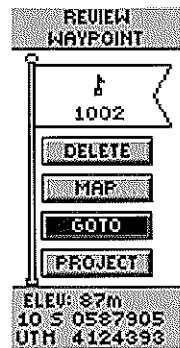
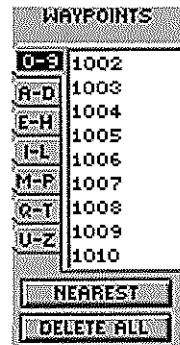
## To Navigate to a Stored Position

One of the primary reason to store locations into your GPS is so that you can use the GOTO feature of your GPS to get bearing and distance information from your current location to a stored location. Once you have activated the GOTO feature and you are moving towards the target, your GPS will be able to tell you the distance and bearing to the target. Additionally it will calculate your current heading, speed, and estimated time of arrival. Your GPS can also have a pointer that points towards the target. All of this information can be useful while navigating to the target.

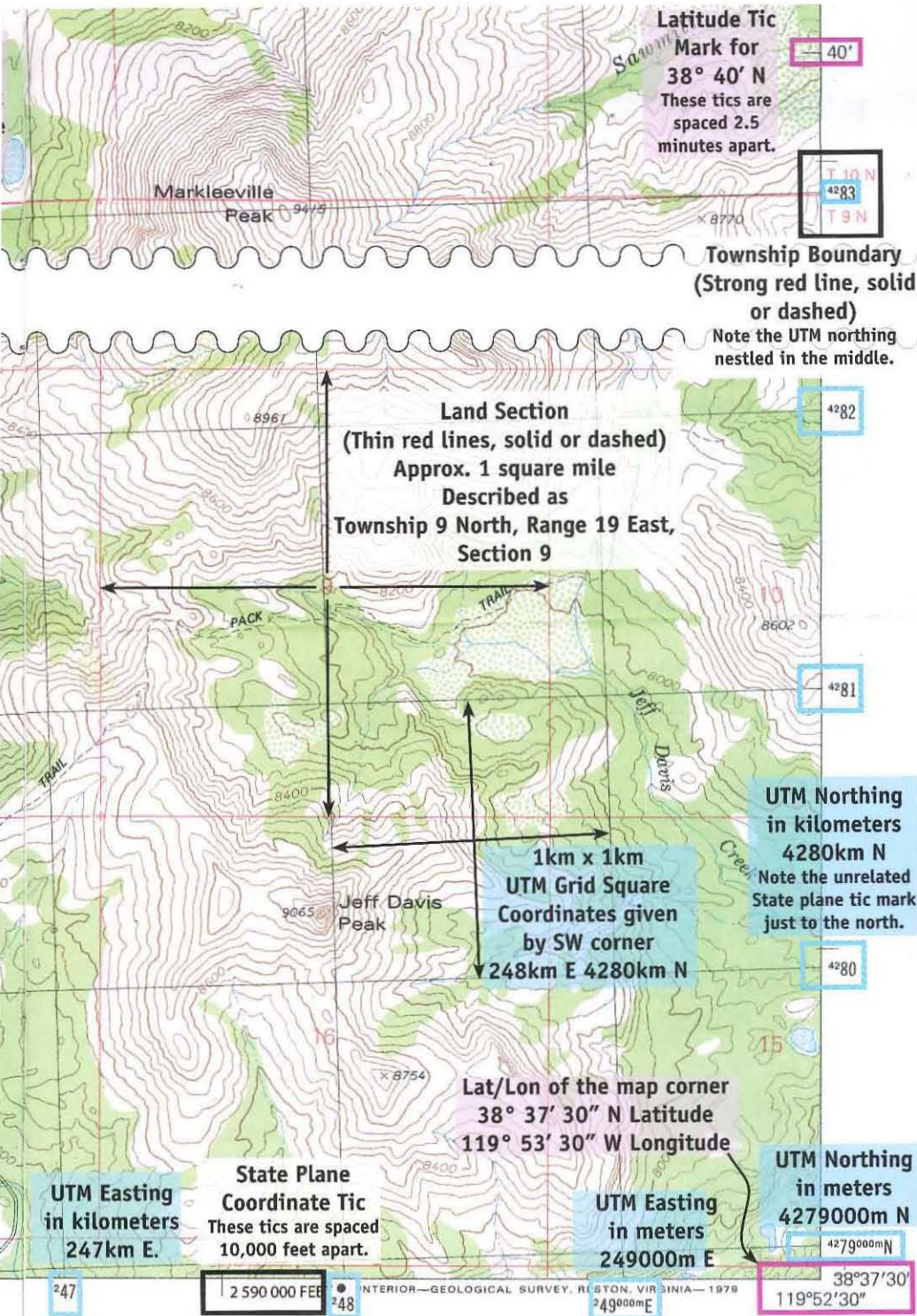
The first thing to remember when using your GPS's GOTO feature, is that the path computed is a straight line to the target. **A straight path is rarely the best path to take when you are navigating on land!** Plot the target on your map, and figure out the best route to follow to reach it. Many a beginning GPS user has ended up tangled in the brush along the straight line path, when they could have used their map and taken the trail.

The second important thing to keep in mind is that some of the data your GPS is providing is only meaningful if the GPS can determine the direction in which it is pointed, or when you are moving.

Distance and bearing to the target can be calculated from your current position. But, to calculate the information needed to display a compass rose and the arrow pointing towards the target the GPS unit needs to know the direction it is facing. There are two ways to accomplish this. The first and most common method, is to calculate the direction in which the GPS is moving by comparing it's present position with its position a few seconds ago. Thus for the compass rose and target pointer to be valid you must be moving. This method also assumes that you are holding the GPS so that it is pointed in the direction of travel. The second method is to use the built in electronic compass found in some GPS units. This allows the compass rose and target pointer to display valid information when you are stationary and regardless of the orientation with which the unit is held. Make sure that you regularly perform the electronic compass calibration procedure for your unit. It is a quick and easy procedure that should be done at the beginning of every day you use the electronic compass.







Latitude Tic  
 Mark for  
**38° 40' N**  
 These tics are  
 spaced 2.5  
 minutes apart.

40'

T 10 N  
 4283  
 T 9 N

Markleeville  
 Peak

x 8770

Township Boundary  
 (Strong red line, solid  
 or dashed)

Note the UTM northing  
 nestled in the middle.

Land Section  
 (Thin red lines, solid or dashed)  
 Approx. 1 square mile  
 Described as  
 Township 9 North, Range 19 East,  
 Section 9

4282

4281

UTM Northing  
 in kilometers  
**4280km N**  
 Note the unrelated  
 State plane tic mark  
 just to the north.

1km x 1km  
 UTM Grid Square  
 Coordinates given  
 by SW corner  
 248km E 4280km N

4280

Lat/Lon of the map corner  
**38° 37' 30" N Latitude**  
**119° 53' 30" W Longitude**

UTM Easting  
 in kilometers  
**247km E.**

State Plane  
 Coordinate Tic  
 These tics are spaced  
 10,000 feet apart.

UTM Easting  
 in meters  
**249000m E**

UTM Northing  
 in meters  
**4279000m N**

4279000m N  
 38°37'30"  
 119°52'30"

247

2 590 000 FEET

248

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1979

249000m E

# Tools to Measure Within the Grid

## 6

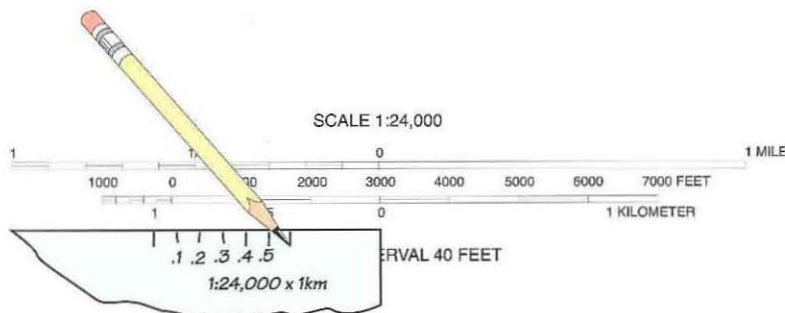
There are many different devices and methods for measuring position within a UTM grid square. The different methods vary in both accuracy and ease of use. The basic requirements for all of these tools are that they be scaled to match the map scale, that they be marked to measure metric distance, and that they are sized to match the grid spacing on the map.

### Eyeball Estimate

The simplest technique is to “eyeball” estimate tenths within the grid. This is relatively easy to do, requires no special equipment, but is not particularly accurate.

### Rulers

It is somewhat more accurate to mark a ruler on the edge of a scrap piece of paper. If the map has a scale bar marked off in kilometers and tenths of a kilometer. It's easy to transfer these distances to the paper.



Without a scale bar you can do a simple calculation to get the measurements for your paper ruler.

For a 1:24,000 scale map the calculation would look like this...

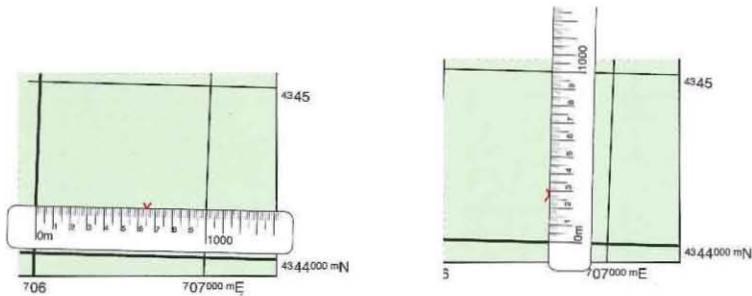
$$1000\text{m} / 24000 \times 1000 = 41.6\text{mm}$$

which tells us that a 1000m ruler would be 41.6mm long. The 100m marks on this ruler would be 4.16mm apart.

More generically the equation is

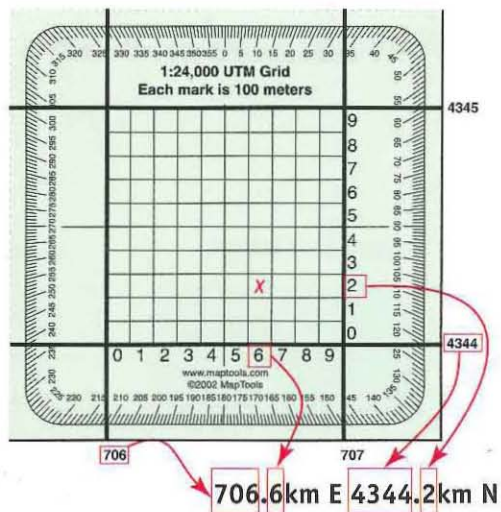
$$\frac{\text{Grid Spacing in meters} / \text{Scale Value} \times 1000}{\text{Length of ruler to match the grid in millimeters}}$$

Whether your ruler is self made or preprinted, it is used to take two measurements, The easting is measured from the western edge of the grid. Then the northing is measured from the southern edge of the grid.



## Grid Tool

The grid tool included with this guide is the tool style that is easiest for a beginner to learn to use. Placed into the grid it allows both the easting and northing to be measured with a single quick and easy tool placement. The disadvantage of this tool style is that they only divide the grid into tenths, less precision than may be desired. This style of tool is easy to use with partial grids on the edge of the map.

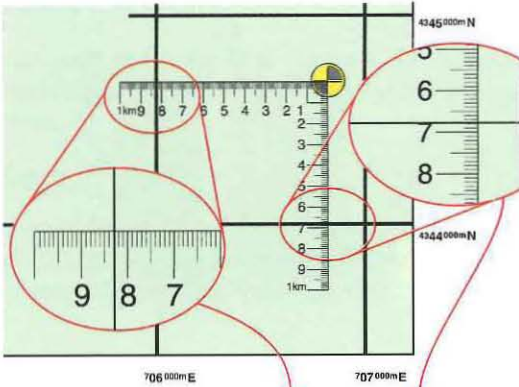


# Corner Rulers or Roamers

The next step in the evolution of grid measurement tools is to place two rulers together at a right angle. This tool is referred to as a corner ruler or a "roamer." The tool is used by placing the corner on the map feature to be measured. With the two rulers parallel to the grid lines, the measurements can be read where the rulers cross the western and southern grid lines. These tools can either be printed onto the corner of a piece of paper, or printed onto clear material with a small hole at the corner to allow marking of the map.

When either the west or south grid line is missing on a partial grid at the edge of the map, the user is forced to use a single ruler aligned on the eastern or northern grid line.

**Corner Ruler Tool**



**Partial Grid Usage**



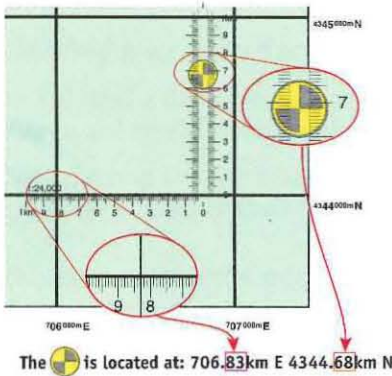
The  is located at: 706.83km E 4344.68km N

# Military Style or Slot Style Tool

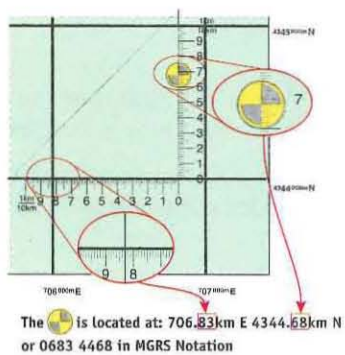
The next evolutionary step was to rotate the two rulers 90°. Now one of the rulers is placed along the southern edge of the grid, while the tool is positioned so that the vertical ruler is aligned with the feature to be measured. The easting is read where the horizontal ruler crosses the western edge of the grid. The northing is read where the vertical ruler crosses the feature. This tool has two big advantages over the corner ruler tool. It is easy to keep the tool parallel to the grid lines, and the vertical ruler gives a positive confirmation that the ruler fits the grid. The latter is important when there are multiple scales on a single tool. Access to the map varies with the different variations of this tool, including cut out triangles, slots, or simply the edge of the tool.

Once again when there is a partial grid at the edge of the map, the user may need to revert to separate tool positioning for measuring the easting and northing, with the end of the ruler aligned with whichever grid lines are present.

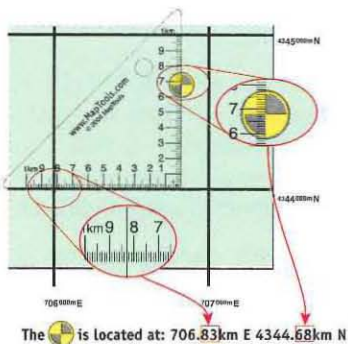
**Slot Tool**



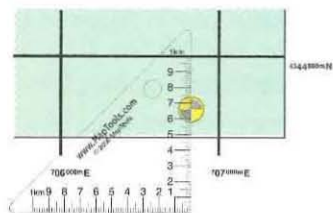
**Military Style Tool**



**MiniCorner Tool**



**Partial Grid Usage**



## Two Tools in One

### *It easy to use the same UTM tool when the scales are multiples of 10*

It's easy to use a single UTM tool on several map scales that are multiples of 10 of each other. For example, a 1:100,000 x 10km tool can be used as a 1:10,000 x 1km tool, and as a 1:1,000,000 x 100km tool. Just multiply or divide both the scale and the grid distance by 10.

# Drawing the UTM Grid Lines

## 7

Many USGS topographic maps do not have UTM grid lines printed on them. They do have UTM tic marks along their edges. You will need to draw in the grid lines.

### Selecting Your Tools

Using the right tools to grid a map will help you produce a neat looking and long lasting map grid. The wrong tools will likely result in smeared ink, grid lines that do not photocopy well, or lines that fade or run when exposed to the elements.

### Selecting a work surface

You will need a flat work surface to spread out your map. The surface should be clean and free of holes or cracks that could catch your pen.

Gridding a map is something better done at your home or office, rather than at the last minute, on the hood of your truck or a nearby flat rock.

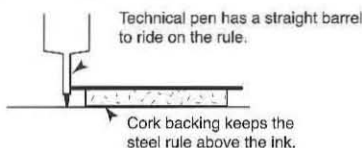
### Selecting a straight edge

The straight edge you choose to use should be at least 60cm or 24 inches long. This length will span across most of the 7.5 minute and 15 minute series topo maps. If you need to grid large 1:100,000, 1:250,000 or 1:500,000 scale sheets, you will need a longer straight edge.

Make sure it is straight. Some poor quality wooden yardsticks are warped. Hold the straight edge up and sight along the edge. It should appear straight.

Ideally the edge of the tool you select should be raised off the surface of the map. This will keep the edge away from the ink and will help to prevent smears and smudges. This may be accomplished by using a cork-backed ruler or by placing several layers of tape centered on the bottom of the ruler.

In a pinch you can roll over the edge of the map to use as a straight edge.



## Selecting a pen

You will want a pen that will draw a uniform thin line. You want to select ink that is waterproof, dries quickly to resist smudging, and that will not fade over time. A thin straight barrel will follow the straight edge well. Avoid pens with large tapered ends. They are hard to position along the ruler.

Grid lines that are too thin or that are made in a light color may not photocopy well.

I've found that a black line that is 0.2 to 0.25 mm thick works well. You can find technical drawing pens that meet these criteria in an art or drafting supply store, or at the MapTools web site.

Good mechanical pencils meet many of these criteria, but their lines do not photocopy well.

Waterproof paper or coatings may make it difficult to draw grid lines. Test your pen on the edge of the map first. I've had good luck using solvent based pens like an extra fine point Sharpie

## Drawing the Grid Lines

Once your map is laid out, and your straight edge and pen are at hand, you're ready to begin drawing grid lines.

Work slowly and with care, you don't get a chance to erase any mistakes.

Starting at the north edge of your map, locate the UTM grid ticks on the east and west edges of your map. The grid line will likely not be parallel to the map's edges. Double check that the two tick marks you are aligning your straight edge with have the same UTM coordinate values. Touch your pen down at one of the tick marks, and make sure the ruler is positioned so that the tip of the pen is exactly centered over the tick mark. Repeat this check at the other end. Now, carefully draw your grid line. Avoid moving the pen too rapidly for the ink to flow to the tip. Lift up your straight edge carefully to avoid smearing your new grid line. Wipe the edge of your ruler with a tissue. If you get ink on the tissue, you need to be extra careful not to leave any smudges as you work. You may need to wipe the edge frequently. Continue working towards the south edge of the map, progressing away from your previous lines. Once you have finished your east - west grid lines, repeat the procedure for the north - south grid lines.

# Practice Map



Using the map on the following pages, answer these questions. Try using the grid tool in the back, an improvised ruler made using the scale bar, and any other 1:24,000 scale tools you have. Answers follow the map.

Determine coordinates for the following locations:

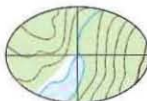
#1 Brady Mtn



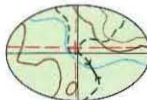
#2 Grouse Ridge  
x7181



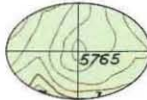
#3 North end of  
Lake Spaulding



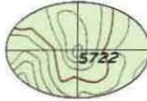
#4 Trail junction of  
Grouse Ridge and  
Beyers Lake trails



#5 Knoll marked  
x5765



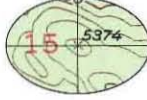
#6 Knoll marked  
x5722



#7 Knoll marked  
x5424



#8 Knoll marked  
x5374



What map features are located at the following coordinates?

#9 707.39km E 4358.03km N

#10 708883m E 4358712m N

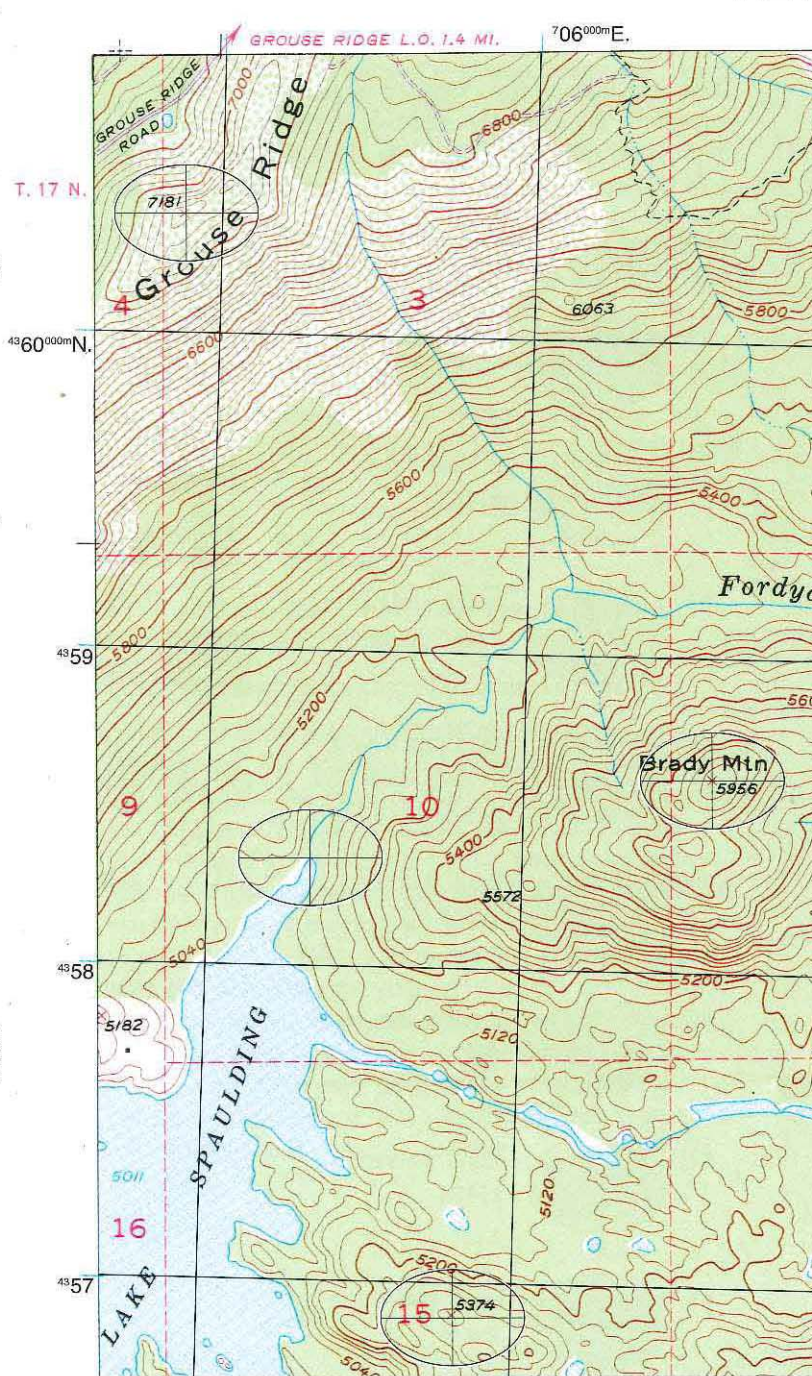
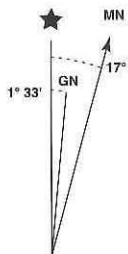
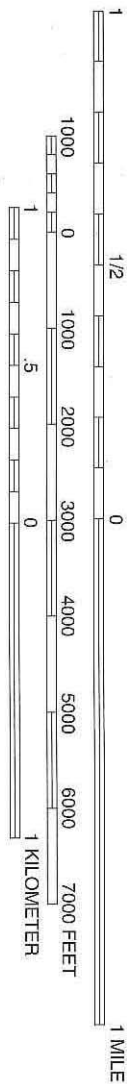
#11 706.02km E 4358.27km N

#12 10S 0708032  
UTM 4359711

#13 707.78km E 4358.77km N

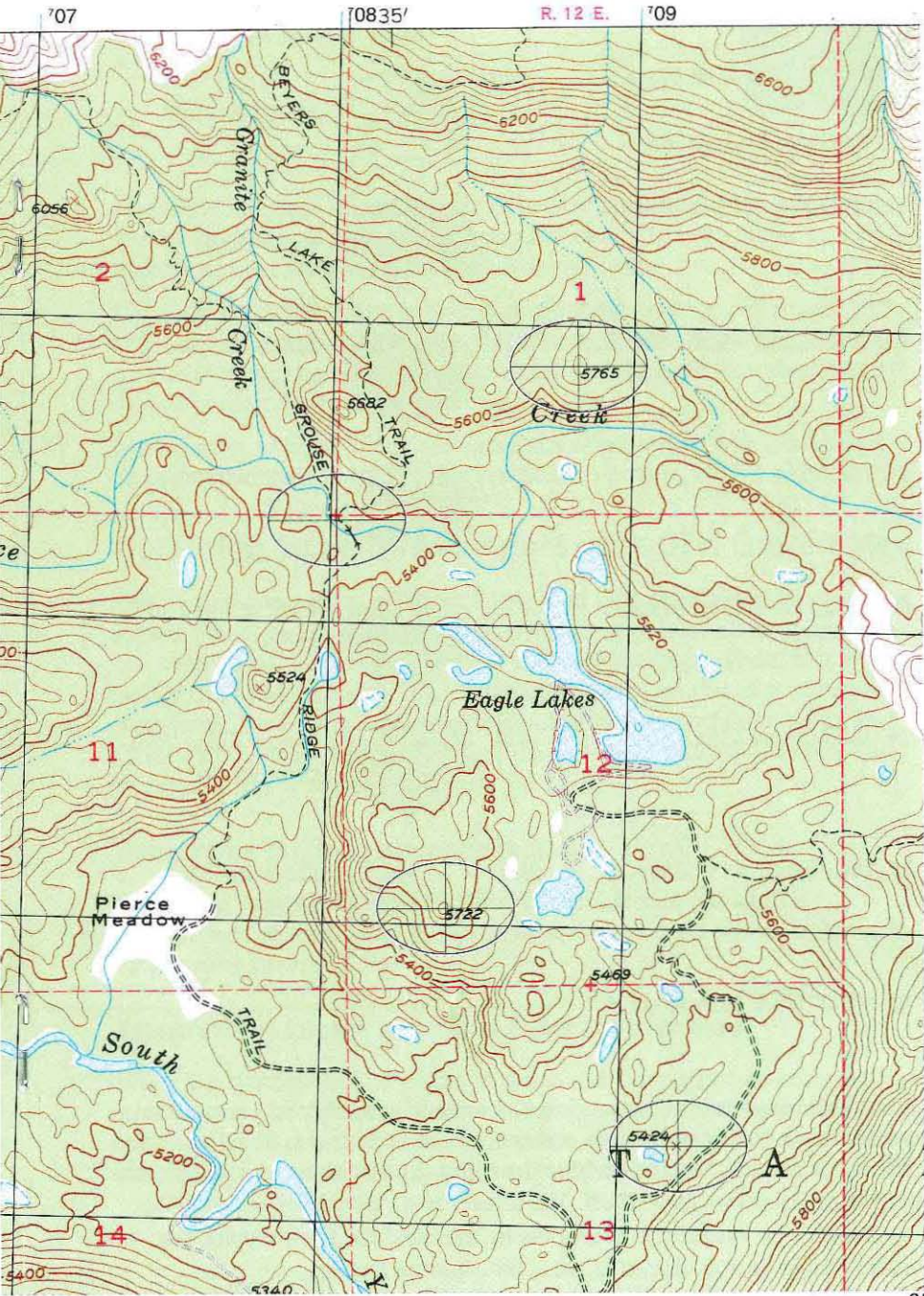
#14 706.30km E 4360.59km N

#15 704.69km E 4357.82km N



,000

1000-meter Universal Transverse Mercator grid, zone 10.  
1927 North American Datum



## Answers to the Map Problem

Determine coordinates for the following locations:

#1 706.59km E 4358.62km N  
or  
706590m E 4358620m N

#2 704.88km E 4360.38km N

#3 705.32km E 4358.34km N

#4 708.03km E 4359.34km N

#5 708.82km E 4359.87km N


#6 708.40km E 4358.05km N

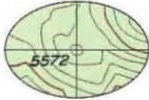
#7 709.20km E 4357.28km N


#8 705.82km E 4356.89km N


What map features are located at the following coordinates?

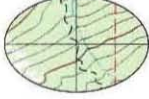
#9  Pierce Meadow


#10  Eagle Lakes

#11  Knoll marked x5572

#12  Knoll marked x5682

#13  Knoll marked x5524

#14  Grouse Ridge Trail switchbacks

#15  Knoll marked x5182

Answers are shown with 10m precision, for the benefit of folks using a tool marked with a 10m interval. The grid tool in the back of this book, and hand made rulers are only marked at 100m intervals. In this case you can estimate the 10m digit, or just leave it off. The answer to #1 would become 706.5km E 4358.6km N or 706500m E 4358600m N. You may also have decided the easting should be 706.6km, it is, after all, right on the line.

# Adding UTM Grid Information

## 9

Many existing maps do not include UTM coordinate grid lines or markings around the edges of the map. It is possible to add UTM grid lines to a map, to make it easier to use in conjunction with your GPS.

The steps described in the following section will produce a UTM grid with sufficient accuracy for most outdoor recreation users. Remember that the grid lines you add are approximations and are likely not as accurate as UTM grid information preprinted on a map.

Apologies in advance to any cartographers or surveyors, who will likely cringe at the crude nature of this procedure.

## Obtaining Some Initial Points with UTM Coordinates

The first step in adding a UTM grid is to find UTM coordinates for several known points on the map. Ideally you will have at least three points that are widely separated in both the E-W and N-S directions. These first known points can come from existing lat/lon information on the map, they can be transferred from some easily recognized feature on another map that has UTM coordinate information, or they can be points that you have located using your GPS receiver.

## Converting lat/lon reference marks

If the map you are placing the UTM grid onto already has lat/lon information, you will want to pick several intersections of the lat/lon grid and convert them to UTM.

## Transferring known positions from another map

Often it is possible to find points that are easily identified on both the map you are placing the grid onto, and a map that has UTM coordinate information. High points with a monument or benchmark are good choices. Other choices include stream, and road junctions.

## Locating known position with your GPS

Occasionally you will need to visit recognizable locations with you GPS to determine the UTM coordinates. Road junctions are not the best choice of point, but they are frequently used because of ease of access.

## Decide on the Grid Interval

Decide on the grid interval based on the scale of your map. Use the following table to help determine the grid interval

Scale	Grid Interval
Larger than 1:50,000	1km
Between 1:50,000 and 1:100,000	5km
Between 1:100,000 and 1:500,000	10km
Smaller than 1:500,000	Are you sure you want to use UTM?

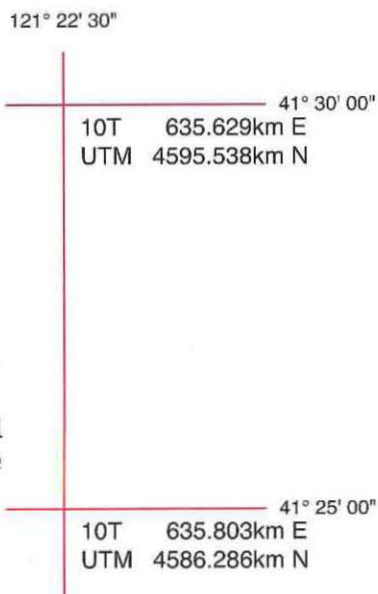
Recall that map scales represent fractions. So a 1:25,000 scale map has a scale where every unit of distance on the map is  $1/25000$  or 0.00004 times smaller than it is on the ground. A 1:25,000 scale map is said to be a larger scale map than a 1:100,000 scale map.

1:62,500 scale 15 minute USGS topographic maps typically have UTM grid tics every 1km. Placing grid lines at a 1km interval is tedious, and will leave the map cluttered. It is better to choose a 5km interval for these maps.

Grid line spacing that is less than 25mm (~1 in.) is not recommended.

## Get a Ruler for the Grid

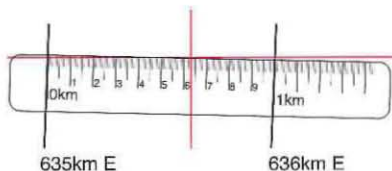
The next step in the process is to find or build a ruler that matches the scale of the map, and that spans the grid interval you have decided to use. If you know the scale of the map, you can use a ready made tool. If you have a metric scale bar on the map, you can transfer it to the edge of a sheet of paper. If you have a feet or miles scale bar, you can use it to determine the scale of the map, and build yourself a ruler. Refer to Chapter 6 for more details on using "map math" to build your ruler.



**Lat/Lon intersections converted to UTM to establish a UTM Grid.**

## Establishing the Reference Grid Lines

If you were to use a map ruler to measure the position within the grid of 635.63km E on a map with a 1km UTM grid, it would look something like this:

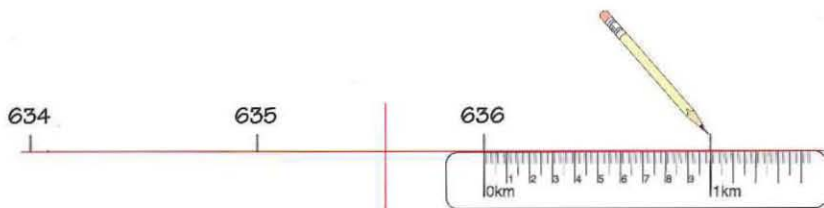


You would expect the 635km grid line to be 0.63km to the left of the point, and the 636km grid line would be 1km east of the 635 grid line.

So if the grid lines were missing, but you placed the ruler at the point lined up with 0.63km, you would be able to place marks where the grid lines should be.



You can mark the positions for additional grid lines to the east and west by spacing them every kilometer.



Even though the grid lines are most likely not lined up exactly with true north, you can place the ruler on an east-west line, without introducing a significant change in the final position of the grid lines.

You should repeat the process of marking the grid line positions with another know point that is north or south of the first point. Ideally the two points you use will be close to the northern and southern edges of your map.

By using two widely space points to establish the grid lines, any angular difference from true north will be included when you connect the marks as you draw the grid lines.



Ideally you will have several more known points that you can use to check the accuracy of your work.

## **A Few Things to Watch Out for...**

### **Errors with the control points**

An incorrect UTM coordinate for one of your control points will result in an inaccurate or potentially useless UTM grid.

### **Map or photo not uniformly scaled**

Many raw aerial photographs have not been adjusted to compensate for scaling effects of the camera position or the different heights of the terrain with respect to the lens. The worse the distortion, the less accurate your grid will be. Photos that have been corrected are referred to as having been *orthorectified*, and will often be called *orthophotos* or *orthoimages*.

### **Incompatible map projection on small scale maps**

Any time the lat/lon grid does not appear to be rectangular, it is unlikely that you will be successful drawing in a UTM grid. This is often the case for maps that are 1:1,000,000 or smaller scale.

### **Two control points is not really enough**

Ideally you would use multiple control points and mathematically adjust the position of the grid you are adding to best fit this larger set of control points. The resulting quality of fit would also give you some idea as to the accuracy of the grid. Of course this procedure is typically beyond the abilities of the kitchen table cartographer or the typical wilderness navigator.

Despite all of these potential pitfalls, it is often relatively easy to create a useful UTM grid where one did not exist before.

# More Details About the UTM Coordinate System

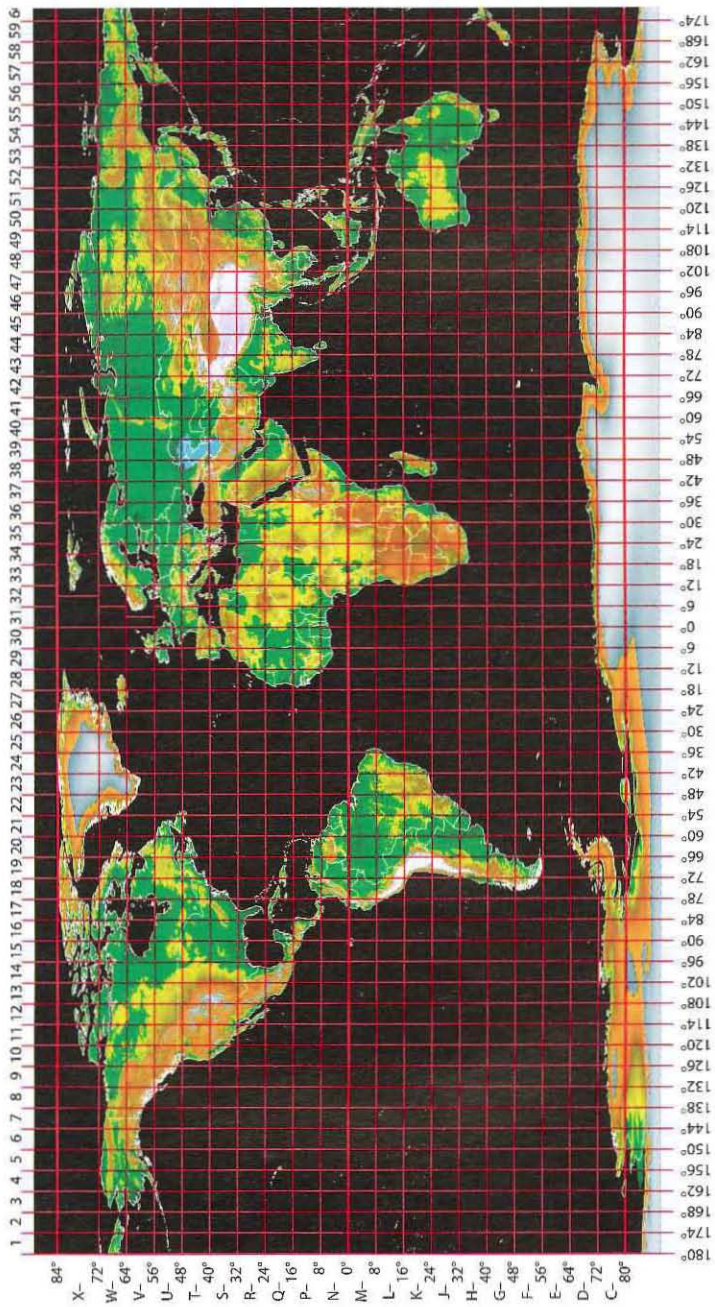
## 10

First lets distinguish between a map projection and a coordinate grid system. So far we have been discussing UTM as a coordinate grid. There is also a map projection named the *Universal Transverse Mercator Projection*. A map projection is a method for translating positions on a round earth into locations on a flat map. Projecting the globe onto a flat surface always involves some form of compromise. The most familiar map projection is the Mercator projection, where lines of latitude are shown as straight lines, but Greenland, and the polar regions are distorted and are shown much larger than they are in reality. Actually the size of everything is distorted as you move away from the equator.

The UTM projection is the geometric basis for the UTM coordinate grid system. However it is not uncommon to see a UTM coordinate grid shown on a large scale map that uses a different map projection. Most users of large scale maps can ignore the projection of the map. It is uncommon to find a UTM grid shown on maps with a smaller scale than 1:1,000,000.

The UTM grid system divides the earth into 60 zones. Each zone is  $6^\circ$  of longitude wide. These zones define the reference point for UTM grid coordinates within the zone. UTM zones are assigned a zone number from 1 through 60, starting at the international date line, longitude  $180^\circ$ , and proceeding east. Zone 1 extends from  $180^\circ$  W to  $174^\circ$  W and is centered on  $177^\circ$  W. UTM zones extend from a latitude of  $80^\circ$  S to  $84^\circ$  N. In the polar regions the Universal Polar Stereographic (UPS) grid system is used. From a users prospective UPS coordinates are rectangular measurements in kilometers or meters, just like UTM coordinates.

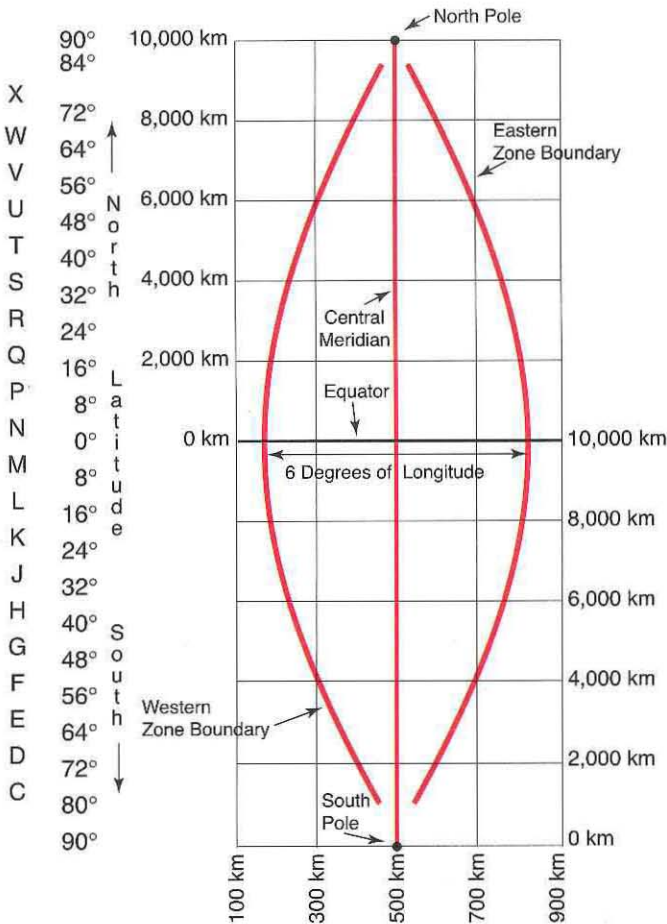
Note that the zone map shown to the right uses the Mercator Projection. Latitude and longitude lines are perpendicular, and the polar regions are badly distorted.



UTM Zone Map

Each zone is divided into horizontal bands spanning 8 degrees of latitude. These bands are lettered, south to north, beginning at 80° S with the letter C and ending with the letter X at 84° N. The letters I and O are skipped to avoid confusion with the numbers one and zero. The band lettered X spans 12° of latitude. These letters are known as the Zone Designator Letter or ZDL. The ZDL is necessary to distinguish a coordinate's position between the northern and southern hemispheres.

When the zone number is combined with the letter for the longitude band, the result is called a *Grid Zone Designator (GZD)*. A GZD identifies a 6° wide by 8° tall portion of the globe.



**UTM Zone Diagram**

Note that there are several exceptions to the zone layout to accommodate the southwest of Norway and the island of Svalbard.

The letters A,B,Y, and Z are used for UPS Grid Zone Designators. UPS coordinates have no zone numbers.

A square grid is superimposed on each zone. It's aligned so that vertical grid lines are parallel to the center of the zone, called the central meridian.

The central meridian and the edges of the zones are all meridians, or lines of longitude. In a Transverse Mercator map projection, the central meridian is a straight line between the poles, other lines of longitude run between the poles, but are curved. Thus the edges of the zones are curved lines

The UTM zone diagram shown is distorted to fit the page. In reality it is 30 times taller than it is wide. Thus the zone boundaries are not as dramatically curved as they appear in the diagram.

## Eastings

UTM easting coordinates are referenced to the central meridian, and is assigned an easting value of 500,000 meters East. Since this 500,000m value is arbitrarily assigned, eastings are sometimes referred to as *false eastings*.

An easting of zero or less than zero, will never occur, since a 6° wide zone is never more than 674,000 meters wide.

Minimum and maximum easting values are approximately:

160,000m E and 834,000m E at the equator

465,000m E and 515,000m E at 84° N

## Northings

UTM northing coordinates are measured relative to the equator. For locations north of the equator, the equator is assigned the northing value of 0 meters North. To avoid negative numbers, locations south of the equator are made with the equator assigned a value of 10,000,000 meters North.

UTM northing values are duplicated both north and south of the equator. In order to avoid confusion the full coordinate needs to specify whether the location is north or south of the equator. Usually this is done by including the Grid Zone Designator.

If this is your first exposure to the UTM coordinate system you may find the layout of zones to be confusing. In most land navigation situations, the area of interest is much smaller than a zone. The notion of a zone falls away and we are left with a simple rectangular coordinate system to use with our large scale maps.

# MGRS & USNG

11

The Military Grid Reference System (MGRS) is a coordinate grid system that is based on the Universal Transverse Mercator projection and grid system. MGRS was adopted by the U.S. Army in 1949 for designating rectangular coordinates on large scale military maps. MGRS is currently used by the United States and NATO armed forces.

The United States National Grid (USNG) system was proposed in 2000 and adopted as a national standard by the Federal Geographic Data Committee in 2002. USNG is almost equivalent to MGRS when the NAD83 or WGS84 datum is used. Refer to the end of the chapter for details on the differences.

## **MGRS is an Abbreviated UTM Coordinate**

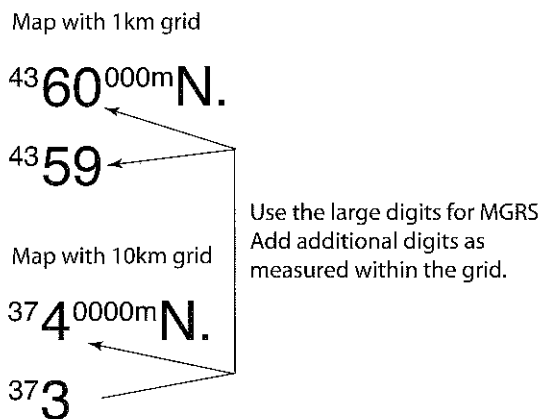
The most common usage of MGRS coordinates is to describe positions within a localized area, such as one covered by a few 1:24,000 map sheets. At a localized level MGRS is an abbreviated form of UTM grid coordinates. This localized coordinate format provides unique coordinates within a 100km square region. This focus on a small area allows us to abbreviate UTM coordinates as follows:

The zone information is dropped. The digits representing 1,000,000m, and 100,000m are dropped, or converted to a letter pair. The 1m, 10m and 100m digits are used only to the extent of precision desired.



## Typographic Hints for MGRS Users

Maps printed by the Defense Mapping Agency (now called the National Geospatial-Intelligence Agency) and the USGS show UTM coordinates in a typographic style that is an aid to MGRS users. To read MGRS abbreviated coordinates, the user should use the large type face digits from the easting and northing, and measure within the grid to the desired precision. The smaller type face digits are not used in the MGRS coordinates.



## Setting Up Your GPS for MGRS

Your GPS can also display coordinates in the MGRS format. Simply select MGRS from the list of position formats in your setup menus. Some GPS receivers will allow you to select the precision that the coordinates are displayed with. Typical choices are 100m, 10m and 1m. Other receivers will always display the coordinates with 1m precision.

## 100,000 Meter Square Letter Pair Identifier

A 6°x8° Grid Zone is broken down into 100,000m x 100,000m squares that are identified by a letter pair. This letter pair replaces the 1,000,000m and 100,000m digits of both the easting and northing. The letter pair is unique within a group of 9 adjacent Grid Zones. Again, as with the Grid Zone Designators, the letters I and O are not used to avoid confusion with the numbers 1 and 0.

## Printed grid reference box

When you are using a map designed for MGRS users, the information along the edge of the map will contain a Grid Reference Box that will contain both Grid Zone Designator and 100,000m square identification information for the map. On most large scale maps, the entire map will fall within a single Grid Zone Designator. However that map may fall within several 100,000m square identifications. In this case the reference box will describe the boundaries and indicate the identifiers for the 100,000m squares that fall within the map. Small scale maps may cross grid zone boundaries as well. In this case the reference box will indicate this as well.

U.S. National Grid
100,000-m Square ID
UH
Grid Zone Designation 18S

U.S. National Grid				
100,000-m Square ID				
<table border="1"> <tr> <td>TJ</td> <td>UJ</td> </tr> <tr> <td>TH</td> <td>UH</td> </tr> </table>	TJ	UJ	TH	UH
TJ	UJ			
TH	UH			
Grid Zone Designation 18S				

U.S. National Grid				
100,000-m Square ID				
<table border="1"> <tr> <td>HJ</td> <td>JD</td> </tr> <tr> <td>HH</td> <td>JC</td> </tr> </table>	HJ	JD	HH	JC
HJ	JD			
HH	JC			
Grid Zone Designation 04Q   05Q 156°W				

## Using the 100,000 meter square letter pair identifier reference chart

In the event you need to determine the 100km letter pair without the benefit of a GPS or the reference box on the map, you can use the reference table on the following page. Follow these steps:

- Locate the Set using the zone number. The table is broken down into six sets. The zone numbers included in each set are listed at the top of the set.
- Use the 100,000m digit of your easting, to identify the column within the set that contains your letter pair. The eastings are labeled along the bottom of the chart. This will determine the first letter of the pair. An easting of 703456m E would use the column just to the right of 700,000m E.
- Use the 1,000,000m and 100,000m digits of the northing to locate the row to use. The rows repeat every 2,000,000m. A northing of 3356123m N would use the row just above 1,300,000m N (we subtracted 2,000,000m from the northing.)
- Use the letter pair found within the set, column, and row you identified.

Note that when the map datum is NAD27 the second MGRS Grid Square letter is advanced by 10 letters (remember I and O are not used). Thus the second letter in the bottom row of the chart would shift from A to L for even numbered zones, and from F to R for odd numbered zones. USNG does not follow this odd convention and the second letter is not shifted for the NAD27 datum.



## Fully Specified MGRS Coordinates

All of the points on the practice map earlier in the book, are in Grid Zone 10S and are within the 100,000m square identified by the letter pair GJ. So Brady Mountain is located at 10SGJ06595862 with 10m precision.

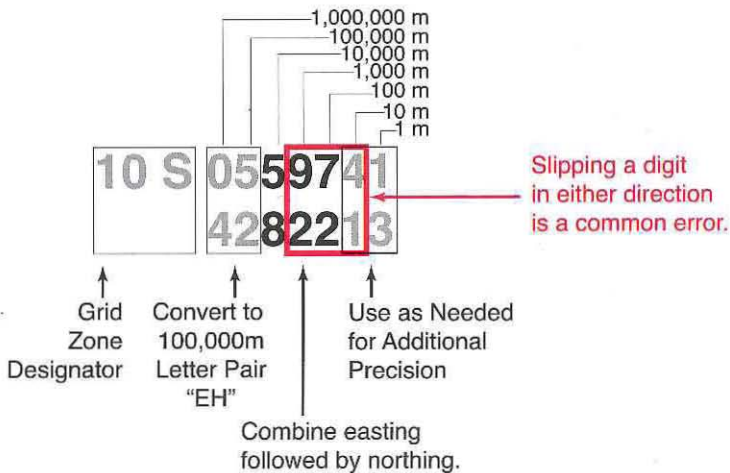
If our activity is all enclosed within grid zone 10S, we can drop the grid zone designator, and our coordinate becomes GJ06595862.

If our activity is within the GJ 100,000m square, we can also drop the 100,000m square id letters, and our coordinate becomes 06595862.

If 100m precision is adequate, we can drop the 10m digit and our coordinate becomes 065586.

## Some Cautionary Words About MGRS Coordinates

Abbreviated MGRS coordinates may have been very valuable back in the days when coordinates were sent by morse code, or over scratchy field radios. Their down side is that it is very easy to "slip a digit" and report the wrong set of digits. The result is a useless coordinate. Worse yet there is not enough redundant information to detect that an error may have been made.



Most military and search and rescue folks that I work with, have quit using the abbreviated MGRS coordinate format. Most SAR users are now reporting the entire easting and northing as read from their GPS.

## Differences Between MGRS and USNG Coordinates

The most significant difference between the two coordinate systems is the shifting of the second MGRS grid letter when the NAD27 datum is used. USNG does not perform the shift and thus the same location will have a different 2 letter pair. Since most land navigation users drop the GZD and Grid Letters, the shift usually has little impact, unless you need to enter MGRS coordinates into your GPS for far away locations.

USNG allows the use of only two datums NAD83/WGS84 or NAD27. The default USNG datum is NAD83/WGS84. When using NAD27 you must explicitly specify it. For example, 10SEH597822 (NAD27). MGRS coordinates may be used with any datum, and there is no formal way to specify the datum. (It is still very important to specify the datum. It's just not formalized how to write it.)

There are also several minor formatting differences. USNG allows spaces in the coordinate, 10S EH 597 822. MGRS requires that there be no spaces with all of the letters and numbers run together. MGRS allows you to reference an entire 100,000m square area, e.g. 10SEH, whereas USNG requires at least two digits and thus the largest area that can be described is a 10,000m square, e.g. 10S EH 5 8.

Finally the USNG coordinate system only covers the United States and its territories and possessions, it does not include the UPS coordinate system for polar regions, nor does it need the zone boundary exceptions defined for Norway.

Many folks have questioned why MGRS was not adopted as the standard by the Standards Working Group of the Federal Geographic Data Committee. Perhaps future revisions of the USNG standard will eventually resolve these differences.



# North Reference

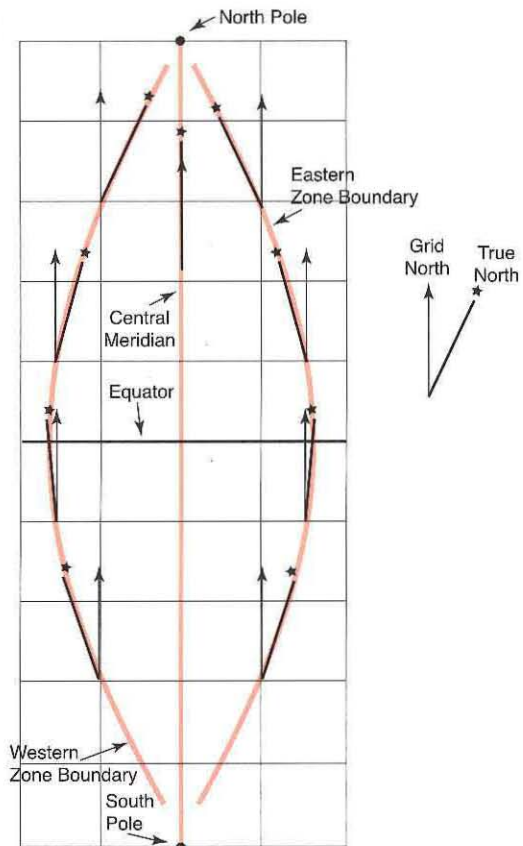
12

The use of the UTM coordinate system also introduces a new north reference. In addition to True North and Magnetic North, we can now refer to Grid North. Grid north is the direction that the North-South UTM grid lines run. Grid North is typically within 2 degrees of True North.

What makes Grid North useful, is that there are lots of Grid North lines on the map. They make a convenient north reference lines when we are working with our compass to plot or determine bearings from the map. Often the only True North reference lines on the map are the left and right edges.

Revisiting the UTM Zone Diagram will help to explain how Grid North differs from True North. First recall that all longitudinal meridians are also True North reference lines. The edges of the UTM zone, and the central meridian are all longitudinal meridians. They are shown in red on the zone diagram.

At the center of the zone, the UTM grid lines are aligned with the central meridian, and thus there is no difference between Grid North and True North at the center of a zone. The further we move from the central meridian, the greater the difference we will see between Grid North and True North. With the maximum difference occurring at the edges of the zone. This difference



also becomes larger as we move towards the poles, and away from the equator. Depending on the location within the zone, Grid North may be either east or west of True North. Within the Continental United States, the difference between Grid north and True North will never be more that about two degrees.

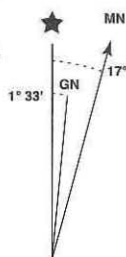
The relationship between True North, Magnetic North, and Grid North is shown on the declination diagram found on most maps. The magnetic declination varies over time. Grid North is related to the zone geometry and does not change over time.

Most GPS receivers can be set to display heading information relative to True North, Grid North, an automatically calculated Magnetic North, or a user specified Magnetic North.

When you are using Grid North as the north reference on your map, you will want to use the difference between Grid North and Magnetic North as the declination you use in calculating magnetic bearings or that you set into your compass.

It is also very common to ignore all that you've just read, use the grid lines as if they are True North lines, and just live with the degree or two error that may result.

The UTM zone diagram shown is distorted to fit the page. In reality it is 30 times taller than it is wide. Thus the zone boundaries are not as dramatically curved as they appear in the diagram nor is the difference between Grid North and True North as large as it appears.



# UPS

# 13

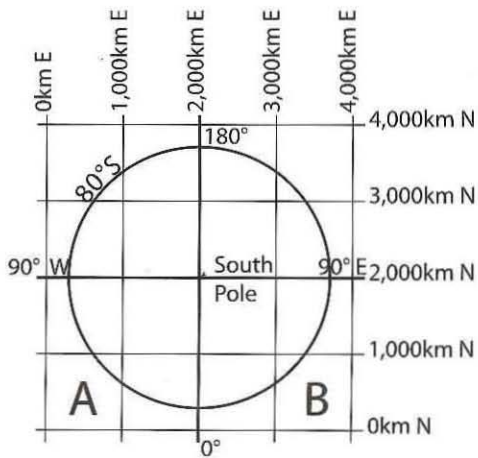
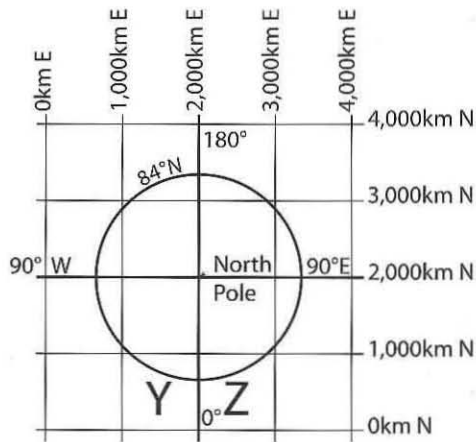
In the polar regions, above  $84^{\circ}\text{N}$  and below  $80^{\circ}\text{S}$ , the coordinate system used is the Universal Polar Stereographic (UPS) system.

UPS is also a square grid system, but it is placed over a polar stereographic projection centered on the pole. The poles are assigned a false easting and a false northing of 2,000km. The East-West direction is defined by the  $90^{\circ}\text{W}$  to  $90^{\circ}\text{E}$  lines of longitude. North-South is defined by  $0^{\circ}$  to  $180^{\circ}$ .

At the North Pole a Grid Zone Designator of 0Y is used "west" of the pole, and 0Z is used "east" of the pole. At the South Pole, it's 0A to the "west", and 0B to the "east."

Your GPS will automatically switch between UTM and UPS depending on the location being displayed. You can try this out. Just store a waypoint in lat/lon format that is above  $84^{\circ}\text{N}$  or below  $80^{\circ}\text{S}$ . Then switch back to UTM/UPS and bring up the waypoint.

A user of a large scale map, will be able to plot UPS coordinates just like they would plot UTM coordinates. The definitions of East and North are a bit fishy, but it is still "read right then up"



**UPS Zone Diagrams**

# Scale Reference

# 14

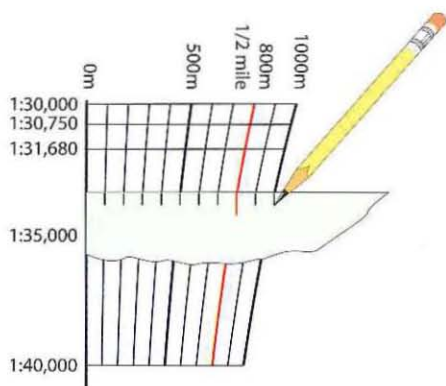
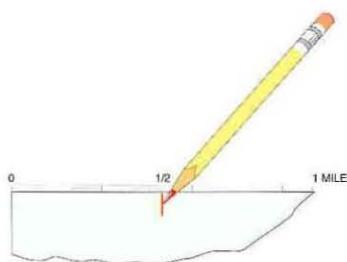
Maps come in an infinite varieties of scales. In many cases the map may not even list it's scale. The charts on the following pages can be used to create a UTM measuring tool along the edge of a scrap of paper for many different scales of maps.

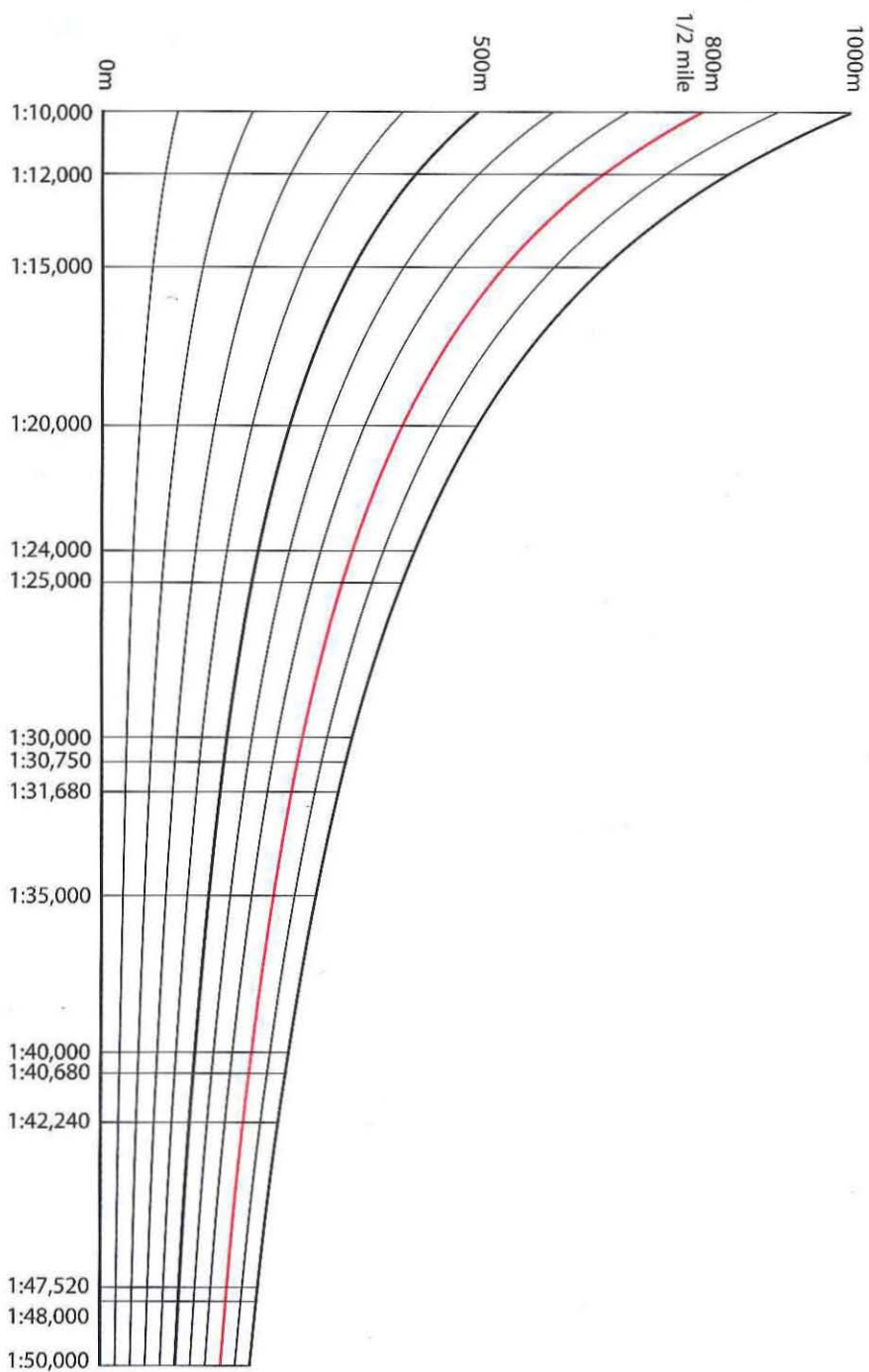
If the map has a metric scale bar, mark a 1 kilometer distance on the edge of your scrap paper, slide your 1km mark along the chart until it fits. Transfer the lines from the chart to the paper, and you have a 100m measuring tool for your map.

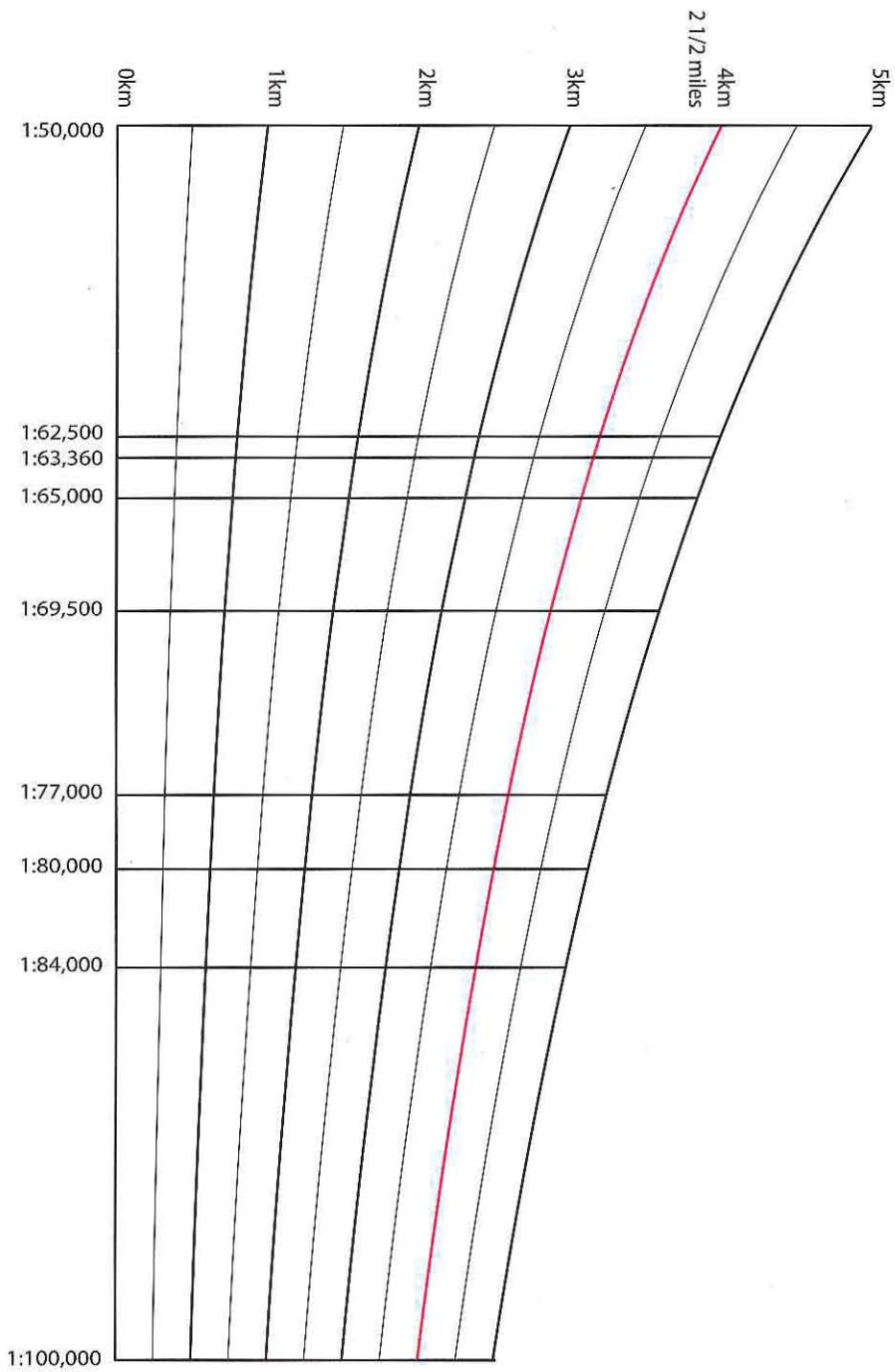
If the map has only a mile scale bar, mark a 1/2 mile distance on the edge of your scrap paper, slide the 1/2 mile mark until it fits with the 800m line (shown in red). Transfer the lines from the chart to the paper, and you have a 100m measuring tool for your map.

For scales between 1:50,000 and 1:100,000, mark either 5km or 2 1/2 mile and use the chart on page 50 to produce a 5km measuring tool. If you want a 10km tool, slide the tool over and add another set of 5km markings.

Remember you can use these charts at a factor of 10 larger or smaller. The 1:10,000 to 1:50,000 by 1000m chart, can be used as a 1:1,000 to 1:5,000 by 100m chart or as a 1:100,000 to 1:500,000 by 10km chart









# MapTools



## *Tools for plotting GPS coordinates*

---

### **Using you GPS with the UTM Coordinate System**

Inexpensive GPS receivers have brought the ability to determine accurate geographic positioning to both professionals and recreational users. To relate the GPS reading to a map, the user needs to understand how to use geographic coordinate systems. Many new GPS users are discovering what military and rescue forces have known for years. UTM coordinates are much easier to work with than latitude longitude coordinates.

This booklet is a great starting point for beginning GPS users and folks that want to learn about UTM, MGRS, and USNG coordinates. With lots of illustrations and step by step instructions, readers will be converting between map locations and UTM coordinates in no time!

**"For field work, UTM coordinates are much easier to use than lat/lon coordinates."**

**Includes a 1:24,000 scale "Pocket Sized" Grid Tool for use with 7.5 minute USGS topographic maps.**

***Visit MapTools on the Internet at [www.MapTools.com](http://www.MapTools.com)***

---

ISBN 0-9710901-1-4



9 780971 090118



Printed in USA