

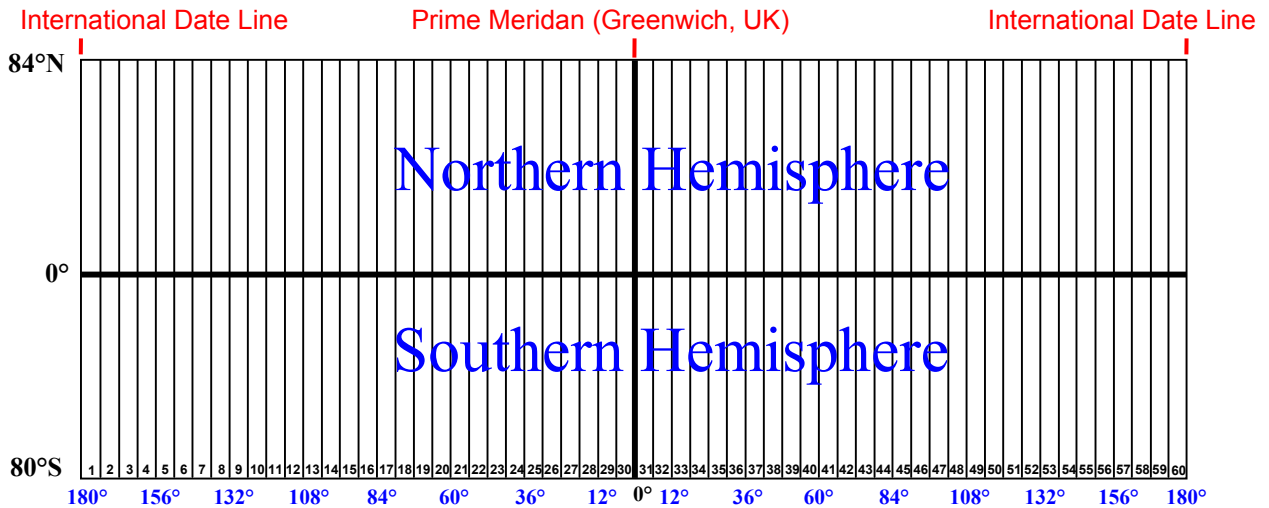
# Military Map Reading 201

This information paper is designed to resolve the confusion between the Universal Transverse Mercator (UTM) and the Military Grid Reference System (MGRS) coordinates. The two systems are often used interchangeably, but they are not the same. Most of our allies, intelligence databases, and many software packages use the UTM system. The Army and Marine Corps proposed the MGRS convention to simplify coordinate exchange for the soldier/marine in the field. The aim of this paper is for users to understand both the UTM and MGRS systems and be able pull coordinates on multiple scales of maps and charts.

## Universal Transverse Mercator Grid

The UTM projection transforms our three-dimensional world into a two dimensional system that allows cartographers and map users to measure distances, angles, and areas accurately. The UTM system divides the world into 60 numbered (1-60) zones with each zone being 6 wide in longitude. The 60 zones begin counting at 1 from the International Date Line, at 180 West longitude (located between Alaska and Russia), to 30 at the Prime Meridian (Greenwich, England), and up to 60 back to the International Date Line. The UTM projection loses the qualities of distortion prevention once we go near the north and south poles. For this reason UTM is valid for areas on the earth from 84 N to 80 S. The polar regions, areas between 84 N to 90 N and 80 S to 90 S, are portrayed on maps and charts using the Universal Polar Stereographic (UPS) projection. The UPS projection is used to avoid the convergence of the longitudinal lines outside of the designated area of the UTM projection.

### Grid Zone Designations of the UTM Coordinate Systems

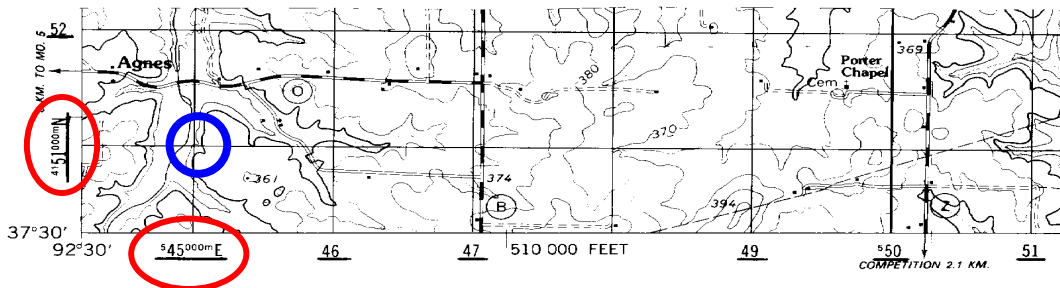


UTM coordinates for a location are determined in a multi-step process. First the user must find the proper UTM zone in which the position is located. The UTM zone number is located in the margin of large-scale maps (TLM, JOG), and in the printed area on medium scale (TPC/ONC) aeronautical charts. Next the user should designate whether the location is in the Northern or Southern Hemisphere. This is an important point because a UTM coordinate can work in both the Northern and Southern Hemispheres.

Next, the position is specified within the zone using a X, Y or Easting and Northing grid system. UTM Coordinates are always read **right** and **up** resulting in Easting and Northing values in meters. The Easting is *always* a six digit value while the Northing figure is *almost always* a seven digit value (near the equator there may be less than seven, but most systems will want you to precede a six digit coordinate with a zero). In the Northern Hemisphere Northing values are determined by counting the number of meters that the location lies north of the equator. For areas in the southern hemisphere the Northing values start at 10,000,000 meters North at the equator and count down. For example a location 1 meter south of the

equator would have a Northing value of 9,999,999 meters North, while a position 1 meter north of the equator would have a Northing value of 0,000,001 meters North.

Below we have depicted an example of a UTM coordinate. To read the Easting value you need to look at the bottom left corner of the map's image area to find the UTM string. The Easting string will generally have one small number (in size), one large number (JOG, TPC, ONC) or two (TLM), then three or four small zeros (six total digits – e.g.  $545^{000m}E$ ). As you can see, the large numbers are the ones that change as you look across the bottom of the map sheet. They correspond to the 1,000 or 10,000 meter squares within a 6 longitudinal belt that fits the Army's Coordinate Scale and Protractor (See following details to obtain coordinate from the protractor). Read over (right) to the furthest grid line without passing the point. This should give you the first two or three numbers depending on scale. To fill in the last three or four digits of the Easting value, you use the protractor overlaid on the appropriate square.

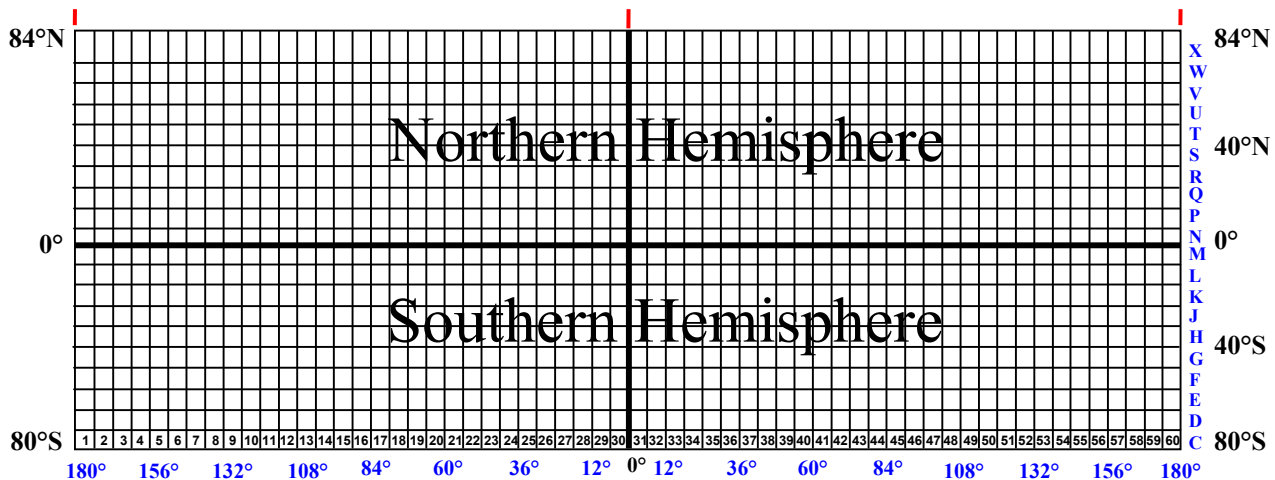


To determine the Northing value you follow a similar process, except that you are now using the numbers associated with the horizontal grid lines. In this example the grid intersection is  $4151^{000m}$  meters north of the equator. Remember that UTM coordinates require you to use all **six** digits in the Easting and all **seven** in the Northing values. Generally, this results in the last one or two digits always being zero because you can not read a protractor any more accurately than one millimeter. For example, the UTM coordinate for the grid line intersection encircled above is **15 545,000mE 4,151,000mN**

### Military Grid Reference System (MGRS)

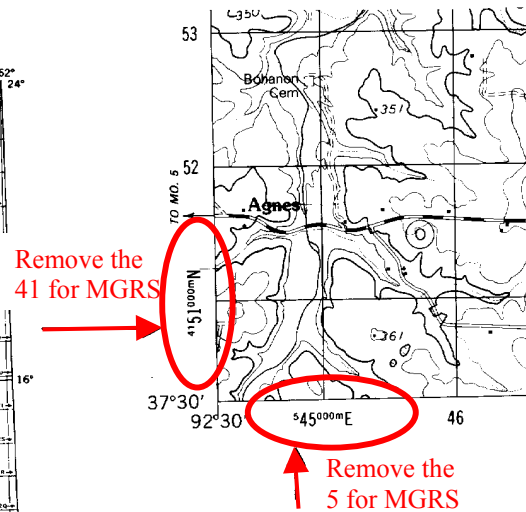
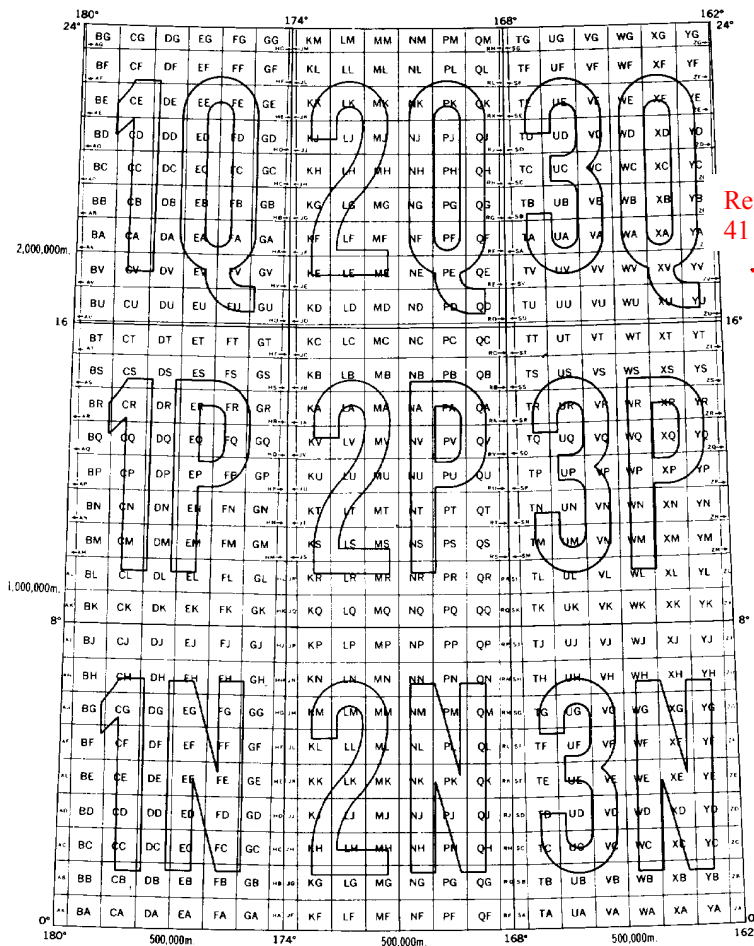
The MGRS system was designed to simplify the specification of position and passing of coordinates for soldiers and marines. The MGRS system allows users to abbreviate the 13-digit UTM coordinate, making it easier to use. You begin the same way, with the Grid Zone Designator, but there it is different. The difference is that the 60 zones are divided every 8 of latitude, which forms 6 x 8 grid zones. The one exception to the 8 latitudinal division is the northern most division "X" which is 12 high. The 8 divisions are denoted by a lettering scheme that starts with "C" at 80 S and letters each 8 latitude zone to "X" excluding the letters I and O which are easily confused with 1 and 0. The basic system is depicted below:

### Grid Zone Designations of the MGRS Coordinate Systems



Next, each 6 x 8 grid zone is further broken down into 100,000 meter squares. Each 100,000 meter square is assigned a two letter scheme to distinguish it from the neighboring squares. The first letter starts with A in the west and goes higher as the zones move east. This letter corresponds to the first digit in the Easting value of a UTM coordinate. The second letter starts with A in the south and rises as you move north. The second letter in the 100,000 meter square identifier corresponds to the second digit in the Northing value of the UTM coordinate. These two letters allow you to remove the small numbers preceding the large ones from the full UTM coordinate in the bottom left corner of the map face. In the example from the previous page, <sup>5</sup>45<sup>000m</sup>E and <sup>41</sup>51<sup>000m</sup>N, the superscript 5 and 41 are no longer required in MGRS because the letters are used in their place to denote 6 X 8 grid zone and 100,000m square.

Basic Plan of the 100,000 meter Square Identifications of the Military Grid Reference System



SAMPLE 1,000 METER GRID SQUARE	100 METER REFERENCE
	<ol style="list-style-type: none"> <li>Read large numbers labeling the VERTICAL grid line left of point and estimate tenths (100 meters) from grid line to point. 46.3</li> <li>Read large numbers labeling the HORIZONTAL grid line below point and estimate tenths (100 meters) from grid line to point. 45.6</li> </ol> <p>Example: 123456</p>
<p>100,000 M. SQUARE IDENTIFICATION</p> <p><b>WM</b></p>	<p>WHEN REPORTING OUTSIDE THE 100,000 METER SQUARE AREA IN WHICH THE POINT LIES, PREFIX THE 100,000 METER SQUARE IDENTIFICATION.</p> <p>Example: WM123456</p>
<p>GRID ZONE DESIGNATION</p> <p><b>15S</b></p>	<p>WHEN REPORTING OUTSIDE THE GRID ZONE DESIGNATION AREA IN WHICH THE POINT LIES, PREFIX THE GRID ZONE DESIGNATION.</p> <p>Example: 15SWM123456</p>

Sample Marginal Data Giving Grid Zone Designation, 100,000m Square ID, and protractor training

To specify a location in the MGRS system you must first determine which 6 x 8 grid zone the point is lies in. Grid zone designator information is normally found in the margin of large scale maps as depicted in the figure above (**15S**). Next, you need to identify the 100,000 meter square identifier for the point's location. Once again look to your margin for TLMs and JOGs to specify the letter combination (**WM**).

Now the process is similar to the UTM system in that coordinates are read right and up. The key difference is that the number of easting digits **must** equal the number of northing digits. First you must

read the Easting value, start the numerical part of your MGRS coordinate with the large number(s) that run along the bottom and side of the map and then use the protractor to obtain more precision. Unlike UTM, you do not have to use every number that would result from a “full” coordinate (10 digits -- five in the Easting and five in the Northing). You can simplify it with six digit (leave off last two digits in each direction) or eight digit (one in both E and N) coordinates.

An often-confusing point is that most NIMA 1:50,000 scale maps are made to an accuracy of 50m at the 90% confidence interval. This means that 90% of all well-defined points on a map will fall within a 50 meter radius of their actual position on the earth’s surface. The confusion comes in when soldiers try to use a map to get a 10-digit grid coordinate, which equates to a 1 meter precision. A 1:50,000 scale map is only accurate to 50m 90% of the time so a 6 digit (100m precision) or an 8 digit (10m precision) are more appropriate. A 1:250,000 scale map maintains an accuracy of 250 meters at the 90% confidence interval.

**MGRS-Old and MGRS-New**

Inventors and users, cartographers, of MGRS have changed several times over the years. With the advent of a modern global datum, WGS-84, the inventors of MGRS decided to modify the existing MGRS 100,000 meter square identifier lettering scheme. To make it obvious to the military map user, DMA instituted a ten-letter shift in the second (northing) letter of the new MGRS 100,000 meter square identifiers. For an area mapped with an old datum (e.g. NAD-27) the 100,000 meter square identifier would be **UT**. The MGRS 100,000m square identifier scheme for the same area changes to **UH** as it’s when mapped using WGS-84 datum. This ten-letter shift in the identifier was designed to alert the user to the problem with old and new maps as well as datum incompatibilities.

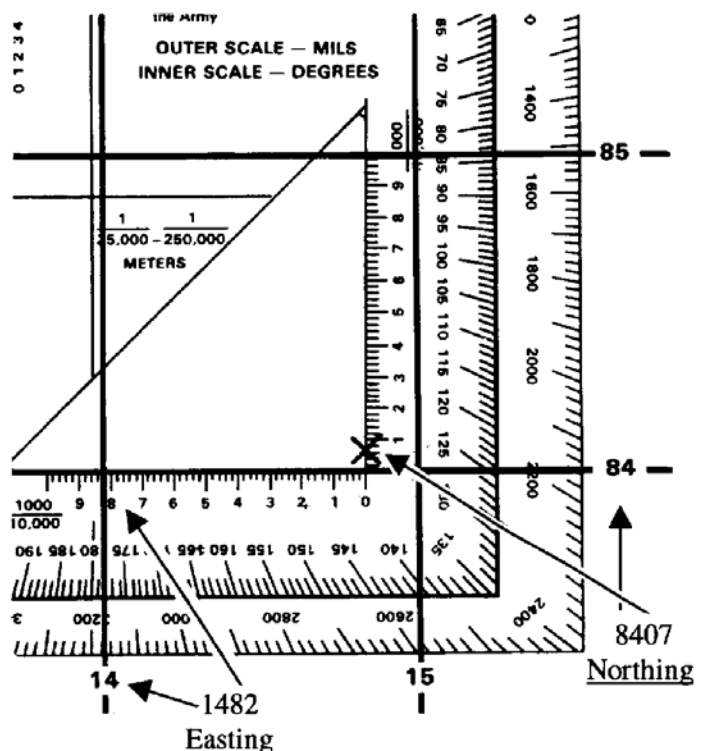
The MGRS Old system was based on three local ellipsoids (Bessel, Clarke 1866, and Clarke 1880) that predominantly were used with North American Datum 1927, Tokyo Datum, and many African datums. The New system is based on eight ellipsoids (Grid Reference System 1980, International, World Geodetic System 1984, WGS72, Australian, Everest, South American 1969 (GRS67), and Clarke 1866 (UTM Zones 47-50)) and is used for *all* global datums and many regional datums like ED50.

***\* The most important note that can be taken from this information paper is that two users at each end of a communication must be using the same coordinate system, grid zone designator and datum/ellipsoid pair. This issue can be rectified by each user verifying the data in the margin to ensure that everyone is using the same system***

**Coordinate Scale and Protractor**

This Department of the Army Training Aid (GTA 5-2-12, 1981) assists you in determining your position within a 1,000 or 10,000 meter square. You begin by aligning the base of the triangle (zero tick mark on the right side) with the UTM grid line below your point of interest (see grid line 84 of example). Align the right side so that it intersects the point as in the example. Read the coordinate right, then up. In the easting you have (1482). In the northing, you have 8407. The full eight-digit MGRS coordinate in this example is **18S UH 1482 8407**.

(18S UH comes from the marginal data.)



## Acronyms

MGRS – Military Grid Reference System	WGS84 – World Geodetic System 1984
UTM – Universal Transverse Mercator	NAD27 – North American Datum 1927
DMA – Defense Mapping Agency (1972-1996)	ED50 – European Datum 1950
TLM – Topographic Line Map ( 1:25,000 to 1:100,000)	GRS80 – Grid Reference System 1980
JOG – Joint Operations Graphic (1:250,000)	TPC – Tactical Pilotage Chart
(1:500,000) ONC – Operational Navigation Chart (1:1,000,000)	

## Glossary

**Ellipsoid** – A mathematical model of the earth that estimates the shape in order to best-fit the model to the actual surface. For local datums, the ellipsoid fits well on primarily one area of the world (e.g. North America). For global datums, the ellipsoid is earth-centered and fits the entire globe as best it can.

**Horizontal Datum** – A base reference for a coordinate system. It includes a point-of-origin of an ellipsoid and the orientation on the ellipsoid for a specific survey control network. With the same location on different datums, your location could be off up to 1000 meters.

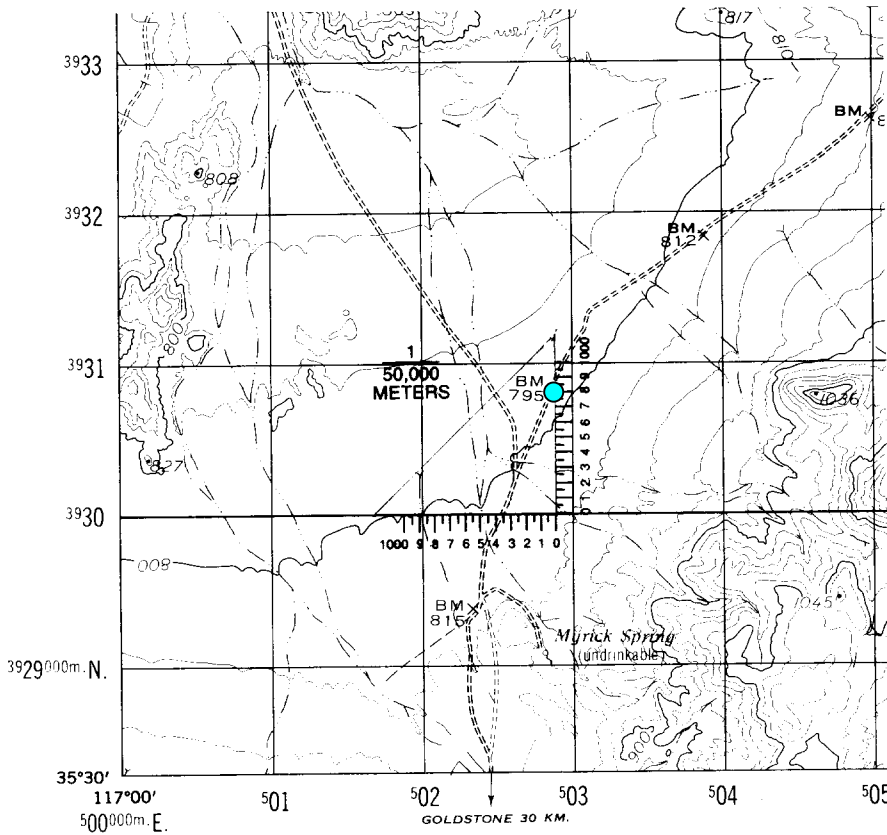
**Local Datum** – A datum that is used in only one area of the world (e.g. NAD27). It is not compatible with other local datums used elsewhere.

**Global Datum** – A datum that provides coordinates for anywhere on the globe (e.g. WGS84). Ideally, all of our maps would be a common global datum. This would eliminate the need to do datum transformations.

## Coordinate Comparison

UTM Coordinate – 18 367,890mE 4,243,210mN	(1 meter square)
MGRS 0 digit coordinate – 18SUH	(100,000 meter square on the ground)
MGRS 2 digit coordinate – 18SUH 6 4	(10,000 meter square)
MGRS 4 digit coordinate – 18SUH 67 43	(1,000 meter square)
MGRS 6 digit coordinate – 18SUH 678 432	(100 meter square)
MGRS 8 digit coordinate – 18SUH 6789 4321	(10 meter square)
MGRS 10 digit coordinate – 18SUH 67890 43210	(1 meter square)

# 1:50,000 (TLM)



<p>SAMPLE 1,000 METER GRID SQUARE</p>	<p><b>100 METER REFERENCE</b></p> <ol style="list-style-type: none"> <li>1. Read large numbers labeling the VERTICAL grid line left of point and estimate tenths (100 meters) from grid line to point. 12 3</li> <li>2. Read large numbers labeling the HORIZONTAL grid line below point and estimate tenths (100 meters) from grid line to point. 45 6</li> </ol> <p>Example: 123456</p>
<p>100,000 M. SQUARE IDENTIFICATION</p> <p style="text-align: center;">NK</p>	<p>WHEN REPORTING OUTSIDE THE 100,000 METER SQUARE AREA IN WHICH THE POINT LIES, PREFIX THE 100,000 METER SQUARE IDENTIFICATION.</p> <p>Example: NK123456</p>
<p>GRID ZONE DESIGNATION</p> <p style="text-align: center;">11S</p>	<p>WHEN REPORTING OUTSIDE THE GRID ZONE DESIGNATION AREA IN WHICH THE POINT LIES, PREFIX THE GRID ZONE DESIGNATION.</p> <p>Example: 11SNK123456</p>

SPHEROID ..... CLARKE 1866  
 GRID ..... 1,000 METER UTM, ZONE 11  
 PROJECTION ..... TRANSVERSE MERCATOR  
 VERTICAL DATUM ..... NATIONAL GEODETIC VERTICAL DATUM OF 1929  
 HORIZONTAL DATUM ..... 1927 NORTH AMERICAN DATUM  
 CONTROL BY ..... NOS/NOAA AND USGS  
 PRINTED BY ..... DEFENSE MAPPING AGENCY TOPOGRAPHIC CENTER 4-78

## Find the UTM and MGRS coordinate of Benchmark (BM) 795

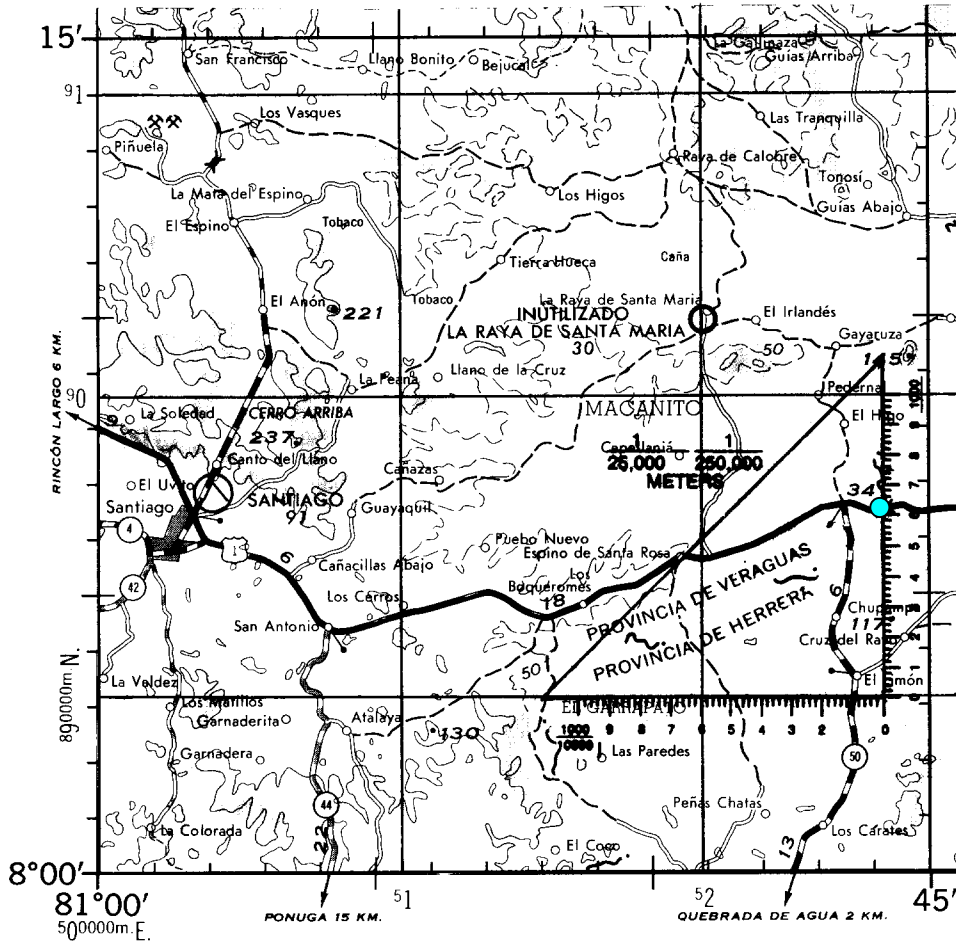
### UTM Coordinate

1. To begin, you need to pull the Grid Zone Designator for this particular area. Looking in the marginal data, you find a box with the designation **11S**. Remember, with UTM you do not need the letter **S**.
2. Then go to the bottom left corner of the map and find the Easting for the corner,  $500^{000}$  mE. Move right to the line just before our point of interest – it happens to be  $502$ .
3. Use the protractor to estimate 880. It is difficult to read the protractor beyond the second eight, but with UTM we must use all six digits contained in the Easting string (so we just fill the last digit with a zero). Putting the easting string together gives us  $502,880$  mE.
4. In the Northing, we start in the corner with  $3929^{000}$  mN and move up to get  $3930$ .
5. We can estimate the last three digits as 790 using the protractor.
6. All together, we have Grid Zone **11 502,880 mE 3,930,790 mN**. It is also important to include the datum with the coordinate, in this case – NAD27.

### MGRS Coordinate (8 digit)

1. Beginning again with the Grid Zone Designator, we have 11S.
2. The 100,000 meter square identifier for this map is found in the margin as NK (just above the GZD).
3. By using the 100,000 meter square identifier, we can drop the 5 in the Easting ( $500^{000} \rightarrow 00^{000}$ ) and the 39 in the Northing ( $3929^{000} \rightarrow 29^{000}$ ). We can also drop the last number in both directions because we can not read a coordinate that precise (gives total of 8 digits).
4. Therefore, we get 02 from the grid line and 88 from the protractor in the Easting. The Northing gives us grid line 30 and 79 from the protractor.
5. The eight digit MGRS coordinate is **11S NK 0288 3079** (NAD27 Datum).

# 1:250,000 (JOG)



GRID ZONE DESIGNATION:  
DESIGNACION DE LA ZONA DE CUADRICULA:

17P

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100,000 M. SQUARE IDENTIFICATION:  
IDENTIFICACION DEL CUADRADO DE 100,000 METROS

NV	PV
NU	PU

IGNORE the SMALLER figures of any grid number, these are for finding the full coordinates. Use ONLY the LARGER figure of the grid number.  
 IGNORENSE los números de TIPO MENOR de cualquier distancia de cuadrícula; dichos números sólo sirven para conocer el valor completo de las coordenadas. UseNSE UNICAMENTE los números de TIPO MAYOR.  
 Example: Ejemplo: 890000

Horizontal Datum: 1927 North American Datum  
 Dato Horizontal: Dato Norte Americano 1927  
 Vertical Datum: Mean Sea Level  
 Dato Vertical: Nivel Medio Del Mar  
 Transverse Mercator Projection  
 Proyección Transversal De Mercator

BLUE NUMBERED LINES INDICATE THE 10,000 METER UNIVERSAL TRANSVERSE MERCATOR GRID, ZONE 17, CLARKE 1866 SPHEROID

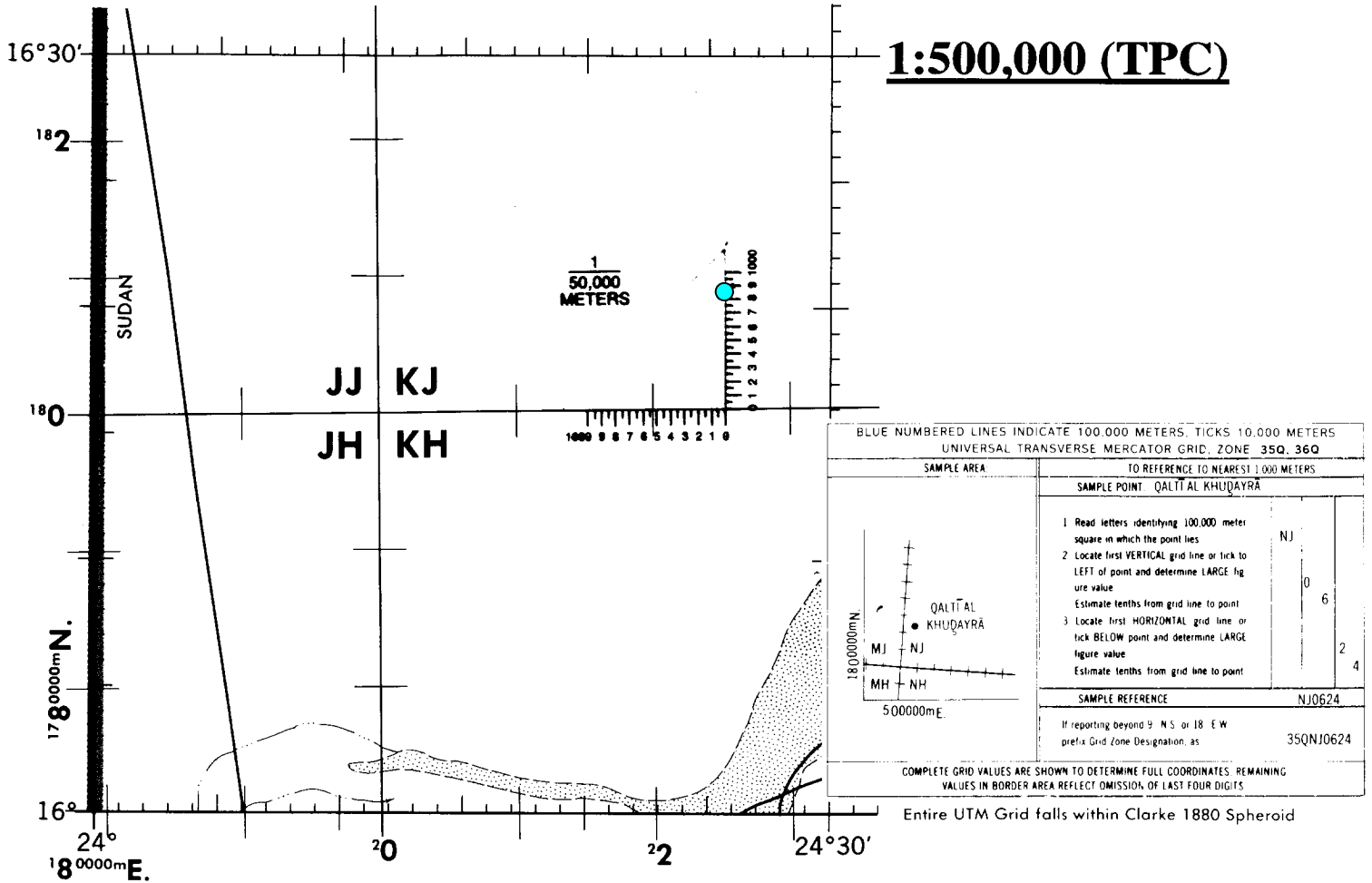
**Find the UTM and MGRS coordinate of the road bridge (just below the mileage marker 34).**

### UTM Coordinate

1. Like the 1:50,000 map, we begin by pulling the Grid Zone Designator from the marginal data (17P), but we ignore the P for UTM.
2. The Easting from the lower left corner reads  $50^{0000}$  mE and our bridge is just to the right of grid line  $52$ . Our protractor helps us get 6000 (the last two zeros are just placeholders) to complete the easting as 526000 mE. Remember that on a JOG each grid line represents 10,000m instead of 1,000m like on a TLM.
3. The Northing string starts with  $89^{0000}$  mN and the protractor gives us 6200 to fill in the last four digits. (Note that this map is near the equator and it only has six digits in the Northing).
4. The full UTM coordinate is **17 526,000 mE 0,896,200 mN (NAD27)**.

### MGRS Coordinate (six digit)

1. With our Grid Zone Designator, 17P, we need to figure out our 100,000 meter square. On a JOG, this two letter code is inside the body of the map, in this case, NU (the letters are usually in blue).
2. In the easting, we are over to grid line 2. We already have the protractor readings from the UTM coordinate so we get 6000 in the easting, but we drop the last two zeros for a six digit coordinate.
3. In the northing, we are at grid line 9, protractor reading 65 (drop last two zeros from UTM northing).
4. The six digit MGRS coordinate is **17P NU 260 965 (NAD27)**.



Find the UTM and MGRS coordinate for this proposed enemy position from this Tactical Pilotage Chart (TPC) above.

#### UTM Coordinate

1. There are usually multiple grid zones on a TPC, so look inside the map sheet. In this case, **35Q** is on the chart, but outside of the clipped area for this example.
2. The UTM easting string looks like  $18^{0000}$  mE and our point of interest is within grid line  $22^{0000}$  (blue tick marks). The protractor helps us get 5400 (the last two zeros are just placeholders).
3. In the Northing we start with  $178^{0000}$  mN and move up to line  $180^{0000}$  mN. With our trusty protractor once again, we measure up to the feature – about 8600 meters.
4. This results in a full UTM coordinate of **35 225,400 mE 1,808,600 mN**.

#### MGRS Coordinate (6 digit)

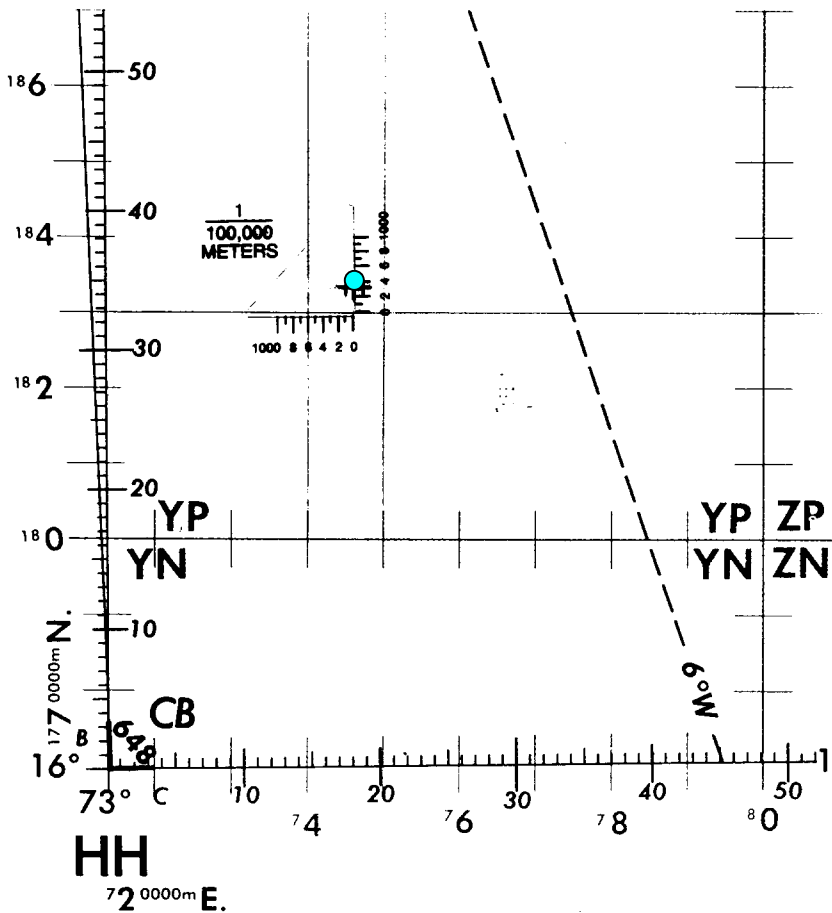
1. With a Grid Zone Designator of 35Q, we also look inside the map for our two letter designator – KJ.
2. The six digit coordinate is simply pulled by taking the 254 in the easting and the 086 in the northing. (We dropped the small preceding numbers and the last two in each direction to give us a six digit MGRS coordinate).
3. The MGRS coordinate is **35Q KJ 254 086**.

Datum Note: At this scale, the datum may not be mentioned. Most datum shifts are not as large as the inaccuracies of the map so they're insignificant. It is important to know which MGRS system is being used



on the chart – Old or New. From the marginal data, we find that this chart uses the Clarke 1880 Ellipsoid. This corresponds to the MGRS-Old numbering system. By using the wrong system and therefore the wrong two letter (100,000 meter square) designators, we'd be 1000 km off. Not many missions would be successful if you ended up 600 miles north of where you intended to be. Be careful with TPCs and ONCs, there may be more than one ellipsoid used on each sheet. In those cases there may be both Old and New schemes on the same chart.

## 1:1,000,000 (ONC)



UTM GRID ZONE DESIGNATION 18Q

UTM GRID ZONE DESIGNATION 19Q

BLUE NUMBERED LINES INDICATE 100,000 METERS. TICKS 10,000 METERS UNIVERSAL TRANSVERSE MERCATOR GRID. ZONES 18Q, 19Q, 20Q, 18R, 19R, 20R	
SAMPLE AREA:	TO REFERENCE TO NEAREST 1,000 METERS
	SAMPLE POINT - BLANCO  1. Read letters identifying 100,000 meter square in which the point lies 2. Locate first VERTICAL grid line or tick to LEFT of point and determine LARGE figure value: Estimate tenths from grid line to point 3. Locate first HORIZONTAL grid line or tick BELOW point and determine LARGE figure value: Estimate tenths from grid line to point:  SAMPLE REFERENCE: CL3989  If reporting beyond 9' N.S. or 18' E.W. prefix Grid Zone Designation, as: 19QCL3989
COMPLETE GRID VALUES ARE SHOWN TO DETERMINE FULL COORDINATES. REMAINING VALUES IN BORDER AREA REFLECT OMISSION OF LAST FOUR DIGITS	

Entire UTM Grid falls within Clarke 1866 Spheroid

**Find the position of the sunken shipwreck.**

UTM Coordinate

1. The Grid Zone Designator for ONCs will be found inside the chart area – in our case it's along 72 West Longitude as 18Q.
2. The Easting string from the bottom left corner is  $72^{0000}$  mE. Our wreck is just past tick mark  $74^{0000}$  mE and the protractor allows us to get 6000. (We had to sketch in grid lines connecting the UTM tick marks for this chart, and TPCs, since putting every line on it would clutter it up and most people use an ONC for Latitude/Longitude only).
3. In the Northing, we start with  $177^{0000}$  mN and move up to  $183^{0000}$  mN to find our location. The protractor gets up within the block to 3200m.
4. The UTM coordinate is **18 746,000 mE 1,833,200 mN.**

MGRS Coordinate (6 digit)

1. We've already found the Grid Zone Designator to be **18Q** and our 100,000m square identification is **YP**.
2. In the easting, we're over to line 4, and 60 from the protractor (460).
3. In the northing, we're up to line 3, and 32 from the protractor (332).
4. The full six digit coordinate is **18Q YP 460 332**.

Additional Notes: 1. Some charts maps will have both the MGRS-New and Old systems represented on them. Check the marginal data to figure out which is which (often they're in different colors). 2. Disregard the brown letters (HH outside the map and CB/DB inside the map on the bottom). They are part of a totally different coordinate system (The World Geographic Reference System – GEOREF) that is not widely used today. 3. If you look at the bottom edge of the protractor on this map, you'll see it doesn't line up with the zero mark along the right edge. The protractor is not an exact instrument and sometimes they're not cut perfectly).

### Coordinate Transformation Software

GEOTRANS2 is a datum transformation and coordinate conversion software utility that was jointly designed and developed by the NIMA and the U.S. Army's Topographic Engineer Center (TEC). The program is government freeware that operates on PC and UNIX platforms. It can easily transform datums, convert coordinates, and change map projections using a wide variety of known factors published in NIMA documents.

Transformations that involve mathematically intensive equations to conduct calculations are made easy with this simple windows based program. The software also contains the Earth Gravitational Model 1996 (EGM 96). This feature allows users to calculate either ellipsoidal heights (geodetic) or Mean Sea Level (orthometric) heights. Another critical feature is batch file processing. GEOTRANS2 can ingest coordinates from a text file, convert them, and output the results into a text file for use in any number of ways.

GEOTRANS2 software is downloadable from NIMA. To obtain the program you must request a user ID and password program from the following web site:  
<http://164.214.2.59/GandG/geotrans/geotrans.html>

