

---

# The Map Grid of Australia 1994

## A Simplified Computational Manual

---

# The Map Grid of Australia 1994

## A Simplified Computational Manual

*'What's the good of Mercator's North Poles and Equators, Tropics, Zones and Meridian lines?'  
So the Bellman would cry: and the crew would reply 'They are merely conventional signs!'  
The Hunting of the Snark (1876) 'Fit the Second: The Bellman's Speech'*

## 1. Introduction

The Geocentric Datum of Australia, 1994 (GDA94) is an Earth-centred datum, which has been adopted for use throughout Australia by the Inter-Governmental Committee on Survey and Mapping (ICSM) with all states and territories adopting it in 2000.

The GDA94 datum will replace the existing AGD66 and AGD84 datums throughout Australia.

The map projection associated with GDA94 is the Map Grid of Australia, 1994 (MGA94), a transverse Mercator projection, which conforms with the internationally accepted Universal Transverse Mercator Grid system.

A [Technical Manual for GDA94](#) has been produced by ICSM to provide rigorous formulae and definitions for geodetic computations of the highest precision on the new Datum.

This Simplified Computational Manual is designed as an adjunct to the ICSM Technical Manual and appropriate cross references for the rigorous formulae are provided where applicable. It is also designed to have particular reference to the Victorian region rather than be applicable Australia wide.

Computations on the ellipsoid require the use of rigorous formulae which may not always be of convenience of use in survey applications of small extent which do not require the highest precision.

The aim of this manual is to provide simplified formulae to enable common computations on the Grid used in everyday surveying applications to be carried out by the use of simple hand held calculators or PC based spread sheet applications.

## 2. Map Grid of Australia

**Datum:** The Geodetic Datum of Australia realised by the coordinate set of 1994, hence GDA94.

**Projection:** Transverse Mercator, utilising 6 degree Zones, Scale Factor at the Central Meridian 0.9996 in conformity with the Universal Transverse Mercator system.

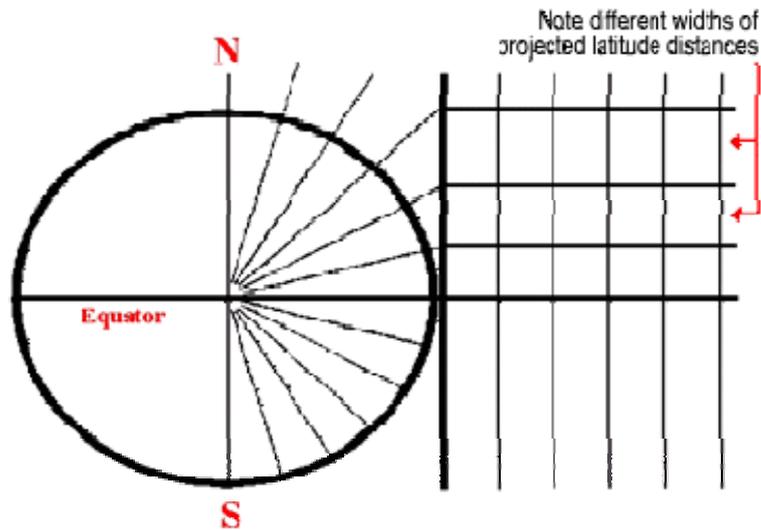
**Units:** International metre.

**False Coordinate Origin (All Zones):** Northing 10,000,000 metres. Easting 500,000 metres.

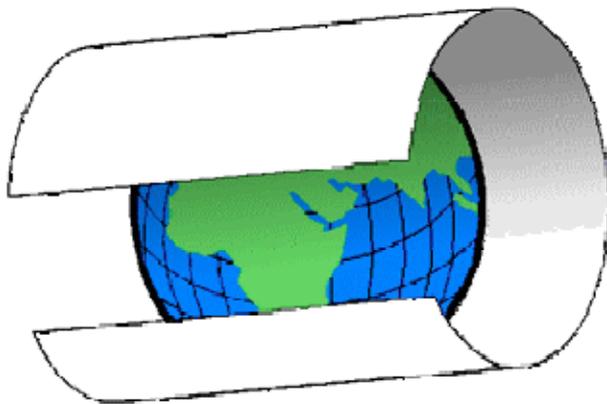
The true origin for each Zone is the Equator for Northings and the Central Meridian for Eastings. To avoid the problem of negative coordinates south of the Equator or west of the Central Meridian, the quantities above are added to the true coordinates.

The Mercator projection is a variation of a simple cylindrical projection drawn or projected onto a vertical cylinder tangential at the Equator to the ellipsoid representing the earth. The Equator then becomes the standard parallel.

This simple cylindrical projection is unsuitable for many mapping purposes as land mass shapes become greatly distorted quite quickly when moving away from the Equator as shown below.



To overcome this problem, the transverse form of this projection is used, where the cylinder is tangential along a meridian of longitude, creating a series of tangential (or central) Meridians rather than parallels of latitude in defined Zones around the Earth's circumference. This then leads to sixty zones each of 6 degrees in longitude for the Universal Transverse Mercator system.

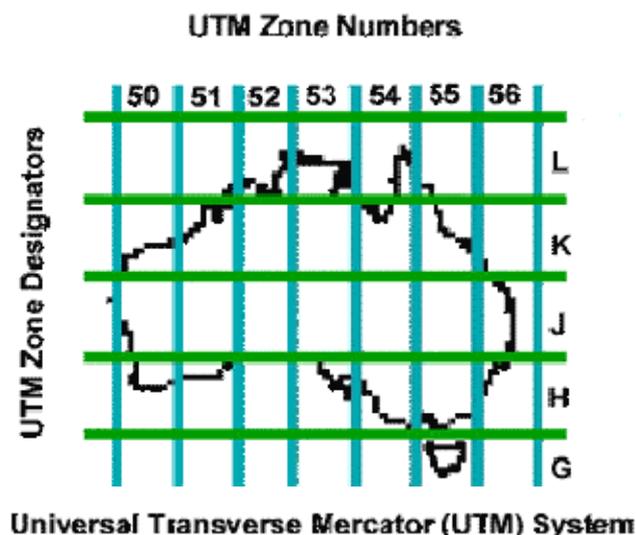


Projection surface using a transverse cylinder.

Mercator's projection is further refined in the UTM system in that for each Zone the cylinder is reduced slightly in size so that it is not tangential but rather cuts the ellipsoid along two meridians at about midway between the centre and each edge of each Zone.

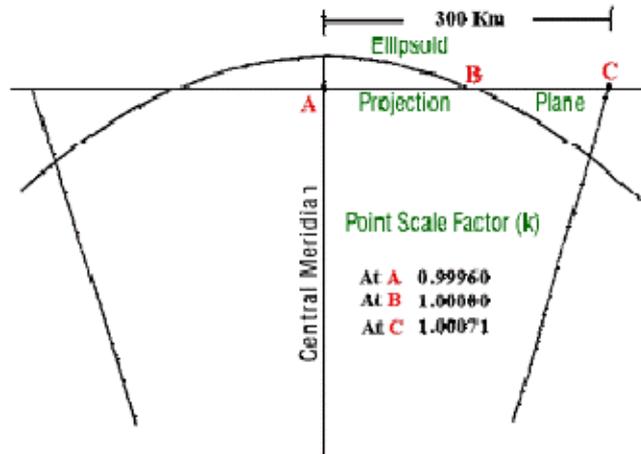
The cuts of the ellipsoid are such that the Scale Factor at the Zone edges is 1.00071 reducing to unity at the point where the projection cylinder cuts the ellipsoid, then reducing to a minimum of **0.9996 at the Central Meridian**. These scale factors apply to all Zones in the UTM system.

Note that Victoria lies wholly within Zones 54 and 55.



### 3. Scale Factor

This is the relationship between the measured survey distance (reduced to the ellipsoid) and that same distance on the map projection and is applied to the measured distance to enable computations on the grid. As noted in the preceding section, Scale Factor will vary with the distance of the survey from the Central Meridian.



For many applications the usual practice is to compute the scale factor at particular points of the survey.

The simplified formula for **Point Scale Factor** is:

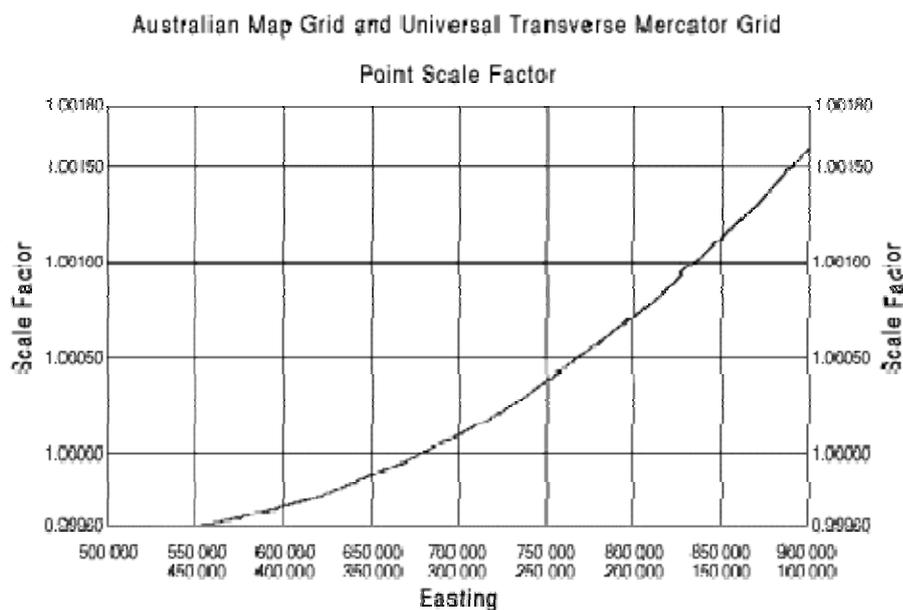
$$\text{Point Scale Factor} = 0.9996 + 1.23(E - 500\,000)^2 \cdot 10^{-14}$$

where E is the MGA94 Easting coordinate of the point in question.

The rate of change of Scale Factor across a Zone is not linear, which means that for precise applications for longer lines, a **line Scale Factor** will need to be computed. [Refer to [Technical Manual for GDA94](#).

For application to surveys of lesser extent a mean Point Scale Factor computed from the above, using the mean Easting of the two ends of the line, will give a grid distance correct to 1ppm. for any line up to thirty km. in extent in Easting. Surveys of small extent may merely require the use of a point scale factor for the centroid of the area in question.

Point Scale Factor may also be read from the nomogram of Scale Factor.



An Microsoft Excel spreadsheet is available for download that will assist you with Point Scale Factor, Height Factor and Grid Convergence calculations.

## 4. Height Factor

As well as Scale Factor a correction for height factor must also be applied to a measured distance to reduce it to the ellipsoid before computations on the grid can commence. The ellipsoidal height of a point is found by the algebraic sum of the AHD height and the geoid - ellipsoid separation. (See Section 9). The grid by definition, is the projection of the ellipsoid onto a flat surface.

In Victoria the GDA ellipsoid varies from the geoid by up to a maximum of 15 metres in the far north east of the state. The geoid, which may be thought of as a mean sea level surface, approximates the Australian Height Datum.

For practical purposes, within Victoria, the geoid - ellipsoid separation can be ignored when computing the height factor as the error is generally less than 1 ppm. It does however reach an extreme of 2.5 ppm at Corryong.

It should be remembered that this is not necessarily the case in all States and Territories. For example the geoid - ellipsoid separation in the Northern Territory ranges from near zero in the far south west to 60 metres in Arnhem Land, leading to an error of up to 10 ppm if the difference in separation is ignored.

A measured distance needs to be corrected for instrumental errors and slope before the application of the Height Factor.

For practical purposes for surveys within Australia the simplified formula for Height Factor is :

$$\text{Height Factor} = 1 - (\text{Mean Height} \cdot 0.1571 \cdot 10^{-6})$$

The height above sea level should be known to +/-10 metres for an accuracy of 1ppm in the Height Factor at a mean height of 100 metres. At a mean height of 1000 metres the height will need to be known to +/- 5 metres for the same accuracy. A Microsoft Excel spreadsheet is available for download that will assist you with Point Scale Factor, Height Factor and Grid Convergence calculations.

## 5. Combined Height and Point Scale Factor

For many surveys the use of a combined Factor rather than the individual application of scale factors may be more convenient.

A combined Factor is simply obtained by the multiplication of the **Point Scale Factor** computed from [3] by the **Height Factor** computed from [4].

Some points of relevance are the east-west distance from the Central Meridian of the survey for scale factor and the amount of topographical undulation present for height factor.

## 6. Grid Convergence

Grid convergence is the angular quantity to be added algebraically to an azimuth between points of known latitude and longitude on the ellipsoid to obtain the MGA 94 grid bearing.

In Australia grid convergence is positive for points East of the Central Meridian and negative West.

To differentiate between directions on the ellipsoid and on the grid, **azimuth** is the term applied to the direction between points of known latitude and longitude on the ellipsoid, while **bearing** is the term applied to the direction between points of known Easting and Northing on the map projection associated with the ellipsoid.

These two quantities are not normally the same. The difference arises because the grid of latitude and longitude is drawn on a curved surface (the ellipsoid) while the map projection grid is designed to both represent the curved surface of the Earth on a flat sheet of paper (the map), and to provide simplified computational procedures for survey activities of relatively limited extent.

The grid convergence at a survey point, if not supplied with the original coordinate information, is most easily determined from latitudes and longitudes. The simplified formula is :

$$\text{Tan Grid Convergence} = -\text{Sin Lat point} \cdot \text{Tan}(\text{Long point} - \text{Long CM})$$

Depending on the precision of the survey, the Latitudes and Longitudes of the survey point may be found by scaling from a suitable map.

Rigorous formulae using both Latitudes and Longitudes and grid coordinates may be found in the Technical Manual for GDA94

An Microsoft Excel spreadsheet is available for download that will assist you with Point Scale Factor, Height Factor and Grid Convergence calculations.

## 7. Arc to Chord Correction

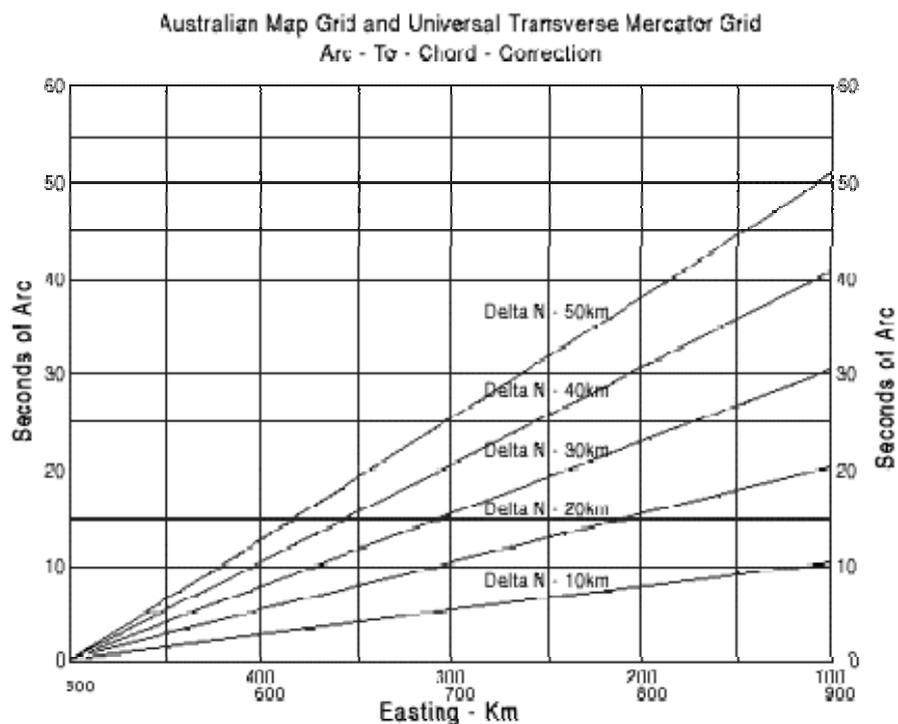
This is the angular quantity to be added algebraically to a grid bearing to obtain a plane bearing.

Depending on the job at hand, it may be more convenient to use plane trigonometry for the necessary computations.

The difference between the two bearings arises from the fact that the shortest line between two points on the ellipsoid (the geodesic) becomes a curved line concave toward the Central Meridian when projected onto the mapping plane (in this case the MGA).



The Arc to Chord correction then corrects the grid bearing to a plane bearing. The nomogram of Arc to Chord Correction will supply correction values of sufficient accuracy for many applications and shows that surveys of limited extent (say less than five kilometres) and requiring lower precision may be able to ignore the correction.



Note : This nomogram has been compiled for latitude 26 degrees South. For a line of delta N = 50 km's lying in either latitude 8 or 45 degrees South, the nomogram is accurate to 0.1" and 0.2" respectively

As a worst case example a north-south line of 5km at the zone boundary has a correction of 2".

## 8. Use of GPS

The GDA94 national adjustment is based on the fixed values of the Australian Fiducial Network and Australian National Network stations which have resulted from an adjustment of continuous (in the case of AFN stations) GPS data collection and specific national GPS observational campaigns (in the case of ANN stations).

By the nature of the national adjustment, with its inclusion of a large amount of GPS data, and by the nature of the reference ellipsoid, observed GPS positions or data which have been related to the WGS 84 ellipsoid are compatible with the GDA94 system and do not require transformation or the use of additive constants.

Obviously the preceding sections do not necessarily assist GPS practitioners as they refer mainly to angle and distance observations which, for limited area surveys, are commonly observed via total station instrumentation.

The suitability of GPS for control surveys over varying distances has led to an increasing preference for this technology over more conventional approaches.

The preceding sections still apply to quantities to be derived from points coordinated by GPS methods where more conventional techniques may be used for extending or infilling the survey.

## 9. GPS Derived Heights and Geoid - Ellipsoid Separation

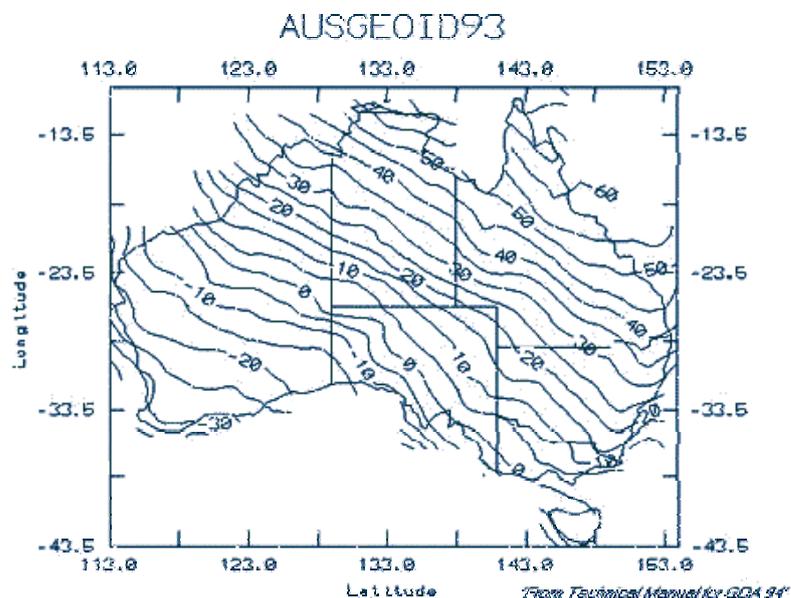
As GPS observations are referenced to the ellipsoid, the heights obtained from GPS observations are ellipsoidal heights. These ellipsoidal heights are not necessarily the same as AHD 71 heights as these are referred to the Australian Height Datum which was determined by a national level adjustment in 1971.

This AHD71 surface, for surveys of practical purposes, in the context of this manual, may be taken as being coincident with the geoid. The geoid-ellipsoid separation [**N**] is the quantity to be applied to ellipsoid heights to equate them to AHD71 values.

This quantity will vary across the continent. In Victoria the variation is 15 metres from SW to NE, however this variation is much greater in most other states.

N may be estimated from the diagram of the geoid-ellipsoid separation model shown below (also shown in the Technical Manual) or may be computed from digital models such as AUSGeoid (provided by AUSLIG) depending on the required accuracy of the height component of the survey at hand. AUSLIG provide the best available model for Australia.

This diagram is based upon AUSGEOID 93 however the model is continually updated.



Another method of possible convenience of determining AHD 71 heights, in areas of high density of existing Bench Marks, is to include sufficient of those marks in the GPS observing schedule to enable the adjustment software to model the separation sufficiently well to produce AHD71 results.

Because of the geometry inherent in the GPS satellite constellation, the precision of GPS heights will be typically two to three times worse than the precision of GPS horizontal positions.

**NOTE: The AHD 71 is NOT affected by the introduction of GDA94, nor by the increasing use of GPS instrumentation.**

## 10. Transformations

Software to enable transformation between the AGD66 and GDA94 systems and the conversion of geographical to grid values (and vice versa) within each system is now available for downloading from GDA Useful tools at [www.dse.vic.gov.au/property](http://www.dse.vic.gov.au/property) > geodesy > GDA useful tools.

## 11. Glossary of Terms

**AFN:** The Australian Fiducial Network. A network of eight permanently tracking GPS stations around and within Australia which provide constant monitoring of the position of the Australian land mass upon which is founded GDA94.

**AGD:** The Australian Geodetic Datum is defined by the defining parameters of the ANS with the Johnson Geodetic Station as origin.

**AGD66:** The data set determined from a national adjustment in 1966 on the AGD. This data set was used originally by all States and Territories but since 1984 by New South Wales, Northern Territory, Tasmania and Victoria alone.

**AGD84:** The data set determined from a more precise national adjustment of 1984 utilising further first order observations effected across Australia since 1966. This data set was adopted by Queensland, South Australia and Western Australia from 1984 onwards.

**AHD71:** The Australian Height Datum which was determined from a national adjustment in 1971 of third order levelling sections founded upon some thirty primary tide gauge stations distributed around the Australian coastline.

**The adoption of GDA94 will not affect AHD71.**

**ANN:** The Australian National Network which consists of some eighty stations distributed across Australia which were observed over multiple-day sessions by GPS receivers and adjusted contemporaneously with the permanently tracking AFN stations to provide the basis for GDA94.

**ANS:** The Australian National Spheroid was adopted in 1965 as the most appropriate figure for the Australian region.

**CM:** The Central Meridian of a six degree Zone of a Universal Transverse Mercator map projection.

**Ellipsoid:** Ellipsoid and spheroid are often used interchangeably however spheroid has been employed as part of the designation of the ANS and hence the definition of the AGD, whilst ellipsoid has been used as part of the definition of GRS80 on which is based the GDA.

**GDA:** The Geocentric Datum of Australia. This earth centred Datum, totally compatible with the GPS satellite system, is realised by the position values for the AFN and ANN stations which resulted from the AFN / ANN adjustment referred to above. This datum was accepted by ICSM in November, 1994.

**GRS80:** The Geodetic Reference System of 1980 is an internationally recognised ellipsoid which has been adopted for GDA.

**MGA94:** The Map Grid of Australia, 1994. This is the Universal Transverse Mercator map projection of the national grid on the GDA ellipsoid. This projection has the same properties as those currently in use with the AGD systems.

**N:** The quantity which is the vertical difference between the ellipsoid and the geoid. This is also known as the Geoid/Ellipsoid separation. Ideally the two surfaces should be coincident, however the ellipsoid is a mathematically smoothed surface whereas the geoid is shaped by physical laws affecting the plastic earth. Obviously the quantity will vary according to the ellipsoid adopted in the area in question. The designation of N should be referenced to the relevant ellipsoid and its date. The geoid, usually taken as mean sea level, may be thought of as a constant ellipsoidal surface which may however be affected by local gravity influences and hence display undulations.

**Spheroid:** See Ellipsoid above.