



Standard for the Australian Survey Control Network

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Terms and definitions

For the purpose of this Standard, the following terms and definitions shall apply.

Term/Acronym	Definition
Accuracy	The level of closeness of an estimated value – measured or computed – of a quantity to its true or accepted value.
AFN	Australian Fiducial Network. The network of 21 Continuously Operating Reference Stations (CORS) on the Australian continent that realise the recognised-value standard of measurement of position in accordance with the National Measurement Act 1960. This recognised-value standard defines the Geocentric Datum of Australia 1994 (GDA94).
AHD	Australian Height Datum. Commonly used in reference to Australian Height Datum 1971 (AHD71) and Australian Height Datum (Tasmania) 1983 (AHD–TAS83).
AHD71	The Australian Height Datum 1971 is the NGRS normal–orthometric height datum for mainland Australia.
AHD–TAS83	The Australian Height Datum (Tasmania) 1983 is the NGRS normal–orthometric height datum for mainland Tasmania.
AUSGeoid	The national quasi–geoid model for converting between GDA94 ellipsoidal heights and AHD heights. The current version of AUSGeoid is AUSGeoid09.
Circular confidence region	A circular measure of uncertainty in the horizontal plane calculated from the standard error ellipse.
Constrained adjustment, fully	An adjustment which has a sufficient number of constrained coordinates to optimally propagate datum and uncertainty throughout the survey control mark network.
Constrained adjustment, minimally	An adjustment which has the minimum number of constrained coordinates required to calculate all dimensions of the network datum (one, two or three dimensions).
Control Survey, Datum	A survey which defines, extends or improves the NGRS. These surveys are included in NGRS adjustments to allow for the most rigorous estimation and testing of position and uncertainty.
Control Survey, General Purpose	A survey which connects to the NGRS for the purpose of estimating the position and uncertainty of new survey control marks relative to the NGRS. Such surveys are not included in NGRS adjustments.
CORS	Continuously Operating Reference Station. A survey control

mark hosting a permanent GNSS station.

Datum	An official, fully-defined, spatial reference system or surface to which measurements and/or coordinates upon the Earth may be defined and related.
GDA94	Geocentric Datum of Australia 1994. Realised by the derived coordinates of the Australian Fiducial Network (AFN) geodetic stations, referenced to the GRS80 ellipsoid and determined with respect to ITRF92 at epoch 1994.0.
Geoid	The equipotential surface of the Earth's gravity field which best fits global mean sea level.
GNSS	A Global Navigation Satellite System(s) – a generic term for satellite based positioning systems.
GRS80	Geodetic Reference System 1980 reference ellipsoid, where $a = 6378137$ m, $f = 1 / 298.257222101$
GUM	The ISO ' <i>Guide to the expression of uncertainty in measurement</i> ' (JCGM, 2008).
ICSM	Intergovernmental Committee on Surveying and Mapping
International System of Units (SI)	The International System of Units (abbreviated SI from French: <i>Système International d'Unités</i>) is the modern form of the metric system.
ISO	International Organization for Standardization – a developer of voluntary International Standards.
ITRF	International Terrestrial Reference Frame - a realisation of the International Terrestrial Reference System (ITRS) produced by the International Earth Rotation and Reference Systems Service (IERS).
JCGM	Joint Committee for Guides in Metrology – a committee chaired by the Director of the Bureau International des Poids et Mesures (BIPM) and created by the seven international organisations that had originally in 1993 prepared the <i>Guide to the expression of uncertainty in measurement</i> (GUM) and the <i>International vocabulary of basic and general terms in metrology</i> (VIM).
Measurement	A measurement is an observed value, the outcome of a repeated set of observations, or the result of processing such observations.
MGA94	Map Grid of Australia 1994. Universal Transverse Mercator projection of the Geocentric Datum of Australia 1994.
MSL	Mean Sea Level – A tidal datum derived from the arithmetic mean of hourly heights of the sea at the tidal station

observed over a period of time (preferably 19 years).

NGRS	National Geospatial Reference System – is Australia’s authoritative, reliable, high accuracy spatial referencing system. It includes the GDA94, AHD71 and AHD-TAS83 datums.
PCG	ICSM Permanent Committee on Geodesy
Precision	A term used to quantify the variability of a measurement or computed value. If several measurements are taken repeatedly to represent the same quantity, precision is used to refer to the degree of closeness or conformity of those measurements to each other.
Quasi-geoid	A reference surface based on the Earth’s gravitational potential. The geoid and quasi-geoid are approximately the same surface over the oceans but diverge over land due to the influence of topography.
Survey control mark	A monument that provides a physical realisation of one or more datums.
The Standard	This document, known as the Standard for the Australian Survey Control Network – Special Publication 1 (SP1).
Uncertainty	In accordance with the GUM meaning, uncertainty in this Standard means doubt about the validity of a measurement or result of a measurement (e.g. a coordinate). It is an indication of how wrong a value may be and is used in this Standard to quantify the level of survey quality. Uncertainty is expressed as a standard deviation in the International System of Units (SI) expanded to the 95% confidence level.
Uncertainty, Positional (PU)	The uncertainty of the horizontal and/or vertical coordinates of a survey control mark with respect to datum.
Uncertainty, Relative (RU)	The uncertainty between the horizontal and/or vertical coordinates of any two survey control marks. RU can be expressed in SI units at the 95% confidence level, or in a proportional form such as a ratio of uncertainty per unit length or survey misclosure.
Uncertainty, Survey (SU)	The uncertainty of the horizontal and/or vertical coordinates of a survey control mark independent of datum. That is, the uncertainty of a coordinate relative to the survey in which it was observed, without the contribution of the uncertainty in the underlying datum realisation.
UTM	Universal Transverse Mercator projection.

1 About this Standard

1.1 Preface

This version of the Standard completes the transition from CLASS and ORDER to uncertainty as the basis for evaluating and expressing the quality of measurements and positions. This Standard's definition of uncertainty is intended to be consistent with the ISO definition. The use of the term Local Uncertainty as defined in SP1 version 1.7 has been discontinued in this Standard.

This document supersedes:

ICSM (2007), *Standards and Practices for Control Surveys – Special Publication 1* (version 1.7), Intergovernmental Committee on Surveying and Mapping, Canberra, Australia

1.2 Introduction

The development of Australia depends upon the availability of a reliable, high accuracy spatial referencing system. The authoritative referencing system in Australia is the National Geospatial Reference System (NGRS).

The NGRS underpins Australia's fundamental positioning infrastructure. It is connected to the global reference frame, enables the integration of all spatial information, and underpins a vast array of public, government and commercial positioning and navigation applications.

Australia's NGRS is realised through an integrated network of Continuously Operating Reference Stations (CORS) and survey control marks, information about those survey control marks, systems for the management and delivery of survey control mark information, and various policies, standards and guidelines.

Australia's survey control mark network comprises the survey control marks within the Australian mainland and Tasmania, Australia's islands and External Territories. The External Territories include the Ashmore and Cartier Islands, Christmas Island, Cocos (Keeling) Islands, the Coral Sea Islands, Heard and McDonald Islands, Norfolk Island and the Australian Antarctic Territory.

The Intergovernmental Committee on Surveying and Mapping (ICSM) through its Permanent Committee on Geodesy (PCG) administers national geodesy policies for the coordination of geodetic activities within Australia. This Standard and associated Guidelines provides an outcomes based framework that supports the highest level of rigour and integrity in the delivery and maintenance of Australia's survey control mark network.

1.3 Scope

The purpose of this Standard is to specify the minimum requirements for the determination of one, two or three dimensional position and associated uncertainty of Australia's survey control marks.

This Standard prescribes ICSM's requirements for control surveys that define, extend, improve or connect to the NGRS. The following control surveys are within the scope of this Standard:

- (a) **Datum Control Surveys** These surveys define, extend or improve the NGRS. These control surveys are included in NGRS adjustments (State, Territory and Australian Government) to allow for the most rigorous estimation and testing of position and uncertainty for new and existing survey control marks in the NGRS.
- (b) **General Purpose Control Surveys** These surveys are not included in NGRS adjustments, but connect to the NGRS for the purpose of estimating the position and uncertainty of new survey control marks relative to the NGRS. These control surveys may be grouped into two categories according to the method used to estimate position and uncertainty, being:
 - (i) least squares; or
 - (ii) other reliable statistical methods.

The provisions in this Standard for expressing uncertainty have been developed primarily for Datum Control Surveys, but are also intended to be adopted, where possible, for all forms of General Purpose Control Surveys.

Government and private sector organisations undertaking Datum Control Surveys shall comply with this Standard.

ICSM recommends that government and private sector organisations undertaking General Purpose Control Surveys comply with this Standard.

Information on how to use this Standard, together with additional technical detail and commentary, is provided in the technical manuals and Guidelines listed in the reference section.

1.4 Normative References

The following Guidelines and ICSM technical manuals may have relevance to the application of this Standard.

International Guidelines

JCGM 100:2008, *Evaluation of Measurement Data – Guide to the Expression of Uncertainty in Measurement*, Joint Committee for Guides in Metrology – Bureau International des Poids et Mesures, Paris, France.

SP1 Guidelines

ICSM (2014), *Guideline for the Adjustment and Evaluation of Survey Control*, Version 2.1, Intergovernmental Committee on Surveying and Mapping, Canberra, Australia.

ICSM (2014), *Guideline for Control Surveys by Differential Levelling*, Version 2.1, Intergovernmental Committee on Surveying and Mapping, Canberra, Australia.

ICSM (2014), *Guideline for Control Surveys by GNSS*, Version 2.1, Intergovernmental Committee on Surveying and Mapping, Canberra, Australia.

ICSM (2014), *Guideline for Conventional Traverse Surveys*, Version 2.1, Intergovernmental Committee on Surveying and Mapping, Canberra, Australia.

ICSM (2014), *Guideline for the Installation and Documentation of Survey Control Marks*, Version 2.1, Intergovernmental Committee on Surveying and Mapping, Canberra, Australia.

ICSM (2014), *Guideline for Continuously Operating Reference Stations*, Version 2.1, Intergovernmental Committee on Surveying and Mapping, Canberra, Australia.

ICSM Technical Manuals

ICSM (2006), *Geocentric Datum of Australia Technical Manual*, Intergovernmental Committee on Surveying and Mapping, Canberra, Australia.

ICSM (2007), *Australian Tides Manual – Special Publication 9*, Intergovernmental Committee on Surveying and Mapping, Wollongong, Australia.

2 Connection to datum

Survey control marks established via Datum Control Surveys and General Purpose Control Surveys for Australia's NGRS shall be coordinated relative to the datums set out below.

2.1 National geodetic datum

For Australia's NGRS, the geodetic datum is the Geocentric Datum of Australia 1994 (GDA94). GDA94 is a three dimensional, static coordinate datum based on the International Terrestrial Reference Frame (ITRF) 1992. It is held fixed at the reference epoch of 1 January 1994 and is referenced to the GRS80 ellipsoid.

Coordinates of survey control marks on the Australian mainland, Tasmania, Australian islands and Australian External Territories, shall be computed in terms of GDA94.

The Universal Transverse Mercator (UTM) projection of GDA94 is the Map Grid of Australia 1994 (MGA94), and is the officially recognised grid coordinate realisation of GDA94.

In the absence of GDA94 survey control marks, coordinates of survey control marks on Australian External Territories may be computed in terms of ITRF. Where ITRF coordinates are used, the definition and epoch of the ITRF shall be clearly specified.

2.2 National height datum

For Australia's NGRS, the height datum is the Australian Height Datum (AHD). Heights for survey control marks on the Australian mainland shall be referred to the Australian Height Datum 1971 (AHD71). Heights for survey control marks on the Tasmanian mainland shall be referred to the Australian Height Datum (Tasmania) 1983 (AHD-TAS83).

ICSM recommends the use of AUSGeoid when converting between AHD heights and GDA94 ellipsoidal heights.

In the absence of AHD survey control marks, heights for Australia's islands and External Territories shall be clearly specified to refer to at least one of the following:

- a locally recognised height datum;
- locally-determined Mean Sea Level (MSL); or
- "Derived AHD" using AUSGeoid or an equivalent geoid (or quasi-geoid) model and either a differential GNSS connection to AHD, MSL or ellipsoidal height.

3 Conducting control surveys

When observing a survey control mark network there are a variety of measurement and processing techniques available to the surveyor. The surveyor shall select the equipment and techniques which best suit the requirements of the project, keeping in mind the limitations of each technique. The survey control Guidelines associated with this version of the Standard (see Section 1.4) outline the recommended survey practices to achieve required levels of uncertainty.

4 Quantifying survey quality

The quality of a control survey shall be quantified in terms of uncertainty. When quantifying survey quality, the following uncertainty categories shall apply:

Survey Uncertainty (SU) is the uncertainty of the horizontal and/or vertical coordinates of a survey control mark relative to the survey in which it was observed and is free from the influence of any imprecision or inaccuracy in the underlying datum realisation. Therefore, SU reflects only the uncertainty resulting from survey measurements, measurement precisions, network geometry and the choice of constraint. A minimally constrained least squares adjustment is the preferred and most rigorous way to estimate and test SU. SU is expressed in SI units at the 95% confidence level.

Positional Uncertainty (PU) is the uncertainty of the horizontal and/or vertical coordinates of a survey control mark with respect to the defined datum and represents the combined uncertainty of the existing datum realisation and the new control survey. That is, PU includes SU as well as the uncertainty of the existing survey control marks to which a new control survey is connected. A fully constrained least squares adjustment is the preferred and most rigorous way to estimate and test PU. PU is expressed in SI units at the 95% confidence level.

Relative Uncertainty (RU) is the uncertainty between the horizontal and/or vertical coordinates of any two survey control marks. Such marks may be connected by measurement directly or indirectly. The preferred and most rigorous means for deriving RU between pairs of marks is by propagating the respective variances and co-variances obtained from a minimally or fully constrained least squares adjustment (i.e. from SU or PU). RU can be expressed in SI units at the 95% confidence level, or in a proportional form such as a ratio of uncertainty per unit length or survey misclosure.

4.1 Evaluating uncertainty

4.1.1 Control surveys using least squares

The horizontal and/or vertical coordinates and uncertainties of survey control marks in a Datum Control Survey shall be estimated using a rigorous least squares adjustment process.

General Purpose Control Surveys should use least squares adjustment to estimate uncertainty.

Throughout and following least squares adjustment, survey control projects shall be evaluated to demonstrate the reliability of the survey and the estimated coordinates and uncertainties. The quality of estimated coordinates in an absolute sense shall be evaluated using SU and/or PU as appropriate. The relative quality of estimated coordinates shall be evaluated using RU.

Refer to the *Guideline for the Adjustment and Evaluation of Survey Control* for ICSM's recommended procedures for the adjustment of survey control, testing of survey measurements and network adjustment, and for estimating and testing uncertainty.

4.1.2 Control surveys using other reliable statistical methods

It is expected that most General Purpose Control Surveys will use least squares to estimate uncertainty. However, in the cases where least squares is not used, SU and RU shall be estimated using redundant measurements within the survey to verify that the survey quality is conforming to the expected quality. In such cases, the method for estimating SU and RU should be clearly documented. Examples of reliable statistical methods, specific to certain measurement techniques, that can be used to estimate control survey quality include:

- analysis of the misclosure between forward and backward runs in a differential levelling survey;
- analysis of the misclosure in a total station control traverse; and
- comparison of coordinates of multiple GNSS occupations.

Where least squares adjustment is not used, PU shall be estimated using a combined uncertainty propagation of the PU of the constrained survey control marks and the SU of the control survey.

4.2 Expression of uncertainty

4.2.1 One, two and three dimensional uncertainty

When reporting the absolute (SU, PU) or relative (RU) uncertainty of survey control marks in one, two or three dimensions, ICSM recommends that uncertainty be expressed in terms of standard deviations or the standard error ellipse/ellipsoid. ICSM has also adopted the circular confidence region as a means for expressing horizontal uncertainty, since the circular confidence region enables the quality of control surveys to be expressed in a way that is compatible with other geospatial datasets.

Therefore, one, two and three dimensional uncertainty shall be expressed in terms of the 95% confidence level using any one of the following as appropriate:

- standard deviations;
- standard error ellipse/ellipsoid; or
- horizontal circular confidence region.

Refer to the *Guideline for the Adjustment and Evaluation of Survey Control* for ICSM's recommended procedure for calculating the horizontal circular confidence region.

4.2.2 AHD uncertainty

For the purpose of this Standard the heights of the levelling junction points of the Australian National Levelling Network (ANLN) are treated as a reference standard with zero PU. Therefore, SU and RU can be used to evaluate or specify the uncertainty of survey control marks relative to any AHD mark, but PU can only be evaluated for those marks with a well understood connection to the ANLN.