SP1 - A New Standard for Control Surveys in Australia

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SUMMARY

For more than forty years the 'Standards and Practices for Control Surveys' document, commonly known as SP1, has been the primary reference for control surveys by government in Australia. However, with limited revision, dramatic changes in technology and field survey methods, and its focus on measurement processes, SP1 has become dated.

A new version of SP1 is presented. The original document has been dramatically reshaped in the modern 'standards' style. The new SP1 now directly connects an outcomes-based structure to the client's expectation; essentially the specification of datum and expected accuracy for a proposed control survey are balanced by the simple and clear process for demonstrating and reporting the survey outcome. Further, SP1 now separates the relatively stable components that define a survey control project from the ever-changing measurement technologies and professional practices.

Separate guidelines and technical manuals shall be developed for each core topic. These will provide practitioners with both the necessary information and freedom to undertake surveys in the rigorous and innovative manner expected from Australian surveyors.

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1. BACKGROUND

Control surveys in Australia are conducted by both government and private industry for a variety of purposes including National and State geodetic infrastructure, scientific studies, mining, construction/infrastructure, mapping and cadastral coordination. For over 40 years, the 'Standards and Practices for Control Surveys' document, commonly known as SP1, has been the primary reference for these control surveys.

'Special Publication 1 (SP1) – Standard Specifications and Recommended Practices for Horizontal and Vertical Control Surveys' was first published in April 1966 (ICSM, 2010a). The document has undergone many revisions to arrive at its current state being Version 1.7 (September 2007) of the now renamed 'Standards and Practices for Control Surveys'. Along the way, the major lasting changes to the document included datum changes and metrication, new technology, principally GNSS, and to introduce positional and local uncertainty as a means of classifying the accuracy of a coordinate.

The Intergovernmental Committee on Surveying and Mapping (ICSM) Geodesy Technical Sub Committee (GTSC) is charged with the responsibility of maintaining SP1. The status of SP1 is a standard agenda item at GTSC meetings and the starting point for any proposal for revision. GTSC has now determined it appropriate for SP1 to adopt a standards-based approach to guide government and industry in their delivery of survey control in Australia. The new SP1 standard will be supported by a series of guidelines and technical manuals to provide information, advice and examples on particular project components and the achievement of project specifications.

The key drivers for change are:

- New technology – Global Navigation Satellite Systems (GNSS) and mobile computing provides new and different options to practitioners.
- User (government and private industry surveyors/project managers) needs – flexibility to enable efficient use of technology, concise, modern, well defined and universally adopted standards.
- Government (ICSM) needs – concise, modern, well defined and universally adopted standards.
- GTSC needs – standards and best practice guidelines that serve the needs of Australian practitioners by integrating current tools and methods and that are easily maintained in a climate of moving technology.

2. A NEW STANDARD - OUTCOMES BASED

The focus of the current version of SP1 is to prescribe the measurement process – attempting to constrain error by controlling the observation process. The new standard focuses on the outcome, being the specified uncertainty for the individual survey control project. This allows the practitioner the flexibility to apply the most efficient and practical technologies and processes that will deliver that outcome. The standard provides both tools and language for the practitioner and project manager to both understand the project specification, then to confirm it has been delivered.

For surveys undertaken under contract, it will simplify the contract specification. SP1 will provide a simple but meaningful set of conditions that define the requirements that fit the purpose of the survey control. The focus of the new SP1 will be on the in-field constraint of error by least squares testing of the survey observations. Adoption of a standards approach also promotes innovation by recognising that a professional and competent survey practitioner will always apply the available tools in whatever is the most efficient manner that achieves the desired outcome. The new document also improves its longevity in that changes in technology and practice will be managed within the individual guidelines and technical manuals. It is expected that these will be easier to maintain, being separate documents of recommended practices not prescribed methods.

As technology or processes evolve, the content or need for specific guidelines will also evolve. This is important as the new standard provides government and industry with an open, reliable and flexible structure to manage and undertake survey control projects. Recognising that specifications for survey control projects are often embedded in Quality Management Systems, the new documents will also support and reduce the management overheads of these systems.

The series of supporting guidelines and technical manuals will provide detailed information for practitioners to achieve a defined outcome. The content of the current SP1 document is currently under review for relevance before it is included in the new guidelines along with updated process and technology information. The technical manuals will include the prescribed and technical information relating to Australia's geodetic datums.

3. PRECISION - CLASS

In Australia, Class is a generalised indicator of the precision of the survey methods applied to a project. It reflects the network's design and survey methods, its instrumentation, measurement precision, observation reduction and ultimate adjustment. Class may also be the application of an accepted survey method expected to deliver a specified uncertainty. Achievement of Class is demonstrated with acceptable survey methods and the testing of the network's minimally-constrained least squares adjustment.

3.1 Class Structure

It is proposed to revise and realign the Class structure to integrate the dramatic changes in survey capability. Since 1990 there has been a paradigm shift in survey practice. The use of differential GNSS and mobile computing has enabled the direct observation, reduction and adjustment of survey observations while in the field. This has allowed the field surveyor to immediately understand and constrain the propagation of error as the survey progresses, ensuring that the project specification is reached before they leave the site. Prior to the 1990s, this level of data analysis could only be undertaken at the completion of the survey when the field party had returned to the office. Hence the need, defined in the old SP1, for very prescriptive survey methods that sought to ensure that survey observations would later meet the requirements of the survey.

In the new definition of Class, a single test value, at 95% confidence level, for both horizontal and vertical survey methods is proposed. The current structure of Class has a strong separation between the horizontal and vertical. There is also a degree of misalignment caused by the two models used to test each. Further, the 95% confidence level for the horizontal is scaled differently to the vertical [2D=2.45 while 1D=1.96 – when the degrees of freedom exceeds 50]. The new Class structure will provide a more consistent approach to specification – that is, to specify Class 3 for both horizontal and vertical, instead of Class A for horizontal and Class C and/or LC for vertical.

Table 1 New Classes for Survey Control

New Class	Typical application	Original Vertical Class	Original Horizontal Class
0	• Datum definition surveys	n.a.	n.a.
1	• Geodetic surveys of national or statewide extent	LA-LC	3A
2	• Construction of very high precision infrastructure (e.g. radio telescopes)	L2A-LB	2A
3	• Major infrastructure (e.g. bridges) • State survey control densification	LB-LC	A
4	• General infrastructure (e.g. roads) • General purpose survey control	LC	B
5	• Cadastral coordination projects	LC-LD	C

A new definition of Class will recognise the differential component of GNSS surveys, the increasing trend within industry to place control at relatively close intervals, especially for engineering and infrastructure projects, and the common use of GNSS to minimise the linear component of error propagation in other survey technologies. Experience has shown that when establishing survey control, the overall pattern of error propagation is not directly proportional to distance but is a combination of instrumental and atmospheric errors, station spacing and network design and other contributing factors. These errors tend to propagate 'normally', with respect to distance, as opposed to the previous linear model. The new formula to test for Class will better accommodate networks with survey control that is both closely- or widely-spaced, or with the variable spacing common in many infrastructure projects.

3.2 Redundancy for Class

To improve the focus on outcome, observational redundancy as a primary test of Class within the minimally constrained adjustment is proposed. This would be in the form of a defined percentage of observational redundancy relative to the number of unknown parameters.

Survey control is normally expected to be some order of magnitude more accurate than the survey work that applies it later. The local and positional uncertainty that represents this accuracy is improved in all cases by redundant and independent observations of an appropriate Class. Merely repeating an observation without a change in the measurement conditions does not produce independent measurements. An independent measurement is defined here as one that has no, or a very low, correlation with any other. A simple principle to demonstrate an independent observation is that it can be shown within the field records that if a gross or systematic measurement error was included in the first observation, it is unlikely to exist, or have the same quantum, in the second or later observations.

GNSS technology, in particular, has focussed attention on the issue of measurement independence. Conventional GNSS software assumes that no correlation exists between all vectors computed from a common observation session. In one session, with N receivers, the number of independent baselines is (N-1). However, N(N-1)/2 baselines may be computed. The baselines in excess of N-1 are considered dependent, or trivial; that is, a trivial baseline is simply a different combination of the same data. Observations of the same baseline, separated in time, are typically considered independent. However, a physical correlation may exist and systematically bias the result. An example is an antenna height applied across two sessions when the antenna was not reset and the original height was incorrectly measured.

It is proposed that a requirement for redundant, independent observations be included in the definition of Class. Redundancy is represented within a Least Squares adjustment by its degrees of freedom (DoF). The DoF of a particular survey network adjustment are fundamentally related to the determination of the network uncertainty. Generally, for a defined set of observation precisions, the higher the DoF the better the computed uncertainty. The table below provides indicative redundancy ratios that may be included in a test for Network Class.

Table 2 Redundancy Ratios for Network Class

Class	1	2	3	4	5

Redundancy Ratio	250%	200%	175%	150%	125%

4. ACCURACY - POSITIONAL, RELATIVE AND LOCAL UNCERTAINTY

In 2000, ICSM adopted Positional and Local Uncertainty as a new easily understood method for classifying the accuracy of coordinates. These concepts were integrated into Version 1.5 (May 2002) of SP1. SP1 currently defines Positional Uncertainty (PU) as 'the uncertainty of the coordinates or height of a point, in metres, at the 95% confidence level, with respect to the defined reference frame'. Local Uncertainty (LU) is defined as 'the average measure, in metres at the 95% confidence level, of the relative uncertainty of the coordinates, or height, of a point(s), with respect to the survey connections to adjacent points in the defined frame' (ICSM, 2010a).

LU was designed to replace Order, originally defined in SP1 as 'a function of the Class of a survey, the conformity of the new survey data with an existing coordinate set and the precision of any transformation process required to convert results from one datum to another' (ICSM, 2010a). The current SP1 states that 'Order may still be used until LU is fully implemented' (ICSM, 2010a) and this is the case in all States as well as in the National Geodetic Database. To date, PU has only been implemented on a limited scale; Geoscience Australia has published PU for horizontal coordinates for all points held within its National Geodetic Data Base and Landgate, the Western Australian government custodian of the state geodetic network, has published PU for its horizontal network. The Land and Property Management Authority in New South Wales and Tasmania's Department of Primary Industries, Parks, Water and Environment have also implemented PU to an extent, pending further work at the national level for a more rigorous approach (Roberts et al, 2009). All other State and Territory jurisdictions are working towards the integration of PU into their databases and systems.

Given the right tools and resources for changes to systems, processes and delivery mechanisms, PU is relatively easy to implement. However, LU has been the subject of much concern about its implementation as a meaningful indicator of survey control precision. The problem stems from the current definition of LU that reflects its roots in mapping standards that ignore measurements and their correlations. For example, where a control survey has both long and short connections, then taking a straight average of the relative uncertainties may provide a skewed LU relative to a similar project with only short connections. LU also does not support the variance-covariance (VCV) information for existing survey control that is required, along with PU, for the proper adjustment of new survey control.

Further, if LU includes only observed connections then, where two points are in close proximity but without an observed connection, then LU may not correctly define their relative uncertainty. To an extent, GNSS technology may resolve part of this later problem as it enables the easy measurement of lines that were previously impractical or impossible to measure. Fortunately, the dominant use of GNSS for control surveys now places the onus on the design and adjustment of a survey control network to highlight any weakness that may undermine LU. This is reflected in the new SP1 with its focus on the rigorous testing of the minimally-constrained, and constrained, network adjustments for the confirmation of Class and Uncertainty.

It is proposed that a third uncertainty – Relative Uncertainty (RU) – and a revised definition for LU, will clarify the situation. Relative uncertainty is referred to in the current definition for LU but was not formalised. Therefore, Relative Uncertainty is proposed as the uncertainty of a coordinate or height difference, in metres, between any two points, at the 95% confidence level relative to the National Geospatial Reference System (NGRS). In turn, LU is redefined to be a parts-per-million factor. It is proposed that LU be computed as the sum of the relative uncertainties for all 'local' connections divided by the sum of their distances. 'Local' would include only those survey connections made within the project area, that is, it ignores any long connections to, say, a regional CORS or an external primary control point. By transformation to a single parts-per-million factor LU becomes a simple and accessible indicator of accuracy that is independent of station spacing.

In summary, it is proposed that the following definitions for uncertainty be used:

— POSITIONAL UNCERTAINTY (PU) is the absolute uncertainty, in metres, of the coordinates, or height, of a single point, at the 95% confidence level relative to the NGRS.

— RELATIVE UNCERTAINTY (RU) is the uncertainty, in metres, of the coordinate, or height, difference between any two points, at the 95% confidence level relative to the NGRS.

— LOCAL UNCERTAINTY (LU) is a single value reflecting the average Relative Uncertainty within the project area expressed in parts-per-million.

An essential component of jurisdictions implementing either the original, or the new, definitions for uncertainty in SP1 will be their capacity to deliver the required information for existing survey control to users.

5. GUIDELINE DOCUMENTS

As the proposed new SP1 Standard will be a high level, outcomes-based document, a number of guidelines will be produced to provide detail and advice on how a particular project component or specification may be achieved. These guidelines will extract the relevant information from the existing SP1, revise and update them to produce a series of recommended practices to guide a survey control project. Guidelines are proposed for:

— Design and Installation of Survey Control
— Testing and Calibration of Survey Control Instrumentation
— Differential Levelling of Survey Control
— Survey Control by GNSS
— Survey Control by Total Station
— Adjustment and Testing of Survey Control
— Reporting and Archiving of Survey Control Data

New guidelines will also be introduced for:

- Specification of a Survey Control Project
- Establishment of Continuously Operating Reference Stations

6. TECHNICAL MANUALS

The Standard will also refer to technical manuals that provide detailed information on datums and survey systems relevant to Australia. These manuals include the existing 'Geocentric Datum of Australia Technical Manual' (ICSMb) and the 'Australian Tides Manual - Special Publication 9' (ICSMc).

It would also be prudent to develop technical manuals for the Australian Height Datum and the National Geospatial Reference System that fully define the intricacies of these systems. Jurisdictions are often fielding requests for information from international and Australian companies and consultants about survey control and datums in Australia, so it is appropriate that all this information is openly available in authoritative documents.

7. THE WAY FORWARD

Although the GTSC has agreed to adopt a standards-based approach for the new SP1, the concepts proposed here remain to be ratified. The draft document will be submitted for approval by GTSC by mid-2010. The development of the new guidelines and technical manuals will follow immediately to coincide with the next wave of innovation in survey control expected with the completion of the AuScope GNSS project.

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