GOVERNMENT OF WESTERN AUSTRALIA

Landgate

Requirements for Geodetic Surveys by Differential Levelling

GSU-03

Locate Value Secure

Survey | September 2025

Document control

Landgate Requirements for Geodetic Surveys by Differential Levelling

Produced and published by: Location Services/Land Boundaries

Document version history

Date	Author	Version	Revision Notes
Sept 2025	Khandu	5.0	Title changed from “Landgate Requirements for Control Surveys by Differential Levelling” to “Landgate Requirements for Geodetic Surveys by Differential Levelling” and minor revisions.
May 2025	Survey	4.0	Medjil implementation
Sept 2023	Survey	3.0	Update to new style and refresh hyperlinks
	Survey	1.0	Initial

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1. Purpose

Differential levelling conducted for the establishment of Geodetic Survey Marks are to be conducted in accordance with the Special Publication No 1 (SP1 v2.2). ***SP1 v2.2 Guideline for Control Surveys by Differential Levelling*** describes the nationally accepted recommended equipment and procedures for differential levelling and some examples for evaluating the uncertainty of estimated height differences between marks.

This document outlines the requirements and procedures for differential levelling surveys, data processing, and documentation in Western Australia. If there is inconsistency between this document and SP1 v2.2, the requirements in this document shall prevail.

2. Definitions and abbreviations

Abbreviation	Definition
AHD71	Australian Height Datum
ASCII	American Standard Code for Information Interchange
BM	Bench Mark
CIHD	Christmas Island Height Datum
CKIHD	Cocos (Keeling) Island Height Datum
Geodetic Survey Mark	SSM or BM or RM
GESMAR	Geodetic Survey Mark Register
Primary Mark	SSM or BM
RL	Reduced Level
RM	Reference Mark
RTK	Real Time Kinematic
SSM	Standard Survey Mark
TCM	Temporary Control Mark
VRS	Virtual Reference Station

3. Connection to height datum

Vertical control surveys shall commence from a Geodetic Survey Mark with a valid Reduced Level (RL) referenced to the Australian Height Datum (AHD71) or a locally recognised height datum (e.g., Christmas Island Height Datum - CIHD or Cocos (Keeling) Island Height Datum – CKIHD).

A Standard Survey Mark (SSM) or a Bench Mark (BM) to be used for a Differential Levelling survey must first be validated – either from its existing Reference Marks (RMs) or by performing a check levelling from another verified Primary Mark. The validation must confirm the physical stability of the Primary Mark before using it as the starting point for differential levelling. See ***GSU-04 – Landgate Requirements for Inspection, Validation & Maintenance of Geodetic Survey Marks***.

4. Differential levelling guidelines

4.1 Differential levelling

4.1.1 Differential levelling using an optical or digital level with a calibrated level staff is the conventional method for height determination in Geodetic Surveys. This method shall be the standard for establishing new Geodetic Survey Marks and measuring height difference between existing Geodetic Survey Marks. Where this method is not feasible – such as in remote areas with no existing Geodetic Survey Marks in the vicinity, alternative techniques may be considered, provided they are justified and documented.

4.1.2 Differential levelling using Total Station can be applied as an alternative method for determining height differences between a Primary Mark and its Reference Marks (RMs). Height differences to RMs can be determined by making a series of zenith angle and slope distance measurements on both faces of the Total Station to high precision prisms on fixed height poles or high precision mini prisms with minimal additional height.

4.1.3 Differential levelling using GNSS (including RTK and VRS) is not acceptable for height determination in Geodetic Surveys, including height differences of RMs. However, where the above two methods are not feasible, this method may be applied to determine heights of SSMs and height differences to RMs, provided that GNSS occupations on RMs (e.g., by static, quick static, or RTK) are connected to the associated SSM that is simultaneously observed using a static method.

4.2 Differential levelling quality

4.2.1 Unless otherwise specified, Geodetic Survey Mark to be used must be validated from its existing RMs or check-levelled to another Primary Mark with a known RL. Refer to Appendix A for an example of an annotated Station Summary or Redline Markup. If the SSM is suspected of physical movement, refer to ***GSU-06 – Landgate Guidelines for Dealing with Disturbed Geodetic Survey Marks*** to determine any further action required.

4.2.2 Differential levelling run should start and finish on the same mark to ensure closure and allow for error checking. This is also known as **two-way levelling**.

4.2.3 Any misclose of forward and backward run of a levelling traverse, including individual bays, must not exceed the maximum allowable value of **6 mm * √k** (where k is distance in km).

4.2.4 The misclose between the known and measured height difference between two existing Primary Marks should not exceed the maximum allowable value of **12 mm * √k** (where k is distance between the two marks in km). However, if either of the Primary Marks has a stated RL accuracy lower than **12 mm*√k** (e.g. **8 mm*√k**), then the misclose must not exceed the stated value.

4.2.5 The RL of a new Primary Mark cannot be assigned an accuracy higher than the accuracy of the known RL(s).

4.2.6 Instruments used for differential levelling shall be maintained in good condition and their components calibrated at regular intervals.

4.2.7 Height difference to RMs measured using Total Station should achieve the same accuracy standards. For more information, refer to Section 3.2 in the ICSM Guideline for Control Surveys by Differential Levelling.

Also see Section 5 of ICSM Guideline for Control Surveys by Differential Levelling for a practical example on differential levelling and derivation of misclose.

4.3 Differential levelling equipment

4.3.1 The equipment requirements for differential levelling are set out in **Section 3.1.1** of the ICSM Guideline for Control Surveys by Differential Levelling.

4.3.2 The equipment requirements for differential levelling using Total Station are set out in **Section 3.2.1** of the ICSM Guideline for Control Surveys by Differential Levelling.

4.3.3 When RTK/VRS method is used for height determination of RMs (see **Clause 4.1.3**), a fixed solution must be obtained for the duration of occupation (typically 30 seconds or more) and repeat observations (at intervals of 30 minutes) must be done to validate the results.

4.4 Differential levelling observation techniques

4.3.1 The following requirements must be considered, where applicable, when conducting differential levelling for Geodetic Surveys using the conventional method (refer to **Clause 4.1.1**):

a) Staff readings are to be recorded or stored to a precision of at least 0.0001 m in the levelling instrument.

b) The length of a backsight or a foresight must not exceed 80 m.

c) Temperature shall be recorded and stored at the start of each levelling bay using a calibrated a thermometer. Generic temperature values obtained from Bureau of Meteorology (BoM) or other online sources are not acceptable.

d) The difference between the sum of the backsight and foresight distances in a levelling bay should be less than 10 m, where practical. When distance measurement is not possible, sight lengths should be visually balanced to the best extent possible to minimise systematic errors.

e) Two-way levelling is mandatory for Geodetic Surveys**.**

More details are provided in Section 3.1.2 and 3.1.2 of the ICSM Guideline for Control Surveys by Differential Levelling.

5. Calibration of levelling instruments

5.1 Onsite calibration

5.1.1 Optical and digital level instrument collimation shall be checked at appropriate intervals and always before commencing a new survey.

5.1.2 A Two Peg Test shall be conducted before commencing a differential levelling survey, and the results recorded. Collimation should be corrected where the error exceeds 0.0015 m over a distance of 80 m.

5.2 Calibration of bar-coded staves

5.2.1 Bar-coded staves shall be regularly calibrated, typically every two (2) years or as required to ensure levelling instruments remain in good working order and achieve the required measurement accuracy. In Western Australia, Landgate maintains a Staff Calibration facility in Boya (Darlington) to enable Surveyors and other users to regularly check their levelling instruments. More information about the location and procedures can be found on https://medjil.lb.landgate.wa.gov.au.

5.2.2 For Landgate-related works, bar-coded staves must be calibrated within 2 months prior to commencement of differential levelling survey. Staves calibrated for use in previous Landgate-related works may continue to be used without recalibration for up to 2 years from the date of the last calibration, provided there is no visible wear or damage.

5.2.3 Levelling staves shall be constructed of wood, fibreglass or invar. Aluminium staves are not acceptable for Landgate-related works.

5.2.4 Staff bubbles shall be checked to ensure verticality and adjusted as necessary.

6. Differential levelling reductions

Differential levelling shall be reduced on the Landgate excel spreadsheet ***GSU-03A – Abstract for Class C Levelling*** (*Levelling abstractv3.xlsm*).

To use the spreadsheet, users must **enable editing and macros** when prompted so that it can populate the required information from the geodetic database via SLIP (account required). See the Landgate Standards and Guidelines page for information and samples of input data.

All levelling is to be reduced into one only excel abstract file. Additional sheets can be added to the excel file for clarity or to separate areas.

All reference mark check levels are to be shown in the abstract and reduced as per the example in the abstract.

7. Data submission and reporting

A digital data submission of a geodetic survey or a differential levelling survey to Landgate usually includes the following and is mandatory for all surveys conducted for or on behalf of Landgate:

a) **A survey report** outlining the purpose of the survey, methods used, and the results obtained from the data processing.

b) **Sketch or diagram of the levelling network** and dates, if applicable.

c) **Fieldnotes** - scanned copies of any handwritten notes and digital files or files downloaded from the instruments (raw and ASCII)

d) **Mark validation or Redline Markup** of the existing Primary Marks used**,** including any relevant digital files. An example of a Redline Markup is given in Appendix A.

e) Completed Abstract of leveling results.

8. Public relations

Maintaining good public relations is vital and essential to Landgate. Where entry onto private or leasehold land or vested reserves is required to access geodetic marks (SSMs or BMs), the relevant owner(s), occupier(s), or authority(s) must be contacted and consent obtained prior to entry.

Entry onto land is governed by the *Standard Survey Marks Act 1924*.

Geodetic marks located in **restricted areas** such as Rail Reserves, Airport Airside, Port restricted and Military installations will require access permission from the relevant authority before entry. These areas may be controlled by statutory legislation and the process of obtaining entry can make visiting a mark impractical or impossible.

9. Appendix A – Redline Markup (Example)