mainroads WESTERN AUSTRALIA

Asset and Geospatial Information Branch
Survey and Mapping Section

Geodetic Control Survey

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Contents

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0.00	11 April 2022	Initial release	All
0.01	12 May 2022	Corrected (SU) description	14.1
0.02	6 May 2026	Entry to Land and Environmental Impact removed	4 and 5

1 PURPOSE

The purpose of this Standard is to detail Main Roads requirements for Geodetic Control Surveys that provide the survey control for projects.

This standard replaces MRWA standards

- Standard Survey Mark Control 67-08-35
- Road Reference marks 67-08-36
- Minor Control Points 67-08-37
- Differential Levelling 67-08-38

2 SCOPE

This Standard shall apply for all Geodetic Control established for Main Roads projects.

Advice and further information can be obtained by contacting the Senior Geodetic Surveyor.

3 DEFINITIONS

The following terms used in this procedure have the specific meanings indicated:

Term	Definition
AHD	Australian Height Datum
ARP	Antenna Reference Point
BM	Benchmark
CORS	Continuously Operating Reference Station
DGPS	Differential Global Positioning System
GDA	Geocentric Datum of Australia
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ICSM	Intergovernmental Committee on Surveying & Mapping
Landgate	WA Land Information Authority
MCP	Minor Control Point
MGA	Map Grid Australia
RM	Reference Mark
RRM	Road Reference Mark
RTK	Real Time Kinematic GNSS
SIP	Star Iron Picket or Star Picket
SSM	Standard Survey Mark
VCM	Vertical Control Mark
VRS	Virtual Reference Station

4 REFERENCES AND RELATED DOCUMENTS

Document Number	Description
	GDA2020 Technical Manual, Version 1.7
	GDA94 Technical Manual, Version 2.4
	ICSM - Guideline for Adjustment and Evaluation of Survey Control v2.2
	ICSM - Guideline for Control Surveys by Differential Levelling v2.2
	ICSM - Guideline for Control Surveys by GNSS v2.2
	ICSM - Guideline for Conventional Traverse Surveys v2.2
	ICSM - Guideline for Installation and Documentation of Survey Control Marks v2.2
	ICSM – Standard for the Australian Survey Control Network (SP1 ver. 2.2)
	Land Surveyors Licensing Board website: www.lslb.wa.gov.au
	Landgate Requirement for Vertical Control by Differential Levelling
	Landgate Requirements for GNSS Geodetic Surveys
	Landgate Requirements for the Placement of Standard Survey Marks
D15#321963	Survey and Mapping Guideline- Metadata Requirements

5 REFERENCE DATUM

The horizontal positions of all MRWA projects will be supplied in the GDA2020 datum and the coordinates projected using the relevant project grid as specified in the scope of works. The use of GDA94 is only to be used if requested by MRWA.

Under no circumstances is data transformed from superseded datums (such as GDA94) to be presented as GDA2020. This data is not compliant to GDA2020 standards. If requested by MRWA to provide transformed data, the use of a transformation is to be clearly highlighted on the metadata statement and in the accompanying report. The metadata and report are to state which transformation method has been used and identify the data that has been transformed within the submission.

The level datum shall be AHD71 unless an alternative is specified in the scope of works.

6 GNSS OBSERVATIONS

6.1 GENERAL

The use of GNSS baselines is the preferred method to observe both SSMs and RRMs. The Landgate specifications for GNSS observations are to be adopted to ensure compatibility between

the agencies and to ensure best practice is followed. The information on these procedures and documentation can be found in the Landgate Requirements for GNSS Geodetic Surveys document.

6.2 INDEPENDENT BASELINES

All survey control networks created for MRWA should contain only independent baselines. Trivial baselines within a network should be removed to allow the network to adjust freely and report the uncertainties correctly.

For each GNSS session with n receivers logging, there are n-1 independent baselines. Occupations and sessions should be planned to generate the designed network utilising only independent baselines.

6.3 NETWORK GEOMETRY

When designing the MRWA project network, emphasis should be on the relative accuracy of the control points that will be used during the MRWA project. The SSMs and RRMs that are outside of the project area should be connected to for the purpose of connecting to datum rather than used to control the network itself.

The exception to this is where the new network is to extend the existing MRWA survey control to cover additional project areas. In this case the existing control must be adequately tied into to ensure the new control is homogeneous with the existing.

Networks that are constructed by several GNSS units setup on SSMs outside the project area, logging for all sessions with one or two roving units running through the MRWA project control creating a disconnected MRWA network is not acceptable. The MRWA network within the project area must be fully connected and cohesive with ties out to the geodetic framework to connect the MRWA network to the datum.

7 DIFFERENTIAL LEVELLING

7.1 EXISTING CONTROL

For every new project it is first necessary to verify the stability of any existing Survey marks on which the new work is to be based. To verify height, original reference marks at existing control, must be found and the height difference to the primary mark measured where the RMs exist. This documentation must be supplied to MRWA.

Differential levelling to all new marks and existing control must be two way unless otherwise specified by MRWA. All new levelling should connect to every existing spirit levelled mark as a change point along the route as a way to isolate any discrepancies found. Much of the levelling completed for Main Roads is now lodged with Landgate so their strict requirements above must be adhered to.

Existing vertical control used shall be defined to $12\sqrt{K}$ (12RootK) or better.

All existing permanent survey ground control along a road reserve regardless of its previous AHD definition must be levelled in order to provide a spread of height datum points during construction and audit.

If the published accuracy of the existing datum marks exceeds 12RootK, or existing control is minimal, contact the Senior Geodetic Surveyor in the Asset and Geospatial Information Branch for consideration of the datum and advice before proceeding.

Rigorous AHD determination is becoming increasingly important for MRWA projects as larger projects are linking together in areas where AHD datum determination is aging and GNSS is being increasingly relied upon. It is vital that the survey contractor, MRWA and Landgate work together to provide the best outcomes.

7.2 LEVELLING REQUIREMENTS

7.2.1 INSTRUMENTS

Levels instruments used shall meet the specifications set out in the SP1 Version 2.2 Differential Levelling Guideline, section 3.1.1. which is a maximum of 2mm per km.

A test for collimation error shall be made before and during the project, by the “Two Peg Test" method and recorded in the appropriate place. The collimation error should be adjusted where it exceeds 0.0015 metres in a distance of 80 metres.

7.2.2 STAVES

To facilitate the lodgement of levelling data to Landgate and ensure repeatable results between survey crews, MRWA requires the following to make this possible.

- Staves used for differential levelling must be of fibreglass, wood or Invar construction. The use of Aluminium staves is forbidden.

- Temperatures at the site during surveys must be recorded and supplied in the level documentation. Level instrument internal temperature measurements are acceptable so long as the data is in the supplied raw files. For some instruments this option will need to be switched on for the temperature to be recorded. Generic local temperature from weather sites or apps are not acceptable.

- Bar code Staves must be calibrated over the Landgate Boya test range using their purpose designed range. Landgate has a self service web based application that computes the staff calibration (https://staffcalibration.es.landgate.wa.gov.au/). As per SP1 V 2.2, the calibration of a staff must be less than 5 years old. A current certificate of calibration for each staff must be supplied with the level data.

- All sectional and Telescopic staves must be kept in good condition and checked regularly across their joins for wear or error. Regular calibration is a good method to check for joint wear.

7.2.3 OBSERVATION TECHNIQUES

Refer to SP1 Ver.2.2 Differential levelling Guideline, section 3.1.2, for observation parameters to achieve 12√K standard levelling. All staff readings are to be recorded to the nearest 0.001 m in level books or nearest 0.0001m in a digital file.

The length of any levelling sight shall not exceed 80 metres.

Between permanent stations the total length of backsights and foresights shall be approximately equal ideally to within 10m.

Reading to the top or bottom 0.3m of a staff should be avoided. Files with excessive use of extreme measurements may be rejected the Senior Geodetic Surveyor and the levelling required to be redone.

7.2.4 USE OF TOTAL STATIONS FOR DIFFERENTIAL LEVELLING

The determination of height differences by Total Station measurements is permissible by prior arrangements with the MRWA senior Geodetic Surveyor. A consultant wishing to use Total Station Differential Levelling will need to demonstrate that the methodology and equipment is achieving similar levels of accuracy and repeatability as the use of optical or digital instruments with a calibrated staff or is meeting the accuracy requirements of the survey scope and standards.

Section 3.2 in the SP1 Version 2.2 Guideline for Control Surveys by Differential Levelling document sets out the instrument and observing techniques for Total Station levelling. The use of alternative techniques that do not meet the precision and accuracy of the SP1 methodology will not be accepted by MRWA.

8 STANDARD SURVEY MARKS

8.1 GENERAL

Standard Survey Marks (SSMs) and Benchmarks (BMs) are the ground marks of the geodetic framework within Western Australia and are the responsibility of LANDGATE. Main Roads adopts the State Geodetic Network as the connection to datum for road projects.

All survey work that requires the installation of new SSMs/ BMs or the relocation of existing SSMs/BMs must be completed in strict accordance with Landgate standards and are submitted with Landgate through the MRWA Senior Geodetic Surveyor.

SSMs/ BMs are registered and legal survey marks and are protected by the Standard Survey Marks Act 1924. It is an offence to move or destroy SSMs/BMs without permission of an Authorised Land Officer at Landgate.

In urban areas, where generally the existing geodetic control network is dense, sufficient SSMs usually exist to meet project requirements. On rural road projects however, where existing SSMs may be sparser, the typical spacing for the placement of new project SSMs is between 5 and 10 km depending on topographic constraints and the need to service cadastral requirements. Where SSMs form the basis for the road reserve boundary definition, these are to be placed according to the LSLB guidelines.

To maintain the integrity of the geodetic network, all SSMs/ BMs that will be disturbed by road works must be relocated prior to the disturbance of the mark. It is the responsibility of the Project Manager to identify all SSMs/ BMs located within the project area and to notify the MRWA Senior Geodetic Surveyor of those likely to be affected by road works.

The Senior Geodetic Surveyor will then arrange for the marks(s) to be re-located or advise when the mark(s) can be removed. MRWA construction contracts generally stipulate the relocation of SSMs is the responsibility of the principle contractor.

8.2 ALLOCATION OF STANDARD SURVEY MARK NUMBERS AND MATERIALS

SSM/ BM number allocations can be applied for by contacting the MRWA Senior Geodetic Surveyor of the Asset and Geospatial Information Branch. The quantity of new SSMs required is to be supplied with your enquiry, together with their approximate location.

The appropriate number of brass plaques or precast marks, witness plates and, where required hatch covers, will also be made available for collection from either MRWA or in limited numbers from Landgate on request. Request for materials from Landgate should be made via the Senior Geodetic Surveyor at MRWA.

Notification of used, unused and upgraded SSM numbers and materials must be returned to the MRWA Senior Geodetic Surveyor on completion of the job.

8.3 PLACEMENT OF STANDARD SURVEY MARKS

All SSMs/ BMs and RMs installed must comply with LANDGATE Requirements for Placement of Standard Survey Marks (SSMs), (https://www0.landgate.wa.gov.au/__data/assets/pdf_file/0018/16344/GSU-04-Landgate-Reqmts-for-Placement-of-Standard-Survey-Marks-V3.pdf) In addition to Landgate placement requirements (see section 1 of Landgate requirements), other considerations when placing new Standard Survey Marks are:

- The mark should be in close proximity to the anticipated work area, and ideally no more than 100 m from the proposed road centreline
- Facility for future use
- Safety of both the survey team and public.
- Ease of access and occupation

The Senior Geodetic Surveyor should be contacted for advice on the suitability of the proposed SSM locations once their intended location has been determined.

8.4 PLACEMENT OF SSMS FOR ROAD CASEMENT SURVEYS

Main Roads WA has adopted the Survey Practice Guidelines for Surveys of Roads Through Open Country using limited marking under General Regulation 26A of the Licensed Surveyors Regulations.

These Guidelines suggest ideal spacing, observation methods and other key responsibilities for the determination of Cadastral boundaries using an SSM control traverse and are available through the Land Surveyors Licensing Board website. https://cdn.lslb.wa.gov.au/wp-content/uploads/2020/07/Survey-Practice-Guidelines-3-Roads-Open-Country.pdf

8.5 POSITIONAL UNCERTAINTY FOR SSM CONTROL SURVEYS

Landgate is the authority responsible for the determination of all new SSM published values. The consultant installing the new SSMs is not required to compute these values.

The Landgate requirements for GNSS Geodetic Surveys and Vertical Control by Differential Levelling are to be adopted. Refer to the ICSM Standard for the Australian Survey Control Network SP1 Ver. 2.2 where the Landgate requirements are not defined for aspects of the observation requirements.

The observation emphasis is on Positional Uncertainty (PU) and Relative Uncertainty (RU) using the best available equipment, set up and observing techniques and enough redundancies to achieve the lowest possible Survey Uncertainty (SU).

Section 4 of the ICSM Standard for the Australian Survey Control Network sets out the definitions of these three uncertainties.

Landgate and MRWA will define the required baselines for the network.

The incorporation of trivial GNSS baselines with the observed network will not be accepted by MRWA or Landgate. It is the responsibility of the consultant to observe the network in such a manner to ensure there is no reliance on trivial baselines to construct the designated GNSS network.

8.6 STANDARD SURVEY MARK SUMMARY PREPARATION

Presentation of SSM summaries is to be completed according to the current Landgate requirements.

Digital copies of summaries are to be in a CAD format using the station summary template are available from the Landgate geodetic section.

8.7 LIASON

MRWA surveying consultants are not to contact Landgate regarding the job instruction but may do so for a copy and clarification of their specifications. All job-related queries and requests should be directed to the Senior Geodetic Surveyor of the Asset and Geospatial Information Branch.

8.8 DOCUMENTATION

A Metadata Statement in accordance with the MRWA Metadata Guideline is required. This should state which existing SSMs/ BMs were found and used for the survey and if there were any problems encountered with them or the check adjustment.

All SSM/ BM survey documentation must be forwarded to the Senior Geodetic Surveyor of the Asset and Geospatial Information Branch for audit and review prior to registration with LANDGATE.

Digital Data is to be supplied according to Landgate standards for GNSS Geodetic surveys, Vertical Control by Differential Levelling and Placement of Standard Survey Marks requirements.

9 ROAD REFERENCE MARKS

9.1 GENERAL

RRMs are established, coordinated and levelled on most project sites to create the control network to facilitate construction set out, audit, monitoring and to support future works. These marks are permanent ground marks intended to remain after the project is complete.

It is preferable, though not always possible; to place these marks outside of the extent of the designed earthworks and after the clearing extents have been cleared/ earth worked/ set out.

It is critical that accuracy standards of the RRMs are maintained to ensure construction tolerances can be met. The Survey Uncertainty (SU) between adjoining RRMs should not exceed **0.006m**. For a definition of SU please refer to the Standard for the Australian Survey Control Network (SP1 ver. 2.2), section 4 and Guideline for Adjustment and Evaluation of Survey Control v2.2.

9.2 PLACEMENT OF ROAD REFERENCE MARKS

Unless otherwise specified, RRMs shall be:

- **Located to ensure safety of the surveyor and public.**
- Installed to a spacing that will support the project requirements (nominally this is 400m) or as directed by MRWA.
- Situated as directed by MRWA survey manager or Senior Geodetic Surveyor.
- A minimum of 15 metres and preferably 25 metres from the design or existing centreline or at other locations considered safe during construction.EG. Outside the clearing line.
- Intervisible to at least one adjacent RRM or SSM. This requirement can be relaxed when the spacing is specified to be greater than 400m.
- Located adjacent to all intersections so that it is possible to define intersection details and be able to see a minimum of 100 metres along the intersecting road. For a large intersection, a pair of marks may be required.
- **Located away from underground services in the area. Due to the depth of the star picket there is a real danger that some underground cables may be damaged. Such damage will be the responsibility of the Surveyors placing the RRMs**
- Facilitates the use of GNSS when occupying the mark where possible.

9.3 CONSTRUCTION OF MARKS

Construction as per Appendix A (Urban) must be adhered to for all RRMs installed in the metropolitan and rural townsite areas. RRMs may be installed under a reticulation type cover (plastic or concrete) where this will improve pedestrian safety and the amenity of the area it is located in.

Construction as per Appendix B and C applies to rural areas outside townsite limits.

Construction as per Appendix D and E may be considered for specific job needs

Where an RRM is a SIP set in concrete, it must have its allocated number stamped on an aluminium plate set flush in the concrete to aid in its identification. MRWA supplied plaques can be stamped directly onto the flat name plate. The top of the SIP in concrete should sit no more that 20mm above the concrete surface. The top of the SIP must not be below the concrete surface.

It is preferable in areas of soft sand, that each RRM be referenced by two spikes set in concrete. In small projects where only one to four RRMs are placed it is a requirement that at least one RRM be referenced.

It is essential to provide a bearing to each Reference Mark placed for future re-location and use in verification of the RRM. These can be magnetic or Grid bearings and labelled as such on the summary. The RMs must be more than 2m away from the primary mark and orientated away from the road and obstructions.

Where a long traverse of 5 or more RRMs is established, then the referencing can be reduced to every fourth mark but must include the first and last mark.

Existing Landgate Benchmarks or SSMs may be used as alternatives to RRMs if suitable and safe to do so. Their coordinates may be upgraded or adopted as appropriate to the survey and their position or height checked from their reference marks found. Upgraded BMs must be referenced with at least 2 RMs.

Witness plates are an important way of visually locating and protecting RRMs and their use is recommended for most situations. A stamped witness plate (RRM number and distance to mark) should be attached to a star picket then placed a suitable distance from the RRM (0 to 1 metre) and on the road side, **only if its placement will not compromise the safety of the Surveyor or the public. Other options for a pedestrian area would be to nail the plate flush into the concrete surround of the RRM or place it on nearby poles or wire fences etc.** In built up urban areas where the safe installation of witness plates is limited, witness plates may be omitted.

Brass plaques and witness plates may be obtained from the Main Roads Senior Geodetic Surveyor (08 9323 6381). Email: rod.stone@mainroads.wa.gov.au

9.4 INSTALLATION OF CONSTRUCTION PILLARS

Construction pillars can be used where the construction techniques may benefit from the installation of force centred pillars and the pillars are located in such a way that a vehicle cannot collide with them.

The spacing of these pillars would be dependent on the requirements of the construction needs. These pillars would be considered RRMs. Thus the types of RRMs shown in Appendix A, B and C may be replaced by more substancial construction pillars with stainless plate and thread to facilitate efficient instrument setup (Photos below). These marks need to be coordinated as accurately as possible into the State Geodetic network as well as two way differential levelled to validated control - prior to the start of construction.

If the pillars are within the road corridor or on Crown land, they could become SSMs in their own right with appropriate numbers obtained from the Survey Section of Landgate. Observations and documentation to Landgate standards would be required.

See appendix D and E for specifications.

9.5 RRM NUMBER ALLOCATION

RRMs are uniquely numbered according to the current Main Roads road number. RRM number allocations are to be obtained from the Senior Geodetic Surveyor. The application for numbers should include road number, road name, start and finish SLK where known, plus the locality section name and the number of marks required. RRM numbers allocated but not used, are to be documented and may be re-allocated by Main Roads to another survey.

9.6 PROTECTION OF RRMs

The protection, replacement and or installation of RRMs required during construction is the responsibility of the principle contractor. Please refer to the contract documents. Any RRMs identified that could potentially be impacted by works must be identified to the Senior Geodetic Surveyor who may provide approval to remove an RRM without replacement.

10 MINOR CONTROL POINTS

10.1 GENERAL

Minor Control Points are established as a point of reference for the acquisition of digital ground survey and other engineering or investigation surveys.

Depending on project needs, minor control is often used to supplement (in-fill) the RRM network that is required for construction, or other permanent survey control that has already been established (i.e. SSM's) on Main Roads survey projects.

It is intended that MCPs have a finite usefulness in a project area. Often they are either destroyed because of their location or unreliable due to their age and ultimately replaced by the RRM network when new road design has been finalised.

MCPs are not intended as an alternative to installing RRMs. Consultants delivering survey and mapping projects with only MCPs as control should re-evaluate the need to install some permanent RRMs to facilitate future use and additions to the survey data. The survey manager at MRWA should be contacted to confirm the use of MCP only survey control prior to installing the control.

10.2 MINOR CONTROL POINT NUMBERING ALLOCATIONS

MCP numbering is allocated in blocks to consulting companies. The consultant issued with MCP numbers is to manage the numbering to ensure there are no duplication of MCP numbers.

MCP number allocations are to be obtained by application from the Senior Geodetic Surveyor. (Phone: 9323 6381). The application should include details such as road name, start and finish SLK, Project description.

10.3 PLACEMENT OF MINOR CONTROL POINTS

MCPs ideally should have a unique identifying label attached to the physical mark where possible. This label will have the MCP number marked on it in a permanent way (ie. the number stamped or engraved on an aluminium tag).

MCPs may be physically marked by any of the following methods;

- Star iron picket, with or without concrete
- Steel spike, Cooke's nail, Deck Spike
- Wooden peg, dumpy
- Nail and plate in a stable medium.
- Ramset nail in concrete
- Or with other similar stable materials

In urban areas with sandy soil, it is important to preserve the vertical stability of the mark so it is suggested that the ground mark be of suitable type and dimensions to achieve this. Such as longer SIPs or spikes or the addition of concrete.

An indicator may be placed adjacent to the mark where this will assist in re-locating the mark and its survival. However, indicators must not be placed where they may present a danger to the public (such as along minor urban roads or footpaths) or within 1 metre of a bitumen road edge.

The prime considerations when placing new MCPs are:

- The safety of the surveyor and public,
- The suitability of the mark for radiate observations,
- The vertical stability of the mark,
- To avoid grazing and close to ground instrument sights when occupied for observations,
- That no single radiate observation shall exceed 130 metres in length.
- Extreme caution to be exercised where underground services may be present-thus long star pickets (0.5m or longer) may not be best.

Should more permanent mark types be required on a project, then these should be placed according to the Main Roads WA RRM requirements.

10.4 REFERENCING AND STATION SUMMARY

Reference marks and summaries are not required for MCPs.

10.5 METHODS OF SURVEY FOR MINOR CONTROL POINTS

Methods of horizontal survey shall include the following:

- A minimum of two and preferably three or more existing validated control points must be included in the new network. Such existing control can be RRMs or SSMs, with GNSS ties to the latter to not exceed 5km if possible. Existing minor control may be included in the traverse provided their origin is known, they have been placed within the past 5 years and the network is not solely based on existing MCPs.

- The position and height of any existing mark shall be verified by check measurements to RMs or to nearby marks if no RMs are available before being adopted and used.

- **No** new MCP shall be coordinated by radiation. There must be sufficient observational redundancy in the new network to do an adjustment. This precludes the use of RTK to position MCPs.

- In the case of conventional surveying methods, an orientation angle must be observed between the existing network and the new network. This angle observation must be between two lines, both of sufficient length to be able to determine the angle between to within 5". Where new control points are less than 260 metres apart, at least two rounds of angles (both faces) and 3 distances are to be recorded between all stations.

Terrestrial observations should be used in preference to GNSS baselines where the MCPS are closely spaced (400m or less). Hybrid networks are encouraged where GNSS baselines assist in containing the error propagation of terrestrial observations. GNSS baselines should be observed and documented to Landgate standards.

11 VERTICAL CONTROL MARKS

11.1 GENERAL

Some projects may benefit from having Vertical Control Marks (VCM) installed. These marks are intended to provide permanent height control in the area where they are installed. These marks have the same vertical precision as a RRM but with the horizontally positioning relaxed.

VCMs are only to be installed when instructed by MRWA. They are not to be installed in general MRWA survey projects.

When requested to install VCMs the height determination must be to the same standards as RRMs.

Horizontal position can be any method that provides coordinates that are comparable to, or better than, navigation GPS units. The purpose of the horizontal coordinate is to enable the VCM to be located via satellite navigation units. In urban areas MRWA may request RTK techniques are used to better position the VCMs.

11.2 PLACEMENT OF VERTICAL CONTROL MARKS

MRWA will generally supply the location and or spacing of the VCMs. Generally, they are to be established well outside of the works area.

11.3 CONSTRUCTION OF MARKS

As VCMs are intended to be permanent control points they are constructed to the same specifications as RRMs. In certain conditions MRWA may instruct to install SIPs without concrete.

11.4 MINOR CONTROL POINT NUMBERING ALLOCATIONS

MRWA will issue VCM numbering at the time of instruction.

12 GEODETIC CONTROL POINT PRECISION

12.1 HORIZONTAL PRECISION

New RRMS and MCPs are to be established by closed survey network or traverse from a minimum of two and preferably more existing registered RRMs and/or Landgate SSMs of suitable positional uncertainty (PU) and Horizontal accuracy. Existing marks used must be validated from their RMs and the measurements documented. A minimum of two RMs (if available) that agree to the published values within 10mm are required.

In Metropolitan or Townsite areas, ideally only Landgate SSMs of 30mm PU (GDA2020) horizontal accuracy or less are to be used for RRM networks. In Rural areas where SSM control may be sparse, it would be preferable to use those marks with 50mm PU stated accuracy or less. The Main Roads Senior Geodetic Surveyor or Survey and Mapping Project Manager must be consulted if existing marks cannot be found that conform to this requirement.

The use of CORS data is encouraged where the stations are located close enough to construct a baseline without overly lengthy GNSS observations. CORS locations can be found in the Landgate KML https://www0.landgate.wa.gov.au/__data/assets/file/0004/65452/Geodetic_Marks_Link.kml and on the Positioning Australia website https://gnss.ga.gov.au/network . RINEX CORS data can be download from https://data.gnss.ga.gov.au/docs . **When incorporating CORS data it is critical to accurately and correctly measure the antenna heights. When mixing antenna types and models the height to the ARP must be correctly established.**

The horizontal accuracy of any existing RRMs used in the new network must be verified in the network least squares adjustment, prior to adoption. Thus, in the initial minimally constrained adjustment, these RRMs should be floated to see if their existing coordinates can be adopted.

In many areas of the State and with the GDA2020 ongoing adjustment updates, the existing RRMs may have values based upon previous adjustment iterations. The coordinate date published by Landgate and the establishment date of the RRM should be compared. Where existing RRMs are used it may be wise to re-observe them fully if they are more than 5 years old or the RRM is older than the published Landgate coordinate date.

When providing a GDA2020 product and the existing RRMs have only GDA94 values, these RRMs are to be resurveyed to update their position within the GDA2020 datum. **Under no circumstances are the GDA94 datum values on the RRMs to be transformed and presented as GDA2020**.

The Survey Uncertainty (SU) for each adjusted control point should not exceed **0.006m** with an appropriately scaled and weighted adjustment. As per the ICSM guideline the SU is at the 95% confidence level.

The SU can be estimated using a minimally constrained least squares adjustment. A minimally constraint for a GNSS baseline network is a single high precision SSM or RRM. For a terrestrially observed network, a minimal constraint is one SSM or RRM held fixed and an azimuth from that SSM or RRM. The definition of a minimally constrained adjustment can be found in the ICSM Standard for the Australian Survey Control Network (SP1 ver. 2.2) under Terms and Definitions. An example of how the SU can be estimated is shown in the ICSM Guideline for Adjustment and Evaluation of Survey Control v2.2 section 6.1.1

To achieve the accuracy required and to align with Landgate Geodetic Standards GNSS static baselines are to be observed for a period no less than 50 minutes plus 2 minutes per km of baseline length. Rapid static baselines are not acceptable.

12.1.1 RTK USE FOR OBSERVATIONS NOT PERMITTED

Static GNSS baselines or total station measurements are required for new mark placement.

The use of RTK techniques to coordinate new RRMs or MCPs is not an acceptable method for MRWA control surveys as the techniques do not meet the required SU. This is in line with ICSM Guideline for Control Surveys by GNSS v 2.2.

12.1.2 AREAS REMOTE FROM EXISTING CORS AND OR STANDARD SURVEY MARKS

In some areas it will be necessary to bring coordinates and or height in utilising the AUSPOS online processing service with a minimum of 4 hours of GNSS data. In these cases, newly placed RRMs must be linked by conventional levelling (and ideally a traverse) by adopting one of the AUSPOS derived level (AHD) values. A least squares adjustment incorporating all data should be performed to reveal and report on any inconsistencies. This method must be stated on the RRM summaries and in the field report and should be approved by the Senior Geodetic Surveyor prior to survey.

12.2 VERTICAL PRECISION

12.2.1 SECTION TOLERANCES

All new RRMs and MCPs shall be levelled with a two way traverse unless otherwise specifically instructed otherwise by MRWA. The level run must include a minimum of one validated Landgate Benchmark or two existing RRMs validated from reference marks.

The definition of a two way level traverse can be found in the ICSM Guideline for Control Surveys by Differential Levelling v2.2 section 3.1.2

The difference between the forward and backward levelling of any section or any combination of adjacent sections shall not exceed:

- $0.012\sqrt{K}$ metres (12RootK) where K is the distance in kilometres. Any section between new marks over 1KM that approach 12RootK should be reviewed for conformity to 12RootK observation methodology (refer to ICSM Guideline for Control Surveys by Differential Levelling v2.2) and consideration of relevelling the section as it is MRWA's expectation that modern digital instruments with calibrated staves will obtain repeatability around 4 to 6 RootK.
- The vertical accuracy for distances less than 1km shall be on a prorata basis relative to a 1 km tolerance (0.012 meters). For example the accuracy for a section 260 meters long shall be $\pm$0.0031 metres or better.

12.2.2 TRAVERSE TOLERANCE

The misclose of a traverse between validated datum bench marks should not exceed 12RootK where K is the total distance of a traverse in kilometres. When this tolerance is achieved, both AHD values of the marks are to be adopted and the level traverse is to be adjusted to those datum values proportionally according to distance along the traverse.

When the misclose between existing Landgate marks is outside of the 12RootK tolerance the Senior Geodetic Surveyor must be notified prior to adjusting the level network.

Where there are large (+20m) height changes the measured height difference should be corrected for staff calibration.

13 ADJUSTMENT OF SURVEY CONTROL

All horizontal networks or traverses must be adjusted using a Least Squares adjustment. When using software that incorporates transformations within the adjustment (such as Trimble Business Centre) this function must be disabled. Adjustments submitted with transformation parameters may be rejected by MRWA.

Results and evaluation of the Geodetic Control for MRWA projects is to be by a rigorous least squares adjustment connected to the datum. This adjustment should follow the procedure as set out in the ICSM Guideline for Adjustment and Evaluation of Survey Control v2.2 sections 4 and 5.

The final coordinates are those from the constrained to the datum adjustment. The resulting adjustment is to be checked to ensure that distortions present in the State Geodetic Network are not impacting the MRWA network. When discrepancies or distortions are noted, the MRWA senior Geodetic Surveyor should be contacted to discuss options. This may include supplying the survey data to Landgate to have the State Geodetic Network upgraded to accommodate the new measurements.

This option is not available for surveys conducted in GDA94 as the GDA94 State Geodetic Network was locked in late 2016 and cannot be upgraded.

Levelling traverses can be adjusted between fixed points using linear proportioning based on measured distance. Level networks that are interconnected can be adjusted within a least squares adjustment. Prior to adjusting levelling networks the measured height difference should be corrected for the staff calibration. See appendix H for a worked example. The formulae for this correction can be found in the Landgate abstract https://github.com/Landgate/Geodetic/raw/master/abstractv3.xltm .

14 VOLUME SURVEYS

A MCP typically in the form of a short star picket shall be established in a safe location for volume surveys of material stockpiles and shall be surveyed to facilitate a survey to Main Roads WA Digital Ground Survey Standard. However, in remote areas, adopted MGA coordinates for one MCP need only be accurate to +/- 5 metres and an assumed level datum may apply. Thus the absolute position of the Stockpile may not be essential and this would allow the use of hand-held GNSS receivers or other methodologies to establish the datum. In these cases, a minimum of two MCPs should be installed.

Statements of expected coordinate accuracies must be included in the Metadata Statement.

15 DATA LODGEMENT

For each project involving the placement of RRMs, the following information must be submitted to the Senior Geodetic Surveyor. **Failing to supply the data to MRWA Senior Geodetic Surveyor renders the installation of RRMs non-compliant to MRWA Geodetic Control Standard.**

a) **SURVEY REPORT -** A brief survey report with details of methodology used, and any other relevant information which expedites finalisation and registration of the new RRMs and clarifies all issues found. The report should assist future surveyors in understanding how the survey was formed. The Survey Report Template can be downloaded from the MRWA technical library https://www.mainroads.wa.gov.au/technical-commercial/technical-library/

b) **NETWORK SKETCH -** A sketch of the network observed shall be provided. This can be generated from the software package used for the least squares adjustment. It is very important for Main Roads to know what marks were adopted or updated to provide coordination for the new RRMs.

c) **RRM SUMMARY** - An RRM summary form (APPENDIX F or G) shall be completed for each RRM established. All details on the RRM Summary form must be completed including MGA

and Project Zone coordinates. Please use the correct form for the datum as required for the survey. This is not required in the case of a MCP.

d) **CONTROL LISTING -** An excel or .csv file showing: pt. #, E, N, RL, Zone, Datum, Constrained H(orizontal) and or V(ertical) in the adjustment for **all points** in the network and a brief header showing project information. State whether marks are new or existing.

e) **RAW GNSS DATA** - GNSS data including raw and RINEX files (preferably 3.x), Antenna measurement and mark images (see Landgate Requirements for GNSS Surveys) and booking sheets or field notes. If the RRMs are positioned exclusively using terrestrial observations then this data is not required. If a combination of both GNSS and terrestrial observations are used, then both sets of raw data is required.

f) **RAW LEVELLING DATA** - Raw levelling instrument files or ascii files of the instrument measurement data are required. Temperature records are to be documented.

g) **ABSTRACT of LEVEL REDUCTIONS** on Landgate Differential Levelling Abstract (see Appendix H for a worked example) or consultants level reduction output. Ensure that the miscloses, adjustment and adopted control are documented

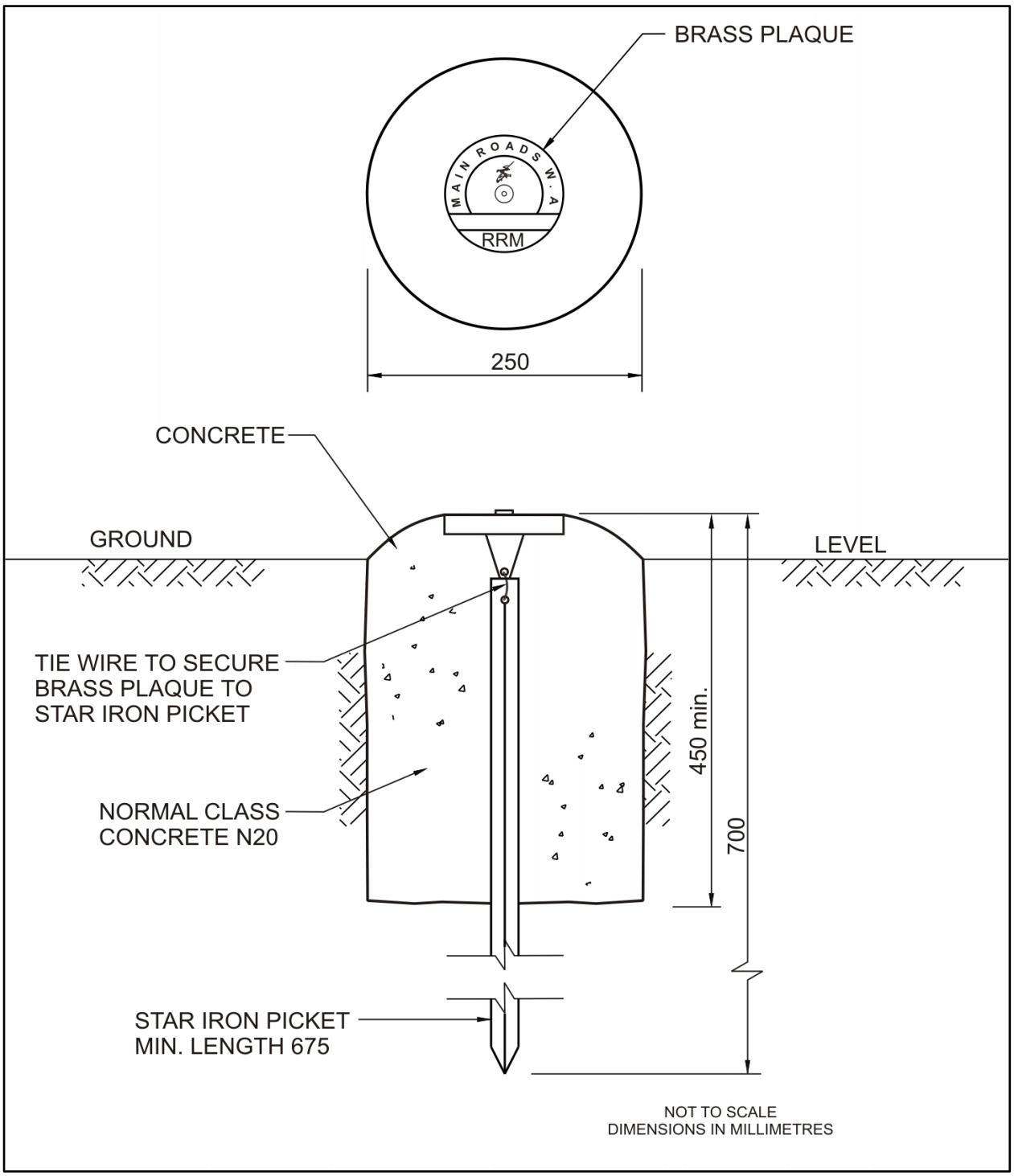
h) **STAFF CALIBRATION CERTIFICATE** – Landgate supplied certification.

i) **EXISTING MARK VALIDATIONS -** Documentation showing the measurements of RMs used to validate the primary existing marks. A marked-up summary sheet is sufficient.

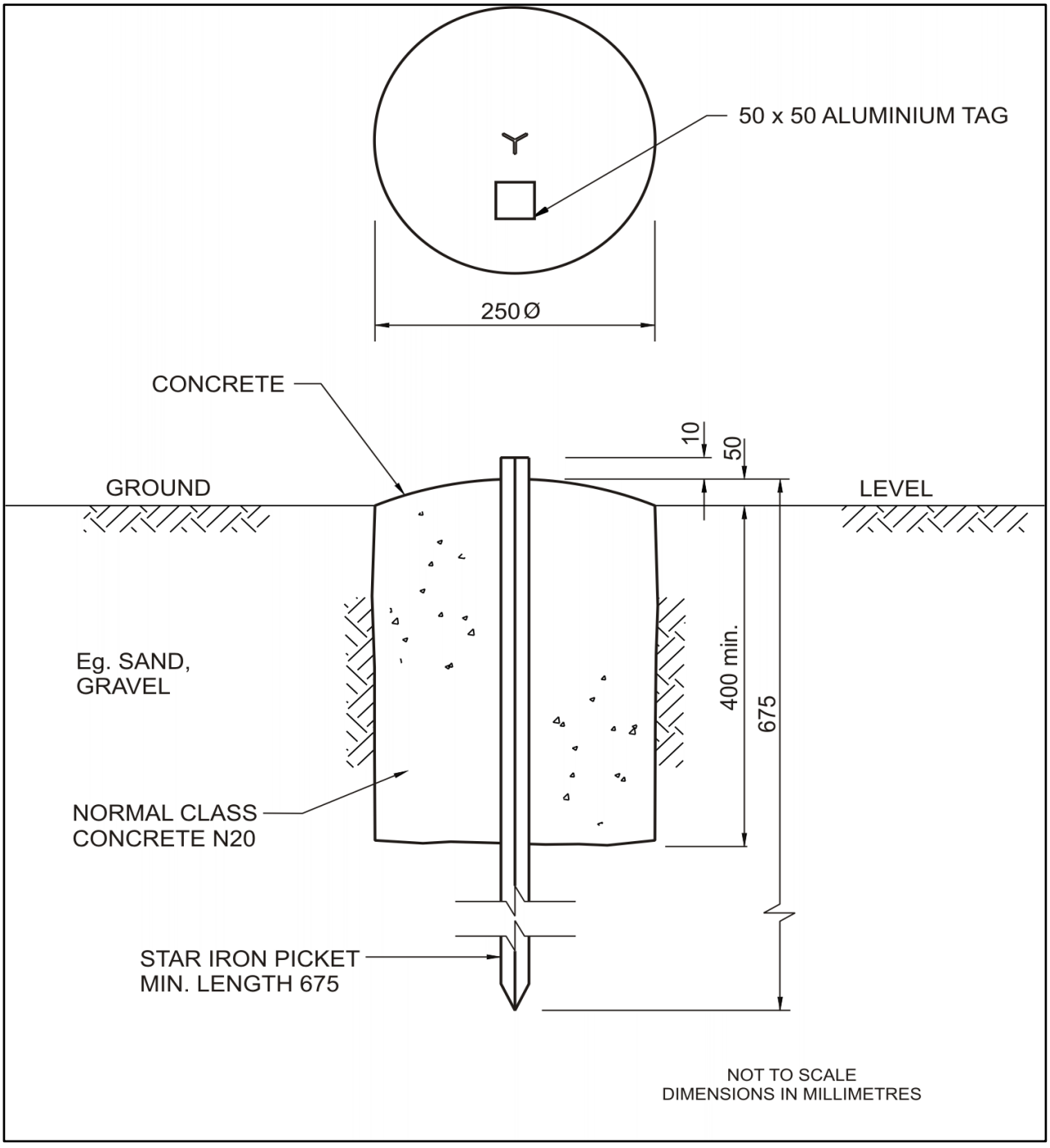
16 APPENDICES

Appendix	Title
Appendix A	Brass Plaque Road Reference Mark Urban and Rural Townsite Areas
Appendix B	Road Reference Mark for Stable Soil Rural Areas Only
Appendix C	Road Reference Mark for Unstable Soil – Where Clay, Blacksoil, “Crab-holes’ Exist. Rural Areas Only
Appendix D	Road Reference Mark Permanent Machine Control Construction Pillar
Appendix E	Road Reference Mark Construction Pillar Temporary
Appendix F	Road Reference Mark Summary for GDA94 datum projects
Appendix G	Road Reference Mark Summary for GDA2020 datum projects
Appendix H	Abstract of Differential Levelling (Example Only)

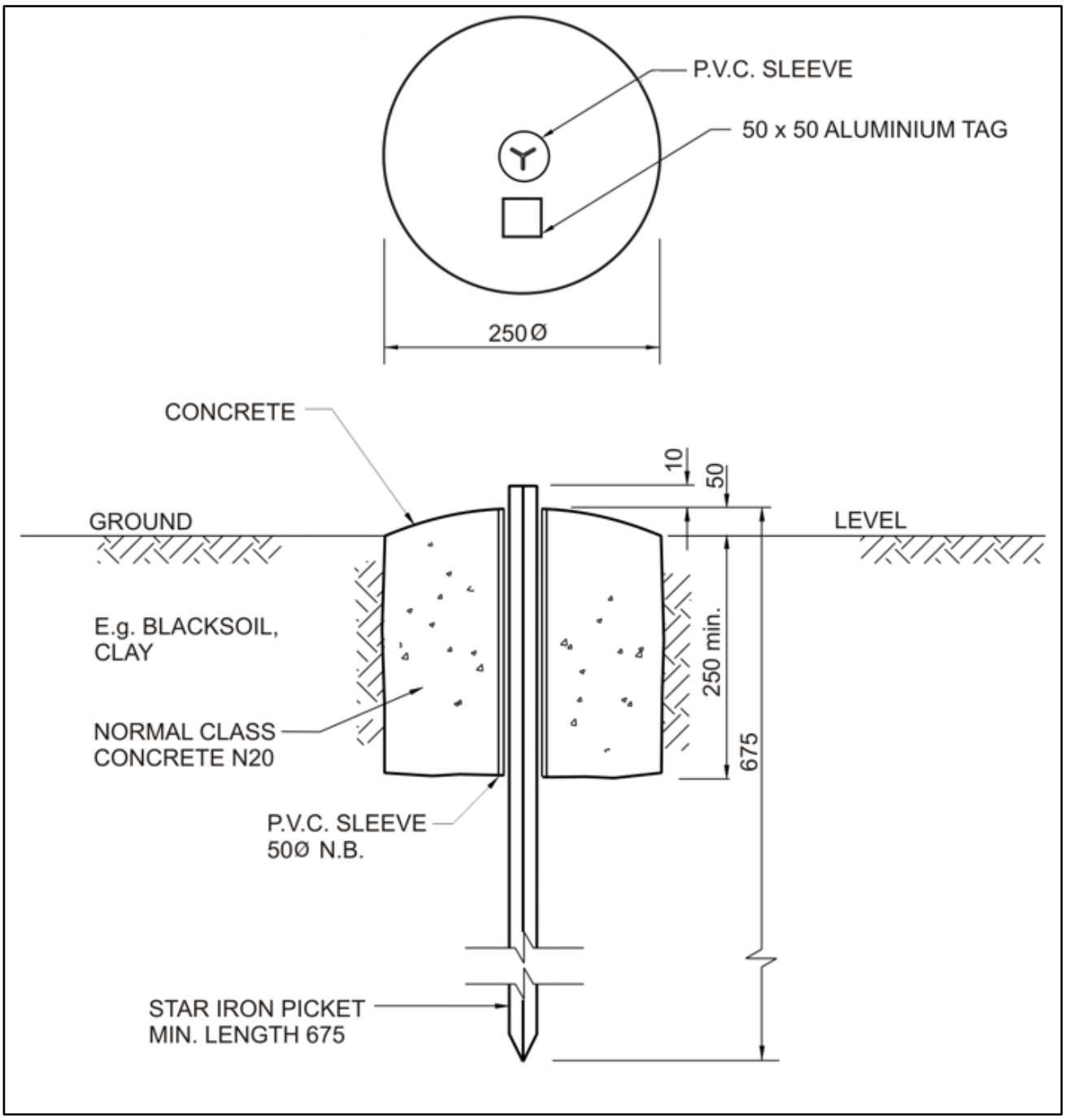
APPENDIX A: BRASS PLAQUE ROAD REFERENCE MARK URBAN AND RURAL TOWNSITE AREAS



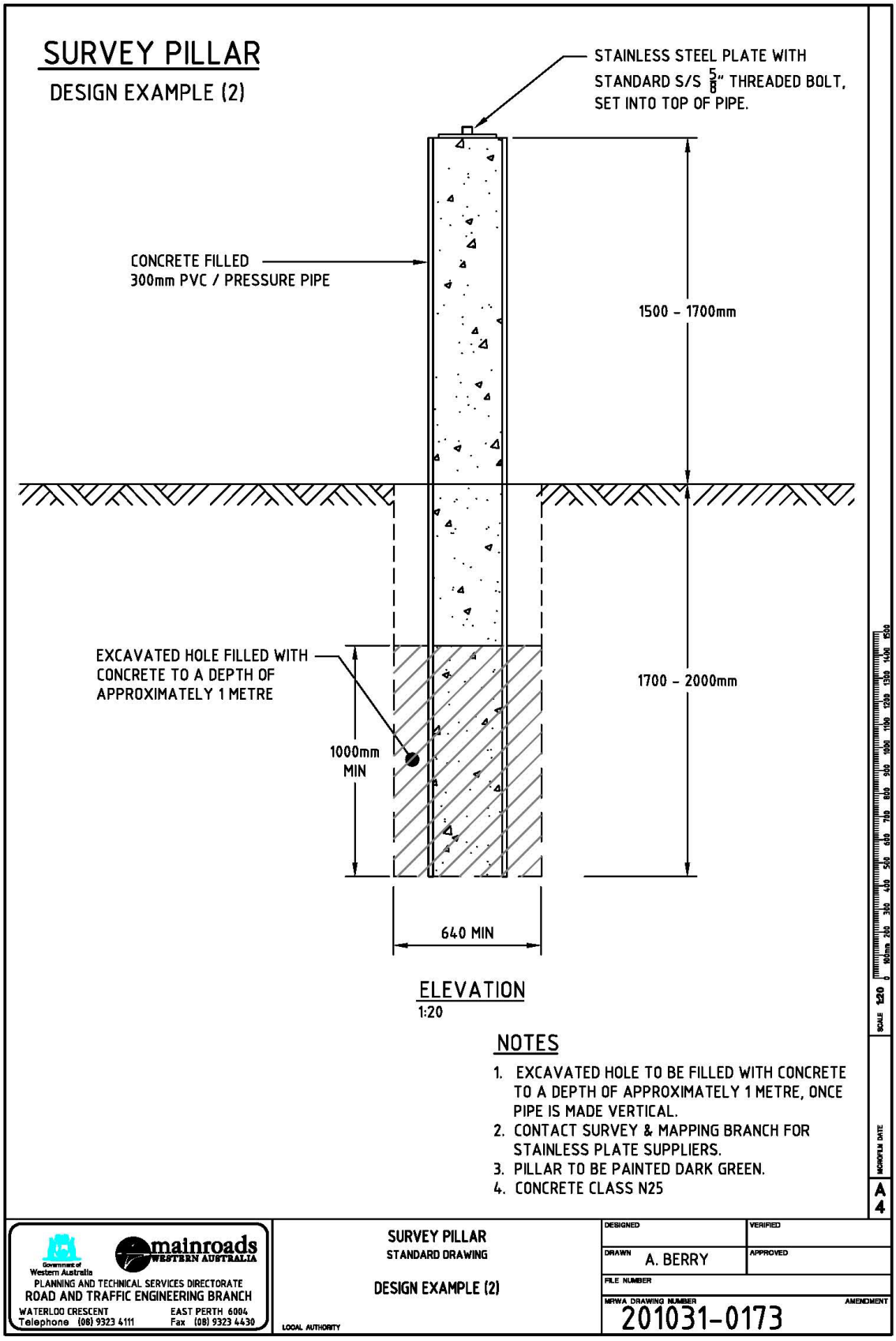
APPENDIX B: ROAD REFERENCE MARK FOR STABLE SOIL. RURAL AREAS ONLY



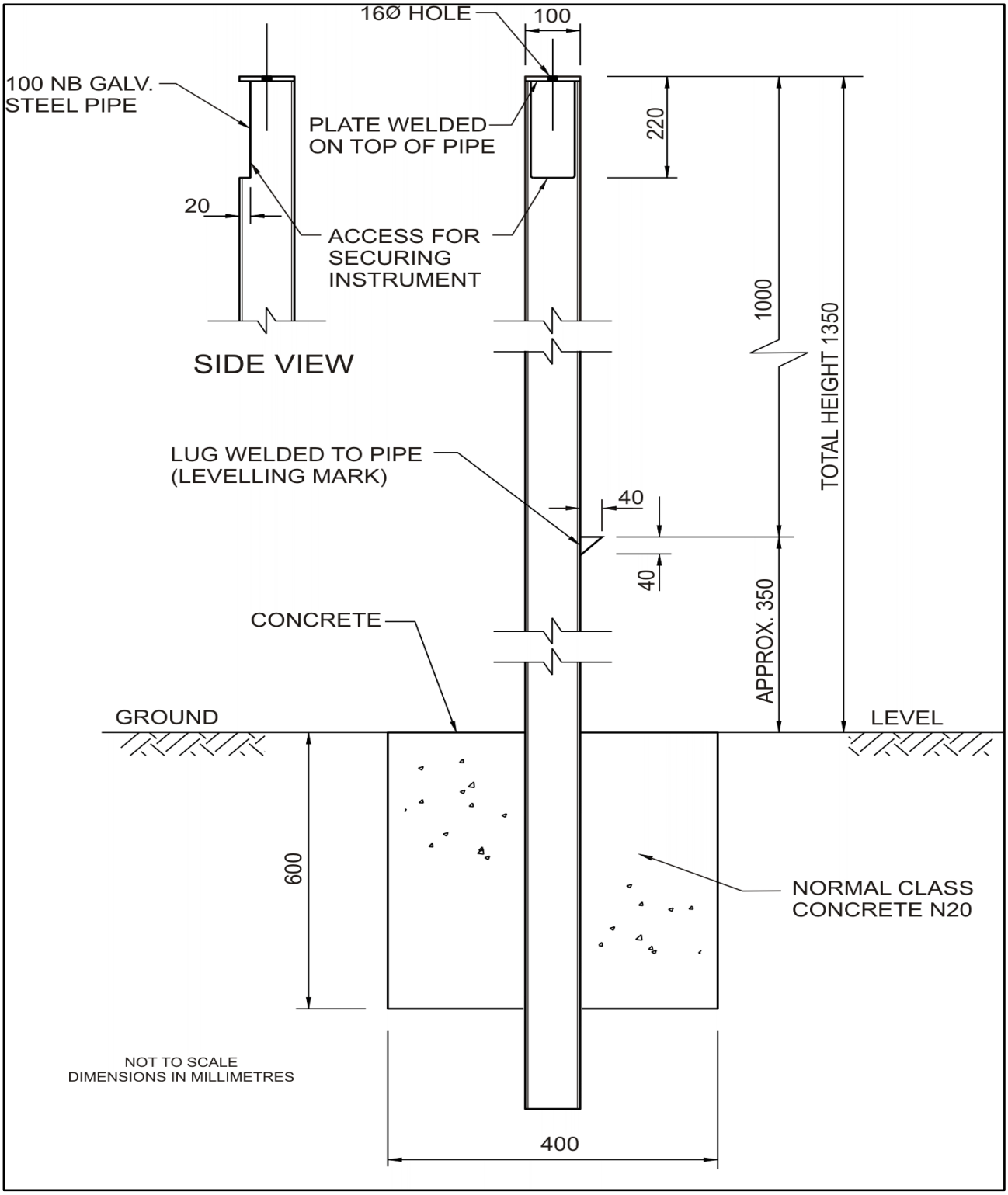
APPENDIX C: ROAD REFERENCE MARK FOR UNSTABLE SOIL – WHERE CLAY, BLACKSOIL, "CRAB-HOLES" EXIST. RURAL AREAS ONLY



APPENDIX D: ROAD REFERENCE MARK PERMANENT MACHINE CONTROL CONSTRUCTION PILLAR



APPENDIX E: ROAD REFERENCE MARK CONSTRUCTION PILLAR TEMPORARY



APPENDIX F: ROAD REFERENCE MARK SUMMARY (GDA94)

ROAD REF MARK No.

MARK HAS BEEN SURVEYED ON THE GDA94 DATUM

ROAD NAME :	**Road No.**
SECTION :	**SLKm :**
REGION :	**LOCAL AUTHORITY** :
SURVEYOR :	**DATE:**

ESTABLISHING SURVEYOR DATA REFERENCES:

MGA 94 ZONE : **EASTING :**
NORTHING :

PROJECT GRID 94 : **EASTING :**
NORTHING :

AHD HEIGHT (MARK) : **(RM1) :** **(RM2) :**

OBSERVATION TYPE: **GNSS STATIC** ☐ **TOTAL STATION** ☐

DESCRIPTION AND LOCATION DIAGRAM

Mark is a

APPENDIX G: ROAD REFERENCE MARK SUMMARY (GDA2020)

ROAD REF MARK No.

MARK HAS BEEN SURVEYED ON THE GDA2020 DATUM

ROAD NAME :	**Road No.**
SECTION :	**SLKm :**
REGION :	**LOCAL AUTHORITY :**
SURVEYOR :	**DATE:**

ESTABLISHING SURVEYOR DATA REFERENCES:

MGA 2020 ZONE :	**EASTING :**	
	NORTHING :	
PROJECT GRID 2020 :	**EASTING :**	
	NORTHING :	
AHD HEIGHT (MARK) :	**(RM1) :**	**(RM2) :**

OBSERVATION TYPE: **GNSS STATIC** ☐ **TOTAL STATION** ☐

DESCRIPTION AND LOCATION DIAGRAM

Mark is a GDA2020

APPENDIX H: ABSTRACT OF DIFFERENTIAL LEVELLING (EXAMPLE ONLY)

SURVEYOR XYZ Surveying — **ABSTRACT OF CLASS C LEVELLING** — **Calculation File** GS — Import level file

Level Book No. GS — **Job No.** 2018MLS1453 — **Computer** R Stone — Update From SLIP

Date of Survey 3 Oct 2018 — **Staff No.** — **C Const =** 1.000130 — **Inst. No.** — **Date** 08 Jan 2020 — Update Formula's

COE = 0.000130 — **STP(°C) = 25**

Temp	Distance km	From BM	To BM	Total Distance From	Difference in Elevation: Forward	Backward Forward	Mean	Calibrated Mean	Adjustment ~~Closure~~	Elevation Above AHD: Observed	BM	Adjusted	Remarks			
											M 43 - 54	52.662				existing RRM
16	0.94	M 43 - 54	M 43 - 61	0.94	-1.942			-1.939		50.723	M 43 - 61					
18	1.24	M 43 - 61	V 1	2.18	-29.736			-29.711		21.011	V 1					
18	1.05	V 1	HB 26A	3.23	0.953			0.952	-0.037	21.964	HB 26A	21.927	Spirit Levelling	Allow	0.022	
18	0.04	HB 26A	M 43 - 62	0.04	-1.037	1.036	-1.036	-1.035		20.892	M 43 - 62					
17	1.85	M 43 - 62	HB 56	1.89	53.291	-53.283	53.287	53.242	0.015	74.133	HB 56	74.148	Spirit Levelling	Allow	0.017	
											HB 26A	21.927	Spirit Levelling			
17	1.10	HB 26A	V 2	1.10	33.848	-33.847	33.848	33.818		55.745	V 2					
17	1.56	V 2	HB 27	2.66	24.231	-24.228	24.229	24.208	-0.004	79.953	HB 27	79.949	Spirit Levelling	Allow	0.020	
17	0.11	HB 27	M 43 - 63	0.11	3.656	-3.655	3.656	3.652		83.601	M 43 - 63					
16	0.45	M 43 - 63	55I	0.57	15.297			15.282		98.883	55I					
14	0.87	55I	V 3	1.44	0.055			0.055		98.937	V 3					
14	1.67	V 3	HB 28	3.10	-0.613			-0.612	-0.007	98.325	HB 28	98.318	Spirit Levelling	Allow	0.021	
14	1.29	HB 28	V 4	1.29	10.635			10.622		108.940	V 4					
14	1.36	V 4	HB 29A	2.65	-13.409			-13.392	0.000	95.547	HB 29A	95.547	Spirit Levelling	Allow	0.020	
											HB 26A	21.927	Spirit Levelling			
16	0.02	HB 26A	HB 26	0.02	0.223	-0.223	0.223	0.223	-0.002	22.150	HB 26	22.148	Spirit Levelling	Allow	0.002	

Import level file | Update From SLIP | Update Formula's

SURVEYOR XYZ Surveying | **ABSTRACT OF CLASS C LEVELLING** | **Calculation File** GS

Level Book No. GS | **Job No.** 2018MLS1453 | **Computer** R Stone

Date of Survey 3 Oct 2018 | **Staff No.** | **C Const =** 1.000130 | **COE =** 0.000130 | **Inst. No.** | **STP(°C) =** 25 | **Date** 08 Jan 2020

Distance km	From BM	To RM	Total Distance From	Difference in Elevation: Forward	Difference in Elevation: Backward Forward	Difference in Elevation: Mean	Difference in Elevation: Calibrated Mean	Difference (Allow 0.010)	Original Diff.	Elevation Above AHD: BM	Elevation Above AHD: Adjusted	Remarks
				0.000								
										HB 29A		
	HB 29A	RM 5		-0.258						RM 5		New RMs
		RM 6		-0.252						RM 6		New RMs
		RM 7		-0.022						RM 7		New RMs
										BUS 209		
	BUS 209	RM 1		0.103				0.000	0.103	RM 1		
		RM 2		0.051				0.000	0.051	RM 2		
		RM 3		0.021				0.001	0.020	RM 3		
										BUS 167		
	BUS 167	RM 3		0.188				-0.005	0.193	RM 3		
										HB 28		
	HB 28	RM 3		-0.340				0.001	-0.341	RM 3		
		RM 4		-0.193				-0.002	-0.191	RM 4		
		RM 5		-0.226				0.000	-0.226	RM 5		
										HB 26		
	HB 26	RM 1		-0.636				-0.006	-0.630	RM 1		