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Standard governance

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Document history

<table>
<thead>
<tr>
<th>Version</th>
<th>Summary of Changes</th>
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<td>1.0</td>
<td>First issue</td>
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Preface

The Asset Standards Authority (ASA) is an independent unit within Transport for NSW (TfNSW) and is the network design and standards authority for defined NSW transport assets.

The ASA is responsible for developing engineering governance frameworks to support industry delivery in the assurance of design, safety, integrity, construction, and commissioning of transport assets for the whole asset life cycle. In order to achieve this, the ASA effectively discharges obligations as the authority for various technical, process, and planning matters across the asset life cycle.

The ASA collaborates with industry using stakeholder engagement activities to assist in achieving its mission. These activities help align the ASA to broader government expectations of making it clearer, simpler, and more attractive to do business within the NSW transport industry, allowing the supply chain to deliver safe, efficient, and competent transport services.

The ASA develops, maintains, controls, and publishes a suite of standards and other documentation for transport assets of TfNSW.

This standard covers the requirements for the provision of conventional surveying services for rail purposes for TfNSW.

It has been developed through consultation across TfNSW divisions and agencies.

This standard was developed from the following RailCorp documents:

- ESC 210 *Track Geometry and Stability*
- SPC 211 *Survey*
- SPC 212 *Contract Survey*
- TMC 212 *Survey*

This standard will replace SPC 211, SPC 212 and TMC 212.

This standard is a first issue.
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1. Introduction

Railway surveying is the branch of the surveying profession involved with providing survey information specific to the railway environment. Railway surveying covers both engineering and cadastral surveying requirements.

Coordinated track alignment is based upon the Rail Survey Control Network. This network is realised on the ground within the Metropolitan Rail Area and other parts of the NSW rail network by Rail Survey Control Marks (Rail SCMs). Due to the unique environment in which rail surveys are undertaken, this network of Rail SCMs within the rail corridor is maintained by the relevant Rail Infrastructure Manager (RIM) on behalf of TfNSW, with external connections to the NSW State Survey Control Network at regular intervals. These marks are fundamental rail assets that are coordinated in three dimensions and provide the reference network for track alignment.

Permanent Track Control Marks (TCMs) provide further densification of survey marks within the rail corridor. These marks are located at regular intervals on one or both sides of the corridor, and together with the plaques or tags related to the mark, provide a direct reference for rail maintenance and construction personnel to locate the track in its correct spatial location.

Conditions outlined within this document shall be deemed as minimum requirements, with nothing precluding these requirements from being exceeded. Further, no requirement shall act to constrain the application of survey best practice in all cases.

2. Purpose

This standard covers requirements for the provision of surveying services in the railway environment and includes information relating to survey control, track control, marking, documentation and instrumentation.

2.1. Scope

This standard provides minimum requirements for the following:

- the Rail Survey Control Network and Track Control Network
- survey observations and check measurements
- documentation
- instruments and equipment

The document also provides a brief overview on railway surveying competency.

This standard does not cover any requirements relating to the use of Global Positioning Systems (GPS) or Global Navigation Satellite Systems (GNSS) equipment or measuring techniques.
2.2. Application

The primary application of this standard is in the heavy rail environment where the network is contained within a dedicated and restricted rail corridor. However, its principles can be applied to any type of rail network (including light rail) regardless of location. The standard specifically applies to:

- The provision of any new surveying services in the railway environment including survey control, track control, marking, documentation and instrumentation.
- All parties involved in the provision of railway surveying services within the Metropolitan Rail Area. It may also be applied to other parts of the TfNSW heavy rail network.

3. Reference documents

The following documents are cited in the text. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document applies.

**International standards**

ISO 17123-2 Optics and optical instruments – Field procedures for testing geodetic and surveying instruments – Part 2: Levels

ISO 17123-3 Optics and optical instruments – Field procedures for testing geodetic and surveying instruments – Part 3: Theodolites

ISO 17123-4 Optics and optical instruments – Field procedures for testing geodetic and surveying instruments – Part 4: Electro-optical distance meters (EDM measurements to reflectors)

**Transport for NSW documents**

ESC 210 Track Geometry and Stability

SPC 211 Survey

SPC 212 Contract Survey

TMC 212 Survey

**Legislation**

All surveys in NSW are conducted under the auspices of the following legislation and directions:

Surveying and Spatial Information Act 2002 No 83

Surveying and Spatial Information Regulation 2012

NSW Surveyor General’s Directions
Other reference documents

D2013/80872 ‘Inspection and Testing of Insulated Sticks, Tools and Equipment used for work On, Near or In the Vicinity of Exposed 1500V OHW or Equipment’ issued by Sydney Trains

Intergovernmental Committee on Surveying and Mapping 2014, Standard for the Australian Survey Control Network Special Publication 1 (SP1), Version 2.1

‘Definition of Railway Boundaries in NSW’ by John T. Webber

4. Terms and definitions

The following terms and definitions apply in this document:

**AHD:** Australian Height Datum; AHD71 is the geodetic datum for altitude in Australia. From measurements undertaken at 30 tide gauges all around Australia in the late 1960s, 0.000 m AHD was assigned to the mean sea level of these results. The resulting surface is the datum to which all vertical control for mapping (and other surveying functions) is referred.

**DSS:** Detailed Site Survey; this is the process of acquiring field data and the preparation of plans, cross sections and long sections of underground and above ground services (both rail and external) within the Metropolitan Rail Area.

**Engineering Surveying:** Engineering surveying is that branch of the surveying profession involved in the planning and execution of surveys for the location, design, construction, operation and maintenance of civil and other engineering projects. This branch of surveying is also known as Civil Surveying.

**GNSS:** Global Navigation Satellite System; GNSS is a generic term for all satellite-based positioning systems.

**GPS:** Global Positioning System; the term GPS is specific to the United States' GNSS system, the NAVSTAR Global Positioning System.

**ISG:** Integrated Survey Grid; this is a historic map projection system that was used in NSW between 1970 and 2000. It is based on the Australian Geodetic Datum (AGD66), and divided NSW into 2° wide zones of longitude designed to minimise scale factor corrections.

**MGA:** Map Grid of Australia; MGA94 is the current official coordinate projection system for NSW. MGA is based upon the global model of the earth.

**MRA:** Metropolitan Rail Area; this is the area bounded by Wickham (in the north), Richmond (in the northwest), Bowenfels (in the west), Macarthur (in the southwest) and Bomaderry (in the south), and all connection lines and sidings within these areas, but excluding private sidings.

**Principal Surveyor:** person responsible for the survey activities of the relevant RIM.
Rail SCM: Rail Survey Control Mark; this is a permanent survey mark made of high quality, durable and corrosion resistant materials, installed in stable ground, solid rock, or on in-situ mass concrete, where the potential for disturbance is minimised.

Railway Surveying: Railway Surveying is a specialist sub-branch of Engineering Surveying, primarily involved in defining and managing spatial information in a rail corridor relating to the horizontal and vertical alignment of a railway track, and the relationship (interface) of this alignment to adjacent track alignments and adjacent civil structures (for example, platforms and overhead wiring structures).

RIM: Rail Infrastructure Manager; in relation to rail infrastructure of a railway, means the person who has effective control and management of the rail infrastructure, whether or not the person:
(a) owns the rail infrastructure, or
(b) has a statutory or contractual right to use the rail infrastructure or to control, or provide, access to it.

running face: sometimes referred to as ‘gauge face’; this is a point 16 mm below the top of the rail on the inside face that defines the point that track gauge is measured from, and is used as a reference point for track-related measurements.

SCIMS: Survey Control Information Management System; SCIMS is an online database managed by NSW Land & Property Information which contains MGA coordinates, AHD heights and other related information for survey marks established as part of the State Survey Control Network.

State Survey Control Network: this is the network of physical permanent ground marks installed and maintained across the state by NSW Land & Property Information that provide a base for accurate spatial data. Examples of these marks are State Survey Marks (SSMs) and Permanent Marks (PMs).

TCM: Track Control Mark; this is a mark specifically placed to provide a reference to the adjacent track, to allow rail maintenance and construction personnel to locate the track in its correct spatial location.

5. Requirements for the Rail Survey Control Network

This section outlines the field procedure requirements to be followed when conducting a survey of the Rail Survey Control Network.

It relates specifically to conventional traverse survey techniques using a total station type of instrument.
The location of track infrastructure shall be established from the Track Control Network. Track Control shall be established from the Rail Survey Control Network.

All rail surveys shall be established using the Map Grid of Australia 1994 (MGA94) or Integrated Survey Grid (ISG), and the Australian Height Datum 1971 (AHD71). Alternative systems shall only be used with the approval of the Principal Surveyor of the relevant RIM. Any infrastructure surveyed within track structure gauge (such as platform copings, tunnels and bridges) shall be described in the same coordinate system as the adjacent track alignment. The Principal Surveyor of the relevant RIM shall be consulted to ensure use of the appropriate coordinate system.

*Note: Given that at the time of publication, approximately 85% of the Metropolitan Rail Area (MRA) is currently defined by the ISG coordinate system, any work being undertaken within this region will need to be compatible with current arrangements. Any opportunities for track alignment conversion from ISG to MGA may be considered in consultation with the Principal Surveyor of the relevant RIM.*

### 5.1. Rail SCM types and installation methods

The primary permanent Rail Survey Control Mark (Rail SCM) is the Brass Triangle (BT).

In rural locations, a Star Picket (SP) set in concrete with a punch mark atop, can be used as a Rail SCM.

In special circumstances, other types of marks may be proposed to the Principal Surveyor of the relevant RIM and to the Asset Standards Authority (ASA) for approval to be used as Rail SCMs.

A services search shall be undertaken before the commencement of ground penetration for mark installation.

Historically, as part of the overall State Survey Control strategy and other projects, the Lands Department installed Permanent Marks (PMs) and State Survey Marks (SSMs) within a number of rail corridors. These marks are now part of the current Rail Survey Control Network. These marks are classified as ‘restricted’ in SCIMS, and are unavailable for use by the wider surveying community. It is not intended for PMs or SSMs to be installed within rail corridors in the future.

The methods of installing BT type marks and SP type marks for the Rail Survey Control Network are as described in Section 5.1.1 and Section 5.1.2.
5.1.1. **Brass Triangle type marks**

Brass Triangle (BT) type marks can be installed in bedrock, concrete, stone or masonry and consist of a triangle with a long or short brass pin. BTs shall be recessed so that the top of the triangle is flush with the surrounding material. Counter sinking of the triangle and dome-shaped pin shall be completed to ensure that a levelling staff can be placed upon the pin without interference. Figure 1 shows a BT mark in a tiled platform and Figure 2 provides a detailed drawing of the BT.

![Figure 1 – Brass Triangle countersunk into a tiled platform](image1)

![Figure 2 – Brass Triangle specifications and details](image2)

BTs installed at other locations shall consist of a long brass pin and triangle set into concrete, and preferably protected within a cast iron cover box at ground level. Where additional support is required in softer ground, a galvanised iron or aluminium star picket may be driven into the ground, with the BT and picket set into concrete. A services search shall be undertaken before installation. Figure 3 shows a hinged cast iron survey cover box. Figure 4 provides a cross-sectional diagram with details regarding BT installation.
5.1.2. Star Picket type marks

In rural locations outside of the MRA, a punch mark in the top of a galvanised iron or aluminium star picket set in concrete at ground level may be used. It is preferable for this type of mark to be protected by a cast iron cover box, concrete collar and lid, or some similar type of arrangement that is acceptable to the Principal Surveyor of the relevant RIM. These marks shall be referenced with at least one adjacent capped indicator picket and flagging tape. Installation of this type of mark is similar to that for the BT and picket as outlined in Section 5.1.1. This type of mark shall only be installed in non-electrified areas.
5.2. Placement of Rail SCMs

Rail SCMs shall be placed at a maximum spacing of 150 m, preferably in a staggered pattern along both sides of the corridor. At regular intervals along the corridor, provision shall be made for connections to nominated adjacent NSW State Survey Control Network marks. The methodology for achieving these connections shall be developed in consultation with the Principal Surveyor of the relevant RIM. This connection allows for a comparison of azimuth between the networks.

The location and installation of Rail SCMs in restricted locations such as tunnels and viaducts, requires careful consideration. These detailed requirements shall be developed in consultation with the Principal Surveyor of the relevant RIM.

Rail SCMs shall be installed in stable structures clear of running lines, and as far as is practicable, clear of access roads and other locations that can pose a risk to survey staff and instrument safety when occupying the mark. The safety of survey personnel and equipment shall be of paramount importance when designing Rail Survey Control Networks and installing Rail SCMs.

5.3. Identification of Rail SCMs

The Principal Surveyor of the relevant RIM shall be informed of the intention to install any Rail SCMs, including replacement marks.

Before any survey work is undertaken, the Principal Surveyor shall be consulted regarding requirements for, and the design of, Survey Control and Track Control Networks. Agreement shall be reached based on the project requirements, the Principal Surveyor’s knowledge of the project, and other survey issues relating to the project and adjoining areas.

A walkthrough of the proposed survey area may be required to identify any potential issues, with any information required to complete the survey being identified. During the walkthrough, all existing Rail SCMs and Track Control Marks (TCMs) shall be identified.

5.4. Missing or damaged Rail SCMs or TCMs

In every case where missing or damaged Rail SCMs or TCMs are encountered, a comprehensive report shall be provided to the Principal Surveyor of the relevant RIM.

The information provided shall detail specific locations and the extent of the missing or damaged marks, with photographs included if possible. Where construction work causes (or has the potential to cause) damage to survey infrastructure, every reasonable attempt shall be made to minimise this damage.
If PMs or SSMs that form part of the Rail Survey Control Network are damaged or destroyed, then additional reporting requirements are contained in the Surveyor General's Direction No. 11, ‘Preservation of Survey Infrastructure’.

5.5. **Observation requirements**

Rail Survey Control shall be measured and levelled according to the following observation requirements:

- **Horizontal and Vertical Angle measurements:**
  - traditional survey traverse techniques shall be employed – face left / face right and back sight / fore sight
  - level instruments and targets directly over SCMs
  - height of instrument and targets shall be measured to the millimetre
  - control observations can be observed as part of a sequence of observations at each occupied station
  - observe 6 full horizontal arcs to each target
  - observations may be carried out at any time during the setup
  - residual from the mean of any horizontal direction shall be $\leq 6"$
  - Rail SCMs shall be traversed and occupied in succession

- **Distance measurements:**
  - distance shall be measured to the millimetre and shall be recorded with each horizontal direction observation

- **Differential levelling:**
  - only non-metallic and non-telescopic survey staves shall be used for control
  - all Rail SCMs shall be double levelled

For instrumentation requirements refer to Section 9.
5.6. **Field observations and preliminary adjustments**

A preliminary adjustment of the observations shall be carried out to ensure any observational errors are detected. Adjustments shall be carried out using a least squares survey adjustment software package, with ‘CompNet’ survey adjustment software being the preferred package.

The results shall be provided to the Principal Surveyor of the relevant RIM, who will authorise or reject the adjustment. Deliverable data requirements are outlined in Section 8.

6. **Requirements for the Track Control Network**

This section outlines the marking requirements and the field procedures for conducting a survey of the Track Control Network. It also details requirements for surveys that are not part of Survey Control or Track Control.

This section relates specifically to conventional traverse survey techniques using a total station type of instrument.

The location of track infrastructure shall be established from the Track Control Network. The primary function of the Track Control Network is to provide permanent recovery monuments relative to the current design alignment of the track.

Track Control shall be established from the Rail Survey Control Network, using the same coordinate reference system. Alternative systems shall only be used with the approval of the Principal Surveyor of the relevant RIM.

Both the physical Track Control Mark (TCM) and the 3D coordinate value associated with the mark are assets.

6.1. **Types of TCMs and installation methods**

The types of marks that may be placed or used for the purpose of the Track Control Network and their installation methods are detailed in Section 6.1.1 through to Section 6.1.6.

6.1.1. **Stainless Steel Pin (SSP)**

A Stainless Steel Pin (SSP) shall be used if a permanent TCM is required to be placed on an overhead wiring structure (OHWS) or other metallic structure or post. The pin requires an appropriately sized drill bit for installation to ensure a secure fit. To inhibit corrosion, the internal surface of the drill hole shall be coated with an anti-corrosive product such as ‘Galmet’ or similar, prior to the installation of the SSP.
The specifications and dimensions of SSPs are as follows:

- construction material: Type 304 Stainless Steel
- overall length: 20 mm
- length of the pin head: 7 mm
- diameter of pin head: 6 mm
- ‘u-drive’ thread length: 11 mm
- stub end length: 2 mm
- 8 gauge nominal screw size:
  - internal \( \varnothing \) \( x = 3.35 \text{ mm} – 3.45 \text{ mm} \)
  - external \( \varnothing \) \( y = 4.11 \text{ mm} – 4.24 \text{ mm} \)

Refer to Figure 5 for a diagram of a SSP.

![Figure 5 – Stainless Steel Pin (dimensions in mm)](image)

6.1.2. Brass Bar (BB)

A Brass Bar (BB) shall be used if a permanent TCM is required to be placed in stable rock, concrete or masonry. The BB requires a 12 mm diameter drill bit for installation in softer material such as sandstone or brick. A 13 mm diameter drill bit shall be used for installation into harder materials, such as concrete. Installation also requires liquid adhesive to be placed into the hole before the bar is inserted to aid mark adhesion. To prevent deformation of the head of the bar during installation, a ‘dolly’ or similar tool shall be used when hammering the bar into place. The BB shall be installed such that the end shall protrude from the face of the material by between 15 mm and 20 mm.
The dimensions of a BB are as follows:

- overall length: 90 mm – 100 mm
- diameter: 12.0 mm – 12.7 mm
- chamfered ends: 2 mm x 1 mm

Refer to Figure 6 for a diagram of a BB.

Refer to Figure 7 for a photograph of SSPs (bottom) and BBs (top).

### 6.1.3. Star pickets

For TCMs being placed in stable ground or firm soil, a galvanised iron or aluminium star picket at ground level may be used. This type of mark shall only be installed in non-electrified areas.

The star picket TCM shall be referenced by at least one capped indicator picket. A metal tag with a unique identifier relating to the mark shall be attached to the indicator picket.

The location of any buried services shall be confirmed before installing this type of mark.
6.1.4. Galvanised iron or black steel pipe (GIP)

Galvanised iron or black steel pipes are a type of mark generally used in rural locations for curve pegging. Nominal size 15 medium grade pipe (21 mm external diameter x 400 mm length) installed at ground level in firm soil. In softer ground, ballast or ash banks, 800 mm pipe or aluminium star pickets should be used. These marks shall be referenced by at least one adjacent capped indicator picket, with a tag to uniquely identify the mark, and should only be installed in non-electrified areas.

The location of any buried services shall be confirmed before any of these types of marks are installed.

6.1.5. Temporary TCMs

For track upgrading and construction works in multiple track sections, temporary TCMs may be placed on the back of the rail of the adjacent track opposite the worksite. These temporary marks are normally labelled with plastic or paper plaques as shown in Figure 8.

![Figure 8 – Temporary TCM with plastic or paper plaque](image)

Depending on the particular circumstances, pegs can also be used as temporary TCMs for construction projects.

6.1.6. Other TCMs

Historical marks such as concrete monuments or cement plaques may be used as TCMs. These types of marks are more prevalent in rural locations, where tracks have not been subject to substantial mechanical upgrading works.
6.2. Placement of TCMs

The requirements for placement of TCMs in electrified and non-electrified locations are detailed in Section 6.2.1 and Section 6.2.2. In all cases, TCMs shall be assigned a unique identifier.

6.2.1. TCMs placed in electrified locations

TCMs shall be placed on stable permanent structures adjacent to the track, such as overhead wiring structures, signals, gantries, and other similar structures. At locations with restricted clearances such as platforms, tunnels and bridges, TCMs shall be installed at 10 m intervals. An additional mark shall be placed at the entrance to and exit from these structures as indicated in Figure 10. For track construction and upgrading works, TCMs shall be placed at intervals of 10 m on curves (including transitions) and 20 m on straights. TCMs may be placed at other trackside locations; however compliance with the nominal 10 m and 20 m spacing requirements shall be attempted.

In electrified locations, TCMs to define alignment, grade and kilometrage shall be placed as detailed in Table 1.

<table>
<thead>
<tr>
<th>Location</th>
<th>Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straights</td>
<td>As a minimum, at every OHWS</td>
</tr>
<tr>
<td>Circular curves and transition curves</td>
<td>As a minimum, at every OHWS</td>
</tr>
<tr>
<td>Platforms</td>
<td>Either end (100 mm in) and every 10 m</td>
</tr>
<tr>
<td>Overbridge abutments and tunnels</td>
<td>Either end (100 mm in) and every 10 m</td>
</tr>
</tbody>
</table>

6.2.2. TCMs placed in non-electrified locations

TCMs shall be placed at intervals of 10 m on transition curves and curves of radius 400 m or less, 20 m on curves of radius greater than 400 m, and at least every 500 m on straights (or more frequently if required). The frequency of TCMs on straights is normally project dependent, and requires the agreement of the Principal Surveyor of the relevant RIM. TCMs may be placed at other trackside locations; however compliance with these nominal spacing requirements shall be attempted. At locations with restricted clearances such as platforms, tunnels and bridges, TCMs shall be placed at 10 m intervals. An additional mark shall be placed at the entrance to and exit from these structures as indicated in Figure 10.

In non-electrified locations, TCMs to define alignment, grade and kilometrage shall be placed as detailed in Table 2.
Table 2 - Placement requirements for TCMs (non-electrified locations)

<table>
<thead>
<tr>
<th>Location</th>
<th>Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straights</td>
<td>At least every 500 m, or as determined by project requirements</td>
</tr>
<tr>
<td>Circular curves ≤ R 400 m and transition curves</td>
<td>Every 10 m</td>
</tr>
<tr>
<td>Circular curves &gt; R 400 m</td>
<td>Every 20 m</td>
</tr>
<tr>
<td>Platforms</td>
<td>Either end (100 mm in) and every 10 m</td>
</tr>
<tr>
<td>Overbridge abutments and tunnels</td>
<td>Either end (100 mm in) and every 10 m</td>
</tr>
</tbody>
</table>

Figure 9 – Typical location of TCMs at overhead wiring structures
TCMs indicated thus ●

Figure 10 – Typical placement locations for TCMs
6.3. **Track control and other railway infrastructure survey observations**

TCMs shall be surveyed according to the following observation requirements. Observations undertaken for surveys other than survey control or track control shall also conform to these requirements:

- for Horizontal and Vertical Angle measurements:
  - traditional survey traverse techniques shall be employed – face left / face right
  - level instruments and targets directly over SCMs
  - height of instrument and targets shall be measured to the millimetre
  - observe one full arc (face left + face right) to each TCM
  - observe one full arc (face left + face right) to each infrastructure clearance point surveyed (such as platform copings and bridge abutments)
  - single-face radiations to the track and other minor details are acceptable
  - observations may be carried out at any time during the setup

- for Distance measurements:
  - distance shall be measured to the millimetre and shall be recorded with each horizontal direction observation
  - radiations to TCMs shall be ≤ 90 m

- for Levelling:
  - the heights of all permanent TCMs shall be independently checked, either by differential levelling or trigonometrical heighting
  - track, infrastructure clearance points and other minor detail, may be levelled by trigonometrical heighting
  - the heights of critical clearance points shall be verified independently

For instrumentation requirements refer to Section 9.

6.4. **TCM survey plaques**

Each permanent TCM shall be referenced by a survey plaque containing the following information:

- track referenced
- overhead wiring structure identification number (if applicable)
- kilometrage of the TCM to 1 mm (for example, 49 km 357.345 m)
• design track centres from referenced track to adjacent track (if applicable)
• design superelevation of referenced track (mm)
• horizontal offset from TCM to the design running face of the nearest rail of the referenced track (mm)
• vertical offset from the TCM to design low (datum) rail of the referenced track (mm)

6.4.1. TCM survey plaque template

Refer to Figure 11 for an example of a TCM survey plaque template.

![TCM survey plaque template diagram]

Figure 11 – TCM survey plaque template
6.4.2. Material and lettering requirements for TCM survey plaques

The manufactured TCM survey plaque and the information engraved thereon, shall comply with the following requirements:

- Material
  - type: marine grade aluminium 5251 W34 Anodised 20 micron
  - thickness: 1.5 mm

- Lines
  - thickness: 0.6 mm

- Lettering
  - height
    - top and bottom headings: 4 mm
    - elsewhere: 3 mm
    - lowercase: = 75% uppercase
  - height thickness: 5 : 1
  - style: US Block 1L

- Engraving depth: 0.4 mm

After plaque engraving is completed, the face of the plaque shall be treated to ensure that the engraved information contrasts with the plaque surface to enhance legibility.

A standard aluminium plaque shall be attached at any location where a permanent TCM has been installed. The plaque shall be affixed adjacent to the TCM. If a TCM references more than one track, an additional plaque is required for each track referenced. Refer to Figure 12 for a photograph showing two plaques relating to one TCM referencing two separate tracks.

Figure 12 – Multiple tracks referenced from one TCM
Figure 13 and Figure 14 are photographs of TCMs with survey plaques.

Figure 13 – SSP TCM and plaque located on an overhead wiring structure

Figure 14 – BB TCM and plaque located on a platform wall

6.5. **TCM survey plaque engraving – data requirements**

Information required for the TCM plaque engraving process forms part of the documentation requirements for TCMs, as outlined in Section 8.2. Specific requirements can be obtained from the Principal Surveyor of the relevant RIM.
6.6. Installation of TCM survey plaques

TCM survey plaques may be affixed to metal structures with suitable stainless steel or aluminium pop rivets. Two rivets only are required, placed in the centre holes at the top and the bottom of the plaque. The internal surface of holes drilled for these pop rivets shall be coated with an anti-corrosive coating such as ‘Galmet’ or a similar product, prior to the placement of the rivets. In certain circumstances, the use of a suitable construction adhesive may be sufficient to ensure adequate adhesion.

TCM survey plaques shall be affixed at non-metallic locations such as rock cuttings, brick walls or concrete abutments, using a minimum of two x 5 mm diameter nylon anchors. The use of a construction adhesive may also be considered in these situations.

In all cases, the plaque shall be securely affixed to ensure its potential for removal by accident or malicious intent is minimised.

7. Survey observation check measurements

In addition to any checks that are carried out by the surveyor to ensure the veracity of the observed data, the following checks shall also be measured and recorded:

- At each Rail Survey Control Mark occupied for the purpose of observing radiations, a minimum of two other Rail SCMs shall be observed, to confirm the orientation of the observation set.

- Common radiated points - a minimum of two points, preferably permanent TCMs (or other well-defined points if no TCMs are available) shall be radiated from two adjacent Rail SCMs. These common radiated points shall be positioned approximately midway between the two Rail SCMs from which they are radiated.

All radiations to TCMs or other infrastructure clearance points, such as platform copings and bridge abutments, shall be checked by an independent means. An acceptable independent check is to compare the physically measured distance between two radiated points with the calculated distance. All checks measured shall be recorded electronically in the field.

Refer to Figure 15 for a photograph of a check measurement being undertaken between a BB and the adjacent radiated running face.
The check measurement shall be compared with the calculated join. The comparison shall have a tolerance of ≤ 5.5 mm, or as agreed with the Principal Surveyor of the relevant RIM. Any check measurement that differs from the calculated distance by more than the agreed tolerance shall be investigated, and the discrepancy corrected. A check measurement comparison report shall be prepared detailing the measured and calculated distances, and the results of any investigation.

The reduced level of all Rail SCMs and TCMs shall be checked. This check shall be achieved by the following methods:

- For Rail SCMs, a check involving forward and back digital levelling of all Rail SCMs in closed loops is required. Each Rail SCM shall be a change point for both forward and back levelling runs. Differences in the reduced levels of any Rail SCM of more than 3.5 mm shall be investigated and eliminated. The final mean adjusted reduced level of the Rail SCM thus obtained shall be assigned to the mark.

- For TCMs, a check involving one way levelling is required as a minimum. The one way levelling shall close between Rail SCMs. The check is achieved by comparing the reduced level obtained by total station observations, with the level value obtained from digital levelling. Differences in reduced levels of more than 5.5 mm shall be investigated and eliminated. The final reduced level assigned to the TCM shall give due regard to the relative accuracies of the total station and digital level observations.

Adjacent closed levelling loops shall overlap with a minimum of two common points. These common points shall include at least one Rail SCM.

None of the above conditions shall reduce the general requirements of good survey practice.

8. Documentation

All surveys shall be documented in accordance with the information detailed in this section. Any variation shall only be permitted by agreement with the Principal Surveyor of the relevant RIM.
8.1. Documentation requirements for Rail SCMs

Rail Survey Control Marks shall be documented by recording the following information into spreadsheet format:

- mark identifier (for example, BT number)
- final adjusted Easting and Northing coordinates, and AHD level
- kilometrage and offset of the mark to the running face of the nearest rail
- the track that this kilometrage refers to
- location of Rail SCM with respect to the track referenced (Up or Down side)

Plus, an additional item required is:

- a locality photo of the Rail SCM

8.2. Documentation requirements for TCMs

TCMs shall be documented by recording the following information into spreadsheet format:

- unique identifier, or TCM point number
- final adjusted Easting and Northing coordinates, and AHD level
- description of the TCM
- the track referenced
- OHWS identification if applicable, for example CK 94 + 674
- kilometrage of the TCM
- design track centres of referenced track to adjacent track (if applicable)
- design superelevation of referenced track
- horizontal offset from TCM to design running face of near rail of the referenced track
- vertical offset from TCM to design datum rail (low rail) of the referenced track

Details relating to the production of TCM survey plaques are outlined in Section 6.5.

8.3. Coding of rail survey data

Rail survey projects shall be undertaken using standard Rail Survey Codes, which can be obtained from the Principal Surveyor of the relevant RIM.
8.4. **Survey data formats**

To ensure uniformity and compatibility, all data supplied to the Principal Surveyor of the relevant RIM shall be provided electronically in GSI-16 format (unless specified otherwise).

An example of GSI-16 format for horizontal and vertical data as required for the MRA is illustrated in Figure 16 and Figure 17.

<table>
<thead>
<tr>
<th>Job Header</th>
<th>W41 = Control Code “O”</th>
<th>W42 = Job Name</th>
<th>W43 = Surveyor’s Name</th>
<th>W44 = Instrument Serial Number</th>
<th>W45 = Date</th>
<th>W46 = Software Version Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Occupied Station Header</th>
<th>W41 = Control Code “K”</th>
<th>W42 = Occupied Station Number</th>
<th>W43 = Height of Instrument</th>
<th>W44 = Occupied Station Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Control Code</th>
<th>W41 = Control Code “PP”</th>
<th>W42 = Control Description</th>
<th>W43 = Information (not required)</th>
<th>W44 = Information (not required)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measurement Block</th>
<th>W111 – Record Number or Pointer Number</th>
<th>W212 – Horizontal Circle Reading</th>
<th>W313 – Slope Distance</th>
<th>W614 – RMB–Point Constant</th>
<th>W815 – Height of Target(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

The requirements for the format of data within the electronic radiation files are as follows:

- Radiations to known control stations shall be designated by a ‘?’ recorded in the point code (W1 71) field. The ‘?’ symbol is only required in radiation observations, not in control observations.

- Offset radiations shall be designated by a ‘/’ (forward slash) followed by ‘R’ or ‘L’ (right or left) respectively, followed by the offset (in mm).
This format is illustrated in Figure 18.

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>71...+000000000000000?</td>
<td>Radiation to control station</td>
</tr>
<tr>
<td>71...+000000000000/R200</td>
<td>Radiation to Offset Prism (200mm offset to right)</td>
</tr>
<tr>
<td>71...+000000000000/R200?</td>
<td>Radiation to control station using Offset Prism</td>
</tr>
</tbody>
</table>

Figure 18 - Control station and offset data format requirements (GSI-16 format)

8.5. Deliverables

In addition to any deliverables specifically required for a survey project, the following data shall be supplied to the Principal Surveyor of the relevant RIM, within a mutually agreed timeframe. The examples shown below are as required in the MRA.

The following separate field data files shall be provided:

- An electronic file containing control observations only. The file format shall be raw GSI-16 (see Section 8.4). The file naming convention is 'jobname_control.GSI'.
- An electronic file containing observations to TCMs and observations to track and other infrastructure detail. The file format shall be raw GSI-16 (see Section 8.4). Observations to TCMs are to be recorded in a single consecutive block with a separate occupied station header. The file naming convention is 'jobname_radiations.GSI'.
- An electronic file containing digital level observations. The file format shall be raw standard DNA GSI-16. The file naming convention is 'jobname_level.GSI'.
- An electronic file containing all horizontal check measurement field data. The file format is a text file, comma separated ('from' point, 'to' point, measured distance). The file naming convention is 'jobname.K01'.
- An electronic file containing the horizontal check measurement report. The file format is a text file, comma separated ('from' point, 'to' point, measured distance, calculated distance, difference). The file naming convention is 'jobname_hor_check.txt'.
- An electronic file containing the check level report. The file format is a text file, comma separated (point number, reduced level by total station, reduced level by digital level, difference). The file naming convention is 'jobname_vert_check.txt'.
- An electronic file containing final reduced levels of all SCMs and TCMs. The file naming convention is 'jobname_final_red_level.txt'.
- A report outlining the calibration status and electrical testing of all instruments and equipment used.
9. Instruments and equipment

This section provides the requirements relating to survey instrumentation and equipment for use on the rail network and covers the following:

- type and accuracy requirements of survey equipment used for conventional traverse type surveys in the rail environment
- calibration requirements of this survey equipment

All survey instruments and equipment used for rail surveys shall meet minimum standards to ensure the integrity and accuracy of the rail survey network.

For differential levelling, only non-conducting timber or fibreglass survey staves shall be used. All staves shall be tested and tagged annually in accordance with D2013/80872 Inspection and Testing of Insulated Sticks, Tools and Equipment used for work On, Near or In the Vicinity of Exposed 1500V OHW or Equipment.

The use of metallic and invar staves is prohibited, and they shall not be used in the rail environment.

Instrument calibration requirements are common for all rail surveys.

9.1. Specifications for instruments and equipment

For the purposes of measuring survey control and track control within the rail corridor, and for the purposes of undertaking other rail infrastructure surveys, electronic total stations, digital levels and other equipment meeting the specifications detailed in Table 3 through to Table 6 shall be used.

Table 3 - Electronic total station specifications

| Horizontal / vertical angle measurement | • electronic total stations only to be used  
| • instrument least count – 1" of arc  
| • standard deviation ≤ 1.0" (ISO 17123-3)  
| • diametrical vertical circle reading and automatic tilt compensator  |
| Distance measurement | • instrument least count – 1 mm  
| • standard deviation ≤ ± 1 mm + 2 ppm  
| • temperature to be recorded to 1 °C  
| • pressure to be recorded to 1 hPa / 1 mbar  
| • atmospherics to be entered into the instrument at the time of observation |
Table 4 - Electronic digital level specifications

| Differential levelling | • electronic digital level only to be used  
|                       | • instrument accuracy ≤ 1.5 mm (standard deviation height measurement per 1 km double run levelling ISO 17123-2)  
|                       | • maximum misclosure for forward and back levelling run ≤ 12 mm * √k (where k – distance in kilometres) |

Table 5 - Associated equipment requirements

| Tools and equipment | • only non-metallic, non-telescopic survey staves shall be used for Survey Control and Track Control surveys  
|                     | • non-metallic, telescopic survey staves may be used for ‘other’ surveys  
|                     | • use of insulated and specialist track tools |

Table 6 - Rail survey equipment calibration requirements

| Total station | • calibration service within 12 months prior to date of observations  
|               | • baseline check of instrument immediately following servicing  
|               | • calibration process to provide values for additive constant, cyclic error and scale error |
| Digital level | • calibration service within 12 months prior to date of observations  
|               | • vertical collimation (two peg) test to be completed within three months prior to date of observations |
| Thermometer   | • least count of 1 °C and calibrated within six months prior to the date of observations |
| Barometer     | • least count of 1 hPa / 1 mbar calibrated within six months prior to date of observations |
| Non-metallic, non-telescopic staves, other fibreglass measuring staves, and fibreglass measuring sticks | • all survey staves and measuring sticks used are to be tested and tagged according to D2013/80872  
|               | • for telescopic staves, annual confirmation that adjoining staff sections telescopically align correctly and measure correctly across joints |
| Staff bubbles | • bubbles calibrated within six months prior to date of observations (to within 10’ of vertical) |
| Target posts and tribrachs | • bubbles and centring to be checked at least every 12 months (more frequently if usage or the work environment dictates), and immediately following servicing or repair |
9.2. Specialist rail survey equipment

Surveyors working in the rail industry have been responsible for the development of specialist tools to ensure the safety of personnel, and to enhance the accuracy and the precision of rail surveys. A description of the main tools, along with their calibration requirements is listed below in Table 7.

Table 7 - Specialist tools and calibration requirements for rail survey work

<table>
<thead>
<tr>
<th>Tool</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offset prism</td>
<td>This tool is used for the measurement of TCMs placed in vertical faces such as platform coping walls, stanchions, tunnel or overbridge walls. Bubbles and sighting telescope shall be checked daily.</td>
</tr>
<tr>
<td>Coping tool</td>
<td>This tool is used to define the edge of a platform coping, and similar detail points. It is especially useful for the definition of rounded or chamfered platform edges. Bubbles shall be checked daily.</td>
</tr>
<tr>
<td>Track bar</td>
<td>This insulated extendable bar is used to define the running face and track centreline. The fixed end shall be aligned against the low rail running face on curves, and the Down rail running face on straights. This tool is used in conjunction with the invertible ranging pole.</td>
</tr>
<tr>
<td>Invertible ranging pole</td>
<td>This ranging pole has two fixed heights, with an inverted option allowing for the provision of more accurate measurements. Bubbles shall be checked daily.</td>
</tr>
<tr>
<td>Magnetic rail prism</td>
<td>This adjustable magnetic clamp is used to define the running face of a rail. Bubbles shall be checked daily.</td>
</tr>
</tbody>
</table>

The following photographs, Figure 19 to Figure 27, are typical examples of the various tools and equipment detailed in this section.
Figure 20 - Offset prism used to measure a SSP

Figure 21 - Offset prism used to measure a BB
Figure 22 - Use of a coping tool by hand

Figure 23 - Use of a coping tool by removable pole attachment
Figure 24 - Track bar and inverted ranging pole used to measure position of track centreline

Figure 25 - Track bar and upright ranging pole used to measure position of rail running face
Figure 26 - Magnetic rail prism used to measure rail running face

Figure 27 - Magnetic rail prism used to measure temporary TCM on the back of rail
10. **Competency**

Survey activities detailed in this standard shall only be undertaken by persons with the appropriate competency for each task, with these competency requirements managed by the Principal Surveyor of the relevant RIM on behalf of TfNSW.

The Principal Surveyor is also responsible for identification and allocation of resources required to complete survey tasks.

The Principal Surveyor shall demonstrate that the people employed have the necessary knowledge, skills and experience, to competently and safely discharge their duties in providing the required railway surveying services.

Railway surveyors authorised to perform works on behalf of TfNSW are responsible for the precise location of Rail SCMs, TCMs, and other relevant infrastructure, such as platforms and bridges. They have the authority to locate infrastructure precisely using surveying techniques, and they are the only persons authorised to place, amend or relocate Rail SCMs, TCMs and associated survey plaques.

Lists of typical rail survey activities are located at Appendix A. These lists are not exhaustive, but are designed to assist in the utilisation and allocation of scarce authorised railway surveying resources.
Appendix A  Typical tasks undertaken by authorised railway surveyors

Survey work undertaken by authorised railway surveyors within the rail Danger Zone requires specific railway surveying competencies.

The following list (List 1) contains specific examples of survey tasks undertaken by railway surveyors within the Danger Zone:

- survey control (in the rail environment)
- track control
- track design (alignment and grading), track realignment
- track pulls and shifts
- track work on ballasted track, track slabs, transition slabs, direct fixation
- track reconditioning, track renewal, track maintenance
- half-block replacement
- retaining walls
- track drainage
- underline track crossing (ULX) installations, under track bores and associated monitoring
- location of buried infrastructure (both rail and external) and DSS
- platform interface issues (rebuilt, coping location, platform heights, cutbacks, platform gap reduction, level and standard access)
- underbridges, ballast top, transom top, direct fix, deck replacement
- tunnels, deflection walls, overbridges
- line side equipment, km posts, speedboards (regarding location and kinematic clearance)
- signals, dwarf signals, gantries
- overhead wiring structures, including precast footings, portal and planted post (PP) positioning
- OHWS drop verticals, contact wires, catenary wires, and C-Calc requirements
The following list (List 2) provides examples of survey work undertaken within the rail corridor (but external to the Danger Zone), where specific railway surveying competencies are NOT required:

- access roads
- power poles (clear of the danger zone)
- earthworks, sound mounds, noise walls
- embankments, cuttings, retaining walls
- buried infrastructure, DSS (clear of the danger zone)
- fencing, boundary determination
- platform works behind the yellow line
- substation works, feeders, general electrical set out work
- car parks, road works, kerb and gutter
- stations, buildings
- drainage (non-track)
- stabling yard infrastructure
- creep measurements

Due to safety concerns for survey personnel and equipment, it may be necessary to plan for a track possession to undertake some of these survey projects.