TRANSPORT

Digital Engineering Survey Requirements Guide

IP Integrated Management System

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NSW GOVERNMENT

Preface

Transport for New South Wales (TfNSW) is developing the Digital Engineering (DE) Framework to facilitate time, cost and quality improvements to the way that projects are planned, designed, constructed, operated and maintained throughout their life cycle.

DE processes included in the DE Framework provide TfNSW with an approach that creates digital information in an accessible format that will support and enhance stakeholder engagement, decision-making, asset management, capability and capacity planning.

Implementing and adhering to this vision will enable individuals, who are responsible for the delivery and management of TfNSW's assets, to make more informed decisions.

This document should be read in conjunction with all related DE Framework documentation. Any application of the DE Framework, or any of its parts, must be considered in a project-specific context. Adoption of the DE Framework should be undertaken in consultation with the DE Team to ensure best appropriate practice. Contact the DE Team via email at **Digital.Engineering@transport.nsw.gov.au.**

Engagement with the Digital Engineering Team

The first point of contact for the project team (using this guide for a TfNSW project) is your project TfNSW DE Manager.

For information on help and support, see Section 6.

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1 General

1.1 Context and purpose

The purpose of this document is to establish a common approach for the development of requirements for the procurement and delivery of spatial data (digital surveys) that are conducted to support the planning, design, and delivery of Transport for NSW (TfNSW) digital engineering enabled projects. These requirements are also valid for surveys that are conducted during the Operate/Maintain and Renew/Dispose phases of the asset life cycle.

The guide has been developed to interface with the TfNSW Digital Engineering (DE) Framework but can also be used along with other policies and standards for projects that do not use the DE Framework.

1.2 Scope and application

This document is applicable to all TfNSW project teams, or other entities interested in procuring surveys, to better support planning, design or construction of digital engineering enabled projects, or to gain a better understanding of the current state of existing assets. This may also include capturing environments or assets of ecological or historical significance.

This guide provides guidance on the elements to include as part of a works or services brief to procure the appropriate survey outcomes. The guide also provides points of contact within TfNSW for further information, standards, specifications and expertise in the surveying discipline. The core elements covered in the guide include:

- **scope requirements**, which cover defining the scope of work elements such as identifying planned and potential survey uses, type of survey required, scope of the actual survey target area, whether a 3D model is to be developed from the survey data, provision of any existing information, and the expected timeframes for conduct of the survey
- **management requirements**, which include defining requirements on collaboration and survey management plans
- **technical requirements**, which provide information on technical standards the survey is to comply with survey accuracy and level of detail (for example, TfNSW QA Specifications), horizontal and vertical datums to be adopted (for example, MGA2020 and AHD), survey control network, metadata requirement and classification of survey and modelled data
- **deliverable requirements**, which provide guidance on the expected survey outcomes and project reporting deliverables.

Project teams are expected to modify or supplement the information provided in this document to meet project specific needs. It is critical to coordinate the development of survey requirements, as well as the delivery of survey projects, with the relevant domain expertise such as the Sydney Trains Principal Surveyor or TfNSW Director Survey Services.

Note that this document does not provide any guidance on whether a survey should be applied to a specific project or not. This topic may be covered in future updates of this document.

1.3 Terms and definitions

The terms and abbreviations used in this document have the meaning/definitions provided in DMS-SD-123 – *DE Terms and Definitions*.

The following terms and definitions are specific to this document:

Term	Definition
ASTM	ASTM International – with ASTM being the American Society for Testing and Materials
DEM	Digital Elevation Model
DSM	Digital Surface Model
DTM	Digital Terrain Model
GDA	Geocentric Datum of Australia
GLONASS	Russian 'GLObal NAvigation Satellite System'
GNSS	Global Navigation Satellite System (incl. GPS, GLONASS, and so on)
LiDAR	Light Detection and Ranging
MGA	Map Grid of Australia
RGB	Red, Green Blue colour definition
SCIMS	Survey Control Information Management System
Survey Contractor	An organisation outside of Transport for NSW offering and delivering surveying services.
TIN	Triangulated Irregular Network

2 Process

Surveys are typically conducted as separate activities (generally under separate contracts) within a project's overall delivery process, unless the survey is conducted by a subcontractor, in which case TfNSW is not directly responsible for the requirements and management of the survey outcomes.

Figure 1 shows indicative alignment between the types of surveys and the different phases of the TfNSW asset life cycle.

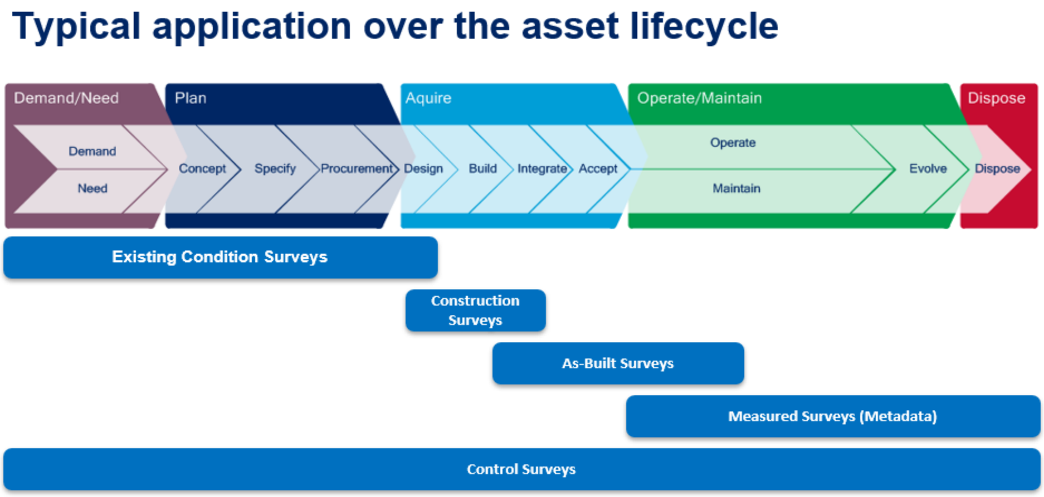

Figure 1 – Types of surveys across the asset life cycle

The different survey types fulfil different functions across the phases of the asset life cycle:

- **Existing condition surveys** – surveys that capture existing conditions, with the aim to provide input into the evaluation of, design, and construction of projects.
- **Construction surveys** – surveys which set out the reference points and markers that will guide the construction of new structures on a construction site.
- **As-built surveys** – surveys which accurately determine the position and levels of recently constructed elements of a project (also referred to as works as executed) to validate quality and to ensure compliance with design standards.
- **Measured surveys** – surveys to document existing assets, capturing both graphical and non-graphical information, such as accurate measured floor plans and attributes.
- **Control surveys** – surveys to establish stable reference points with accurate horizontal and vertical coordinates (control networks) usually derived from the NSW state survey control network. A control survey provides a reference framework for all of the abovementioned types of surveys.

See Section 3.2.4 for a more detailed description of the types of surveys.

This guide is linked to the following frameworks, standards, processes and procedures:

- Infrastructure and Place (IP) Digital Engineering (DE) Framework, including the IP DMS-ST-202 – *DE Standard, Part 1: Concepts and Principles*, and DMS-ST-207 – *DE Standard, Part 2: Requirements*

- IP Commercial Management Framework, including the DMS-PR-031 – *CPS Procurement: Procurement Procedures*
- TfNSW QA Specification G73 – *Detail Survey* and TfNSW QA Specification G71 – *Construction Surveys*
- T HR TR 13000 ST – *Railway Surveying.*

From a surveying perspective the process and outcomes outlined in this document also fall under the current versions of the following New South Wales Acts and regulations:

- *Surveying and Spatial Information Act 2002* (NSW)
- NSW Surveying and Spatial Information Regulation 2017 (this is the current version at time of document issue)
- NSW Surveyor-General's Directions (NSW).

3 Digital engineering survey requirements

3.1 Overview

Surveyors use a broad range of technologies to assist with the collection, analysis and delivery of spatial information about the environment, existing infrastructure or assets. The information generated by surveys provides benefits during project development and delivery and is also useful during the operation and maintenance of existing or new assets.

The typical survey project process to be followed by TfNSW and the Survey Contractor is outlined in Figure 2.

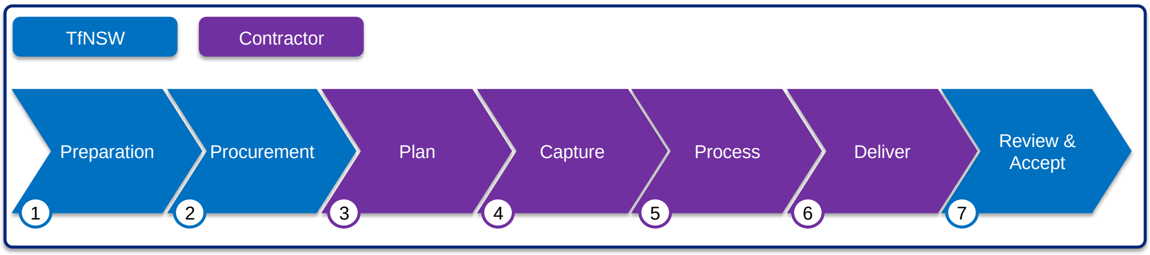

Figure 2 – Phases of a typical survey project

The process includes the following key activities:

1. **Preparation**, which involves TfNSW identifying the survey requirements using the information provided in this document, and other TfNSW survey policies and standard documents depending on the project.

2. **Procurement**, which involves development of a Survey Brief to be issued to the market for responses, the assessment of the market submissions, and selection of a suitable Survey Contractor.
3. **Plan**, which is predominantly a contractor activity that involves the TfNSW project team agreeing on the key Contractor activities required to survey the relevant target area(s) and assets. This activity will provide the inputs required for the Contractor to develop and submit a Survey Management Plan to be approved by the TfNSW project team.
4. **Capture**, which focuses on the Survey Contractor collecting the survey data within the timeframes approved by TfNSW.
5. **Process**, which is the period of the engagement when the Survey Contractor will be processing the data capture. If the scope of the survey includes the generation of 3D survey models (Scan-to-BIM) this will also occur during this phase of the survey project.
6. **Deliver**, which involves the handover of the deliverables, and should include the Survey Contractor demonstrating (explaining) the deliverables provided. Deliverables will generally include the raw survey data, the processed survey outputs, as well as the relevant project documentation, for example, quality statements.
7. **Review and accept**, which involves the TfNSW project team reviewing and accepting the survey deliverables, enabling the survey information to be used to conduct project planning, assess project progress, or confirm whether construction has been done in accordance with the design.

This document provides a standardised set of survey requirements to assist TfNSW projects to procure appropriate survey outcomes, including:

- scope requirements (see Section 3.2)
- management requirements (see Section 3.3)
- technical requirements (see Section 3.4)
- deliverable requirements (see Section 3.5).

Note that the guidance provided in this document is not an exhaustive set of requirements and must be tailored to meet project specific requirements. Deliverables must also comply with domain specific survey requirements such as TfNSW QA Specification G73 –*Detail Survey*, which must be incorporated into the relevant brief.

The project requirements for a survey are generally incorporated into a services brief based on the standard TfNSW Infrastructure and Place services contract.

3.2 Scope requirements

3.2.1 Introduction

Scope requirements define two main elements in relation to the survey:

- The larger overall TfNSW program or project that the survey relates to, and which the survey outcomes must support.
- The scope of the actual survey itself including the type of survey, the survey target area, whether a 3D model is required, any existing information that may be needed or incorporated for the survey, and the timeframes for the survey.

The following sections provide a description of the types of information that a project team should include when defining the survey scope requirements.

3.2.2 Project overview

Provide a general overview of the project, highlighting specific information on:

- the objectives of the program/project, including what the survey data will be used for, and who will be using the survey data, and so on.
- a high-level overview of the project scope, including an outline of the geographical area impacted by the project
- whether the project is adopting the TfNSW DE Framework for project delivery. If the project is a DE Framework project there are various considerations to be included, including information on concepts, principles and requirements (for example, collaboration, sharing of data, preferred data and file formats, and so on) as outlined in the DMS-ST-202 – *DE Standard, Part 1: Concepts and Principles* and DMS-ST-207 – *DE Standard, Part 2: Requirements*
- the project phase the survey relates to, including what the survey will be used for as part of the overall project.

The majority of this scope information should be available from the project's Project Management Plan (PMP).

3.2.3 Survey objectives

Define the objectives of the survey, including the planned and potential uses of the outputs from the survey. Survey objectives should include an outline of the measurements to be taken to address the uses of the survey.

Uses of the survey, including survey data and outcomes, are to be described to help both TfNSW and contractors understand which type of survey, data formats, and standards will be the most appropriate.

Potential uses will impact on the survey requirements and assist contractors to identify key aspects in their proposals. Also note that defining future uses, including later project and maintenance phases, may impact on the data capture process during surveys such as laser scanning and on the level of data processing required.

To define survey objectives, it may be useful to answer the following questions:

- Who will use the survey data, that is, who are the project's survey stakeholders?
- How will the various project stakeholders use the survey data?
- What survey data is required to support the intended uses of the data, for example, what data is required to support informed decisions on the project?
- What level of detail and accuracy is required to support appropriate use of the data to support decision-making (including possible future decisions)?
- When is the data required, that is, when does the survey need to be completed by?
- What survey related data does the project team already have access to, including internal and external to TfNSW?
- Does the existing data support the needs and requirements of the project team, that is, can any existing survey information be re-used, and what updates and verifications are required to do so?
- What are the gaps, if any, in the survey data?
- How will the data be received, stored and managed by the project team/TfNSW?

3.2.4 Type of survey

Define the type of survey required for the project, which may include a combination of the types of surveys outlined below to achieve the desired outcomes:

- **Existing condition surveys** – surveys that capture existing conditions, with the aim to provide input into the evaluation of, design, and construction of projects. Types of surveys to capture existing conditions include:
  - **Detail surveys**, which capture both natural and man-made structures. Natural features may include site topography, spot heights, trees, gullies, high and low points. Man-made structures may include buildings, walls, roads, paths, and kerb and gutter, while below ground these structures may include utility services such as water and sewer mains, drainage, power, and gas mains.

  - **Cadastral surveys**, which establish, or re-establish, the boundaries of an area of land using a legal definition as described by the cadastre.
  - **Utilities surveys**, which refer to the location, positioning and identification of utility assets both above the ground and subsurface.
- **Construction surveys** – surveys which set out the reference points and markers that guide the construction of new structures on a construction site.
- **As-built surveys** – surveys which document the location, dimension, and type of recently constructed elements of a project. As-built surveys are typically used as part of completion evaluation to establish a record of the constructed assets and to support project milestone payments. Two main subsets of as-built surveys, also known as works as executed (WAE) surveys, are:
  - **Construction verification**, which is recording the constructed assets in order to make a comparison with the design. An accurate record helps to reduce risk and identify mistakes that cannot be rectified once construction has been completed.
  - **Monitoring surveys**, which are a series of high precision surveying (carried out over a period of time) of infrastructures or features in order to determine the amount and/or direction of movement or deflection.
- **Measured surveys** – surveys to document existing assets, capturing both graphical and non-graphical information. This type of survey is generally used to document an asset that does not have the relevant asset documentation or plans available, which is quite often the case with heritage buildings. Measured surveys can also be used to do comparisons of asset condition over time.
- **Control surveys** – surveys to establish stable reference points with accurate horizontal and vertical coordinates (control networks) usually derived from the NSW state survey control network. A control survey provides a reference framework for all of the abovementioned types of surveys.

As stated, the scope of a survey project does not need to be confined to one type of survey. The project may require multiple types of surveys to be conducted. For example, an existing condition survey may require all three sub-types of surveys to provide a comprehensive view of the existing conditions of the survey target area. In addition to the main survey, TfNSW always requires a control survey to be conducted at the same time to confirm the tolerance and accuracy in the survey area.

It is generally not required for the project team to specify the method of survey in the services brief, as the method of surveying will typically be defined by the Survey Contractor. However, where the method is a key requirement, it should be defined in the services brief. The method of surveying is based on how data is collected, including:

- **Terrestrial data capture**, which is static, ground-based data collection mainly using robotic total station, real-time kinematic (RTK) GNSS, or laser scanning technology.
- **Mobile data capture**, which can be broken down into:
  - **ground-based surveys**, which range from handheld or backpack laser scanning devices to vehicle mounted laser scanners (for example, on a car or train)
  - **aerial surveys (photogrammetry),** which cover both manned (that is, planes) and unmanned (that is, unmanned aerial vehicle (UAV)/drones) aerial platforms.
- **Satellite data capture**, which provides imagery and remote sensing data captured by satellites and forms the basis for applications like Google Earth.
- **Subsurface survey**, which provides subsurface information that is usually derived from electromagnetic locators, ground penetrating radars (GPR) and potholes information.

In addition to the method of surveying, it is worthwhile for projects to understand the surveying technology or sources of surveying information that is available. Appendix A provides an overview of current surveying technology.

3.2.5 Survey scope

The survey scope is to provide specific information on the geographical extent of the survey required for the project, including details on the following:

- The target area, infrastructure, facilities and services to be surveyed, including:
  - description of the survey area with reference to detailed maps and diagram(s)
  - identification of zones of interest within the survey area that may require higher resolution or have specific survey requirements, for example, rail track.
- Any specific areas or assets that are to be excluded from the survey
- Assumptions and limitations for the survey, including identifying inaccessible areas that may impact on the ability of the Survey Contractor to provide a full 3D model (traditional survey measurements typically require line of sight)

- Security constraints, including security issues related to the physical sites that are being surveyed, as well as any security issues with the survey data acquired during the survey.

3.2.6 3D model development

If the survey is to inform the design aspects of the project, it is critical to define the requirements for BIM model development. Benefits of a 3D model include that it allows for quicker turnaround as the modelling of the new design can be based on the model generated from the laser scan data. A scan-to-BIM 3D model also provides significantly more information than standard 2D as-built drawings (for example, PDF).

It is also easy to extract features like planes, surfaces, lines and edges, making it easier to interface the new design with the existing structures.

The intended use of the 3D scan-to-BIM model needs to be clearly defined, including key parameters such as the:

- general level of development, for example, which parts or elements of the survey area or physical aspects needs to be modelled
- level of detail (LoD) and level of information (LoI) of the 3D model components as defined in the DMS-ST-207 – *DE Standard, Part 2: Requirements*
- accuracy of the 3D model in relation to the registered point cloud, including modelling tolerances.

Defining the 3D modelling requirements and parameters provide guidance to the Survey Contractor to ensure that they plan for optimal scan coverage (overlap) and scan density required for the survey, including allowing for future data extraction requirements where possible. This information also informs the development of the Survey Management Plan to minimise obstructions of features or significant shadowing within the scan data. This ensures a continuous and unified dataset for the area while minimising time lost and cost of capturing data that is not needed.

The resulting registered point cloud can also be used for context in relation to features that are not modelled, but which provide an overview of the site or asset context.

Additional information on requirements for these parameters is provided in Section 3.5.2.6.

3.2.7 Existing information

Define the contents and source (internal or external) of any existing information to be provided to the Contractor to support the survey, as outlined in Table 1. Note that in general the Contractor will be expected to acquire information that is available from external sources, such as utility providers, NSW Land Registry Services, and so on.

Table 1 – Examples of existing information to be provided

Information	Format	Source
Maps – digital	DWG/DGN	Project team
Maps – hard copy	PDF	Project team
Before You Dig Australia (BYDA) – utility information	Various	Project team/Before You Dig Australia (BYDA)

Existing survey data and information (point cloud or other formats) are to be reviewed for relevancy to the project. Where existing data is to be utilised as part of the survey project, this data is to be classified in accordance with the DMS-ST-207 – *DE Standard, Part 2: Requirements*, if not already compliant. The information may include existing 2D CAD drawings, plans in PDF, or existing services information.

It is important to verify the accuracy of the information provided, as this information may be used during the planning of the survey, or aid in development of the scan-to-BIM 3D model. Verification of existing data will need to take place prior to use, including by the Survey Contractor or related technical SMEs.

3.2.8 Survey timeframe

Clearly define the expected start and delivery dates for the survey. The expected timeframes are usually driven by the overall program or project that the survey relates to. Even though laser scanning has largely automated the data capture process, the outcomes required impact on the level of data processing required. Data processing (Step 5 in the process) is typically where the majority of effort is expended for surveys (see Figure 3) and must be taken into consideration when specifying survey timeframes.

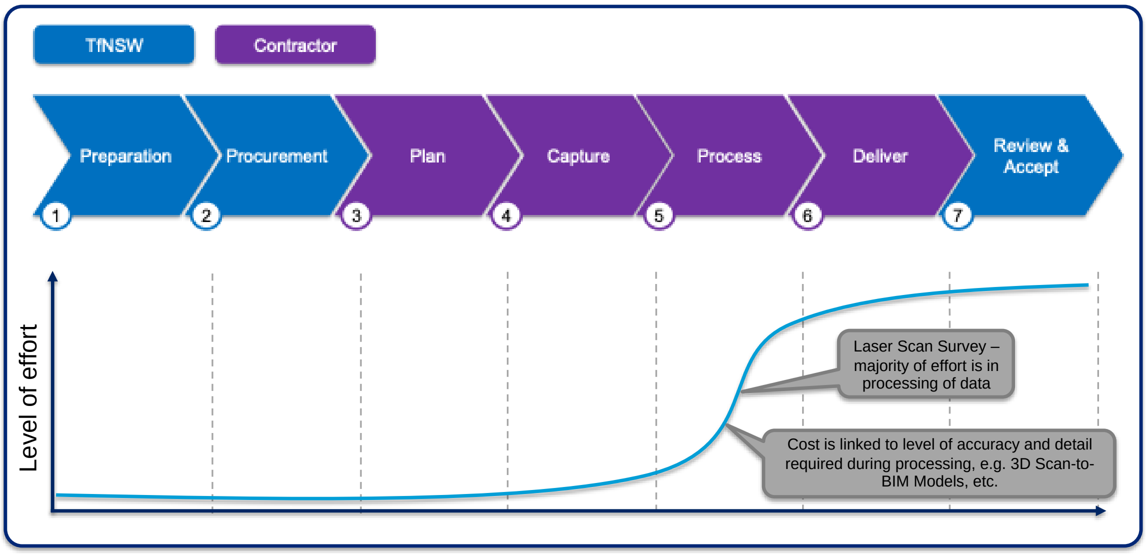

Figure 3 – Level of effort

If available, key milestone dates should be defined for:

- expected project start date
- data capture dates and constraints, that is, identify specific windows of opportunity to conduct surveys, for example, time restrictions for access to conduct surveys within the rail corridor
- survey deliverables due date. When determining the due date keep in mind that survey data processing can be time consuming.

An interesting impact of windows of opportunity for survey data capture is that if data capture for a 3D laser scanning survey can only be conducted at night, there is no point in asking for RGB values as part of the scan and it would be better to specify a black and white (or intensity) survey. The laser scanner will not be able to capture colours accurately at night.

Other scope information may be listed in the project's brief (services or works) and must be aligned with the survey technical requirements outlined in Section 3.4.

3.3 Management requirements

3.3.1 Introduction

Management requirements typically define how the Survey Contractor is to work with TfNSW with the aim to understand the Contractor's proposed approach, governance arrangements, general project management, and specific survey management activities.

The standard IP Services and Works Brief TfNSW Standard Requirements (TSR) include the development of a Contract Management Plan (CMP), which includes a range of management requirements. However, the CMP does not necessarily identify the unique survey management requirements that are key to successful delivery of surveys.

Due to the complexities involved in many TfNSW projects, for example, accuracy of cadastral boundaries, asset ownership across multiple agencies or entities, and so on, it is important for the Survey Contractor to work closely with TfNSW to minimise the realisation of risks during the conduct of surveys.

The key management requirements to be considered for a survey project and to be included in the services brief, are outlined in the following sections 3.3.2 and 3.3.3.

3.3.2 Collaboration

Survey Contractors are to provide a high performance and highly skilled team, which will work collaboratively with TfNSW, other contractors and key stakeholders.

Collaboration can be established through different mechanisms, which should be discussed and agreed at a pre-planning survey meeting. This meeting should be held immediately after contract award.

The different ways of ensuring collaboration throughout the engagement include:

- Holding a pre-planning meeting to confirm the survey requirements, clearly identifying lines of communication for all stakeholders, and identifying all milestone deliverables. Additional items to be discussed and agreed at the meeting include the measurement objectives, security or access constraints, mobilisation strategy (to be confirmed in the Survey Management Plan), and the details about the survey control network.
- The delivery and review of sample survey data at the earliest opportunity, including making available mechanisms for stakeholders to access the survey data (for example, online access to point cloud data or 3D models, and so on).
- Holding regular progress meetings and providing communications on progress throughout the life of the survey project.
- Holding a post-delivery review to ensure that the TfNSW requirements have been met.

It is critical for TfNSW to continue to expand the corporate knowledge of the Transport network, including identifying and accessing survey data collected by individual projects. Ensuring TfNSW receives re-useable data and information from surveys is a key enabler for this to be realised.

3.3.3 Survey Management Plan

The Survey Contractor is required to develop a Survey Management Plan (SMP), which must be submitted and approved by TfNSW prior to the start of the actual surveying activities, that is, prior to commencement of work on site. The SMP may form part of the Contract Management Plan (CMP) or be developed as a sub-plan to the CMP. The requirements for a CMP are defined as part of the standard TfNSW services agreement.

In addition to the standard plan requirements, the SMP must also cover quality management requirements such as quality assurance and quality control. The quality management section, at minimum, needs to provide information on the items listed under Section 3.4.

3.4 Technical requirements

3.4.1 Introduction

The technical requirements of the survey must define the requirements related to:

- relevant Acts, regulations and standards that apply to the survey
- Survey Contractor's surveying capability
- survey accuracy (absolute and relative), including validation
- coordinate system and height datum (typically GDA2020 and AHD71) to be used for the survey
- establishment and use of a survey control network and reports
- accurate geometry by coordinates
- classification of scanned and modelled data
- metadata statement (IP-0043-GD01 – *Survey Schema and Specification*).

These items provide a baseline for technical requirements to be included in the survey brief, however depending on specific project requirements additional technical items should be added where required.

3.4.2 Acts, regulations and standards

As outlined in the DMS-ST-207 – *DE Standard, Part 2: Requirements*, it is important that surveys are conducted in accordance with the relevant Acts, regulations and standards. Table 2 outlines the general regulatory requirements relevant to NSW. Projects must nominate the relevant Acts, regulations, standards and specifications relevant to the survey.

Table 2 – Acts, regulations, standards and specifications

Type	Description
Acts and regulations	Relevant Acts and regulations for NSW including: • *Surveying and Spatial Information Act 2002* (NSW) • Surveying and Spatial Information Regulation 2017 (NSW) – use current version, this version is current at time of document issue • Surveyor-General's Directions (NSW) (including Direction No. 11 which covers the preservation of survey infrastructure) • *Conveyancing Act 1919* (NSW) and NSW conveyancing regulations • Registrar General's Guidelines (NSW Land Registry Services).
Standards	Key standards related to surveying for TfNSW, including: • T HR TR ST 13000 – *Railway Surveying* • AS 5488.1, *Classification of Subsurface Utility Information (SUI), Part 1: Subsurface utility information* • AS 5488.2, *Classification of subsurface utility information (SUI), Part 2: Subsurface utility engineering (SUE)* • Intergovernmental Committee on Surveying and Mapping (ICSM) *Australian Survey Control Network (SP1)*, Version 1.7 • ICSM *Australian Map and Spatial Data Horizontal Accuracy Standard,* 2009 • ASTM E2807-11(2019) – *Standard Specification for 3D Imaging Data Exchange*, Version 1.0.
Specifications	Specifications to be used to inform survey requirements, including: • GDA94 Technical Manual • GDA2020 Technical Manual • TfNSW QA Specification G71 – *Construction Surveys* • TfNSW QA Specification G73 – *Detail Survey* • US Institute of Building Documentation *USIBD Level of Accuracy (LOA) Specification Guide.*

Additional regulatory requirements and guidance may be specified based on the location, type or method of survey to be conducted.

3.4.3 Contractor's surveying capability

The Survey Contractor is responsible for providing the appropriate resourcing and support for the conduct of the survey, which is a standard requirement in the IP procurement templates.

The standard TfNSW capability requirements specify that Contractors are to provide skilled and capable personnel to perform the works required. However, for survey work it is important that the Survey Contractor provides qualified surveyors to direct and be responsible for all survey work, where a qualified surveyor is a person who holds a Diploma in Surveying, or recognised equivalent, from a recognised tertiary institution and has at least five subsequent years of practical experience in surveying satisfactory to TfNSW.

Requesting the following information will assist TfNSW project teams to assess suitability of Survey Contractors:

- Experience and qualifications of key personnel which, for projects in NSW, should include a qualified surveyor as part of the proposed surveying team.
- Management systems to support survey projects.
- Survey equipment for acquiring, processing and delivery of survey outcomes, including information on calibration of survey equipment.
- Collaboration and data sharing practices to be employed on the survey project (for example, information exchange standards, including using a common data environment).

3.4.4 Survey accuracy

TfNSW project teams have an expectation that the survey results are accurate enough to meet the specific requirements and tolerances of the project whether that is for concept, detail design or construction verification. In defining accuracy requirements for the survey deliverables, the Survey Contractor can assess whether they are able to provide survey results to the accuracy required. It is important to select a fit-for-purpose survey method depending on the scope of work and accuracy required. If the Survey Contractor uses instruments and methods delivering an accuracy higher than the required level this may potentially lead to unnecessary effort and cost for the project.

A number of factors affect the accuracy of surveys and the associated point cloud data, including:

- survey instrument capabilities and calibration
- survey quality control measures
- accuracy of the survey control network (report, including all the benchmarks used in the projects, calculations and residuals prepared by contractors and confirmed by the technical SME)
- daily field checks reports
- surface reflectivity
- the angle between scanner and target (angle of incidence)
- the range to the target object, that is, the laser beam diverges with distance, so measurements further from the instrument are less accurate.

Note that the last three points listed above only relate to laser scanning and are not applicable to total station and GNSS technologies.

The planned and future uses of the survey deliverables inform the survey functional performance requirements that the Survey Contractor will be using to define field data acquisition equipment, scanning position(s), and acquisition times, and so on. Some factors that impact on increased survey accuracy for laser scanning surveys are listed in Table 3.

Table 3 – Factors impacting survey accuracy

Accuracy level	Factors
Higher accuracy	• Instrument accuracy • Number of scanning locations and percentage overlap between scans • Number of control points • Number of quality control measures.
Lower accuracy	• Distance to target/target area • Surface reflectivity • Scanning speed.

To define the survey accuracy requirements requires a phased approach, with the final choice depending on the intended and future use of the survey outcomes. For example:

- For surveys to support rail track design work (survey control and track control networks) in the rail corridor – use the guidance provided in T HR TR ST 13000 – *Railway Surveying* standard to define the required survey accuracy.
- For surveys that support the design of roadways and bridges – use the guidance provided in TfNSW QA Specification G73 – *Detail Survey*, and *CADD Manual* Section 3.2 Surveying on spatial data tolerances, to define the survey accuracy for the relevant survey areas.
- For all other surveys or remaining survey areas not covered sufficiently by the accuracy guidance provided by the documents referenced above, use the guidance provided in Table 4 to define the accuracy levels for the survey.

The most appropriate survey accuracy band in Table 4 must be used to define what accuracies should be achieved from the survey. Note that the accuracies listed are the accuracy of individual points relative to the survey control points.

TfNSW projects need to identify an accuracy band that meets their requirements for accuracy and confidence level. For example, if a project needs 10mm plan accuracy at 95% confidence level the project should select band C accuracies for the survey.

If unsure about which accuracy to use consult with the DE Team or domain specific surveyors for support.

Table 4 – Survey accuracy guidance (adapted from: Royal Institution of Chartered Surveyors (RICS) (2014), *Measured surveys of land, buildings and utilities*, 3rd edition)

Horizontal accuracy (X,Y)			Vertical accuracy (Z)					
Band	**1 sigma (68% confidence level)**	**2 sigma (95% confidence level)**	**Band**	**Accuracy hard detail (1 sigma)**	**Accuracy soft detail (1 sigma)**	**Example survey types/uses**	**Indicative legacy plot scale output required to achieve accuracy band**	**Minimum size of feature shown true to scale (not symbolised)**
A	+/- 2mm	+/- 4mm	A	+/- 2mm	N/A	Monitoring, high accuracy engineering setting out, and fabrication surveys.	1:5	4mm
B	+/- 4mm	+/- 8mm	B	+/- 4mm	N/A	Monitoring, high accuracy engineering and measured building surveys and setting out.	1:10	5mm
C	+/- 5mm	+/- 10mm	C	+/- 5mm	N/A	Engineering surveying and setting out, high accuracy measured building surveying, heritage recording.	1:20	10mm
D	+/- 10mm	+/- 20mm	D	+/- 10mm	+/- 25mm	Engineering surveying and setting out, measured building surveys, high accuracy topographic surveys, determined boundaries, area registration.	1:50	20mm
E	+/- 25mm	+/- 50mm	E	+/- 10mm	+/- 50mm	Measured building surveys, topographic surveys, low accuracy setting out, net area surveys, valuation surveys, area registration, utility verification (AS 5488 Quality Level-A).	1:100	50mm
F	+/- 50mm	+/- 100mm	F	+/- 50mm	+/- 100mm	Low accuracy measured building surveys, topographic surveys, high accuracy utility tracing, gross area surveys.	1:200	100mm

Horizontal accuracy (X,Y)			Vertical accuracy (Z)					
Band	**1 sigma (68% confidence level)**	**2 sigma (95% confidence level)**	**Band**	**Accuracy hard detail (1 sigma)**	**Accuracy soft detail (1 sigma)**	**Example survey types/uses**	**Indicative legacy plot scale output required to achieve accuracy band**	**Minimum size of feature shown true to scale (not symbolised)**
G	+/- 100mm	+/- 200mm	G	+/- 50mm	+/- 100mm	Topographic surveys, low accuracy measured building surveys, utility tracing surveys, boundary mapping, high accuracy geotechnical, detection (AS 5488 Quality Level B).	1:500	200mm
H	+/- 250mm	+/- 500mm	H	+/- 125mm	+/- 250mm	Low accuracy topographic surveys, national urban area mapping, geotechnical mapping, tree surveys, asset mapping, utility survey – detection (AS 5488 Quality Level C).	1:1000	500mm
I	+/- 500mm	+/- 1000mm	I	+/- 500mm	+/- 1000mm	Low accuracy topographic mapping, national non-urban mapping, general boundary mapping.	1:2500	1000mm
J	+/- 1000mm	+/- 2000mm	J	+/- 1000mm	+/- 2000mm	Low accuracy route/corridor planning surveys, large area GIS asset mapping.	1:5000	2000mm

3.4.5 Validation

To validate the accuracy of the data collection process it is recommended that an independent measurement validation step is adopted by projects.

The validation step can occur during or immediately following data capture. These data validation measurements can then be used to validate the quality of the captured dataset during processing. Validation measurements must be captured using a survey independent method, for example when doing a laser scan survey use a total station for validation purposes. All checked data needs to be saved and documented for further reference.

Validation measurement should include horizontal, vertical, and diagonal measurements to validate the original data set. This will improve the level of confidence in the captured data set, for example ensuring the accuracy of a point cloud along a section of track. The survey control network report needs to be attached with the daily checks to use in survey data validation procedure. For further information regarding survey data quality assurance please consult with TfNSW technical SMEs.

Further guidance on survey validation is provided in Section 3.5.2.9.

3.4.6 Coordinate system

All BIM, CAD, GIS and digital survey models having a relationship with the mapping grid and relative levels must be developed maintaining the relationship between the CAD coordinate system, the nominated map coordinate system and Australian Height Datum (AHD).

The datum and projection information outlined in Table 5 must be agreed for the project.

Table 5 – Datum and projection

Item	Recommended specification
Horizontal datum	Geocentric Datum of Australia 2020 (GDA2020)
Vertical datum	Australian Height Datum (AHD71)
Map projection	Map Grid of Australia (MGA)

The geodetic datum that TfNSW is now using is the Geocentric Datum of Australia 2020 (GDA2020). Projects need to consider the impact of the implementation and adoption of GDA2020 versus GDA94 and older datums. See SVTD 2019/01 – *Technical Direction – Implementation of revised Geocentric Datum of Australia (GDA) GDA 2020* for further guidance on the adoption of GDA2020 by TfNSW, including how to deal with previous datums such as GDA94.

When planning surveys, project teams need to be aware of the impact of using either or both GDA94 and GDA2020, and clearly specify the coordinate system and datum to be adopted for any survey related activities. Note that some areas of the NSW rail network are still defined by the Integrated Survey Grid (ISG) coordinate system, which was introduced in NSW to minimise projection corrections for cadastral surveys. In accordance with the TfNSW standard T HR TR 13000 ST – *Railway Surveying* work undertaken in these areas will need to be compatible with the existing coordinate system, unless otherwise agreed with the relevant TfNSW representative.

If data has been transformed the metadata statement should detail which transformation model has been used (for example, GDA94 to GDA2020 via 7Parameter, NTv2 CON or NTv2 CPD).

For vertical GNSS data related to the Australian Height Datum the metadata statement must also detail the version of AUSGeoid2020 used to derive height information.

A GDA2020 logo as defined by the ICMS must be used on all drawings that have adopted the GDA2020 datum.

All project data used for design will undergo the quality assurance (QA) process in this section to provide assurance of project coordinates and where data cannot be provided in GDA2020, the data will be reprojected to GDA2020.

It is recommended that where possible, reference points should be marked at extents of the project on all datasets, and below workflow to be implemented:

8. Determine the coordinates of reference points and original points at extents of the project.
9. Compare coordinates to the values in control point validation table.
10. Ensure the values match those specified for GDA2020.
11. If coordinates do not match, then the transformation to GDA2020 is unsuccessful.
12. Check the raw data and transformation to ensure that you have the correct information.

For information on coordinate conversions, refer to **Transformation methods** on the NSW Government’s Spatial Services website.

The Australian Height Datum (AHD71) was adopted by the National Mapping Council as the datum to which all vertical control for mapping is to be referred.

The map coordinate projection system for TfNSW is the Map Grid Australia (MGA) Zones for NSW, which are zones 54, 55 and 56 from west to east across the state.

3.4.7 Project control network

An important aspect of the survey data collection process is determining a control network to which all the other field data can be referenced. Control networks also increase the level of confidence for subsequent data queries, quality assessments, and inferred measurements from the data set, and are an essential part of the planning process.

A survey plan showing the survey control network must be established showing the following:

- underlying cadastre
- location and type of control point, including date placed/located
- adjustment method
- origin of survey control
- project scale factor.

The control network also helps to align the survey data to the wider map networks (coordinate systems) called georeferencing.

The survey plan, showing the control network for a project, must be updated as the project progresses and must be made available to all project participants, including subcontractors where necessary. The control network set-up and maintenance procedures need to be aligned with Surveyor-General's Direction No. 11 and the Surveying and Spatial Information Regulation 2017.

3.4.8 Accurate geometry by coordinates

All plans and profiles that have a relationship with the projection, or height levels, must be modelled maintaining the relationship between the software coordinate system and the MGA map coordinate system and the AHD height datum.

All locations of structures, grid lines, contract boundaries, and so on, must be defined by MGA map coordinates. A chainage (kilometrage) system must be used only to locate the positions of match lines, services crossings and for certain other contracts such as system-wide E&M (electrical and mechanical) and track work installation contracts.

3.4.9 Classification

The classification of survey data is linked to the intended use as well as the primary domain (whether rail, roads, maritime, and so on, assets) the project is conducted in. Appropriate classification of surveyed and 3D modelled data (scan-to-3D models) is key to the ongoing effective use of the survey deliverables.

Laser scan survey data points (point cloud data) are generally initially classified based on the type of objects scanned, for example, bare ground, building, vegetation, and so on. This initial classification serves as a basis for identification of the features captured in the point cloud data set. Depending on the intended use the point cloud data is then processed to identify strings, planes (surfaces) and objects.

Surveys that are to be used as input for data modelling (scan-to-3D models) require classification of both surface and underground features. For these survey deliverables the following classifications are to be used:

- Surveys of surface features, in particular those that support the development of a 3D object-based model (that is, scan-to-3D model), adopt the data classification (location, asset and discipline) and referencing as outlined in the DMS-ST-207 – *DE Standard, Part 2: Requirements.*
- Surveys of utility services inside the metropolitan rail area must comply with the Detailed Site Survey (DSS) requirements listed in T MU MD 00006 ST – *Engineering Drawings and CAD Requirements*, which defines the standard codes representing services and their installation type within the rail corridor.
- Surveys of all other underground utility services outside the metropolitan rail area must comply with AS 5488.1, *Classification of Subsurface Utility Information (SUI), Part 1: Subsurface utility information,* AS 5488.2, *Classification of subsurface utility information (SUI), Part 2: Subsurface utility engineering (SUE)* and DMS-FT-493 – *Utility Schema and Specification*, as well as discipline classification as outlined in DMS-ST-207 – *DE Standard, Part 2: Requirements*.
- Surveys of roads and bridges must comply with the classification requirements outlined in QA Specification G73 – *Detail Survey* and QA Specification G71 – *Construction Surveys*.
- Survey strings must be in accordance with the relevant domain standards and/or requirements (*CADD Manual* Section 3.2 Surveying).

Classifying surveys correctly, in particular 3D objects and models extracted from surveys, enables the project team to use this information for planning, design, construction, and operations and maintenance in a consistent manner.

Where there is conflict between different standards and requirements due to the multi-mode nature of the project the rail standard requirements must take precedence, unless otherwise agreed with TfNSW.

3.4.10 Metadata statement

A metadata statement must be included with all survey datasets provided as deliverables to TfNSW. The specific elements to be covered by the metadata statements must comply with domain specific requirements and IP-0043-GD01 – *Survey Schema and Specification*. (See **Error! Reference source not found.** for more information on survey metadata statements.)

3.5 Deliverable requirements

3.5.1 Overview

Deliverables are defined in two main categories:

- Survey deliverables, which includes the direct survey deliverables to be provided by the Survey Contractor and in most cases will be a combination of the items as outlined under Section 3.5.2.
- Survey reporting, which includes the project documentation to be provided to TfNSW by the Survey Contractor in support of the survey deliverables as described in Section 3.5.3.

Table 6 provides guidance on the deliverables required for the different types of surveys. The guidance indicated shows whether a deliverable should be considered as part of the different types of surveys, with 'Y' to be included, 'O' as being optional, and '-' not required.

Table 6 – Survey deliverables matrix

	Type of survey							
	Existing conditions				As-built			
Deliverables	**Detail**	**Cadastral**	**Utility**	**Construction (set-out)**	**As-built**	**Monitoring**	**Measured**	**Control**
Point cloud	Y	-	-	-	Y	Y	Y	Y
2D drawings	Y	Y	Y	Y	Y	Y	Y	Y
3D drawings	Y	Y	Y	Y	Y	Y	Y	Y
Mesh models	Y	-	-	-	O	O	O	-
3D BIM models	Y	-	Y	-	Y	Y	Y	-
Imagery	Y	O	Y	Y	Y	Y	Y	-
Survey control points	Y	Y	Y	Y	Y	Y	Y	Y
Survey validation	Y	Y	Y	Y	Y	Y	Y	Y
Metadata statement	Y	Y	Y	-	Y	-	-	Y

Depending on the specific needs of the project, additional survey and reporting deliverables may be required and, if so, must be added to the list of deliverables outlined in this section. For example, a project may require the following range of 3D digital survey derived deliverables:

- registered (georeferenced) point cloud
- survey control network
- 2D drawings
- 3D surface data (DEM, DSM, TIN, and so on)
- rendered 3D object model, that is, static visualisation (IFC)
- animated visualisations (for example, walk-throughs, fly-throughs or fly-overs)
- 3D model (non-BIM)
- 3D BIM model
- orthophoto and DEM (typically from unmanned aerial vehicles (UAVs)).

Survey deliverable files are generally large compared to other project deliverables. The submission, management and use of large files should be discussed with TfNSW to ensure that all parties are able to access and use the deliverables. See DMS-SD-146 – *Large File Storage Guide* for guidance on management and storage of large files within TfNSW.

3.5.2 Survey deliverables

3.5.2.1 Overview

The type and format of final deliverables required for a project must be defined, including whether the project requires 2D drawings, 3D model(s), integration with BIM, additional metadata like supporting imagery, environmental conditions, the field acquisition, the processed point cloud, and so on.

File naming conventions of all deliverables should follow the ECM file naming conventions agreed for the project, as required and outlined in the DMS-ST-207 – *DE Standard, Part 2: Requirements*.

Note the following general requirements with regards to survey deliverables:

- The registered point cloud must remain as an overall reference of approved and verified existing conditions for the purposes of future upgrades, redevelopments or maintenance activities.
- The as-built version of the BIM model must reflect the as-built survey and data capture. All as-built survey and associated data must be delivered together with the BIM models.

- The as-built geometric model would only be updated if inconsistencies between verification point cloud survey and the as-built model were significantly different or areas of operational plant were incorrect, in accordance with TfNSW QA Specifications G71 – *Construction Surveys*.
- Where linear assets are surveyed and represented, the native file and/or 3D model remains the source for true geometry and alignment. A LandXML or native file format of the alignment is to be included as part of the survey deliverables.
- Typical metadata to be supplied with survey deliverables must be agreed for the project. Guidance on typical content for a survey metadata statement is provided in **Error! Reference source not found.**.

3.5.2.2 Point cloud

Overview

Point cloud is a data set produced from a laser scan (LiDAR) survey, which captures existing conditions to a high level of detail, that is, a point cloud is a very accurate digital record of an object or space. Point clouds from photogrammetric techniques are mathematically calculated points, which have different levels of accuracy depending on the site, capture system, ground control, overlap, and so on. Essentially, from a technical perspective, a point cloud is a database containing points in the three-dimensional coordinate system.

Laser scanning and photogrammetry are both viable methods for capturing point clouds for 3D modelling of the environment and man-made structures. Even though both methods produce point clouds, the manner of capturing data differs in many ways, resulting in point clouds with differing characteristics. Figure 4 shows an example of laser scanning.

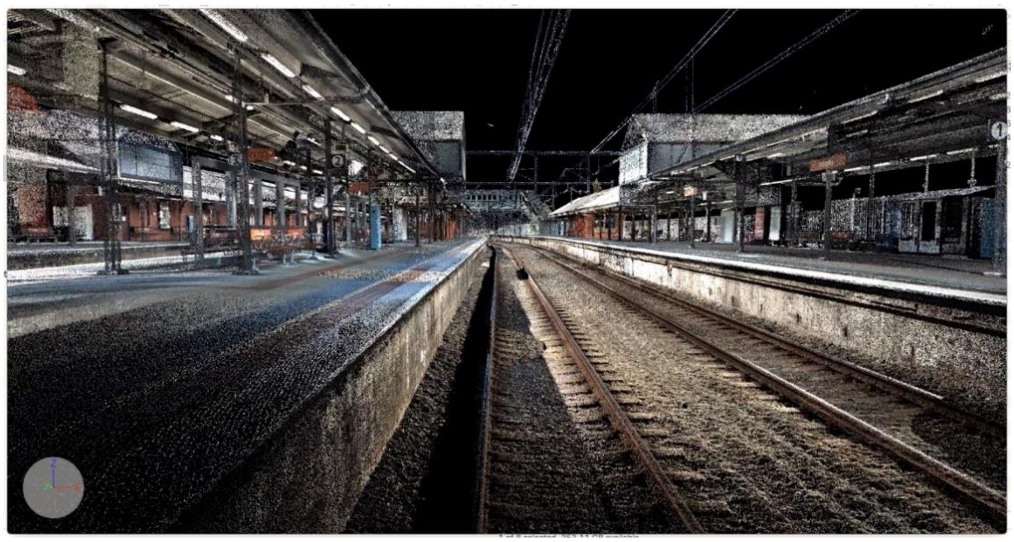

Figure 4 – Example laser scan – Hornsby Station

For the majority of survey projects point clouds form the basis of the 2D and 3D survey deliverables. Point clouds are also a deliverable in their own right and may be supplemented with videos and photographs to improve the real-world quality of the deliverables.

Point cloud density

This section focuses on point clouds generated from laser scanning. The process of capturing laser scan data has many variables, and an important consideration is the point spacing at which the laser scanning will be carried out. The term 'scan density' is used to describe resolution on the data collected and means the distance from a point to point. The lower the density required the quicker it takes to capture the data, with corresponding loss in accuracy. The following aspects need to be taken into consideration when deciding on the scan density, including:

- scan density required to enable suitable identification for modelling purposes (that is, required LoD)
- time available for data capture on site
- deliverable file sizes, including TfNSW's ability to handle large data sets
- potential future uses of the survey data
- amount of site coverage required
- scan overlap.

As a general guideline, point spacing should be considered at the intervals provided in Table 7, but should be discussed and agreed prior to a survey taking place:

Table 7 – Point cloud density – recommended spacing for LiDAR

LOD* of extracted model	Point spacing
LOD 100/200	20mm
LOD 300	10mm
LOD 400	5mm

Table note: * LOD in accordance with definitions in the DMS-ST-207 – *DE Standard, Part 2: Requirements*.

Point cloud density based on photogrammetry will be different to laser scanning and is normally quoted in ground sampling distance (GSD). The GSD is the distance between two consecutive pixel centres measured on the ground. The bigger the value of the image GSD, the lower the spatial resolution of the image and the less visible details. For example, a GSD of 15cm means that one pixel in the image represents linearly 15cm on the ground (15 x 15 = 225 square centimetres).

Deliverables

Point cloud data itself is also a deliverable and can be specified as different types of point cloud deliverables, as outlined in Table 8. Note that to ensure general use and application all point clouds received by TfNSW must be georeferenced and already validated through related survey procedure.

Table 8 – Point cloud deliverables and formats

Deliverables	Formats
Point cloud data sets, including RGB and intensity values, which may include: • Raw, which is the point cloud data set as captured by the laser scanning equipment. • Registered, which means that various 3D point cloud data sets have been aligned/merged into a complete model. • Georeferenced, which means that the point cloud is linked to a coordinate system (that is, linked to the state survey control network), or to a map projection such as GDA2020. • Classified, which requires a georeferenced point cloud, where each point is classified into predefined groups, such as ground, water, road surface, high or low vegetation, building, man-made objects, and so on.	TfNSW's preference is for open data standard formats. Acceptable formats include: • XYZ – standard ASCII text file format with the X,Y,Z and colour information for each point of the point cloud • E57 – the ASTM file format for 3D imaging data exchange (which is an open data format) • LAS – LiDAR LAS file with X,Y,Z position and colour information for each point of the point cloud • LAZ – compressed LiDAR LAS file with X,Y,Z position and colour information for each point of the point cloud. If using LAS files TfNSW and Contractors should discuss and agree the use of compressed LAS, which is a free and lossless LiDAR compression format.

Deliverables	Formats
• Intensity mapped and black and white, where intensity is only shown as grayscale. This option should be considered when data capture can only be done at night or is for underground tunnels with limited light. • Intensity mapped and colourised (including RGB), where intensity can be shown as grayscale or as a range of colours. In most cases point cloud in intensity is good enough but some applications require RGB (real colours). In order to capture RGB scanning needs to be followed by taking images with either external or integrated cameras. In both cases the scanning and processing data is slower.	Typically LAS files can be compressed to 7–20% of their original size when using LAZ. Note that if raw point clouds are required, the file may be in the format of the scanning device, for example: • POD – Pointools and Bentley format • PCG, RCP and RCS – AutoDesk formats • IMP, PTX – Leica formats • JOB, VCE – Trimble formats • ZFC – Aveva, LFM Modeller format. **Note**: The formats listed above are not a complete list.

The following supplementary metadata should also be captured and provided with point clouds to provide context to the data captured, including:

- data capture details, for example, date captured, scanning system used, environmental conditions, and so on.
- the Survey Contractor's details, for example, company name, site/facility/asset scanned, project information, and so on.

As noted, point clouds can also be generated from photogrammetry and aerial surveys and can be used to generate high point density surveys. However, it is important when using photogrammetry point clouds that ground control points (GCP) are used to ensure the data is accurate on the horizontal plane.

Photogrammetric point clouds can be generated in LAS format, which allows the same workflows used for processing of LiDAR data. However, it is worth noting that photogrammetric point clouds are not LiDAR point clouds, but when factors such as cost, safety, timeliness, and survey target area are considered they may offer a better solution for a project at a point in time.

E57 format

The E57 file format, as listed under formats in Table 8, is a standardised point cloud format that not only stores the 3D spatial information but other metadata such as calibrated images, laser source or scan positions, and so on. As it is a vendor-neutral format it can be used to export the survey data of a LiDAR project. A key advantage of E57 is its versatility as it can be used to store terrestrial laser scans using raster-based storage format and is also capable of storing unordered point clouds from an airborne or mobile scanning system. The E57 formats should be discussed with the Survey Contractor and may be an alternative to using the LAS format. More information on E57 format is available on the ASTM Committee E57 page on the **ASTM International website**.

Point cloud viewing

To support collaboration between TfNSW and Survey Contractors, it is important for Contractors to provide TfNSW with the ability to view the point cloud and associated data. There are various free web-based viewers available that may be sufficient for the purposes of viewing point cloud data.

Other options include providing the survey results in 3D PDFs or as video files. See the relevant sections below for typical deliverables and proposed file formats.

3.5.2.3 2D drawings

2D drawings (as CAD files) have traditionally been the standard output of survey data and there are various CAD packages that allow viewing and manipulation of survey data supplied in 2D CAD formats. 2D drawings can also be requested in Adobe PDF format especially when the survey results are required for general distribution and field use in 2D form.

Survey information provided as 2D drawings may limit the usability of the information to support Digital Engineering but remains useful for traditional mapping activities.

Table 9 outlines the 2D drawing deliverables and formats.

Table 9 – 2D drawing deliverables and formats

Deliverables	Formats
Survey information provided as 2D drawings (CAD or PDF), including plan, elevation, or section views.	Formats to be provided must be in accordance with the contract requirements. Depending on the asset owner, drawings may need to be provided in accordance with TfNSW AMB (formerly ASA) CAD requirements, *CADD Manual*, and/or other owner standards, and where applicable, also be aligned with the requirements defined in the DMS-ST-207 – *DE Standard, Part 2: Requirements*.

The 2D drawing output requirements listed in this section are also valid for underground utility surveys.

Figure 5 shows a 2D drawing with 3D model extract.

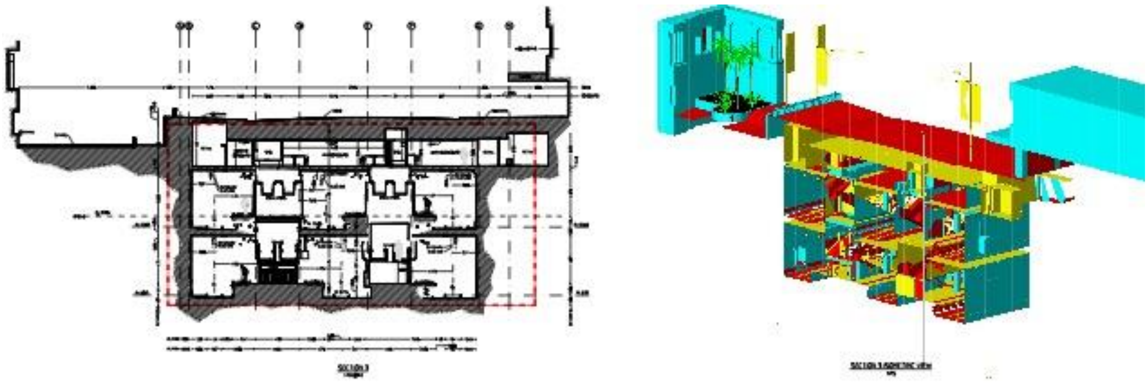

Figure 5 – 2D drawing with 3D model extract – Town Hall Station

3.5.2.4 3D drawings

3D CAD or 3D (BIM) models are a useful format for digital surveys, as the models developed from the laser scan (scan-to-BIM) can serve as the basis for concept and detail designs. As an output format the option of 3D Adobe PDFs should also be explored to eliminate the need for specialist CAD or other viewing software, especially if the information needs to be distributed for general distribution and field use.

Section 3.5.2.6 provides more information on the requirements to be defined for the development of 3D (BIM) models via a scan-to-BIM process.

Table 10 outlines the key requirements for 3D CAD drawing deliverables.

Table 10 – 3D drawing deliverables and formats

Deliverables	Formats
Survey information provided as 3D drawings (CAD, BIM or PDF).	Formats to be provided must be in accordance with the contract requirements. Depending on the asset owner, drawings may need to be provided in accordance with TfNSW AMB (formerly ASA) CAD requirements, *CADD Manual*, and/or other owner standards, and where applicable, also be aligned with the requirements defined in the DMS-ST-207 – *DE Standard, Part 2: Requirements*.

The 3D drawing output requirements listed in this section are also valid for underground utility surveys.

3.5.2.5 Mesh models

General

Site and topographic surveys form the foundation for most developments or planning applications. Topographic surveys capture and record the topography of the ground surface with both natural and man-made features within the built environment. They provide an accurate representation and location of a site, built infrastructure and site buildings, as well as a good understanding of the levels, physical features, boundaries and drainage in surrounding areas. These maps also form the basis for other activities such as boundary determination, drainage analysis and utility mapping.

Topographic surveys have traditionally been delivered in a 2D format, however receiving the information in a 3D format improves the overall level of detail and accuracy. Mesh models are to provide a 3D perspective as 3D surface models, which include digital elevation models (DEMs).

DEMs include digital terrain models (DTMs) and digital surface models (DSMs) where DTM represents the elevation of the bare ground of a terrain, while DSM represents the elevation of a terrain including vegetation (for example, trees) and man-made features (for example, buildings), as illustrated in Figure 6.

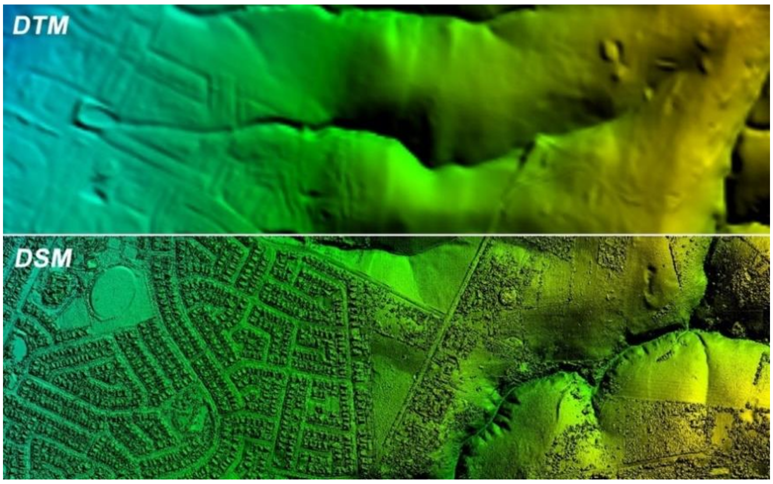

Figure 6 – Difference between DTM and DSM

Terrain models can be enhanced with the modelling of other physical features to provide a fully integrated 3D topographic survey and may take the form of vector files (points, polylines where each entity has height information), a raster file (where each pixel or cell has height information), or triangulated irregular network (TIN) model.

TIN models are vector-based lines with three-dimensional coordinates and are good when points are irregularly distributed geographically. However, TIN models are less suited than a raster DEM for some GIS applications, such as analysis of a surface's slope and aspect.

Table 11 outlines the mesh model deliverables and formats.

Table 11 – Mesh model deliverables and formats

Deliverables	Formats
Mesh model deliverables need to conform to TfNSW requirements for 3D topography, cadastral, contour and terrain models, including provision of:	TfNSW's preference is for open data standard formats. Acceptable formats include:
• cadastral boundary overlay	• dwg, pdf or gdb file (if associating other attributes to the parcel of land, for example, ownership, address data, and so on)
• triangular irregular network (tin) model	• TIN (.tin)
• digital terrain model or digital elevation model	• TIFF/GeoTIFF (.tif), ecw • xyz, las, laz for DEM, DTM and DSM • TIN (.tin) for DEM • AutoDesk (.dwg) or Microstation (.dgn) for DSM
• textured mesh model – plain or photographic	• AutoDesk (.dwg) or Microstation (.dgn)
• GIS application	• Esri GRID for import into GIS

Mesh model viewing

To support collaboration between TfNSW and Survey Contractors, it is important for Contractors to provide TfNSW the ability to view the mesh models and associated data. There are various free web-based viewers available that may be sufficient for the purposes of viewing these mesh models.

Other viewing options include providing the models in PDF, 3D PDF or video files. See the relevant sections below for typical deliverables and proposed file formats.

3.5.2.6 3D BIM models (modelled data)

Where surveys are required to develop a 3D BIM model (scan-to-BIM) it is recommended that the 3D BIM model deliverable are provided in accordance with the DMS-ST-207 – *DE Standard, Part 2: Requirements*. To ensure the appropriate elements are considered the relevant sections of a DE Execution Plan (DEXP) should be completed as part of the survey planning process.

As part of the 3D BIM model development process the following considerations are important:

- Classification of BIM model elements in alignment with the Project Data Schema (PDS), including appropriate asset classification and location referencing as defined in the DMS-ST-207 – *DE Standard, Part 2: Requirements*. The resultant BIM model allows the design team to extract any additional plans, sections or elevations required during design and construction based on a consistent and common set of information.

- General level of development, that is, what to include and exclude from the 3D BIM model, including whether the terrain, general site details down to whether mechanical electrical and utilities are to be added. 3D BIM models are not exclusively for infrastructure or built structures and can be extended to include 3D modelling of the topography of surrounding areas. For road and rail networks this is essential as part of an integrated design of a part of the network such as a station. These requirements will impact on the level of data capture, and more importantly what needs to be modelled.
- The level of detail (LoD) and level of Information (LoI) for the 3D model components are to be appropriate for the intended use of the 3D BIM model. For example, if the model is to be used for clash detection, the LoD needs to reflect the detail required (that is, LOD300 or LOD400). The LoD and LoI used must be in accordance with the guidance provided in the DMS-ST-207 – *DE Standard, Part 2: Requirements*. In particular the table in the DE Standard that defines the recommended minimum LoD by technical discipline.
- The Level of Accuracy (LOA) of the 3D model in relation to the survey point cloud, including modelling tolerances. For example, on deviations of structures, walls, floors, and so on, considering the degree to which the modelled alignment relates to the scan data in all axes (X, Y and Z). Note that the required level of accuracy is not linked to LoD, as any level of accuracy can apply to any given LoD. There is also no link between level of accuracy and project phases. However, increased levels of accuracy will require higher density scanning and more effort during processing of scanned data.

The US Institute of Building Documentation (USIBD) has defined a Level of Accuracy (LOA) specification (refer to **USIBD website**), which is useful to adopt and works well with the LoD and LoI as adopted by the DE Framework for BIM development.

The USIBD's LOA is structured in five increments of ten beginning with LOA10 through to LOA50. Each of the five levels can be applied within the same project as the LOA may be applied to different elements of the target area and not necessarily to the whole project survey area. Table 12 outlines the lower and upper ranges for the different LOAs.

Table 12 – Level of accuracy (LOA) ranges

Level	Upper range	Lower range
LOA10	User defined	50mm
LOA20	50mm	15mm
LOA30	15mm	5mm

Level	Upper range	Lower range
LOA40	5mm	1mm
LOA50	1mm	0mm

The USIBD specification provides additional templates that allow for a more granular level of detail. It is recommended that Projects Teams explore the use of providing more information if required.

Note that modelling of point cloud data is an interpretive process. In many cases point cloud data contains shadow areas, is not complete, and/or is difficult to process so best fit approaches are used to reconcile the differences between the real world and the 3D BIM model. The completed 3D BIM model will not be as accurate as the data from which it was derived.

Table 13 outlines the 3D model deliverables and formats.

Table 13 – 3D model deliverables and formats

Deliverables	Formats
Scan-to-BIM 3D model deliverables (modelled data) can be provided in different formats, including: • 3D CAD – plans, elevations, sections and models • 3D data – 3D surface data (see mesh models, Section 3.5.2.5); and Rendered 3D object models, or • 3D BIM models	3D BIM model file formats are defined in the DMS-ST-207 – *DE Standard, Part 2: Requirements*, and are repeated here for completeness: • All 3D BIM models must be submitted to TfNSW in their original native file format. • All BIM models must be submitted as a Navisworks Cache (NWC) (individually), Navisworks Document (NWD) (federated), or other collaboration file format agreed with TfNSW. • All 3D BIM models must be submitted in the Industry Foundation Classes (IFC) format 2x3 or higher, as individual files to form part of the federated file. These submissions will be required at key project milestones as agreed. Newer versions of IFC format may be submitted if approved by TfNSW. • String-based models must be submitted as a LandXML format 1.2 or higher to retain true geometry. For any inconsistencies between this section and the DMS-ST-207 – *DE Standard, Part 2: Requirements*, the DE Standard requirements take precedence.

Figure 7 provides an example of a scan-to-BIM.

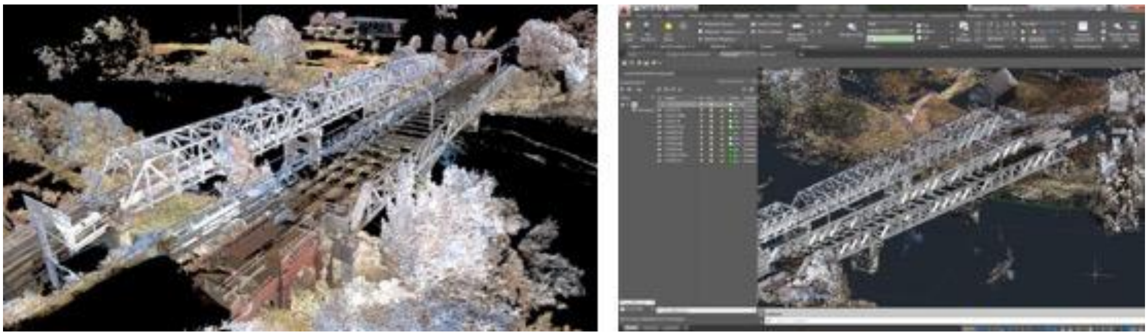

Figure 7 – Scan-to-BIM of Parramatta River Rail Crossing

The management of large file size deliverables, including submission to TfNSW, must be discussed and agreed with TfNSW during the survey project initiation. The topic of submission of large files must also be covered in the Survey Management Plan as outlined in Section 3.3.3.

3.5.2.7 Imagery

Georeferenced images are an important component of a laser scan data set. Images increase information content and decrease the time required to identify and extract features, 3D models, and so on, from the data. Georeferenced images typically contain metadata on the camera model, image location and orientation within the project coordinate frame, which is the same as the delivered point cloud. These images can thus be very accurately mapped to the point cloud data.

Image metadata requirements include:

- camera calibration model (for each camera)
- image out file format (for example, JPEG)
- image location in project coordinates (same as final point cloud)
- image orientation in project coordinates.

Performance requirements can simply be given as images that must be aligned with point cloud to within 'X' pixels. This is easily checked by using the point cloud to extract CAD elements of vertical and horizontal objects, for example, corner of building, edge of asphalt (lane marks) in road, and so on.

Laser scanning provides accurate geometric information, however, complemented with the collection of high-quality imageries or video footage it is possible to enhance the interpretation of point cloud data, and provide additional detail to 3D models developed from the point cloud data.

Imagery can also enhance the opportunity to generate 3D visualisations such as fly-throughs from point clouds and scan-to-BIM models.

Table 14 outlines the imagery deliverables and formats.

Table 14 – Imagery deliverables and formats

Deliverables	Formats
Imagery (georeferenced to the point cloud), including:	TfNSW's preference is for open data standard formats. Acceptable formats include:
• photographs/still images (including panoramic, and so on)	• JPEG or TIF
• videos	• MPEG, MOV or AVI
• animated visualisations (including viewing software if in proprietary format)	• MPEG, MOV or AVI

3.5.2.8 Survey control points

A project control network is required that establishes a network of precise survey control marks that covers the survey target area. The control network must integrate with existing control networks and with the NSW state survey control network (refer to NSW Government's **Spatial Services website**).

A survey control network, including survey points, must be established in accordance with the relevant NSW Acts and regulations, including with specific Surveyor General's Directions (for example, No. 12 Control Surveys and SCIMS) and the Intergovernmental Committee on Surveying and Mapping's (ICSM) *Standard for the Australian Survey Control Network (SP1)* to ensure compatibility with any existing control networks. Distance limits, tolerances and line of sight requirements must also be met.

Where required, the Survey Contractor must also liaise with NSW Spatial Services' survey control section to ensure the survey is carried out to their satisfaction. The control survey network must be connected to Spatial Services' network where available and applicable. All survey data, adjustments and locality sketches must be provided to Spatial Services to be integrated into the Survey Control Information Management System (SCIMS).

The deliverables outlined in Table 15 are typically required to document the establishment and use of a survey control network.

Table 15 – Survey control network deliverables and formats

Deliverables	Formats
Provide a survey control network suitable for all property, engineering and construction aspects of the project, including:	TfNSW's preference is for open data standard formats. Acceptable formats include:
• field book showing survey points	• PDF

Deliverables	Formats
• survey control point schedule listing all survey points, including surveyed MGA coordinates, surveyed AHD levels, class/order information and scale factor	• MS Excel
• control network report prepared by a registered surveyor in accordance with NSW Spatial Services requirements	• Native adjustment files (for example, GSI) • PDF
• geodatabase layer showing all marks including attributes containing all information provided by SCIMS database (if required, which will be based on the ongoing use of information, including access to additional metadata)	• GDB
• copies of locality sketches prepared for new survey points placed	• PDF
• CAD file showing all survey points with name/number shown as text	• DWG or DGN

3.5.2.9 Survey validation

The purpose of survey validation is to confirm the quality of the survey points, including that the survey has achieved the expected accuracy.

The accuracy of the survey must be confirmed by an independent method of survey. The suggested method is the use of validation strings (called QQ strings) as outlined in the TfNSW QA Specification G73 – *Detail Survey*.

Depending on the survey target area, key survey elements must be validated through the capture of QQ string sections. The expected number of validation strings, their position and the frequency of confirming these strings should be provided.

It is recommended that the tolerance expectations for different features should be provided, with an example listed in Table 16.

Table 16 – Validation string tolerances

Feature	Horizontal tolerance	Vertical tolerance
Road, bridge, drainage	+/- 0.03m	+/- 0.015m
Footpath, other hardstand	+/- 0.06m	+/- 0.03m
Other detail, including natural surfaces	+/- 0.2m	+/- 0.1m

Note that the horizontal limits are only used when the QQ string is used to validate a 3D survey.

The key deliverable from the survey validation activity is a report that shows the comparisons between the survey and the survey validation strings, in both horizontal and vertical planes.

3.5.2.10 Metadata statement

Metadata, or data about data, describes the content, quality, currency and availability of data. It assists projects and other stakeholders who use digital information to make decisions in an informed manner. By documenting the characteristics of data, the data can be accessed and used by others.

A metadata statement must be included and provided with the survey deliverables. The metadata statement must comply with IP-0043-GD01 – *Survey Schema and Specification*. The specific content and format must be confirmed with the relevant domain specific surveyors.

3.5.3 Survey reporting

Reporting on surveys must include all final digital survey deliverables (including data sets – with reference to metadata supplied with the delivery) and supporting documentation, including the following:

- data processing documentation – each step in the post-processing of the acquired data must be documented in sufficient detail to allow an independent, third party to reproduce the results. At minimum the data processing documentation should include:
  - quality control and trajectory analysis (mobile surveys)
  - an adjustment report
  - a registration report
  - a system calibration report.
- construction verification (conformances) reports
- overall assessment of final deliverable quality control (including details on any scans and subsequent models)
- as-built report (work as executed survey).

The overall survey report is to outline the methods used during the survey, identify any significant variations to the methodology proposed due to site conditions or similar, and the results achieved. The report must, at a minimum, address the following:

- survey date, limits and purpose
- personnel and equipment details

- copies of field notes including scan diagrams, control information, instrument and target heights, atmospheric conditions, and so on
- details of additional control marks placed during data capture
- occupied and targeted control points
- reference points, including a comparison of coordinates
- adjustment report for control marks
- results of target and cloud-to-cloud registration
- Quality Assurance/Quality Control (QA/QC) reports
- comparison of processed points to references points
- discussion of any issues encountered, and the methods used to overcome them
- discussion of accuracies achieved
- any other relevant information to the survey process and results.

4 Reference documents

The following documents are referenced in the text:

- IP Commercial Management Framework
- DMS-ST-202 – *Digital Engineering (DE) Standard, Part 1: Concepts and Principles*
- DMS-ST-207 – *Digital Engineering (DE) Standard, Part 2: Requirements*
- DMS-PR-031 – *CPS Procurement: Procurement Procedures*
- T HR TR ST 13000 – *Railway Surveying*
- QA Specification G73 – *Detail Survey*
- QA Specification G71 – *Construction Surveys*.

All documents can be found on DeskSite, the IMS (DMS) or the Asset Management Branch (AMB) website.

5 Document history

Version	Published date	Summary of changes
1.0	February 2020	First release

Version	Published date	Summary of changes
1.1	December 2022	1.2 Revised Scope and application 1.3 Updated Terms and Definitions 2 Better definition for survey types, new linked survey specifications 3.1 Revised “preparation” and “review and accept” 3.2.4 Revised “Type of survey”, new definitions added 3.2.7 Revised “existing information” Table 1 amended, .dgn added 3.4 Technical requirement revised 3.4.2 Updated “act, regulations and standards” Table 2 updated 3.4.3 “Register surveyor” replaced by “qualified surveyor” , definition added 3.4.4 Revised “survey accuracy” Table 4 updated 3.4.5 Revised “Survey Validation” 3.4.6 New recommendation added to check coordinates transformation through reference points and related workflow 3.4.7 Related standard addressed 3.4.8 Terminology changed; “location” replaced by “accurate geometry” 3.4.9 Updated classifications 3.4.10 Survey schema and specification added and mandated as new metadata statement 3.5.1 Table 6 survey deliverables matrix amended 3.5.2.2 Deliverables revised 3.5.2.5 Table 11 amended 3.5.2.7 Better terminology 3.5.2.8 Survey control points revised Table 15 amended 3.5.2.10 Survey schema and specification added and mandated as new metadata statement 3.5.3 Survey reporting revised and updated 4 Reference documents updated 5 Document history added 6 Title changed Appendix A revised and updated Appendix B Metadata statement aligned with survey schema and specification Table 17 Proposed elements for survey metadata statement added

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6 Feedback and help

For general enquiries and assistance with the application of this guide and associated Digital Engineering standards, guidelines, education, training, or planning and commencing a digital engineering project, please contact the Digital Engineering Team at **Digital.Engineering@transport.nsw.gov.au**.

The DE Team will liaise with the relevant domain experts where necessary to provide the relevant support.

The DE Framework embraces a culture of continuous improvement. Suggestions, comments and feedback are welcomed and encouraged.

For more information refer to **Digital Engineering** on the Transport for NSW website.

Appendix A Surveying technology

Surveying technology will continue to change and improve. The main types of technology currently available for surface and underground surveying are:

- **Surface (above ground) surveys**:

  Data capture technology typically used for surface-based surveys (or large tunnels or underground spaces), include:

  - **Total stations** – conventional survey technology, which also includes digital levels
  - **3D laser scanning** – also known as LiDAR (light detection and ranging), which is the most common technology used to capture 3D laser scans
  - **GNSS receivers** – satellite-based survey technology that includes systems such as GPS, GLONASS, BeiDou, and so on
  - **photogrammetry** – which includes technology such as digital imaging systems, digital photogrammetry, and digital orthophotography, where orthophotography is when the image has been geometrically corrected so that the scale on the image is uniform
  - **video** – which is normally captured to complement an existing survey, including 360-degree videos to complement laser scanning. However, technology is now available to use video as the basis of a survey, complete with enhanced data analysis through artificial intelligence.

- **Underground (subsurface) surveys:**

  The surveying technologies available for underground (subsurface) scanning include:

  - **utility locating technology** – which includes radio detection technology, including electro-magnetic induction (EMI) and high frequency induction (HFI) for cables and pipes, ground penetrating radar (GPR) technology for conductive and non-conductive utilities or structures, and magnetometer technology for metal-based underground objects, which cannot be detected with GPR
  - **concrete imaging technology** – which uses GPR with a high frequency antenna, but has limited sensing depth capability
  - **video inspection technology** – which for underground applications are mainly inspection of pipes such as sewers, drains and empty conduits using either push rods or pipe crawlers.

  As technology is continually changing it is recommended that projects explore the availability of improved technology solutions to support the survey outcomes required.

- **Other sources of survey information**:

  There are also other sources of survey information available to TfNSW projects, which may reduce or eliminate the need for highly detailed surveys to be conducted during the early stages of a project, including:

  - **Spatial Services**, a division of the NSW Department of Customer Service. The service includes the **NSW Spatial Collaboration Portal**. This portal will be expanded to 3D and 4D GIS information, but currently is only available for small areas in the Sydney Metropolitan region
  - **Elvis Elevation and Depth**, a system developed in partnership between Geoscience Australia, Intergovernmental Committee on Surveying and Mapping (ICSM) and other participating agencies, which provides elevation data
  - internet mapping solutions, such as **Nearmap** and **Google Earth** including related products such as Earth Engine, which provides more advanced analytical capabilities.

  The **TfNSW TransPortal**, provided by the TfNSW Spatial Centre of Excellence, can also be used to gather survey and GIS related information. The TransPortal is accessed via the TfNSW intranet site.

Appendix B Survey metadata statement

This appendix provides a list of proposed elements to include in a survey metadata statement. This proposed list must be verified with the relevant domain surveyors. Following internal agreement on the content, the metadata statement requirements must be included in the contract requirements, as well as discussed and agreed with the Survey Contractor at the start of the survey project.

Table 17 – Proposed elements for survey metadata statement

Field group	Field name	Field type	Property type	IFC property set	IFC attribute name	Mandatory
Project Detail	TfNSW Project No.	Alphanumeric	Model properties	TfNSW_Project	TfNSW_ProgramProjectAlias	Yes
Project Detail	Project Contract Code	Domain List: Project And Contract Code	Model properties	TfNSW_Project	TfNSW_ProjectContractCode	Yes
Project Detail	Project And Contract Name	Domain List: Project And Contract Name	Model properties	TfNSW_Project	TfNSW_ProjectAndContractName	Yes
Project Detail	Corridor Number and Name	Alphanumeric	Model properties	TfNSW_Project	TfNSW_Corridor	Yes
Project Detail	Local Gov't Area	Domain List: Local Gov't Area	Model properties	TfNSW_Project	TfNSW_LGA	Yes
Project Detail	Survey Project Location Description	Free Text	Model properties	TfNSW_Project	TfNSW_SurvProjLocationDesc	Optional
Project Detail	Security Classification	Domain List: Security Classification	Model properties	TfNSW_Project	TfNSW_SecurityClassificationDesc	Yes
Project Detail	File Reference	Free Text	Model properties	TfNSW_Project	TfNSW_DocumentNo	Yes
Project Detail	Document title	Free Text	Model properties	TfNSW_Project	TfNSW_DocumentTitle	Yes
Project Detail	Coordinate System	Domain List: tbCoordSys	Model properties	TfNSW_Project	tbCoordSys	Yes
Project Detail	Height Datum	Domain List: tbHghtDatum	Model properties	TfNSW_Project	tbHghtDatum	Yes
Project Detail	State Description	Domain List: State Description	Model properties	TfNSW_Project	TfNSW_StateDesc	Yes

Field group	Field name	Field type	Property type	IFC property set	IFC attribute name	Mandatory
Project Detail	Suitability Description	Domain List: Suitability Description	Model properties	TfNSW_Project	TfNSW_SuitabilityDesc	Yes
Project Detail	Project Milestone Description	Domain List: Project Milestone Description	Model properties	TfNSW_Project	TfNSW_ProjectMilestoneDesc	Yes
Project Detail	Discipline Code	Domain List: Discipline Code	Model properties	TfNSW_Project	TfNSW_DisciplineCode	Yes
Project Detail	Sub-discipline Code	Domain List: Sub-discipline Code	Model properties	TfNSW_Project	TfNSW_SubDisciplineCode	Yes
Project Detail	Contractors Code	Domain List: Organisation Code	Model properties	TfNSW_Project	TfNSW_ContractOrgCode	Yes
Project Detail	Contractors Name	Domain List: Organisation Name	Model properties	TfNSW_Project	TfNSW_ContractOrgName	Yes
Survey Detail	Survey Project Contract Number	Domain List: TfNSW Survey Project Reference Number	Model properties	TfNSW_Survey	TfNSW_SurvProjContractNo	Yes
Survey Detail	Survey Instruction Number	Domain List: Survey Instruction Number	Model properties	TfNSW_Survey	TfNSW_SurveyInstructionNo	Conditional
Survey Detail	Survey Organisation Code	Domain List: Organisation Code	Model properties	TfNSW_Survey	TfNSW_SurveyOrgCode	Yes
Survey Detail	Survey Organisation Name	Domain List: Organisation Name	Model properties	TfNSW_Survey	TfNSW_SurveyOrgName	Yes
Survey Detail	Survey Type	Domain List: Survey Type	Model properties	TfNSW_Survey	TfNSW_SurveyType	Yes
Survey Detail	Survey Activity	Domain List: Survey Activity	Model properties	TfNSW_Survey	TfNSW_SurveyActivity	Yes
Survey Detail	Survey Commencement Date	Date (YYYY/MM/DD)	Model properties	TfNSW_Survey	TfNSW_SurveyCommencmentDate	Yes
Survey Detail	Survey Completion Date	Date (YYYY/MM/DD)	Model properties	TfNSW_Survey	TfNSW_SurveyCompletionDate	Yes
Survey Detail	Surveyed by	Free Text	Model properties	TfNSW_Survey	TfNSW_SurveyedBy	Optional
Survey Equipment	Survey Instruments Type	Domain List: Instruments Type	Model properties	TfNSW_Survey	TfNSW_SurveyInstType	Yes
Survey Equipment	Survey Instrument Serial No	Alphanumeric	Model properties	TfNSW_Survey	TfNSW_SurveyInstSerialNo	Optional

Field group	Field name	Field type	Property type	IFC property set	IFC attribute name	Mandatory
Survey Equipment	Survey Instrument Calibration Date	Date (YYYY/MM/DD)	Model properties	TfNSW_Survey	TfNSW_InstCalibDate	Yes
Survey Control	Horizontal adjustment Report	Free Text	Model properties	TfNSW_Survey	TfNSW_HzAdjustRep	Conditional
Survey Control	Vertical adjustment Report	Free Text	Model properties	TfNSW_Survey	TfNSW_VtAdjustRep	Conditional
Survey Control	Survey Class Horizontal	Domain List: Survey Class Horizontal	Object Property	TfNSW_Survey	TfNSW_SurveyClassHz	Yes
Survey Control	Height Class Vertical	Domain List: Survey Class Vertical	Object Property	TfNSW_Survey	TfNSW_ SurveyClassVt	Yes
Survey Control	Mean Combined Scale Factor	Real Number	Model properties	TfNSW_Survey	TfNSW_MCSF	Conditional
Data Transfer	Survey Data Reference Number	Alphanumeric	Model properties	TfNSW_Survey	TfNSW_SurveyDataRefNo	Yes
Data Transfer	Survey Data Transfer Date	Date (YYYY/MM/DD)	Model properties	TfNSW_Survey	TfNSW_SurveyDataTransferDate	Yes
Data Transfer	Recipient(s)	Free Text	Model properties	TfNSW_Survey	TfNSW_SurveyDataRecipients	Optional
Quality Assurance	QA Validation Method(s)	Domain List: QA Validation Method(s)	Model properties	TfNSW_Survey	TfNSW_QAValMethod	Optional
Quality Assurance	QA Report filename	Alphanumeric	Model properties	TfNSW_Survey	TfNSW_QARepFile	Optional
Quality Assurance	Quality Specification	Domain List: Quality Specification	Model properties	TfNSW_Survey	TfNSW_QAQualitySpec	Yes
Quality Assurance	Coordinate Transformation	Domain List: Coordinate Transformation	Model properties	TfNSW_Survey	TfNSW_QACoordTransform	Conditional
Notes	Notes	Free Text	Model properties	TfNSW_Survey	TfNSW_Notes	Optional