Standard and Specifications for 3D Topographic Surveying (Mapping) in Singapore

Version 1.0

November 2013

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Revision History

Revision	
Version 1.0	November 2013

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1. Introduction

Executive Summary

This document establishes the standard and specification for three dimensional (3D) topographic mapping and survey in Singapore. It encapsulated detailed procedures from acquisition to production of 2D/3D topographic CAD drawings and 3D topographic model. This document covers the 2 major elements of topographic survey process, the data capturing and the data presentation (output).

For data capturing, to embrace and respond to rapid evolution of technologies, terrestrial laser scanning (TLS) and mobile laser scanning (MLS) are covered in the document as a tool to capture high quality 3D data output to produce 3D models with well-defined absolute and relative accuracy. Surveyors shall determine the appropriate equipment and efficiency to satisfy user's requirements.

Lastly, the document is not intended to replace technical specifications stipulated by clients. Contractual agreements between practitioners and clients shall take precedence over this document in the event of disputes.

Objectives

- To create a common understanding on the acquisition and production of 3D topographic mapping information. This would facilitate the efficient exchange of information among users and professionals in their work.
- To ensure standardised and consistent quality of output using best practices standard and survey techniques. This will lead to efficiencies and less double handling of data.
- To supply documented processes to survey contractors such that specification and requirement can be met in an effective manner.
- To illustrate all digital information requirements with relevant examples, independently of processing software used.
- To establish a platform where topographic information can be easily shared, reused, fused and translated into multiple formats, therefore increase the value of topographic survey as a long-term digital asset.

Intended Audience

The document is designed and intended to be of benefits to any party who procures, specifies, or carries out topographic surveys. This includes local agencies, registered surveyors, engineering consultants, survey companies, and professional institutes involved in surveying and mapping.

Future Additions to the Specifications

The document is crafted based on inputs from professionals on their current practices and consulting government agencies on their needs. It is intended that the specification will be revised continuously to support broader range of survey activities in the future, either via new technologies advancement or great degree of user feedback.

Compliance with Land Surveyors Board (LSB) Survey Directives

The directives on Surveying Practices, Control Survey and As-built/Topographical Survey stipulated in the LSB Directive on Engineering and Hydrographic Survey Practices are also to be adhered to when executing a topographic survey.

2. Types of Topographic Surveys

Topographic surveys are performed for the master planning, design, and construction of installations, buildings, housing complexes, roadways, airport facilities, flood control structures, navigation locks, etc. Some of the more common surveys are described below:

2.1 General/Preliminary Site Plans

General or Preliminary site plans shall performed at scales from 1:2,000 to 1:5,000. They depict general layout for potential construction, proposed transportation systems, training areas, and existing facilities.

2.2 Detailed Topographic Surveys for Construction Plans

These surveys are performed at scales from 1:200 to 1:2,000 and at varying contour intervals. They are performed to prepare a base map for detailed site plans (general site layout plan, utility plan, grading plan, paving plan, airfield plan, demolition plan, etc.). The scope of mapping is confined to an existing/proposed building area. These drawings are used as a base for subsequent as-built drawings of facilities and utility layout maps, i.e., Amenity Mapping / Facility Management (AM/FM) databases.

2.3 As-Built Surveys and Amenity Mapping (AM)/Facility Management (FM)

As-built drawings may require topographic surveys of constructed features, especially when field modifications are made to original designs. These surveys, along with original construction site plans, should be used as a base framework for a facility's AM/FM database. Periodic topographic surveys also may be required during maintenance and repair projects in order to update the AM/FM database.

3. Topographical Survey Accuracy Standard

The following standard for topographic surveys is taken from The Royal Institution of Chartered Surveyors, “Specification for Surveys of Land, Building and Utility Services”. Some projects may require higher or lower accuracy levels which should be agreed with the client on an individual basis. For planimetric and vertical control, the LSB Directive on Engineering and Hydrographic Survey Practices are referred.

3.1 Horizontal Control

The LSB Directive on Engineering and Hydrographic Survey Practices requires the use of at least four (4) ISN markers to establish the horizontal datum. The ISN markers shall as far as possible, encompass the site under survey, and could be used only if the residuals in Northing and Easting co-ordinates are within 0.020 m of the recorded ISN values for GPS surveys by taking reference to the Singapore Satellite Positioning Reference Network (SiReNT). GNSS survey would also be required if there are less than four (4) stable or intact ISN markers. Further details on establishment of ISN markers should refer to Guidelines and Specifications for GPS Surveys of ISN Markers.

When a traverse is created, the minimum closure standard for horizontal control is 1:20,000 with angular closure of $5\sqrt{N}$, where N is the number of angle stations. Summary as below:

Minimum Closure Standard	1:20,000
Angular Closure	$5\sqrt{N}$

3.2 Vertical Control

The LSB Directive also stipulates that vertical datum shall be derived from at least two reliable Vertical Control Points (VCP), each verified with two witness marks established by SLA.

Where a local vertical control is to be established for allowable height accuracy of 5 cm, the SGeoid09 - geometric geoid model established by SLA - might be adopted to convert ellipsoidal heights, obtained in accordance to the recommended procedure published by SLA, to reduced levels.

The minimum closure standard for vertical control is $6\sqrt{k}$, where k is the distance in kilometres between the two points being considered. Summary as below:

Minimum Closure Standard	$6\sqrt{k}$

3.3 Planimetric Information

The absolute paper plan position of any well define point of detail shall be correct to within ± 0.3 mm RMSE (Root Mean Square Error) at the plan scale, when checked from the nearest control station. Summary as below:

RMSE (Root Mean Square Error)	Within ± 0.3 mm

3.4 Height Information

Ground survey spot levels on hard surfaces should be correct to ± 10 mm RMSE and elsewhere to ± 50 mm, except on ploughed or otherwise broken surfaces in relation to the nearest control station.

4. Detail to be surveyed

The “Specification for Surveys of Land, Building and Utility Services” published by the Royal Institution of Chartered Surveyors lists the general categories of detail to be surveyed. The specification also provides an expanded list of the categories of features. Appendix A lists the features and their expanded list. This list could serve as a useful reference for future extension of the general features to be surveyed in the Singapore context.

From the list compiled from some Registered Surveyors, the following general features were identified for Singapore context as illustrated in Table 1 below:

Table 1: List of Features

No.	Features
1	Buildings / Structures
2	Visible boundary features: walls, fences, hedges
3	Roads, tracks, footways, paths
4	Facilities
5	Utilities
6	Landscape and vegetation
7	Water features
8	Earthworks
9	Railway features
10	Others

4.1 Level of details to be surveyed

(a) All visible details shall be surveyed. Where relevant, indicate features that are considered encroachments. If encroachment survey is to be carried out, it shall be done according to cadastral survey standards.

(b) Saplings and trees where required shall be surveyed and described. Generally, trees with girth 300 mm and above (measured 1 m above ground level) are surveyed.

(c) For sewer manholes, electrical manholes and inspection chambers, the cover levels and invert levels shall be surveyed if accessible. The type of manhole and inspection chamber, approximate direction of flow shall be reflected in the plan.

(d) For drains, invert levels and coping/top levels shall be surveyed generally at 20 m interval. For cascading drain, the coping and invert levels shall be surveyed. Covered drains with iron grating shall be surveyed.

(e) Over-ground electric boxes, lamp/cable posts with numbers, exposed/overhead cables, etc. shall be surveyed.

(f) Cross-sections must be right-angle to centre line and shall be surveyed generally at 30 m interval and 15 m along curves, tunnels roads etc.

(g) Road names and house/block numbers shall be picked up and shown.

(h) Edges of pond shall be surveyed.

4.2 Height Information

Height information shall be provided

either (a) as elevation to entail details true to ground as specified in para. 5.1,

or (b) as spot heights throughout the survey area.

or (c) as height of detail specified in para. 5.1, i.e. from ground terrain to top level of the details, e.g. height of a lamp post.

4.2.1 Elevation

Elevation shall be surveyed such that the ground terrain of a feature which attached or intersected with the ground is derived. Thus***, when using reflectorless Total Station, correct location(s) of detail point(s) must be surveyed to feature from the ground terrain.*** For instance, the base of a street lamp pole should be surveyed instead of random point on the pole.

4.2.2 Spot Height

Generally, spot heights shall be taken at intervals of not more than 15 m to allow capturing of possible discontinuities of terrain. Spot heights shall be taken on all roads, at intersections, building corners, edges of carriageways, invert of drains, footpaths, bridges, fire hydrants, other salient ground features and at all changes in grade.

4.2.3 Height

Height of any features (manmade or natural) is referred as height from ground terrain to top of the feature as illustrated in Figure 1 below. This information must be surveyed for subsequent modeling of object.

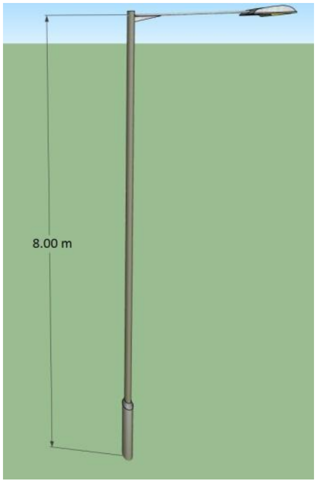

Figure 1: Geometry Height of a Lamp Post

5. Specifications for Topographic Survey Techniques

5.1 Total Station

(a) Standard operating procedures

It should require that control points be measured and noted immediately on the data collector and/or in the field book after the instrument has been set up and levelled. In making observations for an extended period of time at a particular instrument location, re-observe the control points from time to time, and also before the instrument is relocated.

(b) Positioning Topographic Features with a Total Station

Topographic features are usually observed by multiple radial sideshots from primary project control points. This is usually a straightforward process: the remote point is occupied with the prism pole, the height of reflector and feature code recorded, and the angle and slope distance observed and recorded. If necessary, supplemental feature attributes may be added. The process is similar when using a reflectorless total station or robotic total station where the data collector is at the prism pole.

Quite often objects cannot be directly occupied with a prism pole or targeted with a reflectorless total station. Off-center (or eccentric) corrections are automatically available in most data collectors to cover these situations. Offset cases include trees or circular tanks where only direction to the centre of the circular object can be sighted; a distance to the circumference and a direction to the centre of the circular object; or high objects that are beyond the reach of a prism pole.

5.2 Global Navigation Satellite System (GNSS)

5.2.1 Real Time Kinematic (RTK)

Real-time Kinematic surveying is a GNSS (Global Navigation Satellite System) carrier phase surveying technique that allows the user to rapidly and accurately measure baselines while moving from one point to the next, stopping only briefly at the unknown points, or in dynamic motion such as a survey boat or aircraft. A reference receiver is set up at a known station, such as one of the SiReNT stations, and a remote, or rover, receiver traverses between the unknown points to be positioned. The data is collected and processed real-time to obtain accurate positions to the centimeter level. Real-time phase are referred to as "real-time kinematic" (RTK) surveys. RTK survey techniques require some form of initialization to resolve the carrier phase ambiguities. This is done in real-time using "On-the-Fly" (OTF) processing techniques. Periodic loss of satellite lock can be tolerated and no static initialization is required to regain the integers. This differs from other GNSS techniques that require static initialization while the user is stationary. A communication link between the reference and rover receivers is required to maintain a real-time solution. Further details on RTK Survey should refer to the section on GPS RTK Survey, LSB Directives on Engineering and Hydrographic Survey Practices.

5.2.2 Post-processed Kinematic

Post-processed Kinematic is a technique whereby carrier phase signal is received at remote receiver and adjusted using data from reference station after completion of data collection (not real time). Post-processed Kinematic solutions of X-Y-Z locations using the carrier (not code) allows greater flexibility of post-processing which would enhanced the final outcome of the results.

5.3 Static Terrestrial Laser Scanning

Static Terrestrial Laser Scanner (STLS) operates similarly to reflectorless Total Station Positioning System (TPS). However, instead of a single shot point being observed, a full field-of-view scan could be performed - at a speed upwards of 1,000,000 points per second for phase-based or 50,000 points per second or more for time-of-flight (TOF) or pulsed-based design. Time-of-flight (also known as "pulse based”), rather than the phase-based, scanners are preferred type of laser scanner for civil engineering projects because of their longer effective maximum range (typically 125 m -1000 m).

Newer STLS models with dual-axis compensators allow input of the scanner coordinates from which all observed pixels may be directly geo-referenced are desired for use. The resultant imagery from a scan (termed a “point cloud”) provides a full 3D model of the facility, utility, or terrain that was scanned. Objects can be scanned at high scanning density or spot spacing (also known as sampling spacing) of around 1 mm. Most commercial mid- and long-range systems provide an accuracy of about 6 to 10 mm (3DRiskMapping, 2008). The duration of the scan depends on the density of the point cloud set. Multiple setups generally are required to fully detail a given site or structure. STLS can be used to perform traditional topographic surveys (detailed planimetry and elevations) of project sites and facilities - providing ground elevations at a high density.

Defining a specification for TLS data is complicated by the wide variety of systems and workflows available. The specification could be divided into three interrelated segments. These three segments represent the clear logical progression of laser scanning (or indeed any other survey technique): *data capture*, *data use* and *data storage* (Barberi, D et al., 2003):

(a) **Data capture -** The capture of data clearly depends on the scanning system in use as this will dictate the workflow and techniques applied. This includes issues such as methods for registration, available/required field of views, the density of data capture and the requirements for any additional information.

(b) **Data use -** Although scanning has been used for architectural survey, standard products have yet to be defined. In order to ensure the specification is sensitive to the needs of possible end users the following were defined as potential outputs although no specification of how they should be presented or to what level they should attain, was provided:

- CAD models (by primitive modelling)
- Meshed models
- Profiles and cross sections
- Animations

(c) **Data storage and retrieval -** storage of data is a vital part of the specification process. Care must be taken to ensure the media storage does not become obsolete.

5.3.1 Considerations in using STLS

(a) **Accuracy** - Scanner performance and accuracy can be adversely affected by *surface reflectivity and color, edges, temperature, atmospheric conditions, and interfering radiation such as bright lights or direct sunlight* (AHMCT, 2011). Boehler (2003) elaborates on the said influences.

(b) **Density of scanned points** - Laser scanners can be set to any desired sampling spacing, e.g., from 1 mm onwards, usually based on some short nominal distance. *Sampling Spacing* and *Point Density* are used interchangeably in this report. The smaller the sampling spacing, i.e. the higher the density, the larger is the resulting dataset and more time-consuming the data editing and processing. For general 3D planimetry or buildings or ground elevations, a low density can be set. For detailed maps of structural members or concrete cracks, a high density is required. *As a general rule the sampling spacing should be at least half the size of the smallest feature that is required to be discerned in the scan* (English Heritage, 2009). Pesci el al. (2011) also shows that *the discrimination of elements smaller than a third of the beam divergence* is not possible and that *the ratio between the used sampling spacing and the target size is linearly related to the acquisition range*.

(c) **Field-of-View** - Depending on the model and project requirements, scanners can be set to scan a full 360 degree field or zoomed (windowed) into a narrowly set field-of-view. Laser-shadowing forces data to be collected from multiple angles for complete data coverage. Also, the angle of incidence of a measurement will have a profound impact on its accuracy and the resolution of the data in general. If the angle between the scanner beam and the surface of the object decreases, the intensity of beam reflection also decreases. To avoid this phenomenon the angle between surface and laser beam must be at least greater than 10° (3DRiskMapping, 2008).

(d) **Range -** In general, most detailed scans of facilities, buildings, and structures are kept at close range - usually less than 200 m and not much beyond 300 m. The useful range will be determined by factors such as the range and accuracy specifications of the individual scanner as well as the accuracy requirements of the final survey products. Methods for accomplishing this might include the implementation of range and/or intensity filtering during data collection or culling any out-of-useful range data during post processing. Surface properties including color, albedo or surface reflectivity, and surface texture can limit scanner effective range. For instance, *a scanner with maximum range of 300 m, the useful range will hardly be close to the maximum range, but half or even a third of it*. The size of the laser spot which varies with different manufacturers of scanners and increases with range is another factor which restricts the useful range of laser scanner. *As a guide, the laser spot size should not be greater than twice the sampling spacing to avoid too much blurring of the scanned feature due to the averaging of the overlapping scans*.

(e) **Scanner Targets** - Total station targets reduce pointing error when placed at long distances. Laser scanning targets, however, are designed for a specific distance. Most laser scanners do not have telescopes to orient the instrument to a backsight. Cylindrical, spherical, and planar targets must be scanned with a sufficient density to model their centers, with planar targets tending to yield better results. *The size of the target, laser spot size, and distance from the scanner determine how precisely the center can be modeled*. If the distance from the scanner to the target exceeds the manufacturer's recommended distance, the error can increase dramatically. Vendor-specific targets, which are tuned for the laser scanner frequency, are recommended. Follow the manufacturer's recommended distance for placement of targets.

(f) **Calibration of TLS -** Being a relatively new technology, the accuracy specifications given by laser scanner producers in their publications and pamphlets are often not comparable. The scanners do not have the same properties, e.g. accuracy, precision, reproducibility, repeatability and reliability as traditional surveying instrument, such as TPS and GNSS. The precision and accuracy of a TLS could only be ascertained by calibrating the instrument. Field calibration procedure is still not enabled for users. Laboratory-based calibration done by equipment manufacturers is the only means of ascertaining the quality of the TLS. Field calibration procedure towards ISO certification is being investigated (Gottwald, 2008).

At the moment, some TLS have built-in system check, either automatically or require user activation. For the latter design, user should carry out the system check before capturing of scan data.

(g) **Sampling Spacing (SS)** - The key question when carrying out a laser scanning project is choosing the correct SS or point density. The SS is defined as the distance between two subsequent measured points, and thus determines the density of points in the point cloud. SS is a function of angular increment and the scan distance.

The SS is mainly governed by the smallest detail of the surface structure that needs to be recognizable in the final deliverable. The size of the detail is referred as **Target Size** TS in this report. Therefore it is also directly related to the scale of the deliverable.

Pesci et al. (2011) found *an empirical linear relation between the range and the SS/TS ratio*. User can settle the optimal sampling spacing, SS, for which a required object separation, TS, is obtained. The relationship holds for ILRIS-3D instrument, but it had been verified (Tor, 2012) that the proposed method of obtaining the empirical linear relationship can easily be applied to other instruments to obtain the corresponding empirical equations. In the case of a “complex” surface, the sampling spacing should be about 10% shorter than the threshold.

5.3.2 Template Specification for Collection of Point Cloud Data using STLS

This template specification refers to (a) Theory and Practice on Terrestrial Laser Scanning by 3DRiskMapping Project (2008); (b) 3D Laser Scanning for Heritage by English Heritage (2007) and (c) CALTRANS (2011). The specification described here defines the standard which point clouds must meet if they are to be accepted by Client. It does not define the standard to which products derived from point clouds must attain.

(a) Provision of point cloud data

(i) Pre-survey deliverables

Prior to survey a method statement is required. In the case of terrestrial laser scanning the method statement will also include:

1.	Technical specifications about the scanning system, or systems, to be used.
2.	The proposed sampling spacing, i.e. point density
3.	A description outlining the location and extent of potential data voids and a proposed method for data collection in these areas

(ii) Certification requirements

Laser scanning systems used must be accompanied with:

1.	A certificate confirming the system is in good working order
2.	Or details of tests, performed in the last 12 months, which show the scanner to be achieving the required precision and accuracy.

Exact requirements for certification or tests should be discussed with Client and described in the method statement before work begins.

(iii) Sampling Spacing (also known as Point Density) and measurement precision

The accuracy and sampling spacing required will be stated in the project brief. This will either be defined based on laser spot size or based a minimum feature size defined in the project brief.

The laser spot size of the measurement beam must not be greater than double the effective sampling spacing. This is to minimize, if not avoid, the blurring effect to the scanned features.

English Heritage, a non-departmental public body of the United Kingdom with substantial expertise in managing the historic environment, created a table which helps a user to determine the appropriate quality **Q** for the project in discerning feature size as illustrated in Figure 2 below:

feature size	*example feature*	*point density required to give 66% probability that the feature will be visible*	*point density required to give a 95% probability that the feature will be visible*
10000mm	large earth work	3500mm	500mm
1000mm	small earth work/ditch	350mm	50mm
100mm	large stone masonry	35mm	5mm
10mm	flint galleting/large tool marks	3.5mm	0.5mm
1mm	Weathered masonry	0.35mm	0.05mm

Figure 2: Appropriate point densities (sampling spacing) for various sizes of cultural heritage features

This table is generated based on the following formula:

$$Q = 1 - (m / \lambda)$$

Where **Q** is the quality of the data, **m** is the sampling spacing or point density on the object and λ is the minimum feature size required. The value **Q** therefore indicates the level to which the object has been scanned.

All reference to point density will be provided as the average 3-D distance between points at a defined range.

(iv) Overview and detail scans

The number and location of overview and detail scans required will be specified in the project brief were required.

(v) Overlapping scans

Where it is acceptable to filter areas of overlapping scan data, to reduce the sampling spacing in the final registered point cloud and hence reduce file sizes and improve software performance/data handling during processing, this will be noted in the project brief. Overlapping adjacent scans as percentage of scan distance is between 5% to 15 %.

(vi) Data voids

The number of data voids must be minimised during the survey. The project brief will outline the requirements for handling and acceptance of data voids in point cloud.

(vii) High level coverage

Methods used to achieve high level coverage must be described in the method statement and outlined in the final survey report.

(viii) Methods used and required accuracy of control

The methods and networks used for providing survey control are required and details of the method and equipment proposed must be included in the method statement.

Where a previously defined survey co-ordinate system exists:

1.	The necessary information will be supplied in the project brief to allow the re-occupation of previously installed points. This will include a full listing of 3-D coordinates and witness diagrams

Where a previous survey co-ordinate system does not exist:

1.	A new system may be established.

Individual survey control points are to be provided to a geometric precision/accuracy of twice the geometric precision/accuracy required by individual measurements.

(ix) Registration procedures

The residuals of the registration process must be shown to be equal to or better than the geometric precision required by the end deliverable. CALTRANS (2011) stipulates maximum registration error in horizontal and vertical dimension for Type A topographic survey (refers to “Hard Surface”) as 0.010 m and 0.006 m, respectively; and that of Type B topographic survey as 0.050 m and 0.030 m, respectively (refers to Earthwork and lower accuracy topographic survey).

Where registration is done solely via a resection calculation:

1.	Each scan must contain a minimum of 4 appropriately distributed XYZ control points/targets.
2.	Least squares based with use of combined, multiple registration methodologies (i.e. survey methods, cloud-to-cloud and objects in scene such as lamp posts, pillars, etc.)
3.	The residuals of the registration process and the geometric precision of the estimated parameters should be noted in the survey report.

Where registration is performed using surface matching techniques:

1.	The data must include at least n + 3 appropriately distributed XYZ control points/targets, where n is the number of scans made.
2.	In-Field on-board registration and residual review - to enable efficient field work process (no need to return to site)
3.	The residuals of the registration process and the precisions of the estimated parameters should be noted in the survey report.
4.	The geometric accuracy of the fit should be noted in the survey report

Where registration is done using a known station position and orientation:

1.	The data must include at least 3 appropriately distributed XYZ control points
2.	The residuals of the registration process and the precisions of the estimated parameters should be noted in the survey report
3.	Survey-grade dual-axis compensator (1.5 sec accuracy at minimum) to enable proper resection and efficient geo-referencing of scans

Irregular features in the scan data caused by cracks or features on the subject that could be misinterpreted as errors in the registration must be augmented with illustrative photography and noted in the final survey report.

(x) Targeting/control points

A description of the targets to be used must be given in the method statement and the location and naming of targets is to be clearly given on the site sketches that accompany the survey report.

The use of natural detail points should be avoided, but where necessary the use of distinct features is acceptable providing the sampling spacing of the scan is sufficient to maintain the registration requirements in Section 5.3.2.(a)(ix). The use of features at distinct corners or edges is not permitted. Where natural detail points are to be used this must be noted in the method statement.

The horizontal and vertical surveyed positional local accuracies of control points for STLS as recommended by CALTRANS (2011) are 0.010 m and 0.006 m, respectively, for Type A topographic survey, i.e. for hard surface. For Type B lower order topographic survey, the corresponding accuracies are both 0.030 m.

(xi) Intensity/colour

Intensity/colour information will be recorded on a per point basis at each scan position where the instrumentation allows this and such information has been specified in the project brief.

(xii) Supporting imagery

Additional image data to show the location of the scanner and the subject being scanned is required for narrative purposes. This imagery will be of a high resolution and clearly portray the subject in question.

(xiii) Virtual Survey

The submission of deliverables must be in a format supporting the techniques of “Virtual Surveying” using relevant software packages

(xiv) Web-Based Point Cloud Format

Web-based point clouds with color-coded information must be supplied with free viewers. These viewers should have collaborative functions to share markups such as measurements, textual information, basic drawings or links to external documents, images, videos, etc

(xv) Delivery of survey material

Certain standard deliverables are required for every survey performed. See Section 5.3.2.(c)(iii) for a full description of the appropriate media, formats and required metadata. The standard deliverables in digital form, unless stated in the project brief, are:

1	Project metadata.
	• Raw scan data. • Scan metadata • Control information. • Registration information for all raw scans to the site coordinate system. • Registered scan data. • Web-Base Point Cloud Data

A hard copy survey report is also required containing:

1	Witness/illustrative diagrams outlining the position of scanning stations and control points.
2	Details of the traverse/control network used, a list of the three-dimensional positions of all control points and residuals for the computed XYZ control.
3	The precision of any parameters derived in the registration process for each scan along with the residuals of the registration.
4	A summary outlining the completeness of the point cloud and all known data voids.
5	All site sketches/additional field notes.

(xvi) Other operation specifications

Table 2 shows other operation specifications of STLS.

Table 2: Operation Specifications for STLS (CALTRANS, 2011)

Operation Specification	STLS Scan Application	
	Scan Type A	**Scan Type B**
Level compensator should be turned ON unless unusual situations (See Note 1) require that it be turned OFF.	Each setup	
Strength of figure: α is the angle between each pair of adjacent control targets measured from the scanner position.	Recommended $60^\circ \leq \alpha \leq 120^\circ$	Recommended $40^\circ \leq \alpha \leq 140^\circ$
Target placed at optimal distance to produce desired results	Each setup	
Fixed height targets (when occupying control)	Required	Recommended
Check position of instrument and targets over occupied control points	Begin and end of each set-up	
Distance to object scanned not to exceed best practices for laser scanner and conditions - Equipment dependent	Manufacturer's specification	
Distance to object scanned not to exceed scanner capabilities to achieve required accuracy and point density.	Each setup	
Minimum measurement distance	Manufacturer's specification	
Registration of multiple scans in post-processing	Required	
Post-processing software registration error report	Required	

Notes:

1. Unusual situations could include bridge set-up with heavy truck traffic or high winds which cause excessive instrument vibration.
2. Type A refers to "Hard Surface" topographic survey and Type B refers to Earthwork and lower accuracy topographic survey

(b) Health and Safety

Readers are referred to IEC 60825:1 (2001) for the full precautions on the user of lasers. However, explicitly:

1	Systems that use Class 3B or Class 4 lasers are not acceptable for use on Client sites.

(c) Storage and archive of point cloud data

(i) Data format

To assist in the future management of scan data all data is required to be delivered in a pre-specified format with emphasis on the transferability of data between software systems. The proposed delivery format of the point cloud should be discussed with Client before the survey and outlined in the method statement.

(ii) File naming convention

Filenames should agree with the following file-naming convention

No of Characters	Code
Flexible (~15 preferred)	Alphanumeric code for project in question + "_"
6	Date of data capture in YYMMDD
2	Code defining data type: • US – unregistered scan data • RS – registered scan data • SM – scan metadata • SR – scan registration information • PM – project metadata • SC – Survey control information • ID– image displaying scan data
3	Number of scan (leading/trailing zeros to be used)

The following examples are given for NTU in 2 May 2008:

EXAMPLE	DESCRIPTION
NTU_080502US001.***	The raw (un-registered) scan data, where *** is the appropriate extension.
NTU_080502RS001.***	Registered scan data, where *** is the appropriate extension.
NTU_080502ID001.jpg	An image showing the scan data in the file NTU080502L001.*** and/or NTU080502K001.***.
NTU_080502SM001.txt	An ASCII text file providing the metadata for the file NTU080502L001.*** and/or NTU080502K001.*** outlined in Section 7.3.2 (d)(iii).
NTU_080502SR001.txt	An ASCII text file providing the registration parameters required to transform the data onto the defined system (normally the local site coordinate system) for the file NTU080502L001.*** as outlined in Section 7.3.2 (d)(v).
NTU_080502PM.txt	An ASCII text file providing the project metadata outlined in Section 7.3.2 (d)(iv).
NTU_080502SC.txt	An ASCII text file providing the survey control information outlined in Section 7.3.2 (d)(vi).

(iii) Scan metadata

Metadata (information relating to the captured information) is required with all raw scan data and scanning projects. Metadata should be provided in both hardcopy and digital form.

It must include:

1	File name of the raw data
2	Date of capture
3	Scanning system used (with manufacturers serial number)
4	Company name
5	Monument name
6	Monument number (if known)
7	Survey number (if known)
8	Scan number (unique scan number for this survey)
9	Total number of points
10	Point density on the object (with reference range)
11	Weather during scanning (external scans only)
12	The file name of an image, located at the point of collection, showing the data collected – the filename should be the same as the filename of the raw data file.

(iv) Project metadata

A single project metadata file is required with the project. This must include the following:

1	Filename(s) of the raw data used in the registration
2	Data of capture (month and year)
3	Scanning system(s) used (with manufacturers serial number(s))
4	Company name
5	Monument name
6	Monument number (if known)
7	Survey number (if known)
8	Number of individual scans
9	Scan numbers of all scans
10	Total number of points
11	Filename of the control data
12	Description of registration method (e.g. “All scans registered to local site grid using targeted points.”)
13	An index plan showing the data collected with individual scan points named
14	Weather during survey (external scans only)
15	Any scanner specific information.

(v) Registration information

The following information should be supplied as registration information:

1	Translations in the X, Y and Z axes necessary to transform the scan origin to the scan position.
2	Rotations around the X, Y and Z axes. This should be carried out in the order X, Y and Z.

(vi) Control information

The following information should be supplied as control information

1	Point ID, X, Y, Z, σDX, σDY, σDZ, comment (optional)

Individual file sizes are to be limited to the capacity of a standard single CD-ROM. The compression of files is acceptable using standard compression software such as Winzip. If capacity allows, multiple scans can be placed on a single CD

(viii) Media

Unless otherwise stated, all data is to be provided on CD-ROM's. Any text referencing is to be provided on a suitable label applied to the top surface of the CD-ROM.

(ix) Retention of survey documentation

On request the Contractor shall make available to Client all materials used for the compilation of the required survey. This information must be retained on file by the contractors for a minimum of six years.

This will include: field notes and/or diagrams generated whilst on site; the raw and processed data used for the final computation of coordinate and level values; and a working digital copy of the Metric Survey data that forms each survey (this is to include formatted 2-D and 'raw' 3-D data files). The precise digital format and file type of this archive is that specified in the project brief. If during this period the contractor wishes to change the format of this data archive, they are to seek Client's permission.

(d) Example metadata

(i) Scan position metadata

PARAMETER	EXAMPLE
File name of the raw data	NTU_080502US02.xyz
Scanning system used (with serial number)	HDS6000 (123456)
Monument name	NTU_1
Survey number (if known)	NA
Total number of points	857 446
The file name of an image, located at the point of collection	NTU_080502ID02.jpg
Date of capture	29/01/2008
Company name	NTU
Monument number (if known)	NA
Scan number (unique scan number for this survey)	2
Sampling spacing on the object	0.015 m (@ 30 m)
Weather during survey	Sunny and calm

(ii) Project metadata

Filename(s) of the raw data used in the registration	NTU_080502US001.txt (1 – in index plan) NTU_080502US002.txt (2 – in index plan) NTU_080502US003.txt (3 – in index plan) NTU_080502US004.txt (4 – in index plan) NTU_080502US005.txt (5 – in index plan) NTU_080502US006.txt (6 – in index plan)
Data of capture (month and year)	Jan 2008
Scanning system(s) used (with serial number(s))	HDS6000 (123456)
Company name	NTU
Monument name	NTU_1
Monument number (if known)	NA
Survey number (if known)	NA
Number of individual scans	6
Scan numbers of all scans	1- 6
Total number of points	8270541
Description of registration method	All scans registered to local site grid using targeted points and resection calculation
Filename of control data	NTU_080502SC.xyz
Weather during survey	Sunny and calm
An index plan showing the data collected with individual scan points named	See Plan A

5.4 Mobile Terrestrial Laser Scanning

Reference is made to Chapter 15 of the California Department of Transport (Caltrans) Survey Manual on Terrestrial Laser Scanning Specifications (2011).

Mobile terrestrial laser scanning (MTLS) is an emerging technology that uses laser scanner technology in combination with Global Navigation Satellite Systems (GNSS) and other sensors to produce accurate and precise geospatial data from a moving vehicle. MTLS platforms may include Sport Utility Vehicles, Pick-up Trucks, boats, and other types of vehicles. Safety and efficiency of data collection are compelling reasons to use mobile laser scanning. The potential to acquire a great deal of data in a short time is enormous, especially in areas that are not conducive to traditional methods of data collection.

The MTLS collects laser measurement data continuously throughout each MTLS run. The position and orientation of the scanner(s) are determined using a combination of data from GNSS, an inertial measurement unit (IMU), and possibly other sensors, such as precise odometers. An IMU uses a computer, motion sensors (accelerometers) and rotation sensors (gyroscopes) to continuously calculate and record the position, orientation, and velocity (direction and speed) of a moving object without the need for external references.

GNSS has vertical accuracy limitations and will not meet engineering and topographic survey standards. Additional control points (local transformation points) within the MTLS scan area are required to calibrate the point cloud data by adjusting point cloud elevations. The point cloud is adjusted by a local transformation to well defined points throughout the project area to produce the final geospatial values. The final scan values are then compared to independently measured validation points.

5.4.1 Considerations in using MTLS

(a) **Useful Range of Scanner -** Since a laser scanner is capable of scanning features over long distances, and the accuracy of the scan data diminishes beyond a certain distance, care should be taken to ensure that the final dataset does not include any portion of point cloud data whose accuracy is compromised by measurements outside the useful range of the scanner.

(b) **Local Transformation and Validation Points -** Local transformation points serve as control for transformation of the point clouds. Validation points allow for QA/QC checks of the adjusted scan data. Local transformation and validation points may be targeted control points, recognizable features, or coordinate positions within the scans. When used, targets should be located as close to the MTLS vehicle path possible without compromising safety. The MTLS vehicle operator(s) should adjust the vehicle speed at the target area so that the target(s) will be scanned at sufficient density to ensure good target recognition. Local transformation points and Validation Points shall be located at the beginning, end, and evenly spaced throughout the project to ensure that the project is “bracketed.” Validation points are used to check the geospatial data adjustment to the local transformation points.

(c) **Mission Planning -** Before the MTLS project commences a mission planning session should be conducted to assure that there are enough satellites available during the data collection and that the PDOP meets the requirements.

(d) **GNSS Project Control -** The GNSS Control Stations that will be used to control the post-processed kinematic adjustment of the MTLS data shall be placed at a maximum of 15-km intervals to ensure that under normal circumstances, no processed baseline exceeds ten (10) km in length.

(e) **Equipment Calibration -** Before and after collecting the MTLS data all of the equipment in the MTLS system shall be calibrated to the manufacturer’s specifications. Sensor alignment procedures shall be performed prior to scanning if the system has been disassembled for transport.

(f) **Redundancy -** MTLS data collection shall be conducted in such a manner as to ensure redundancy of the data.

(g) **Quality Management Plan (QMP) -** The MTLS data provider shall provide a QMP that includes descriptions of the proposed quality control and quality assurance plan. The QMP shall address the requirements set forth in this document as well as other project specific QA/QC measures The QA/QC report shall list the results of the MTLS including but not limited to the following documentation:

- MTLS system reports
- PDOP values during the survey
- Separation of forward and reverse solutions (difference between forward and reverse post-processed roll, pitch, yaw and XYZ positions solution). Forward and reverse refers to time: processing from beginning-to-end and end-to-beginning.
- Areas of the project that the data collected exceeded the maximum elapsed time or distance traveled of uncorrected IMU drift due to degraded, lost, or obstructed GNSS signal reception.
- Comparison of elevation data from overlapping (sidelap) runs
- Comparison of points at the area of overlap (endlap) if more than one GNSS base is used.
- Statistical comparison of point cloud data and finished products to validation points
- Statistical comparison of adjusted point cloud data and redundant validation points

(h) **MTLS Deliverables -** The deliverables from a MTLS project should be specified in the contract with the provider. If a point cloud is the final deliverable, considerable office time will be required to extract data in a CADD/DTM usable format. The ratio of field time to office time will vary greatly with the complexity of the scanned roadway. Resources for data extraction (computers, programs, and trained personnel) must be available. If the mobile scan provider is delivering a finished CADD/DTM file, office time will be reduced to QA of the final product. The simplest form of the processed MTLS data is a “point cloud”, which can be saved in a scanner specific format or an ASCII file format containing XYZI data. If image overlay data is available, the post-processed point cloud may be delivered in an XYZIRGB format. Deliverables specific to MTLS surveys may include, but are not limited to:

- Registered point clouds (XYZI or XYZIRGB files) in ASCII, CSV, ASTM E57 3D Imaging Data Exchange Format (E2761), XML, LAS, or other specified format
- Raw data files
- Digital video or photo mosaic files
- Survey narrative report and QA/QC files
- Geospatial metadata files

(i) **MTLS Documentation -** The documentation of MTLS projects must show clear data lineage from the published primary control to the final deliverables. The data path of the entire process must be defined, documented, assessable, and allow for identifying adjustment or modification. The survey report, completed by the person in responsible charge of the survey, shall contain the following general information, the specific information required by each survey method, and any appropriate supplemental information, including geospatial metadata files:

- Project name & identification
- Survey date, limits, and purpose
- Datum, epoch, and units
- Control found, held, and set for the survey
- Personnel, equipment, and surveying methods used
- Problems encountered
- Any other pertinent information such as GNSS observation logs
- Dated signature and seal of the person in charge

Documentation specific to mobile terrestrial laser scanning surveys includes, but is not limited to:

- **Control Lineage or Pedigree**
  - Primary control held or established
  - Project control held or established
  - Local transformation points

  - Validation points
  - Adjustment report for control and validation points
  - Base station observation logs (occupation data, obstruction diagram, atmospheric conditions, etc.)

- **Control for Scanner Registration and QC**
  - Local transformation points
  - Validation points
  - GNSS Accuracy Report
  - GNSS satellite visibility and PDOP reports
  - IMU Accuracy Report
  - Trajectory reports
- **Registration Reports**
  - Results of target and cloud to cloud registration
  - QA/QC reports as described in Section 7.4.1 (g)
  - Results of finished products to validation points
  - Geospatial metadata files

5.4.2 Template Specifications for Collection of Point Cloud Data using MTLS

The template specifications for STLS are generally applicable for MTLS, except for Sections 5.3.2 (a)(ix) and 5.3.2 (c)(v) on Registration Procedure and Information and Sections 5.3.2 (a)(x) and 5.3.2 (c)(vi) on Targeting/control points and Control information.

California Department of Transportation (CALTRANS, (2011) publishes a specification for MTLS (Table 3).

Table 3 (part 1 of 2): Specifications for MTLS (CALTRANS, 2011)

Operation Specification	MTLS Scan Application	
	Scan Type A@	Scan Type B@
MTLS equipment must be capable of collecting data at the intended accuracy and precision for the project.	Required	
Initial calibration of MTLS system (per manufacturers specs)	As Required	
Dual-frequency GNSS recording data at 1 Hz or faster	Required	
Minimum IMU positioning data sampling rate capability	100 Hz	
Maximum IMU Gyro Rate Bias	1 degree per hour	
Maximum IMU Angular Random Walk (ARW)	0.125 degree per √hour	
Maximum IMU Gyro Rate Scale Factor	150 ppm	
Minimum IMU uncorrected positioning capability due to lost or degraded GNSS signal	GNSS outage of 60 seconds or 1.0 km distance travelled	
Maximum duration or distance travelled with degraded or lost GNSS signal resulting in uncorrected IMU positioning	GNSS outage of 60 seconds or 1.0 km distance travelled	
Maximum uncorrected IMU X-Y positioning drift error for 60 second duration or 1.0 km distance of GNSS outage	0.100m	
Maximum uncorrected IMU Z positioning drift error for 60 second duration or 1.0 km distance of GNSS outage	0.070m	
Maximum uncorrected IMU roll and pitch error/variation for 60 second duration or 1.0 km distance of GNSS outage	0.020 degrees RMS	
Maximum uncorrected IMU true heading error/variation for 60 second duration or 1.0 km distance of GNSS outage	0.020 degrees RMS	
Project control should be the constraint for GNSS positioning	Yes	
Minimum order of accuracy for GNSS base station horizontal (H) and vertical (V) project control	Horizontal – 2nd Vertical – 3rd	
MTLS Local Transformation Point and Validation Point surveyed positional accuracy requirements.	H ≤ 0.010 m V ≤ 0.005 m	H and V ≤ 0.030 m
GNSS base stations located at each end of project	Recommended	
Maximum post-processed baseline length	8 km	
Maximum PDOP during MTLS data acquisition	Five (5)	

Note: Type A refers to "Hard Surface" topographic survey and Type B refers to Earthwork and lower accuracy topographic survey.

Table 3 (part 2 of 2): Specifications for MTLS (CALTRANS)

Operation Specification	MTLS Scan Application	
	Scan Type A	Scan Type B
Minimum number of common healthy satellites in view for GNSS base stations and mobile scanner (See Notes 1 and 4)	Five (5)	
Minimum overlapping coverage between adjacent runs	20% sidelap	
Monitor MTLS system operation for GNSS reception	Throughout each pass	
Monitor MTLS system operation for IMU operation and distance and duration of any uncorrected drift	Throughout each pass	
Monitor MTLS laser scanner operation for proper function	Throughout each pass	
Monitor MTLS system vehicle speed	Throughout each pass	
Minimum orbit ephemeris for kinematic post-processing	Broadcast	
Observations – sufficient point density to model objects (See Note 1)	Each pass	
Vehicle speed – limit to maintain required point density	Each pass	
Filter data to exclude measurements exceeding scanner range	Each pass	
Local transformation point maximum stationing spacing throughout the project on each side of scanned roadway	500 m intervals	750 m intervals
Validation point maximum stationing spacing throughout the project on each side of scanned roadway for QC purposes as safety conditions permit. (See Note 3)	150 m intervals	250 m intervals

Notes:

Type A refers to “Hard Surface” topographic survey and Type B refers to Earthwork and lower accuracy topographic survey

1. Areas in the project that have poor satellite visibility should be identified and a plan to minimize the effect on the data developed.
2. Reconnaissance of the project area shall be carried out to determine the best time to collect the data to minimize excessive “noises” in the data collection from surrounding traffic or other factors.
3. If safety conditions permit, additional validation points should be added in challenging GNSS environments such as mid sections of tunnels and urban canyons.
4. GNSS coverage of less than five (5) satellites in view must not exceed the uncorrected position time or distance travelled capabilities of the MTLS system IMU.

6. CAD Drawing Standard

Reference is made to “A/E/C CADD Standard Release 3”, published by The CADD/GIS Technology Center (CGTC) for facilities, infrastructure, and environment, and Singapore Standard CP 83 on Code or Practice for Construction Computed-Aided Design (CAD).

The A/E/C CAD Standard Manual developed by the CADD/GIS Technology Center (CGTC) for Facilities, Infrastructure, and Environment is to eliminate redundant CAD standardization efforts.

6.1 Organisation and Naming of CAD Files

This guideline covers a filename format and a recommended directory structure. Each filename format and directory structure can be further sub-divided into fields. Each field describes certain attributes of the file or directory.

(a) Formats of filename

The format requires 6 mandatory fields and an optional user-defined field. The length of project identification filed may vary from 3 to 5 characters depending on the user's need. To enhance computer processing and readability, the project identification field is to be separated from the remaining fields by means of an underscore character "_". The description details as in Table 4 below.

Table 4: Description of fields in filename format

Name of field	Description of field	Number of characters
Project identification	Represent files of the same project.	3 -5; 4 is recommended
Author	Individual/company/organisation responsible for creating the file.	2
Type-of-work	Nature and scope of work.	2
View plane	Level in a multi-storey building or orientation of an elevation view.	2
Zone	Zone of the construction site	2
Version	Major revisions	2
User-defined	User-defined code for in-house applications. (optional field)	-

The seven fields in filename format are to be arranged in the format as shown in Table 5.

Table 5: Filename Format (*Optional field)

<table>
<tr><th colspan="4">Project I.D.</th><th></th><th colspan="2">Author</th><th colspan="2">Type-of-work</th><th colspan="2">View Plane</th><th colspan="2">Zone</th><th colspan="2">Version</th><th>User-defined*</th></tr>
<tr><td></td><td></td><td></td><td></td><td>–</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

For Author field, the first character indicates the discipline of the originator of the layer. It is a single alphabet in capital letter as shown in Table 6.

Table 6: Codes for the first character of author field

Code	Author description
A	Architect
C	Civil Engineer
E	Electrical Engineer
L	Land Surveyor
M	Mechanical Engineer
N	Equipment Supplier
S	Structural Engineer
T	Telecommunication/Signal Engineer
V	Other disciplines
X	Contractor

The second character provides further definition of the author whenever necessary. If the first character is sufficient to define the author of the layer, a hyphen "_" shall be used as the second character of this field. Example: A- for architect and S- for structural engineer.

This second alphanumeric character can also be used to denote different authors from the same discipline involved in the same project. Example: A1 & A2 represent two different architects working on the same project.

Type-of-work field represents the nature and scope of work in the CAD file. Please refer to Appendix A and Appendix A of CP83 Part 3 for the list of codes.

View plane field represents the level in a multi-storey building or the orientation of the elevation view. In Table 7, numeric variables are represented by "1".

Table 7: Codes for the view plane field

Code	Description
11	Numeric -Level of storey or lowest level of a typical level (11)
A-	Attic
B1	Basement 1
M1	Mezzanine 1
R-	Roof
--	Whole project (two "dashes")
N-	North elevation view
E-	East elevation view
S-	South elevation view
W-	West elevation view
NE	Northeast elevation view
SE	Southeast elevation view
SW	Southwest elevation view
NW	Northwest elevation view
3D	3-dimensional/isometric view
AA	Duplicated alphabet -Section view (AA)
LX	Longitudinal section for civil works
DT	Details

When the CAD file contains only page information such as notes, legend, diagrams, or schedules instead of CAD models, the view plane is no longer relevant and the two characters can be used for description of the form of information presented. Table 8 depicts the forms of information and codes.

Table 8: Forms of information and codes

Code	Forms of information
DG	Diagram
LG	Legend
NT	Notes
SH	Schedule
SD	Standard drawings

Zone field represents the construction zone or block number of the project. One (1) alphanumeric character is used for this field. The codes allowed in this field are A to Z, 1 to 9 and the hyphen. character (-). "-" represents all the zones in the project. If the three characters allocated for the view plan and zone fields are not relevant to the type of construction, they can be used for further description of the type-of-work with in-house codes. However, these codes are required to be documented and communicated between different parties of the project.

Version field represents major revisions of the CAD file. One (1) alphanumeric character is used for this field. The sequence of codes denoting the version is A, B, C ... Z, 1, 2, 3, ... 9. The character "X" is reserved for referenced files so that the filename does not have to be amended each time it is updated.

Examples of Filename format

Example 1: **EWOO_A2FP31B2C**

A file of the East Wood project in the year 2000 (EWOO in the Project Identification field), prepared by a second architect (A2 in the Author field), containing floor plans (FP in the Type-of-work field), at level 31 (31 in the View Plane field) of zone B2 (B2 in the Zone field), and is the third version of the file (C-in the Version field).

Example 2: **EW01_C-RDXX12B**

A file of the East Wood project in the year 2001 (EW01 in the Project Identification field), prepared by a civil engineer (C-in the Author field), containing road works (RD in the Type-of-work field) of section "XX" (XX in the View Plane field) in zone 12 (12 in the Zone field), and is the second version of the file (B in the Version field).

6.2 Level/Layer Assignments

This guideline was prepared with reference to the following publications:

1. ISO 13567: 1998 Technical product documentation - Organisation and naming of layers for CAD, Part 1 : Overview and principles

2. ISO 13567: 1998 Technical product documentation - Organisation and naming of layers for CAD, Part 2 : Concepts, format and codes used in construction documentation

Acknowledgement is made for the use of the information from the above references and Singapore Standard CP 83 which is also based on the above.

This guideline covers the organisation and allocation of layers that are used in CAD files for construction projects and is intended to be used for communication and management purposes. A list of standard CAD layer element names is provided in this code.

(a) Format of layer name

A layer name consists of the following five fields as shown in Table 9.

Table 9: Description of fields in a layer name

Name of field		Description of field	Number of characters
Originator		Individual/company/organisation responsible for preparation and creation of information	2
Element	Main	Main element classification	4
	Sub*	Sub-element classification	4
Presentation*		Forms of information presented, e.g. element, dimension, or text	2
Status*		Status of the construction work, e.g. alterations, to be removed, or existing installations (optional)	1
User-defined*		User-defined code for in-house applications (optional)	-

The above five fields of a CAD layer name are to be arranged in the format as shown in Table 10.

Table 10: Layer Name Format

<table>
<tr><th colspan="2" rowspan="2">Originator</th><th rowspan="2"></th><th colspan="8">Element</th><th rowspan="2"></th><th colspan="2" rowspan="2">Presentation*</th><th rowspan="2"></th><th rowspan="2">Status</th><th rowspan="2"></th><th colspan="4" rowspan="2">User-defined*</th></tr>
<tr><th colspan="4">Main</th><th colspan="4">Sub*</th></tr>
<tr><td></td><td></td><td>–</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>–</td><td></td><td></td><td>–</td><td></td><td>–</td><td></td><td></td><td></td><td></td></tr>
</table>

(NOTE: * -Optional field)

(b) Coding conventions

The first two fields, namely originator and element shall always be used. The underscore character "_ " is used between fields to enhance readability.

Originator field

This first character indicates the discipline of the originator of the layer. It is a single alphabet in capital letter as shown in Table 6.

The second character provides further definition of the originator whenever necessary. Example: AL to denote Landscape Architect. If the first character is sufficient to define the originator of the layer, a hyphen "-" shall be used as the second character of this field. Example: A- for architect and S- for structural engineer.

This second alphanumeric character can also be used to denote different originators from the same discipline involved in the same project. Example: A1 and A2 represent two different architects working on the same project.

Element field

This field indicates the type of construction work or system of the element in the layer. Classification for the construction elements or systems is in the form of eight (8) letters of the alphabet. This element field has two levels of classification, namely, the main and sub-elements (Table 11).

The main element consists of four (4) letters of the alphabet and is mandatory. It identifies the main construction work or system of the element.

The sub-element consists of four (4) letters of the alphabet and is only used for further classification of the main element. For elements where classification using the main element is sufficient, the sub-element may be coded with four (4) hyphen characters "----".

Table 11: shows some examples of classification in element field.

Name of element		Description of elements
Main	**Sub**	
STRC	**---**	Staircases
STRC	**HANR**	Handrails of staircases
WALL	**---**	Walls
WALL	**FIRE**	Fire rated walls

Standard main element names defined based on this classification are provided in the Appendix A of CP83 Part 1. To achieve consistency in the construction industry, existing main element of relevance to topographical survey are provided in Appendix C of this report as well as their sub-elements.

Based on the input from Registered Surveyors, proposed main elements and sub-elements of relevance to topographical survey are also provided in Appendix C.

Users may generate element names that are not in the list of standard elements provided in the appendices of this code for their internal use. However, these user-defined layers shall be properly documented and communicated among the parties involved in the project. While there is no fixed rule in arriving at the 4-character abbreviation for the main and sub-elements, the general rule is to truncate the vowels and try to maintain the first and last characters.

Note that DTM layer (Item: H.1.12 TOPODTM-) is also added in Appendix C. This layer represents terrain and shall include all ground elevations. As this DTM layer can be created from the combination of other layers (so long as the other layer has ground elevations), Appendix C includes an additional column ("contribute to TOPODTM-") to indicate if the respective layer shall also be contributed to the DTM layer.

Presentation field

The Presentation field represents the format or type of information presented and is denoted by one (1) or two (2) alphanumeric characters.

<u>First character</u>

There are two levels of classification in the first character field:

(1) Basic classification

- Element graphics;
- Annotation;
- Model (combination of element and annotation in model space);
- Paper/Page (paper space or page information).

(2) Further classification

- Further classification of annotations: Text, hatching, dimension and marking;
- Further classification of paper/page: Border, tabular information, notes, legends, schedules, and diagrams. The valid codes for the first character of the presentation field are given in Table 12.

Table 12: Codes for first character of presentation field

Code	Content
-	Whole model and drawing page
M	Model, Marking
E	Element graphics
A	Annotation
T	Text, Title *
H	Hatching, Hidden
D	Dimension
P	Page/Paper
B	Border
I	Tabular information
N	Notes
L	Legends
S	Schedules
R	Diagrams

* If Text and TItle need to be on separate layers, "TL" can be used for the latter

Second character

For element graphics, the second character represents the projection/view of the element shown in the layer. The respective views are denoted by one (1) corresponding character as shown in Table 13.

Table 13: Codes for second character of presentation field

Code	Description of views
-	All views
1	Elevations
2	Sections
3	3D views
4	Plans
0	Details

Status

The Status field is optional and it represents the status of entities used in addition and alteration (A & A) works. It is denoted by one (1) character code as shown in Table 14.

Table 14: Codes for status field

Code	Content
N	New work
E	Existinq to remain
R	Existinq to be removed
0	Existinq to be moved -Oriqinal position
F	Existinq to be moved -Final position
T	Temporary work

User-defined field

Users may use the user-defined field for additional information or for further subdivision of layers. However, information of these user-defined fields must be properly documented and communicated among the various parties involved.

(c) Examples of layer name structure

Example 1: **A-_WALL----_E-**

A layer prepared by an architect (A- in the Originator field) containing element graphics (E- in the Presentation field) of walls (WALL as main element and ----as the sub-element in the Element field).

Example 2: **A2_AREACALC_I-**

A layer prepared by a second architect (A2 in the Originator field) containing tabulated information (I- in the Presentation field) of area calculation (AREA as main element and CALC as the sub-element in the Element field).

Example 3: **C-_ANOT----_D-**

A layer prepared by a civil engineer (C- in the Originator field) containing dimensions (D- in the Presentation field) for the whole CAD file (ANOT as main element and ---- as the sub-element in the Element field).

Example 4: **C-_SDRNPIPE_ED**

A layer prepared by a civil engineer (C- in the Originator field) containing element graphic details (ED in the Presentation field), for a surface water drainage pipe installation (SDRN as main element and PIPE as the sub-element in the Element field).

Example 5: **S-_SLAB----_M-**

A layer prepared by a structural engineer (S- in the Originator field) containing only markings (M- in the Presentation field) of slab (SLAB as main element and ---- as the sub-element in the Element field).

Example 6: **C-SEWRMINR_E-_R**

A layer prepared by a civil engineer (C- in the Originator field) containing element graphics (E- in the Presentation field) showing the existing minor sewers (SEWR as main element and MINR as the sub-element in the Element field) to be removed (R in the status field).

Example 7: **E-_ELECCABL_R-_T**

A layer prepared by an electrical engineer (E- in the Originator field) containing electrical wiring (ELEC as main element and CABL as the sub-element in the Element field) single line diagrams (R in the Presentation field) for temporary work (T in the Status field).

6.3 CAD Symbology

The standard symbology in CAD drawings could be categorized into 2D or 3D applications. 2D symbols shall not to be used in the creation of surfaces uses TIN (Triangular Irregular Network).

Both the 2D and 3D symbols could be surveyed using 0-symbol (i.e. with continuous, dashed or dashdot line only), 1-point symbol, 2-point symbol, 3-point symbol or 2-point+width symbol. Appendix D shows the features with 2D symbols.

7. Data Presentation

Most current topographic products are limited to representing the real world in only two dimensions. As the real world exists in three dimensional objects, which are becoming more and more complex due to increasing multiple land use, accurate topographic models have to portray the third dimension. The addition of this third dimension indicates that the model allows multiple z coordinates at a specific x,y location, for instance in vertical faces Applications of 3D modeling are not limited to the terrain surface and also objects built directly on top (e.g. aerial features) or beneath (e.g. subsurface features) it.

Switching from 2D to 3D data representation causes a substantial increase in data volume. Even in the simplest cases the increase is larger than what the non-expert might expect. For instance, consider a cube-shaped building. In a 2D map, this building will be represented by a single polygon, whereas the 3D representation already consists of six (four walls, a roof and a floor) polygons. In real 3D data sets this increase will be larger, as more details will be captured, like roof shapes and more complex building designs. To complicate matters further, one will integrate terrain heights.

7.1 Point, Line, Surface

Generally, a topographic map is printed on a flat piece of paper yet it provides a picture of the terrain and manmade features through the use of contour lines, colour and symbols. Contour lines are normally employed to represent the general undulating and elevation of the land, such as ridges, valleys, and hills. Colour and symbols are used to represent other features on the land, such as water, vegetation, roads, boundaries, urban areas and structures.

Topographic features on earth surface are captured using various surveying techniques and commonly derived as survey points with x,y,z encrypted on a native format. These survey points are essentially represented on plain drawings environment by a native cross and relevant symbols multiple points are then connected to illustrate linear objects such as Road, footpath, drainage, wall etc with corresponding z values at each vertices. Contour lines with specific intervals are generated using survey points to represent the general height of a particular undulating surface. Subsequently, multiple lines are connected to form a closed polygon known as Surface. . Surface could be appeared in regular or irregular shape such as building footprint, swimming pool or lake.

7.2 Contours

Contour lines show the height above sea level. The closer the lines, the steeper the slope. Figure 3 showed when close together, contour lines indicate steep slope; when far apart, contour lines indicate a gentle slope.

At least 90% of all contours shall be within one half of the specified contour interval. Any contour which can be brought within this vertical tolerance by moving its plotted position in any direction by an amount equal to 1/10 of the horizontal distance between contours, or 0.5 mm whichever the greater, shall be considered to be correct.

Different scale of map or plan may have different contour interval. For instance, in a topographical plan, contour interval may vary between 0.5m to 1m depends on steepness of the site and the resolution of final output to be produced. However contour only limited to illustrate in 2D presentation, thus Digital Terrain Model (DTM) is needed to further describe the terrain surface in 3D. Appendix B shows the recommended contour interval for different kind of project and activities.

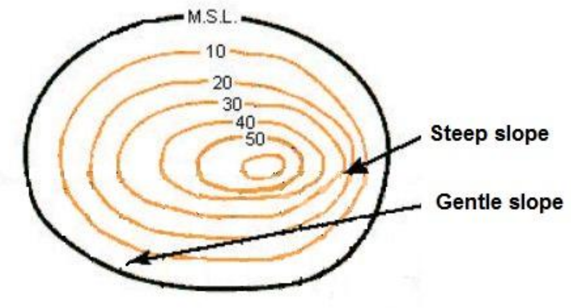

Figure 3: Contour

7.3 Digital Terrain Model (DTM)

A Digital Terrain Model (DTM) is a digital model or 3D representation of a continuous surface of terrain and it represents the bare ground surface without any objects like plants and buildings. Continuous surfaces can be discretized into sets of single basic units, such as square, triangular, or hexagonal cells, or into irregular triangles (which known as Triangulated Irregular Network,TIN) or polygons which are tessellated to form geographical representations. The use of irregular triangles, long used in land surveying, is based on the principle of triangulation whereby the continuous surface of the land is approximated by a mesh of triangles whose apices or nodes are given by measured 'spot heights' at carefully located trigonometric points. Figure 4 showed the sample of vector terrain in the form of TIN. To optimize and better illustration of terrain surface, TIN are normally converted into raster grid terrain which commonly shared across any functional organizations.

Figure 4: Terrain in the form of TIN

Terrain model will then serve as the base to 3D topographic features which will be placed on top or beneath the model. Note that it is presumed that all 3D features are connected to the earth surface. The footprint of these volumetric features (e.g. buildings, tunnels, bridges) shall sit and intersect to the terrain model without any gap in between.

7.4 2D and 3D Symbols

ArcGIS Resource Centre cites that “3D symbol is a 2D symbol with extended properties. These properties enhance 2D symbols so they can be viewed in 3D …”. Additional properties would be referred as geometrical height of topographical objects including manmade and natural feature. These height information would be beneficial for various analysis purposes such as shadow analysis, wind-flow analysis, climate studies, civil aviation control etc. 3D features could be modeled as 3D models by import from Collaborative Design Activity (COLLADA) (.dae), OpenFlight 15.8 (.flt), SketchUp (.skp), 3ds max (.3ds), or VRML 2.0 models (.wrl), or Billboards (PNG, JPEG, BMP, TIFF, GIF, and so forth). The available eight (8) categories of features are 3D Basic, 3D Billboards, 3D Buildings, 3D Industrial, 3D Residential, 3D Street Furniture, 3D Tree and 3D Vehicles which are about half the 14 features as listed in Table A of Appendix A.

On the assumption that 2D topographic plan are still required to be produced according to stipulated drawing standard, such as CP83, there is a need to incorporate 2D symbols into the 3D model in separate layers or treat as separate objects. These 2D symbols could be drapped to the DTM of the model. Figure 5 showed a DTM with contour lines and 3D buildings. 2D Cadastral boundary could also be draped over the DTM (Fig. 6).

Figure 5: DTM with Contours and Building

Figure 6: 3D Scenes with draped 2D features which take on the z-coordinates of the DTM

From the illustrations as demonstrated in Figs. 5 and 6, it is feasible, with relevant selection of the layers or 3D objects, to produce 2D topographical plan by printing the plan view of the 3D scene. This negative effect of this approach is the duplicated 2D symbols of some of the 3D objects.

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Glossary

Accuracy	The ability of a measurement to match the actual value of the quantity being measured.
Ambiguity	The unknown number of whole wavelengths of the carrier signal contained in an unbroken set of measurements from a single satellite at a single receiver.
Annotation	A critical or explanatory note or body of notes added as text.
ASCII	*American Standard Code for Information Interchange* A standard code, consisting of 128 7-bit combinations, for characters stored in a computer or to be transmitted between computers.
ASTM	American Society for Testing Materials
Baselines	A line with a specific value that can serve as a basis of comparison or control, for the purposes of measurement, calculation, or location.
Cadastre	An official register showing details of ownership, boundaries, and value of real property in a district, commonly used for taxation purposes
Contour Line	A line joining points of equal height or depth of a surface on a map.
Contour intervals	The difference in altitude represented by the space between two contour lines on a map
CSV	*Comma Separated Values* A file format used as a portable representation of a database. Each line is one entry or record and the fields in a record are separated by commas. Commas may be followed by arbitrary space and/or tab characters which are ignored. If field includes a comma, the whole field must be surrounded with double quotes.
Datum	A reference from which measurements are made.
DTM	Digital Terrain Model A digital representation of ground surface elevation or terrain.
Eccentric corrections	Off-center correction
Elevation	The height of something above a given or implied place, often above sea level
Ellipsoidal heights	The height of an object above the reference ellipsoid in use. This term is generally used to qualify an elevation as being measured from the ellipsoid as opposed to the geoid. GPS systems calculate ellipsoidal height.
Encroachment	Entry to another's property without right or permission
Geographic Information System (GIS)	A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information.

Geoid	A model of the equipotential surface of the earth's gravity field that is best approximated by the mean sea level over the oceans which extends hypothetically beneath all land surfaces
GNSS	*Global Navigation Satellite Systems* Various operational and proposed satellite positioning systems, including the U.S. Global Positioning System (GPS), the Russian Global'naya Navigatsionnaya Sputnikovaya Sistema (GLONASS), the European Union Galileo, and others.
GPS	*Global Positioning System* A system of earth-orbiting satellites, transmitting signals continuously towards the earth, that enables the position of a receiving device on or near the earth's surface to be accurately estimated from the difference in arrival times of the signals
Grading plan	A plan which shows the proposed finish of the ground surface of a given site, usually by means of contours and grade elevations.
Height	The vertical distance from the base of something to the top.
Horizontal Control	A system of points whose horizontal positions and interrelationships have been accurately determined for use as fixed references in positioning and correlating map features.
IMU	Inertial measurement unit
Intensity	A measure of field strength or of the energy transmitted by radiation
ISN	Integrated Survey Network
LAS	A public file format for the exchange of 3-dimensional point cloud data between users
Metadata	Information on the dataset
Mosaic	A composite picture or decorative design made by setting small coloured pieces into a surface
Point Cloud	A set of vertices in a three-dimensional coordinate system. These vertices are usually defined by *X*, *Y*, and *Z* coordinates, and typically are intended to be representative of the external surface of an object
Real Time Kinematic (RTK)	A technique used in surveying based on the use of carrier phase measurements of the GNSS signals where a single reference station provides the real-time corrections, providing up to centimetre-level accuracy.
Redundancy	Repetition of information or inclusion of additional information to reduce errors in telecommunication transmissions and computer processing
RMSE	Root Mean Square Error
SGeoid09	Geometric geoid model established by SLA
SiReNT	*Singapore Satellite Positioning Reference Network* An infrastructure set up by the Singapore Land Authority to define Singapore's official spatial reference framework and to support the gazetted cadastral system in SVY21. It is a multi-purpose high precision positioning infrastructure which provides both Post Process Differential Global Positioning System (DGPS) DGPS

	services and Real Time DGPS services. The system supports all types of GPS positioning modes and formats.
Site Plan	A drawing that shows the boundaries of a parcel of land, the topography, important landscape elements that impact design (such as a large oak tree),and the placement of all anticipated major improvements, including buildings, roads and driveways, sanitary sewer lines, and utility connections.
Spot heights	A figure on a map indicating the height of a certain point.
Spot spacing	Interval between adjacent sampling points
Terrain	A particular geographic area; often referred as 'ground'
Terrestrial Laser Scanning (TLS)	A technology that provides highly accurate, three-dimensional imagery of point cloud which enabling designers to experience and work directly with real-world conditions by viewing and manipulating rich point-clouds in computer-aided design software.
TIN	*Triangular Irregular Network* A vector based representation of the physical land surface or sea bottom, made up of irregularly distributed nodes and lines with three dimensional coordinates (x,y, and z) that are arranged in a network of non-overlapping triangles.
Topography	Detailed and precise description for the surface features of a place or region in graphic by indicating their positions and elevations.
Validation points	Used to check the geospatial data adjustment to the local transformation points.
Vertical Control	A series of points on which precise heights, or elevations, have been established. Vertical control stations are typically called bench marks.
XML	*eXtensible Markup language* A simplified version of SGML that can be used, especially on the World Wide Web, to create a tagging scheme that allows elements of a document to be marked according to their content rather than their format.
XYZI	Three dimensional X,Y,Z axes and intensity value
XYZIRGB	Three dimensional X,Y,Z axes, intensity and red green blue value

Appendix A

Table A: List of Features

No.	Feature
1	Permanent buildings/structures
2	Temporary/mobile buildings
3	Visible boundary features: walls, fences, hedges
4	Roads, tracks, footways, paths
5	Street furniture
6	Statutory Authorities' plant and service covers where visible
7	Changes of surface
8	Isolated trees/wooded areas/limits of vegetation
9	Pitches/recreation
10	Private gardens or grounds (off-site areas) – no details listed below
11	Water features
12	Earth works
13	Industrial features
14	Railway features with arranged access
15	Other (specify)

Table A-1: Permanent buildings/structures

No.	Detailed Features
1	Archways, underpasses, culverts
2	Bridge over, bridge under
3	Buildings detailed at plinth line
4	Foundations
5	Overhead features, canopies, porches, etc.
6	Ramps, loading bays
7	Ruins
8	Steps: steps generalised, (‡) Steps individual
9	Structures detailed at plinth line
10	Threshold levels
11	(‡) Boot scraper
12	(†) Gullies
13	(†) Rain water down pipes
14	(†) Rodding eyes
15	(‡) Waste pipes
16	Other (specify)

Note:

(†) Features usually shown only at 1:200 scale and above.

(‡) Features usually shown only at 1:100 scale and above.

Table A-2: Temporary/Mobile building

No.	Detailed Features
1	Garden sheds, greenhouses
2	Mobile buildings
3	Overhead features, canopies, porches, etc.
4	Temporary buildings or structures

Table A-3: Visible boundary features - walls, fences, hedges

No.	Detailed Features
1	Fences: with type, with height
2	Gate: (†) direction of opening shown
3	Hedges, conventionalised below 0.5m width, (‡) to scale
4	Walls: with type, with height, piers generalised, wall single line below 0.25m width
5	(†) Walls, piers surveyed, wall single line below 0.11m width
6	(‡) Walls, piers and widths fully surveyed

Table A-4: Roads, tracks, footways, paths

No.	Detailed Features
1	Channel line - road
2	Centre line - road
3	Camber line on roundabouts
4	Carriageway edge
5	Drop kerbs
6	Top of kerb
7	Crash barriers
8	Gullies, kerb outlets
9	Pedestrian barriers
10	Pedestrian crossings
11	Road markings, e.g. giveway, crossing limits, parking bays, etc.
12	Speed bumps
13	Traffic islands, (†) details
14	Other road features, e.g. vehicle sensors
15	Back edge of footway
16	Paving pattern details
17	Unmade tracks and paths, centre only, (†) sides
18	Footbridge
19	Boardwalk

Table A-5: Street furniture

No.	Detailed Features
1	Belisha Beacons
2	Barriers
3	Bollards
4	Bus stops, bus shelters
5	Control boxes
6	Hoardings
7	Lamp posts
8	Letter (post) boxes
9	Mile posts
10	Notice boards
11	Posts
12	Road signs
13	Street name plates, (‡) wall mounted
14	Ticket machines
15	Traffic signals
16	Troughs
17	Vent pipes
18	(†) Drainage channels
19	(†) Cellar hatches and pavement lights
20	(†) Coal holes
21	(†) Cycle racks
22	(†) Litter bins
23	(†) Reflector posts
24	(†) Salt/grit bins
25	(†) Seats
26	Other (specify)

Table A-6: Statutory Authorities' plant and service covers where visible

No.	Detailed Features
1	Air valves
2	(‡) Cable TV house points
3	Cable TV inspection covers
4	Cabinets (identified)
5	Electric covers
6	Electric poles
7	Fire hydrants, (†) shown to scale
8	Gas/water stop valves and stop cocks (cover)
9	Inspection covers with level
10	Lamp holes
11	Marker posts
12	Overhead wires, (†) building connections to be shown
13	(†) Pole stay wires
14	Surveillance cameras
15	Telecommunications inspection covers
16	Telegraph poles
17	Telephone call boxes
18	(†) Water meter or gas meter covers (distinguished from valve)

Table A-7: Changes of surface

No.	HARD SURFACES	No.	SOFT SURFACES
1	Brick	7	Cultivated
2	Concrete	8	Grassed
3	Metalled	9	(†) Grass, maintained area
4	Paving	10	Planted
5	Setts	11	Rough ground
6	Other (specify)	12	Other (specify)

Table A-8: Isolated trees, wooded areas, limits of vegetation

No.	Detailed Features
1	Bushes/shrubs above 2m diameter
2	Isolated trees above 0.15m trunk diameter, (‡) above 0.1m
3	Ornamental/road side trees, (‡) planting box shown
4	(‡) Staked saplings (individual)
5	Areas of saplings/young trees
6	Edge of vegetation
7	Woodlands perimeter trees/tree canopy only
8	**Tree/bush details required on the drawing or on schedule**
9	Height ... estimated
10	Height ... measured
11	Spread ... (canopy diameter)
12	Trunk diameter/circumference/(girth) at 1.2m above ground
13	Species
14	Other special requirements

Table A-9: Pitches/recreation

No.	Detailed Features
1	Pitch/playground limits only
2	(†) Pitch markings, goal posts
3	(†) Playground apparatus

Water features surveyed in outline only, (†) surveyed in detail.

Table A-11: Water features

No.	Detailed Features
1	Fountain
2	Groynes/sea defences
3	Harbour wall, breakwater
4	High water mark
5	Landing stage
6	Lock, perimeter and gates
7	Low water mark
8	Mooring posts
9	Navigation beacons
10	Outfall pipes
11	Pier, jetty
12	Pond/lake
13	Pond/lake, top of bank
14	Pond/lake, bottom of bank
15	Pond/lake, water level
16	Pond/lake, bed level
17	Pumps
18	River, top of bank
19	River, bottom of bank
20	River, water level
21	River, direction of flow
22	River, bed level
23	Shore line detail exposed at low tide
24	Streams and ditches, top of bank
25	Streams and ditches, bottom of bank
26	Streams and ditches, water level
27	Streams and ditches, direction of flow
28	Streams and ditches, bed level
29	Weirs/waterfalls, indicative features surveyed from the bank

Table A-12: Earthworks

No.	Detailed Features
1	Bank bottom
2	Bank top
3	Mounds, spoil heaps
4	Quarries, pits and mineral workings (limit only)
5	Quarries, pits and mineral workings, detailed survey
6	Retaining wall, base
7	Retaining wall, top
8	Sloping masonry, bottom
9	Sloping masonry, top
10	Terraces
11	Other (specify)

Table A-13: Industrial features

No.	Detailed Features
1	Aerial
2	Cable ducts (specify detail required)
3	Chimneys
4	Chimneys, (with height) (specify)
5	Electric sub stations or transformers (perimeter fence only)
6	Filter beds, limits only
7	Flagstaffs
8	Inspection pits
9	Overhead pipes/cables, (†) height required
10	Pipe work or ducts (specify detail required)
11	Overhead line tower/freestanding mast or pylon
12	(‡) Overhead line tower/freestanding mast or pylon, bases shown
13	Tanks/storage chambers individually surveyed
14	Tanks by bund walls or perimeter only
15	(†) Flood lights
16	(†) Water taps/Stand pipes/Troughs
17	(‡) Earth rods
18	Other (specify)

Table A-14: Railway features

No.	Detailed Features
1	Ballast shoulder
2	Buffers/stop blocks
3	Cabinets, switch boxes
4	Cable ducts
5	Catchpits
6	Cess limits
7	Electrified rails (indicative only)
8	Gantries
9	Height gauges
10	Huts
11	Mile posts
12	Platform furniture (specify)
13	Platforms
14	Points and crossovers
15	Power masts
16	Rails (gauge faces)
17	Refuges
18	Signals
19	Signal boxes
20	Signs
21	Telephones
22	TV monitors/cameras
23	(†) Gradient posts
24	(†) Grease points
25	(†) Grit bin
26	(†) Point rods (symbolised)
28	(†) Track (distance) markers
29	(‡) Check rail (on curves or bridges)
30	(‡) Non ducted cables
31	(‡) Points box/lever
32	Other (specify)

Appendix B

Table B: RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS
Table adapted from U.S. Federal Geographic Data Committee,
Geospatial Positioning Accuracy Standards: Part 4, Standard for A/E/C and Facility Management

Project or Activity	Target Map Scale	Contour Interval
DESIGN, CONSTRUCTION, OPERATION & MAINTENANCE OF FACILITIES		
Maintenance and Repair/Renovation of Existing Installation Structures, Roadways, Utilities, etc.		
General Construction Site Plans & Specs: Feature & Topographic Detail Plans	1:500	250 mm
Surface/subsurface Utility Detail Design Plans Elec, Mech, Sewer, Storm, etc Field construction layout	1:500	N/A
Building or Structure Design Drawings Field construction layout	1:500	250 mm
Airfield Pavement Design Detail Drawings Field construction layout	1:500	250 mm
Grading and Excavation Plans Roads, Drainage, Curb, Gutter etc. Field construction layout	1:500	500 mm
Recreational Site Plans Golf courses, athletic fields, etc.	1:1,000	500 mm
General Location Maps for Master Planning AM/FM and GIS Features	1:5,000	1,000 mm
Space Management Plans Interior Design/Layout	1:200	N/A
As-Built Maps: **Surface/Subsurface Utilities** (Fuel, Gas, Electricity, Communications, Cable, Storm Water, Sanitary, Water Supply, Treatment Facilities, Meters, etc.)	1:1000 or 1:500	250 mm
Housing Management GIS (Family Housing, Schools, Boundaries, and Other Installation Community Services)	1:5,000	N/A
Environmental Mapping and Assessment Drawings/Plans/GIS	1:5,000	N/A

Table B (cont.): RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS
Table adapted from U.S. Federal Geographic Data Committee,
Geospatial Positioning Accuracy Standards: Part 4, Standard for A/E/C and Facility Management

Project or Activity	Target Map Scale	Contour Interval
DESIGN, CONSTRUCTION, OPERATIONS AND MAINTENANCE OF CIVIL TRANSPORTATION & WATER RESOURCE PROJECTS Site Plans, Maps & Drawings for Design Studies, Reports, Memoranda, and Contract Plans and Specifications, Construction plans & payment		
General Planning and Feasibility Studies, Reconnaissance Reports	1:2,000	1,000 mm
Soil and Geological Classification Maps	1:5,000	N/A
Engineering Geological Plans	1:500 – 1:1,000	N/A
Land Cover Classification Maps	1:5,000	N/A
Archeological or Structure Site Plans & Details (Including Non-topographic, Close Range, Photogrammetric Mapping)	1:10	100 mm
Land Utilization GIS Classifications Regulatory Permit Locations	1:5,000	N/A
Grading & Excavation Plans	1:1,000	1,000 mm
Construction In-Place Volume Measurement Granular cut/fill, dredging, etc.	1:1,000	N/A
Beach Renourishment	1:1,000	250 mm
Project Condition Survey Reports Base Mapping for Plotting Hydrographic Surveys: line maps or aerial plans	1:2,000	500 mm
Dredging & Marine Construction Surveys New Construction Plans	1:1,000	250 mm
Maintenance Dredging Drawings	1:2000	500 mm
Hydrographic Project Condition Surveys	1:2000	500 mm

Table B (cont.): RECOMMENDED ACCURACIES AND TOLERANCES: ENGINEERING, CONSTRUCTION, AND FACILITY MANAGEMENT PROJECTS
Table adapted from U.S. Federal Geographic Data Committee,
Geospatial Positioning Accuracy Standards: Part 4, Standard for A/E/C and Facility Management

Project or Activity	Target Map Scale	Contour Interval
REAL ESTATE ACTIVITIES: ACQUISITION, DISPOSAL, MANAGEMENT, AUDIT Maps, Plans, & Drawings Associated with Military and Civil Projects		
Tract Maps, Individual, Detailing Installation or Reservation Boundaries, Lots, Parcels, Adjoining Parcels, and Record Plats, Utilities, etc.	1:1,000	1,000 mm
Guide Taking Lines/Boundary Encroachment Maps: Fee and Easement Acquisition	1:500	250 mm
GIS or LIS Mapping, General		
Land Utilization and Management, Forestry	1:1,000	N/A
Management, Mineral Acquisition	1:5,000	N/A
Easement Areas and Easement Delineation Lines	1:1,000	-

Appendix C

S/N	ITEM	DESCRIPTION	MAIN	SUB	Contribute to H.1.12 TOPODTM-
A.		**Buildings / Structures**			
	A.1	**Buildings**	BLDG		
1	A.1.1	Building block number	BLDG	BNUM	N
2	A.1.2	Building column	BLDG	COLN	Y
3	A.1.3	Building eave	BLDG	EAVE	N
4	A.1.4	Building footprint	BLDG	LINE	Y
5	A.1.5	Building profile/cross section	BLDG	PROF	N
6	A.1.6	Building block (General)	BLDG	GNRL	Y/N
7	A.1.7	Building Height(Roof Top)	BLDG	RTOP	N
	A.2	**Areas**	AREA		
8	A.2.1	Area (General)	AREA	GNRL	N
9	A.2.2	Area of land lot	AREA	AREL	N
10	A.2.3	Area of strata lot	AREA	ARES	N
11	A.2.4	Area of building block	AREA	BDBA	N
12	A.2.5	Area of Communal open space	AREA	COSA	N
13	A.2.6	Area of outdoor refreshment areas	AREA	GFAR	N
	A.3	**Floors**	FLOR		
14	A.3.1	Floor (General) - Concrete floor	FLOR	GNRL	Y (Ground Only)
15	A.3.2	Floor/platform levels	FLOR	LEVL	Y (Ground Only)
	A.4	**Staircases**	STRC		
16	A.4.1	Staircase steps	STRC	STEP	N
	A.5	**Bridge**	BRDG		
17	A.5.1	Bridge (General)	BRDG	GNRL	N
B.		**Visible boundary features: walls, fences, hedges**			
	B.1	**Site, external works**	SITE		
18	B.1.1	Site boundaries, survey/work limit	SITE	BNRY	N
19	B.1.2	Cemetery boundary	SITE	BNRY	N
20	B.1.3	Site (General) - external works	SITE	GNRL	N
	B.2	**Walls**	WALL		
21	B.2.1	Fence	WALL	FNCE	Y
22	B.2.2	Gate	WALL	GATE	Y
23	B.2.3	Wall - Trellis	WALL	GNRL	Y
24	B.2.4	Wall	WALL	GNRL	Y
25	B.2.5	Retaining walls survey points	WALL	RETP	Y
26	B.2.6	Retaining walls	WALL	RETW	Y
27	B.2.7	Rubble walls	WALL	RUBB	Y
28	B.2.8	Fire rated walls	WALL	FIRE	Y
29	B.2.9	Parapet walls	WALL	PARP	Y
30	B.2.10	Partition walls	WALL	PRTN	Y
31	B.2.11	Structural walls	WALL	STRU	Y

S/N	ITEM	DESCRIPTION	MAIN	SUB	Contribute to H.1.12 TOPODTM-
C.		Roads, tracks, footways, paths			
	C.1	**Parking lots**	PRKG		
32	C.1.1	Bicycle parking lot	PRKG	BPRK	Y
33	C.1.2	Car parking lot	PRKG	CPRK	Y
34	C.1.3	Handicapped parking lot	PRKG	HPRK	Y
35	C.1.4	Car parking lot spot levels	PRKG	LEVL	Y
36	C.1.5	Motorcycle parking lot	PRKG	MPRK	Y
	C.2	**Footpaths, walkways**	PATH		
37	C.2.1	Footpaths (General) - Walkways, pebble path/walk, pedestrian footpath	PATH	GNRL	Y
38	C.2.2	Linkways, covered linkway, link building	PATH	LINK	N
39	C.2.3	Path Ramp	PATH	RAMP	Y
40	C.2.4	Tactile	PATH	TACT	Y
41	C.2.5	Pedestrian overhead bridges	PATH	OVER	N
42	C.2.6	Entrance and exit of pedestrian underpasses	PATH	UNDR	Y
	C.3	**Roadways**	ROAD		
43	C.3.1	Bus stop post	ROAD	BUS-	Y
44	C.3.2	Bus stop shelter	ROAD	BUS-	N
45	C.3.3	Controlled pedestrian road crossing	ROAD	CRSS	Y
46	C.3.4	Bollard	ROAD	ELEM	Y
47	C.3.5	Lamp post/elevated lamp post	ROAD	ELEM	Y
48	C.3.6	Gantry	ROAD	ELEM	Y
49	C.3.7	Gate barrier	ROAD	ELEM	Y
50	C.3.8	Jay walking restriction sign	ROAD	ELEM	Y
51	C.3.9	Lighting box	ROAD	ELEM	Y
52	C.3.10	Reflective bollard	ROAD	ELEM	Y
53	C.3.11	Surveillance camera	ROAD	ELEM	N
54	C.3.12	Dustbin (Round)	ROAD	ELEM	Y
55	C.3.13	Dustbin (Square)	ROAD	ELEM	Y
56	C.3.14	Road (General)	ROAD	GNRL	Y
57	C.3.15	Guardrail, vehicle guardrail, vehicle impact guardrail, elevated guardrail	ROAD	GRDR	Y
58	C.3.16	Road name	ROAD	NAME	N
59	C.3.17	Road ramp	ROAD	RAMP	Y
60	C.3.18	Road signage - Kilometre post	ROAD	SIGN	N
61	C.3.19	Road signage - Pedestrian crossing sign	ROAD	SIGN	N
62	C.3.20	Road signage - Road sign	ROAD	SIGN	N
63	C.3.21	Road signage - Traffic sign	ROAD	SIGN	N
64	C.3.22	Road tunnels	ROAD	TUNL	N
65	C.3.23	Flyover structures	ROAD	RSUP	N
66	C.3.24	Viaducts	ROAD	VIAD	N
67	C.3.25	Road humps	ROAD	HUMP	Y
68	C.3.26	Road kerbs, kerb line	ROAD	KERB	Y
69	C.3.27	Road spot levels	ROAD	LEVL	Y
70	C.3.28	Survey points of road lines	ROAD	PONT	Y
71	C.3.29	Road reserves	ROAD	RESV	N
72	C.3.30	Traffic lights	ROAD	TLGT	Y
73	C.3.31	Road widening lines	ROAD	WIDL	N
74	C.3.32	Road Markings	ROAD	MARK	N

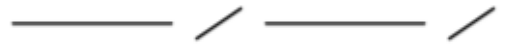
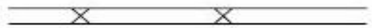
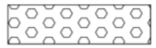
S/N	ITEM	DESCRIPTION	MAIN	SUB	Contribute to H.1.12 TOPODTM-
D.		Facilities			
D.1		Facilities	FCLT		
75	D.1.1	Community services - amphitheatre, ATM kiosk, barbeque pit, josspaper burner, outdoor refreshment area, refuse bin centre, hard court, food outlet/food factory, market, advertisement board	FCLT	CSRV	N
76	D.1.2	Flag pole/staff	FCLT	CSRV	Y
77	D.1.3	Letter Box/Singpost letter box	FCLT	CSRV	Y
78	D.1.4	Public telephone booth/telephone booth	FCLT	CSRV	Y
79	D.1.5	Stool/chair/park bench	FCLT	CSRV	Y
80	D.1.6	Telephone pole	FCLT	CSRV	Y
81	D.1.7	Fire facility - Fire engine access, fire engine hardstanding	FCLT	FSRV	Y
82	D.1.8	Fire hydrant	FCLT	FSRV	Y
83	D.1.9	Facilities (General) - Up light	FCLT	GNRL	Y
84	D.1.10	Playground, park facilities	FCLT	PGRD	Y
85	D.1.11	Railings	FCLT	RALG	Y
86	D.1.12	Public toilets	FCLT	TOIL	Y
E.		Utilities			
E.1		Utilities	UTIL		
87	E.1.1	Electrical utilities - Earth pit/earth electrode inspection pit	UTIL	ELEC	Y
88	E.1.2	Electrical utilities - Electrical box	UTIL	ELEC	Y
89	E.1.3	Electrical utilities - Electrical cable	UTIL	ELEC	Y
90	E.1.4	Electrical utilities - Electrical pole	UTIL	ELEC	Y
91	E.1.5	Electrical utilities - Electrical manhole	UTIL	ELEC	Y
92	E.1.6	Electrical utilities - Telecommunication manhole	UTIL	ELEC	Y
93	E.1.7	Electrical utilities - Over ground box	UTIL	ELEC	Y
94	E.1.8	Electrical utilities - Singapore cable vision	UTIL	ELEC	Y
95	E.1.9	Gas utilities - Air valve	UTIL	GAS-	Y
96	E.1.10	Gas utilities - Gas indicator	UTIL	GAS-	Y
97	E.1.11	Gas utilities - Gas inspection chamber (Round)	UTIL	GAS-	Y
98	E.1.12	Gas utilities - Gas inspection chamber (Square)	UTIL	GAS-	Y
99	E.1.13	Gas utilities - Gas valve	UTIL	GAS-	Y
100	E.1.14	Gas utilities - Gas pipeline	UTIL	GAS-	Y
101	E.1.15	Gas utilities - Gas pipeline marker	UTIL	GAS-	Y
102	E.1.16	General utilities - Cable	UTIL	GNRL	Y
103	E.1.17	General utilities - Cable joint indicator	UTIL	GNRL	Y
104	E.1.18	General utilities - Inspection chamber (Round)	UTIL	GNRL	Y
105	E.1.19	General utilities - Inspection chamber (Square)	UTIL	GNRL	Y
106	E.1.20	General utilities - Unknown manhole	UTIL	GNRL	Y
107	E.1.21	General utilities - Valve (Big/unknown)	UTIL	GNRL	Y
108	E.1.22	Oil utilities - Oil pipeline	UTIL	OIL-	Y
109	E.1.23	Oil utilities - Oil pipeline marker	UTIL	OIL-	Y
110	E.1.24	Water utilities - Water inspection chamber (Round)	UTIL	WATR	Y
111	E.1.25	Water utilities - Water inspection chamber (Square)	UTIL	WATR	Y
112	E.1.26	Water utilities - PUB manhole	UTIL	WATR	Y
113	E.1.27	Water utilities - Water pipeline	UTIL	WATR	Y
114	E.1.28	Water utilities - Water pipeline marker	UTIL	WATR	Y
115	E.1.29	Water utilities - Water meter	UTIL	WATR	Y
116	E.1.30	Water utilities - Water valve (Big)	UTIL	WATR	Y
117	E.1.31	Water utilities - Water valve (Small)	UTIL	WATR	Y

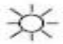
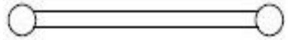
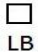
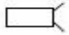
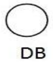
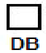
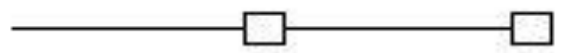
S/N	ITEM	DESCRIPTION	MAIN	SUB	Contribute to H.1.12 TOPODTM-
F.		Landscapes and vegetation			
F.1		Landscapes and tree planting	LNSP		
118	F.1.1	Flower bed/box	LNSP	FLWR	N
F.2		Tree	TREE		
119	F.2.1	Tree (General)	TREE	GNRL	Y
120	F.2.2	Hedge	TREE	HEDG	Y
121	F.2.3	Palm tree	TREE	PALM	Y
122	F.2.4	Sapling	TREE	SAPL	Y
123	F.2.5	Shrubs	TREE	SHRU	Y
124	F.2.6	Tree tabulation	TREE	TBLE	N
125	F.2.7	Tree number	TREE	TNUM	N
126	F.2.8	Vegetation	TREE	VEGE	Y
G.		Water features			
G.1		Hydrography	HYDR		
127	G.1.1	Sea/Strait name	HYDR	NAME	N
128	G.1.2	Shoreline/Coastline	HYDR	SLNE	Y
129	G.1.3	Jetty, floating platform, pier, rock bund, shore protection	HYDR	STRU	Y
130	G.1.4	Water mark line (Contract, low & high, proposed)	HYDR	WML-	Y
G.2		Sanitary systems	SANI		
131	G.2.1	Sanitary waste systems (General)	SANI	GNRL	N
132	G.2.2	Sanitary drainage	SANI	DRAN	Y
133	G.2.3	Sanitary pipes	SANI	PIPE	Y
134	G.2.4	Sanitary vent pipes	SANI	VENT	Y
G.3		Surface water drainage	SDRN		
135	G.3.1	Canal	SDRN	CANL	Y
136	G.3.2	Covered drain/concrete covered drain	SDRN	COVD	Y
137	G.3.3	Drain culvert	SDRN	CULV	Y
138	G.3.4	Drop inlet chamber	SDRN	DIC-	Y
139	G.3.5	Earth drain	SDRN	EDRN	Y
140	G.3.6	Grating over drain	SDRN	GRAT	Y
141	G.3.7	Iron grating	SDRN	GRAT	Y
142	G.3.8	Drainage manhole	SDRN	MH--	Y
143	G.3.9	Sump (Small)	SDRN	MINR	Y
144	G.3.10	Sump (Big)	SDRN	MINR	Y
145	G.3.11	Open drain/concrete open drain	SDRN	OPND	Y
146	G.3.12	Slab over drain	SDRN	SLAB	Y
147	G.3.13	Flow directions in drains	SDRN	FLOW	N
148	G.3.14	Gutter channels	SDRN	GTTR	N
149	G.3.15	Invert levels of surface drainage, iron grating	SDRN	LEVL	N
150	G.3.16	Drainage, pumping mains and ducting, cable troughs	SDRN	MAJR	Y
151	G.3.17	Outlines of outlet/roadside drains	SDRN	OUTD	Y
152	G.3.18	Surface water drainage pipes,	SDRN	PIPE	Y
153	G.3.19	Drainage reserves	SDRN	RESV	N
154	G.3.20	Drainage for basements, tunnels and underground facilities	SDRN	UGDS	N
G.4		Water features	WFEA		
155	G.4.1	Water features (General) - Basin, pond, reservoir, river, swamp	WFEA	GNRL	Y
156	G.4.2	Swamp	WFEA	GNRL	Y
157	G.4.3	Water features/Basin/Reservoir/River name	WFEA	NAME	Y
158	G.4.4	Water structures - Dam, well	WFEA	STRU	Y
159	G.4.5	Well	WFEA	STRU	Y
160	G.4.6	Swimming pools	WFEA	POOL	N

S/N	ITEM	DESCRIPTION	MAIN	SUB	Contribute to H.1.12 TOPODTM-
G.		Water features			
G.5		**Sewers**	SEWR		
161	G.5.1	Sewer manhole	SEWR	MH--	Y
162	G.5.2	Sewer (General)	SEWR	GNRL	Y
163	G.5.3	Septic tank (Round)	SEWR	TANK	Y
164	G.5.4	Septic tank (Square)	SEWR	TANK	Y
165	G.5.5	Deep tunnel sewers and drop shafts	SEWR	DEEP	Y
166	G.5.6	Invert levels of sewers/pumping	SEWR	LEVL	N
167	G.5.7	Major/main sewers and manholes for diameter 300 mm - 900 mm	SEWR	MAJR	Y
168	G.5.8	Minor sewers and manholes for diameter< 300 mm	SEWR	MINR	Y
169	G.5.9	Sewer pipes	SEWR	PIPE	Y
H.		Earth works			
H.1		**Topography**	TOPO		
170	H.1.1	Topography element - concrete lining/structures	TOPO	ELEM	Y
171	H.1.2	Level, elevation, ground/spot levels, stone level, top level	TOPO	LEVL	Y
172	H.1.3	Top Slope	TOPO	TSLO	Y
173	H.1.4	Bottom slope	TOPO	BSLO	Y
174	H.1.5	Slope	TOPO	SLOP	N
175	H.1.6	Soffit	TOPO	SOFF	N
176	H.1.7	Site contour lines and elevations	TOPO	CONT	Y
177	H.1.8	Cross sections	TOPO	CROS	N
178	H.1.9	Longitudinal sections	TOPO	LONG	N
179	H.1.10	Platform levels	TOPO	PLVL	N
180	H.1.11	Spot level points for earthworks computation	TOPO	PONT	Y
181	H.1.12	Digital Terrain Model	TOPO	DTM-	Y
I.		Railway features			
I.1		**Railways**	RAIL		
182	I.1.1	Rail (General) - LRT/MRT railways, railways leading to depot	RAIL	GNRL	N
183	I.1.2	Railway tunnels/viaducts	RAIL	TUNL	N
184	I.1.3	Master alignments, chainage/labels, tangent points	RAIL	MALG	N
185	I.1.4	Station platforms	RAIL	PLFT	N
186	I.1.5	Railway protection corridors/zone	RAIL	ZONE	N
J.		Cadastre			
J.1		**Cadastral information**	CADI		
187	J.1.1	Land lot boundary	CADI	CLBY	N
188	J.1.2	Land lot number	CADI	CLNO	N
189	J.1.3	Land lot boundary point	CADI	CLPT	N
190	J.1.4	Airspace lot boundary	CADI	CABY	N
191	J.1.5	Airspace lot number	CADI	CANO	N
192	J.1.6	Airspace lot boundary point	CADI	CAPT	N
193	J.1.7	Subterranean lot boundary	CADI	CSBY	N
194	J.1.8	Subterranean lot number	CADI	CSNO	N
195	J.1.9	Subterranean lot boundary point	CADI	CSPT	N
196	J.1.10	Strata lot boundary	CADI	STRA	N
197	J.1.11	Lot history schedules, coordinates table	CADI	TBLE	N
198	J.1.12	Proposed new house numbers, inset diagrams, plot boundaries	CADI	CADN	N
199	J.1.13	Elevation sketches, including accessories, lot tables, height, lot and house numbers	CADI	ELES	N
200	J.1.14	Mukim/town sub-division boundaries and numbers	CADI	MKTS	N
201	J.1.15	Share value tables	CADI	SHAV	N
202	J.1.16	Site plan diagrams	CADI	SITP	N
203	J.1.17	Storey plan diagrams, house numbers, common properties	CADI	STOP	N

S/N	ITEM	DESCRIPTION	MAIN	SUB	Contribute to H.1.12 TOPODTM-
K.		Other			
K.1		**Air field related elements**	AIR-		
204	K.1.1	Aircraft obstruction light	AIR-	OLGT	Y
K.2		**Annotations**	ANOT		
205	K.2.1	Grid line	ANOT	GRID	N
206	K.2.2	Key plans	ANOT	KPLN	N
207	K.2.3	Table	ANOT	TBLE	N
208	K.2.4	Title blocks, legend boxes, north point, plan format, scale bar, graphic scale, legend, inset	ANOT	TBLK	N
209	K.2.5	Revision notes	ANOT	REVN	N
210	K.2.6	Sketch numbers, plan numbers	ANOT	SPNO	N
211	K.2.7	Texts	ANOT	TEXT	N
K.3		**Signage (General) - signboard, sign post, signage**	SIGN		
212	K.3.1	Sign board (Big)	SIGN	GNRL	N
213	K.3.2	Sign board (Small)	SIGN	GNRL	N
K.4		**Traverse information, markers and coordinates**	TRAV		
214	K.4.1	Traverse line	TRAV	LINE	Y
215	K.4.2	Precise Levelling Benchmark Network, benchmark	TRAV	PLBM	Y
216	K.4.3	Traverse points, control stations	TRAV	PONT	Y
217	K.4.4	Integrated survey networks marker information	TRAV	ISNM	Y
K.5		**Plan endorsement by regulatory authorities**	ENDO		
218	K.5.1	BCA - Building Plan	ENDO	BCAB	N
219	K.5.2	BCA - Civil Defence Shelter	ENDO	BCAC	N
220	K.5.3	BCA - Structural Engineering	ENDO	BCAS	N
221	K.5.4	CAAS	ENDO	CAAS	N
222	K.5.5	DSTA	ENDO	DSTA	N
223	K.5.6	FSSB	ENDO	FSSB	N
224	K.5.7	HDB	ENDO	HDB-	N
225	K.5.8	IDA	ENDO	IDA-	N
226	K.5.9	JTC - Building Control Unit	ENDO	JTCB	N
227	K.5.10	LTA	ENDO	LTA-	N
228	K.5.11	MPA	ENDO	MPA-	N
229	K.5.12	NEA- Environmental Health	ENDO	NEAE	N
230	K.5.13	NEA- Pollution Control	ENDO	NEAP	N
231	K.5.14	Nparks	ENDO	NPKS	N
232	K.5.15	PowerGas	ENDO	PGAS	N
233	K.5.16	PUB - Drainage	ENDO	PUBD	N
234	K.5.17	PUB- Water Reclamation	ENDO	PUBR	N
235	K.5.18	PUB - Sewerage	ENDO	PUBS	N
236	K.5.19	PUB- Water	ENDO	PUBW	N
237	K.5.20	SLA	ENDO	SLA-	N
238	K.5.21	URA	ENDO	URA-	N

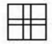
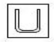
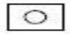
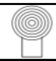
Appendix D

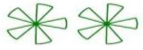
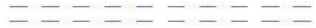
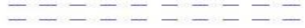
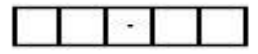
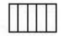
DESCRIPTION	MAIN	SUB	2D SYMBOLOGY
Buildings	**BLDG**		
Column (Round)	**BLDG**	**COLN**	
Column (Square)	**BLDG**	**COLN**	
Building eave	**BLDG**	**EAVE**	
Building line/footprint	**BLDG**	**LINE**	
Site, external works	**SITE**		
Cemetery boundary	**SITE**	**BNRY**	
Walls	**WALL**		
Fence	**WALL**	**FNCE**	
Gate	**WALL**	**GATE**	
Wall	**WALL**	**GNRL**	
Parapet walls	**WALL**	**PARP**	
Retaining walls	**WALL**	**RETW**	
Rubble walls	**WALL**	**RUBB**	
Footpaths, walkways	**PATH**		
Footpaths (General) - Walkways, pebble path/walk, pedestrian footpath	**PATH**	**GNRL**	
Path Ramp	**PATH**	**RAMP**	
Tactile	**PATH**	**TACT**	

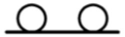
DESCRIPTION	MAIN	SUB	2D SYMBOLOGY
Roadways	**ROAD**		
Bus stop post	**ROAD**	**BUS-**	
Bus stop shelter	**ROAD**	**BUS-**	
Controlled pedestrian road crossing	**ROAD**	**CRSS**	
Bollard	**ROAD**	**ELEM**	
Lamp post/elevated lamp post	**ROAD**	**ELEM**	
Gantry	**ROAD**	**ELEM**	
Gate barrier	**ROAD**	**ELEM**	
Jay walking restriction sign	**ROAD**	**ELEM**	
Lighting box	**ROAD**	**ELEM**	
Reflective bollard	**ROAD**	**ELEM**	
Surveillance camera	**ROAD**	**ELEM**	
Dustbin (Round)	**ROAD**	**ELEM**	
Dustbin (Square)	**ROAD**	**ELEM**	
Road (General)	**ROAD**	**GNRL**	
Guardrail, vehicle guardrail, vehicle impact guardrail, elevated guardrail	**ROAD**	**GRDR**	

DESCRIPTION	MAIN	SUB	2D SYMBOLOGY
Roadways	ROAD		
Road kerbs, kerb line	ROAD	KERB	
Road reserves	ROAD	RESV	
Road signage - Kilometre post	ROAD	SIGN	
Road signage - Pedestrian crossing sign	ROAD	SIGN	
Road signage - Road sign	ROAD	SIGN	
Road signage - Traffic sign	ROAD	SIGN	
Traffic lights	ROAD	TLGT	
Facilities	FCLT		
Flag pole/staff	FCLT	CSRV	
Letter Box/Singpost letter box	FCLT	CSRV	
Public telephone booth/telephone booth	FCLT	CSRV	
Stool/chair/park bench	FCLT	CSRV	
Telephone pole	FCLT	CSRV	
Fire hydrant	FCLT	FSRV	
Up light	FCLT	GNRL	
Railings	FCLT	RALG	

DESCRIPTION	MAIN	SUB	2D SYMBOLOGY
Utilities	**UTIL**		
Electrical utilities - Earth pit/earth electrode inspection pit	**UTIL**	**ELEC**	
Electrical utilities - Electrical box	**UTIL**	**ELEC**	
Electrical utilities - Electrical cable	**UTIL**	**ELEC**	
Electrical utilities - Electrical pole	**UTIL**	**ELEC**	
Electrical utilities - Electrical manhole	**UTIL**	**ELEC**	
Electrical utilities - Telecommunication manhole	**UTIL**	**ELEC**	
Electrical utilities - Over ground box	**UTIL**	**ELEC**	
Electrical utilities - Singapore cable vision	**UTIL**	**ELEC**	
Gas utilities - Air valve	**UTIL**	**GAS-**	
Gas utilities - Gas indicator	**UTIL**	**GAS-**	
Gas utilities - Gas inspection chamber (Round)	**UTIL**	**GAS-**	
Gas utilities - Gas inspection chamber (Square)	**UTIL**	**GAS-**	
Gas utilities - Gas valve	**UTIL**	**GAS-**	
Gas utilities - Gas pipeline	**UTIL**	**GAS-**	
Gas utilities - Gas pipeline marker	**UTIL**	**GAS-**	
General utilities - Cable	**UTIL**	**GNRL**	
General utilities - Cable joint indicator	**UTIL**	**GNRL**	
General utilities - Inspection chamber (Round)	**UTIL**	**GNRL**	

DESCRIPTION	MAIN	SUB	2D SYMBOLOGY
Utilities	**UTIL**		
General utilities - Inspection chamber (Square)	**UTIL**	**GNRL**	
General utilities - Unknown manhole	**UTIL**	**GNRL**	
General utilities - Valve (Big/unknown)	**UTIL**	**GNRL**	
Oil utilities - Oil pipeline	**UTIL**	**OIL-**	
Oil utilities - Oil pipeline marker	**UTIL**	**OIL-**	
Water utilities - Water inspection chamber (Round)	**UTIL**	**WATR**	
Water utilities - Water inspection chamber (Square)	**UTIL**	**WATR**	
Water utilities - PUB manhole	**UTIL**	**WATR**	
Water utilities - Water pipeline	**UTIL**	**WATR**	
Water utilities - Water pipeline marker	**UTIL**	**WATR**	
Water utilities - Water meter	**UTIL**	**WATR**	
Water utilities - Water valve (Big)	**UTIL**	**WATR**	
Water utilities - Water valve (Small)	**UTIL**	**WATR**	
Landscapes and tree planting	**LNSP**		
Flower bed/box	**LNSP**	**FLWR**	
Sanitary systems	**SANI**		
Sanitary vent pipes	**SANI**	**VENT**	
Tree	**TREE**		
Tree (General)	**TREE**	**GNRL**	

DESCRIPTION	MAIN	SUB	2D SYMBOLOGY
Tree	**TREE**		
Hedge	**TREE**	**HEDG**	
Palm tree	**TREE**	**PALM**	
Sapling	**TREE**	**SAPL**	
Shrubs	**TREE**	**SHRU**	
Vegetation	**TREE**	**VEGE**	
Surface water drainage	**SDRN**		
Covered drain/concrete covered drain	**SDRN**	**COVD**	
Drain culvert	**SDRN**	**CULV**	
Drop inlet chamber	**SDRN**	**DIC-**	
Grating over drain	**SDRN**	**GRAT**	
Iron grating	**SDRN**	**GRAT**	
Drainage manhole	**SDRN**	**MH--**	
Sump (Small)	**SDRN**	**MINR**	
Sump (Big)	**SDRN**	**MINR**	
Open drain/concrete open drain	**SDRN**	**OPND**	
Slab over drain	**SDRN**	**SLAB**	
Water features	**WFEA**		
Swamp	**WFEA**	**GNRL**	
Well	**WFEA**	**STRU**	

DESCRIPTION	MAIN	SUB	2D SYMBOLOGY
Sewers	**SEWR**		
Sewer manhole	**SEWR**	**MH--**	
Septic tank (Round)	**SEWR**	**TANK**	
Septic tank (Square)	**SEWR**	**TANK**	
Topography	**TOPO**		
Bottom slope	**TOPO**	**BLOP**	
Slope	**TOPO**	**SLOP**	
Railways	**RAIL**		
Rail (General) - LRT/MRT railways, railways leading to depot	**RAIL**	**GNRL**	
Annotations	**ANOT**		
Revision notes	**ANOT**	**REVN**	
Title blocks, legend boxes, north point, plan format, scale bar, graphic scale, legend	**ANOT**	**TBLK**	
Signage (General) - signboard, sign post, signage	**SIGN**		
Sign board (Big)	**SIGN**	**GNRL**	
Sign board (Small)	**SIGN**	**GNRL**	
Traverse information, markers and coordinates	**TRAV**		
Precise Levelling Benchmark Network, benchmark	**TRAV**	**PLBM**	
Traverse points, control stations	**TRAV**	**PONT**