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Level 2

Topographic, engineering, land and measured building surveying – Strategy and general

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Issue record

Issue	Date	Comments
1	September 2010	First issue.

Compliance

This Network Rail standard is mandatory and shall be complied with by Network Rail and its contractors if applicable from 4 December 2010.

When this standard is implemented, it is permissible for all projects that have formally completed GRIP Stage 4 to continue to comply with the Issue of any relevant Network Rail Standards current when GRIP Stage 4 was reached and not to comply with requirements contained herein, unless the designated Standard Owner has stipulated otherwise in the accompanying Briefing Note.

Reference documentation

NR/GN/TRK/3103, *Topographic, engineering, land and measured building surveying – Survey and mapping.*

NR/L1/AMG/1010, *Policy on working safely in the vicinity of buried services.*

NR/L2/AMG/1030, *Working safely in the vicinity of buried services*

NR/L2/EDT/002, *Computer Aided Design drawing specification.*

NR/L3/MTC/PL0094, *Planning and documenting the Safe System Of Work Arrangements* (formerly NR/PRC/MTC/PL0094).

NR/L3/TRK/3101, *Topographic, engineering, land and measured building surveying – Track.*

Benchmarks to GNSS heighting – Virtually level. RICS (Royal Institution of Chartered Surveyors) Guidance note.

OSGB36. *A guide to Co-ordinate systems.* Produced by the OS.

Thameslink Programme – Survey and Mapping Grids. CCMS No: N000-PP-2570926.

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1 Purpose

This standard has been written to enable Network Rail to utilise and specify appropriately all high accuracy (better than $\pm 100\text{mm}$ in position) Topographic, Engineering, Land and Measured building surveying associated with Track, Building and Civils, Signalling, Control and Plant, OLE, and Property. Such surveys are not an automatic requirement for all projects. It specifically excludes ground investigation, geotechnical, building condition, dilapidation surveys and surveys associated with Network Rail owned and operated measurement trains.

The standard is intended to provide a clear and unequivocal way to project manager and specify survey work, by identifying key stages to deliver good quality work to satisfy current needs and also assist with those for the future. "Survey once and use many times" thus providing better value for the money spent.

This standard fits with Network Rail policy on sustainability in that it seeks to embed good sustainability policy and practice into our maintaining, renewing and enhancing the railway. It also provides guidance and seeks to raise the competency of those involved with specifying and managing surveying activities.

This is the initial document of a suite of standards that provides a strategy and general introduction, establishing some basic principles that should be applied across all disciplines. Further standards have been written covering the main disciplines for which this form of surveying is utilised. A guidance note (NR/GN/TRK/3103, *Survey and Mapping techniques*) has been written that provides guidance on current techniques and the suitability of their application for the various stages of the GRIP process. However, consultation with the Senior Survey Engineer or team or the Project Survey Systems Engineer (Client's Survey Manager) is recommended as the technology in use for Surveying is a rapidly changing field of activity.

In conjunction with the standard, a number of training courses are being created to develop the understanding of Topographic, Land, Engineering and Measured building surveying appropriate for identified needs within Network Rail for Project management, Contracts and procurement and other parts of the organisation.

The standard seeks to minimise site visits by specifying that all information needed is collected in an appropriate manner, first time, preventing the need for re-visits and emissions created by more vehicle traffic and the exposure of staff to further safety risks. Multiple visits to site may also be limited by better forward planning, especially when possessions are involved, deriving the most efficient use of time and also driving down costs.

Network Rail considers that economic sustainability is about exceeding the expectations of our customers, suppliers, stakeholders and funders. To do this, we need to exploit the railway asset base more effectively by improving the way data collected by our surveys is utilised in the corporate asset information systems in addition to its initial use for projects. This way, Network Rail gets better value from the investment in good survey information.

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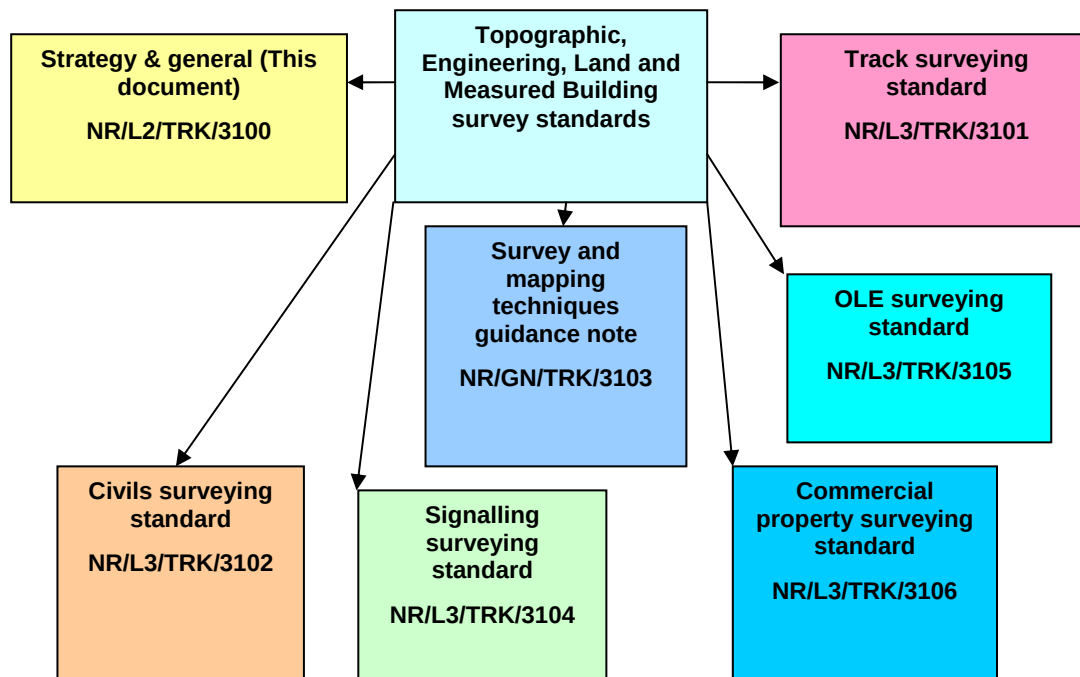


Figure 1 – Standards suite

The full hierarchy of the standards is given in more detail in Appendix A.

This standard is intended to be used with the discipline document related to the type of survey required.

NOTE For example, where a track survey and then a design for S&C renewal is needed, this standard and NR/L3/TRK/3101 would be consulted to understand what is required. A project survey strategy would be defined as specified in this standard and the detailed specification would be derived from NR/L3/TRK/3101.

A value-added benefit of appropriate techniques and standards being used is that of a digital model of the infrastructure for future use in the corporate asset information systems is created.

2 Scope

This Network Rail standard specifies all surveying activities for which a co-ordinated Topographic, Engineering, Land, or Measured Building survey is required. This standard is applicable to individual project scopes during the life-cycle of a renewal or project.

It is intended to be used by the Project Manager or Designated Project Engineer (DPE), in consultation with the Senior Survey Engineer or team or the Project Survey Systems Engineer (Client's Survey Manager), to define the most suitable survey techniques.

This standard is also applicable to commercial remits.

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3 Definitions

For the purposes of this standard, the following terms and definitions apply.

Absolute accuracy

accuracy of a measured point related to the reference framework or survey grid.

DTM/DGM

Digital terrain or ground model

computer generated surface representing the surface of the ground from which contours and volumes may be derived.

ETRF89

European Terrestrial Reference Framework

physical realisation of the ETRS fixed to the Eurasian Plate as defined in 1989, the framework upon which GNSS in Europe works.

ETRS89

European Terrestrial Reference System defining parameters of the origin, scale, orientation and adopted ellipsoid.

GNSS

Global Navigation Satellites Systems including GPS, Glonass & Galileo.

GRIP

Guide to Railway investment Projects detailing the stages all projects must pass through

Level Datum

The level obtained directly from GNSS in ETRF89 and converted to OS Newlyn datum utilising OSGM02 available directly from OS website.

NOTE 1 To achieve compatibility between adjacent ground markers (GMs) they should be orthometrically levelled.

NOTE 2 OS Benchmarks are no longer maintained.

LiDAR

Light Detection And Ranging

Remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target using laser pulses. The range to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal.

OSGB36/OSNG

The Ordnance Survey grid

NOTE A direct link to it may be obtained by using GNSS equipment and "OS Smart Net".

Primary Control

First Order survey monuments (ground markers) providing the primary planimetric and vertical control (benchmarks) for the survey

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Secondary Control

Second Order ground markers between the primary control.

Survey Grid

Geodetic framework upon which the survey is based.

tertiary control

Third order ground markers, usually trackside, between the secondary control

Terrestrial Laser Scanning

TLS

Survey technique involving the use of a survey grade laser scanning instrument to collect tens of thousands of measurement points per second and millions of points per setup by rotation through a 360 degree field of view

NOTE The instrument can be mounted in a fixed position (static) or moving position (kinematic) such as on a track measurement device.

track measuring device

TMD

Device formerly known as a track trolley, such as Amberg GRP series of track geometry measurement devices.

TMG/spigot/stud Track machine guidance points

Installed to enable a survey prism to be attached directly.

NOTE These may replace the third order control in some areas. They are usually installed in OLE masts or other fixed vertical structures.

total station

Combined electronic theodolite and EDM measuring equipment that also includes a computer for computations and measured data storage.

trig heighting

A technique to obtain the height of a location by measuring the VA (vertical angle) and SDi (Slope distance) that is computed to get the horizontal distance to the point.

NOTE To obtain best results this should be done from a minimum of two independent instrument set ups.

TruView

Leica scan cloud publishing and viewing software providing instrument position view of scan data with reflectivity light image superimposed on co-ordinated points.

4 Roles and responsibilities

Client's Survey Manager

CSM

HQ Senior Survey Engineer, or Network Rail Survey Systems Engineer or Network Rail project representative acting as Client's Survey manager.

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5 Planning

5.1 Project Survey Strategy

A Project Survey strategy shall be created by the Project Manager with assistance from the CSM prior to the commencement of work.

NOTE This is to achieve the integration of all survey and asset information data.

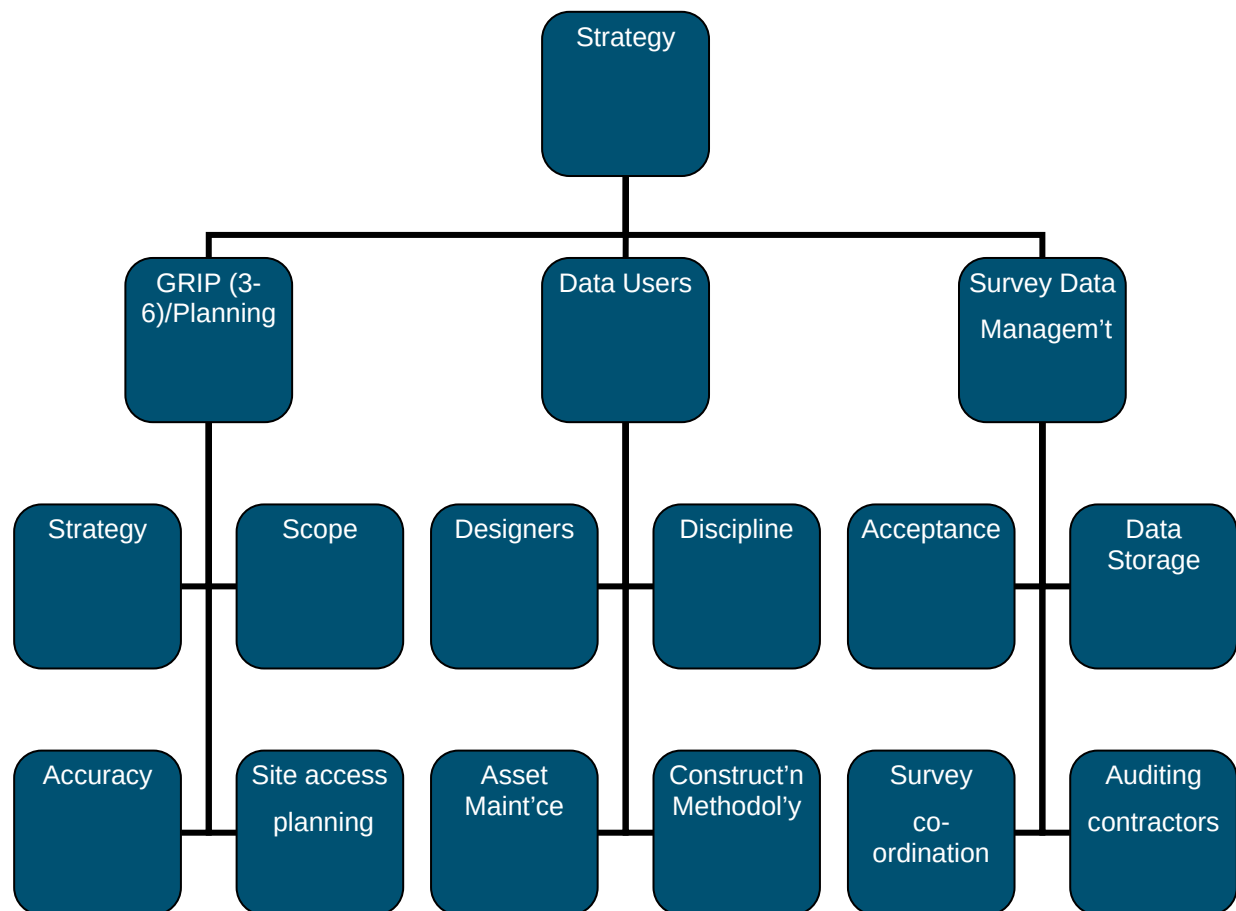


Figure 2 – Project Survey strategy

The Project Survey strategy shall be split into the following three sections:

- Planning for GRIP 3 to GRIP 6 stages;
- Data Users;
- Survey Data Management

5.2 Planning for GRIP 3 to GRIP 6 stages

The Planning for Grip 3 to GRIP 6 stages shall include the following, where applicable:

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- a) definition of survey budget associated with the associated risks for each GRIP phase;
- b) sources of any existing survey data for the area in question;
- c) scope of survey including survey specification, survey grids, permanent ground markers (PGMs) to be used and accuracy requirements;
- d) strategy for the procurement of the survey and how this fits within the overall project procurement strategy;
- e) definition of the form of tender;
- f) the make up of the Tender review team;
- g) definition of the commercial/technical scoring split. Risks shall be acknowledged in writing by a Project manager when commercially favourable bids with limited technical abilities are favoured.
- h) Identification of the post to plan and book track access.

NOTE This should be addressed at the earliest opportunity. The last opportunity is T-12 weeks. See clause 8.

- i) how the sourcing of buried services records for the project area from Network Rail Buried services team will be managed, as specified in NR/L2/AMG/1030.

5.3 Data Users

The project strategy shall define the following, where applicable:

- a) the additional disciplines involved as well as the main discipline and their data needs;
- b) what the designers for the project shall receive; e.g. Will design for track be done by Hallade or 3D methods?
- c) what the construction contractor shall be provided with and the methodology we want them to use to enable construction;
- d) the data required by the maintainer at the end of the project to enable maintenance of the infrastructure.

5.4 Survey data management

NOTE The survey is needed for all aspects of a project in a consistent fashion (i.e. property, engineering, design, maintenance, monitoring, inspection, set-out and installation).

The Project manager shall ensure that survey data is stored in a “data management system” enabling robust storage, searching and management of the data.

NOTE Such a system is not a document management system designed for Word and pdf documents.

Data shall be prepared in accordance with Network Rail standards, such as NR/L2/EDT/002.

Survey data management shall include definition of the role of Client’s Survey Manager (CSM) when applicable. They shall:

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- a) undertake quality assurance (QA) checks to verify and validate (accept) the pre-existing and new survey data. Critical items requiring QA shall be identified in the project risk register. The degree of QA checks to be undertaken shall be associated with the project risk register created by the Project Manager or Designated Project Engineer and updated through out the course of the project;
- b) manage the interfaces between survey suppliers and audit the survey contractors;
- c) be responsible for the on going management, storage, maintenance and updating of the survey data during the project life cycle, including the hand back period;
- d) take responsibility for managing the survey grid as specified in clause 9.

NOTE An example document for Survey and Mapping grids is from the Thameslink Programme – Survey and Mapping Grids. CCMS No: N000-PP-2570926. CCMS is Network Rail's content management system.

- e) manage the longitudinal chainage system.

NOTE For example, when track alignment design is being considered the start point of the design metreage is required to be defined or, for an OLE survey, a longitudinal chainage may be defined relative to the track ELR and chainage system.

6 Survey risk management

A survey risk register shall be set up by the Project manager or Designated project engineer with assistance from the CSM.

NOTE 1 The Project manager or Designated project engineer wants a survey that they have confidence in and, if obvious errors are found, they will lose that. Gross errors can cause consequential losses on other parts of the project, such as delay and additional costs.

NOTE 2 An example of a simple risk register is given as Table 1. It is not exhaustive and other risks may be identified.

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Cause of risk	Consequence	Owner	Mitigation
Competence and capability of survey company	Delay in programme due to poor deliverables from multiple suppliers	Project manager/ Contracts and procurement	CSM to advise on appropriate companies providing full range of services, not only from "Link-up"
Site Access	Delay in programme	Project manager	Plan 6 months or more ahead and book possessions
Poor specification	Surveyor revisit, Delay	Engineering design manager/CSM	Use standard documentation to outlaw inappropriate local grid solutions and plan for access to allow pre-survey visit
Multidiscipline scope poorly defined	Revisit, Delays and cost overrun	Engineering design manager/CSM	CSM to advise appropriate modern survey techniques that collect all data needed in one visit
Survey planning	Unforeseen costs	Project manager/ Engineering design manager/CSM	Project survey strategy developed to enable Survey to be part of "whole life project costs".
Weather	Delays and cost overrun	Project manager/Contracts and procurement	Contract to define if day rate or fixed price service. Plan work when bad weather least likely
Permanent ground marker (PGM) installations	Delay	Project manager/ Engineering design manager/CSM	Buried services searches carried out six months in advance for site (12 week minimum turn round needed)
Gross Errors	Revisit, Delay	Survey company	External company procedures and Network Rail checking process See clause 12.
Survey data management	Possible resurvey when already completed	Project manager/ Engineering design manager/CSM	Project survey strategy defines how this will be done
Survey data management	Possible resurvey when already completed	Project manager/ Engineering design manager/CSM	Project survey strategy defines how this will be done

Table 1 – Example of simple risk register

The approach to risk management shall be applied in a way similar to that for health and safety issues.

Identified risk and likelihood considered shall be against impact to derive a risk rating.

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NOTE An example of identified risk and likelihood given as Table 2.

Risk	Likelihood	Impact	Control measure	Rating Before/After control measure control measure
Incompetence of survey company	4 1	5 5	CSM to advise on appropriate companies not only from "Link-up"	20 5
Site Access	4 3	5 5	Plan 6 months or more ahead and book possessions	20 15
Survey planning	4 1	4 2	Project survey strategy developed to enable Survey to be part of "whole life project costs".	16 2
Poor specification	4 2	5 3	Use standard documentation defining survey grid and plan for access to allow pre-survey visit	20 6
Multidiscipline scope poorly defined	4 3	4 3	CSM to advise appropriate modern survey techniques that collect all data needed in one visit	16 9
Survey planning	4 1	4 2	Project survey strategy developed to enable Survey to be part of "whole life project costs".	16 2
Weather	3 2	4 4	Contract to define if day rate or fixed price service. Plan work when bad weather least likely.	12 8
Permanent ground marker (PGM) installations	5 2	4 2	Buried services searches carried out six-month in advance for site (12 week minimum turn round needed). CAT used on site	20 4
Gross Errors	3 1	5 2	Company procedures and Network Rail checking process	15 3
Survey data management	4 2	4 2	Project survey strategy defines how this will be done	16 4
KEY 1 is low, 5 is high.				

Table 2 – Example of risk management table

NOTE Application of control measures brings risks down to manageable level. Further control measures can be needed to address the risk. Such a concept allows focusing on critical aspects of survey planning

7 Site access planning

At the earliest stage, when it is established that a ground survey will be required, the Project manager shall consideration the site access requirements as specified in NR/L3/MTC/PL0094.

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NOTE Access to the track to undertake permanent way surveys is strictly controlled and can have a lead time of six months to enable possessions in a green zone to be booked and arranged. It might be possible to "piggy-back" another possession, arranged for a different purpose, but careful planning and consideration of the other planned activities is needed so that these do not prevent the survey taking place (e.g. storage of materials trains awaiting access to track renewals site) at the location needed. In some instances, red zone working might be accepted but this cannot be assumed.

8 Survey grids

8.1 Choice of survey grids

NOTE 1 A project grid is important as it enables the curved earth to be mathematically defined as a plane. A number of variations may be appropriate. The best to use is dependant on the nature of the project and what other pre-existing infrastructure it is required to interface with.

A project requiring a survey shall utilise one of the following types of survey grids where applicable:

- a) WGS84/ETRF89;
- b) Ordnance Survey national grid (OSGB36);
- c) bespoke design of Absolute project grid (APG)
- d) utilise a pre-existing survey grid (e.g. the London Survey grid (LSG));
- e) Local project grid (LPG).

The Project Manager or Designated Project Engineer shall consult with the CSM to define the appropriate survey grid and longitudinal chainage or metrage to be used.

NOTE 2 A description of these grids is shown in Table 3.

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Grid	When	Comments
WGS84/ETRF89 (see 9.2.1)	Establishment of new grid for an area	Based on GNSS observations giving Latitude and longitude values
Ordnance Survey national grid (OSGB36) (see 9.2.2)	Allows linking to existing OS mapping and Nation framework.	Need to apply a Scale factor
Absolute project grid (APG) (see 9.2.3)	Bespoke grid for specified purpose	Example is "Snakegrid" for a long thin project like a railway with high accuracy needs and length greater than 10 Km.
Existing survey grid (see 9.2.4)	New project abuts an existing project with pre-existing grid that may be extended	Care needed if grid extended that additional errors are not introduced as not working from "whole to part".
Local project grid (LPG) (see 9.2.5)	Simple grid that may be based on abridged OSNG values but with unity scale factor. Use when away from areas with APG.	Prudent to alter origin values so they are not confused with OSNG co-ordinates

Table 3 – Survey Grid choices

The survey grid shall be defined on the ground by a network of permanent ground markers (PGMs).

They shall be based on a hierarchy of Primary, Secondary or Tertiary PGMs.

NOTE 3 Once PGMs are defined on the ground, their preservation is essential to maintaining the absolute accuracy and usefulness of the survey grid.

NOTE 4 Utilising a survey grid which is tied to National Grid monumentation (OSGB36, ETRF89, LSG) via GNSS surveying provides centimetric reassurance of PGM maintenance and re-establishment.

NOTE 5 PGM control networks should be sufficiently accurate to facilitate future engineering setting-out. Only Slab track setting-out requires tolerances of ± 2 mm in location.

8.2 WGS84 and ETRF89

8.2.1 General

NOTE WGS84 (World Geodetic system grid 1984) is the world wide co-ordinate grid on which GNSS measurements are made. However, Global datums such as ITRS and WGS84 are not suitable for national mapping, as tectonic movements of the Earth's surface are apparent in these. Britain is moving at 2.5 mm per year north-east with respect to ITRS. Over a decade such a change would be significant in national mapping (the difference between ETRF89 and ITRS co-ordinates in Britain in 1999, was about 250 mm). To remove this effect, a fixed epoch GNSS co-ordinate system is used, ETRF89. This represents all GNSS co-ordinates at the tectonic epoch 1989.0. A transformation is used to convert WGS84 co-ordinates to ETRF89.

ETRF89 and EUREF is a European 3D reference grid based solely on space techniques

The co-ordinate system that GNSS measures to directly in Europe is set up to be ETRF89.

In day-to-day usage, this grid system shall be converted into one of the following four grid systems for general usage:

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- a) OSG36;
- b) Absolute project grid (APG);
- c) pre-existing survey grid;
- d) Local project grid (LPG)

8.2.2 OSGB36

NOTE 1 In the earliest stages of most projects, it is best to utilise the national survey grid, whose infrastructure is provided by the GB national mapping organisation, the Ordnance Survey (OS). This enables the use of the mapping and aerial photography data from Network Rail's service level agreement with the OS. However, there are limitations to this grid in that it is based on a Transverse Mercator map projection that introduces a scale factor, depending on how far the location is away from the central meridian (a line running north south). Read 9.2.5 on LPG for a measure of the size of the Scale Factors introduced. Distances also need to be reduced to mean sea level (MSL). This means that a distance measured on the ground will not be the same as that measured from a CAD drawing of the same place.

NOTE 2 For more information on OSGB36, read A guide to Co-ordinate systems, produced by the OS.

8.2.3 Absolute project grid (APG)

NOTE 1 The limitations of OSGB36 may be overcome by using an Absolute project grid. This is a bespoke project grid designed for use on a particular project and has carefully defined criteria allowing its use within a defined area.

An example of this is the "Snakegrid" concept, which may be used for any geographically long and thin project over 10 km in length. This grid has been defined by using an approximate centreline of the main route, known as a trend line and using bespoke algorithms, which incorporate the effects of reduction to mean sea level (MSL) and scale factor so that errors will be no greater than 1/50,000 or 20 mm per kilometre (20 ppm). Consequently, all work using such a grid may be computed without the application of a scale factor or consideration of reduction to MSL.

Such grids have been established for numerous routes (see Appendix D). Levels are based on OS Newlyn datum and where new work is proposed in these areas these grids shall be utilised to avoid the confusion of a proliferation of survey grids.

A GNSS control survey shall be carried out to form the main co-ordinate framework or network.

NOTE 2 GNSS surveys are specified in clause 10.

Initially all control shall be computed using GNSS WGS84/ETRF89 co-ordinates.

Baselines shall also be observed to a minimum of three Ordnance Survey Active Network GNSS locations to form a gross error check. Rinex data for these three OS points and precise ephemeris data shall be downloaded and used for post processing.

Real-time Active net GNSS co-ordination alone shall not be considered suitable for primary, secondary or tertiary control. For high precision engineering survey networks (i.e. rail survey or setting out works to sub-centimetre accuracy), GNSS techniques shall be used as part of a network of permanent ground markers (PGMs).

The network shall consist of a hierarchy of PGMs as follows: