Standard Category 1

S1054 A6 Civil Engineering - Earth Structures

Contents

1 Purpose

The purpose of this standard is to define the whole life cycle requirements for Earth Structure assets. The Earth Structures comprise:

a) Embankments of soil with slopes equal or greater than 1m high

b) Cutting slopes of soil and rock (chalk) equal or greater than 1m high.

Note: This standard does not deal with the requirements for slopes less than 1m high.

2 Scope

This standard applies to Earth Structures owned by LU.

This standard describes the requirements for Earth Structures through the following life cycle stages:

a) Inception and design

b) Construction, installation, testing and commissioning

c) Inspection

d) Analytical assessment

e) Condition assessment and certification

f) Maintenance

g) Strengthening and renewal

h) Decommissioning

i) Evidence of compliance.

3 Requirements

3.1 General

3.1.2 Requirements applying to the use of reinforcement in Earth Structures by placing structural elements or materials (including Geosynthetics) within the soil so that slopes stand at angles steeper than the earth would eventually adopt if no structural elements or materials were present are included in this standard.

3.1.3 The Global Stability of composite slopes, where differences in grade beside the railway are created by combining Retaining Structures and Earth Structures, is a geotechnical issue and shall meet the stability requirements for Earth Structures as defined in this standard.

Note: Retaining Structures (including gabion walls) in composite slopes are included in LU standard S1051 'Civil Engineering - Bridge Structures'.

3.1.4 In defining requirements specifically applicable to Earth Structures, this standard complements LU standard S1050 'Civil Engineering - Common Requirements' that defines mandatory requirements generally applicable to all Civil Engineering assets including the Earth Structures.

3.1.5 Associated documents G0054A and G0054B give guidance and explanation on Earth Structure assets.

3.2 Inception and design

3.2.1 General

3.2.1.1 The inception and design of new works including works of Strengthening and Renewal to existing assets shall ensure that the Earth Structure assets will satisfy their Required Duty.

Note:	The Required Duty for Earth Structures is as follows:
1	Meet railway operating requirements (within the performance specification at system installation or at the most recent system upgrade).
1.1	Maintain inherent structural integrity (support itself so as not to suffer complete or partial collapse), i.e. meet or exceed factors of safety currently specified in LU standards.
1.2	Maintain the ability to carry without restriction any permitted applied static and dynamic design loads.
1.3	Allow adequate clearance to ensure the safe passage of rail vehicles.
1.4	Provide appropriate access and egress for all planned uses (including maintenance), and for reasonably anticipated emergency uses.
1.5	Sustain a condition and state so as not to cause unplanned interruption to, or restriction of, any aspect of the operating railway.
1.6	Sustain a condition and state so as to maintain all interfacing non-railway services and facilities at full design capability.
1.7	Meet or exceed the serviceability requirements currently specified in LU standards (e.g. deformation).
2	Ensure support at asset interfaces without undue wear and tear.
2.1	Minimise the degradation of all interfacing assets (e.g. as evidenced through maintenance cycles). This includes interfaces with the railway and adjacent infrastructure (e.g. track, structures, stations and premises).
2.2	Minimise the degradation of all interfacing assets which support non-railway services or facilities (e.g. as evidenced through maintenance cycles). Includes interfaces with dynamic & static assets (e.g. roads, buildings, walkways, etc).
3	Match LU policy in respect of realistic user perceptions.
3.1	Ensure the asset does not cause undue degradation of interfacing assets, disruption to railway operations or unacceptable environmental nuisance.
4	Provide resistance against external interference and events.
4.1	Asset minimises the likelihood and consequence of asset abuse. Asset abuse encompasses, vandalism, planned/unplanned work, damage due to external event, etc.
5	Present acceptable environmental impact.

5.1	Present an acceptable societal environmental impact (noise, vibrations, vegetation cover, adverse weather management, etc).
5.2	Provide resilience against the effects of climate change.
6	Minimise environmental impact throughout lifecycle.
6.1	Minimise environmental impact and demands at all stages in the lifecycle; this includes effects now and into the future, including successive maintenance and renewal, final decommissioning, and disposal routes.
7	Function within the legal and standards framework.
7.1	Ensure the asset functions within the framework defined by legislation (including environmental); regulatory guidance and applicable national and international standards; and LU policies.
8	Ensure safe operation as defined by LU.
8.1	Ensure safe operation and condition as specified by LU requirements; this includes passengers, employees and members of the general public.
8.2	Ensure safe ingress/egress by passengers, employees, and emergency services in planned & reasonably anticipated emergency scenarios.
8.3	Safeguard the health and safety of passengers, employees and members of the general public.
9	Provide above within reliability and availability targets. Provide all aspects of the Required Duty within the defined LU requirements.
10	Ensure Required Duty is performed without incurring excessive or prohibitive costs.

3.2.1.2 Earth Structure assets shall be designed to the principles of whole life asset management planning.

3.2.1.3 Design of the track-bed and formation shall be carried out in accordance with LU standard S1157 'Track – Performance, Design and Configuration'.

3.2.2 Inception

3.2.2.1 All proposals for new works, including Strengthening and Renewal shall be initiated and controlled in accordance with LU standards S1538 and S1050.

3.2.3 Design process

3.2.3.1 The design shall proceed in a staged manner in accordance with LU Assurance standard S1538.

3.2.3.2 The design shall be in accordance with the requirements of Eurocode and other standards listed in section 3.2.9.

Note:	In accordance with BS EN1997-1 section 2.1, the design requirements of a slope within the LU environment generally meets the classification of a Geotechnical Category 2 Structure.

3.2.3.3 The design process for Earth Structure assets shall be managed by a Geotechnical Specialist.

3.2.3.4 The design check certificate for Earth Structure assets shall be signed by a Geotechnical Specialist.

3.2.4 Structure gauge

3.2.4.1 No part of any Earth Structure shall encroach upon the structure gauge as defined in LU standard S1156 under any conditions of loading or deformation.

3.2.5 Geotechnical information and site investigation

3.2.5.1 The Conceptual Design Statement (CDS) for design shall include proposed soil parameters and Groundwater conditions for the design derived from a desk study of the existing site investigation information and other available data, provided sufficient existing information to establish design criteria is available.

3.2.5.2 The design CDS shall consider the potential for contamination at the site.

3.2.5.3 In the absence of sufficient existing information to establish the criteria for design, the design CDS shall include proposals for additional ground investigation and monitoring to obtain the required level of information.

3.2.5.4 Where there is evidence of historical slope instability or failure and pre-existing shear surfaces the designer shall consider the need for and propose additional ground investigation in order to ensure that adequate information for the back analysis and detailed design is available.

3.2.5.5 Ground Investigations shall be carried out in accordance with BS EN 1997-2, BS 5930, UK Specification for Ground Investigation and LU standard S1050.

3.2.5.6 The proposal for Ground Investigation at existing Earth Structures shall include the considerations defined in section 3.5.3 of this standard.

Note: The design parameters for the Strengthening and Renewal of an asset will normally be the parameters previously established for use in the Analytical Assessment of the asset, and for which a desk study and site investigation will already have been carried out as provided in section 3.5 of this standard. In that case no further investigation should be required.

3.2.5.7 Interpretation of the Site Investigation results shall include the factors listed in section 3.4.3.7 of this standard.

3.2.5.8 The design shall not be finalised until all the required geotechnical information is available and incorporated as appropriate to determine ground model and geotechnical design parameters.

Note: This requirement does not preclude rigorous application of the Earth Structure Observational Method to design and construction, in which a hierarchy of appropriate contingency procedures are fully established ahead of the works for the possible range of conditions and circumstances that could be encountered.

3.2.6 Soil parameters

3.2.6.1 The characteristic soil parameter values for use in the design of new works shall generally be determined in accordance with BS EN 1997-2.

3.2.6.2 The characteristic soil parameter values for use in the design of Strengthening and Renewal works to existing assets shall generally be determined in accordance with Section 3.5.4 of this standard. The designer shall consider the impact of climate change and the effect on strength degradation following recommendation of LU guidance G0054B.

3.2.6.3 The designer shall consider the influence of historical slope instability or failure and presence of pre-existing shear surfaces in the derivation of soil parameters for the design of Strengthening and Renewal works.

3.2.7 Groundwater and drainage

3.2.7.1 The groundwater conditions applicable for use in the design shall be the most unfavourable anticipated conditions during the Design Life of the asset, This shall include the impact of climate change following the recommendations of LU Earth Structures Inclement Weather Report and LU guidance G0054B.

3.2.7.2 The groundwater conditions for the design of Strengthening and Renewal to existing assets shall be determined in accordance with section 3.5.5 of this standard.

3.2.7.3 The design shall take account of the following:

a) changes in long-term groundwater levels

b) seasonal variations in groundwater levels.

3.2.7.4 Earth Structure design shall, as far as reasonably practical, avoid modification to groundwater tables outside the asset area during both construction and operation, and shall include a risk assessment of the consequences of anticipated groundwater level changes when avoidance is considered impractical.

Note: CIRIA Report C515 provides guidance on the design and operation of Groundwater control systems involving pumping from wells.

3.2.7.5 Where the assumed groundwater regime is dependent on the performance of existing track or land drainage, the condition of the existing drainage shall be confirmed as fulfilling its required function up to the point of secure discharge by Inspection in accordance with LU standard S1052.

3.2.7.6 Cleaning or replacement of existing drainage shall be included in the design if the existing drainage does not fulfil its required function in the new works, including Strengthening and Renewal.

3.2.7.7 Inspection, improvement and design of drainage shall be carried out in accordance with LU standard S1052.

3.2.7.8 Existing counterfort drains on the slope of cuttings shall not be relied upon as providing a drainage function in the long term during the design life of the earth structure, unless it can be demonstrated that they are fully functional or can be improved to be fully functional through maintenance. Checks shall also be made to

determine if the counterfort drains are positively discharged into an outfall through a collector pipe located at the toe of the cutting. Further guidance on the effects of existing counterfort drains is provided in the LU guidance G0054B.

3.2.7.9 The design shall consider the topography of the area adjacent to the toe of embankments and ensure that ponding at the toe or flooding of the adjacent properties is avoided. Where necessary, toe drainage shall be incorporated in the design in order to mitigate the risk.

3.2.7.10 The design shall consider the topography of the area adjacent to the crest of cuttings and ensure that flooding of the cutting and the railway from the adjacent property is avoided. Where necessary, a crest drain or ditch shall be incorporated in order to mitigate the risk.

3.2.7.11 All new drainage shall be designed to have a suitable outfall or discharge location.

3.2.7.12 The review of the need to install new drainage shall include considerations of the effects of climate change over the life of the structure and recommendations of LU Earth Structures Inclement Weather Report and LU guidance G0054B

Note: For clay slopes, the increase in rainfall intensity predicted by the climate change projection is likely to lead to increased surface runoff. This may present challenges to drainage management and potentially cause more flooding or erosional failures.

The increase in intensity of rainfall could surcharge the local drainage network and direct flow towards the adjacent earthworks, leading to flooding and surface erosion. A catchment study shall be carried out during the drainage design to assess the susceptibility of the slope to this effect, so that appropriate mitigation measures can be considered as part of the design.

3.2.8 Design methodology

3.2.8.1 The slope stability analysis for the design including Strengthening and Renewal to existing earth structures shall be carried out in accordance with section 3.5.7 of this standard.

3.2.8.2 The effects of historical slope instability or failure and presence of pre-existing shear surfaces shall be investigated and considered in the temporary and permanent works design of earth structures renewal works and/or other interfacing projects.

3.2.8.3 Earth Structures shall be designed to have adequate stability against shear failure and to ensure that deformation is within acceptable limits.

3.2.8.4 Except as described in section 3.2.8.4 of this standard, adoption of BS EN1997-1 for design, coupled with a sound, well-drained trackbed formation and a crest width of embankments meeting the requirements of section 3.2.15 and 3.2.16, shall be considered sufficient to limit deformation to below that of the Serviceability Limit State (SLS).

3.2.8.5 In cases where the investigation and assessment of an existing Earth Structure has indicated that it is undergoing deformation that may be detrimental to track performance, including but not limited to ravelling of ash embankments or seasonal track deformation by high water demand trees on high plasticity clay fill, the design

of Strengthening and Renewal works shall specifically address limiting future track deformations to within the maintenance target level of LU standard S1159.

Note: High water demand trees are defined in National House Building Council, Building Near Trees, 2003 and LU Guidance Document G0058 Civil Engineering – Technical Advice Notes.

3.2.9 Design standards

3.2.9.1 Design of Earth Structure assets, including Strengthening and Renewal to existing assets shall be carried out in accordance with the latest revision of the codes of practice in section 9 of this standard.

3.2.9.2 The stability assessment of existing Earth Structures shall use the assessment procedure defined in section 3.5 of this standard to determine the critical Factor of Safety for the proposed sections.

3.2.10 Retaining structures

3.2.10.1 The geotechnical design of retaining structures used to strengthen or renew Earth Structures assets shall be in accordance with BS EN 1997-1, the National Annex to BS EN 1997-1 and BS 8002.

3.2.10.2 Retaining structures and any supports they rely upon must be designed against structural failure in accordance with LU standard S1051, BS EN 1992 (concrete), BS EN 1993 (Steel), BS EN 1996 (Masonry) and BS EN 1536.

Note: BS EN 1997-1 does not explicitly cover the detailed design of soil nails or reinforced earth soil structures. The design of reinforced soil structures should be carried out in accordance with the National Standards i.e. BS 8006-1 and CIRIA C637

3.2.11 Actions (loading)

3.3.11.1 Actions (variable and permanent loadings) to be used in the design of Earth Structure assets shall be as given in section 3.5.6 of this standard.

3.2.12 Design life

3.2.12.1 The Design Life for Earth Structure assets shall be 120 years.

3.2.12.2 The design shall state any monitoring and maintenance liability required to achieve the Design Life and this shall be identified in the design report.

3.2.12.3 The Design Life shall apply to the Earth Structure asset as a whole and all elements within the Earth Structure contributing to its performance of the Required Duty other than drainage elements covered by LU standard S1052.

3.2.13 Fire resistance

3.2.13.1 Earth Structure design within areas covered by the Fire Precautions (Sub-surface Railway Stations) Regulations shall meet the requirements for fire performance in LU standard S1085.

3.2.13.2 Earth Structure design for assets requiring a fire safety strategy shall be designed to the requirements for passive fire resistance in LU standard S1083 in support of the fire safety strategy.

3.2.14 Constructability and Temporary Works

3.2.14.1 The overall stability of slopes for temporary cuttings and open excavations during construction should be determined in accordance with principles of BS EN 1997-1.

Note The Design Life of Temporary Works to support construction activities, in most cases, is of sufficient duration to adopt effective stress analysis. Adoption of total stress (undrained) analysis should be limited to short term Temporary Works where the designer is satisfied that insufficient time is available for porewater pressure to dissipate and drained conditions to develop. This decision must be carefully considered as the transition from undrained to partially drained conditions occurs relatively quickly in most fine grained soils on the LU system.

3.2.14.2 The design shall evaluate Temporary Works and intended construction methods required for the construction of the permanent works in accordance with LU standard S1062.

3.2.14.3 Where there is evidence of historical slope instability and presence of pre-existing shear surfaces the construction methodology and the temporary works design shall be developed such as to avoid reactivation of the relic shear surfaces.

3.2.14.4 Monitoring of temporary works, the track, the earth structure and other associated structures (e.g., culverts, bridges, abutments, wingwalls, etc.) shall be carried out as appropriate in order to ensure stability of the works and the operation of the railway during construction.

3.2.15 Impact on operational railway and adjacent structures

3.2.15.1 The design shall take account of LU standard S1050.

3.2.15.2 The design shall take account of the top level railway safety principles in the “Railway Safety Principles and Guidance” (RSPG).

3.2.15.3 The design shall provide for supporting other infrastructure elements of the railway, such as track bed, cable posts, signals, signage and lighting.

3.2.15.4 The design shall provide for adequate access and working space to any cable run.

3.2.15.5 The design shall provide adequate space including access and working space for the installation of a new cable run if none is currently provided wherever practicable.

Note: LU standard S1156 requires that “The minimum distance from running edge to the face of a cable post shall be 2.44m. This dimension shall be increased to allow for cant effect and vehicle throw on curves as shown on the appropriate structure gauge diagram.” A further distance is required from the cable post to the edge of an embankment to provide stability of the cable posts as determined by analysis.

3.2.16 Provision for Inspection and Maintenance.

3.2.16.1 The design shall incorporate provisions to facilitate the Inspection and Maintenance operations necessary for the achievement of the Required Duty over the Design Life of the Earth Structure asset.

3.2.16.2 The design shall provide for an unobstructed cess with a minimum width of 700mm at a distance not less than 430mm from the swept envelope at both sides of the line along which persons can walk and may stand in safety during the passage of trains to be maintained at all times during Maintenance work of Earth Structures.

3.2.16.3 The design shall provide for an unobstructed corridor with a minimum width of 1000mm between the outermost part of the cable run and the edge of an embankment for inspection and maintenance of the cable run and embankment.

3.2.16.4 The design shall consider the need for provision of cable stiles to facilitate access to the widened crest from track. The design of cable stiles shall be in accordance with LU standard S1057.

3.2.16.5 The design shall provide for an unobstructed corridor with a minimum width of 1000mm between the boundary fence and the toe of an embankment or crest of a cutting for inspection and maintenance of the earth structure and the boundary fence. In areas where space is limited the width of the corridor may be locally reduced to 700mm. Approval for this reduction in width will be required before the design can be finalised.

3.2.16.6 A geotextile material such as a Terram Rootguard or similar approved shall be installed below the clear corridors in 3.2.16.3 and 3.2.16.5 above in order to prevent vegetation growth.

3.2.17 Operational boundary fence

3.2.17.1 Where the existing boundary fence at the toe of an embankment or crest of a cutting is sub-standard or is affected by the remedial works it shall be replaced with a new boundary fence.

3.2.17.2 The specification, design and installation of the boundary fence shall be in accordance with LU standard S1167.

3.2.18 Steps

3.2.18.1 The design shall consider whether steps are required to facilitate access from the toe to the crest of an earth structure. Where steps are required the design shall be carried out in accordance with the LU standard S1133 and LU guidance G0054A.

3.2.18.2 A handrail shall be provided on one side of the steps as a minimum. The design of the handrail shall be in accordance with LU standard S1133.

3.2.19 Noise barriers

3.2.19.1 Where a noise barrier is required to be installed to mitigate the noise disturbance from the railway to the local residents, the noise barrier shall be designed and installed in accordance with HA 65/94 and HA 66/95 the relevant LU, national and international standards.

3.2.20 Services

3.2.20.1 The design shall investigate the location of all services affected by the works in accordance with PAS 128 “Specification for underground utility detection, verification and location” and clearly identify these on the design drawings by hazard triangles.

3.2.20.2 The design shall avoid the location of services where possible. Otherwise the design shall arrange for diversion or protection of the services, as appropriate. The design intent shall be clearly shown on the design drawings and included in the designer’s risk assessment.

3.2.21 Buried structures

3.2.21.1 The design shall identify the location of any buried structures affected by the works and shall take appropriate measures to comply with the relevant LU and other applicable standards regarding exclusion zones and loading requirements.

3.2.21.2 Where it is considered not possible to comply with the requirements of relevant LU and other relevant and applicable standards a concession to the requirements will be required before the design can be finalised.

3.2.22 Ground improvement techniques

3.2.22.1 Ground improvement techniques included in the design shall be assessed over the whole Design Life of the new works including quantification of all anticipated Maintenance and Monitoring work.

3.2.23 Geosynthetics

3.2.23.1 The design for Earth Structures that incorporate geosynthetic materials at appropriate locations to enhance the natural behaviour of soil and rock (chalk) shall demonstrate that the specified materials have been assessed for the railway environment, including assessment of risks due to fire, vandalism, and the short and long-term exposure to chemical, biological and ultra-violet degradation.

Note: Potential uses of geosynthetics in Earth Structures include:

a) separation - the geosynthetic forms a boundary between different soil materials, thus segregating two or more particle sizes;

b) reinforcement - the geosynthetic imparts tensile strength to a reinforced soil system;

c) filtration - the geosynthetic effectively retains particles while allowing water to flow through with little or no increase in pore pressure;

d) drainage - the geosynthetic effectively allows water to flow in the plane of the fabric, thus allowing drainage of water away from a structure or system.

A given geosynthetic material may fulfil several of these uses. In erosion control the primary function of a geosynthetic is filtration with the separation function playing a secondary role.

3.2.23.2 The design shall determine the minimum Design Life required for geosynthetic materials incorporated in the works in relation to their design function, and relate

these to the properties of proposed materials as established by Agrément Certificates or other verified testing.

3.2.23.3 For permanent works the geosynthetic shall retain the properties required to fulfil the in service design function throughout the Design Life of the Earth Structure asset.

3.2.23.4 Where a geosynthetic material is proposed to be incorporated into works, both its beneficial and detrimental effects on the performance of the structure shall be taken into account in the design of the works. This shall include the long-term effects of geosynthetics included for a temporary purpose.

3.2.23.5 Testing shall be carried out to confirm properties of geosynthetics affecting Earth Structures design except where the required information is available from Agrément Certificates and other such quality assured sources, which may include appropriate guidance documents and recommendations of the manufacturer and validated performance records.

3.2.23.6 The need for and extent of testing shall be assessed from the safety implications of the work and the performance record of the proposed material in equivalent applications to that under consideration.

3.2.23.7 Justification of the design parameters used for geosynthetics shall be included in the design records, including tensile, shear, burst strength, creep, frictional, filtration and hydraulic characteristics as applicable to the usage.

3.2.24 Instrumentation and monitoring

3.2.24.1 The design shall state the requirements for instrumentation and monitoring to assist construction, to evaluate performance including ongoing deformation in relation to the requirements of section 3.2.8.4 over an annual cycle, and to improve understanding for the long-term management and maintenance of the asset.

3.2.25 Landscaping and planting

Note: Vegetation plays an important role in controlling the pore pressure regime in the clay slopes, as well as the swell-shrink behaviour and the shallow stability. Hence, vegetation on the earth structures shall be managed in a manner to maximise the beneficial effects of reducing the pore pressures and increasing the near surface shear strength through root reinforcements, as well as minimising the detrimental impact of swell-shrink behaviour.

3.2.25.1 The design shall consider the implementation of a landscaping and planting scheme to environmentally enhance the appearance of the Earth Structure in accordance with LU standard S1165.

3.2.25.2 As part of any new works at an Earth Structure, the design shall ensure that the resulting slope vegetation is consistent with the requirements of LU standard S1165. Where necessary this shall include provision of measures to prevent the erosion of topsoil before the vegetation is established.

3.2.25.3 The species and associations of grass, trees, shrubs and other plants for landscaping shall be selected on the basis of their growth characteristics and site conditions and compliance with LU standard S1165, except that only low water

demand trees, as defined by National House Building Council (NHBC), shall be planted on Earth Structure slopes to ensure an even water demand during the Design Life.

3.2.25.4 The landscaping design shall minimise future maintenance and risk of tree and leaf fall to the operation of the railway. In principle where it is not required by local environmental or aesthetic factors grass seed only vegetation shall be planted, provided that this is consistent with the design pore pressures.

3.2.25.5 For slopes steeper than 30° where topsoil is unlikely to remain stable in the long term, consideration shall be given to the use of erosion mats, hydroseeding or ground covering planting.

3.2.26 Design documents

3.2.26.1 A design report shall be prepared in addition to the requirements of LU standard S1050.

3.2.26.2 The design report shall describe any requirements for instrumentation and monitoring including full details of purpose, installation requirements, and frequency of readings.

3.2.26.3 The Designer shall have a process for checking and verifying design calculations.

3.3 Construction, installation, testing and commissioning

3.3.1 General

3.3.1.1 All construction, installation, testing and commissioning work shall be carried out in accordance with Construction (Design and Management) Regulations and all relevant safety legislations.

3.3.1.2 Prior to breaking ground at any time, a ‘permit to dig’ procedure shall be implemented and followed by the Contractor.

3.3.1.3 Construction installation, testing and commissioning shall put into effect the design requirements as defined in section 3.2 of this standard.

3.3.1.4 No new or Strengthening and Renewal construction work shall start until the permanent works and temporary works designs for that work has been approved in accordance with LU standards S1538 and S1050.

3.3.1.5 A system to control and manage the construction process shall be maintained.

Note: This system is required to enable LU:

a) to discharge their responsibilities to Office of Rail and Road (ORR);

b) to discharge their responsibilities to maintain safe structures and operating railway systems during construction works;

c) to satisfy itself that the construction is in accordance with the design; and

d) to satisfy itself in respect of the adequacy of the system for the recording of construction data and information that may be relevant to the subsequent

Maintenance, Strengthening and Renewal and eventual decommissioning of the Earth Structure assets.

3.3.1.6 Procedures shall be in place for controlling any changes to the design during the construction, installation, testing and commissioning phases including staged and temporary construction work. Such procedures shall ensure that:

a) proposed design changes are not implemented until they have been duly considered and approved by a person competent to appreciate their impact on construction methodology and their implications for the safety of the operational railway; and

b) records are made of the design changes and their approval.

3.3.1.7 Adjacent buildings, structures, utilities and facilities, and the track shall be protected from the effects of construction work in accordance with LU standard S1050.

3.3.1.8 Sufficient testing of systems, sub-systems, materials and components shall be carried out to give assurance that they are in accordance with those specified in the approved design.

3.3.1.9 All necessary attendance during site visits shall be afforded to LU to enable LU to discharge its responsibilities in respect of its duties including verification.

3.3.1.10 Where appropriate to the scope of work, a design capability shall be made available throughout construction to ensure and certify implementation of the design intent.

Note: Ensuring implementation of the design intent includes interpretation of Monitoring data and modification of the design if necessary.

3.3.2 Work sites and access

3.3.2.1 The location and size of the working sites required for the efficient and safe servicing of construction activity shall be selected.

3.3.2.2 Arrangements necessary to obtain permission to use sites for the intended purpose for the duration of construction activity shall be made.

3.3.2.3 The provision of an unobstructed cess with a width of at least 700mm at a distance not less than 430mm from the swept envelope at both sides of the line along which staff can walk and may stand in safety during the passage of trains shall be maintained at all times during Earth Structures construction activity alongside an operational railway.

3.3.3 Construction methods

3.3.3.1 The construction method(s) shall meet the requirements defined in the documentation for implementation within the specified tolerances and of the specified dimensions and quality.

3.3.3.2 Before any modifications are made to a construction method the design shall be checked and if necessary modified.

3.3.4 Materials

3.3.4.1 All construction materials supplied to the works shall comply with the requirements of LU standard S1050 and the project specification. The project specification shall comply with Tfl Specification T0007.

3.3.5 Instrumentation and monitoring

3.3.5.1 Where appropriate to the scope of work, the following shall be carried out:

a) Verify the predictive ground movement and the effects which such ground movement will have on LU and adjacent assets by measurement.

b) Determine the impact on Outside Party assets in accordance with LU standard S1023.

c) Establish Monitoring base readings of the construction activity sufficiently in advance to ensure underlying and seasonal environmental trends are understood.

d) Implement contingency plans if the results of Monitoring so indicates.

3.3.6 Pumping

3.3.6.1 Pumping of water shall wherever practical be performed within the boundary of the excavation.

3.3.6.2 Where pumping is to be undertaken, provision shall be made to prevent the removal of fines from the soil, such that adjacent buildings, structures utilities or facilities are not affected by the pumping operations.

3.3.6.3 Pumping shall be undertaken in the manner foreseen by the design determinations of the effect of modifying groundwater level.

3.3.7 Construction documents

3.3.7.1 Construction documents shall be prepared in accordance with LU standard S1050.

3.3.7.2 At the end of construction the drawings shall record the works as built.

3.3.7.3 A record of all as-built drawings shall be provided in an electronic format.

3.3.7.4 The as-built drawings shall record the location of all temporary works.

3.3.7.5 All temporary works left in place shall be clearly shown on the as-built drawings.

3.4 Inspection

3.4.1 General

3.4.1.1 Inspections shall be undertaken to achieve the following objectives:

a) to provide information necessary for the managed maintenance of Earth Structure assets

b) to confirm that Earth Structures are safe for railway operations and for public and third party use

c) to provide the information necessary to assess the condition of the Earth Structure assets in a consistent and accurate manner

d) to provide information enabling the Engineering Asset Register (LU standard S1041, Engineering Asset Information) to be maintained as an accurate record of the physical nature of the Earth Structure assets

e) to provide the information required for Stage 1 of the Asset Condition Assessment and Certification (ACAC) process as defined in section 3.6 of this standard

f) to maintain quantitative records of the on-going changes of condition of the Earth Structure assets for long-term asset management planning

g) to identify defects, the causes and effects of deterioration and high risk Earth Structures.

Note: Inspection is the core procedure by which LU are able to maintain awareness of the condition of the Earth Structure assets for which they are responsible, detecting incipient defects at an early stage and identifying the need and urgency for corrective action.

In addition, the Inspection records provide the knowledge basis needed for the long-term management of LU's Earth Structure assets.

3.4.1.2 Any usage of Earth Structure assets or development of defects which might place at risk the operational railway, interfacing assets, passengers, staff, or the public shall be identified, made safe, recorded and brought to the immediate attention of LU.

3.4.1.3 Where defects are observed, a decision shall be made whether a more detailed appraisal is necessary to ensure that appropriate information is available to meet the requirements of the Condition Assessment and Maintenance obligations.

3.4.1.4 Following completion of each Inspection the Engineering Asset Register for each Earth Structure shall be reviewed and the records updated as part of the reporting process.

3.4.1.5 All inspections shall be preceded by a sufficient review of recent maintenance history, previous inspections and any known changes of circumstances to establish as far as possible the background information about the asset and likely hazards.

3.4.1.6 The role of Inspection in the ACAC/ACR process shall be as shown in Attachment 11.4.

3.4.2 Types of inspection

3.4.2.1 Earth Structure assets shall be subject to the following types of Inspection:

a) Principal

b) Special

c) Defect Advice

d) General.

3.4.2.2 Obtaining and recording of information by Principal Inspections shall be the primary means of achieving the objectives for Inspection of Earth Structure assets set out in section 3.4.1.1 of this standard.

3.4.3 Principal Inspections

3.4.3.1 Principal Inspections shall provide all the information required to make a visual evaluation of the condition of the asset and its ability to perform the Required Duty and to complete Stage 1 of the Asset Condition Assessment and Classification (ACAC) process.

3.4.3.2 Principal Inspections shall be carried out in accordance with the procedure set out in Attachment 11.1 to this standard except as provided in section 3.4.4 below.

3.4.3.3 The information to be recorded in a Principal Inspection shall as a minimum be sufficient to complete a full entry of the Inspection into the LU Earth Structures Database and use of the accompanying condition rating tool (see section 3.4.10 below) except where a reduced scope of Inspection has been justified in accordance with section 3.4.4. The information to be recorded to meet the entry requirements for the database is tabulated on the sheets in Attachment 11.3.

3.4.3.4 The information to be recorded in a Principal Inspection shall include a description of the visible elements of all Strengthening and Renewal works or other support works in place, and an appraisal of their condition.

3.4.4 Reduced scope of Principal Inspection

3.4.4.1 A reduced scope of Principal Inspection may be undertaken where there is a negligible risk to rail traffic, passengers, staff and the public, e.g. along branch lines where trains are no longer running, provided no change in condition from the most recent full Principal Inspection is anticipated. Justification of the reduction in scope of the Inspection shall be recorded. This inspection shall be recorded as a General Inspection.

3.4.5 Special Inspections

3.4.5.1 Special Inspections shall be instigated under the following circumstances and at the following intervals in order that awareness of the condition of particular areas or defects causing concern is maintained.

a) Earth Structures that have failed to meet the minimum condition to operate without restriction in accordance with section 3.6.8 (3 monthly maximum interval). Less frequent intervals can be adopted subject to approval by the Head of Earth Structures;

b) Earth Structures supporting track that have a current speed restriction in force as a result of a previous Assessment of Earth Structure condition to the requirements of section 3.5 of this standard (3 monthly maximum interval);

c) Earth Structures of concern after previous routine inspections e.g. classified as ‘poor’ condition and continued Monitoring recommended following a Principal Inspection (interval as recommendation).

3.4.5.2 The scope of Special Inspections and reporting shall be determined based on the extent of the concerns identified, but will typically involve the recording of defects

with a comparison of those defects from one inspection to the next, for the purpose of identifying deterioration of the asset. This comparison may be achieved using measurements, photographs or such other means as may be appropriate.

3.4.6 Defect Advice Inspections

3.4.6.1 Defect Advice Inspections shall be carried out following defect notification from any source, or in response to a report of an Incident that causes damage to an Earth Structure asset or has the potential to affect adversely the ability of the asset to perform its Required Duty.

Note: Typically Defect Advice inspections at Earth Structures are required by reports of sub-standard track, slope bulges and cracks, etc, or by events such as cloud bursts and local flooding, blocked drains, etc.

3.4.6.2 Defect Advice Inspections shall bring to notice obvious deteriorations in condition, unusual conditions and any short term development of defects which might place at risk the traffic, passengers, staff, the public or the Earth Structure asset as a whole.

3.4.6.3 The Inspector shall inspect the Earth Structure asset from all readily accessible locations and levels as necessary to evaluate the cause for concern.

3.4.6.4 The Inspector shall certify in his report that the structure appears to be in a satisfactory condition, and shall note any exceptions where action may be required before the next scheduled Inspection and the associated degree of urgency, or shall call for immediate action if the situation so demands.

3.4.6.5 Where defects are observed which, in the opinion of the Inspector, require closer Inspection, the Inspection report shall include recommendations for further investigation.

3.4.6.6 The information to be recorded in the Inspection report shall include details of the defect notification or Incidents that triggered the Inspection and shall make use of photographic records as appropriate, including photographs of all observed defects.

3.4.6.7 Sufficient information shall be collected to enable the full reporting of any notifiable Incident to the ORR.

3.4.7 General Inspections

3.4.7.1 These inspections are intended to provide a more frequent but less onerous means of monitoring the condition of an asset.

3.4.7.2 General Inspections may be carried out between principal inspections for assets where there is an inclement weather risk or serviceability concern identified that justifies an increased inspection frequency but which does not require more frequent principal inspections.

3.4.7.3 General inspections are carried out for the entire earth structure, but do not require recording of transects as in a Principal Inspection.

3.4.7.4 The purpose of the inspection is to highlight any defects or areas of deterioration in the condition of the asset and to record any unusual conditions on the asset which may compromise the stability of the asset and its ability to perform its required duty.

3.4.8 Preparation for inspections

3.4.8.1 Inspectors undertaking Earth Structure Inspections shall be trained to ensure that a consistent level of reliable Inspections is maintained.

3.4.8.2 All new Inspectors shall demonstrate by the Inspection of a typical Embankment and Cutting under supervision, at locations where historic assessments have been undertaken, that they have been trained to provide Principal Inspection results consistent with experienced inspectors.

3.4.8.3 Training shall cover the preparatory steps needed to achieve a safe and comprehensive Inspection of the target site, such as assessing access requirements and special safety considerations, and the examination and understanding of previous Inspection and Maintenance history, available construction records, etc.

3.4.8.4 The records shall be maintained to permit the auditing of Inspector training.

3.4.8.5 The Inspector shall establish the known issues associated with an Earth Structure before undertaking its Inspection commensurate with the scope of the Inspection in accordance with section 3.4.1.5.

3.4.8.6 In the case of a Principal Inspection the known issues shall include the design and function of any existing Strengthening and Renewal works or other slope support works recorded at the asset.

3.4.9 Maximum inspection intervals

3.4.9.1 The maximum interval between inspections shall be such that:

a) Sufficient information is gathered for the timely identification of defects and deterioration for action within the asset management plan such that the risk to railway safety from events and changes of condition is ALARP.

b) Information is obtained to meet the requirements of the ACAC/ACR process for Earth Structures.

3.4.9.2 The maximum interval between Principal Inspections shall not exceed that given in Table 1 for the appropriate condition rating category of the asset, as qualified by any recommendation for geotechnical investigation. The condition rating category shall be as determined from Table 3 (see section 3.4.10.5) following the most recent Inspection or Assessment.

Condition rating category	Maximum interval between Principal Inspections (years)
Earth Structures categorised as in 'Poor' condition and where further geotechnical investigation is recommended or assessed to present a higher risk based on factor of safety and/or physical condition	1
Earth Structures categorised as in 'Poor' condition	2
Earth Structures categorised as in 'Marginal' condition	5
Earth Structures categorised as 'Serviceable' or 'Good'	10

Table 1 - Maximum interval between Principal Inspections of Earth Structures

3.4.9.3 As a minimum Defect Advice Inspections shall be carried out following any report or event that may indicate an abnormal change of condition may have occurred at an Earth Structure asset.

3.4.9.4 The maximum interval between Special Inspections shall be in accordance with section 3.4.5.1.

3.4.9.5 The maximum interval between General Inspections shall not exceed that given in Table 2. These inspections shall be in addition to the Principal Inspections.

Condition rating category	Maximum interval between General Inspections (years)
Earth Structures categorised as being at 'High' risk of flow failure, frost shattering or scour erosion.	1
Earth Structures categorised as having 'Poor' (D_S) serviceability concern. Earth Structures categorised as being at 'Medium' risk of flow failure, frost shattering or scour.	2
Earth Structures categorised as having 'Moderate' (C_S or B_S) serviceability concern. Earth Structures categorised as being at 'Low' risk of flow failure, frost shattering or scour.	5

Table 2 - Maximum interval between General Inspections of Earth Structures

3.4.10 Information from inspections

3.4.10.1 The information from inspections shall be held in databases having the equivalent record structure to the "LU Earth Structures Database" or in a format compatible with future entry into such a database.

Note: The "LU Earth Structures Database" refers to a database set up by LU to hold Inspection information for all transects along the LU railway system that cross Earth Structures. Information at inspected sections not covered by the transect records is also held. The database structure is set up to hold all the information collected in a full Principal Inspection, which encompasses the data that might be collected by other classes of Inspection. The original database is no longer maintained but the record structure remains and is to be retained as part of the long-term asset management of Earth Structure assets. Populating databases having this common record structure with the results of inspections over an extended period will enable the long-term changes to the Earth Structures to be quantified and better understood across the network.

3.4.10.2 The information held shall maintain a consistent and repeatable standard that shall ensure compatibility in condition rating for inspected Earth Structure assets across the railway network and through time.

3.4.10.3 A response shall be provided to any condition revealed by the collection or processing of Inspection information that calls for immediate action ahead of completion of the Inspection report in order to achieve compliance with section 3.4.1.2 and section 3.6.8 of this standard.

3.4.11 Determination of condition rating

3.4.11.1 The information from Principal Inspections shall be used to determine a condition rating for the slope at each inspected Transect and Feature as a measure of the state of the slope compared with a slope in a notional perfect condition, i.e. 100% represents a slope in perfect condition and 0% represents a slope in very poor condition.

3.4.11.2 The calculation of condition ratings shall be based on the standardised condition rating algorithm used by the LU Earth Structures Database Condition Rating Tool (CRT). The logic of that algorithm may be incorporated into the working module provided any such module has been independently checked and audited to show that it gives the same results as the standard LU Earth Structures Condition Rating Tool. Copies of the check and audit of the condition rating procedure shall be maintained. Refer to LU Guidance Document G0054A for further details on CRT and the algorithm.

Note: The LU Earth Structures Condition Rating Tool (CRT) is a module that accompanies the LU Earth Structures Access Database. It is available in an Excel spreadsheet format. The tool is used to determine a provisional condition rating from inspection for each completed record in the Principal Inspection data. The calculated condition ratings from the condition rating tool ranges from 5% to 90%. Reference should be made to the LU Guidance Document G0054A for guidance on CRT.

3.4.11.3 For recently remediated assets, some of the defects may be residual defects relating to movement prior to remediation (e.g. leaning cable posts), and that if this is established, the effect of these defects need not be taken into account in the determination of the condition rating. However, the presence and magnitude of such defects should always be recorded accurately, to allow monitoring of future changes.

3.4.11.4 The Earth Structure shall be assigned a condition rating category from the overall condition rating as given in Table 3:

Condition rating category	Overall condition rating %
Poor	0 to ≤40
Marginal	>40 to ≤65
Serviceable	>65 to ≤85
Good	>85 to 100

Table 3 - Earth Structure condition rating categories

3.4.11.5 If the Inspector considers that there are concerns in the performance or condition of Strengthening and Renewal or other support works that are beyond the scope of an Inspection to reasonably evaluate then he shall recommend further Analytical Assessment to determine the condition and performance of those works.

3.4.12 Inspection reports

3.4.12.1 Inspection reports shall be prepared by the Inspector as part of the Inspection process that record the data collected and the conclusions and recommendations of the Inspectors appropriate to the type of Inspection carried out as indicated in sections 3.4.3 to 3.4.7 of this standard.

3.4.12.2 All Inspection reports shall include a full copy of the recorded data and photographic records of any defects noted. In addition the reports of Principal Inspections shall include at least one general photograph of each Transect or Feature inspected.

Note: Photographs shall be presented in the inspection report with the LCS reference and location and orientation of view clearly stated.

3.4.12.3 The Inspection report shall classify the extent and severity of any defects observed together with the recommendations of any necessary action and associated urgency in accordance with the system shown in Table 4.

Extent	A	-	No 'significant' defect
	B	-	'Slight', not more than 5% affected (of area, length, etc)
	C	-	'Moderate', 5% to 20% affected
	D	-	'Extensive', over 20% affected
Severity	1	-	No 'Significant' defect
	2	-	'Minor' defects of a non-urgent nature
	3	-	'Heavy' defects of an unacceptable nature
	4	-	'Severe' defects where action is needed. These shall be reported immediately to the supervisor.
Recommended action	R	-	Repair
	M	-	Monitor
	I	-	Special Inspection regime
	D	-	Design remedial works
	C	-	Replace
	G	-	Ground investigation
	T	-	Topographic survey
	A	-	Slope stability assessment
	S	-	Speed restriction
Priority	I	-	Immediate (within 4 weeks)
	H	-	High (within 12 months)
	M	-	Medium (within 2 years)
	L	-	Low (before next Principal Inspection)
	R	-	Review (at next Principal Inspection)

Table 4 - Earth Structure defect classification system

3.4.12.4 The Inspection report shall recommend the date for the next principal or special Inspection where appropriate. The maximum interval between Principal Inspections is given in Table 1, for General Inspections in Table 2, and for Special Inspections in section 3.4.5.1.

3.4.12.5 The inspection report of a Principal Inspection shall contain the provisional condition ratings derived from the procedures in section 3.4.11. Justification for changing the provisional condition ratings shall be recorded in the report and shall be auditable.

Note: Condition ratings calculated using the LU Earth Structures Condition Rating Tool algorithm as described in section 3.4.10 of this standard are in significant part derived from a parametric estimate of inherent slope stability for a range of standard soil profiles and slope heights which are matched to the observed and measured data on the basis of reported geology, slope height and geometry. The Assessor should use professional engineering judgement in assessing the impact of this approach, in particular whether soil conditions have been reasonably represented in the data used by the algorithm to select the dominant material controlling slope stability. If the soil conditions are not well represented by the basic data input procedure then the Assessor can obtain more realistic results by suitably adjusting the data input for geology and recalculating the condition rating values. Reference shall be made to LU Guidance Document G0054A for CRT and the algorithm.

3.4.12.6 All Principal Inspection Reports shall be reviewed and approved by an accredited Inspection Review Engineer (IRE) before being finalised. Any revisions to the condition ratings for the asset by the IRE shall be recorded in the report.

3.4.12.7 Any proposed change in the Asset Condition Classification and/or inspection frequency shall be submitted for approval by the Head of Earth Structures or his accredited representative.

3.4.12.8 The recommendations of the finalised Inspection report shall be included in the asset management programme as soon as reasonably practical after completion of the report.

3.4.12.9 The finalised Inspection report with the Inspection records securely attached shall be retained for the life of the asset.

3.5 Analytical Assessment

3.5.1 General

3.5.1.1 The Analytical Assessments of existing Earth Structure assets shall be carried out in order to achieve the following objectives:

a) determination as to whether the asset remains fit to safely fulfil its Required Duty in the current environment and condition and if not of the degree to which it fails to reach that requirement;

b) determination of the Factor of Safety against slope failure of the asset for all foreseen modes of failure;

c) evaluation of the asset Assessment Condition Rating which places the asset in a condition category; and

d) fulfilment of the requirements of Stage 3 of the Asset Condition Assessment and Classification (ACAC) process as defined in section 3.6 of this standard.

3.5.1.2 The Assessment of an Earth Structure asset shall include:

a) examination of information on the physical conditions in the vicinity of the asset, including the topography and layout of the site

b) consideration of the nature of the ground, Groundwater and surface water conditions and seasonal variations, including the impact of climate change.

c) examination of details of adjacent foundations and services, and other adjacent and interfacing assets, including track, cess and walkways

d) characterisation of the type and location of vegetation on the slope, particularly the presence of bare or grass covered slopes or the presence of high water demand trees

e) determination of the Factor of Safety against failure of the slopes under the applicable loadings

f) determination of the deformation behaviour, where this is a separate consideration in the performance of the Required Duty

g) evaluation of the performance of installed works that contribute to the support of the slope including Strengthening and Renewal works

h) determination of the asset Assessment Condition Rating

i) recommendations for future management of the asset

j) undertaking of appropriate risk assessment depending on the derived Assessment Condition Rating.

Note: This list is not exhaustive and other items may be required on a case-by-case basis.

3.5.1.3 The information required to perform the Assessment shall be obtained from a thorough desk study and walk-over survey and from Site Investigation.

Note: The desk study and walk-over survey constitute stage 2 of the Asset Condition Assessment and Classification (ACAC) process as defined in section 3.6 of this standard.

3.5.1.4 The results of the Analytical Assessment shall be presented in an Assessment report as described in section 3.5.14.

3.5.1.5 The processes of Analytical Assessment for Earth Structure assets shall be managed and assessed by Geotechnical Specialists.

3.5.2 Desk study

3.5.2.1 Before undertaking the Analytical Assessment of an Earth Structure or as otherwise required by the ACAC/ACR process all the information available for the asset, and for adjacent foundations and services, and other adjacent and interfacing assets as appropriate, shall be collected and reviewed in a thorough desk study.

3.5.2.2 The desk study shall identify all the issues to be resolved by an Analytical Assessment.

3.5.2.3 The desk study shall determine the information required for an Assessment, which as a minimum shall cover the factors listed in section 3.5.1.2 of this standard, and shall consider the sufficiency of existing information at cross-sections for stability analysis, including the zoning of materials and their properties, Groundwater levels, and factors determining the influence of vegetation on the slope.

3.5.2.4 A list of potential sources of information to be reviewed in the desk study is given in Table 5. This list should not be considered as exhaustive.

Information Source	Typical information available or to be obtained
Inspection reports	All current and previous inspection reports for the same asset; All current and previous inspection reports for interfacing assets; and Inspection reports of assets with similar material properties and geometry to the asset undergoing assessment.
Walkover survey reports	All current and previous walkover reports for the same asset; All current and previous walkover reports for interfacing assets; and Walkover reports of assets with similar material properties and geometry to the asset undergoing assessment.
Analytical Assessments	All current and previous Analytical Assessments; All current and previous Analytical Assessments for interfacing assets; and Analytical Assessments of assets with similar material properties and geometry to the asset undergoing assessment.
Inclement Weather Report	Mode of failure Risk classification
As built data	Date of construction; Method of construction; Material properties used in the design; and Design calculations.
Monitoring data	All monitoring reports.
Operational information	Operational history of the asset; Operational history of adjacent assets; and Operational history of interfacing assets.
Incident reports	For the asset under assessment ; For adjacent assets; and For interfacing assets.
Literature review	Asset type behaviour; and Material properties.

Table 5 - Information sources to be reviewed by a desk top study

3.5.2.5 The desk study shall include a walkover survey made after initial review of the data but before completing the interpretation of the data and preparation of the report.

3.5.2.6 In the case of an Assessment being made as part of the process the Assessor for the desk study shall re-evaluate the condition rating and condition category of the asset in accordance with the Stage 2 requirements for a Level 1 Condition Assessment as described in section 3.6.3.3 of this standard.

3.5.2.7 The results of the desk study shall be presented in a desk study report.

3.5.2.8 In the event that the desk study report concludes that there has been insufficient existing information identified to carry out required slope stability and other calculations, the desk study report shall provide the technical information needed to complete a CDS/CWS for a Site Investigation to be carried out to obtain the additional data.

Note: Earth Structures that have not previously been the subject of Analytical Assessment will in almost all cases require further Site Investigation.

3.5.3 Site investigation for assessment

3.5.3.1 A ground investigation in accordance with the requirements of LU standard S1050 and BS EN 1997-2 shall be carried out on a series of cross-sections to provide the necessary information for an Analytical Assessment in accordance with the findings of the desk study.

3.5.3.2 A topographic survey of the slope shall be carried out in order to establish the slope geometry at the cross-sections undergoing Analytical Assessment. The topographic survey shall include the measurement of ground level outside the LU boundary fence.

3.5.3.3 An Earth Structure Assessment requires a judgement to be made of the effect that the pore pressure regime will have on the stability of the Earth Structure. During the Ground Investigation, piezometers or standpipes shall be installed to assist in determining the ground water and pore pressure conditions.

3.5.3.4 Where appropriate, movement monitoring instrumentation shall be installed during the ground investigation to establish the Earth Structure's deformation mechanisms.

3.5.3.5 Where possible, the instrumentation shall be monitored through at least a twelve month period to account for the seasonal variation of pore-water pressure prior to completing an Analytical Assessment.

3.5.3.6 The effect of existing vegetation on slope stability, track deformation, retaining structures loadings and drainage shall be investigated and monitored during site investigation as recommended by the desk study to verify vegetation type and location on the slope. In particular the changes in the moisture content of the soil and any associated swell/shrinkage within the Earth Structure shall be measured wherever possible prior to undertaking the Analytical Assessment, recognising the potential effects of different vegetation types.

3.5.3.7 The interpretation of existing information and new information from site investigation shall include:

a) review of previous recorded instability at the site or the surrounding locality

b) investigation into the presence of existing shear surfaces within Earth Structure assets or founding materials, produced by previous instability or periglacial action

c) establishing appropriate values for drained soil parameters

d) establishing appropriate values for undrained soil parameters (if required)

e) establishing appropriate values for consolidation and deformation behaviour (if required)

f) establishing appropriate values for compaction behaviour (if required)

g) assessment of any special considerations with respect to chalk (if required)

h) establishing parameters to quantify groundwater conditions, including the conditions applicable to stability analysis

i) review of desk study for the site, including geology, hydrogeology and topography

j) review of Inspection report and condition ratings

k) review of maintenance and track recording vehicle records

l) review of inclement weather report.

Note: This list is not exhaustive and other items may be required on a case-by-case basis.

3.5.3.8 Factual and interpretative reports of the Site Investigation shall be prepared containing the data recorded and the interpretation and recommendations arising from the data.

3.5.4 Soil parameters

3.5.4.1 Earth Structures shall be assessed using drained soil parameters and appropriate pore-water pressure values consistent with guidance for selection of suitably cautious parameters, allowing for relevant material degradation processes and seasonal effects.

Note: Characteristic soil parameter values appropriate for the slope stability assessment of first time failures of Earth Structures have been established by previous detailed research, laboratory and field studies, including surveys of past slope performance and back analysis of failures. Reference shall be made to LU guidance G0054B for derivation of soil parameters.

3.5.4.2 The characteristic soil parameter values given in this section for the assessment of first time failures of Earth Structure slopes shall be used for Design and Assessment analyses where their use is appropriate to the site conditions and in the absence of further site specific information that enables these values to be modified.

3.5.4.3 Characteristic soil parameter values shall be selected in accordance with Table 6 for the materials listed unless the materials at a particular site are sufficiently different to those normally encountered that other values are deemed appropriate. The difference shall be demonstrated through appropriate ground investigation and laboratory testing.

3.5.4.4 Parameters for materials not shown in Table 6 such as chalk, chalk fill, clay with flint, Lambeth Group or Brickearth shall always be determined on a site-by-site basis in accordance with BS EN1997-1 and LU guidance G0054B.

Material	γ (kN/m^3)	c′ (kN/m^2)	ϕ'
Alluvium	19	1	25
Ash	11	0	35
Ballast	18	0	40
Embankment fill: cohesive (see notes below)	19	1	21
Embankment fill: granular	18	0	35
London Clay (see notes below)	19	2	21
Reworked London Clay (see notes below)	19	2	18

Terrace gravels	19	0	35
Weathered London Clay (see notes below)	19	2	21

Table 6 – Characteristic Values of Soil Parameters for Earth Structures

Notes: Drained shear strength parameters for high plasticity overconsolidated clays and clay fills such as London Clay and embankment fill: cohesive predominantly derived from London Clay shall be derived based on the methodology presented in LU guidance G0054B". The index properties necessary for derivation of the shear strength parameters shall be determined on a site-by-site basis from laboratory test data. In the absence of any such laboratory test data the values given in Table 6 shall be adopted for the slope stability analysis.

Embankment fill: granular – loose well graded sub-angular to sub-rounded sands and gravels with less than 15% passing the 63μm sieve, or medium dense poorly graded sub-angular to sub-rounded sands with less than 15% passing the 63μm sieve. For newly placed well compacted granular fill on embankments and cuttings parameters shall be derived on site specific basis in accordance with the guidance in the LU guidance G0054B.

3.5.4.5 Where there is evidence of previous slope failures and pre-shearing of clay soils, back-analysis shall be used to calculate appropriate soil parameters following the procedure in the LU guidance G0054B. Where there is inadequate information to carry out an accurate back analysis then the following soil parameters shall be used in the assessment and design for high plasticity overconsolidated clays and clay fills such as London Clay and embankment fill: cohesive:

Instability Feature	c' (kN/m^2)	φ'
Known pre-existing shear surface	1	13
Uncertain or not extensive pre-existing shear surface	1	16

Table 7: Required Strength Parameters for Pre-existing Shear Surfaces

Note: Evidence of pre-shearing may include significant spreading of the Embankment, deep irregular depths of ash and extensive slope or toe bulges.

3.5.4.6 Zero cohesion shall generally not be used for slope stability assessment of clay soils, as this highlights extremely shallow failure modes at the expense of examining deeper surfaces of greater concern to the operation of the railway.

3.5.4.7 Technical Justification for using parameters other than those in Table 6 and Table 7 shall be provided and submitted for approval. The scope of the technical justification shall include but not limited to the following:

a) geological and other background information;

b) recognised differences between actual in-situ conditions and properties measured by field or laboratory testing;

c) relevant data from previous projects and the performance of existing Earth Structures

d) Back-analysis of previous slope failures;

e) influence of seasonal and long term changes which may occur in the field due to variations in the environment or weather;

f) the possibility of progressive slope failure induced by cyclic seasonal stress changes;

g) Methodology presented in LU LU guidance G0054B;

h) the results of previous applied research;

i) the application of appropriate non-linear numerical modelling of progressive failure, provided such models have been calibrated against relevant case history data.

Note: This list is not exhaustive and other considerations may be applicable on a case-by-case basis.

3.5.5 Pore pressures in embankments and cuttings for assessment and design

Note: For clay slopes, it will rarely be possible to measure the critical long-term porewater pressure condition particularly that following prolonged exceptional heavy rainfall. Therefore for most Assessments and Designs the guide values detailed in LU guidance G0054B should be adopted for consistency in the slope stability analysis.

3.5.5.1 The Groundwater conditions applicable shall be for the most unfavourable anticipated conditions during the life of the asset.

3.5.5.2 Where long-term groundwater monitoring is carried out the duration of monitoring shall be sufficient to allow the most unfavourable conditions to be established.

3.5.5.3 Pore pressures shall be assessed for cohesive materials in the form of the hydrostatic pressure below the anticipated zero pressure boundary in accordance with the values given in the LU guidance G0054B.

3.4.5.4 No negative pore pressures shall be used in the stability analysis.

3.5.6 Actions (loadings)

3.5.6.1 A live load (uniform variable unfavourable action) of 10kN/m² shall be applied to the crest of all cuttings where vehicle access or further development is deemed possible by the designer.

3.5.6.2 If appropriate, a surcharge loading (action) greater than that specified in section 3.5.6.1 shall be applied in the design and assessment process to take into account the presence on or near the ground surface of nearby buildings, parked or moving vehicles and facilities present at the crest of the cutting that will impact on the performance of the Earth Structure.

3.5.6.3 Where buildings, parked or moving vehicles and facilities are present at the crest of the cutting, the impact and additional loading criteria shall be specified in the assessment and design documentation with justifications for the values used.

3.5.6.4 Assets supporting LU railway tracks shall be designed for RL loading (reference LU standard S1051 section 11.5), except where a Train Operating Company (TOC) has rights to operate over the LU railway tracks. Accidental design situations defined in BS EN 1991-2 clause 6.7.1 are not applicable for RL loading.

3.5.6.5 Assets supporting LU railway tracks, where a TOC has rights to operate, shall be designed for Load Model 71 as defined in BS EN 1991-2.

3.5.6.6 Equivalent live loads (uniform variable unfavourable actions) derived from the RL and LM71 loadings, have been provided in Table 8 for adoption on Earth Structures.

Earth Structure Actions category	Railway lines carried	Actions
1	Metropolitan Line – Neasden to Amersham and beyond (including the Chesham and Watford branches)	BS EN 1991-2 LM71 - loading of 50 kN/m^2 UDL over the area occupied by the tracks i.e. sleeper end to sleeper end.
	Jubilee Line – Neasden to Wembley Park	BS EN 1991-2 LM71 - loading of 50 kN/m^2 UDL over the area occupied by the tracks i.e. sleeper end to sleeper end
	District Line – East Putney to Wimbledon	BS EN 1991-2 LM71 - loading of 50 kN/m^2 UDL over the area occupied by the tracks i.e. sleeper end to sleeper end
2	All Lines not in category 1	RL loading - 30 kN/m^2 UDL over the area occupied by the tracks i.e. sleeper end to sleeper end (reference LU standard S1051 section 11.5)

Table 8 – Unfactored Variable Action (Live load) categorisation for Earth Structure assets carrying LU railway lines

3.5.6.7 For design purposes, appropriate partial factors shall be applied to all actions in accordance with section 3.5.7 of this standard.

3.5.7 Stability analyses

3.5.7.1 The slope stability analysis shall consider all modes of instability including the progressive failure mechanism for intermediate to high plasticity clays. The mode of instability which produces the most onerous factor of safety shall be adopted.

3.5.7.2 The slope stability analysis shall be carried out in accordance with the requirements of BS EN 1997-1 and LU guidance G0054B, adopting the appropriate partial factors.

3.5.7.3 When using BS EN 1997-1 the overall stability of the slope shall be established in accordance with Design Approach 1 Combination 2. Where the Assessor considers

that the loading applied to the slope (other than the mass of the ground in the slope) might control the failure mechanism rather than the ground strength parameters, then in accordance with BS EN 1997-1 clause 2.4.7.3.4.2(3), Design Approach 1 Combination 1 shall also be considered.

3.5.7.4 The Partial Factors required to ensure stability against deep seated slips may be conservative for shallow slips and/or shallow slope movement. For these cases, adoption of a lower Partial Factor of 1.15 on the Angle of Shearing Resistance and the Effective Soil Cohesion parameters shall be adopted.

Note: Where back analysis is used to determine the value of mobilised shear strength along a pre-existing failure surface, partial factors of unity should be used for actions, the effect of actions, soil parameters and soil resistance.

3.5.7.5 The Partial Factors normally used for overall stability analysis may not be appropriate for slopes with pre-existing failure surfaces where the reduced or residual strength parameters are adopted. For these cases, reference shall be made to BS EN1997-1 clause 11.5.1(8) and LU guidance G0054B regarding the adoption of appropriate Partial Factors using the concept of progressive failure.

The following partial factors shall be used when using the parameters in Table 9.

Instability Feature	Partial Factor
Known existing shear surface giving rise to residual strength parameters and worst credible groundwater condition	1.05
Uncertain or not extensive pre-existing shear surface giving rise to the use of reduced strength parameters and worst credible groundwater condition	1.15

Table 9 : Required Partial Factors for slopes with Pre-existing Shear Surfaces

Note: The partial factor used for the residual angle of shearing resistance should be chosen with due consideration to the confidence level of the data and the consequence of subsequent failure of the slope. The partial factor applied to the residual angle of shearing resistance shall be selected based on the guidance provided in LU guidance G0054B.

3.5.7.6 Slope stability Assessment shall be undertaken to calculate the Factor of Safety along the range of potential slip surfaces until the minimum Factor of Safety for the section being analysed is obtained.

3.5.7.7 The calculation of Factor of Safety shall use a limit equilibrium method and be made in terms of effective stresses.

3.5.7.8 Non-circular analysis shall be used when:

a) a pre-existing planar shear surface determines the position of a section of the failure surface i.e. where the slope is considered to have failed since construction;

b) circular failure is prevented, e.g. by the presence of a stronger layer of soil at shallow depth;

c) the soil profile contains a thin weak layer, which will act as a preferential shear path; alternatively the depth of this layer may be increased to allow circular surfaces to intersect it for an adequate distance.

3.5.7.9 The Assessment of a slope where the position of the slip surface is not pre-determined requires the position of the critical slip surface to be identified. The overall worst circle centre shall be that with the lowest Factor of Safety.

3.5.7.10 For each local minimum Factor of Safety the factors in the slope which have given rise to it shall be determined.

3.5.7.11 Factors of safety for slopes shall be obtained for the following cases of deep seated slip surfaces:

a) slip surfaces daylighting at the nearest track

b) slip surfaces daylighting at the lineside services, where present

c) the worst slip surface affecting services or track or both.

The minimum Factor of Safety calculated for these three conditions for deep seated slip surfaces shall be used in the determination of the condition rating.

Note: Slip surfaces which pass through the sloping part of the Earth Structure outside the lineside services and have a maximum depth of 1.5 m are considered to be Shallow Slips.

Deep Seated Slip surfaces are slip surfaces not confined to the sloping part of the Earth Structure with a minimum depth to the face exceeding 1 m.

Slip surfaces which fall outside the lineside services but their depth and extent are considered to be adequately significant to affect the lineside services or track may be treated as Deep Seated Slips.

Slip surfaces which pass through the lineside services and/or track but they are considered to be limited in depth and extent may be treated as Shallow Slips.

3.5.7.12 Variable (Live) and permanent Actions (loadings) shall be included in the required effective stress analysis to establish the long term assessment of stability.

Note: Although there may be an apparent logic for using undrained soil parameters in conjunction with Live Loading, it is considered that using drained parameters will not be unduly conservative in the long term. Moreover, the investigation techniques suitable for use along the railway are not suited to producing consistent undrained strength results, and determining how these will be affected by cyclic loads in the long term. This stipulation applies both to Earth Structure slopes and to loadings on earth Retaining Structures formed within slopes.

3.5.7.13 Sensitivity analysis shall also be performed for each case without the application of any Live Load to determine the effects on short-term stability.

3.5.8 Earth retaining structures

3.5.8.1 Where Earth Structures include Earth Retaining Structures, global slope stability analyses shall be performed to determine the minimum Factors of Safety for slip surfaces which daylight above and below the Retaining Structure.

3.5.8.2 The local stability and structural adequacy of the Retaining Structure itself shall be determined in accordance with LU standard S1051.

3.5.9 Existing support works

3.5.9.1 Where Earth Structures incorporate designed support measures with calculations and as-built drawings available such as Strengthening and Renewal works that control the performance of the slope no Assessment analysis is normally required. However, where the current Inspection report has indicated that the works may not be acting in accordance with the original design intent or that the original design intent may be inadequate in the current circumstances and the Inspector has recommended further study then a re-analysis of the design shall be made using the currently assessed parameters and knowledge to establish whether the original design and its implementation were correct and remain sufficient for the asset to perform its Required Duty.

3.5.10 Serviceability

3.5.10.1 Where Earth Structures are reported to be undergoing unusual deformations that influence the attainment of track maintenance targets, the Assessment shall determine the cause of the movement, for example whether it is a seasonal influence of high water demand trees or large depths of ash, sufficient to establish what corrective actions might be adopted.

3.5.10.2 The assessment shall identify any serviceability concerns and incorporate these into the final Condition Classification of the asset in accordance with sections 3.5.13.5 and 3.5.6.2 of this standard. Typical serviceability concerns for Earth Structures are listed below inter alia:

a) Shoulder instability
b) Shallow instability
c) Toe debris
d) Swell/shrinkage movements
e) Scour erosion (see section 3.5.11)
f) Wash out erosion

3.5.11 Inclement Weather and Climate Change

The assessment shall consider the risk to the Earth Structure assets from the effects of inclement weather in accordance with the recommendations of the LU Earth Structures Inclement Weather Report and LU guidance G0054B. The assessment shall review the risk and where appropriate incorporate in the Condition Classification of the asset and/or make appropriate recommendations regarding management of the asset in order to minimise or remove the risk.

Note: The projected climate change shows that UK will experience more extreme weather conditions which is likely to lead to hotter, drier summers and warmer, wetter winters. This will likely lead to an increase in both the frequency and the intensity of storm events as well as an increase in the duration of rainfall in the winter.

The above will have adverse impact on the stability and serviceability of earth structures and safety of the operational railway. Hence, the impact of climate change on the stability and performance of earth structues shall be carefully considered at all stages of earth structures lifecycle.

3.5.12 Checking and validation

3.5.12.1 Slope stability calculations shall be checked and certified for the following:

a) that the criteria and assumptions are valid and in accordance with this standard

b) that ground model, soil parameters, and groundwater levels are correct

c) that the slope geometry at each cross-section is correct

d) that data input to computer programs is correct

e) that the analysis programs have been properly validated for the use made of them against industry standard programs and

f) that the programs have been operated correctly and the output interpreted accurately.

3.5.13 Assessment rating

3.5.13.1 Principal Inspections in accordance with section 3.4 of this standard shall be carried out at each of the transects used in the Assessment analysis except where relevant existing Inspection records are available that are fully representative of the current condition of an analysed section.

3.5.13.2 The information from new Principal Inspections shall be managed in accordance with section 3.4.10 of this standard and used to derive an Inspection condition rating for each inspected section in accordance with section 3.4.11.

3.5.13.3 The condition ratings from Principal Inspection at the analysed sections shall be reviewed by the Assessor using engineering judgement and all the information obtained from the Desk Study and Site Investigation and the improved understanding of asset behaviour gained from the analyses for stability and deformation.

Note: The LUL Earth Structures Condition Rating Tool (CRT) provides a facility for including the factors of safety from Analytical Assessments directly into the algorithm in order to evaluate the Assessment Condition Rating.

Determination of the inspection Condition Rating of an earth structure using the Condition Rating Tool is based on a required single factor of safety of 1.3 for first time deep seated slips affecting track or lineside services or affecting the stability of Retaining Structures which support the track or lineside services.

Therefore, the factors of safety obtained from slope stability analysis using BS EN 1997-1 or LU guidance G0054B will need to be converted to equivalent of 1.3 by extrapolation before inserting into the CRT.

3.5.13.4 The Assessor shall insert the converted calculated Factor of Safety for each transect obtained from the stability analysis into the CRT to obtain the Inspection Condition Rating.

3.5.13.5 Where the earth structure meets the requirements of the factor of safety for deep-seated stability the effects of serviceability concerns (see section 3.5.10.2), on the Assessment Condition Rating shall be considered separately. Where appropriate, separate Condition Classifications for deep-seated stability and serviceability concerns shall be determined in accordance with section 3.6.6.2 of this standard.

3.5.13.6 The Assessor shall adjust the condition ratings from Inspection at the analysed sections in accordance with his review. The values after adjustment shall be the Assessment Condition Ratings of the corresponding transects.

3.5.13.7 As the Assessment Condition Rating incorporates the calculated Factor of Safety from stability analysis, it shall form the basis for Condition Classification of each transect. However, the Assessor shall consider if the Factor of Safety is more representative of the condition of the asset and shall form the basis for the Assessment Condition Rating. The Assessor shall provide and record justification for this decision.

3.5.13.8 The Assessor shall use engineering judgement and based on the slope geometry and physical condition of the asset determine from the section Assessment Condition Classification an overall condition classification (s) for the asset. This shall be representative of the ability of the earth structure to perform the Required Duty as a whole, the value(s) of which shall be the asset's assessed condition classification (s).

3.5.14 Reporting

3.5.14.1The report of an Analytical Assessment shall incorporate the Desk Study Report and the Geotechnical Interpretative report for Site Investigation and the records of new Principal Inspections carried out.

3.5.14.2 The report shall fully describe the stability and deformation calculations made, including the basis for the selection of the parameters for soil properties and pore-pressure and the range of potential failure and deformation mechanisms analysed.

3.4.14.3 The report shall highlight any abnormal aspects of the calculations in relation to the requirements of this standard.

3.5.14.4 The report shall present the critical Factor of Safety, Assessment Condition Rating and Condition Category for the sections analysed, and the overall Assessment Condition Rating and Condition Category of the asset.

3.5.14.5 The report shall include the Assessor's justification for adjustments made to Inspection condition ratings in order to derive Assessment Condition Ratings and for his determination of the overall Assessment rating for the asset.

3.5.14.6 The report conclusions shall include recommendations for Strengthening and Renewal where required, dividing the asset into sub-sections with different recommendations as appropriate. The report shall also include recommendations for the future Inspection regime of the asset.

3.5.14.7 The report shall include the results of appropriate risk assessment in order to determine whether the asset risk to the operational railway is acceptable and what mitigation measures (if any) are recommended to reduce the risk to As Low As Reasonably Practicable (ALARP). The risk assessment shall be carried out in accordance with section 5.6 of this standard.

3.5.14.8 The Assessment Report shall be subject to peer review before submission to the Head of Earth Structures for approval.

3.5.14.9 The recommendations of the finalised Assessment Report shall be included in the asset management programme as soon as reasonably practical after completion of the report.

3.5.14.10 The Assessment Report with the incorporated reports and records shall be retained for the life of the asset.

3.6 Asset Condition Assessment and Classification

3.6.1 General

3.6.1.1 This section identifies specific requirements and processes for establishing the Asset Condition Assessment of Earth Structures.

3.6.1.2 This section shall be read in conjunction with the Asset Specific Process for Earth Structures contained in LU standard S1042 (Asset Condition Reporting).

Note:	This section also defines the requirements for the minimum condition for Earth Structures to operate without restriction.

3.6.1.3 The specific Asset Condition process for Earth Structures is summarised and diagrammatically represented in Attachment 11.4 of this standard. It comprises a two-tiered Condition Assessment, where further and more detailed Assessment works (Level 2) are required when the asset condition rating from the first tier (Level 1) falls below a specified trigger level. The process leads to the Condition Classification of Earth Structure assets and MEAV/RAV % allocation.

3.6.1.4 The Condition Assessment of Earth Structures involves three stages in the determination of asset condition, any uncertainties being progressively reduced in the later stages, as follows:

a) Level 1 Condition Assessment

b) Stage 1 – Inspection and condition rating calculation (section 3.4 of this standard);

c) Stage 2 – Desk study and walkover survey (section 3.5 of this standard);

Level 2 Condition Assessment

d) Stage 3 – Analytical Assessment (section 3.5 of this standard).

3.6.1.5 Level 1 Condition Assessment uses the Inspection report and condition ratings derived from the current Inspection survey (stage 1) and, where required, the results of the desk study (stage 2) to determine Asset Condition.

3.6.1.6 All Earth Structure assets shall have a Level 1 Condition Assessment.

3.6.1.7 Level 2 Condition Assessment builds on the information gathered from the Level 1 Condition Assessment and includes the undertaking of slope stability analysis and a full Analytical Assessment (stage 3) to determine Asset Condition.

3.6.2 Level 1 Condition assessment – stage 1

Note: The process of review of a Principal Inspection report by the Assessor constitutes Stage 1 of ACAC for Earth Structures.

3.6.2.1 The Assessor shall consider all relevant records available for the asset when undertaking a review of a Principal Inspection report.

3.6.2.2 Where the Assessor determines that the asset has a condition rating from Inspection of greater than 65%, the Condition Classification of the asset shall be A, unless there are known Specific Concerns or further study has been recommended.

3.6.2.3 A review of the condition of the assets in 3.5.2.2 shall be carried out as appropriate based on the following parameters:

a) Time from previous inspection
b) Asset type
c) Asset Geometry
d) Ground condition
e) Risk to railway

The review shall consider the following inter alia:

a) Review of the Principal Inspection history and latest Principal Inspection Report
b) Review of the ground conditions
c) A walkover survey
d) Risk assessment.

3.6.3 Level 1 Condition assessment – stage 2

3.6.3.1 The Level 1 Condition Assessment shall proceed to Stage 2 if:

a) the condition rating, as identified in the Inspection report and as reviewed by the Assessor, is 65% or less, or
b) the finalised Inspection report has recommended further study.

3.6.3.2 Stage 2 of the Level 1 Condition Assessment shall be a desk study and walkover survey as defined in section 3.5.2 of this standard.

3.6.3.3 The Assessor shall carry out the desk study and using engineering judgement confirm or adjust as necessary the condition rating and Condition Classification from Stage 1 in response to the new information obtained. Justification for changing the

condition rating and Condition Classification shall be recorded, and shall be auditable. The Assessor shall include a recommendation for further Analytical Assessment or more frequent inspections if he considers that to be required to understand the behaviour of the asset even if the condition rating is above the threshold for Stage 3 assessment.

3.6.4 Level 1 Condition assessment – classification of assets

3.6.4.1 Following completion of a review of the current Inspection report (Stage 1 study) and, where required, completion of the desk study (Stage 2 study), the Classification of the asset shall be determined by identifying the corresponding Generic Concern(s) and their corresponding indicative Condition Classifications as given in the Foundation Documents.

3.6.4.2 All earth structure assets with a condition rating of 65% or less (after completing Stages 1 and 2) but without a full Analytical Assessment shall be Grey. The Assessor shall refer to the Asset Specific Processand shall determine the Condition Classification (Grey B to Grey E1/E2) of the asset by comparing information that is available about the asset with any appropriate Generic Concern, in whole or in part.

3.6.4.3 Where no information is available, or where the Asset Condition Assessment process has not been completed and no Specific Concerns have been identified, then the asset shall be classified as Grey A.

Note:	E1 is the most onerous classification and A is the least onerous.

3.6.5 Level 2 Condition assessment – stage 3

3.6.5.1 A Level 2 Condition Assessment shall be undertaken for all earth structure assets where following the completion of a Level 1 Condition Assessment the earth structure has a condition rating of 65% or less, or if recommended by the Assessor.

3.6.5.2 A Level 2 Condition Assessment shall require completion of an Analytical Assessment in accordance with section 3.5 of this standard to derive the critical Factor of Safety of the asset against deep-seated failure and to assess other factors affecting asset performance.

3.6.6 Level 2 Condition assessment – classification of assets

3.6.6.1 Following completion of Stage 3 (full Analytical Assessment) and hence the determination of the Factor of Safety against deep-seated failure, the conclusions from the Level 1 Condition Assessment shall be reviewed and modified as necessary. Justification for modifications shall be recorded, and shall be auditable.

3.6.6.2 Using final interpretation of the information gathered from the site Inspection (stage 1), desk study (stage 2) and the full Analytical Assessment (stage 3), the Condition Classification of the asset shall be obtained from the Asset Specific Processby aligning the output of the Condition Assessment and identified Specific Concerns to any Generic Concerns that apply to the asset.

3.6.6.3 The Assessor shall refer to the Earth Structures Asset Specific Processin LU standard S1042 for full and current details of all Generic Concerns and corresponding indicative Condition Classifications (A to E1/E2 and B_s to D_s).

3.6.7 Allocation of MEAV/RAV

3.6.7.1 The allocation of MEAV/RAV shall be undertaken in accordance with the Asset Specific Process in LU standard S1042.

3.6.8 Minimum condition for Earth Structure assets

3.6.8.1 The minimum condition for Earth Structures to operate without restriction is as follows:

a) an Inspection/Assessment condition rating of more than 20%; and/or

b) a Factor of Safety against deep-seated slope failure of more than 1.15. This condition shall be considered by including the beneficial effects of existing slope vegetation on the pore pressure regime and by ignoring any Live Loading in the slope stability analysis. This condition shall be considered in combination with Section 3.5.13.7 of this standard.

3.6.8.2 If the above minimum conditions are not met then control measures shall be introduced to the Earth Structure. These typically consist of

a) Withdrawal from service

b) Track speed restrictions

c) Special Inspection and monitoring regime.

3.6.9 Asset Condition Reporting

3.6.9.1 For each Earth Structure Asset, the data described in 3.5.1 shall be collected and processed to create a catalogue of the complete Earth Structure asset base that contains the following information:

a) The Asset Equipment Reference.

b) The Asset Definition

c) The line and location of the Asset.

d) The length of the Asset.

e) The Modern Equivalent Asset Value (MEAV)/Relative Asset Value (RAV) for the Asset.

f) The Generic concerns and specific concerns applicable to each asset and the resulting Condition Classification (A to E2 and B_s to D_s) and the Timscale for Intervention(TFI) for each asset.

g) A summary report of works undertaken to the assets during the year.

Note: The Asset definitions, generic and specific concerns and the Condition Classifications are defined in the Asset Specific Process for Earth Structures in LU standard S1042 – Asset Condition Reporting.

3.6.9.2 The method of allocation of the MEAV/RAV shall be undertaken in accordance with the Asset Specific Process.

3.6.9.3 Where two or more Generic Concerns are applicable to an asset then the more onerous classification shall apply.

3.6.9.4 The compliant Asset Condition Assessment shall be used to create an Asset Condition Report (ACR) compliant with LU standard S1042 (Asset Condition Reporting).

3.6.9.5 The Asset Condition Assessment shall be completed annually as a minimum to an agreed programme so that the final ACR is delivered on scheduled date.

3.7 Strengthening and Renewal

Note: Strengthening and renewal of Earth Structures should be part of a holistic approach to whole life asset management.

3.7.1 General

3.7.1.1 Works to Strengthen and Renew existing Earth Structure assets to address life-expired assets or elements shall be undertaken in accordance with LU's programme for life-cycle management or in response to a change in use, function or duty of the asset or element, or following the undertaking of emergency remedial works.

3.7.1.2 The Strengthening and Renewal works shall be prioritised based on Safety and Performance Risks to the railway operation, knowledge of the condition of the asset and historical performance of the asset.

3.7.1.3 Design and construction of works for Strengthening and Renewal of existing Earth Structures shall be in accordance with sections 3.2 and 3.3 of this standard in addition to the requirements of this section.

3.7.1.4 Strengthening and Renewal solutions adopted to improve operational Earth Structures shall be suitable for construction alongside the working railway such that the works shall not prejudice safe operation of the railway or lead to disruption of services.

3.7.2 Works following emergency remedial measures

3.7.2.1 The design process shall include an investigation that shall establish the failure or potential failure mechanism and the properties of the materials affected both before and after the failure or near failure event and the Groundwater conditions at the time of the event. The results of the investigation shall be included in the CDS and shall supplement the normal information from Analytical Assessment in the design process.

3.7.2.2 If safe construction requires the permanent repair works to be progressed in bays then the design shall reflect this or other exceptional restrictions on working that arise consequent to the failure and the emergency stabilisation measures.

Note: The final repair works may or may not include the emergency stabilisation measures.

3.7.3 Earth Structure Observational Approach

3.7.3.1 Where appropriate adopting an observational approach for the management of existing earth structures as an alternative to strengthening and renewal on the basis of risk shall be considered.

Note: The observational approach is most effective where there is a wide range of uncertainty regarding long-term earth structure behaviour and performance following slope stability assessment. The observational method offers potentially significant economic advantages where earth structures exhibit acceptable condition; behaviour and performance yet have failed to demonstrate an adequate factor of safety following a detailed slope stability assessment to the requirements of section 3.5 of this standard.

The observational approach should not be used where there is insufficient time to implement fully and safely any required contingency actions.

3.7.3.2 Where adopted, the implementation of an observational approach for the management of earth structures shall include the following:

a) Implementation of a detailed inspection and monitoring scheme to establish whether the Earth Structure behaviour and performance is within the acceptable limits as defined by this standard. The inspection and monitoring regime shall also consider the performance of any drainage system that is directly associated with the Earth Structure. The inspection and monitoring regime shall establish Earth Structure behaviour and performance at a sufficiently early stage and with an adequate frequency to allow contingency actions to be undertaken successfully if required. The monitoring shall be sufficient in duration to ensure that the Earth Structure experiences a representative range of environmental conditions e.g. climate extremes. The frequency of Principal and Special Inspections for any Earth Structure subject to an observational approach shall be determined. Justification for any reduction in the frequency of inspection from the requirements in section 3.4 of this standard shall be recorded.

b) The range of possible Earth Structure behaviour and performance shall be assessed e.g. by back analysis to allow for the development of appropriate intervention levels based on the requirements for Earth Structure stability and serviceability. The intervention levels shall be defined in terms of limiting ground movement, pore pressure, strain or other variable.

c) A management action plan shall be established with actions to be implemented if the monitoring indicates that an intervention level is reached or likely to become so. The plan may prescribe one or more of the following actions:

   i. detailed risk assessment
   ii. enhanced monitoring and inspection
   iii. implementation of emergency remedial works
   iv. speed restriction
   v. line closure
   vi. implementation of Strengthening and Renewal works

3.7.3.3 The output from any detailed monitoring scheme shall be utilised in any optimisation of the Earth Structure slope stability assessment and any requirements for Strengthening and Renewal works. Where appropriate sophisticated analytical methods e.g. advanced numerical modelling shall be used to determine earth

structure stability and to confirm long-term earth structure behavior and performance.

3.7.4 Inclement Weather and Climate Change

3.7.4.1 The design shall consider the risk to the earth structure assets from the effects of inclement weather and climate change in accordance with the recommendations of the LU Earth Structures Inclement Weather Report and LU guidance G0054B. . Appropriate mitigation measures shall be incorporated into the design in order to remove or minimise any risk from the effects of inclement weather.

3.8 Maintenance

3.8.1 General

3.8.1.1 Maintenance work shall be justified on the principles of whole lifecycle asset management.

3.8.1.2 Routine Maintenance shall be carried out as necessary from time to time to arrest the deterioration of defects and ensure the Required Duty is fulfilled for as long as reasonably practical before the need for Strengthening and Renewal works in accordance with an asset management programme.

Note: Earth Structures are adversely affected through their Design Life by seasonal variations of rainfall and temperature conditions, influences of vegetation and animals, and the general degradation of materials. Maintenance slows this process by arresting the development of defects at an early stage before they affect the ability of the asset to fulfil its Required Duty.

3.8.1.3 The asset management programme shall include both regular schedules for Maintenance and systems of response to any adverse reports of asset condition, including but not confined to actions in response to the recommendations of Inspection reports, so that maintenance actions can be undertaken to ensure the asset performs its Required Duty with risk to ALARP.

3.8.1.4 Works carried out as Maintenance, other than emergency remedial measures covered by section 3.8.2 shall comprise only minor works that maintain or improve locally components of the asset without any adverse impact on asset performance. Additionally they shall be works that are routinely carried out as part of the normal operation of the railway. All works not meeting these criteria, and not emergency remedial measures, are Strengthening and Renewal works in terms of this standard and are covered by section 3.7.

3.8.1.5 The toes and crests of slopes shall be maintained in order to prevent ongoing loss of material.

3.8.1.6 Vegetation, including trees, shall be managed to avoid destabilisation of slopes and, where possible, to enhance stability.

3.8.1.7 Drainage runs shall be kept clear and drainage ditches kept open, clearing vegetation and rubbish as necessary, as part of the maintenance for Earth Structure assets where they would otherwise adversely influence the Groundwater regime at an asset.

3.8.1.8 Maintenance of drainage at Earth Structures, including slope drainage, shall be in accordance with LU standard S1052.

3.8.1.9 Wildlife shall be controlled to prevent potential destabilising effects (e.g. burrowing).

3.8.1.10 The Maintenance requirements for the strengthening and renewal works shall be specified in the design in accordance with LU standard S1050.

3.8.1.11 Maintenance of the strengthening and renewal works shall be carried out in accordance with the corresponding Maintenance requirements in 3.8.1.10.

3.8.2 Emergency remedial measures

3.8.2.1 If an earth structure slope failure, or the identification of signs of an incipient failure, occurs that affects the safe running of the railway, emergency remedial measures shall be carried out that restore normal traffic working as soon as possible.

3.8.2.2 When stability improvement is required as an emergency measure, immediate temporary solutions shall be undertaken that are inherently safe in the short term without the need to follow the design and construction processes set out in sections 3.2 and 3.3 of this standard.

Note: Examples of immediate temporary solutions include toe loading of Embankment slopes or crest removal at Cutting slopes, or steel sheet piling may be undertaken on a conservative empirical basis. This list is not exhaustive and other such measures may be initiated by an experienced Geotechnical Specialist on a case-by-case basis.

3.8.2.3 As soon as possible after completing the emergency repair works, design and construction of permanent Strengthening and Renewal works shall be undertaken.

3.9 Decommissioning

3.9.1 General

3.9.1.1 No structure shall be decommissioned without prior approval in accordance with the requirements of LU standard S1538.

3.9.1.2 The design and implementation of decommissioning shall ensure:

a) the long-term mass stability of the decommissioned asset shall not be dependant on Maintenance operations and

Note: This requirement prohibits reliance on installed drainage measures and unencased metalwork to provide long-term deep-seated stability of earth slopes.

b) railway safety shall be maintained following decommissioning of the asset.

3.9.1.3 Shallow surface movements of decommissioned slopes shall be acceptable if environmental considerations allow and there is no safety implication.

3.9.2 Planning and implementation

3.9.2.1 Whether the asset remains accessible following decommissioning or is made redundant shall be decided on the basis of the risk to railway operations for each option.

3.9.2.2 If the asset remains accessible following decommissioning, continued Inspection and condition Assessment shall be undertaken in accordance with sections 3.4 and 3.6 of this standard.

3.9.2.3 Planning and implementation of decommissioning shall follow the requirements of sections 3.2 and 3.3 of this standard.

3.9.3 Interfacing assets and systems

3.9.3.1 The impact of decommissioning on interfacing structures and systems shall be evaluated to ensure that the risks to railway operations associated with all aspects of decommissioning are reduced to ALARP.

3.10 Evidence of compliance

3.10.1 Compliance with the requirements of this standard shall be demonstrated to LU by each party contracted to LU. Additionally LU may audit compliance as part of its surveillance regime.

4 Responsibilities

4.1 The requirements of this LU standard shall be incorporated in any contract to which it is relevant and shall stipulate that a programme of audits are implemented which ensures that these requirements are complied with.

5 Supporting information

5.1 Background

5.1.1 This standard is one of a suite of standards which cover the whole life cycle of Civil Engineering assets. Other standards in this suite have a bearing on the activities covered by this standard. In many cases a direct reference to another standard is given; in other instances the need to refer to another standard is implied.

5.1.2 The suite of LU Civil Engineering standards comprises inter alia the following documents.

Number	Title
S1050	Civil Engineering – Common Requirements
S1051	Civil Engineering – Bridge Structures
S1052	Civil Engineering – Gravity Drainage Systems
S1053	Civil Engineering – Building and Station Structures
S1054	Civil Engineering – Earth Structures
S1055	Civil Engineering – Deep Tube Tunnels and Shafts
S1056	Civil Engineering – Pumping Systems
S1057	Civil Engineering – Miscellaneous Assets
S1062	Civil Engineering – Temporary Works

5.1.3 The following guidance documents have also been prepared to give guidance and explanation for the above standards:

Number	Title
G-050	Civil Engineering – Common Requirements
G0051	Civil Engineering – Bridge Structures
G0052	Civil Engineering – Gravity Drainage Systems
G0053	Civil Engineering – Building and Station Structures
G0054A	Civil Engineering – Earth Structures
G0054B	Civil Engineering – Earth Structures: Guide for Slope Stability Analysis
G0055	Civil Engineering – Deep Tube Tunnels and Shafts
G0056	Civil Engineering – Pumping Systems
G0057	Civil Engineering – Miscellaneous Assets
G0058	Civil Engineering – Technical Advice Notes

5.2 Safety considerations

5.2.1 Safety aspects shall be considered throughout the design process and due account taken of the Construction (Design and Management) Regulations.

5.2.2 Earth Structures deteriorate with time under cyclic loading and the influence of seasonal effects such as high winter water levels and water demand of trees, as well as vandalism and the effect of burrowing animals,

5.2.3 Many of the existing Earth Structures have already passed a 120 year Service Life, and were constructed without known standards and with primitive methods. Many failed during and soon after construction and have been the subject of phases of repair.

5.2.4 In view of these considerations this standard requires a structured approach to Earth Structures management based on standard procedures of Inspection and Assessment of the existing Earth Structures to reduce the safety risks in accordance with ALARP principles.

5.3 Environmental considerations

5.3.1 All activities including planning, design, procurement, construction, installation, testing, commissioning, operation, Maintenance, decommissioning and disposal must comply with current environmental legislation, approved Codes of Practice and authoritative guidance literature issued by relevant statutory bodies.

5.4 Customer considerations

5.4.1 The Earth Structures shall provide effective support to the track formation, service posts, etc, and maintain the structure gauge requirements, all as described in this standard, so as to allow uninterrupted and smooth operation of the railway to meet the needs of Customers.

5.5 Other information

5.5.1 Risk Assessment

Note:	Guidance on the process for managing Civil Engineering risk including Earth Structures is provided in LU guidance E0029 and guidance on Civil Engineering asset strategic and tactical risk models is provided in LU guidance G1299. The risks associated with Earth Structure assets consist of two types; Strategic Risks and Tactical Risks in the Strategic & Tactical Risk Assessment Model (STRATA).

5.5.1.1 A Strategic Risk Assessment shall be carried out for Earth Structure assets which are compliant with the minimum requirements of this Standard.

5.5.1.2 A Tactical Risk Assessment (TRA) shall be carried out for the following cases:

a) Assets which do not meet the minimum requirements to operate without restriction in accordance with section 3.6.8 of this standard.

b) Assets that have credible potential to present a threat to safety or to operation of the railway including (but not limited to) assets with serviceability concerns and assets with concerns due to the effects of inclement weather.

TRAs may be required in other circumstances as defined in section 6.2 of the LU guidance E0029.

TRAs shall be carried out in accordance with the guidance provided in the LU guidance G1299.

6 Person accountable for this document

Name	Job title
Nader Saffari	Profession Head - Earth Structures

7 Definitions

Term	Definition	Source
Actions	Variable and permanent loadings and or displacements imposed on a structure	Jargon Buster
Analytical Assessment	the numerical evaluation of an asset(s) through a formally defined and industry recognised analytical process as set out in LU standards or, where no LU standards exist, through compliance with British standards or standard industry practices, accepted by LU. Analytical Assessments include structural and hydraulic analysis.	Jargon Buster
Asset Condition Assessment and Classification (ACAC)	the process through which the overall Condition of the total population of Operational Assets is determined and recorded; and provides evidence that they have been managed to an agreed Asset Management Regime.	Jargon Buster
Asset Condition Reporting (ACR)	Define the requirements for annual reporting and certification of the condition of assets in accordance with LU Standard S1042.	Jargon Buster

Assessment for Earth Structures	analysis of condition of an Earth Structure which includes detailed mathematical examination of the stability of the structure for all foreseen modes of failure. Site investigation is necessary to collect the information required to undertake an Earth Structure Assessment. The result of an Assessment is a Factor of Safety. This is used to obtain an Asset Assessment rating, which places the Earth Structure in a condition category;	Jargon Buster
Assessor	a competent person responsible for undertaking the Condition Assessment of Civil Engineering assets	Jargon Buster
Asset Register	a group of information sources, which in combination, permit identification of engineering asset base and the attendant safety, legal and commercial risks over the whole life of the assets.	Jargon Buster
Characteristic Value	A cautious estimated value of the parameter affecting the limit state under consideration established in accordance with BS EN 1990 and BS EN 1997 sections 2.4.5.	Jargon Buster
Condition	the state of an asset in terms of its ability to meet its Required Duty on account of its physical or other attributes.	Jargon Buster
Condition Assessment	the evaluation of the Condition of an asset(s) through a formally defined and controlled process. The process shall include all relevant information, site inspection surveys and Analytical Assessments where required by this or any other LU standard.	Jargon Buster
Condition Classification	the grading of a Generic Concern, ranging from E1/2 to A Condition Classification as defined in LU standard S1042, Asset Condition Reporting (ACR). For the avoidance of doubt, the completed Condition Classification must include the analytically assessed stability.	Jargon Buster
Cutting	a slope and its immediate hinterland created by Cutting into natural ground. Cuttings are generally made to create a working area for operations at the lower level. An LU railway may be at either the top or the bottom of a Cutting.	Jargon Buster
Defect Advice Inspection	inspections following defect notification or in response to a report of an Incident that causes damage to an Earth Structure asset or has the potential to affect adversely the ability of the Earth Structure to perform its Required Duty	Jargon Buster

Deep Seated Slip	Slip surfaces that are not confined to the sloping part of the Earth Structure and tend to impact on the track and/or line side services. These slip surfaces usually have a minimum depth to the face exceeding 1m.	Jargon Buster
Design Life	the period for which the asset has been designed to withstand the combined effects of all the deteriorating forces to which it may reasonably be expected to be exposed before it becomes more economic to replace the element than to repair it assuming that regular Maintenance is undertaken.	Jargon Buster
Earth Structure	Cuttings (soil & rock) and embankments (soil) with a slope equal or greater than 1m high.	Jargon Buster
Earth Structure Observational Approach	Implementation of a detailed inspection and monitoring regime for the management of existing earth structures as an alternative to strengthening and renewal works. It requires the development of a management action plan with defined actions to be implemented if the inspection or monitoring regime indicates that an intervention level is reached or likely to become so.	Jargon Buster
Earthwork	work of excavating or raising the ground.	Jargon Buster
Embankment	a zone of filled material, generally reworked natural ground but also possibly including some man-made materials such as ash or clinker, normally constructed to create a working area for operations at the higher level. An LU railway may be at either the top or the bottom of an Embankment.	Jargon Buster
Factor of Safety	the ratio of available strength of the soil to the strength required just to maintain the Earth Structure in a state of limiting equilibrium along a failure surface.	Jargon Buster
Feature	an indication of distress recorded at an Earth Structure which may occur between transects or extend across several transects.	Jargon Buster
Asset Specific Process	a set of Information which comprises the Asset Definition, Required Duty, Generic Concern List, the Basis of MEAV Calculation and Specific Concern List contained in LU standard S1042.	Jargon Buster
Generic Concern	a concern (expressed in terms of failure to meet Required Duty) which acts as a basic prompt as defined in LU standard S1042.	Jargon Buster

Geosynthetics	the generic classification of all synthetic materials used in geotechnical engineering applications; it includes geotextiles, geocells, geogrids, geomembranes, and geocomposites. It would not include natural fabrics such as jute products.	Jargon Buster
Geotechnical Specialist	a Chartered Engineer or a Chartered Geologist with a postgraduate qualification in geotechnical engineering or engineering geology, equivalent to at least an MSc and with three years post chartered experience in geotechnics or a Chartered Engineer or Chartered Geologist with at least five years post-chartered experience in geotechnics .	Jargon Buster
Global Stability	the factor of safety against failure of the critical slip surface in a composite slope (a slope combining an Earth Structure and a Retaining Structure) that daylights each side of the Retaining Structure.	Jargon Buster
Grey Earth Structure	Operational Asset or Operational Asset parts which do not have a completed Condition Assessment, which includes a full asset Analytical Assessment	Jargon Buster
Ground Investigation	exploration and recording of the location and characteristics of soil, rock and ground conditions.	Jargon Buster
Groundwater	all water below the surface of the ground and in the saturated zone and in direct contact with the ground or sub-soil	Jargon Buster
Incident	an event which results in damage to a structure	Jargon Buster
Inspection	visual examination of an Earth Structure and collation of results to obtain an asset Inspection rating.	Jargon Buster
Inspector	a person competent in the Inspection of Earth Structures and responsible for implementing the requirements of this standard	Jargon Buster
Inspection Review Engineer	a Geotechnical Specialist who has been accredited to review and approve the Principal Inspection Reports.	Jargon Buster
Limit State	state beyond which the structure no longer satisfies the design performance requirements	Jargon Buster
Live Loading	loading due to rail vehicles, highway vehicles and pedestrians. In terms of EC 7, known as a variable action.	Jargon Buster
Maintenance	the undertaking of preventative or corrective action, or both, including repairs, to ensure that the condition of the asset continues to meet the Required Duty over the service life of the asset.	Jargon Buster

Modern Equivalent Asset Value (MEAV)	to enable the proportion of each asset type with a particular Condition to be classified and recorded, a common currency is required. This is the Modern Equivalent Asset Value, which is the current estimated cost of an asset, or part of an asset, on the basis of replacement or renewal with an asset that meets all mandatory standards and legislative and/or statutory requirements, and will perform the Required Duty. The basis for calculating MEAVs for all Operational Assets is defined in LU standard S1042.	Jargon Buster
Asset Monitoring	the act of taking a series of measurements at regular intervals at a specific location on a structure to assist in the engineering evaluation of a defect identified by the Assessment or Inspection process or to gain knowledge of Groundwater variations and Earth Structure behaviour.	Jargon Buster
Operational Asset	an asset that is used or in existence for the delivery of, or direct support to, the railway service. This includes a fixed asset that is not currently used for the railway service.	Jargon Buster
Principal Inspection	close visual Inspection of Earth Structure assets carried out at 100m spaced transects and any particular features of interest between transects along the length of asset to record all visible factors related to the performance of the asset.	Jargon Buster
Required Duty	a statement of the requirements placed on an Operational Asset type in order to deliver satisfactory service to the railway and supporting services and is included in LU standard S1042. The Required Duty is prepared in accordance with a generic guidance list and includes the full range of functions and interactions with other Operational Asset types. The Required Duty is not limited to engineering aspects of performance.	Jargon Buster
Retaining Structure	an external structure constructed to create a steeper difference in level than would be possible for an earth slope. Retaining structures may be part of Earth Structures, enabling the remainder of the slope to have flatter gradients appropriate to the soil characteristics, or they may be a structure in their own right. Generally they are considered to be structural assets in their own right when bending and shear stresses in the structural elements are more than nominal.	Jargon Buster

Serviceability Limit State	state of deformation of an element such that its use is affected, its durability is impaired or its maintenance requirements substantially increased.	Jargon Buster
Site Investigation	determination of physical characteristics of sites as they affect design and construction of building and Civil Engineering works and stability of neighbouring structures.	Jargon Buster
Shallow Slip	Slip surfaces that only pass through the sloping part of the Earth Structure outside the line side services and are typically limited in depth.	Jargon Buster
Special Inspection	an Inspection to maintain awareness of the Condition of particular areas or defect of an Earth Structure causing concern	Jargon Buster
Specific Concern	a concern developed as a statement of how a particular Operational Asset type, Operational Asset type element or individual Operational Asset fails to meet Required Duty. Each Specific Concern must be linked to a Generic Concern as part of the process to assure the ACAC is complete.	Jargon Buster
Strengthening and Renewal	corrective action to address life-expired assets or elements in accordance with the programme for lifecycle management or a change in use, function or duty of the asset or element.	Jargon Buster
Temporary works	site installations, not forming part of the permanent works that are necessary for the progress of the work in safety.	Jargon Buster
Timesclae for Intervention (TFI)	TFI is used for Assets which are managed to provide a nominally infinite life and therefore residual life is not meaningful. The TFI will be the time until the next intervention is required to stem the degradation of the Asset and increase its life.	Jargon Buster
Transect	a condition survey slope cross section generally logged at 100m intervals along the railway at LCS plates	Jargon Buster
Ultimate Limit State	state associated with collapse or with other similar forms of structural failure. Generally corresponds to the maximum load-carrying resistance of a structure or structural part.	Jargon Buster

8 Abbreviations

Abbreviation	Meaning
ACAC	Asset Condition Assessment and Classification
ALARP	As Low as Reasonably Practical
c′	Drained cohesion

CDS	Conceptual Design Statement
CWS	Conceptual Work Statement
EC	European Commission
HA	Highways Agency
IRE	Inspection Review Engineer
LCS	Location Coding System
LU	London Underground
MEAV	Modern Equivalent Asset Value
ORR	Office of Rail and Road
RL	Reduced railway live loading for use where main line locomotives and rolling stock do not operate. Refer to LU standard S1051 (Civil Engineering - Bridge Structures), Section 3.1.16.3 for details.
Load Model 71 (BS EN 1991-2) (Formerly RU)	Standard railway live loading allowing for the combinations of vehicles currently running or projected to run. Refer to LU standard S1051 (Civil Engineering - Bridge Structures), Section 3.1.16.3 for details.
RAV	Relative Asset value
ROGS	The Railway and Other Guided Transport Systems (Safety) Regulations, 2006 (ROGS)
r_u	Porewater pressure ratio
SLS	Serviceability Limit State
TOC	Train Operating Company
UDL	Uniformly distributed load
ULS	Ultimate Limit State
ϕ'	Drained angle of internal friction
γ	Unit weight

9 References

9.1 Statutory documents

Document no.	Title or URL
	Construction (Design and Management) Regulations
	The Fire Precautions (Sub-surface Railway Stations) Regulations
	Goal-setting Principles for Railway Health and Safety, Office of Rail and Road

9.2 British standards

Document no.	Title or URL
BS EN 1990	Eurocode: Basis of Design
BS EN 1991	Eurocode 1:Actions on structures
BS EN 1992	Eurocde 2:Design of concrete structures

BS EN 1993	Eurocode 3: Design of Steel structures
BE EN 1994	Eurocode 4: Design of composite steel and concrete structures
BS EN 1996	Eurocode 6: Design of masonry structures
BS EN 1997-1	Eurocode 7: Geotechnical design. General rules
BS EN 1997-2	Eurocode 7: Geotechnical design. Ground investigation and testing
NAto BS EN 1997-1	UK national annex to Eurocode 7. Geotechnical design. General rules
NA to BS EN 1997-2	UK national annex to Eurocode 7. Geotechnical design. Ground investigation and testing
BS 8002	Code of practice for earth retaining structures
BS8004	Code of practice for foundations
BS 8006-1	Code of practice for strengthened/reinforced soils and other fills
BS 8006-2	Code of practice for strengthened/reinforced soils, Part 2: Soil nail design
BS 8081	Code of practice for ground anchorages
BS EN 1536	Execution of special geotechnical works – Bored piles
BS EN 1537	Execution of special geotechnical works - Ground anchors
BS EN 14490	Execution of special geotechnical works – Soil nailing
BS EN 12063	Execution of special geotechnical works – Sheet pile walls
BS6031	Code of Practice for Earthworks
BS 5930	Code of practice for site investigations
PAS 128	Specification for underground utility detection, verification and location

9.3 Other national standards

Document no.	Title or URL
ISO 13431	Geotextiles and geotextile-related products Determination of tensile creep and creep rupture behaviour

9.4 Industry codes of practice

Document no.	Title or URL
CIRIA C515	Groundwater Control: design and practice
CIRIA C574	Engineering in chalk
CIRIA C637	Soil nailing – best practice guidance
CIRIA C591	Infrastructure cuttings condition appraisal and remedial treatment
CIRIA C550	Infrastructure embankments condition appraisal and remedial treatment

CIRIA C583	Engineering in Lambeth Group
CIRIA C760	Guidance on embedded retaining wall design

9.5 TfL company documents

Document no.	Title or URL
S1023	Infrastructure Protection
S1042	Asset Condition Reporting (ACR)
S1050	Civil Engineering – Common Requirements
S1051	Civil Engineering – Bridge Structures
S1052	Civil Engineering – Gravity Drainage Systems
S1057	Civil Engineering – Miscellaneous Assets
S1062	Temporary Works
S1083	Passive Fire Protection Systems
S1085	Fire Safety Performance of Materials
S1156	Gauging and Clearances
S1538	Assurance
S1157	Track - Performance, Design and Configuration
S1159	Permanent Way – Dimensions and Tolerances
S1160	Permanent Way – Track Support
S1165	Permanent Way – Landscaping and Vegetation
S1167	Operational Boundary Fencing
S1552	Contract QUENSH Conditions
G0054A	Guidance Document – Earth Structures
E0029	Managing civil engineering asset risk
G0054B	Guidance Document – Guide to Slope Stability Analysis
CPD-9999-EST-RPT-00001	Effects of Inclement Weather on Earth Structures, Transport for London , December 2023.

9.6 Other documents

Document no.	Title or URL
	Highways Agency – Specification for Highway Works
	National House Building Council, Building Near Trees
	Specification for piling and embedded retaining walls, The Institution of Civil Engineers, Thomas Telford
	British Steel Piling Handbook, Jan 2008, Arcelor Group
Design guide for environmental barriers	DRMB Volume 10 Section 5 Part 1 (HA65/94)
DMRB Volume 10 Section 5 Part 2 (HA66/95)	Environmental barriers: technical requirements

10 Document history

Issue no.	Date	Changes	Author
1-054 A1	October 2007	Standard 2-01304-005 re formatted and re-numbered to 1-054, no technical changes have been made to the content other than changing references to other standards where their numbers have changed. Authorised for use. Previous authorisation is valid	
1-054 A2	March 2010	Revised after PSC S1-01213 comments. clauses 3.7.4, 3.7.4.1, 3.7.4.2 and 3.7.4.3 added. Updated to incorporate Written Notice WN00775. Authorised for use.	
1-054 A2 updated for PSC 01355	July 2010	Standard updated in accordance with PSC 01355. Reformatted to new template.	
1-054 A3	December 2010	Updated as per DRACCT 00062 (PSC 01355) - Correction of References and associated clauses to reference new Eurocodes, - Section 3.1.14 deleted as information duplicated in section 3.4 - Written Notice LU-WN-00890 removed as adequately covered in 1-051	Karen Gates
S1054 A4	December 2014	Updated as per DRACCT No. 02168 1. Incorporate the Earth Structures Design Guide. 2. Incorporate information on Inclement Weather concerns. 3. Include information on Serviceability concerns and classification. 4. Include information on inspection of chalk cuttings. 5. Update inspection and assessment procedures.	Nader Saffari

		6. Include information on Risk Assessment. 7. Update information on Drainage. 8. Include information on Boundary Fencing along Earth Structures. 9. Include information on Vegetation Management. 10. Include information on Steps. 11. General update and formatting.	
S1054 A5	June 2018	Updated as per DRACCT No. 05243 1. Incorporate information on the effects of pre-existing shear surfaces. 2. General update and formatting.	Nader Saffari
S1054 A6	December 2023	Updated information on the following sections: 1. climate change. 2. drainage design. 3. vegetation management. 4. construction safety and permit to dig. 5. information on ACR. 6. risk assessment. 7. general update and formatting As per the Change Request No. CR-18502	Nader Saffari

11 Attachments

11.1 Procedure for Principal Inspection

11.1.1 General

11.1.1.1 The Inspector shall make a close Inspection of the Earth Structure sufficient to identify and quantify all external evidence of its internal Condition. Inspectors shall walk over the Earthwork slope wherever vegetation obscures the view.

Note: The survey cannot be adequately carried out from the cess or any other location remote from the slope.

11.1.1.2 The Inspection information shall be collected on recording forms or data-logger in a standard manner structured to replicate the record input format of the LU Earth Structures database. (Pro-forma's of suitable recording forms are given in Attachment 11.3). Where it is not possible to record all relevant details of each Earth Structure within the standard data format, the significant details of any additional uncommon conditions shall be recorded appropriately in comment fields on the recording forms and in the inspection report.

11.1.1.3 The principle behind a Principal Inspection survey of an Earth Structure, shall be the systematic examination of cross-sections along the structure in order to select appropriate answers to the multi-choice questions that represent the database input requirements.

11.1.1.4 Earth Structures greater than one metre in height shall be inspected in detail and all required information recorded.

11.1.1.5 For assets which have been subject to analytical assessment, the transects shall coincide with the assessment transects. For all other assets, the transects will be undertaken at 100m intervals, to be coincident with the LCS plate markers ± 5 m which are positioned every 100m on the sleepers. In either case, additional transects may be carried out where the previous transects do not adequately cover a feature of interest. This might include the highest or steepest part of the asset, if this is not typical of the previous transects. In areas where there are two or more adjacent sets of tracks, LCS plates are not generally coincident on adjacent tracks and in such cases, the outside plates nearest the Earthworks side slopes shall be used for the recording of survey location.

11.1.1.6 Any noteworthy features that are indicative of Earth Structure instability shall be logged by an additional inspection transect in accordance with Section 11.1.1.5 of this standard.

Note: Features include indicators of potential Earthworks distress such as increased depths of ballast, displaced lineside services and slope instability as well as earlier remedial works.

11.1.1.7 The Inspector shall record information relating to the following:

a) location, date and time, and other reference information;

b) photographs;

c) Earthworks structure type;

d) track condition;

e) lineside service condition;

f) evidence of previous grouting work;

g) geology/material;

h) slope geometry/slope condition;

i) Retaining Structures condition;

j) Earthworks drainage;

k) water;

l) wildlife;

m) vegetation;

n) adjacent property.

11.1.1.8 The Inspector shall record whether further geotechnical or topographical investigations or monitoring are required by the observed Condition of the Earth Structure.

11.1.2 Condition survey reference information

11.1.2.1 Location information shall uniquely position the survey location within the LU system. To achieve this and to save manually measuring 100m intervals, the existing sleeper mounted LCS location plates shall be used wherever possible.

11.1.2.2 Other reference information to be recorded with the location shall include the name of the Inspector, date, time, weather and if currently within a station boundary or not. On single line track where two way travel occurs, e.g. Chalfont-Chesham, a side is specified, either right or left, relative to the arrow containing the location information on the LCS plates.

11.1.2.3 If LCS plates are missing e.g. depots and sidings, manual measuring of locations shall be necessary.

11.1.3 Photographs

11.1.3.1 Photographs shall be taken every 100m half-section and at feature locations or any noteworthy areas of interest. The photograph date shall be part of the photographic record and details shall be given on the Inspection forms.

11.1.4 Structure type

11.1.4.1 This section categorises the type of structure. There are two descriptions of structure permitted in the recording scheme. These are:

a) Embankment

b) Cutting.

11.1.4.2 The descriptions ‘Cutting’ and ‘Embankment’ are Earth Structures and for these all sections in the survey forms shall be answered. The definition of whether an earth slope falls into these categories is based on height. If the height from the toe to the

crest of a slope exceeds one metre excluding any depths of ballast then it is classified as an Earth Structure and all details shall be logged.

11.1.4.3 The Earth Structure type shall be noted as “accessible” when it has been possible to enter and walk over it.

11.1.5 Slope definition

11.1.5.1 The slope shall be defined as having three basic sections (see sketch in Section 11.1.20 of this Attachment). These are essentially two horizontal sections and an angled section, i.e. the slope. Section (i) is always the part including the rails, to the start of the slope and any offsets are measured with the nearest running rail being the origin. Section (ii) is the sloping section and offsets are always measured parallel to the line of steepest slope from the break point with Section (i), the start of the slope. It is the slope surface length from the initial break point that is measured and although the slope may be sub-divided when the slope geometry is complex it is all still Section (ii). Section (iii) is designated as being between the end of Earthwork slope and the fence line. It shall be noted that it is not always necessary to have a Section (iii) on a section. In some cases the slope may continue beyond the LU boundary in which case the full extent of the slope shall be recorded.

Note: It is necessary to uniquely define the complex nature of many of the Earth Structure slopes and to formalise the method of recording offset lengths to various points on the slope.

11.1.6 Track condition

11.1.6.1 Frequently corrected track settlement or misalignment results in large ballast depths. For this reason the depth and width of ballast shall be recorded as it has been observed in previous inspections. The shoulder width of Embankments, which usually coincides with the cess width (historically due to poor shoulder of embankments), is also an indicator of stability as unstable ash or clay Embankments usually have subsiding shoulders, which result in a reduced width of the cess or shoulder and an undulating cess. The density of the cess material is an indicator of stability as replacement cess material in the event of settlement has historically been tipped and not compacted and may indicate an unstable shoulder.

Note: The information to be recorded on track condition is primarily designed to highlight any Earthwork defects that may be easily revealed as a result of the existing track condition. It is not intended to be comprehensive in terms that LU track engineers might use.

11.1.6.2 Pumping shall be recorded where there is movement of waterborne fines up through the track formation under the influence of cyclic loading from train wheels and is evident as boils of light slurry between or adjacent to the tracks. This indicates the track has insufficient or defective drainage with the potential for a detrimental effect on Earth Structure stability.

11.1.7 Lineside service condition

11.1.7.1 The assessment of movement of the lineside services shall be qualitative in terms of vertical and horizontal displacement. The judgement of whether displacement is slight, moderate or extensive is relative and based on a reference taken from

adjacent lineside service posts and no specific measurements are to be taken. The angular displacement of the cable posts shall be measured by placing a clinometer onto the post. Horizontal movement shall generally be considered as being positive towards the downslope in the direction perpendicular to the track. Where movement is noted parallel to the track this shall be recorded in a comment field and in the inspection report.

Note: Evidence of movement on or in Earth Structures can be identified clearly by displacement of the lineside services located on cable posts usually at the edge of the cess. In many cases the movement of these services may be an oversensitive indicator to Embankment movement as they are often constructed at the shoulder where ash may be less compact than central portions. However, lineside service displacements can indicate the extent of movements and how differential settlement has occurred with time.

11.1.7.2 The approximate age of the lineside services shall be indicated as either first or second generation. In general, concrete cable post routes shall be recorded as first generation and steel cable post routes as second generation. Where further information relating to the age of the cable route is available, this should be recorded in the inspection report. Such information might include the approximate year of installation, where known, or where there is evidence that the generation of the cable route is not typical of its age. This is to alert the interpreter of the data to the fact that new services are unlikely to show significant deformation, although movement may be taking place at a slow rate. If, however, lineside services estimated as less than 5 years old are recorded as showing displacement then this may be indicative of fairly rapid and significant movement. However, it should also be noted that in many cases, distortion of the cable route is more likely to be due to the adequacy of the foundations or to poor installation than indicative of slope movement.

11.1.8 Grouting

11.1.8.1 Evidence of grouting remedial works shall be recorded.

Note: Grouting has been used over many years in an attempt to stabilise Embankments, especially those with large depths of ash. It is usually difficult to find positive evidence of previous grouting without leaving the cess. Much of the difficulty in locating where grouting has taken place is due to extensive vegetation cover. If grouting is present it can often be found on the slope surface especially around tree trunks. Locations where grouting was undertaken are often indicated by the poor state of the lineside services and vegetation.

11.1.9 Geology and material

11.1.9.1 The surface material shall be broadly categorised into a group such as clay, sand, chalk, ash and made ground.

Note: This section is designed to record the general material forming the Earth Structure if it is evident. It is not intended to give an engineering description but to broadly categorise the surface materials.

11.1.10 Slope geometry

11.1.10.1 The measuring of the slope geometry shall be carried out using a clinometer and a 50 m tape or suitable laser measurement device. The method of slope geometry determination is cumulative measurement of distance along the slope surface up or down the line of steepest overall slope using the start of Section (ii) as the datum, i.e. the break point between the cess and the slope (see sketch in Section 11.1.20 of this Attachment). Using this procedure the distance to the end of each sub-section is recorded together with the inclination from the horizontal of the slope in that sub-section.

11.1.10.2 For each slope sub-division the offset length and angle shall be recorded. The offset lengths of Sections (i) and (iii) are recorded to complete the geometry. A facility to record whether any measurements were estimated is provided in case slopes are visible but not accessible.

11.1.10.3 Exposed surfaces of retaining structures within the slope shall be measured as sub-divisions of the slope section (also see Section 11.1.12.1)

11.1.11 Slope condition

11.1.11.1 A list of eleven possible movement indicators are included in the Earth Structure database source data requirements. The list is constructed to include the likely forms of slope distress. If any of these indicators are observed then their location and offset shall be recorded.

Note: Most of the information recorded in the Inspection is factual. However the completion of this section involves making geotechnical judgements based on recognising key geotechnical features.

11.1.11.2 The next sub-section requires an assessment of the likely mode of slope failure. It shall be noted that the purpose of this Assessment is to judge the overall movement characteristics of the slope and it does not attempt to classify the magnitude of movement. It is inappropriate to classify or grade the seriousness of slope instability as individual judgement may vary and difficulty arise from setting a scale that would be valid across the whole system.

11.1.11.3 Difficulties arise in identifying movement indicators on some slope surfaces. Indications such as slope bulges, toe bulges, slip scars and tension cracks are sometimes difficult to identify when they are small and vegetation cover is thick. When a slope bulge is observed in such circumstances care is needed to ensure it is an indication of slope instability and not an original non uniform slope construction. Where in doubt a Feature shall be recorded rather than ignored.

11.1.11.4 Excessive waste or litter on the Earth Structure slope shall be recorded in the comment section. This will identify sub-standard conditions representing an unacceptable fire risk and contravention of the Environmental Protection Act.

11.1.12 Retaining structure condition

11.1.12.1 To enable a consistent interpretation of the data to be made at a later date, the retaining structure wall geometry shall be incorporated into the slope geometry as a slope sub-section. Therefore, only the visible height and width of any wall is recorded. The exact location of a wall can be gained from the slope geometry. Any

retaining wall shall be included within Section (ii) of the Earthwork. All retaining walls shall be recorded where they occur on the line of a regular 100m section. Walls that are located between sections shall be recoded in the text of the inspection report.

11.1.12.2 The determination of the structure type shall include reference to background information from the preparation stage study for the inspection where available information on the retaining works shall have been examined.

11.1.13 Earthworks drainage

11.1.13.1 Evidence of cess, slope and toe drainage shall be recorded.

Note:	This section is relatively straight forward to record, the only difficulty being observing some slope counterfort drainage due to overgrown vegetation. Cess drains are to be recorded if catch pits are observed either side of the Transect being logged.

11.1.14 Water

11.1.14.1 As insufficient drainage and softening due to water or moisture can significantly affect Earthworks stability, evidence of water shall be recorded outside as well as within LU boundaries.

11.1.15 Wildlife

11.1.15.1 The impact of wildlife is to be considered outside the normal ±5m taken into account on other categories whilst logging a transect section. The density of animal burrows shall be measured. The classification is as follows:

a) isolated 1 hole within ± 10m

b) moderate 2 to 4 holes within ± 10m

c) dense >4 holes within ± 10m.

11.1.16 Vegetation

11.1.16.1 The vegetation Inspection is concerned with recording the type of vegetation cover in a simplified manner. Vegetation shall be recorded in a form that would be helpful in terms of recording features that might be indicative of Earthworks instability.

11.1.16.2 The vegetation is broadly divided into two groups. The first is the understorey and the second is the canopy. The understorey is further categorised into five groups. These are:

a) bare ground

b) grass and herbs

c) ivy

d) brambles

e) shrubs.

11.1.16.3 Bare ground shall be recorded wherever present. The condition rating tool assumes that bare ground is an indication of slope surface movement and reduces the crude factor of safety for the slope, on the basis that vegetation will not be able to establish itself on a translating slope surface. However, it should be noted that

bare ground can be caused by a number of factors which may not be related to movement, including vegetation management and weed killer application, shading by trees or structures, or dumping of materials on the slope surface.

11.1.16.4 The category of grass covers all grass, nettles and bracken. Brambles include any thorned shrub like bramble, rose, blackberry and raspberry. The density of these brambles usually gives an indication of the difficulty of access to the Earthwork slope.

11.1.16.5 The condition of the canopy includes the density of trees as well as whether they are leaning towards or away from the track. This may indicate down slope movement depending on whether it was a Cutting or Embankment. However, care is again needed when recording the lean of trees as this may be due to natural growth towards light which would be inwards in a Cutting and outwards on an Embankment.

11.1.17 Adjacent property

11.1.17.1 This section is additional to that required in the slope information section and is intended to be useful in four ways. These are:

a) to provide information of adjacent fence condition in terms of necessary repairs. Inspection staff shall be aware of LU's duty to properly maintain the fencing of the railway and the need to liaise with the appropriate persons to arrange fence repairs where they are apparent;

b) to provide access information to enable efficient planning and plant access if remedial works are undertaken;

c) to provide information on the nature of the property in relation to the possible difficulties with subsidence or heave or both as a result of tree growth or removal or both;

d) to provide information on potential surcharge loads from adjacent property.

11.1.18 Features

11.1.18.1 Any apparent feature indicative of earthwork instability between 100 m Transect sections shall be logged. Only information relating to the location and the particular Feature being logged shall be recorded. The list of possible features is as follows:

a) track condition

b) lineside services

c) slope condition

d) grouting

e) Retaining Structure

f) Earthworks drainage

g) water

h) wildlife

i) vegetation.

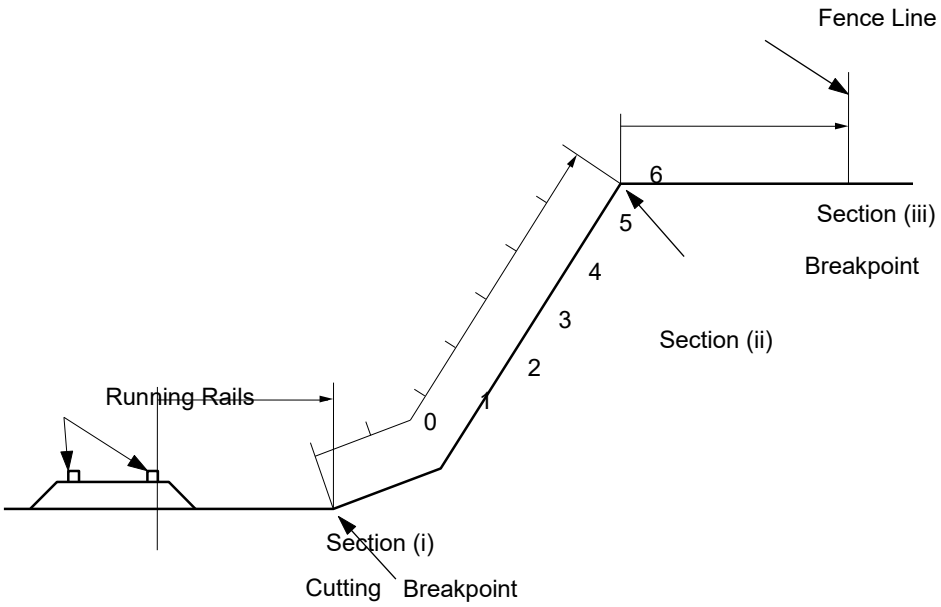
11.1.18.2 The details of earthwork instability features shall be recorded in the inspection report. The information to be recorded shall include the start and end chainages and photographs.

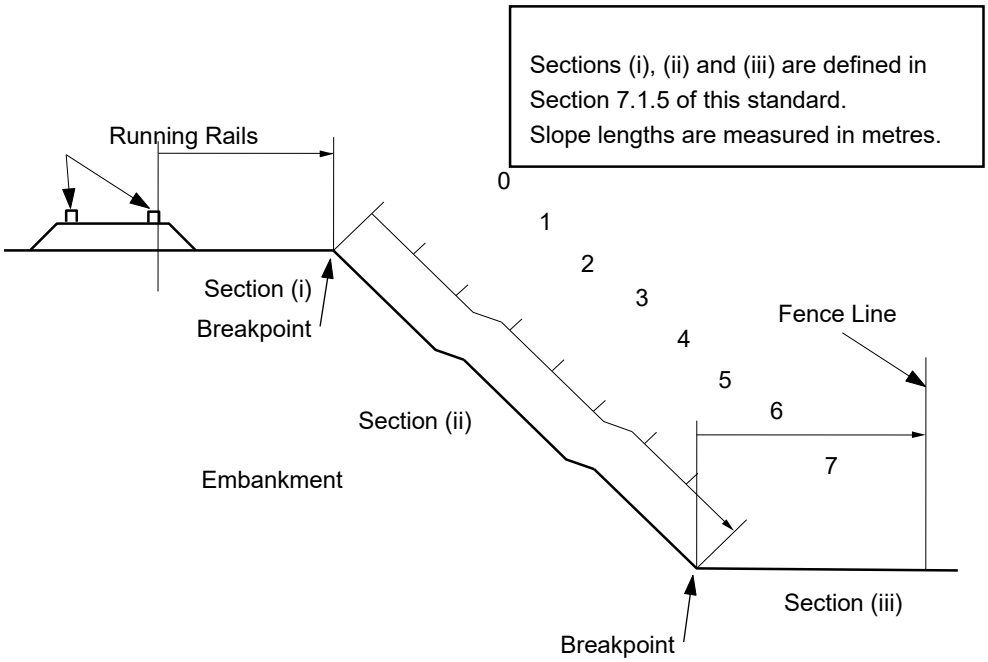
11.1.19 Strengthening and renewal works

11.1.19.1 Comment sheets shall be added to the Inspection record to record information in relation to any recent Strengthening and Renewal works, or other works that help support the slope, that are present along the Earth Structure. The Inspector shall examine such works for signs of deterioration from the installed condition of the visible elements and for any indications of ongoing adverse behaviour of the asset that the installed works were intended to halt.

11.1.20 Sketch of the recording scheme for slope geometry

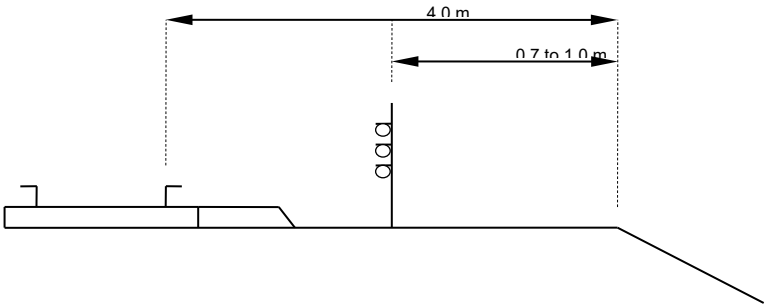
11.1.20.1 The method for recording slope geometry shall be as follows:





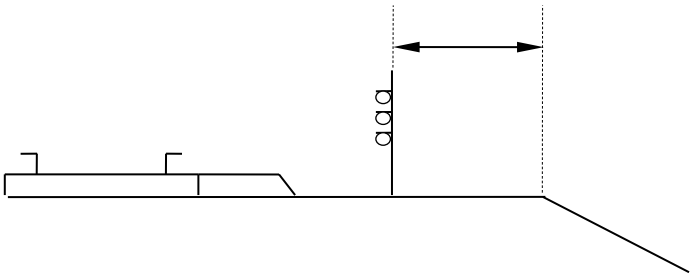
11.1.21 Sketch of the recording scheme for shoulder condition

11.1.21.1The method for recording shoulder condition shall be as follows:



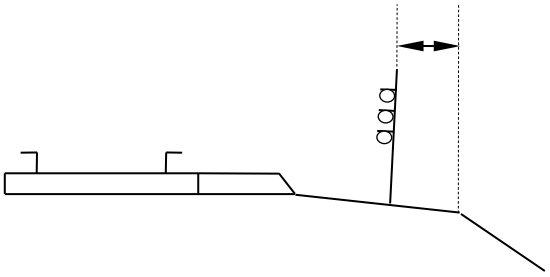
Shoulder condition: Good

G-054 suggests design for remediation should provide 4.0m distance between nearest running rail and breakpoint of asset (there is no requirement documented in 1-054). Asset has walkable area between the ballast shoulder and the services and preferably



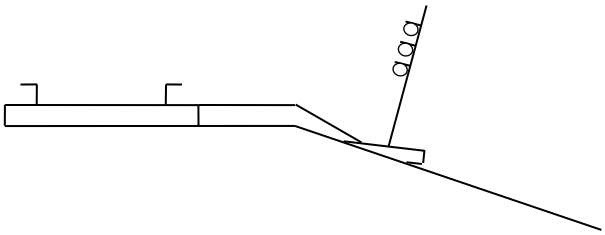
Shoulder condition: Serviceable

Asset has a flat walkable area between the ballast shoulder and the services and there is between 0.3m and 0.7m width beyond the services.
The services may have a slight lean.



Shoulder condition: Marginal

Walkable area between the ballast shoulder and the services is narrow and sloping away from the track and may be undulating along its length with between 0.0m and 0.3m width beyond the services. The above condition may have led to the following:
The depth of ballast may be increasing – up to 0.4m.



Shoulder condition: Poor

No walkable area between the ballast shoulder and the services and less than 0.3m width beyond the services. Ballast shoulder ravelling down slope. Cable post toes are exposed. Access along the slope may be difficult due to localised oversteepening.
The above condition may have led to the following:
Ballast depth greater than 0.4m.

11.2 Procedure for Principal Inspection of Chalk Cuttings

11.2.1 General

11.2.1.1 The inspection of chalk cuttings shall be generally as for other earth structures. However, certain additional information should be recorded beyond that required for a soil slope, and a separate recording sheet is provided for this purpose (see section 11.3). The notes given in Section 11.1 for Principal Inspections shall apply for chalk cuttings; this section records additional items that are relevant only to the inspection of chalk cuttings.

Note:	The survey cannot be adequately carried out from the cess or any other location remote from the slope. Due to the steepness of many chalk cuttings, this may require the use of rope access techniques to achieve safe access to the slope.

11.2.1.2 In addition to the information required for other earth structures assets, the Inspector shall record information relating to the following:

a) whether rope access techniques were required for the inspection;

b) details of the formation of the chalk and superficial materials present and the extent of chalk exposed in the cutting face;

c) the extent and nature of toe debris and any mitigation measures;

d) slope geometry, identifying the boundaries between chalk and superficial materials;

e) vegetation clearance and the presence of hazardous trees or stumps;

f) topography and nature of adjacent property.

11.2.2 Chalk Cutting Classification

11.2.2.1 The cutting should be classified as Class A (Chalk), Class B (Composite) or Class C (superficial). These classifications shall be defined as below:

a) Class A (Chalk) Chalk cutting with superficials <2m thick

b) Class B (Composite) Chalk cutting with superficials >2m thick

c) Class C (Superficial) Cutting where superficial thickness > slope height, such that the top of the chalk is below track level.

This classification may be determined on site or from previous assessment of the asset. The classification of the cutting will determine the likely modes of instability; in general chalk slopes are expected to be stable, but may experience ravelling and frost shattering, while superficial slopes may be subject to instability or flow failure mechanisms.

11.2.2.2 The specific chalk formation should be identified as the stratum present will indicate the likely presence of flints, marl seams, fractures and other features that may influence the behavior of the slope. This information can be determined from geological maps.

11.2.2.3 The nature of the superficial materials should be identified as the composition of the superficial deposits will influence their likely behaviour and stability.

11.2.2.4 The extent of chalk not covered by topsoil and/or vegetation in the face shall be recorded as an indication of the susceptibility of the asset to frost shattering. It is assumed that chalk not covered by topsoil and/or vegetation is more susceptible to frost shattering effects.

11.2.3 Toe Debris

11.2.3.1 Toe debris represents one of the most widespread defects on chalk cuttings. The extent and composition of the debris, along with the presence and condition of any toe debris mitigation measures should be recorded. The presence of flint cobbles/boulders in the cess is recorded as an indication of the likelihood of further flint being present in the slope face. Flints cobbles/boulders potentially represent a risk to the operation of the railway if they fall down the slope.

11.2.4 Slope geometry

11.2.4.1 The subsections of Section (ii) shall be identified as toe debris, chalk or superficial material. This allows the stability of the slope to be considered in line with the different behaviours for chalk and superficial materials.

Note: It is necessary to uniquely define the complex nature of many of the Earth Structure slopes and to formalise the method of recording offset lengths to various points on the slope.

11.2.5 Slope condition

11.2.5.1In addition to the list of eleven possible movement indicators for conventional cuttings, Flow Failure scar shall be recorded as a specific mode of failure.

Note: Most of the information recorded in the Inspection is factual. However the completion of this section involves making geotechnical judgements based on recognising key geotechnical features.

11.2.5.2 Ravelling is added as an additional movement type.

11.2.6 Water

11.2.6.1 The presence of water flowing over the crest of the slope is to be recorded as an indication of potential flow failure risk.

11.2.7 Wildlife

7.2.7.1 The nature of the spoil from burrows is to be recorded as an indication of the geology.

7.2.7.2 An indication of the species thought to be present shall be recorded in order to give an indication of the likely measures required to exclude the burrowing animals. This is not to replace the involvement of a qualified environmental specialist.

11.2.8 Vegetation

7.2.8.1 The approximate timing and extent of vegetation clearance shall be recorded as an indication of the risk of slope degradation following vegetation works.

7.2.8.2 The presence of dead or dormant tree stumps on the slope is a risk as stumps may fall from the cutting slope as roots decay. The size and location of such stumps shall be recorded as an indication of the likely risk to the railway.

11.2.9 Adjacent property

11.2.9.1 The topography and surface nature of the adjacent property is to be recorded to determine the risk of flow failure. Where the topography tends to direct surface water towards the railway, there is a higher risk of flow failures occurring.

11.3 Information to be recorded at a Principal Inspection

11.3.1 The example sheets given in Section 11.3.3 tabulate the information to be recorded at existing Earth Structure slopes by a Principal Inspection.

11.3.2 Additional information shall be recorded on comment sheets with regard to Strengthening and Renewal works and other works that help support the slope as noted in section 11.1.19.

11.3.3 Examples of Principal Inspection recording sheets:

Note: The example sheets in this section are suitable to be used as proformas for the field recording of Inspection Information or for the creation of input screens for data loggers to achieve a data record structure that meets the requirements of section 11.1.1.2.

Inspection of Earth Structures:
Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section

A) Condition survey (one side of track only)

Recorded by | Date

At station Y ☐ N ☐ Station

From station | To station

LCS code / | Chainage

Line owner | Line direction | Line type

B) Photographs

None	☐	With traffic	☐
Up slope	☐	Against traffic	☐
Down slope	☐	Across track	☐

Inspection of Earth Structures:

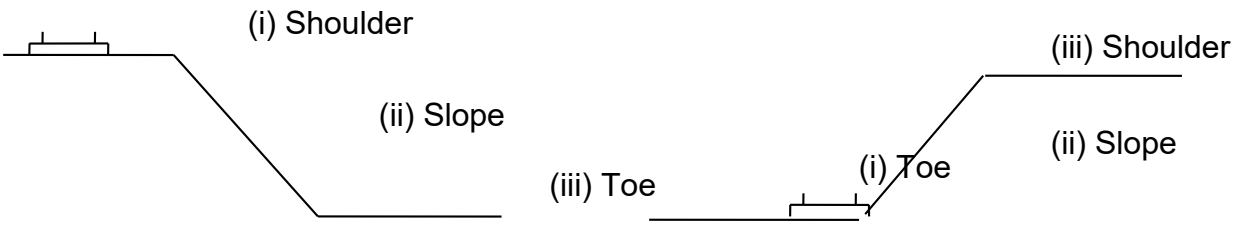
Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section (continued)

C) Earthworks structure type

Accessible Y ☐ N ☐

Cutting ☐ Embankment ☐ At grade ☐ At a structure ☐

Depot ☐ Other ☐



For slope definitions see Section 7.1.5 and the sketch in Section 7.1.20. of Attachment 7.1 of this standard.

SLOPE GEOMETRY - CONDITION SURVEY

D) Track condition

Depth of ballast (from top of sleeper to top of cess) ☐ m Not measurable ☐

Width of ballast (from outside of running rail) ☐ m Not measurable ☐

Pumping Y ☐ N ☐ Limited ☐ Moderate ☐ Extensive ☐

Cess present Y ☐ N ☐ Cess width ☐ m

(walkable area beyond the ballast)

Cess material: Ash ☐ Gravel ☐ Other type ☐

Cess: Dense ☐ Medium dense ☐ Loose ☐

Condition: Undulating ☐

Vegetation intrusion of cess ☐

Comments

Inspection of Earth Structures:
Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section (continued)

E) Lineside services condition

No services ☐

Old services

Location	Section	(i)		(ii)			(iii)				
Offset from running rail or breakpoint	Section	(i)		m	(ii)		m	(iii)			m
Angular displacement	None ☐	Leaning towards rail ☐			Leaning away from rail ☐			Angle ☐			°
Vertical displacement	None ☐	Slight ☐			Moderate ☐			Extensive ☐			
Horizontal displacement	None ☐	Slight ☐			Moderate ☐			Extensive ☐			
Undulating services	None ☐	Slight ☐			Moderate ☐			Extensive ☐			

2nd generation services (new)

New services location	Section	(i)		(ii)			(iii)				
Offset from breakpoint	Section	(i)		m	(ii)		m	(iii)			m
Angular displacement	None ☐	Leaning towards rail ☐			Leaning away from rail ☐			Angle ☐			°
Vertical displacement	None ☐	Slight ☐			Moderate ☐			Extensive ☐			
Horizontal displacement	None ☐	Slight ☐			Moderate ☐			Extensive ☐			
Undulating services	None ☐	Slight ☐			Moderate ☐			Extensive ☐			

Comments

F) Grouting

Evidence of grouting Y ☐ N ☐

G) Geology / material

Clay ☐ Sand ☐ Chalk ☐ Gravel ☐

Other

Inspection of Earth Structures:
Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section (continued)

H) Slope geometry

Offset length (i) ☐ m

(Nearest running rail to slope breakpoint[start of Section (ii)])

Slope facing: North ☐ South ☐ East ☐ West ☐

North East ☐ North West ☐ South East ☐ South West ☐

Slope form: Regular ☐ Irregular ☐ Very irregular ☐

Number of Section (ii) slope sub divisions ☐

1	Length		m	E		M		Angle°		E		M		Wall	
2	Length		m	E		M		Angle°		E		M		Wall	
3	Length		m	E		M		Angle°		E		M		Wall	
4	Length		m	E		M		Angle°		E		M		Wall	
5	Length		m	E		M		Angle°		E		M		Wall	
6	Length		m	E		M		Angle°		E		M		Wall	
7	Length		m	E		M		Angle°		E		M		Wall	
8	Length		m	E		M		Angle°		E		M		Wall	
9	Length		m	E		M		Angle°		E		M		Wall	

Offset length (iii) ☐ m Measured ☐ Estimated ☐

(Slope breakpoint to boundary [end of Section (iii)])

Slope diagram sketch

Comments

Inspection of Earth Structures:
Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section (continued)

I) Slope condition

No evidence of movement ☐

Movement indicators key:

1) Lineside services	2) Slip scars	3) Slope bulges	4) Terracing
5) Structure distortion	6) Dislocated trees	7) Toe bulges	8) Toe debris
9) Tension cracks	10) Dislocated fence	11) Cracked roads	

Indicator number(s) ☐

Indicator location	Section	(i) ☐	(ii) ☐	(iii) ☐				
Offset from running rail	Section	(i)	Start	☐	m	Finish	☐	m
Offset from breakpoint	Section	(ii)	Start	☐	m	Finish	☐	m
Offset from breakpoint	Section	(iii)	Start	☐	m	Finish	☐	m

Indicator number(s) ☐

Indicator location	Section	(i) ☐	(ii) ☐	(iii) ☐				
Offset from running rail	Section	(i)	Start	☐	m	Finish	☐	m
Offset from breakpoint	Section	(ii)	Start	☐	m	Finish	☐	m
Offset from breakpoint	Section	(iii)	Start	☐	m	Finish	☐	m

Indicator number(s) ☐

Indicator location	Section	(i) ☐	(ii) ☐	(iii) ☐				
Offset from running rail	Section	(i)	Start	☐	m	Finish	☐	m
Offset from breakpoint	Section	(ii)	Start	☐	m	Finish	☐	m
Offset from breakpoint	Section	(iii)	Start	☐	m	Finish	☐	m

Indicator number(s) ☐

Indicator location	Section	(i) ☐	(ii) ☐	(iii) ☐				
Offset from running rail	Section	(i)	Start	☐	m	Finish	☐	m
Offset from breakpoint	Section	(ii)	Start	☐	m	Finish	☐	m
Offset from breakpoint	Section	(iii)	Start	☐	m	Finish	☐	m

Overall slope assessment

Movement type:	Creep ☐	Flow ☐	Subsidence ☐
	Translational ☐	Rotational ☐	Unknown ☐
Depth of movement:	Shallow movement ☐	Unknown ☐	Deep movement ☐

Comments

Inspection of Earth Structures:
Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section (continued)

J) Retaining structures condition

No structure ☐

Structure type key:

1) Brick wall	2) Sheet piled wall
3) Mass concrete wall	4) Bored pile wall
5) RF concrete wall	6) Gabion
7) Precast concrete panels	8) Rubble wall
9) Slabs	10) Sleepers

Structure type number ☐

Remedial Y ☐ N ☐ Unknown ☐

Dimensions Height ☐ m Width ☐ m

Location Section (i) ☐ (ii) ☐ (iii) ☐

Condition: Good	☐	Serviceable	☐	Collapsed	☐
Cracked	☐	Bulging	☐	Overtopping	☐
Tilting towards rails	☐	Tilting away from rails	☐		

Structure type number ☐

Remedial Y ☐ N ☐ Unknown ☐

Dimensions Height ☐ m Width ☐ m

Location Section (i) ☐ (ii) ☐ (iii) ☐

Condition: Good	☐	Serviceable	☐	Collapsed	☐
Cracked	☐	Bulging	☐	Overtopping	☐
Tilting towards rails	☐	Tilting away from rails	☐		

Comments

Inspection of Earth Structures:
Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section (continued)

K) Earthworks drainage
No evidence ☐

Remedial Y ☐ N ☐ Unknown ☐
Drainage type key: 1) Crest 2) Slope 3) Toe
Material key: 1) Gravel 2) Rubble 3) Pipe 4) Catchpit 5) Ditch
Condition key: 1) Good 2) Serviceable 3) Cracked 4) Deformed 5) Collapsed 6) Overgrown
Extent of condition key: 1) Slight 2) Moderate 3) Extensive
Flow key: 1) Dry 2) Slight 3) Moderate 4) Significant

Drainage type number ☐
Material number ☐ Extent of condition number ☐
Condition number ☐ & ☐ Flow number ☐

Location Section (i) ☐ (ii) ☐ (iii) ☐
(All offsets are measured from the running rail or breakpoint parallel to the line of steepest slope i.e. Perpendicular to the track)

Offset from running rail	Section	(i)	Start	☐ m	Finish	☐	m
Offset from breakpoint	Section	(ii)	Start	☐ m	Finish	☐	m
Offset from breakpoint	Section	(iii)	Start	☐ m	Finish	☐	m

Drainage type number ☐
Material number ☐ Extent of condition number ☐
Condition number ☐ & ☐ Flow number ☐

Location Section (i) ☐ (ii) ☐ (iii) ☐
(All offsets are measured from the running rail or breakpoint parallel to the line of steepest slope i.e. Perpendicular to the track)

Offset from running rail	Section	(i)	Start	☐ m	Finish	☐	m
Offset from breakpoint	Section	(ii)	Start	☐ m	Finish	☐	m
Offset from breakpoint	Section	(iii)	Start	☐ m	Finish	☐	m

Comments

Inspection of Earth Structures:
Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section (continued)

L) Water
No evidence ☐
Feature type key:

1) Issues	☐	2) Stream	☐
4) Ponding	☐	3) Marshy	☐
5) Culvert	☐	6) Hydrophilic vegetation	☐
7) River	☐	8) High moisture content	☐

Feature type number ☐

Location Section (i) ☐ (ii) ☐ (iii) ☐
(All offsets are measured from the running rail or breakpoint parallel to the line of steepest slope i.e. perpendicular to the track)

Offset from running rail	Section	(i)	Start	☐ m	Finish	☐	m
Offset from breakpoint	Section	(ii)	Start	☐ m	Finish	☐	m
Offset from breakpoint	Section	(iii)	Start	☐ m	Finish	☐	m

Flow: Dry ☐ Slight ☐ Moderate ☐ Extensive ☐

Feature type number ☐

Location Section (i) ☐ (ii) ☐ (iii) ☐
(All offsets are measured from the running rail or breakpoint parallel to the line of steepest slope i.e. Perpendicular to the track)

Offset from running rail	Section	(i)	Start	☐ m	Finish	☐	m
Offset from breakpoint	Section	(ii)	Start	☐ m	Finish	☐	m
Offset from breakpoint	Section	(iii)	Start	☐ m	Finish	☐	m

Flow: Dry ☐ Slight ☐ Moderate ☐ Extensive ☐

Comments

M) Wildlife
No evidence ☐
Density of burrows 1) Dense ☐ 2) Moderate ☐ 3) Isolated ☐
Location Section (i) ☐ (ii) ☐ (iii) ☐

Comments

Inspection of Earth Structures:
Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section (continued)

N) Vegetation

Understorey								
Bare ground	None	☐	Isolated	☐	Moderate	☐	Extensive	☐
Grass/herbs	None	☐	Sparse	☐	Moderate	☐	Dense	☐
Ivy	None	☐	Sparse	☐	Moderate	☐	Dense	☐
Brambles	None	☐	Sparse	☐	Moderate	☐	Dense	☐
Shrubs	None	☐	Sparse	☐	Moderate	☐	Dense	☐
Evidence of clearance	Y	☐	N	☐				
Canopy								
Trees cover	☐	None	☐					
Coppice	☐	None	☐					

Age:	Immature	☐	Mature	☐	Standard	☐	
Type:	Deciduous	☐	Evergreen	☐			
Dimensions:	Mean height	☐	m	Mean dia.	☐	m	
Density:	Dense	☐	Moderate	☐	Sparse	☐	
Condition:	Vertical	☐	Lean toward rail	☐	Lean from rail	☐	
	Overhanging rails	☐	Evidence of felling	☐	Fallen trees	☐	

Comments

O) Adjacent property

Boundary type:	Fence	☐	Hedge	☐	Wall	☐		
Condition:	Good	☐	Moderate	☐	Poor	☐	Collapsed	☐
Property type:	Recreational	☐	Residential	☐	Farmland	☐	Other	☐
	Roadway	☐	Rail	☐	Commercial	☐		
	Derelict	☐	Woodland	☐	Common land	☐		
Access:	Possible	☐	Limited	☐	No access	☐		

Comments

Further topographical investigation required	Y	☐	N	☐
Further geotechnical investigation and assessment required (FGIR)	Y	☐	N	☐
Further monitoring required	Y	☐	N	☐

Inspection of Earth Structures – Chalk Cuttings:

Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section

A) Condition survey (one side of track only)

Recorded by | Date

At station Y ☐ N ☐ Station

From station | To station

LCS code / | Chainage

Line owner | Line direction | Line type

B) Photographs

None	☐	With traffic	☐
Up slope	☐	Against traffic	☐
Down slope	☐	Across track	☐

Inspection of Earth Structures – Chalk Cuttings:

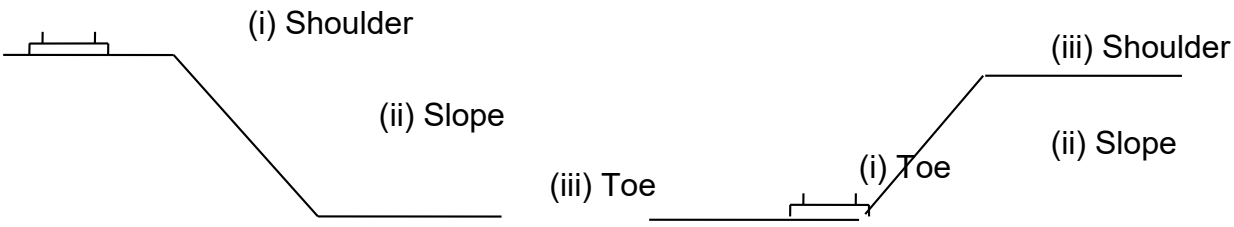
Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section (continued)

C) Earthworks structure type

Accessible Y ☐ N ☐ Rope Access ☐

Cutting ☐

Depot ☐ Other ☐



For slope definitions see clause 7.1.5 and the sketch in clause 7.1.20. of Attachment 7.1 of this standard.

SLOPE GEOMETRY - CONDITION SURVEY

D) Track condition

Depth of ballast (from top of sleeper to top of cess) ☐ m Not measurable ☐

Width of ballast (from outside of running rail) ☐ m Not measurable ☐

Pumping Y ☐ N ☐ Limited ☐ Moderate ☐ Extensive ☐

Cess present Y ☐ N ☐ Cess width ☐ m

(walkable area beyond the ballast)

Cess material: Ash ☐ Gravel ☐ Other type ☐

Cess: Dense ☐ Medium dense ☐ Loose ☐

Condition: Undulating ☐

Vegetation intrusion of cess ☐

Comments

Inspection of Earth Structures – Chalk Cuttings:
Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section (continued)

E) Lineside services condition

No services ☐

Old services

Location Section (i) ☐ (ii) ☐ (iii) ☐

Offset from running rail or breakpoint Section (i) ☐ m (ii) ☐ m (iii) ☐ m

Angular displacement None ☐ Leaning towards rail ☐ Leaning away from rail ☐ Angle ☐ °

Vertical displacement	None ☐	Slight ☐	Moderate ☐	Extensive ☐
Horizontal displacement	None ☐	Slight ☐	Moderate ☐	Extensive ☐
Undulating services	None ☐	Slight ☐	Moderate ☐	Extensive ☐

2nd generation services (new)

New services location Section (i) ☐ (ii) ☐ (iii) ☐

Offset from breakpoint Section (i) ☐ m (ii) ☐ m (iii) ☐ m

Angular displacement None ☐ Leaning towards rail ☐ Leaning away from rail ☐ Angle ☐ °

Vertical displacement	None ☐	Slight ☐	Moderate ☐	Extensive ☐
Horizontal displacement	None ☐	Slight ☐	Moderate ☐	Extensive ☐
Undulating services	None ☐	Slight ☐	Moderate ☐	Extensive ☐

Comments

F) Chalk Cutting Classification

Class A (Chalk)	☐	Class B (composite)	☐	Class C (superficial)	☐
Chalk Geology					
Seaford Chalk Fm	☐	Lewes Nodular Chalk Fm	☐	New Pit Chalk Fm	☐
Superficial Geology					
Clay with Flints	☐	Terrace Gravel	☐	Other	☐

Other

Presence of Exposed Chalk in Slope Face

Widespread ☐ Localised ☐ None ☐

G) Toe Debris

Extent of Toe Debris	None	☐	Limited	☐	Confined behind lineside services	☐
			Intruding on cess	☐	Intruding on track	☐
Composition of Toe Debris	Topsoil	☐	Vegetation	☐	Clay	☐
	Sand/gravel	☐	Flint cobbles	☐	Chalk	☐
Toe Debris Mitigation Measures	None	☐	Concrete slabs	☐	Anchored mesh	☐
	Other	☐				
Condition of Toe Debris Mitigation	Good	☐	Serviceable	☐	Marginal ☐	Poor	☐

Inspection of Earth Structures – Chalk Cuttings:

Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section (continued)

H) Slope geometry

Offset length (i) ☐ m

(Nearest running rail to slope breakpoint[start of Section (ii)])

Slope facing: North ☐ South ☐ East ☐ West ☐

North East ☐ North West ☐ South East ☐ South West ☐

Slope form: Regular ☐ Irregular ☐ Very irregular ☐

Number of Section (ii) slope sub divisions ☐

1	Length		m E		M		Angle°		E		M		Material	
2	Length		m E		M		Angle°		E		M		Material	
3	Length		m E		M		Angle°		E		M		Material	
4	Length		m E		M		Angle°		E		M		Material	
5	Length		m E		M		Angle°		E		M		Material	
6	Length		m E		M		Angle°		E		M		Material	
7	Length		m E		M		Angle°		E		M		Material	
8	Length		m E		M		Angle°		E		M		Material	
9	Length		m E		M		Angle°		E		M		Material	

Material Key:
W – Wall T – Toe Debris C – Intact Chalk S - Superficial

Offset length (iii) ☐ m Measured ☐ Estimated ☐
(Slope breakpoint to boundary [end of Section (iii)])

Slope diagram sketch

Comments

Inspection of Earth Structures – Chalk Cuttings:

Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section (continued)

I) Slope condition

No evidence of movement ☐

Movement indicators key:

1) Lineside services	2) Slip scars	3) Slope bulges	4) Terracing
5) Structure distortion	6) Dislocated trees	7) Toe bulges	8) Toe debris
9) Tension cracks	10) Dislocated fence	11) Cracked roads	12) Flow failure

Indicator number(s) ☐

Indicator location	Section	(i)	☐	(ii)	☐	(iii)	☐		
Offset from running rail	Section	(i)	Start	☐	m	Finish	☐	m	
Offset from breakpoint	Section	(ii)	Start	☐	m	Finish	☐	m	
Offset from breakpoint	Section	(iii)	Start	☐	m	Finish	☐	m	

Indicator number(s) ☐

Indicator location	Section	(i)	☐	(ii)	☐	(iii)	☐		
Offset from running rail	Section	(i)	Start	☐	m	Finish	☐	m	
Offset from breakpoint	Section	(ii)	Start	☐	m	Finish	☐	m	
Offset from breakpoint	Section	(iii)	Start	☐	m	Finish	☐	m	

Indicator number(s) ☐

Indicator location	Section	(i)	☐	(ii)	☐	(iii)	☐		
Offset from running rail	Section	(i)	Start	☐	m	Finish	☐	m	
Offset from breakpoint	Section	(ii)	Start	☐	m	Finish	☐	m	
Offset from breakpoint	Section	(iii)	Start	☐	m	Finish	☐	m	

Indicator number(s) ☐

Indicator location	Section	(i)	☐	(ii)	☐	(iii)	☐		
Offset from running rail	Section	(i)	Start	☐	m	Finish	☐	m	
Offset from breakpoint	Section	(ii)	Start	☐	m	Finish	☐	m	
Offset from breakpoint	Section	(iii)	Start	☐	m	Finish	☐	m	

Overall slope assessment

Movement type:	Creep	☐	Flow	☐	Subsidence	☐
	Translational	☐	Rotational	☐	Ravelling	☐
	Unknown	☐				
Depth of movement:	Shallow movement	☐	Unknown	☐	Deep movement	☐

Comments

Inspection of Earth Structures – Chalk Cuttings:
Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section (continued)

J) Retaining structures condition

No structure ☐

Structure type key:

1) Brick wall	2) Sheet piled wall
3) Mass concrete wall	4) Bored pile wall
5) RF concrete wall	6) Gabion
7) Precast concrete panels	8) Rubble wall
9) Slabs	10) Sleepers
11) Anchored mesh	12) Pinned mesh

Structure type number ☐

Remedial Y ☐ N ☐ Unknown ☐

Dimensions Height ☐ m Width ☐ m

Location Section (i) ☐ (ii) ☐ (iii) ☐

Condition: Good	☐	Serviceable	☐	Collapsed	☐
Cracked	☐	Bulging	☐	Overtopping	☐
Tilting towards rails	☐	Tilting away from rails	☐		

Structure type number ☐

Remedial Y ☐ N ☐ Unknown ☐

Dimensions Height ☐ m Width ☐ m

Location Section (i) ☐ (ii) ☐ (iii) ☐

Condition: Good	☐	Serviceable	☐	Collapsed	☐
Cracked	☐	Bulging	☐	Overtopping	☐
Tilting towards rails	☐	Tilting away from rails	☐		

Comments

Inspection of Earth Structures – Chalk Cuttings:

Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section (continued)

K) Earthworks drainage
No evidence ☐

Remedial Y ☐ N ☐ Unknown ☐

Drainage type key: 1) Crest 2) Slope 3) Toe
Material key: 1) Gravel 2) Rubble 3) Pipe 4) Catchpit 5) Ditch
Condition key: 1) Good 2) Serviceable 3) Cracked 4) Deformed 5) Collapsed 6) Overgrown
Extent of condition key: 1) Slight 2) Moderate 3) Extensive
Flow key: 1) Dry 2) Slight 3) Moderate 4) Significant

Drainage type number ☐
Material number ☐ Extent of condition number ☐
Condition number ☐ & ☐ Flow number ☐

Location Section (i) ☐ (ii) ☐ (iii) ☐
(All offsets are measured from the running rail or breakpoint parallel to the line of steepest slope i.e. Perpendicular to the track)

Offset from running rail	Section	(i)	Start	☐ m	Finish	☐	m
Offset from breakpoint	Section	(ii)	Start	☐ m	Finish	☐	m
Offset from breakpoint	Section	(iii)	Start	☐ m	Finish	☐	m

Drainage type number ☐
Material number ☐ Extent of condition number ☐
Condition number ☐ & ☐ Flow number ☐

Location Section (i) ☐ (ii) ☐ (iii) ☐
(All offsets are measured from the running rail or breakpoint parallel to the line of steepest slope i.e. Perpendicular to the track)

Offset from running rail	Section	(i)	Start	☐ m	Finish	☐	m
Offset from breakpoint	Section	(ii)	Start	☐ m	Finish	☐	m
Offset from breakpoint	Section	(iii)	Start	☐ m	Finish	☐	m

Comments

Inspection of Earth Structures – Chalk Cuttings:
Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section (continued)

L) Water
No evidence ☐
Feature type key:

1) Issues	☐	2) Stream	☐
4) Ponding	☐	3) Marshy	☐
5) Culvert	☐	6) Hydrophilic vegetation	☐
7) River	☐	8) High moisture content	☐
		9) Water flowing over crest	☐

Feature type number ☐

Location Section (i) ☐ (ii) ☐ (iii) ☐
(All offsets are measured from the running rail or breakpoint parallel to the line of steepest slope i.e. perpendicular to the track)

Offset from running rail	Section	(i)	Start ☐ m	Finish ☐ m
Offset from breakpoint	Section	(ii)	Start ☐ m	Finish ☐ m
Offset from breakpoint	Section	(iii)	Start ☐ m	Finish ☐ m

Flow: Dry ☐ Slight ☐ Moderate ☐ Extensive ☐

Feature type number ☐

Location Section (i) ☐ (ii) ☐ (iii) ☐
(All offsets are measured from the running rail or breakpoint parallel to the line of steepest slope i.e. Perpendicular to the track)

Offset from running rail	Section	(i)	Start ☐ m	Finish ☐ m
Offset from breakpoint	Section	(ii)	Start ☐ m	Finish ☐ m
Offset from breakpoint	Section	(iii)	Start ☐ m	Finish ☐ m

Flow: Dry ☐ Slight ☐ Moderate ☐ Extensive ☐

Comments

M) Wildlife
No evidence ☐
Density of burrows 1) Dense ☐ 2) Moderate ☐ 3) Isolated ☐
Location Section (i) ☐ (ii) ☐ (iii) ☐

Spoil Material Granular superficials ☐ Cohesive superficials ☐ Chalk ☐

Likely species Badger ☐ Fox ☐ Rabbit ☐ Other/unknown ☐

Comments

Inspection of Earth Structures – Chalk Cuttings:

Transect information at (LCS) chainage point (+/- 5m) - 100m half slope section (continued)

N) Vegetation

Understorey

Bare ground	None	☐	Isolated	☐	Moderate	☐	Extensive	☐
Grass/herbs	None	☐	Sparse	☐	Moderate	☐	Dense	☐
Ivy	None	☐	Sparse	☐	Moderate	☐	Dense	☐
Brambles	None	☐	Sparse	☐	Moderate	☐	Dense	☐
Shrubs	None	☐	Sparse	☐	Moderate	☐	Dense	☐

Evidence of clearance	Understorey	☐	Trees	☐	None	☐
Timing of clearance	Understorey		Current Year	☐	Historical	☐
	Trees		Within last 2 years	☐	Historical	☐
Extent of clearance			Pollarding	☐	Coppice	☐

Canopy

Trees cover	☐	None	☐	
Coppice	☐	None	☐	

Age:	Immature	☐	Mature	☐	standard	☐		
Type:	Deciduous	☐	Evergreen	☐				
Dimensions:	Mean height		m	Mean dia.		m		
Density:	Dense	☐	Moderate	☐	Sparse	☐		
Condition:	Vertical	☐	Lean toward rail	☐	Lean from rail	☐		
	Overhanging rails	☐	Evidence of felling	☐	Fallen trees	☐		

Presence of Dead or Dormant Tree Stumps on Slope Number of stumps

	Mean height		m	Mean dia.		m		
	On slope	☐	At breakpoint	☐				
	Secure	☐	Loose	☐	Unknown	☐		
	Evidence of soil erosion/burrowing around roots	☐						

Comments

O) Adjacent property

Boundary type:	Fence	☐	Hedge	☐	Wall	☐			
Condition:	Good	☐	Moderate	☐	Poor	☐	Collapsed	☐	
Property type:	Recreational	☐	Residential	☐	Farmland	☐	Other	☐	
	Roadway	☐	Rail	☐	Commercial	☐			
	Derelict	☐	Woodland	☐	Common land	☐			
Access:	Possible	☐	Limited	☐	No access	☐			

Topography – Falling...	Towards track	☐	Away from track	☐	Parallel to track	☐	Flat	☐
Surface	Hard	☐	Grassed	☐	Ploughed	☐		
	Other	☐	Specify					

Comments

Further topographical investigation required (FTIR)	Y ☐	N ☐
Further geotechnical investigation and assessment required (FGIR)	Y ☐	N ☐
Geotechnical Monitoring required	Y ☐	N ☐

11.4 Condition assessment and certification process