AS 7638:2021

Australian STANDARD®

Railway Earthworks

RISSB
RAIL INDUSTRY SAFETY AND STANDARDS BOARD

Infrastructure Standard

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This Australian Standard® AS 7638 Railway Earthworks was prepared by a Rail Industry Safety and Standards Board (RISSB) Development Group consisting of representatives from the following organisations:

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The Standard was approved by the Development Group and the Enter Standing Committee Standing Committee in Select SC approval date. On Select Board approval date the RISSB Board approved the Standard for release.

Choose the type of review

Development of the Standard was undertaken in accordance with RISSB's accredited process. As part of the approval process, the Standing Committee verified that proper process was followed in developing the Standard.

RISSB wishes to acknowledge the positive contribution of subject matter experts in the development of this Standard. Their efforts ranged from membership of the Development Group through to individuals providing comment on a draft of the Standard during the open review.

I commend this Standard to the Australasian rail industry as it represents industry good practice and has been developed through a rigorous process.

Deb Spring
Exec. Chair / CEO
Rail Industry Safety and Standards Board

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Railway Earthworks

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This Standard was prepared by the Rail Industry Safety and Standards Board (RISSB) Development Group AS 7638 Railway Earthworks. Membership of this Development Group consisted of representatives from the organisations listed on the inside cover of this document.

Objective

This Standard is to describe the requirements for the design, construction and maintenance of earthworks in connection with railway operations in Australia.

Compliance

There are four types of provisions contained within Australian Standards developed by RISSB:

1. Requirements.
2. Recommendations.
3. Permissions.
4. Constraints.

Requirements – it is mandatory to follow all requirements to claim full compliance with the Standard. Requirements are identified within the text by the term 'shall'.

Recommendations – do not mention or exclude other possibilities but do offer the one that is preferred. Recommendations are identified within the text by the term 'should'.

Recommendations recognise that there could be limitations to the universal application of the control, i.e. the identified control is not able to be applied or other controls are more appropriate or better.

Permissions – conveys consent by providing an allowable option. Permissions are identified within the text by the term 'may'.

Constraints – provided by an external source such as legislation. Constraints are identified within the text by the term 'must'.

For compliance purposes, where a recommended control is not applied as written in the standard it could be incumbent on the adopter of the standard to demonstrate their actual method of controlling the risk as part of their WHS or Rail Safety National Law obligations. Similarly, it could also be incumbent on an adopter of the standard to demonstrate their method of controlling the risk to contracting entities, or interfacing organisations where the risk may be shared.

RISSB Standards address known hazards / hazardous events within the railway industry. Where applicable to this Standard, these are listed in Appendix A: Australian Rail Risk Model (ARRM).

Contents

Appendix Contents

1 Scope and general

1.1 Scope

1.1.1 This Standard provides a whole-of-life approach to rail structures, and covers the general management requirements, material composition, manufacturing, construction, maintenance, decommissioning and disposal of rail structures used in Australian rail operations. This includes:

(a) cuttings and excavations;

(b) embankments;

(c) sub-ballast / capping layer.

1.1.2 This Standard covers railways classified in AS 7630, except for high speed passenger (HSP) lines.

1.1.3 This Standard does not cover ballast, rails, sleepers, or rail jewellery.

1.1.4 This Standard is not specifically intended to cover urban on-street tramway or light rail systems, cane railways, or heritage railways operating on private reservation, however items from this Standard may be applied to such systems as deemed appropriate by the relevant railway infrastructure manager (RIM).

1.1.5 This Standard is not intended for use in the design and operation of HSP lines, monorail networks, or miniature or amusement park railways.

1.1.6 This Standard is also not intended for use in the design of the following:

(a) Works intended to be of a temporary or emergency nature e.g. derailment site bypass.

(b) Piled foundations.

(c) Flood levee banks.

1.2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document:

(a) AS 1141 Methods for sampling and testing aggregates

(b) AS 1170 Structural design actions, Part 4: Earthquake actions in Australia

(c) AS 1289 Methods of testing soils for engineering purposes

(d) AS 1726 Geotechnical site investigations

(e) AS 2187 Explosives – Storage, transport and use

(f) AS 3706 Geotextiles - Methods of test Determination of durability series

(g) AS 4799 Installation of underground utility services and pipelines within railway boundaries

(h) AS 5100 Bridge design series

(i) AS 7630 Railway infrastructure – Track classification

(j) AS 7664 Railway signalling cable routes, cable pits, and foundations

(k) AS ISO 11453 Statistical interpretation of data – Tests and confidence intervals relating to proportions

NOTE: Documents for informative purposes are listed in a Bibliography.

1.3 Terms and definitions

For the purposes of this document, the terms and definitions given in RISSB Glossary: https://www.rissb.com.au/products/glossary/ and the following apply.

1.3.1
batter

constructed slope (cut or fill) commonly of uniform gradient usually expressed as a ratio of horizontal to vertical

1.3.2
borrow pit

excavation where material can be removed and obtained for use in earthworks/construction

1.3.3
capping

layer of compacted, specified coarse grained material that is intended to seal the earthworks

1.3.4
clearing

removal and disposal of all trees, logs, timber, scrub, vegetation, minor structures, refuse and other material unsuitable for incorporation in the work

1.3.5
collapsible soil

unsaturated soil that is stable in the natural state that suffers a sudden decrease of volume after wetting, loading or a combination of both

1.3.6
compaction

process whereby the dry density of soil is increased by mechanical or other means

1.3.7
contaminated materials

material containing a chemical substance(s) at above background levels and posing, or potentially posing, a risk of harm to human health, the environment, water supply or agriculture, based on applicable legislation and standards

1.3.8
cutting

cut

earth and/or rock excavation that is made below an existing surface

1.3.9
defined event

events such as earth movement, rainstorm, earthquake, blasting or inundation, as defined by the RIM

1.3.10
dispersive soil
soil that has the ability to pass rapidly into suspension in the presence of water

1.3.11
earth
soil

all materials such as clay, sand, gravel, weathered or loose rock

1.3.12
embankments
fill

earth and / or rockfill structure constructed above an existing and/or excavated surface

1.3.13
expansive soil
soil that exhibits a great amount of volume change as a direct result of a change in soil moisture

1.3.14
drainage blanket
discrete layer of free-draining material to promote drainage at areas of seepage

1.3.15
formation
earthworks structure including all foundation, structural treatments and capping layer, on which ballast is laid

1.3.16
formation level
finished level at the top of capping at the centre of the formation preparatory to laying ballast

1.3.17
foundation treatment
special layer or treated zone within the foundation for the purpose of strengthening, stiffening, managing settlement, aid construction, drainage, etc.

1.3.18
free-draining material
hard, strong and durable particles containing a low percentage of fines that provides a high level of permeability

1.3.19
geosynthetics
range of polymeric products comprising eight main categories: geotextiles, geogrids, geonets, geomembranes, geosynthetic clay liners, geofoam, geocells and geocomposites

1.3.20
graded filter
layer of unconsolidated material used to prevent fine soil particles washing from the body of the structure, embankment, etc.

1.3.21
grubbing
removal of the base of stumps, roots, perishable material, underground parts of redundant structures, and other minor obstructions

1.3.22
poor ground
soil and/or rock which does not provide adequate foundation strength or support for the placement and compaction of fills or support for railway ballast and track

1.3.23
relative compaction
ratio of the as-compacted field dry density to a laboratory maximum dry density, expressed as a percentage

1.3.24
rip rap
cobble sized rock placed on the surface for the protection of the underlying material to prevent erosion, scour or sloughing of a structure or surface such as on an embankment or cut slope

1.3.25
rock
mineral matter of variable composition, consolidated or unconsolidated, assembled in masses in nature. Naturally occurring solid mass or aggregate of minerals

1.3.26
rock armour
revetment made of typically large rocks used to provide erosion protection against tidal, flood or wave action

1.3.27
root jacking
process of roots penetrating joints and defects in the rock and movement of rock masses due to pressure generated by growing roots

1.3.28
select fill
material for use adjacent to structures or in other distinct applications that require specific properties defined for that purpose

1.3.29
special location
location prone to or with a history of earthworks instability

1.3.30
sub-ballast layer
permeable layer which is more appropriate than the impermeable capping under certain circumstances where the foundation consists of free draining materials such as rockfill or sand

1.3.31
sub-ballast material
material generally consisting of well-graded, well-mixed natural or artificially blended gravel/soil

1.3.32
subgrade
existing ground below the sub-ballast or capping layer upon which the track formation is constructed that provides a stable foundation for the formation and ballast layers and comprises of imported soil in embankments and in situ material or imported material in cuttings

1.3.33
ULX
under line crossing

The passage of pipes, cables, etc. below a railway line. Also known as UTX (under track crossing)

1.3.34
Unsuitable material
material considered unsuitable for earthworks due to its adverse characteristics

1.4 Abbreviations

1.4.1
H
Height

1.4.2
V
Vertical

1.4.3
MPa
Megapascal

1.4.4
t
tonne

1.4.5
kPa
kilopascal

1.4.6
RIM
rail infrastructure manager

2 Design and rating

2.1 General

2.1.1 Design and rating of earthworks should include geotechnical investigation of, and specialist geotechnical advice on, the site and materials.

2.1.2 All earthworks subject to train loading should be designed for railway loading, as detailed in AS 5100 and / or other relevant standards.

2.1.3 Example design drawings are provided as below:

(a) Appendix G – Earthworks cross section.
(b) Appendix H – Earthworks at cut/fill interface.
(c) Appendix I – Widening of existing embankment.
(d) Appendix J – Embankments.
(e) Appendix K – Cuttings.
(f) Appendix L – Centre Drains.
(g) Appendix M – Special width requirements.

2.2 Design

2.2.1 The following factors should be assessed, as appropriate to individual sites, when designing the rail earthworks structure:

(a) Proposed current and likely future loading patterns (refer AS 7630), such as traffic type, axle load, speed, track geometry.

(b) Topography.

(c) Local geology, including subsurface bedrock topography, pre-existing failure planes and weathering patterns.

(d) Soil type, consistency and lithological characteristics.

(e) Areas of engineered or uncontrolled filling.

(f) Geotechnical hazards.

(g) Problematic soils requiring special consideration, including expansive soils, dispersive soils, collapsible soils, soluble soils, soft-compressible soils and potential/actual acid sulphate soils, and other soil types.

(h) Poor ground.

(i) Groundwater and surface water regime.

(j) Design gradients and the proposed extent of cutting and filling.

(k) Existing and resultant drainage patterns.

(l) Erosion and siltation.

(m) Sinkholes and washaways.

(n) In situ and design moisture contents.

(o) Locally available material types.

(p) Location and type of structures (bridges, culverts, etc.) and slope surcharges, including the effects of local changes in soil stiffness.

(q) Existing vegetation, including that requiring protection (environmental) or specialist disposal during earthworks.

(r) Pre-existing formation construction and performance, including available records.

(s) Proximity to and potential impact on adjoining properties and infrastructure.

(t) Rehabilitation of worksites, haul routes, borrow pits, etc.

(u) The availability and suitability of the use of geosynthetics.

(v) The impacts of vibration and the mitigation measures.

(w) Outside influences, such as dewatering and blasting.

(x) Calculation of quantities.

(y) Bulking and compaction factors.

(z) Sources of water for compaction.

(aa) Existing underground structures and services.

(bb) Cultural heritage.

(cc) Soil and rock settlement including creep conditions.

(dd) The short-term and long-term stability of the structure.

(ee) Benching and subsurface drainage details at cut-fill interfaces.

(ff) Historical records of the site.

(gg) Track stiffness, modulus and uniformity thereof.

2.2.2 Design inputs should include:

(a) design requirements for flood immunity and overtopping;

(b) data regarding relevant historical events;

(c) earthquake loading factors as per AS 1170.4;

(d) potential for liquefaction or other undesirable consequences of earthquakes or other vibration events.

2.3 Rating

This Standard is prescribed for railway earthworks in the track classifications detailed in AS 7630.

2.4 Investigation and planning

2.4.1 General

Before work activity is undertaken which may affect earthworks, an assessment and / or investigation should be carried out to the RIM requirements.

2.4.2 Design Investigation

2.4.2.1 Approvals from local statutory bodies and consent from affected land owners should be obtained prior to commencing the investigative works.

2.4.2.2 Geotechnical investigation should be undertaken to provide input into the design, construction and maintenance of the proposed works, as determined by the RIM.

2.4.2.3 Geotechnical investigations should be conducted in accordance with AS 1726.

2.4.2.4 Where the surface has been disturbed during the investigation process, these areas should be backfilled, compacted and otherwise reinstated where appropriate, such that they do not reduce the performance of the existing or proposed railway, or pose a risk to public safety.

2.4.2.5 In addition to the geotechnical investigation, a review of the site history (which could include previous geotechnical failures or mining activities) and an assessment of potential for contaminated materials, including acid sulphate soils, should be undertaken.

2.4.2.6 The results of any contamination investigations/studies should be compared with the limits for contaminants provided by legislation then managed in accordance with legislation and RIM policies.

2.5 Drainage

The design of the formation shall assess the requirements for drainage. This may include the incorporation of surface and subsurface drainage systems appropriate to their relative position on embankments, cuttings, etc.

2.6 Sub-ballast or capping layer

2.6.1 A well compacted, sub-ballast or capping layer with material strength suitable for track superstructure and train load should be placed immediately beneath the track ballast layer, with sufficient cross-fall to drain pluvial flow clear of the formation or into the track drainage system.

2.6.2 The form and construction of the sub-ballast or capping layer should be as determined and specified by the RIM.

2.6.3 Where there are multiple tracks (three or more), consideration should be given to providing drainage systems which have the sub-ballast or capping layer cross-fall oriented, such that each track is drained separately.

2.7 Embankments

2.7.1 General

2.7.1.1 The composition and grading of embankment materials shall comply with the requirements set by the RIM.

2.7.1.2 Embankment fill shall consist of engineered material, with specified zone thickness and properties. This may include:

(a) adopting suitable methods for grading of layers to avoid particle mixing of adjacent layers, in particular in the upper layers of the formation to avoid pumping of fines under traffic;

(b) zoning of engineered fill materials to minimize risk and shrink swell effects;

(c) confinement/encapsulation of contaminated materials, potential acid sulphate soil and rock, etc.;

(d) zoning of engineered fills to optimize use/reuse of site won materials.

2.7.2 Drainage blanket

2.7.2.1 Where specified, or directed by the RIM during construction, a layer of free-draining material shall be provided, such as in embankment fill or in areas where the adjacent geology or the terrain is likely to produce seepage.

2.7.2.2 The RIM should determine the typical composition of any drainage blanket. The composition may include:

(a) a suitably thick layer of free-draining material, according to the local area conditions;

(b) a geotextile layer encapsulating the free-draining material to reduce the ingress of fines;

(c) scour protection at the outfall.

2.7.2.3 The position of any drainage blanket should consider potential interaction with surface drainage systems.

2.7.3 Embankment protection

2.7.3.1 Scour protection should be provided to all embankments, with the type and extent of the embankment protection noted on the design drawings.

2.7.3.2 Embankment scour protection should be determined by the RIM, but in general should be provided in the following ways:

(a) Rock armour protection placed against the embankment face.

(b) Rip rap (rock facing), which should be separated by a graded filter (see Section 3.5.6) or geosynthetic.

(c) Topsoiling, grassing and seeding.

(d) Collecting the runoff and directing the flow to lined channels and drop down structures (e.g. trapezoidal concrete or rock lined channel) down the batter.

(e) Directing the runoff to drainage pits and piping the flow down the batter in buried pipes.

(f) Providing scour protection in the form of endwalls, rip rap and/or energy dissipaters at the outlets of steep pipes and open drains.

2.7.3.3 Scour protection of embankments from water courses should be provided, including wave action on causeways.

2.7.4 Physical separation of dissimilar materials

Filters (comprising material of selected particle size distribution and/or geosynthetics) may be used in the design to avoid the mixing of materials after placement. For example:

(a) softer materials being forced into voids of granular material;

(b) erosion and migration of fine particles into adjacent granular material.

2.8 Cuttings

The design of cuttings should specify the following:

(a) Batter slope dimensions including the location and width of benches.

(b) Preparation of batter surfaces and finishing treatments (e.g. shotcrete, gabion baskets).

(c) Details of soil nailing/rock bolting required.

(d) Treatment of cutting floors, drainage and floor stabilisation.

(e) The placement of drainage along and down the sloping face of cuttings, top drain / catch drain, as well as access to drains or drainage for maintenance.

(f) Buffer zone at the toe of cuttings to accommodate fallen soil or rock.

(g) The inclusion of benching for cuttings e.g. for erosion control, access to maintain the cut face.

(h) Collection, control and erosion protection for discharge from cess drains at the ends of cuttings.

2.9 Slope stability

2.9.1 General

2.9.1.1 Cuttings and embankments shall provide a stable, safe foundation to the track and associated structures.

2.9.1.2 The design stability of batters should take into account drainage, material properties, height, foundation conditions, static and dynamic loading, potential seepage, earthquake loading, pre-existing failure planes, long-term settlement, and maintenance access.

2.9.2 Slope or fill batters

2.9.2.1 Batters should be no steeper than the following guidelines unless otherwise determined by the RIM:

(a) Sand at 2.5 H : 1.0 V

(b) Clay or loose gravel at 2.0 H : 1.0 V

(c) Sandy clay, boulder clay, compacted gravelly soil, or scree at 1.75 H : 1.0 V

(d) Rock fill at 1.5 H : 1.0 V

2.9.2.2 Batter design should take into consideration maintenance and access requirements.

2.9.2.3 Slopes for rock cuttings should be constructed as determined by geotechnical assessment.

2.9.3 Other slopes

An assessment of the impact of the works on existing slopes, including those outside the rail corridor, should be undertaken as part of the design and investigation phase (e.g. the impact of additional ground surcharging and dewatering).

2.10 Geosynthetics

Appropriate geosynthetics should be selected on the basis of their anticipated service life, considering:

(a) local conditions;

(b) design requirements;

(c) the required puncture and tear strength;

(d) interlocking characteristics;

(e) durability;

(f) fire resistance;

(g) aggressiveness of the local soils and water.

2.11 Poor ground

2.11.1 General

2.11.1.1 The following sections describe the types and suggested treatments to be considered during design for poor ground.

2.11.1.2 Compressible soils within the foundation of embankments, at the base of cuttings or other railway structures shall be managed as per a geotechnical assessment and within the settlement limits as determined by the RIM, such as by replacement with suitable fill.

2.11.1.3 The recommended moisture content of expansive soils should take into account the estimated long-term equilibrium moisture content, to ensure the long-term durability and serviceability of the earthworks.

2.11.1.4 The design should specify the foundation treatment techniques to be adopted where expansive soils are present. Suggested approaches to treatment and management are provided in Appendix N.

2.11.2 Existing filled ground

2.11.2.1 Where fill materials are present and no records exist of its construction, it shall be assumed to be uncontrolled fill.

2.11.2.2 Where areas of existing uncontrolled fill are located within the formation, these shall be accounted for in design.

2.12 UTX/ULX and utilities

2.12.1 The ground conditions at proposed ULX locations should be reviewed by the RIM, and information provided to inform trenching or boring operations.

2.12.2 Where it is necessary to construct a ULX across an existing railway corridor, construction methods shall be prepared and approved by the RIM prior to commencement of the works.

2.12.3 The construction of ULXs and UTXs shall comply with the requirements of AS 7664. AS 4799 and other relevant Australian Standards.

2.13 Rail reserve width

2.13.1 New lines should be constructed on a corridor wide enough to accommodate all permanent earthworks.

2.13.2 The width of the rail corridor should take account of the associated earthworks drainage system, communications cables and other services, and allow access for maintenance purposes.

2.14 Discrete locations

2.14.1 General

Retaining walls and ground anchors shall comply with the relevant sections in AS 5100.3

2.14.2 Acid sulphate soils and rock

2.14.2.1 The RIM shall develop plans to manage potential adverse environmental impacts where there is a reasonable likelihood of affecting these materials.

2.14.2.2 The RIM should arrange for the testing of soils and rock for potential and/or actual acid sulphate soils and rock, in areas where there is a reasonable likelihood of affecting these materials.

2.14.2.3 The relevant environmental authority should be consulted prior to the excavation, handling or use of potential and actual acid sulphate soils, where appropriate.

3 Construction and maintenance

3.1 Site separation

3.1.1 General

Earthworks construction management should consider as a minimum:

(a) work methods and plant appropriate to the physical limitations of the site;

(b) specific measures to avoid and/or minimize undermining of existing track or structures where earthworks are planned in close proximity to these locations;

(c) environmental impacts during and after the course of the project;

(d) management of live rail operations;

(e) management of underground services;

(f) management of emergency situations;

(g) management of sediment generated by the works;

(h) locating haul routes to avoid areas of soft or compressible soil, or using ground improvement techniques to improve soil properties in such areas during construction;

(i) locating haul routes away from the proposed track formation, unless mitigation measures are in place to make good the prepared formation layers prior to the placement of the track ballast layer;

(j) management of dewatering operations;

(k) management of temporary drainage and site runoff;

(l) the potential for nuisance to the public and local residents;

(m) the potential effects on adjacent infrastructure, such as roads and drains;

(n) the potential effects on other services, such as emergency services.

3.1.2 Site clearing and grubbing

3.1.2.1 Prior to clearing and grubbing relevant permits required by Federal, State and Local legislation must be obtained.

3.1.2.2 The area to be occupied by the completed works, including ancillary earthworks for drains and diversion levees, plus a suitable clearance from tops of cuttings and toes of embankments, should be cleared and grubbed.

3.1.2.3 Voids left in close proximity to or within the formation boundary after grubbing should be filled with suitable material and compacted in layers.

3.1.2.4 Timber and combustible material should be disposed of as determined by the RIM and in accordance with any relevant regulations.

3.1.3 Stripping of topsoil

3.1.3.1 Topsoil covering the area to be occupied by the finished earthworks structure should be removed.

3.1.3.2 Topsoil suitable for revegetation should be placed in a stockpile clear of the work to enable its re-use in landscaping and revegetation.

3.1.3.3 The area where topsoil has been removed should be inspected by the RIM prior to continuation of earthworks construction.

3.1.3.4 The requirement for further removal of topsoil and replacement with suitable material, treatment with additives, etc. should be determined by the RIM.

3.2 Materials

3.2.1 General

3.2.1.1 All materials intended for use in the construction of railway earthworks should be clearly specified and meet the requirements of relevant material Standards and RIM specifications.

3.2.1.2 All materials shall be transported in a manner which does not affect the physical properties of the material.

3.2.2 Borrow materials

3.2.2.1 All permits required by Federal, State and Local legislation must be obtained before commencing excavation at a borrow pit site, with the conditions of the permit followed at all times.

3.2.2.2 Where the borrow pit is located within the rail corridor, the borrowing activities should not be detrimental to the stability or performance of the earthworks, adjacent structures or drainage.

3.2.3 Unsuitable materials and spoil

3.2.3.1 Unsuitable materials can be defined as either:

(a) inherently unsuitable – unsuitable due to their composition;

(b) unsuitable by virtue of their position; or

(c) unsuitably wet or unsuitably dry.

3.2.3.2 Unsuitable earthworks construction materials may include the following:

(a) Topsoils, organic soils, peats, logs, etc.

(b) Materials susceptible to piping, such as fine clean sand, windblown sand and non-cohesive silt.

(c) Organic silt and clay of low strength.

(d) Expansive or swelling clays.

(e) Dispersive soils.

(f) Dissolvable soils and rock containing substances such as gypsum and sodium chloride.

(g) Contaminated materials or fill with metals, plastic, hydrocarbons, etc.

(h) Collapsible materials.

(i) Chemically aggressive soils.

(j) Erodible soils.

3.2.3.3 Unsuitable materials should not be used to construct the sub-grade layers or otherwise be present in the formation, except for those made suitable conforming to Clause 3.2.4 below.

3.2.3.4 Materials included in 3.2.3.2(d), (e) and (f) above may be used if treated by additives, or by other suitable controls as approved by the RIM.

3.2.3.5 Unsuitable earthworks construction materials should be removed as spoil or removed from site in accordance with relevant statutory requirements.

3.2.3.6 Contaminated or potentially contaminated materials being transported beyond the rail corridor should be tested and managed in accordance with relevant legislation.

3.2.4 Suitable materials

3.2.4.1 Suitable materials comprise of material that meets the design and construction requirements of the formation, such as general fill, structural fill, select fill, capping or sub-ballast material, free-draining material, rock and rock fill, and are generally free from unsuitable materials.

3.2.4.2 The material properties of suitable materials for the layers shown in Appendix B should be defined by the RIM during the design and investigation phase (based upon the general requirements and purpose detailed in this standard).

3.2.4.3 The properties of some inferior materials may be improved by artificially blending a selection of materials to provide suitable grading and structural properties, or by chemical stabilisation, subject to appropriate geotechnical advice and laboratory testing.

3.2.5 Sampling and testing

3.2.5.1 Materials proposed for use in the earthworks design should be subject to testing, and the results used to determine the suitability of the material.

3.2.5.2 Samples of fill material for laboratory testing should be taken and handled as directed by the RIM.

3.2.5.3 Where fill material is tested, this should be in accordance with the requirements of this Standard, AS 1289, AS 1141 and other relevant standards.

3.2.5.4 Geosynthetics should be tested in accordance with AS 3706.2, AS 3706.4, AS 3706.5, AS 3706.7, AS 3706.9 and other relevant standards.

3.2.6 Water for compaction

3.2.6.1 The suitability of non-potable water to increase the moisture content in fill should be evaluated by field and laboratory tests.

3.2.6.2 Saline water and mineral salts should not be used where they can have an adverse effect. This may include:

(a) in areas where vegetation could require to be established;

(b) in fill, where steel elements or steel reinforced concrete are to be buried.

3.2.7 Stockpiles

3.2.7.1 Stockpiles shall be maintained in a safe condition.

3.2.7.2 Stockpiles should be maintained in a neat, well-shaped state, capable of shedding water.

3.2.7.3 Different materials should be stockpiled separately to prevent cross-contamination.

3.2.7.4 Consideration should be given to the location of stockpiles, such that they do not overload the edge of embankments or cuttings, interfere with signal sighting, or present undue risk to nearby water bodies.

3.3 Excavation

3.3.1 General

3.3.1.1 The excavated faces should be neatly trimmed to a regular and uniform shape and the top edges of the cuttings neatly rounded.

3.3.1.2 The excavated face in cuttings should not have significant rills or undulations in the general plane of the batter.

3.3.1.3 The excavated cutting face and floor should be inspected and tested as necessary by the RIM prior to foundation treatment or the placement of formation materials.

3.3.1.4 Any filling on the floor of the cutting should be consistent with the construction of subgrades in embankments.

3.3.2 Excavation stability

3.3.2.1 The safety of excavated work faces shall be determined by the RIM, subject to the occupational health and safety limitations.

3.3.2.2 Consideration should be given to carrying out excavation in a timely manner, so as to prevent ponding, erosion, undercutting or slips including, where necessary, the installation of stabilisation measures and temporary drainage.

3.3.2.3 Where there is a possibility of seepage any dewatering requirement shall be determined by the RIM.

3.3.2.4 Bench drains should be constructed progressively as each batter face is complete.

3.3.2.5 Overhanging and loose or unstable materials with the potential to slip should be cut back, removed or stabilized.

3.3.2.6 Loose rock particles which cannot be completely removed from the slope face or batter shall be prevented from falling on to the railway. This may be achieved using netting, shotcreting, catch fences, or rockfall catch zones.

3.3.2.7 Loading on excavated slopes and, in particular the sides of trenches and slopes supported by retaining walls, should not exceed design loads, unless a risk assessment allows for additional loading.

3.3.3 Use of Explosives

3.3.3.1 Licences from the appropriate authorities shall be obtained prior to the commencement of any excavation work involving the use of explosive substances.

3.3.3.2 Blasting activities must comply with all government legislation regarding the planning, documentation, transport, storage, handling and use of explosives.

3.3.3.3 Blasting activities shall comply with AS 2187 and all other relevant standards and codes for the use of explosives in construction.

3.3.3.4 The RIM shall be responsible for the establishment of third party agreements, to be prepared prior to the commencement of any blasting or related activities.

3.3.3.5 Detailed records should be kept of all excavation work involving the use of explosive substances.

3.3.3.6 The RIM shall assess the impact of explosives on, for example, ground vibrations, flyrock, track disturbance and air blasts, on rail assets and operations, and on external receptors.

3.3.3.7 Detailed inspections / dilapidation surveys should be carried out on railway infrastructure, including track geometry and adjacent third party assets prior to and following the completion of excavation by use of explosives.

3.3.4 Excavation near existing structures and track infrastructure

3.3.4.1 Excavation below the base or the footing of any structure (including signals, overhead masts, retaining walls or station platform walls) should not be undertaken until an appropriate assessment of the effects of the excavation on structure stability has been undertaken by the RIM, including the proposed construction method and need for temporary supports.

3.3.4.2 Alternatively, a zone of influence should be determined by the RIM, to determine excavation profiles adjacent to structures.

3.3.4.3 To control the risk of embankment or cutting slope destabilisation, excavation should not be carried out at the toe, crest or at any point on the sloping surface, without prior approval from the RIM.

3.4 Ground preparation

3.4.1 Where a new embankment is to be constructed or where an existing embankment is to be widened, the RIM should determine the requirements for the progressive cutting-in of horizontal terraces (see Appendix C).

3.4.2 The minimum slope for which benching or keying-in is required should be specified by the RIM, considering the height and width of the embankment, location, existing ground conditions, and the consequences of ground movement.

3.4.3 The area of the base of the embankment or cutting should be scarified to a depth determined by the RIM parallel to the embankment axis, followed by the placement of embankment fill.

3.4.4 When poor ground is unexpectedly encountered, advice should be sought from the RIM on the most appropriate remedial solution.

3.4.5 Floors of cuttings should be suitably treated to prevent the pooling of water under the track.

3.5 Material placement and compaction

3.5.1 General

3.5.1.1 The material should be prepared and compacted as specified in the following sections.

3.5.1.2 Compaction requirements for each material type should be defined by the RIM.

3.5.1.3 Compaction of the exposed face of the fill on batters should be undertaken as a separate exercise, or alternatively overfilled and cut back.

3.5.1.4 Trimmed and compacted batter faces should have a roughed surface to reduce pluvial flow run-off velocity and aid revegetation, if required.

3.5.1.5 Where a compacted slope or surface has deteriorated, its condition should be rectified prior to placement of further material.

3.5.2 Compaction methods / plant

3.5.2.1 Compaction plant shall be capable of compacting the fill materials to specification, including at edges and junctions with natural ground.

3.5.2.2 Consideration should be given to adopting alternatives to vibratory compaction methods where earthworks are being undertaken in close proximity to vulnerable structures, services or sensitive receptors.

3.5.2.3 Consideration should be given to appropriate compaction methods where high moisture contents are present in the existing sub-grade and in areas with shallow groundwater.

3.5.3 Sub-ballast / capping layer

3.5.3.1 A sub-ballast / capping layer should be constructed and compacted as determined by the RIM.

3.5.3.2 Immediately prior to placement of the sub-ballast / capping layer, any excess or loose fill shall be trimmed to the final smooth profile and compacted to form a sound base for the sub-ballast / capping material.

3.5.3.3 The material shall be spread across the full width of the sub-ballast / capping in uniform horizontal layers, using a method which will not rut or disturb the compacted material.

3.5.3.4 Following compaction of the sub-ballast / capping layer, the top of the final layer should be graded and trimmed, with material added as necessary to produce an even sealing layer without ruts or sags.

3.5.3.5 Care shall be taken not to damage the sub-ballast / capping layer during the construction phase.

3.5.4 Earthfill embankments

3.5.4.1 Earthen embankments should be constructed in full width horizontal layers not exceeding a compacted depth of 200 mm, unless otherwise determined by the RIM.

3.5.4.2 Larger particles within earthfill material should be evenly distributed to minimize the formation of voids and compacted to produce dense homogenous layers throughout the embankment structure (see clause 3.5.4.4 below).

3.5.4.3 Prompt compaction of each layer of placed material should be performed to ensure that the moisture content remains conforming and uniform.

3.5.4.4 Compaction should be completed over the full area and depth before the next layer is commenced.

3.5.4.5 The maximum particle size should be less than two-thirds of the compacted layer thickness.

3.5.4.6 Construction of embankment structures should be carried out in such a manner as to ensure adequate drainage of the works, to minimize scour and erosion.

3.5.5 Rockfill embankments

3.5.5.1 A rockfill embankment is defined as being composed of material for which standard field and laboratory soils testing methods are no longer applicable due to a high proportion of rock fragments (particles retained on a 19 mm square mesh screen).

3.5.5.2 As a guide, rockfill material should contain a minimum of 30 % rock fragments and a maximum 15 % silt and clay fraction.

3.5.5.3 Special rock equipment and procedures should be developed for the placement, testing and compaction of rockfill embankments, including:

(a) large-scale test fills should be performed to define site-specific construction method, compaction effort and moisture conditioning requirements;

(b) the use of large-scale rock dump techniques is not encouraged due to the tendency for material segregation and the lack of compaction and placement control;

(c) rock particle size distribution may be assessed using visual rock gradation estimates. However, this should be backed up with large-scale gradation tests for structural embankment applications;

(d) oversized rocks greater than the loose lift thickness should be raked or dozed outside the limits of the compacted embankment.

3.5.5.4 The RIM shall determine the maximum loose layer thickness for any single lift applicable to the range of compaction equipment available

3.5.5.5 The RIM shall determine a series of tests required to define the minimum acceptable rock quality (strength, durability, etc.).

3.5.5.6 Weak rock material that breaks down under compaction effort should be classified as earthfill material.

3.5.5.7 The maximum particle size should be less than two-thirds of the compacted layer thickness, with some allowance for larger rocks that do not protrude above the top of each lift.

3.5.5.8 Consideration should be given to the inclusion of an upstream impervious facing to direct surface flows along and away from the embankment, where required.

3.5.6 Erosion control

3.5.6.1 Where required for earthen embankments, rock facing (rip rap) should be built up in layers on the face of each layer of filling.

3.5.6.2 Rock facing should be placed to maximize mechanical interlocking (e.g. by orienting particles such that their least dimension is in the vertical plane).

3.5.6.3 The rock facing should be separated from the earthfill embankment with a graded filter or geosynthetic.

3.5.6.4 Where earthen embankment material could be subject to wave action or frequent inundation may occur, a geosynthetic should be placed in relation to the rock facing so as to prevent egress of fines.

3.5.6.5 The outer rock layer should be carefully placed to prevent rocks from being subsequently dislodged and falling down the batter slope.

3.5.6.6 Embankment scour protection should be determined by the RIM, but in general should be provided in the following ways:

(a) Rock armour, protection placed against the embankment face.

(b) Rip rap (rock facing), separated from the embankment fill by a graded filter or geosynthetic.

(c) Topsoiling, grassing and seeding.

(d) Concrete slabs.

(e) Asphalt paving.

(f) Grout filled mats.

3.5.6.7 Alternatively, or in addition, diversion of water from slopes by means of channel diversion, blocking banks, etc. may be adopted.

3.5.6.8 Erosion control of water courses is covered in AS 7637.

3.5.7 Drainage blanket

3.5.7.1 Joins in geosynthetics shall be seam welded or overlapped in accordance with manufacturer's instructions.

3.5.7.2 The free-draining material shall be placed and spread in such a way as to preserve material properties and avoid contamination with foreign materials.

3.5.7.3 The free-draining material shall be spread in uniform layers to give the specified thickness, and carefully spread to avoid damage to the fabric.

3.5.7.4 The properties of free-draining materials should be specified by the RIM.

3.5.7.5 Typically the free-draining material will comprise hard, strong (minimum point load strength index $I_{s(50)}$ of 1 MPa) and durable particles (Los Angeles value [Grading A] no more than 30 %) containing less than approximately 5 % fines.

3.5.8 Field moisture control (earthfill)

3.5.8.1 The moisture content should be adjusted within the range specified by the RIM, to facilitate the required compaction.

3.5.8.2 The moisture content of fill should be maintained within the range specified by the RIM (e.g. to be within 2 % of optimum moisture content) throughout the compaction process.

3.5.8.3 When fill moisture content falls below the specified range minimum, water should be added uniformly, and thoroughly mixed with the material until a homogeneous mixture is obtained.

3.5.8.4 When fill moisture content exceeds the specified maximum range, compaction should not be undertaken until the moisture content has been reduced to be within the specified range. This process may be assisted by one or a combination of the following:

(a) Scarifying and aeration.

(b) Use of hydrated or quick lime (as approved by the RIM).

(c) Removal to stockpile for drying out and later use.

3.5.8.5 The bond between material layers shall be ensured, if necessary by wetting or scarifying.

3.5.9 Compaction activity near existing structures

3.5.9.1 Non-vibratory compaction using hand-held equipment should be used where earthworks are undertaken within 5 m of existing structures, or as listed below (H = overall height of structure):

(a) at bridge abutment and wingwall structures, for the full structure height for a distance of 2/3H from the wall;

(b) at box culverts, culvert wing walls and retaining walls, for full structure height for a distance equal to 2/3H from wall;

(c) at pipe culverts, for a distance equivalent to the pipe diameter from the sides and above the top of the pipe.

3.5.9.2 The RIM shall determine the method of compaction by evaluating, for example:

(a) depth of fill;

(b) type of fill and in situ materials;

(c) condition of existing structure;

(d) available plant.

3.5.9.3 Select fill shall be placed adjacent to structures in accordance with the RIM's requirements.

3.5.9.4 Select fill for use adjacent to structures may, for example, have 60 % of material passing the 2.36 mm sieve and should be able to achieve a compaction of at least 95 % maximum dry density using light compaction equipment.

3.5.9.5 Fill shall be placed in horizontal layers starting at the structure and working progressively away.

3.5.9.6 Fill layers shall be placed simultaneously on both sides of structures to avoid differential loading.

3.5.9.7 In the case of open structures fill should be built up evenly around or against the columns or retaining walls.

3.5.9.8 In the case of framed structures, embankments at both ends of the structure should be brought up simultaneously. The difference between the levels of the embankments at the respective abutments shall not exceed 500 mm, unless otherwise specified in the drawings or within the specifications.

3.5.9.9 Free-draining material encapsulated in a suitable geotextile fabric should be placed adjacent to weep holes, extending at least 300 mm horizontally from and 450 mm vertically above the weep hole.

3.6 Maintenance

3.6.1 Activities required to maintain the structural integrity of the earthworks should include:

(a) carrying out routine inspections;

(b) clearing out and re-profiling of drains, including sub-soil, spoon, top, cess or trapezoidal drains;

(c) clearing out and repair of culverts;

(d) vegetation maintenance (mowing, clearing fallen branches, root jacking, etc.);

(e) replacement or repair of rip rap / slope facing;

(f) clearing of loose or unstable rock faces;

(g) repair/rectification of formation at fouling points;

(h) any activities deemed necessary following site inspections;

(i) maintaining strategic borrow pits.

3.6.2 Spoil removed from drainage systems should be disposed of appropriately.

3.6.3 Access should be provided for maintenance and inspection activities.

4 Commissioning

4.1 General

4.1.1 Works dependent upon completion of earthworks should not commence until successful commissioning of earthworks has been achieved and documented.

4.1.2 Commissioning of earthworks may be defined as the successful completion of a portion of work, verified by issue of test results, inspection records, materials certificates and other documents, which confirm that the specified design has been achieved within the prescribed tolerances and that the earthworks structure is ready to be taken into use.

4.2 Testing and testing frequency

4.2.1 General

Sampling frequencies and testing methods should be undertaken in accordance with AS 1726, AS 1141, AS 1289 and ISO 11453 or other standards determined by the RIM**.**

4.2.2 Compaction testing

4.2.2.1 Sampling locations should be selected at full depth, width and length that are representative of the compacted layer and tested for moisture content and relative compaction.

4.2.2.2 Sampling and testing should be carried out by an independent laboratory.

4.2.2.3 The RIM shall determine the field (in situ) density and laboratory tests to be undertaken. Testing should be carried out in accordance with relevant Australian Standards.

4.2.2.4 The frequency of testing should be agreed in advance with the RIM, with a maximum interval of one day's production.

4.2.2.5 Materials susceptible to breakdown should be subject to testing following placement of the material.

4.2.2.6 The following process should be undertaken in the event of samples failing to meet the compaction specification:

(a) Upon receipt of the first failed compaction test result, that earthworks activity should be halted until further assessment has been undertaken by the RIM.

(b) The RIM should review the situation to determine the extent of rework required, based upon the location of the failed sample in the earthworks profile, and the magnitude of the non-conformance.

(c) The RIM may request additional intermediate testing be performed. Intermediate testing should determine the lateral extent of non-conformance and action to be taken to rectify the situation.

4.2.3 Test rolling (proof rolling)

4.2.3.1 Test rolling should be undertaken on the following surfaces:

(a) After stripping of material.

(b) Areas upon which fills are to be constructed.

(c) Each layer of fill.

(d) Materials within 150 mm of designed sub-grade level in cuttings.

4.2.3.2 Typical examples of test rolling plant are given below:

(a) Static smooth, steel wheeled rollers with a mass of not less than 12 t and load intensity under either the front or rear wheels of not less than 6 t/m width of the wheel.

(b) Pneumatic tyred plant with a mass of not less than 20 t and a ground contact pressure under either the front or rear wheels of not less than 450 kPa per tyre (contact area not less than 0.035 m^2 per tyre).

(c) Highway truck with rear axle or axles loaded to not less than 8 t each with tyres inflated to 550 kPa.

4.2.3.3 Test rolling shall be observed by the RIM for indications of visible deformation or springing.

4.2.3.4 Where the RIM observes visible deformation or springing which does not meet with their satisfaction, the compaction should be rectified and re-presented for test rolling.

4.2.3.5 Where greater than 20 % of an area fails test rolling, the entire area should be replaced, or scarified, adjusted for moisture content, re-compacted and re-tested or otherwise managed as required (including appropriate re-testing of material properties).

4.3 Acceptance standards (tolerances)

4.3.1 General

Completed earthworks shall comply with the vertical and horizontal tolerances as specified or redetermined by the RIM.

4.3.2 Vertical tolerances

4.3.2.1 The top of the structural zone other than in rock should be constructed to a tolerance of +0 mm to -50 mm.

4.3.2.2 The top of the general fill zone should be constructed to a tolerance of +40 mm to -40 mm.

4.3.2.3 The floor of the cutting other than in rock should be constructed to a tolerance of +40 mm to -40 mm.

4.3.2.4 The floor of the cutting in rock should be constructed to a tolerance of +0 mm to -80 mm.

4.3.2.5 The floor of the bench should not vary from levels shown on the drawings by more than +0 mm / -100 mm.

4.3.2.6 The finished surface of the sub-ballast / capping layer should be within 25 mm of the level shown on the drawings.

4.3.2.7 The algebraic difference of the deviations from the correct level for any two points 20 m apart on the centreline of the sub-ballast / capping should not exceed 15 mm.

4.3.3 Horizontal tolerances

4.3.3.1 The width of cuts and fills, and width of benches and berms should not be less than the specified dimensions.

4.3.3.2 The maximum positive tolerance should be specified by the RIM.

4.3.3.3 Embankment batters should not be steeper than the slope specified.

4.3.3.4 The sub-ballast / capping layer should extend to provide a continuous cross-fall to the track drainage system in cuttings or to the embankment slope.

4.3.3.5 Batter slopes should be no steeper than design.

4.4 Records

4.4.1 Earthworks activities shall be documented and maintained in accordance with current legislation. This may include recording the following activities:

(a) Investigation and planning.

(b) Design and specification.

(c) Construction.

4.4.2 Construction records should include conditions encountered, works as executed, as-built drawings, testing records, and any alterations or deviations from standards, specification or drawings.

4.4.3 As a minimum, construction records should include:

(a) areas in which fill was placed;

(b) levels after stripping;

(c) location of any trees or large shrubs that have been removed;

(d) materials exposed during and after stripping, and the criteria upon which the decision to cease stripping was made;

(e) levels after completion of the filling;

(f) details of test rolling;

(g) types of fill material in various zones;

(h) sources of fill material in various zones, where applicable;

(i) location and level of each compliance test, together with test results and notes;

(j) action taken where testing indicated that a specified criterion had not been met;

(k) levels of top of formation or sub-ballast/capping layer;

(l) areas of cutting faces requiring stabilisation measures (e.g. rock bolts, shotcrete, soil nails, etc. including details of the measures adopted);

(m) details of where remedial works have been undertaken.

5 Inspection and assessment

5.1 General

5.1.1 The RIM should develop appropriate monitoring regimes to enable the performance of earthworks to be measured.

5.1.2 All earthworks prone to (e.g. with a history of) instability and those demonstrating poor performance should be identified and managed according to the identified risk.

5.1.3 Inspection frequencies and maintenance regimes should be reassessed following significant changes in traffic density, patterns, annual tonnage or other changes which affect these regimes.

5.2 Roles and responsibilities

5.2.1 The RIM shall ensure that the responsibilities of all persons responsible for the safe asset management of embankments, cuttings and natural slopes are clearly identified in writing and understood by these persons.

5.2.2 The RIM shall be responsible for organising all scheduled and unscheduled inspections.

5.3 Records

5.3.1 Records of all scheduled inspections, defined events assessments and remediation shall be established and maintained by the RIM, in keeping with the requirements of Section 4.4 of this standard.

5.3.2 To promote consistency, the RIM should develop a set of templates/forms for earthwork records, examples of which are provided in Appendix C,D and E.

5.4 Scheduled inspections

5.4.1 General

5.4.1.1 Scheduled inspections may comprise regular periodic general visual inspections. The frequency and detail of inspection should be determined by the RIM, based upon the history of the site, assessed risk of geotechnical instability and other relevant factors.

5.4.2 Visual Inspections

5.4.2.1 Visual inspections along the rail corridor shall be undertaken at regular time intervals, to allow early detection of changes in the condition or appearance of the earthworks, or other discrete defects that could affect stability, including:

(a) indications of recent movement including slippage, slumping, settlement, pumping or heaving;

(b) fissures and cracks in formation or earth batters;

(c) rock, earth or other debris falling on or near the track;

(d) loss of track geometry, or tilting of posts, trees and masts;

(e) track subsidence due to ground movements;

(f) water ponding on track and cess drains;

(g) sinkholes;

(h) mud pumping on tracks;

(i) earthwork scour and / or erosion, including that leading to loss of ballast and undercutting of the toe of embankments;

(j) water seepage from embankments and cuttings;

(k) condition of the top drain, blockages of top and cess drains

(l) damage to embankments or cuttings, including that caused by construction or vehicle access;

(m) conditions that may cause future slip, scour or settlement, such as burning off or clearing of steep embankments and cuttings;

(n) open joints, wedge formations, fragmentation, root jacking and differential weathering in rock cuttings;

(o) any excavations left behind without back filling;

(p) any other occurrence likely to impact on the stability of the earthworks.

An example defect examination report is provided in Appendix F

5.4.2.2 Where sections of the railway have suspected defects which relate to the integrity of earthworks the inspection frequency should be subject to a review as determined by the RIM.

5.4.3 Detailed Inspections

5.4.3.1 Detailed inspections should gather sufficient information on the condition of the earthworks at a special location or of a feature noted as part of a basic visual inspection, to determine whether changes have occurred which increase the risk of instability.

5.4.3.2 The inspection should include identification of defects and conditions as described for a visual inspection.

5.4.3.3 Detailed inspections should be scheduled at intervals appropriate to each location, dependent on its nature, condition and other factors as defined by the RIM.

5.5 Unscheduled inspections

5.5.1 Unscheduled inspections include defined event inspections, opportunistic inspections and for inspections initiated by reports.

5.5.2 Inspections shall be carried out to confirm the presence of suspected defects identified from track patrol inspections or in response to reported movement, instability or failure of earthworks (e.g. by drivers), to allow the necessary actions to be determined.

5.6 Defined events inspections

5.6.1 Where earthworks are nominated as special locations, following the onset of defined events as specified by the RIM, the locations should be subject to unscheduled detailed earthworks inspection and, if necessary, inspections should be continued until rectification or stabilising works can be carried out.

5.6.2 Operating restrictions may also be appropriate at some special locations upon the onset of defined events, up until the results of the inspection and assessment have been completed and the operating restriction assessed as not being required.

5.7 Assessment

5.7.1 Following the collection of site data from visual inspections, non-destructive testing (e.g. ground penetrating radar, magnetics) and/or installed monitoring equipment, the integrity of the earthworks should be reviewed by the RIM, to verify the capacity to safely perform the necessary function.

5.7.2 The assessment should include:

(a) recommendations for the design and programming of remedial works for any identified risks;

(b) the installation of monitoring equipment, as appropriate.

5.8 Remedial action / rehabilitation

Remedial action or rehabilitation shall be undertaken as prescribed by the RIM.

6 Modification

6.1 Widening of existing embankments

6.1.1 Where existing embankments are to be widened, a design process in accordance with this Standard shall be undertaken.

6.1.2 The following steps are provided as a guide to undertaking embankment widening works or compaction against an existing slope steeper than 4H:1V:

(a) Survey and pegging out of the new embankment toe and drainage structures.

(b) Stripping the new embankment floor of unsuitable materials (Section 3.2.3).

(c) Ground preparation, including proof rolling and rectification of poor ground (Section 4.2.3).

(d) Extension and clearing out of existing culverts (by hydroblasting or similar), taking care that water is not trapped between the existing and new embankments.

(e) Placement of a drainage blanket at the base of the embankment and at locations where seepage paths are present .

(f) Progressive benching into the existing embankment, and placement of fill materials to key in the new embankment zone (see Appendix C).

(g) Revegetation, placement of rip rap or other slope erosion protection measures.

6.1.3 Where free-draining soils or seeping water have been identified, the bench should be connected to the lower drainage blanket, or an additional drainage layer may be constructed as described in Section 2.7.2 and Section 3.5.6.

6.1.4 A sub-ballast / capping layer of suitable material should be placed on top of the widened embankment (as per Section 2.6 and Section 3.5.3), with a cross-fall away from any existing track or tracks.

6.1.5 Cess drains, catch drains, sub-soil drains and mitre drains should be provided to drain the track formation and minimize the risk of saturated sub-grade and capping materials.

6.2 Widening of existing cuttings

6.2.1 Where existing cuttings are to be widened, a design process in accordance with this Standard shall be undertaken.

6.2.2 A sub-ballast / capping layer of suitable material should be placed on top of the widened cutting floor (as per Section 2.6 and Section 3.5.3), with a cross-fall away from the track.

6.2.3 Cess drains, top drains / catch drains and mitre drains should be provided in accordance with the relevant drainage standards.

6.2.4 Consideration should be given within the construction method to avoid ponding of water in the floor of the cutting.

7 Decommissioning and disposal

7.1 General

Safe decommissioning and disposal of the rail corridor earthworks should be considered in the design or modification of new or existing sites.

7.2 Decommissioning

7.2.1 Decommissioning, including excavation, compaction and handling of materials, shall comply with the design and construction requirements provided in Section 2 and Section 3 of this Standard.

7.2.2 A decommissioning plan should be composed prior to the commencement of works, including consideration of the following:

(a) Drainage regimes during and following the completion of works.

(b) The stability of embankments during decommissioning works.

(c) Volumes of material types to be generated by the works.

(d) The long-term stability of slopes remaining at the completion of works.

(e) The potential for soil and groundwater contamination from continued railway operations.

(f) Likelihood of alternative, in situ uses of the formation.

(g) Protection of existing utilities to remain in place.

7.2.3 Records shall be kept of decommissioning activities.

7.3 Disposal

7.3.1 Railway operations have the potential to contaminate the soil and groundwater, in addition to pre-existing contamination at the site.

7.3.2 Contamination testing should be undertaken prior to bulk excavation.

7.3.3 The results of contamination investigations/studies should be compared with the limits for contaminants provided by State and Federal authorities, and recommendations made for disposal to an appropriately resourced facility, or ground remediation, where required.

Appendix A Australian Rail Risk Model (ARRM) risk table

Informative

Hazardous event	Publishable consequence / Hazardous event / Publishable precursor
Non-passenger-train collision with obstruction on running line not at a level crossing	Natural object - rock(s)
Non-passenger-train derailment on running-line	Misaligned track
Non-passenger-train derailment on running-line	Structural failure of the permanent way
Passenger-train collision with obstruction on running line not at a level crossing	Natural object - rock(s)
Passenger-train derailment on running-line	Misaligned track
Passenger-train derailment on running-Line	Structural failure of the permanent way

Appendix B Earthworks examination record sheet

Informative

Earthworks examination record sheet	
Examination number	
Route name	
Nearest station	
Earthwork type	Embankment / soil cutting / mixed soil: Rock cutting / natural soil slope / mixed soil: Rock natural slope.
Brief description of site	
Earthwork 'Name' (Where applicable)	
Rail chainage (start)	From track markers _ _ _ Km _ _ _ _ m
Grid reference (start)	Using GPS equipment E N
Rail chainage (end)	From track markers _ _ _ Km _ _ _ _ m
Grid reference (end)	Using GPS equipment E N
Upside or downside	
Camera and photo numbers	
Date of examination	
Weather conditions	
Examined by	

Appendix C Field datasheets – hazard index for soil embankments

Informative

Stability indicators	Stability index parameter	Observed / measured value	Ref no	
1 Slope geometry	Slope angle and slope height (One tick only)	< 15º (and) < 3 m high	1.1.1	
		15º to < 25º (and) < 3 m high	1.1.2	
		25º to < 35º (and) < 3 m high	1.1.3	
		> 35º (and) < 3 m high	1.1.4	
		< 15º (and) 3 m to < 10 m high	1.2.1	
		15º to < 25º (and) 3 m to < 10 m high	1.2.2	
		25º to < 35º (and) 3 m to < 10 m high	1.2.3	
		> 35º (and) 3 m to < 10 m high	1.2.4	
		< 15º (and) > 10 m high	1.3.1	
		15º to < 25º (and) > 10 m high	1.3.2	
		25º to < 35º (and) > 10 m high	1.3.3	
		> 35º (and) > 10 m high	1.3.4	
	Slope angle adjacent to earthwork (i.e. sidelong ground) (One tick only)	-ve (falls towards earthwork)	1.4.1	
		+ve (falls away from earthwork) < 5º	1.4.2	
		+ve (falls away from earthwork) 5 to 15º	1.4.3	
		+ve (falls away from earthwork) >15º	1.4.4	
	Retaining walls 1m high or greater (Multiple cumulative)	None	1.5.1	
		< 1 m height (but) > 20 m length	1.5.2	
		No evidence of distress	1.5.3	
		Minor distress (spalling, pointing, etc.)	1.5.4	
		Cracking / evidence of lateral displacement	1.5.5	
		Evidence of Repairs	1.5.6	
	Construction activity at slope toe (i.e. excavation) (One tick only)	None	1.6.1	
		Excavation (< 10 m3)	1.6.2	
		Excavation (> 10 m3)	1.6.3	
2 Minimum Slope to Track Separation	Distance between sleeper ends and crest of embankment (One tick only)	Embankment cess width > 6 m	2.1.1	
		Embankment cess width 3 m – 6 m	2.1.2	
		Embankment cess width 1 m – 3 m	2.1.3	
		Embankment cess width < 1 m	2.1.4	

Stability indicators	Stability index parameter	Observed / measured value	Ref no	
3 Underlying geology (Common geologies are shown; each route is to compile a list of local geologies)	Geological strata (Desk study) (Tick all that apply)	**Disturbed / Granular material**		**Depth (m)**
		Alluvium	3.1.1	
		Colluvium	3.1.2	
		Sand and gravel	3.1.3	
		Filling	3.1.4	
		Slope wash	3.1.5	
		Mapped landslip	3.1.6	
		Windblown sand	3.1.7	
		Other (specify):	3.1.8	
		In Situ / Competent material		**Depth (m)**
		Over-consolidated (O/C) clay	3.2.1	
		Normally consolidated (n/c) clay	3.2.2	
		Highly to extremely weathered rock		
		Sedimentary rock (type, bedding, weathering):	3.2.3	
		Metamorphic rock (type, massive/platy, weathering):	3.2.4	
		Igneous (type, jointing, weathering):	3.2.5	
		Other (specify):	3.2.6	
4 Slope composition at crest	Predominant material type (One tick only)	Coarse granular	4.1.1	
		Fine granular / ash	4.1.2	
		Mixed granular / cohesive	4.1.3	
		Cohesive (low - intermediate plasticity)	4.1.4	
		Cohesive (high - very high plasticity)	4.1.5	
		Unknown	4.1.6	
5 Slope composition at toe	Predominant material type (One tick only)	Very weak or weak rock	5.1.1	
		Coarse granular	5.1.2	
		Fine granular	5.1.3	
		Mixed granular / cohesive	5.1.4	
		Cohesive (low - intermediate plasticity)	5.1.5	
		Cohesive (high - very high plasticity)	5.1.6	
		Unknown	5.1.7	
6 Drainage	Slope face drainage condition (Multiple cumulative)	Face dry	6.1.1	
		Functioning drainage	6.1.2	
		Blocked drainage	6.1.3	

Stability indicators	Stability index parameter	Observed / measured value	Ref no	
		Marshy areas on slope	6.1.4	
		Surface issues on lower slope	6.1.5	
		Surface issues on upper slope	6.1.6	
	Slope toe drainage condition (Multiple cumulative)	Dry / free draining	6.2.1	
		Marshy ground / standing water at or immediately beyond slope toe	6.2.2	
		Groundwater issues at toe	6.2.3	
	Embankment sub-drainage (culverts) (One tick only)	Absent and not required	6.3.1	
		Absent, despite adjacent topography and drainage suggesting they are required	6.3.2	
		Present and functional	6.3.3	
		Present, but impaired / blocked / not observed	6.3.4	
	Drainage of adjacent land (Multiple maximum)	None	6.4.1	
		Natural water course within 20 m of slope toe	6.4.2	
		Artificial water course within 20 m of slope toe	6.4.3	
		Scour close to embankment toe	6.4.4	
	Track drainage	Adequate drainage	6.5.1	
		Minor ponding on track	6.5.2	
		Significant ponding on track	6.5.3	
		Scouring caused through ponding on track	6.5.4	
	Adjacent catchment depth (One tick only)	> 5 km	6.6.1	
		1 km to 5 km	6.6.2	
		100 m to 1 km	6.6.3	
		< 100 m	6.6.4	
	Adjacent catchment gradient (One tick only)	> 25º	6.7.1	
		5º - 25º	6.7.2	
		< 5º	6.7.3	
		Slopes away from structure	6.7.4	
	Catchment surface (Multiple maximum)	Rough grass	6.8.1	
		Grazed pasture	6.8.2	
		Ploughed	6.8.3	
		Wooded / large scrub	6.8.4	
		Other	6.8.5	
		Residential	6.8.6	
		Industrial / hard-standing	6.8.7	
		Permeable	6.9.1	

Stability indicators	Stability index parameter	Observed / measured value	Ref no	
	Catchment geology (From desk study) (One tick only)	Impermeable	6.9.2	
		Mixed	6.9.3	
7 Movement indicators (Overall failure)	Slope Form of Earthwork (Multiple cumulative)	Uniform toe	7.1.1	
		Terracing in mid-slope	7.1.2	
		Hummocky ground in mid-slope	7.1.3	
		Toe bulging	7.1.4	
		Uniform Crest	7.1.5	
		Stepped Crest	7.1.6	
	Geomorphology of adjacent land (Multiple cumulative)	Deep-seated landslips	7.2.1	
		Hummocky ground / solifluction lobes	7.2.2	
		No significant features	7.2.3	
	Track movements (Visible to naked eye)	Track slacks (vertical misalignment)	7.3.1	
		Track slews (horizontal misalignment)	7.3.2	
		Track slacks & slews	7.3.3	
		Evidence of mud pumping	7.3.4	
		Track subsidence	7.3.5	
		No significant features	7.3.6	
	Ballast (Multiple cumulative)	Loss of ballast from 4 foot	7.4.1	
		Maximum <0.5 m thickness	7.4.2	
		0.5m <1.5 m thickness, sleeper ends covered	7.4.3	
		0.5m <1.5 m thickness, sleeper ends exposed	7.4.4	
		Maximum >1.5 m thickness, sleeper ends covered	7.4.5	
		Maximum >1.5 m thickness, sleeper ends exposed	7.4.6	
	Troughing (Multiple cumulative)	Misalignment	7.5.1	
		Tilting	7.5.2	
		Stilted	7.5.3	
		Restrained	7.5.4	
		No significant features or absent	7.5.5	
	Attitude of mature trees/ fence lines/ signals (Multiple maximum)	Vertical or absent	7.6.1	
		Random	7.6.2	
		Bent tree trunks (convex upslope)	7.6.3	
		Bent tree trunks (convex downslope)	7.6.4	
		Predominantly tilted downslope (< 10 ^{o} off vertical)	7.6.5	
		Predominantly tilted downslope (> 10 ^{o} off vertical)	7.6.6	

Stability indicators	Stability index parameter	Observed / measured value		Ref no	
7 Movement indicators (Overall failure) - continued	Cracking (One tick only)	None visible		7.7.1	
		Random orientation		7.7.2	
		Cracked culvert		7.7.3	
		Persistent and parallel to slope crest			
		Width (mm)	Vertical displacements (mm)		
		< 10	< 30	7.7.4	
		< 10	> 30	7.7.5	
		10 to 50	< 30	7.7.6	
		10 to 50	> 30	7.7.7	
		> 50	< 30	7.7.8	
		> 50	> 30	7.7.9	
	Mass movements (Multiple cumulative)	None visible		7.8.1	
		Slope washout evident		7.8.2	
		Soil creep movements		7.8.3	
		Local slumping/earthflow evident		7.8.4	
		Translational failure evident		7.8.5	
		Rotational failure evident		7.8.6	
	History of instability (Multiple cumulative)	None		7.9.1	
		Presence of piezometers, slip indicator tubes / inclinometers		7.9.2	
		Regular maintenance required		7.9.3	
		Repaired previous failure		7.9.4	
		Grout on slope		7.9.5	
		Counter fort drainage		7.9.6	
	Mining/removal of support (One tick only)	Known mining area		7.10.1	
		No significant features		7.10.2	
	Burrows (Multiple maximum)	None observed		7.11.1	
		Occasional rabbit		7.11.2	
		Occasional fox / wombat		7.11.3	
		Frequent rabbit		7.11.4	
		Frequent fox / wombat		7.11.5	

Stability indicators	Stability index parameter	Observed / measured value	Ref no	
7 Movement indicators (Overall failure) - continued	Tree cover (Multiple maximum)	Absent	7.12.1	
		Saplings but no mature trees	7.12.2	
		Occasional mature trees, slope < 25º	7.12.3	
		Occasional mature trees, slope > 25º	7.12.4	
		Frequent mature trees, slope < 25º	7.12.5	
		Frequent mature trees, slope > 25º	7.12.6	
	Ground cover (Multiple maximum)	Bare areas	7.13.1	
		Sparse salt bush or similar	7.13.2	
		Dense salt bush or similar	7.13.3	
		Scrub	7.13.4	
		Grass / low crops	7.13.5	
		Immature or shallow rooted trees	7.13.6	
		Mature or deep-rooted trees	7.13.7	
		Rainforest	7.13.8	
8 Condition of opposite side of embankment	Geometry and drainage conditions on opposite side (One tick only)	Geometry does not promote earthflow failure on sidelong ground	8.1.1	
		Geometry does promote earthflow failure on sidelong ground but no drainage problem present	8.1.2	
		Geometry does promote earthflow failure on sidelong ground and drainage problem present	8.1.3	
		No inspection data available for opposite side of embankment	8.1.4	

Appendix D Field datasheets – hazard index for soil cuttings

Informative

Stability indicators	Stability index parameter	Observed / measured value	Ref no	
1 Slope geometry	Slope angle and slope height (One tick only)	< 15º (and) < 3 m high	1.1.1	
		15º to < 25º (and) < 3 m high	1.1.2	
		25º to < 35º (and) < 3 m high	1.1.3	
		> 35º (and) < 3 m high	1.1.4	
		< 15º (and) 3 m to < 10 m high	1.2.1	
		15º to < 25º (and) 3 m to < 10 m high	1.2.2	
		25º to < 35º (and) 3 m to < 10 m high	1.2.3	
		> 35º (and) 3 m to < 10 m high	1.2.4	
		< 15º (and) > 10 m high	1.3.1	
		15º to < 25º (and) > 10 m high	1.3.2	
		25º to < 35º (and) > 10 m high	1.3.3	
		> 35º (and) > 10 m high	1.3.4	
	Slope angle adjacent to earthwork (i.e. sidelong ground) (One tick only)	-ve (falls towards earthwork)	1.4.1	
		+ve (falls away from earthwork) < 5º	1.4.2	
		+ve (falls away from earthwork) 5 to 15º	1.4.3	
		+ve (falls away from earthwork) >15º	1.4.4	
	Retaining walls 1 m high or greater (Multiple cumulative)	None	1.5.1	
		< 1 m height (but) > 20 m length	1.5.2	
		No evidence of distress	1.5.3	
		Minor distress (spalling, pointing, etc.)	1.5.4	
		Cracking / evidence of lateral displacement	1.5.5	
		Evidence of Repairs	1.5.6	
	Construction activity at slope crest / toe (Multiple cumulative)	None	1.6.1	
		Removal of material from crest	1.6.2	
		Addition of fill < 1 m high	1.6.3	
		Addition of fill between 1 m and 5 m high	1.6.4	
		Addition of fill > 5 m high	1.6.5	
		Excavation at toe of slope	1.6.6	
2 Minimum Slope to Track Separation	Distance between sleeper ends and crest of embankment (One tick only)	Embankment cess width > 6 m	2.1.1	
		Embankment cess width 3 m – 6 m	2.1.2	
		Embankment cess width 1 m – 3 m	2.1.3	
		Embankment cess width < 1 m	2.1.4	

Stability indicators	Stability index parameter	Observed / measured value	Ref no	
3 Geology of cutting from BGS Map (Common geologies are shown; each route is to compile a list of local geologies)	Geological strata (Desk study) (Tick all that apply) (Multiple maximum)	**Drift**		**Depth (m)**
		Alluvium	3.1.1	
		Colluvium	3.1.2	
		Sand and gravel	3.1.3	
		Filling	3.1.4	
		Slope wash	3.1.5	
		Mapped landslip	3.1.6	
		Windblown sand	3.1.7	
		Other (specify):	3.1.8	
		Solid		**Depth (m)**
		Over-consolidated (O/C) clay	3.2.1	
		Normally consolidated (n/c) clay	3.2.2	
		Highly to extremely weathered rock		
		Sedimentary rock (type, bedding, weathering):	3.2.3	
		Metamorphic rock (type, massive/platy, weathering):	3.2.4	
		Igneous (type, jointing, weathering):	3.2.5	
		Other (specify):	3.2.6	
4 Slope crest	Width (One tick only)	Crest to boundary < 1.5 m	4.1.1	
		Crest to boundary 1.5 m – 3 m	4.1.2	
		Crest to boundary > 3 m	4.1.3	
5 Slope composition at crest	Predominant material type (Multiple maximum)	Very weak or weak rock	5.1.1	
		Coarse granular	5.1.2	
		Fine granular	5.1.3	
		Mixed granular / cohesive	5.1.4	
		Cohesive (low - intermediate plasticity)	5.1.5	
		Cohesive (high - very high plasticity)	5.1.6	
		Unknown	5.1.7	
6 Slope composition at toe	Predominant material type (Multiple maximum)	Very Weak or Weak Rock	6.1.1	
		Coarse granular	6.1.2	
		Fine granular	6.1.3	
		Mixed granular/cohesive	6.1.4	
		Cohesive (low - intermediate plasticity)	6.1.5	
		Cohesive (high - very high plasticity	6.1.6	

Stability indicators	Stability index parameter	Observed / measured value	Ref no	
		Unknown	6.1.7	
7 Drainage	Slope face drainage conditions (Multiple cumulative)	Face dry	7.1.1	
		Functioning drainage	7.1.2	
		Blocked drainage	7.1.3	
		Marshy areas on slope	7.1.4	
		Surface issues on lower slope	7.1.5	
		Surface issues on upper slope	7.1.6	
	Drainage of adjacent land (Multiple maximum)	Dry / free draining	7.2.1	
		Marshy ground / standing water at or immediately beyond slope toe	7.2.2	
		Groundwater issues at toe	7.2.3	
	Adjacent catchment depth (One tick only)	Absent and not required	7.3.1	
		Absent, despite adjacent topography and drainage suggesting they are required	7.3.2	
		Present and functional	7.3.3	
		Present, but impaired / blocked / not observed	7.3.4	
	Adjacent catchment gradient (One tick only)	None	7.4.1	
		Natural water course within 20 m of slope toe	7.4.2	
		Artificial water course within 20 m of slope toe	7.4.3	
		Scour close to embankment toe	7.4.4	
	Catchment surface (Multiple maximum)	Rough grass	7.5.1	
		Grazed pasture	7.5.2	
		Ploughed	7.5.3	
		Wooded/large scrub	7.5.4	
		Other	7.5.5	
		Residential	7.5.6	
		Industrial / hard standing	7.5.7	
	Catchment geology (One tick only	Permeable	7.6.1	
		Impermeable	7.6.2	
		Mixed	7.6.3	
	Slope and condition top/crest drainage (Tick Q1 or one tick per subsection) (Multiple maximum)	None visible	7.7.1	
		French drain	7.7.2	
		V channel	7.7.3	
		U channel	7.7.4	
		Size > 0.25 m^2	7.7.5	
		Size 0.1 m^2 to 0.25 m^2	7.7.6	

Stability indicators	Stability index parameter	Observed / measured value	Ref no	
		Size < 0.1 m^2	7.7.7	
		Gradient < 5°	7.7.8	
		Gradient 5° to 15°	7.7.9	
		Gradient > 15°	7.7.10	
		Free draining	7.7.11	
		Partially blocked	7.7.12	
		Blocked	7.7.13	
	Slope crest concentration features (One tick only)	Multiple narrow – well defined	7.8.1	
		Single narrow – well defined	7.8.2	
		Multiple - shallow	7.8.3	
		Single - shallow	7.8.4	
		None	7.8.5	
	Slope erosion (One tick only)	Multiple – well defined	7.9.1	
		Multiple – poorly defined	7.9.2	
		Single – well defined	7.9.3	
		Single – poorly defined	7.9.4	
		None	7.9.5	
	Cess drainage (Multiple maximum)	None	7.10.1	
		Present clear running	7.10.2	
		Present unknown condition	7.10.3	
		Flooding apparent	7.10.4	
		Present - impaired/blocked	7.10.5	
8 Movement indicators (Overall failure)	Slope form of earthwork (Multiple cumulative)	Uniform toe	8.1.1	
		Terracing in mid-slope	8.1.2	
		Hummocky ground in mid-slope	8.1.3	
		Toe bulging	8.1.4	
		Uniform crest	8.1.5	
		Stepped crest	8.1.6	
	Geomorphology of adjacent land (Multiple cumulative)	Deep-seated landslips	8.2.1	
		Hummocky ground / solifluction lobes	8.2.2	
		No significant features	8.2.3	
	Track movements (Visible to naked eye) (One tick only)	Track heave / subsidence	8.3.1	
		No significant features	8.3.2	
	Attitude of mature trees / fence lines / signals (multiple maximum	Vertical or absent	8.4.1	
		Random	8.4.2	
		Bent tree trunks (convex upslope)	8.4.3	
		Bent tree trunks (convex downslope)	8.4.4	

Stability indicators	Stability index parameter	Observed / measured value		Ref no	
		Predominantly tilted downslope (< 10° off vertical)		8.4.5	
		Predominantly tilted downslope (> 10° off vertical)		8.4.6	
		Tilted upslope near cutting crest		8.4.7	
	Cracking (One tick only)	None visible		8.5.1	
		Random orientation		8.5.2	
		Persistent and parallel to slope crest			
		Width (mm)	Vertical displacements (mm)		
		< 10	< 30	8.5.3	
		< 10	> 30	8.5.4	
		10 to 50	< 30	8.5.5	
		10 to 50	> 30	8.5.6	
		> 50	< 30	8.5.7	
		> 50	> 30	8.5.8	
	Mass movements (Multiple cumulative)	None visible		8.6.1	
		Slope washout evident		8.6.2	
		Soil creep movements		8.6.3	
		Local slumping/earthflow evident		8.6.4	
		Translational failure evident		8.6.5	
		Rotational failure evident		8.6.6	
	History of instability (Multiple cumulative)	None		8.7.1	
		Presence of piezometers, slip indicator tubes / inclinometers		8.7.2	
		Regular maintenance required		8.7.3	
		Counter fort drains		8.7.4	
		Repaired previous failure		8.7.5	
	Mining / removal of support (One tick only)	Known mining area		8.8.1	
		No significant features		8.8.2	
9 Animal Activity	Burrows (Multiple maximum)	None observed		9.1.1	
		Occasional rabbit		9.1.2	
		Occasional fox / wombat		9.1.3	
		Frequent rabbit		9.1.4	
		Frequent fox / wombat		9.1.5	

Stability indicators	Stability index parameter	Observed / measured value	Ref no	
10 Vegetation	Tree cover (Multiple maximum)	Absent	10.1.1	
		Saplings but no mature trees	10.1.2	
		Occasional mature trees, slope < 25º	10.1.3	
		Occasional mature trees, slope > 25º	10.1.4	
		Frequent mature trees, slope < 25º	10.1.5	
		Frequent mature trees, slope > 25º	10.1.6	
	Ground cover (Multiple maximum)	Bare areas	10.2.1	
		Sparse salt bush or similar	10.2.2	
		Dense salt bush or similar	10.2.3	
		Scrub	10.2.4	
		Grass / low crops	10.2.5	

Appendix E Field datasheet - rock slope hazard index

Informative

Field datasheet - rock slope hazard index	
Route name	
Nearest station	
Position	
Length ID number	
Length start (Km and m)	
Length finish (Km and m)	
Length start (MGA Grid Ref.[1])	
Length finish (MGA Grid Ref.[1])	
No of rock slopes in 100 m length	

Note: One set of sheets is to be completed for each rock slope in 100 m length and appended to this cover

[1] Where available and applicable

Field data sheet for rock slope hazard index determination

Slope Reference Details Slope Reference Number

Route

		Easting	Northing
Slope Start Ch		Slope Start Grid Ref	

1. Geometric data – rock slope details

1.1 Slope height

< 3 m	3 - 6 m	6 - 10 m	10 - 20 m	20 - 40 m	> 40 m

1.2 Slope Angle

< 30	30º - 45º	45º - 70º	70º - 90º	> 90º	< 30

Local overhangs:	

1.3 Berms

None	< 2 m wide	2 m - 4 m wide	> 4 m wide

Effective:	Yes	No
Vegetated:	Yes	No

1.4 Rock slope vegetation

None	Ground cover	Shrubs	Trees
	% Cover	% Cover	% Cover

1.5 Slope profile

Even (mean relief < 1 m)	Rough (mean relief > 1 m)

1.6 Slope type	
Sidelong	Box

1.7 Slope length

1.8 Slope azimuth

2 Upper slope details

None

2.1 Upper slope height		
< 5 m	5 m – 10 m	> 10 m

2.2 Upper slope angle (degrees)				
< 20º	20º – 30º	30º – 45º	45º – 60º	> 60º

2.3 Upper slope vegetation			
None	Ground cover	Shrubs	Trees
	% Cover	% Cover	% Cover

3 Lower slope details

None

3.1 Lower slope height		
< 5 m	5 m – 10 m	> 10 m

3.2 Lower slope angle (degrees)		
< 30º	30º – 45º	45º

3.3 Lower slope materials		
Overburden	Scree	Rock

3.4 Lower slope vegetation			
None	Ground cover	Shrubs	Trees
	% Cover	% Cover	% Cover

4. Cess geometry

4.1 Offset of cess to edge of rail					
< 1 m	1 m - 2 m	2 m - 4 m	4 m - 6 m	6 m - 10 m	> 10 m

4.2 Ditch width					
None	< 1 m	1 m – 2 m	2 m – 4 m	4 m – 6 m	> 6 m

4.3 Ditch depth				
None	< 0.5 m	0.5 m – 1 m	1 m – 2 m	> 2 m

4.4 Cess vegetation			
None	Ground cover	Shrubs	Trees
	% Cover	% Cover	% Cover

4.5 Cess safe	Yes	No

5 Above slope details

5.1 Distance from crest of slope to most significant feature

< 1 m	1 m - 2 m	2 m - 4 m	4 m - 6 m	6 m - 10 m	> 10 m

5.2 Significant features above slope

Live Rail		Residence/buildings above slope		
Water above slope		Road/ access above slope		
Services above slope		Footpath above slope		
Crest drain				

6 Base of slop details

6.1 Significant features at toe of slope

Live Rail		Buildings		
OH lines		Other services		
Signalling		Other		

6.2 Associate hazards

Slope below slope	Yes / No	River / Open water	Yes / No

6.3 Comments/ photograph or sketch

7 Geotechnical data

7.1 Rock strength

Extremely low	Low	Moderate	High	Extremely high

7.2 Rock weathering

Fresh	Slightly	Moderately	Highly	Extremely	Residual

7.3 Percentage (%) rock mass < moderately strong

< 10 %	10 % – 50 %	51 % – 70 %	> 70 %

7.4 Discontinuity set characteristics (average for set)

Type		Set 1	Set 2	Set 3	Set 4	Set 5	Set 6
Dip (degrees)	< 30º						
	30º – 45º						
	45º – 70º						
	70º – 90º						
	Overturned						
	Low Phi possible						
Azimuth (degrees)	+/- 20º						
	20º to 90º (+or-)						
	> 90º (+or-)						
Average principal spacing	< 0.1 m						
	0.1 m – 0.3 m						
	0.3 m – 0.6 m						
	0.6 m – 2 m						
	> 2 m						

7.4 Discontinuity set characteristics (average for set)

Type		Set 1	Set 2	Set 3	Set 4	Set 5	Set 6
Visible Average Trace Extent	< 1 m						
	1 m – 3 m						
	3 m – 5 m						
	5 m – 10 m						
	> 10 m						

7.5 Average discontinuity dilation

< 2 mm	2 mm – 5mm	5 mm – 10 mm	10 mm – 25mm	> 25 mm

7.6 Potential failure observed on slope

None

Frequency observed	Plane	Wedge	Toppling	Ravelling
High				
Medium				
Low				

7.7 Size of potential failure observed on slope

Failure type	Size m^3					
Plane	0.1 m^3 – 1 m^3	1 m^3 – 3 m^3	3 m^3 – 6 m^3	6 m^3 – 10 m^3	10 m^3 - 50 m^3	> 50 m^3
Wedge	0.1 m^3 – 1 m^3	1 m^3 – 3 m^3	3 m^3 – 6 m^3	6 m^3 – 10 m^3	10 m^3 - 50 m^3	> 50 m^3
Toppling	0.1 m^3 – 1 m^3	1 m^3 – 3 m^3	3 m^3 – 6 m^3	6 m^3 – 10 m^3	10 m^3 - 50 m^3	> 50 m^3
Ravelling	< 0.1 m^3	0.1 m^3 – 0.3 m^3	0.3 m^3 – 0.5 m^3	>0.5 m^3	Size - notional block diameter m	

Ravelling shape	Angular	Rounded	Equi-dimensional	Tabular / Elongated

7.8 Failure history			
Previous Failures on Face	None	< 20 m^3	> 20 m^3

7.9 Upper slope geotechnical characteristics			
Material type	Overburden	Scree	Rock

7.10 Groundwater seepage		
None	Minor	Major

8 Remedial work data

8.1 Existing rock containment - netting			
Draped	Contoured	Fixed	% Area

8.2 Existing rock strengthening	
Rock Reinforcement	% Area

8.3 Support				
Retaining wall	Buttress	Sprayed concrete	Walling	Strapping
% Area	% Area	% Area	% Area	% Area

8.4 Protection	
Sprayed concrete	Dentition
% Area	% Area

8.5 Total percentage of hazards treated							
Plane	None	< 25 %	25 % – 50 %	51 % – 75 %	76 % – 90 %	91 % – 99 %	100 %
Wedge	None	< 25 %	25 % – 50 %	51 % – 75 %	76 % – 90 %	91 % – 99 %	100 %
Toppling	None	< 25 %	25 % – 50 %	51 % – 75 %	76 % – 90 %	91 % – 99 %	100 %
Ravelling	None	< 25 %	25 % – 50 %	51 % – 75 %	76 % – 90 %	91 % – 99 %	100 %

8.6 Effectiveness of remedial works							
Plane	None	< 25 %	25 % – 50 %	51 % – 75 %	76 % – 90 %	91 % – 99 %	100 %
Wedge	None	< 25 %	25 % – 50 %	51 % – 75 %	76 % – 90 %	91 % – 99 %	100 %
Toppling	None	< 25 %	25 % – 50 %	51 % – 75 %	76 % – 90 %	91 % – 99 %	100 %
Ravelling	None	< 25 %	25 % – 50 %	51 % – 75 %	76 % – 90 %	91 % – 99 %	100 %

8.7 Photographs

No. of photos taken | Photo ID | From | To

Logged by: | Date:

Input by: | Date:

Checked by: | Date:

Appendix F Examination report – defect description sheet

Informative

Defect number:		**Type of defect:**	
Chainage:		**GPS coordinates:**	

Description of defect:

Is the entire defect visible, or is vegetation clearance required to fully appreciate the effect of the defect on the stability of the earthwork?

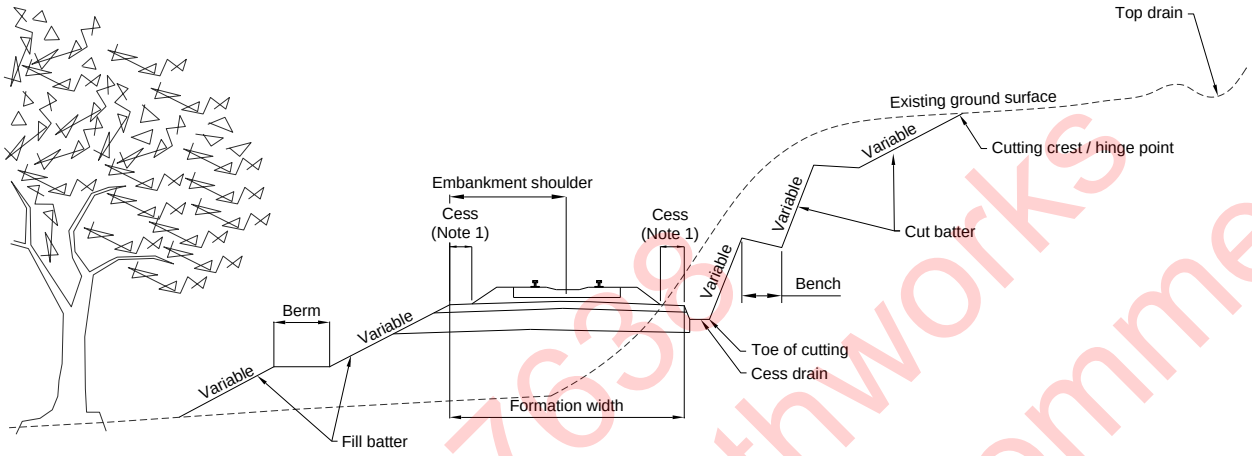
Photograph of defect:

Camera number:		**Photograph Number:**	

Appendix G Earthworks cross-section

Informative

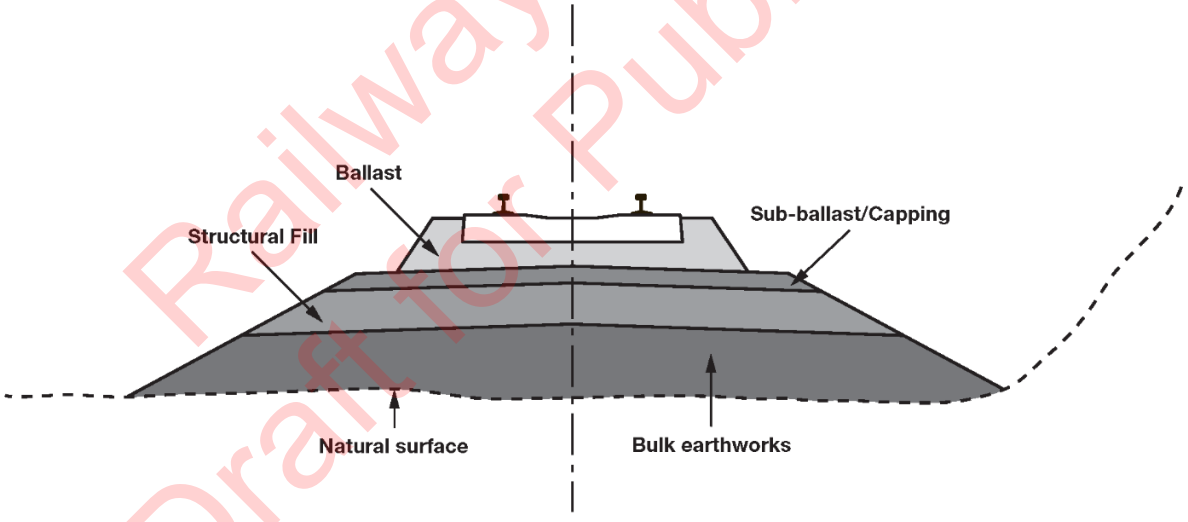
G.1 General cross-section



Notes :

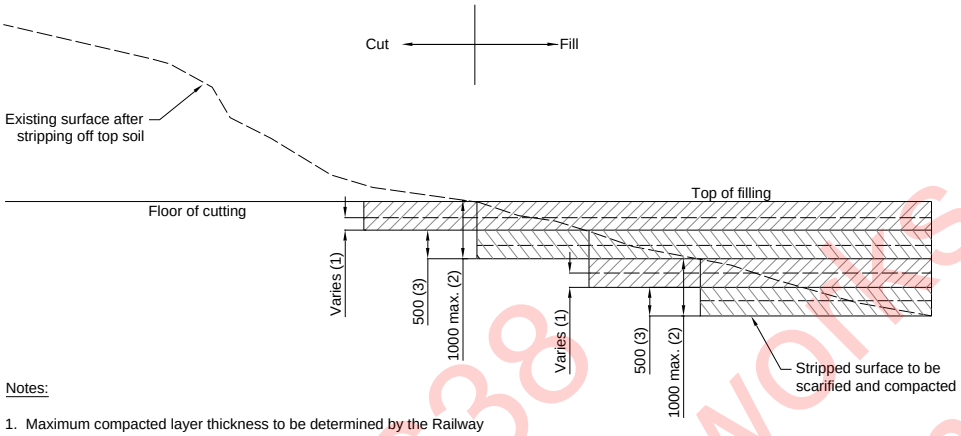
1. Clear width may be increased to suit access or other requirements

G.2 Formation cross-section



Appendix H Earthworks at cut/fill interface

Informative

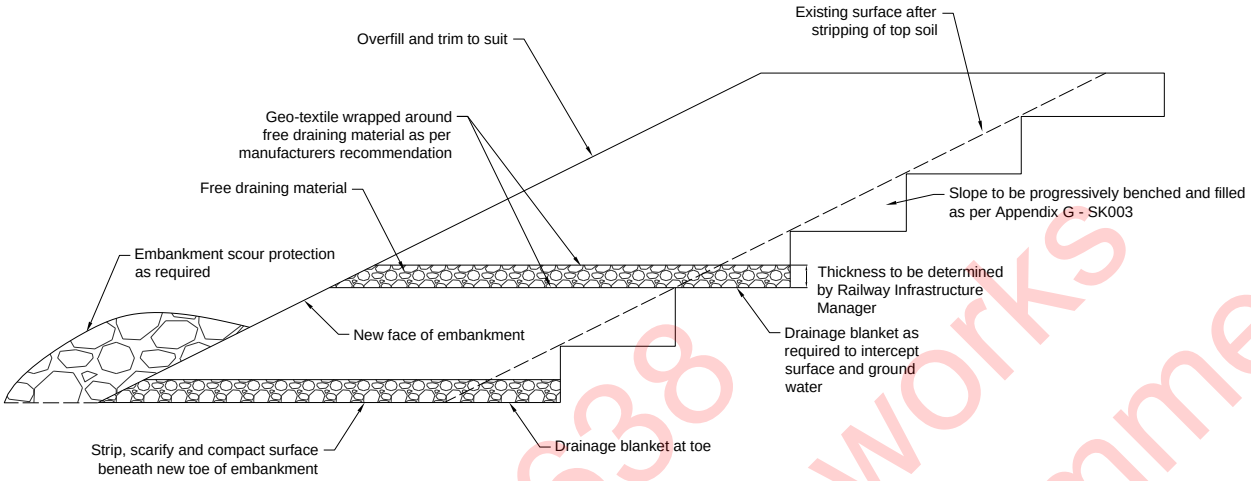


Notes:

1. Maximum compacted layer thickness to be determined by the Railway Infrastructure Manager based upon material type and available plant.
2. Maximum bench height or cut scarp to be 1.0m, or as determined by the Railway Infrastructure Manager.
3. New bench to be cut once filling on bench reaches 500mm thickness.
4. Maximum bench length 20m, or as determined by the Rail Infrastructure Manager.
5. All dimensions on sketch are shown in mm.

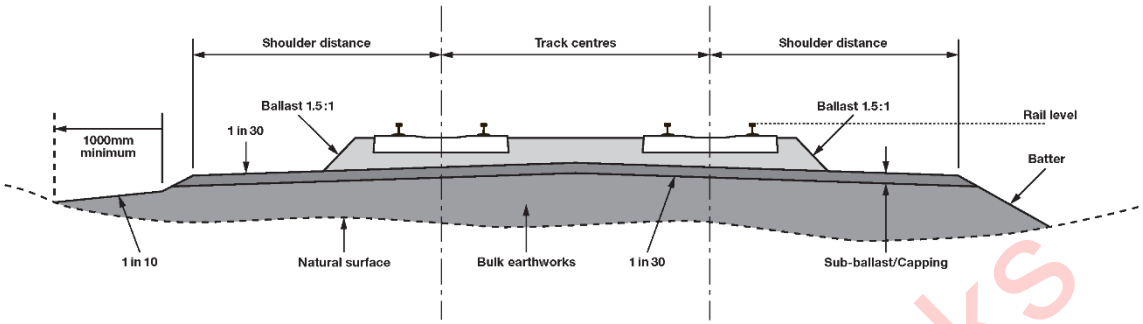
Appendix I Widening of existing embankment

Informative



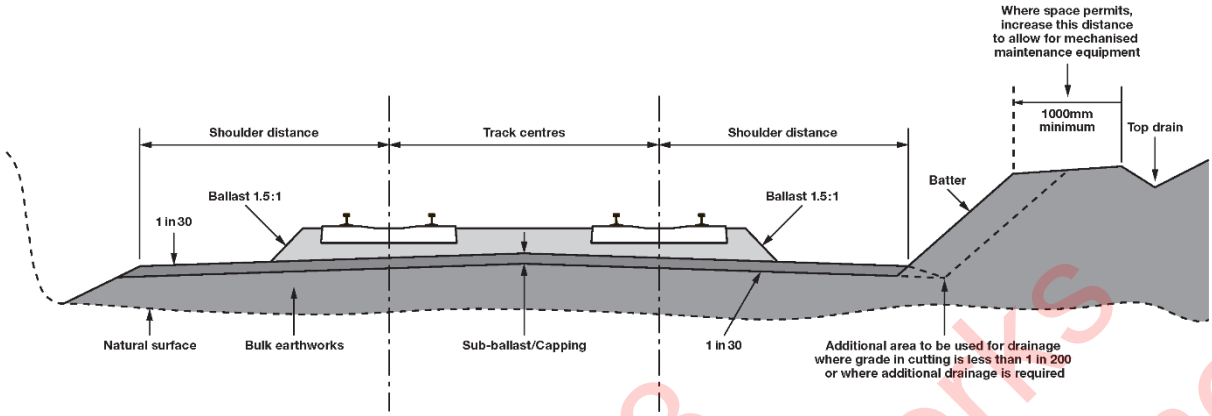
Appendix J Embankment

Informative



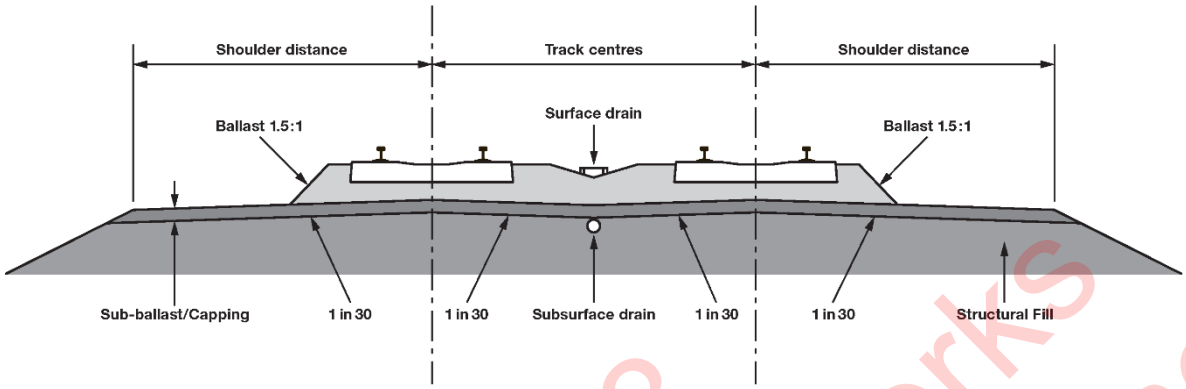
Appendix K Cutting

Informative



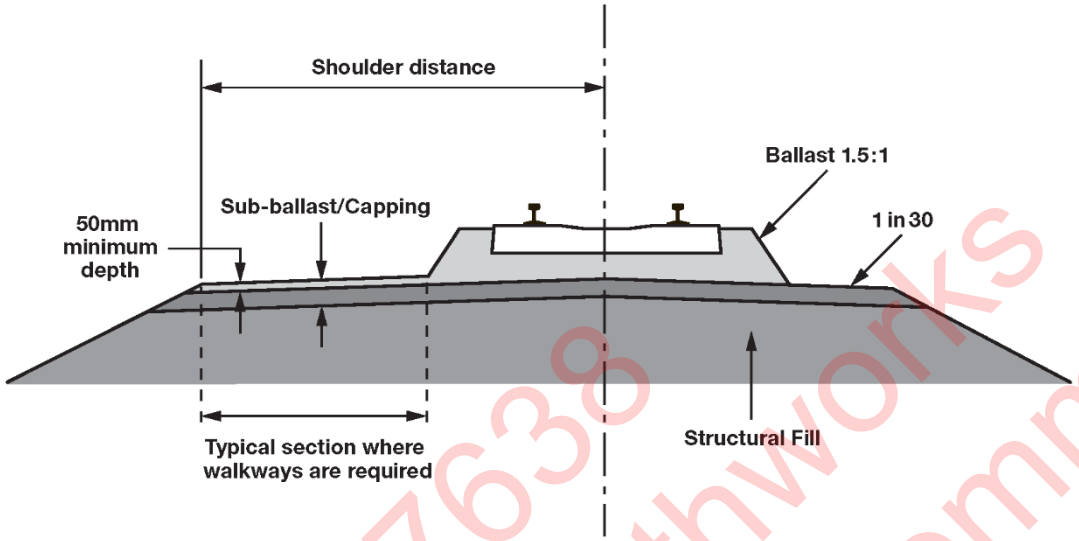
Appendix L Centre drain

Informative



Appendix M Special width requirements

Informative



Appendix N Treatments for poor ground

Informative

N.1 Compressible soils

Problems caused by compressible soils can be mitigated through:

(a) preloading the soil above the future load requirements;

(b) providing suitable vertical drainage through the entire compressible layer;

(c) a combination of a) and b);

(d) lowering of the groundwater table;

(e) use of stone, lime, or cement columns.

Whilst using vertical drainage will reduce the primary consolidation settlement it may not be effective at reducing the secondary compression issue. This is better managed using preloading.

When preloading the soil a thickness equivalent to 1.1 times the settlement should be placed on top of the compressible soils to compensate for any shortfall.

N.2 Expansive soils

Problems with expansive soils can be mitigated through either:

(a) chemical stabilization, using cementing agents: or

(b) mechanical stabilization, using reinforcing, cushioning, or inclusion materials.

The use of geosynthetics is recommended as a suitable method of mechanical stabilization.

Appendix O Bibliography

Informative

The following referenced documents are used by this Standard for information only:

(a) AS 4292.1 Railway safety management.

(b) AS 2758.7 Aggregates and rock for engineering purposes – Railway ballast.

(c) AS 7633 Track stability

(d) AS 7639 Rail support systems.

(e) AS 1170 Structural design actions – Earthquake actions in Australia.

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