NZGS Specification

NZGS_0510 EARTHWORKS

VERSION 1.0 – 15/02/2024

NEW ZEALAND GEOTECHNICAL SOCIETY INC

A Collaborating Technical Society of Engineering New Zealand

Document Status

Version	Date	Purpose	Status
1.0	February 2024	Final committee amendments	Final
0.3	January 2024	Update following public consultation	Draft
0.2	August 2022	Member consultation	Draft
0.1	June 2022	Committee and peer review	Draft

Document Updates

The document may be updated from time to time following the issue date. The latest version is available from the New Zealand Geotechnical Society (NZGS) website www.nzgs.org

About the New Zealand Geotechnical Society

The New Zealand Geotechnical Society (NZGS) is the affiliated organisation in New Zealand of the International Societies representing practitioners in Soil Mechanics, Rock Mechanics, and Engineering Geology.

NZGS is a collaborating Technical Society of Engineering New Zealand (EngNZ).

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Foreword

This document has been developed to be used in conjunction with:

- NZS3910:2013 Conditions of contract for building and civil engineering construction
- NZS4431:2022 Engineered fill construction for lightweight structures
- The other components of the NZGS Specification series, notably:
  - NZGS_000 Standard specifications user guide
  - NZGS_100 Preliminary and general
  - NZGS_200 Ground investigations
  - NZGS_110 Method of measurement
  - NZGS_520 Reinstatement
- The project-specific details in the form of NZGS_0100P

It may be used in conjunction with other specifications where appropriate.

This document is intended to be appropriate for use as an earthwork's construction specification on most residential or light commercial development projects with common soil and rock types found in New Zealand, with or without project-specific details, as determined by the Geotechnical Designer.

The document could be adapted for use as an earthwork's construction specification on larger earthworks and multidisciplinary projects, with or without project-specific details, as determined by the Geotechnical Designer.

Acknowledgements

This document was developed by a volunteer subcommittee from the NZS4431 working group comprising Ross Roberts, William Gray, Tony Kao, Tim Farrant, Guy Forrest, Chris Massey, Barbara Rouse, Andrew Rose, Sally Hargraves, Tony Fairclough, Simon Barber, Mark Stringer, and Ali Shokri.

A technical review has been undertaken by Richard Neate and Hayden Bell of GHD Ltd.

Specialist review and comments on Version 0.2 were sought and received from Burt Look.

The document development was supported by Auckland Council, the Ministry of Building, Innovation and Employment (MBIE), and NZGS.

Document Version 0.2 was released for NZGS membership and industry review in mid-2022.

Feedback was subsequently received from the following individuals and organisations:

- Nick Barounis of Cook Costello Ltd.
- Burt Look.

This document Version 0.3 acknowledges and responds to feedback received.

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NZGS_510.1 General

NZGS_510.1.1 Introduction and scope

This specification details requirements for earthworks only. Where the Contract includes other works, appropriate sections from this document can be included in the project-specific preliminary and general specifications for the Contract.

This specification shall either be used in conjunction with NZGS_100 “Preliminary and General”, or relevant sections from that specification shall be incorporated into the main Contract specification.

> Notes for guidance are presented in this document in blue boxes like this example. They do not form part of a specification or Contract.

This document shall be read together with all documents forming part of the Contract.

> The order of precedence for the documents that together form a Contract, including the specification(s), should be defined in the Contract.
>
> NZGS_000.1.3 describes the recommended taxonomy and numeration for the NZGS Specification based on the UK Civil Engineering Standard Method of Measurement Revision 3 (CESMM3). These have not been repeated here to avoid contradiction.

NZGS_510.1.2 Standards, Codes of Practice and Guidelines

All works shall comply with the current versions of the minimum standards, codes of practice and guidelines set out in:

- NZS4431 Engineered fill construction for lightweight structures
- NZS4402 Methods of testing soils for civil engineering purposes
- NZS4404 Land development and subdivision infrastructure
- NZS3604 Timber framed buildings
- NZS4229 Concrete masonry buildings not requiring specific engineering design
- NZGS Guideline for the Field Description of Soil and Rock
- WorkSafe NZ Code of Practice for excavations and shafts

When the minimum standards, codes of practice and guidelines above are referred to elsewhere in this document, abbreviations are used. For example, NZS4431 Engineered fill construction for lightweight structures is NZS4431, NZGS Guideline for the Field Description of Soil and Rock is NZGS Guideline (Soil and Rock) and WorkSafe NZ Code of Practice for excavations and shafts is WorkSafe NZ CoP.

When updates to these minimum standards, codes of practice and guidelines have been published these shall take precedence.

Additional standards (including client or region-specific requirements) shall be defined in the project-specific specification.

In the case of any contradictions, the following order of precedence shall be applied (items higher up list take precedence over items lower down list):

- NZGS_0510P (project-specific Earthworks specification)
- NZGS_0510 (NZGS Earthworks specification)
- NZS4431

Where any parties involved in the works identify that the specified works would fall below the minimum standards set out in NZS4431 they shall inform the Engineer, Geotechnical Designer, and the Client. Work may then only continue if the Engineer, Geotechnical Designer and Client agree in writing that a lower standard is acceptable.

NZGS_510.1.3 Preliminary and General

Refer NZGS_0100 for preliminary and general support for the Contract, including definitions and abbreviations, quality assurance, safety, site management and other requirements.

These have not been repeated here to avoid contradiction.

NZGS_510.2 Classification of soil and rock material

NZGS_510.2.1 Purpose

This section allows the classification of soil and rock materials, using the NZGS Guideline (Soil and Rock), sourced from excavations or stockpiles for use in the construction of new engineered fill

The soil and rock classifications can be further categorised and used for payment purposes, when allowed for in the Contract.

Refer also NZGS_110, specifically NZGS_110.4.2, and the Project-Specific Specification NZGS_110P.

NZGS_510.2.2 General requirements

Soil and rock materials proposed for use in the construction of a new engineered fill shall be classified as follows, unless otherwise required in the Contract:

- Source material type
- Material condition
- Fill use type

Soil and rock materials which will not be used in a new engineered fill construction but may be used for other purposes such as landscape fill can be classified by source material type and material condition only.

Tables A1 and A2 in the Technical Appendix provide specific information about the soil and rock materials for use in new engineered fill and landscape fill construction for residential or light commercial projects using selected site-won or imported materials.

Tables A1 and A2 include test requirements to be used by the Contractor to successfully source, classify, place and compact soil and rock materials in accordance with NZS4431.

All Contract and site-specific test requirements shall be included in the Contractor's ITP.

Additional materials may be defined by the Geotechnical Designer in the Project-Specific Specification Tables A1P and A2P.

> The Geotechnical Designer will investigate and design the earthworks in response to the local geological, ground and groundwater conditions, the nature and condition of the expected new engineered fill material(s), and the specific project requirements.
>
> Where the project is being undertaken for the purposes of lightweight residential or commercial construction, in most circumstances the requirements of NZS4431 should be met in full.
>
> For well understood soils, acceptable earthwork and foundation outcomes maybe achieved with alternate, possibly less rigorous material test requirements than defined in Tables A1 and A2, when based on well documented investigation and design advice by the Geotechnical Designer,

and provided that robust evidence of agreed alternate compliance targets for the purposes of lightweight residential or commercial construction is documented in the Earthworks Completion Report (refer NZS4431, Section 7).

For other purposes, lower (or higher) performance requirements may be appropriate, when based on well documented investigation and design advice by the Geotechnical Designer.

For landscape fill, the Geotechnical Designer will determine for what purposes testing is needed, based on the project specific requirements. Acceptable landscape earthwork outcomes maybe achieved with alternate, possibly less rigorous material test requirements than defined in Tables A1 and A2, when based on well documented investigation and design advice by the Geotechnical Designer, and provided that robust evidence of agreed alternate compliance targets is documented in the Earthworks Completion Report (refer NZS4431, Section 7).

NZGS_510.3 Source Material Type

NZGS_510.3.1 Primary categories

Source materials (including site-won, stockpiled, and imported soil and rock materials, or manufactured equivalents) shall be classified as defined in Section 3 of NZS4431 into the following primary categories:

- Material type T (topsoil)
- Material type F (fine-grained soil)
- Material type I (intermediate-grained soil)
- Material type C (coarse-grained soil or aggregate)
- Material type R (rock)
- Material type M (manufactured)

A numerical suffix may be added to each of these categories to allow for project-specific or site-specific requirements. This suffix may be sequential numbers or a more descriptive term reflecting the name in common usage.

> Examples of such categorisation are provided in NZS 4431, Clause C3.3.1.

The Geotechnical Designer shall ensure that the ways in which different soil and rock materials have been incorporated into the design and are to be used in construction are confirmed by way of the Fill Use Type descriptions (refer NZGS_510.5 that are clearly identified on the drawings and in the specification.

The descriptions of the primary categories may be changed by the Geotechnical Designer in response to project specific material requirements. Any such changes must be presented as an alternative Fill Use Type with a different name. The Geotechnical Designer shall confirm that any such alternative Fill Use Types will meet the requirements of the design and Section 3.5 of NZS4431. Any changes shall then be incorporated into the design of the engineered fill and subsequently confirmed in the Project-Specific Specification (refer NZGS_110P) and the Contract.

NZGS_510.3.2 Material Type T (topsoil)

Material Type T (topsoil) is a natural material that comprises the ‘O’ and ‘A’ horizons.

> For more information about topsoil, including descriptions of the O and A horizons, refer NZS4431, Clause C3.3.2.

NZGS_510.3.3 Material Type F (fine-grained soil)

Material Type F is a natural soil material with more than 35% material passing the 63µm sieve.

NZGS_510.3.4 Material Type I (intermediate soil)

Material Type I is a natural soil material with between 15% and 35% material passing the 63µm sieve.

NZGS_510.3.5 Material Type C (coarse-grained soil)

Material Type C is a natural soil material with no more than 15% by mass passing the 63µm sieve.

NZGS_510.3.6 Material Type R (rock)

Material Type R is any natural material described as rock using the NZGS Guideline for the Field Description of Soil and Rock

> Rock can be further categorised as R1, R2 and R3 for payment purposes, refer NZGS_0110, specifically NZGS_110.4.2.
>
> The rock excavation production rates given in NZGS_110.4.2.2 may be changed by the Geotechnical Designer in response to project specific material requirements (refer NZGS_110P) and when based on robust, documented evidence.

NZGS_510.3.7 Material Type M (manufactured)

Material Type M is manufactured material specifically created or modified for the purpose of earthworks construction, as defined on the drawings and in the specification. Type M material could include crushed concrete; recycled asphalt; natural materials that have been mixed with cement or other binding agents to change their physical properties.

NZGS_510.4 Material condition

NZGS_510.4.1 Condition suffixes

The condition of each soil and rock material shall be described as one or a combination of the following suffix codes alongside the source material classification given in NZGS_510.3.1.

- A (acceptable).
- W (wet).
- D (dry).
- U (unsuitable).
- X (restricted).

The condition shall be assigned when the material is excavated or taken from stockpile for use in the new engineered fill. The suffix descriptor shall be modified if the condition changes whether this change be through treatment or the result of natural changes.

Whenever the Contractor wishes material excavated or taken from stockpile for use in the new engineered fill to be classified as other than A, the Contractor shall notify the Engineer in writing immediately seeking a reclassification decision which shall not be unreasonably withheld.

NZGS_510.4.2 Material Condition A (acceptable)

Condition A material is material which can be placed and compacted using normal engineering practice/methods and which does not fall into any other material condition.

NZGS_510.4.3 Material Condition W (wet)

Condition W material is significantly wetter than optimum moisture content (OMC) and likely to need controlled drying before placement and compaction.

The Contractor shall employ a Recognised Laboratory to determine the OMC using the specified compaction effort from NZS 4402, Test 4.1.1, Test 4.1.2, or Test 4.1.3.

The Contractor shall then seek confirmation from the Engineer in writing of the moisture content beyond which a particular soil and rock material is too wet to be successfully compacted. Materials with moisture contents at or exceeding this limit shall be classified as wet (W).

In the absence of project-specific limits, materials shall be classified as wet (W) if their moisture content is 4% or more above the OMC for that material or mixture of materials as determined by laboratory testing.

NZGS_510.4.4 Material Condition D (dry)

Condition D material is significantly drier than OMC and likely to need controlled wetting before placement and compaction.

The Contractor shall employ a recognised laboratory to determine the OMC using the specified compaction effort from NZS 4402, Test 4.1.1, Test 4.1.2, or Test 4.1.3.

The Contractor shall then seek confirmation from the Engineer in writing of the moisture content below which a particular soil and rock material is too dry to be successfully compacted. Materials with moisture contents at or below this limit shall be classified as dry (D).

In the absence of a project-specific limit, materials shall be classified as dry (D) if their moisture content is 2% or more below the OMC for that material or mix of materials as determined by laboratory testing.

NZGS_510.4.5 Condition U (unsuitable)

Condition U material is unsuitable for use in its current form because it has one or more physical and/or chemical properties that make it unsuitable for placement in a new engineered fill.

Sections 3.4.5 and 3.4.6 of NZS4431 describe the physical and chemical properties likely to render the material as being unsuitable, and further subdivide Condition U into U1 (physically unsuitable) and U2 (chemically unsuitable).

The U1 and U2 descriptions may be used by the Geotechnical Designer, Contractor, and the Engineer, in response to material and project-specific requirements, as outlined in the design of the new engineered fill and subsequently confirmed in the specification and the Contract.

Otherwise, Condition U will describe all material that is unsuitable for use in its current form.

Condition U material may be processed by mechanical, chemical, or other means to render the material suitable for use. If the Engineer agrees processing is successful, the material may then be reclassified.

NZGS_510.4.6 Condition X (restricted)

Condition X materials are those with recognised construction difficulties, longer-term performance deficiencies, or other complicating factors.

Condition X material may be able to be used in a new engineered fill under project-specific design and construction conditions agreed with the Geotechnical Designer and approved by the Engineer.

> The Geotechnical Designer should refer to Section 3.4.7 of NZS4431 for guidance on the physical properties likely to render the material as being restricted.
>
> Condition X material may be processed by agreed mechanical, chemical, or other means to render the material suitable for possible reclassification and use in a new engineered fill construction.

NZGS_510.5 Fill use type

The fill use type shall be used to confirm where and how materials are used in the construction of engineered fill, in accordance with the design and as detailed on the engineering drawings.

> Refer to NZS4431, Clause C3.5 for guidance on fill use types.

NZGS_510.6 Excavation

NZGS_510.6.1 General

Excavation to project design levels and for the supply of materials for new engineered fill construction involves several inter-related construction operations needed to achieve the specified outcomes including, but not limited to excavation; benching; trimming; foundation treatments (if specified or required).

All excavation works shall be undertaken in accordance with the requirements of NZS 4431.

Materials encountered in excavations and intended for use as fill shall be handled carefully so that they meet the specified classification outcomes from NZGS_510.3, 510.4 and 510.5.

NZGS_510.6.2 Safe practices

Safe excavation practices shall always be followed in accordance with the WorkSafe NZ CoP or as otherwise approved by the Engineer.

NZGS_510.6.3 Excavation management

The batter slopes in cuttings shall be constructed in accordance with the design, as detailed on the engineering drawings or as directed by the Engineer based on observations from on-going site inspection. The Contractor’s planning and implementation of the excavation and cartage operations shall always optimise the use of the available soil and rock materials and prevent unplanned strength loss due to poor management of the earthwork's operations.

Where material is being excavated as cut to fill, cut to stockpile, or cut to waste, the excavations shall prevent the mixing of incompatible materials unless otherwise specified or as directed by the Engineer.

New engineered fill construction operations shall be undertaken preferably as cut to fill. Where double handling is necessary because of the location of material in the borrow areas and cut batters, the works shall be cut to stockpile followed by cut stockpile to fill.

If stockpiling of excavated materials is either specified (into a nominated stockpile area), directed by the Engineer, or is otherwise undertaken by the Contractor during the execution of the earthworks the Contractor shall always use the material in a manner that optimises condition and minimises strength loss.

Should the Contractor choose to use material stockpiling in the operations rather than place material directly into the new engineered fill when this is possible, the works can be treated as a cut to fill operation only for payment purposes.

The Contractor shall take all practicable steps to protect the soil and rock material from unplanned changes in material classification which may compromise later reuse.

The Contractor shall ensure that materials selected by the Geotechnical Designer for use in specific areas of the new engineered fill construction are protected and used for this purpose.

> Examples of specific areas include shear key, new building platform and pavement subgrade construction.

All excavation and blasting works shall be carried out in a manner that limits overbreak and slips as far as is reasonably practicable. Refer also NZGS 510.6.6.

The Contractor shall take all practicable steps to prevent damage to cuts and fills.

NZGS_510.6.4 Topsoil stripping

The depth of topsoil stripped within the limits of the earthworks shall be in accordance with the design and as detailed on the engineering drawings, or as directed by the Engineer.

The Contractor shall take all practicable steps to protect topsoil from contamination during the works.

Topsoil shall, wherever practicable, be re-used immediately after stripping. Topsoil stockpiling, if required, shall be in accordance with NZGS_510.6.12.

NZGS_510.6.5 Ripping productivity trials

Rock materials shall be classified for payment purposes as either Type R1, R2 or R3 as described in NZGS_110.

Where agreement cannot otherwise be reached with the Contractor on classification of excavated materials as Type R1, R2 and R3, ripping productivity trials shall be carried out by the Contractor under the supervision of the Engineer, and with the full support of the Contractor, using a suitable crawler tractor or tracked excavator.

> The rock excavation production rates given in NZGS_110.4.2.2 and used to classify rock as Type R1, R2 or R3 for payment purposes are based on published evidence. These may be reviewed and subsequently changed by agreement and in response to project specific material evidence and testing (refer NZGS_110P).

NZGS_510.6.6 Rock blasting

The Contractor shall be responsible for planning, implementing, and monitoring all rock blasting of Type R3 material, including but not limited to planning drill patterns, charge sizes, rock fall collection and transportation operations, providing appropriate health and safety protection, and for obtaining all necessary regulatory approvals.

The procedures for planning, implementing, and monitoring of all blasting operations shall be documented in the Contractor's Quality Management Plan (QMP).

When planning, implementing, and monitoring blasting work the Contractor shall ensure that the charges used are able to deliver the required outcomes without unnecessary blast or gas pressure damage during or following the works.

Should the Contractor choose to use drill and blast techniques to speed up a normal excavation process, and the material being excavated could have been productively ripped and moved as either Type A, R1, or R2 material, then the material will not be re-classified as R3.

> Regulatory approval for blasting operations may include conditions for monitoring environmental effects of the blasting operations (air blast, noise, dust, and vibration), ensuring that adjoining landowners and other affected parties are notified in advance of blasting operations and are not otherwise adversely affected.

NZGS_510.6.7 Cut batters

Cut batters, including those achieved by blasting (refer to NZGS_510.6.6) shall be constructed to the specified lines, levels, and tolerances as designed, shown on the drawings, or as directed by the Engineer, using suitable excavation equipment that allows the Contractor to present stable and resilient cut shapes, that do not pond water or are vulnerable to surface erosion.

Cut batters shall be cleared of loose or unstable material progressively as the excavation proceeds.

The tops of cuttings shall be rounded and drained to the specified dimensions, shown on the drawings, or as directed by the Engineer.

> Batters generally require progressive shaping at the end of cuttings owing to the likely presence of less stable materials and the need to safely transition in with the surrounding ground contours.

Where cut batters are designed to be re-vegetated, they shall be left with a roughened surface texture to assist with re-vegetation unless otherwise specified, shown on the drawings, or directed by the Engineer.

NZGS_510.6.8 Borrow areas

Borrow areas shall be opened and excavated in a manner that allows work to progress efficiently, does not pond water or are vulnerable to surface erosion. The borrow areas shall be at the specified location(s), shown on the drawings, or as directed by the Engineer. When use of borrow areas is complete, the borrow areas shall be restored as specified, shown on the drawings, or as directed by the Engineer.

In the absence of any specific design or direction from the Engineer, borrow areas shall be cleared of loose or unstable material, shaped to present stable and resilient shapes that transition into the surrounding ground contours and left with a roughened surface texture to assist with re-vegetation with matching plant or grass species.

NZGS_510.6.9 Surface water drains

Surface water drains shall be formed during excavation and temporary works to effectively manage stormwater and surface water discharge and mitigate against flooding and surface erosion.

In the absence of any specific design or direction from the Engineer, surface water drains shall:

- Have even and true grade(s) so that water will not stand in any part.
- Drain to outlets onto stable ground, clear of any deleterious materials.

Surface reinstatement shall limit the potential for erosion during the works. Where borrow areas are designed to be re-vegetated, they shall be left with a roughened surface texture to assist with re-vegetation or otherwise with matching plant or grass species unless otherwise specified, shown on the drawings, or directed by the Engineer.

Material excavated from below the ground water table shall be utilised or disposed of as appropriate to the classification and condition (refer to NZGS_510.3, 510.4 and 510.5).

NZGS_510.6.10 Excavation level and overbreak

Excavation shall be to the specified formation lines, levels, and tolerances as specified, shown on the drawings, or directed by the Engineer.

Where excavation tolerances are not specified, the following tolerances shall apply:

- Subgrades: on level ground, ±25mm; on slopes ±50mm.
- Cuttings: +25mm to –75mm
- Hard rock excavations: ±250mm

The Contractors earthworks planning, operations and site management shall as far as reasonably practicable prevent overbreak.

If overbreak occurs, excavated material shall be utilised or disposed of as appropriate to the classification and condition (refer to NZGS_510.3, 510.4 and 510.5) or as directed by the Engineer.

NZGS_510.6.11 Weather and trafficking protection

At the end of each day of construction and at any time in anticipation of adverse weather, the Contractor shall take all practical steps to ensure that the current as-built earthwork surfaces (both cuts and fills) are rolled smooth and graded to discharge stormwater onto stable ground without causing an erosion or surplus water/silt nuisance and in accordance with all conditions of consent.

Whenever construction traffic needs to use live construction surfaces as haul or access roadways, excavations shall be left a minimum of 0.5m above the design surface or cut batter surface, and fill areas left a minimum of 0.3m below the underside of the design surface until all use by construction traffic comes to an end, or as directed by the Engineer.

NZGS_510.6.12 Stockpiling and handling of earthworks materials

The requirements for stockpiling and handling of earthwork materials on site shall be in accordance with Section 4 of NZS4431.

The Contractor shall control all stockpiling and temporary material storage operations to ensure the safe utilisation of the site without interfering with the passage of traffic and/or pedestrians or affecting the stability of slopes, structures, or excavations.

Unless otherwise specified or required by the conditions of consent, stockpiles of suitable site-won material (including topsoil) shall be held on site.

Wherever possible, material shall be handled and stockpiled in such a way as to maintain or improve the quality of material for future re-use on site, and thereby optimise use of the resource.

Separate stockpiles shall be used for each soil and rock material (refer NZGS_510.4), specified and approved mixture(s) of materials, or specified and approved fill use type(s) (refer NZGS_510.5).

Stockpiles shall be located on stable ground with sloped faces that prevent ponding.

Erosion and sediment controls shall be prepared and maintained around all stockpiles as specified, and in accordance with the conditions of consent.

Where erosion and sediment control details are not specified or detailed in the conditions of consent one or more of the following erosion control measures and edge to edge spacings shall apply.

For slopes up to 5%:

- Vegetation buffers, maximum spacing 75m
- Contour drains, maximum spacing 50m
- Silt fences, maximum spacing 25m

For slopes up to 10%:

- Vegetation buffers, maximum spacing 50m
- Contour drains, maximum spacing 40m
- Silt fences, maximum spacing 15m

For slopes up to 15%:

- Vegetation buffers, maximum spacing 30m
- Contour drains, maximum spacing 30m
- Silt fences, maximum spacing 10m

Vegetation buffers shall be a minimum 10m wide strips of thick grass to trap sediment adjacent to waterways.

Contour drains shall be a minimum 250mm deep excavated ditch or elevated drain formed with compact earth, to control and divert waterflow.

Silt fences shall be a minimum 0.5m high posts supporting site and ground compatible geosynthetic filter fabric buried at least 250mm into the ground along the base.

Stockpiles which are to be in place for more than 14 days, or when heavy rain is forecast, shall have the surface adequately sealed to prevent inundation or erosion and to maintain the viability and stability of stockpiled material.

When the Contractor has stockpiled material inappropriately and in the opinion of the Engineer, the material has become unsuitable for reuse, the material shall be cut to waste (refer NZGS_510.5.13) and replaced as directed by the Engineer.

Topsoil shall be carefully stockpiled and protected to maintain or improve the quality of the organic material for future re-use on site. Topsoil stockpiles shall not be higher than 3 m, not kept for more than six months, nor over compacted.

NZGS_510.6.13 Disposal of unwanted material (cut to waste)

The Contractor shall ensure that the quantities of cut to waste is minimised as far as reasonably practicable to make the best possible use of the available soil and rock materials.

The locations of cut to waste disposal areas shall either be as specified, identified on the drawings or directed by the Engineer or shall be at alternative locations determined by the Contractor.

Should the Contractor plan to use alternative dumpsites either on or off site, the Contractor shall obtain and provide evidence to the Engineer that all necessary site-specific Resource Consents and Land Entry Approvals have been obtained and conditions of consent can be met before work starts.

The Contractor shall plan and undertake all cut to waste operations to make effective use of the disposal areas. Disposal areas shall be shaped during the progress of the work to conform to the contours of the adjoining land, benched, drained, and otherwise protected to prevent ponding and surface water erosion, as specified, or as directed by the Engineer, in accordance with the conditions of consent.

> Temporary and permanent works to protect disposal sites from flooding, erosion and sediment damage can incorporate geosynthetic materials (e.g. geofabric filters, surface erosion matting, rock fall netting, filter wrapped panel and subsoil drains), surface drainage and revegetation with matching plant or grass species (refer NZGS_510.6.12).

Topsoil shall be uplifted, used or stockpiled separately for re-use (refer to NZGS_510.6.12).

NZGS_510.7 Fill construction

NZGS_510.7.1 General

The Contractor shall meet the requirements of NZS4431 for all engineered fill construction, unless otherwise specified or directed by the Engineer.

Unless otherwise specified or directed by the Engineer, the objectives of the fill construction shall be to:

- Optimise the use of the available soil and rock materials within the designated construction site or from approved borrow areas
- Limit future settlement under imposed or self-weight loads
- Control fill permeability to achieve the intended purpose
- Achieve the specified material strengths in support of long-term stable fill slopes and building platform foundations in accordance with the design intent.

NZGS_510.7.2 Fill management

Soil and rock materials used as fill material shall be spread and compacted in layers of uniform quality and thickness, in a manner that avoids segregation or contamination.

The thickness of each layer shall be managed to ensure that the specified compaction outcomes are always achieved for the full depth of the layer.

Unless otherwise specified or directed by the Engineer, fill batters shall be adequately compacted beyond the limits of the design profile as the filling proceeds and then trimmed back to the lines and levels shown on the drawings. The fill shall then present a stable and resilient shape, that does not pond water or undergo erosion.

Construction haul roads shall be located outside the limits of the new engineered fill, unless specifically part of the design, or otherwise approved by the Engineer.

In any case, the movement of construction vehicles and other traffic over new engineered fill construction shall be continuously controlled to prevent surface damage and/or overstressing of soil.

Engineered fill construction shall be a continuous operation unless otherwise specified or directed by the Engineer. The resulting new engineered fill(s) and new building platform(s) shall meet all the requirements of the design.

If material which has already been placed in the fill is considered by the Engineer to be too wet then, the Contractor shall either:

- Dry or mix the material so that it is suitable to remain as fill, or
- Excavate the deleterious material to waste (refer NZGS_510.6.13) and replace with suitable fill material.

When drying is necessary, it shall be carried out to allow the full depth of the layer to dry uniformly. Drying and subsequent compaction operations shall only be carried out under favourable weather conditions.

Wetting of material which has become too dry for use in the fill shall be carried out with sprinkling or direct injection equipment in a manner that ensures uniform and controlled distribution of water. After wetting, the material shall be conditioned to ensure a uniform distribution of moisture throughout the layer.

If the condition of in-place fill has deteriorated (for example where the fill has become either too wet or too dry), and remedial works are required (including but not limited to those described above) these shall be undertaken as specified or directed by the Engineer.

At the end of each day of construction and at any time in anticipation of adverse weather, the current as-built fill surfaces shall be rolled smooth and graded to discharge water evenly onto stable ground clear of the new engineered fill.

NZGS_510.7.3 Choice of compaction plant

When choosing the type and size of compaction plant to be used in the earthworks, the Contractor shall carefully consider the type and condition of soil/rock or mix of soils/rocks being worked, the location of each fill layer in the new engineered fill, and the planned depth of each successive layer to use the most suitable compaction plant to deliver the specified compaction outcomes.

NZGS_510.7.4 Compaction trials

The Contractor shall complete on-going compaction trials over the duration of the engineered fill construction to demonstrate that the specified compaction outcomes can and continue to be delivered in an effective and efficient manner using the available compaction plant.

The Contractor shall complete compaction trials whenever there are changes in the soil and rock material being used in the new engineered fill to demonstrate specified compaction outcomes can and continue to be met.

The Contractor shall be responsible for planning and delivering the compaction trials and associated earthworks testing, as documented in the approved ITP.

The results from each compaction trial shall be reported to the Engineer before any subsequent earthworks are undertaken. The Contractor will be expected to use the outcomes of the compaction trials to support effective and proactive planning and implementation of the compaction works, and ensuring that all staff, including field operations staff, are aware of the expected compaction outcomes and how to achieve these effectively.

NZGS_510.7.5 Site preparation

The requirements of Section 4.3 of NZS4431 shall be met, including site clearance; erosion and sediment controls; topsoil stripping; slope preparation including benching; cleared ground compaction; surface drainage; subsurface drainage, unless otherwise specified or directed by the Engineer

NZGS_510.7.6 Fill placement and compaction

The requirements of Section 4.4 of NZS4431 shall be met, including fill placement and conditioning; compaction; settlement markers; weaving; temporary fill works, unless otherwise specified or directed by the Engineer

Quality assurance of the new engineered fill placement and compaction works shall be in accordance with the Contractor's approved QMP and ITP (refer NZGS_100).

Fill placement and compaction acceptance criteria shall in principle be as presented within the A1 Tables of this specification, or the A1P Tables in the Project-Specific specification where relevant.

The Geotechnical Designer is expected to define appropriate testing for the materials to be used. These shall be defined in the Project-Specific Specification.

A traditional approach to the measurement and control of compaction outcomes in soil and rock fill materials in New Zealand typically uses Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) targets derived from laboratory and field compaction tests.

The MDD/OMC approach alone has been found from practical experience to not suit some New Zealand soils (for example, clay rich fine-grained soils in the Auckland and Bay of Plenty regions).

Soil and rock material properties that can also together be measured and then used to confirm whether the as placed new engineered fill achieves strength and compaction conditions include:

- Shear Strength, Moisture Content and Air Void
- Surface layer(s) deflection under static or dynamic load, Moisture Content and Air Void
- Surface layer(s) stiffness modulus under static or dynamic load, Moisture Content and Air Void

The Geotechnical Designer should determine and document which property or combination of properties gives the best measure of compaction outcomes for selected soil and rock materials.

For example, earthworks involving fill construction with clay rich materials benefits from ongoing testing and control of moisture content, and in-situ measurement of as-compacted air voids and shear strength. It is common for moisture content testing to be undertaken on "grab" samples returned to the laboratory for oven dry back testing, with results processed and analysed daily, to

support ongoing calibration of on-site testing from Nuclear Densometer moisture meter or 'rapid microwave' tests, and thereby enable timely and informed decision making on site.

Results from in-situ testing of air voids by calibrated Nuclear Densometer and alongside this shear strength measurement using a Hand Shear Vane can also be processed and analysed daily to enable timely and informed decision making on site.

NZGS_510.7.7 Finishing works

Fills should be left in a stable condition in accordance with Section 4.5 of NZS4431, unless otherwise specified or directed by the Engineer

NZGS_510.7.8 Engineered fill certification

When the new engineered fill construction is deemed by the Contractor to be complete for the works (or part thereof), the Contractor shall inform the Engineer, and shall supply the evidence of compliance with the specification including:

- Signed, complete ITP
- All in-situ and laboratory test results.

Field and laboratory test results shall be provided in accordance with Section 5.3.5 of NZS4431.

The Engineer will use the evidence provided by the Contractor, and independent Random Verification Testing (RVT), to either confirm that the new engineered fill (or part thereof) meets the design intent and specification, or if additional construction and testing works are required, and inform the Contractor accordingly.

As-built survey and plans shall be in accordance with Section 6 of NZS4431.

Final documentation (Earthworks Completion Report and Certification) shall be in accordance with Section 7 of NZS4431.

The Engineer will not unreasonably withhold certification of the works (or part thereof) if the Contractor has provided sufficient information from which a sound, technical decision can be made.

NZGS_510.8 Earthworks maintenance

The Contractor shall maintain the completed works (or parts thereof), including:

- all earthworks
- new grassing and vegetation cover
- all temporary and permanent environmental protection measures

until either they are covered or otherwise used for later construction or building works or until the end of the specified maintenance period, whichever comes first.

The Contractor shall ensure that any certified engineered fill is protected and not able to deteriorate through excessive drying, wetting or contamination.

Deleterious material from any erosion, over slips and debris flows shall be cut to waste (refer NZGS_510.6.13) or as directed by the Engineer. Material recovered from slips which occur prior to completion of a new engineered fill shall be treated as earthworks cut to waste (where the material is no longer suitable, or where there is no reasonable location to use the material) or as cut to fill where appropriate.

Areas affected by any erosion, over slips and debris flows shall be shaped, trimmed, and repaired to return them to the specified condition or as directed by the Engineer. The extra work involved shall be treated as a variation (refer NZGS_100, 110), unless caused by events resulting from the Contractor's poor site management. In such a case the required works will be part of the Contractor's on-going maintenance obligations and will not be separately compensated.

The Engineer shall be immediately notified if any areas of weakness appear in the new engineered fill either before, or during, the maintenance period. The Engineer will then, in consultation with the Geotechnical Designer, determine what remedial works are required (if any), including but not limited to a new testing under the Contractor's ITP.

All remedial work at this stage shall be treated as a variation (refer NZGS_100, 110), unless the damage has been caused by events resulting from the Contractor's poor site management, including allowing traffic onto the surface without approval, poor surface drainage, or failing to comply with the minimum requirements for classification and testing of fill materials. In such a case the required works will be part of the Contractor's on-going maintenance obligations and will not be separately compensated.

NZGS_510.9 Minimum requirements

Tables A1 and A2 provide templates for the minimum requirements for the classification for source material type, material condition and fill use type acceptance testing for soil and rock used in new engineered fill construction, including for certification.

The tables are expanded from those presented in NZS4431.

The compaction acceptance tests shown are those used routinely in earthworks projects (e.g. field water content, density, air void and shear strength as appropriate), and emerging test alternatives. The Geotechnical Designer shall determine if and how the emerging test options can be used.

All test results shall be presented in the current version of the AGS_NZ geotechnical data transfer format (refer NZGS website).

The Geotechnical Designer will investigate and design the earthworks in response to the local geology, ground and groundwater conditions, the nature and condition of the expected fill material(s), and the specific project requirements.

Where the project is being undertaken for the purposes of lightweight residential or commercial construction, the end-product earthworks should meet the requirements of NZS4431, or as otherwise agreed and directed by the Geotechnical Designer, Engineer, and Certifier.

> For well understood soils, acceptable earthwork and foundation outcomes maybe achieved with lower (or higher) or alternative material test requirements than those given in Tables A1 and A2.
>
> For example, in Auckland clay rich soils, experience can show that adequate foundation support for lightweight residential or commercial construction can be achieved with lower in-situ shear strengths, thereby enabling an alternative approach in this case.
>
> If the alternative approach is agreed by the Geotechnical Designer, Engineer, and Certifier, this shall be based on well documented investigation and design advice by the Geotechnical Designer and be supported with robust evidence from testing by the Contractor (ITP) and Engineer (RVT) demonstrating that agreed alternative compliance targets can be met and are documented in the Earthworks Completion Report.

Table A1.1 - Bulk 4431 fill (F-A)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	F-A (fine grained – acceptable)		
	Typical use description	General fill for residential or light commercial earthworks using selected site-won or imported materials		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 Test 3.8, NZS 4402 Test 2.8.1)	1 for each source 1 for each change in material	As per Table A2	Completed before works begin (and during the works if the source or material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402 Test 4.1.1, NZS 4402 Test 4.1.2)	1 for each source 1 for each change in material	OMC and MDD determined	Completed before works begin (and during the works if the source and material changes) to determine OMC and MDD for later use in compaction acceptance testing
	Water content (NZS 4402 Test 2.1)	1 for each source 1 for each change in material	Between OMC – 2% and OMC + 4%	Ongoing during the works to confirm conditioning requirements
	Solid density of soil particles (NZS 4402 Tests 2.7.1 or 2.7.2)	1 for each source 1 for each change in material	Solid density determined	Used to define the solid density of aggregate particles for later use in compaction acceptance testing with in-situ nuclear moisture-density gauge (NDM) Can be omitted where the Contractor provides a reliable estimate for the specific source material
	Liquid and plastic limit (NZS 4402 Tests 2.2, 2.3 and 2.4)	1 for each source 1 per 4000m³ 1 for each change in material	Plasticity index < 25% Liquid limit < 50%	Completed before works begin (and during the works if the source or material changes) to confirm the material's suitability
Placement requirements	Unless demonstrated otherwise by site trials and approved by the Engineer, loose layer thickness >100mm and < 250 mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Field water content, density, and air void (NZS 4402 Test 2.1 and NZS 4407 Tests 4.1, 4.2 and 4.3)	2 per 1000m³ Minimum 2 per lift	-2% below to 4% above OMC ≥ 95% maximum dry density (MDD) < 10% air voids	Earthwork's supervision involving new engineered fill construction with clay rich materials benefits from ongoing testing and control of moisture content, compacted air voids and shear strength. Locations as agreed by the Certifier. **For emerging test alternatives refer the comment box below.**
	Shear strength and field water content (NZGS Guideline for handheld shear vane test and NZS 4402 Test 2.1)	5 per 1000m³ Minimum 5 per lift	Lowest value >150 kPa -2% below to 4% above OMC	

Emerging test alternatives:

Plate load test (PLT) to DIN 18134 or Light Falling Weight Deflectometer (LFWD) to ASTM E2835-11, when specified by the Geotechnical Designer and agreed by Engineer and Certifier.

Minimum and acceptable range for in-situ dynamic soil modulus E_vD for the soil and rock type. For well compacted soils the ratio of E_v2 over E_v1 is greater than 1 and less than 2.6.

Expected test frequency minimum 5 per 1000m³ and minimum 5 per lift.

Can be used in combination with calibrated continuous compaction control (CCC).

Useful reference: Barounis, N. & Smith, T. (2017) - Proc. 20th NZGS Geotechnical Symposium

Table A1.2 - Bulk 4431 fill (I-A)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	I–A (intermediate – acceptable)		
	Typical use description	General fill for residential or light commercial earthworks using site-won or imported materials		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 Test 3.8, NZS 4402 Test 2.8.1)	1 for each source 1 for each change in material	As per Table A2	Completed before works begin (and during the works if the source or material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402 Test 4.1.1, NZS 4402 Test 4.1.2)	1 for each source 1 for each change in material	OMC and MDD determined	Completed before works begin (and during the works if the source and material changes) to determine OMC and MDD for later use in compaction acceptance testing
	Water content (NZS 4402 Test 2.1)	1 for each source 1 for each change in material	Between OMC – 2% and OMC + 4%	Ongoing during the works to confirm conditioning requirements
	Solid density of soil particles (NZS 4402 Tests 2.7.1 or 2.7.2)	1 for each source 1 for each change in material	Solid density determined	Used to define the solid density of aggregate particles for later use in compaction acceptance testing with in-situ NDM Can be omitted where the Contractor provides a reliable estimate for the specific source material
	Liquid and plastic limit (NZS 4402 Tests 2.2, 2.3 and 2.4)	1 for each source 1 per 4000m^3 1 for each change in material	Plasticity index < 25% Liquid limit < 50%	Completed before works begin (and during the works if the source or material changes) to confirm the material's suitability
Placement requirements	Unless demonstrated otherwise by site trials and approved by the Engineer, loose layer thickness >100mm and < 250 mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Field water content, density, and air void (NZS 4402 Test 2.1 and NZS 4407 Tests 4.1, 4.2 and 4.3)	2 per 1000m^3 Minimum 2 per lift	-2% below to 4% above OMC ≥ 95% maximum dry density (MDD) < 10% air voids	Earthwork's supervision involving fill construction with clay rich materials benefits from ongoing testing and control of moisture content, compacted air voids and shear strength. Locations as agreed by the Certifier. **For emerging test alternatives refer the comment box below Table A1.1.**
	Shear strength and field water content (NZGS Guideline for handheld shear vane test and NZS 4402 Test 2.1)	5 per 1000m^3 Minimum 5 per lift	Lowest value >150 kPa -2% below to 4% above OMC	
	Dynamic cone penetrometer (DCP) (NZS4402 Test 6.5.2)	5 per 1000m^3 Minimum 5 per lift	≥ 5 blows per 100 mm	The DCP test is indicative only and should not be used alone for compaction compliance. DCP locations as agreed by the Certifier.

Table A1.3 - Bulk 4431 fill (C-A)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	C–A (coarse-grained – acceptable)		
	Typical use description	General fill for residential or light commercial earthworks using site-won or imported materials		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 Test 3.8, NZS 4402 Test 2.8.1)	1 for each source 1 for each change in material	As per Table A2	Completed before works begin (and during the works if the source or material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402 Test 4.1.1, NZS 4402 Test 4.1.2)	1 for each source 1 for each change in material	OMC and MDD determined for compaction acceptance testing	Completed before works begin (and during the works if the source and material changes) to determine OMC and MDD for later use in compaction acceptance testing
	Water content (NZS 4402 Test 2.1)	1 for each source 1 for each change in material	Between OMC −2% and OMC +4%	Ongoing during the works to confirm conditioning requirements
	Solid density of soil particles (NZS 4402 Tests 2.7.1 or 2.7.2)	1 for each source 1 for each change in material	Solid density determined for in-situ density testing	Used to define the solid density of aggregate particles for later use in compaction acceptance testing with in-situ NDM Can be omitted where the Contractor provides a reliable estimate for the specific source material
Placement requirements	Unless demonstrated otherwise by site trials and approved by the Engineer, loose layer thickness >100mm and <300 mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	For coarse-grained soils with maximum particle size < 65 mm, test field water content, density, and air voids (NZS 4402 Test 2. 1, NZS 4407 Test 4)	2 per 1000m³ Minimum 2 per lift	-2% below to 4% above OMC > 95% MDD < 15% air voids	Earthwork's supervision involving fill construction with coarse-grained materials benefits from ongoing testing and control of moisture content, density, and compacted air voids. Locations as agreed by the Certifier. **For emerging test alternatives refer the comment box below Table A1.1.**
	For coarse-grained soils with maximum particle size from 65 mm to 250 mm, proof-roll to target maximum calibrated relative density.	Ongoing continuous compaction control	Target minimum calibrated compaction machine specific minimum 80% relative density	
	Dynamic cone penetrometer (DCP) (NZS4402 Test 6.5.2)	5 per 1000m³ Minimum 5 per lift	≥ 5 blows per 100 mm	DCP test is indicative only and should not be used alone for compaction compliance. DCP locations as agreed by the Certifier.
	Clegg Impact test (CIV) – 4.5 kg hammer (ASTM D 5874)	5 per 1000m³ Minimum 5 per lift	CIV > 25	CIV test is indicative only and should not be used alone for compaction compliance. CIV locations as agreed by the Certifier.

Table A1.4 - Landscaping fill (F-A)

Material definition	**Fill use type**	Landscaping fill		
	Source material type	F-A (fine grained – acceptable)		
	Typical use description	General fill for landscaping in areas where no design loads will be imposed and where no infrastructure will rely on the stability of the fill. Using selected site-won or imported materials.		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 Test 3.8, NZS 4402 Test 2.8.1)	1 for each source and 1 for each change in material	As per Table A2	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402 Test 4.1.1, NZS 4402 Test 4.1.2)	1 for each source and 1 for each change in material	OMC and MDD determined	Completed before works begin (and during the works if the material changes) to determine OMC and MDD for later use in compaction acceptance testing
	Water content (NZS 4402 Test 2.1)	1 for each source and 1 for each change in material	Between OMC − 2% and OMC + 4%	Ongoing during the works to confirm conditioning requirements
	Liquid and plastic limit (NZS 4402 Tests 2.2, 2.3 and 2.4)	1 for each source and 1 for each change in material	Plasticity index < 25% Liquid limit < 50%	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
Placement requirements	Unless demonstrated otherwise by site trials and approved by the Engineer, loose layer thickness >100mm and < 250 mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Field water content, density, and air voids (NZS 4402 Test 2.1 and NZS 4407 Test 4.1, 4.2, or 4.3)	1 per 4000m³ Minimum 1 per lift	-2% below to 4% above OMC ≥ 90% maximum dry density < 15% air voids	Earthwork's supervision involving fill construction with clay rich materials benefits from ongoing testing and control of moisture content, compacted air voids and shear strength.
	Shear strength and field water content (NZGS Guideline for handheld shear vane test and NZS 4402 Test 2.1))	2 per 1000m³ Minimum 2 per lift	Lowest value > 100 kPa -2% below to 4% above OMC	

Table A1.5 - Landscaping fill (I-A)

Material definition	**Fill use type**	Landscaping fill		
	Source material type	I–A (intermediate – acceptable)		
	Typical use description	General fill for landscaping in areas where no design loads will be imposed and where no infrastructure will rely on the stability of the fill. Using selected site-won or imported materials.		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 Test 3.8, NZS 4402 Test 2.8.1)	1 for each source and 1 for each change in material	As per Table A2	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402 Test 4.1.1, NZS 4402 Test 4.1.2)	1 for each source and 1 for each change in material	OMC and MDD determined	Completed before works begin (and during the works if the material changes) to determine OMC and MDD
	Water content (NZS 4402 Test 2.1)	1 for each source and 1 for each change in material	Between OMC − 2% and OMC + 4%	Ongoing during the works to confirm conditioning requirements
	Liquid and plastic limit (NZS 4402 Tests 2.2, 2.3 and 2.4)	1 for each source and 1 per 4000 m3 and 1 for each change in material	Plasticity index < 25% Liquid limit < 50%	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
Placement requirements	Unless demonstrated otherwise by site trials and approved by the Engineer, loose layer thickness >100mm and < 250 mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Field water content and density (NZS 4402.2.1 and NZS 4407 Test 4)	1 per 4000m^3 Minimum 1 per lift	-2% below to 4% above OMC ≥ 90% maximum dry density < 15% air voids	Locations as directed by the certifier. Earthwork's supervision involving fill construction with clay rich materials benefits from ongoing testing and control of moisture content, compacted air voids and shear strength.
	Shear strength and field water content (NZGS Guideline for handheld shear vane test and NZS 4402 Test 2.1))	2 per 1000m^3 Minimum 2 per lift	Lowest value > 100 kPa	Locations as agreed by the Certifier.
	Dynamic cone penetrometer (DCP) (NZS4402 Test 6.5.2)	2 per 1000m^3 Minimum 2 per lift	≥ 4 blows per 100 mm	DCP locations as agreed by the Certifier. DCP test is indicative only and should not be used alone for compaction compliance.

Table A1.6 - Landscaping fill (C-A)

Material definition	**Fill use type**	Landscaping fill		
	Source material type	C–A (coarse-grained – acceptable)		
	Typical use description	General fill for landscaping in areas where no design loads will be imposed and where no infrastructure will rely on the stability of the fill. Using selected site-won or imported materials.		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 Test 3.8, NZS 4402 Test 2.8.1)	1 for each source and 1 for each change in material	As per Table A2	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402 Test 4.1.1, NZS 4402 Test 4.1.2)	1 for each source and 1 for each change in material	OMC and MDD determined for compaction acceptance testing	Completed before works begin (and during the works if the material changes) to determine OMC and MDD Not required for coarse-grained soils where continuous compaction control will be used to assure compaction quality
	Water content (NZS 4402 Test 2.1)	1 for each source and 1 for each change in material	Between OMC −2% and OMC +4%	Ongoing during the works to confirm conditioning requirements. Not used if there is no well-defined density-water content relationship
Placement requirements	Unless demonstrated otherwise by site trials and approved by the Engineer, loose layer thickness >100mm and < 300 mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	For coarse-grained soils with maximum particle size < 65 mm, test field water content and density (NZS 4402 Test 2. 1 and NZS 4407 test 4)	1 per 4000m³ Minimum 1 per lift	≥ 90% maximum dry density < 15% air voids	Earthwork's supervision involving fill construction with coarse-grained materials benefits from ongoing testing and control of moisture content, density, and compacted air voids. Locations as agreed by the Certifier. **For emerging test alternatives refer the comment box below Table A1.1.**
	For coarse-grained soils with maximum particle size from 65 mm to 250 mm, proof-roll to target maximum calibrated dynamic response modulus or relative density	Ongoing continuous compaction control	Target minimum calibrated compaction machine specific dynamic response modulus or minimum 75% relative density	
	Dynamic cone penetrometer (DCP) (NZS4402 Test 6.5.2)	2 per 1000m³ Minimum 2 per lift	≥ 4 blows per 100 mm	DCP locations as agreed by the Certifier. DCP test is indicative only and should not be used alone for compaction compliance.
	Clegg Impact test (CIV) – 4.5 kg hammer (ASTM D 5874)	2 per 1000m³ Minimum 2 per lift	IV > 15	CIV locations as directed by the Certifier. The CIV test is indicative only and should not be used alone for compaction compliance.

Table A1.7 - Bulk 4431 fill (R-GAP 150-A)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	R-GAP150-A (processed rock to GAP 150 grading)		
	Typical use description	General fill for residential or light commercial earthworks using selected site-won or imported materials		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 Test 3.8, NZS 4402 Test 2.8.1)	1 for each source 1 for each change in material	As per Table A2	Completed before works begin (and during the works if the source or material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402 Test 4.1.1, NZS 4402 Test 4.1.2)	1 for each source 1 for each change in material	OMC and MDD determined	Completed before works begin (and during the works if the source and material changes) to determine OMC and MDD for later use in compaction acceptance testing
	Solid density of soil particles (NZS 4402 Tests 2.7.1 or 2.7.2)	1 for each source 1 for each change in material	Solid density determined	Used to define the solid density of aggregate particles for later use in compaction acceptance testing with in-situ NDM Can be omitted where the Contractor provides a reliable estimate for the specific source material
	Weathering quality index (NZS 4407 test method 3.11)	1 for each source 1 for each change in material	AA, AB, AC, BA, BB, or CA	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
Placement requirements	Unless demonstrated otherwise by site trials and approved by the Engineer, loose layer thickness >100mm and <300 mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	For coarse-grained soils with maximum particle size < 65 mm, test field water content and density (NZS4402 Test 2.1 and NZS 4407 Test 4)	2 per 1000m^3 Minimum 2 per lift	-2% below to 4% above OMC > 95% MDD < 15% air voids	Earthwork's supervision involving fill construction with coarse-grained materials benefits from ongoing testing and control of moisture content, density, and compacted air voids. Locations as agreed by the Certifier. **For emerging test alternatives refer the comment box below Table A1.1.**
	For coarse-grained soils with maximum particle size from 65 mm to 150 mm, proof-roll to target maximum calibrated relative density.	Ongoing continuous compaction control	Target minimum calibrated compaction machine specific minimum 80% relative density	
	Dynamic cone penetrometer (DCP) (NZS4402 Test 6.5.2)	5 per 1000m^3 Minimum 5 per lift	≥ 5 blows per 100 mm	DCP test is indicative only and should not be used alone for compaction compliance. DCP locations as agreed by the Certifier.
	Clegg Impact test (CIV) – 4.5 kg hammer (ASTM D 5874)	5 per 1000m^3 Minimum 5 per lift	CIV > 25	CIV test is indicative only and should not be used alone for compaction compliance. CIV locations as agreed by the Certifier.

Table A1.8 - Bulk 4431 fill (R-GAP 100-A)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	R-GAP100-A (rock crushed to GAP 100 grading – acceptable)		
	Typical use description	General fill for residential or light commercial earthworks using selected site-won or imported materials		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 Test 3.8, NZS 4402 Test 2.8.1)	1 for each source 1 for each change in material	As per Table A2	Completed before works begin (and during the works if the source or material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402 Test 4.1.1, NZS 4402 Test 4.1.2)	1 for each source 1 for each change in material	OMC and MDD determined	Completed before works begin (and during the works if the source and material changes) to determine OMC and MDD for later use in compaction acceptance testing
	Solid density of soil particles (NZS 4402 Tests 2.7.1 or 2.7.2)	1 for each source 1 for each change in material	Solid density determined	Used to define the solid density of aggregate particles for later use in compaction acceptance testing with in-situ NDM Can be omitted where the Contractor provides a reliable estimate for the specific source material
	Weathering quality index (NZS 4407 test method 3.11)	1 for each source 1 for each change in material	AA, AB, AC, BA, BB, or CA	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
Placement requirements	Unless demonstrated otherwise by site trials and approved by the Engineer, loose layer thickness >100mm and <300 mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	For coarse-grained soils with maximum particle size < 65 mm, test field water content and density (NZS4402 Test 2.1 and NZS 4407 Test 4)	2 per 1000m³ Minimum 2 per lift	-2% below to 4% above OMC > 95% MDD < 15% air voids	Earthwork's supervision involving fill construction with coarse-grained materials benefits from ongoing testing and control of moisture content, density, and compacted air voids. Locations as agreed by the Certifier. **For emerging test alternatives refer the comment box below Table A1.1.**
	For coarse-grained soils with maximum particle size from 65 mm to 150 mm, proof-roll to target maximum calibrated relative density.	Ongoing continuous compaction control	Target minimum calibrated compaction machine specific minimum 80% relative density	
	Dynamic cone penetrometer (DCP) (NZS4402 Test 6.5.2)	5 per 1000m³ Minimum 5 per lift	≥ 5 blows per 100 mm	DCP test is indicative only and should not be used alone for compaction compliance. DCP locations as agreed by the Certifier.
	Clegg Impact test (CIV) – 4.5 kg hammer (ASTM D 5874)	5 per 1000m³ Minimum 5 per lift	CIV > 25	CIV test is indicative only and should not be used alone for compaction compliance. CIV locations as agreed by the Certifier.

Table A1.9 - Bulk 4431 fill (R-GAP 65-A)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	R-GAP65-A (rock crushed to GAP 65 grading – acceptable)		
	Typical use description	General fill for residential or light commercial earthworks using selected site-won or imported materials		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 Test 3.8, NZS 4402 Test 2.8.1)	1 for each source 1 for each change in material	As per Table A2	Completed before works begin (and during the works if the source or material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402 Test 4.1.1, NZS 4402 Test 4.1.2)	1 for each source 1 for each change in material	OMC and MDD determined	Completed before works begin (and during the works if the source and material changes) to determine OMC and MDD for later use in compaction acceptance testing
	Solid density of soil particles (NZS 4402 Tests 2.7.1 or 2.7.2)	1 for each source 1 for each change in material	Solid density determined	Used to define the solid density of aggregate particles for later use in compaction acceptance testing with in-situ NDM Can be omitted where the Contractor provides a reliable estimate for the specific source material
	Weathering quality index (NZS 4407 test method 3.11)	1 for each source 1 for each change in material	AA, AB, AC, BA, BB, or CA	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
Placement requirements	Unless demonstrated otherwise by site trials and approved by the Engineer, loose layer thickness >100mm and <200mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	For coarse-grained soils with maximum particle size <65mm, test field water content and density (NZS4402 Test 2.1 and NZS 4407 Test 4)	2 per 1000m³ Minimum 2 per lift	-2% below to 4% above OMC > 95% MDD < 15% air voids	Earthwork's supervision involving fill construction with coarse-grained materials benefits from ongoing testing and control of moisture content, density, and compacted air voids. Locations as agreed by the Certifier. **For emerging test alternatives refer the comment box below Table A1.1.**
	For coarse-grained soils with maximum particle size up to 65 mm, proof-roll to target maximum calibrated relative density.	Ongoing continuous compaction control	Target minimum calibrated compaction machine specific minimum 80% relative density	
	Dynamic cone penetrometer (DCP) (NZS4402 Test 6.5.2)	5 per 1000m³ Minimum 5 per lift	≥ 5 blows per 100 mm	DCP test is indicative only and should not be used alone for compaction compliance. DCP locations as agreed by the Certifier.
	Clegg Impact test (CIV) – 4.5 kg hammer (ASTM D 5874)	5 per 1000m³ Minimum 5 per lift	CIV > 25	CIV test is indicative only and should not be used alone for compaction compliance. CIV locations as agreed by the Certifier.

Table A1.10 - Bulk 4431 fill (R-GAP 40-A)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	R-GAP40-A (rock crushed to GAP 40 grading – acceptable)		
	Typical use description	General fill for residential or light commercial earthworks using selected site-won or imported materials		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 Test 3.8, NZS 4402 Test 2.8.1)	1 for each source 1 for each change in material	As per Table A2	Completed before works begin (and during the works if the source or material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402 Test 4.1.1, NZS 4402 Test 4.1.2)	1 for each source 1 for each change in material	OMC and MDD determined	Completed before works begin (and during the works if the source and material changes) to determine OMC and MDD for later use in compaction acceptance testing
	Solid density of soil particles (NZS 4402 Tests 2.7.1 or 2.7.2)	1 for each source 1 for each change in material	Solid density determined	Used to define the solid density of aggregate particles for later use in compaction acceptance testing with in-situ NDM Can be omitted where the Contractor provides a reliable estimate for the specific source material
	Weathering quality index (NZS 4407 test method 3.11)	1 for each source 1 for each change in material	AA, AB, AC, BA, BB, or CA	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
Placement requirements	Unless demonstrated otherwise by site trials and approved by the Engineer, loose layer thickness >80mm and <150mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	For coarse-grained soils with maximum particle size <40mm, test field water content and density (NZS4402 Test 2.1 and NZS 4407 Test 4)	2 per 1000m^3 Minimum 2 per lift	-2% below to 4% above OMC > 95% MDD < 15% air voids	Earthwork's supervision involving fill construction with coarse-grained materials benefits from ongoing testing and control of moisture content, density, and compacted air voids. Locations as agreed by the Certifier. **For emerging test alternatives refer the comment box below Table A1.1.**
	Dynamic cone penetrometer (DCP) (NZS4402 Test 6.5.2)	5 per 1000m^3 Minimum 5 per lift	≥ 5 blows per 100 mm	DCP test is indicative only and should not be used alone for compaction compliance. DCP locations as agreed by the Certifier.
	Clegg Impact test (CIV) – 4.5 kg hammer (ASTM D 5874)	5 per 1000m^3 Minimum 5 per lift	CIV > 25	CIV test is indicative only and should not be used alone for compaction compliance. CIV locations as agreed by the Certifier.

Table A1.11 - Bulk 4431 fill (M-GAP 65-A)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	M-GAP65-A (recycled concrete or brick crushed to GAP 65 grading – acceptable)		
	Typical use description	General fill for residential or light commercial earthworks using imported recycled concrete or brick		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 Test 3.8, NZS 4402 Test 2.8.1)	1 for each source 1 for each change in material	As per Table A2	Completed before works begin (and during the works if the source or material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402 Test 4.1.1, NZS 4402 Test 4.1.2)	1 for each source 1 for each change in material	OMC and MDD determined	Completed before works begin (and during the works if the source and material changes) to determine OMC and MDD for later use in compaction acceptance testing
	Solid density of soil particles (NZS 4402 Tests 2.7.1 or 2.7.2)	1 for each source 1 for each change in material	Solid density determined	Used to define the solid density of aggregate particles for later use in compaction acceptance testing with in-situ NDM Can be omitted where the Contractor provides a reliable estimate for the specific source material
	Weathering quality index (NZS 4407 test method 3.11)	1 for each source 1 for each change in material	AA, AB, AC, BA, BB, or CA	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
	Chemical acceptability	1 for each source 1 for each change in material 1 per 1000 m^3	As per Ministry for the Environment, 2011, Methodology for Deriving Standards for Contaminants in Soil to Protect Human Health (Tables 54 and 55)	Recommended testing for recycled crushed concrete or brick from relatively clean sources – alternative testing could be required for other materials/sources with more complex chemistry Completed before works begin (and during the works if the material changes) to confirm the material's suitability, and ongoing throughout placement to allow for source variability Not appropriate for materials from HAIL sites. Advice from a SQEP is needed for these
Placement requirements	Unless demonstrated otherwise by site trials and approved by the Engineer, loose layer thickness >100mm and <200mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	For coarse-grained soils with maximum particle size <65mm, test field water content and density (NZS 4402 Test 4.1.1, NZS 4402 Test 4.1.2)	2 per 1000m^3 Minimum 2 per lift	-2% below to 4% above OMC > 95% MDD < 15% air voids	Earthwork's supervision involving fill construction with coarse-grained materials benefits from ongoing testing and control of moisture content, density, and compacted air voids. Locations as agreed by the Certifier. **For emerging test alternatives refer the comment box below Table A1.1.**
	Dynamic cone penetrometer (DCP) (NZS4402 Test 6.5.2)	5 per 1000m^3 Minimum 5 per lift	≥ 5 blows per 100 mm	DCP test is indicative only and should not be used alone for compaction compliance. DCP locations as agreed by the Certifier.
	Clegg Impact test (CIV) – 4.5 kg hammer (ASTM D 5874)	5 per 1000m^3 Minimum 5 per lift	CIV > 25	CIV test is indicative only and should not be used alone for compaction compliance. CIV locations as agreed by the Certifier.

Table A1.12 - Bulk 4431 fill (M-GAP 40-A)

Material definition	**Fill use type**	Bulk 4431 fill		
	Source material type	M-GAP40-A (recycled concrete or brick crushed to GAP 40 grading – acceptable)		
	Typical use description	General fill for residential or light commercial earthworks using imported recycled concrete or brick		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 Test 3.8, NZS 4402 Test 2.8.1)	1 for each source 1 for each change in material	As per Table A2	Completed before works begin (and during the works if the source or material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402 Test 4.1.1, NZS 4402 Test 4.1.2)	1 for each source 1 for each change in material	OMC and MDD determined	Completed before works begin (and during the works if the source and material changes) to determine OMC and MDD for later use in compaction acceptance testing
	Solid density of soil particles (NZS 4402 Tests 2.7.1 or 2.7.2)	1 for each source 1 for each change in material	Solid density determined	Used to define the solid density of aggregate particles for later use in compaction acceptance testing with in-situ NDM Can be omitted where the Contractor provides a reliable estimate for the specific source material
	Weathering quality index (NZS 4407 test method 3.11)	1 for each source 1 for each change in material	AA, AB, AC, BA, BB, or CA	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
	Chemical acceptability	1 for each source 1 for each change in material 1 per 1000 m^3	As per Ministry for the Environment, 2011, Methodology for Deriving Standards for Contaminants in Soil to Protect Human Health (Tables 54 and 55)	Recommended testing for recycled crushed concrete or brick from relatively clean sources – alternative testing could be required for other materials/sources with more complex chemistry Completed before works begin (and during the works if the material changes) to confirm the material's suitability, and ongoing throughout placement to allow for source variability Not appropriate for materials from HAIL sites. Advice from a SQEP is needed for these
Placement requirements	Unless demonstrated otherwise by site trials and approved by the Engineer, loose layer thickness >80mm and <150mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	For coarse-grained soils with maximum particle size <40mm, test field water content and density (NZS4402 Test 2.1 and NZS 4407 Test 4)	2 per 1000m^3 Minimum 2 per lift	-2% below to 4% above OMC > 95% MDD < 15% air voids	Earthwork's supervision involving fill construction with coarse-grained materials benefits from ongoing testing and control of moisture content, density, and compacted air voids. Locations as agreed by the Certifier. **For emerging test alternatives refer the comment box below Table A1.1.**
	Dynamic Cone Penetrometer (DCP) test (NZS4402 Test 6.5.2)	5 per 1000m^3 Minimum 5 per lift	≥ 5 blows per 100 mm	DCP test is indicative only and should not be used alone for compaction compliance. DCP locations as agreed by the Certifier.
	Clegg Impact Value (CIV) test – 4.5 kg hammer (ASTM D 5874)	5 per 1000m^3 Minimum 5 per lift	CIV > 25	CIV test is indicative only and should not be used alone for compaction compliance. CIV locations as agreed by the Certifier.

Table A1.13 - Water detention clay (F-A)

Material definition	**Fill use type**	Water detention clay		
	Source material type	F-A (fine grained – acceptable)		
	Typical use description	Stormwater detention bunds, low-risk stopbanks (not dams) and trench water-stops.		
Source material acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Particle size distribution (NZS 4407 Test 3.8, NZS 4402 Test 2.8.1)	1 for each source 1 for each change in material	As per Table A2	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
	Dry density/water content relationship (NZS 4402 Test 4.1.1, NZS 4402 Test 4.1.2)	1 for each source 1 for each change in material	OMC and MDD determined	Completed before works begin (and during the works if the material changes) to determine OMC and MDD for later use in compaction acceptance testing
	Water content (NZS 4402 Test 2.1)	1 for each source 1 for each change in material	Between OMC − 2% and OMC + 4%	Ongoing during the works to confirm conditioning requirements
	Liquid and plastic limit (NZS 4402 Tests 2.2, 2.3 and 2.4)	1 for each source 1 for each change in material 1 per 4000 m^3	Plasticity index 10-35% Liquid limit < 70%	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
	Pinhole soil dispersion (ASTM D4647-13)	1 for each source 1 for each change in material 1 per 4000 m^3	Class ND1 or ND2	Completed before works begin (and during the works if the material changes) to confirm the material's suitability
Placement requirements	Unless demonstrated otherwise by site trials and approved by the Engineer, loose layer thickness >100mm and < 250 mm			
Compaction acceptance testing	**Test (and method)**	**Minimum test frequency**	**Normal acceptance criteria**	**Notes**
	Field water content, density, and air void (NZS 4402 Test 2.1 and NZS 4407 Tests 4.1, 4.2 and 4.3)	2 per 1000m^3 Minimum 2 per lift	-2% below to 4% above OMC ≥ 90% maximum dry density (MDD) < 5% air voids	Earthwork's supervision involving new engineered fill construction with clay rich materials benefits from ongoing testing and control of moisture content, compacted air voids and shear strength. Locations as agreed by the Certifier. **For emerging test alternatives refer the comment box below Table A1.1.**
	Shear strength and field water content (NZGS Guideline for handheld shear vane test and NZS 4402 Test 2.1)	5 per 1000m^3 Minimum 5 per lift	Lowest value >100 kPa -2% below to 4% above OMC	

Table A2 – Particle size criteria for material types

Table A2 presents the acceptable ranges for minimum and maximum percentage passing each of the sieve aperture sizes.

Material ↓ / Sieve aperture size (mm) →		150	100	75	65 or 63	40 or 37.5	20 or 19	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.063
F (fine-grained bulk fill)	Min	-	-	-	-	-	100	-	-	-	-	-	-	-	-	35
	Max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
I (intermediate-grained bulk fill)	Min	-	-	100	-	-	-	-	-	-	-	-	-	-	-	15
	Max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35
C (coarse-grained bulk fill)	Min	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15
GAP 150	Min	100	79	64	58	41	28	-	21	15	9	6	4	3	1	-
	Max	-	95	89	85	73	54	-	40	30	23	18	14	10	8	5
GAP 100	Min	-	100	80	70	54	39	32	27	20	15	10	6	3	1	-
	Max	-	-	92	85	75	60	52	46	34	25	18	13	10	7.5	5
GAP 65	Min	-	-	-	100	80	50	-	30	20	15	10	6	4	2	-
	Max	-	-	-	-	90	70	-	55	40	30	22	18	14	10	7
GAP 40	Min	-	-	-	-	100	61	-	38	23	14	7	2	-	-	-
	Max	-	-	-	-	-	80	-	57	43	33	25	19	14	10	7
Clean coarse sand	Min	-	-	-	-	-	-	-	-	100	95	-	-	-	-	-
	Max	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-
Water Detention Clay	Min	-	-	-	-	-	-	-	-	-	80	-	50	-	-	35
	Max	-	-	-	-	-	100	-	-	-	-	-	90	-	-	65