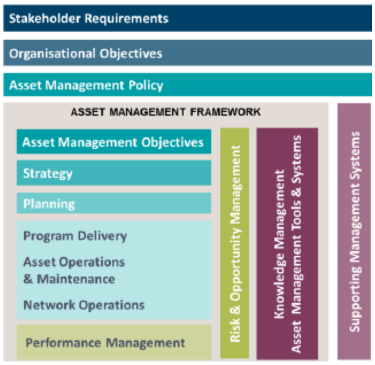
Transmission Line Geotechnical Investigations

Design Standard



DOCUMENT HIERARCHY

This document resides within the Planning component of Western Power's Asset Management System (AMS).

DOCUMENT DATE

This document was last updated 01/11/2023

IMPLEMENTATION DATE

This document came into service 01/09/2020

DOCUMENT CONTROL

Record of endorsement, approval, stakeholders, and notification list is provided in EDM# 28483277 appendix

RESPONSIBILITIES

Western Power's Engineering and Design Function is responsible for this document

CONTACT

Western Power welcomes your comments, questions, and feedback on this document, which can be emailed to standards.excellence@westernpower.com.au

DISCLAIMER

COPYRIGHT

Contents

Revision Details

Version	Date	Summary of change	Section
0	01/09/2020	Initial release	
1	16/06/2023	New template and minor updates	
2	01/11/2023	Update to AMS format	

1. Introduction

This standard provides the scope of geotechnical investigation for foundations of high voltage overhead transmission lines necessary to meet relevant Australian, International standards and Western Power requirements.

This standard outlines the requirements and acceptable methods of geotechnical investigations to determine the foundation design and durability parameters for the transmission structures and associated earthworks.

Sites with archaeological or cultural significance and determination of soil electrical parameters are excluded from this standard.

1.1 Purpose and scope

The purpose of geotechnical investigations is to determine geotechnical design parameters for foundations as detailed in following table.

Table 1.1: Geotechnical Design Parameter

Soil Type	Design Parameters
Cohesive	Soil density, ground water table, undrained shear strength (adhesion and cohesion), vertical bearing capacity and sensitivity.
Cohesionless	Soil density, ground water table, angle of internal friction and vertical bearing capacity.
Rock	Rock density, ground water table, friction, rock strength, degree of joints or cracks and vertical bearing capacity

All geotechnical investigations and interpretation of geotechnical test results shall comply

with the following:

- AS 1289 (1289.0 to 1289.7) Method of testing soils for engineering purposes
- AS 1726 Geotechnical site investigation
- AS 2159 Australian standard piling – design and installation
- AS/NZS 7000 Overhead line design – detailed procedure

1.2 Acronyms

Acronym	Definition
CBR	California Bearing Ratio (CBR) is a penetration test used for evaluating the evaluate the subgrade strength of roads and pavements
CPT	Cone Penetration Test
DCP	Dynamic Cone Penetrometer Test

PSP	Perth Sand Penetrometer Test
SPT	Standard Penetration Test
UCS	Unconfined Compression Strength (UCS) is defined as the load per unit area at which an unconfined cylindrical specimen of soil will fail in a simple compression test. UCS is a measure of the consistency of clays, and is expressed qualitatively by the terms soft, medium, stiff and hard.
GSWA	Geological Survey of Western Australia

1.3 Definitions

Term	Definition
Disturbed soil sample	A disturbed sample is one in which the structure of the soil has been changed sufficiently that tests of the soil properties will not be representative of in-situ conditions and only properties of the soil grains (e.g., grain size distribution, Atterberg limits, and possibly the water content) can be accurately determined.
Undisturbed soil sample	An undisturbed sample is one where the condition of the soil in the sample is close enough to the conditions of the soil in-situ to allow tests of engineering properties of the soil to be used to approximate the in-situ geotechnical design parameters.
Earth tectonic fault line	A fault is a planar fracture or discontinuity in a volume of rock/soil mass, across which there has been significant displacement along the fractures as a result of earth movement. A fault line is the surface trace of a fault, the line of intersection between the fault plane and the Earth's surface.

1.4 References

References which support implementation of this document

Table 1.2 References

Reference No.	Title
AS 1289.0-12.89.7	Method of testing soils for engineering purposes
AS 1726	Geotechnical site investigation - Field Test Methods
AS 2159	Australian standard piling – design and installation
AS 4133.4.1	Methods of testing rocks for engineering purposes - Rock strength tests - Rock strength tests
AS/NZS 7000	Overhead line design – detailed procedure
HB 106	Soil testing

2. Safety in Design

The transmission line geotechnical investigation must consider all safety aspects that can arise from the construction, operation, maintenance and decommissioning of the transmission line and other activities within the line corridor.

The Transmission Line Geotechnical Invesitigation Hazard Management Register (HMR)[1] captures and document what risks have been controlled by this standard, and what residual risks may remain that should be considered at the project design stages and construction.

Every design is required to have its own project specific Hazard Management Register.

3. Geotechnical Investigation Methodologies

The geotechnical investigation methods for transmission assets are staged to align with project phases and are listed in the following tables:

[1] Refer to Western Power's internal document.

Table 3.1: Geotechnical Investigation Methodologies - Transmission Lines

Phase/Stage		Relevant geotechnical investigation	Acceptable exemption	Accuracy level		
				Impact on geotechnical strength factor (øg) assumption[1]	Impact on geotechnical design parameters	Output required from the geotechnical investigation
Scoping	SS-1	Desktop Study	Always required	Øg ≤ 0.5	Assumed as poorest soil.	- Feasibility study to establish appropriate foundation types. - Selection of potential foundation types and anticipates approximate foundation depth. - Adoption of poorest geotechnical design parameters - Very high level foundation type distribution along the transmission line route (up to ±50% variation).
	SS-2	Reconnaissance Survey with or without DCP/PSP test at ≤5km intervals.	Not required if the outputs of SS-1 can be established without SS-2.	Same as SS-1		
	SS-3a	Shallow and/ or deep exploratory boring depending on the foundation depth approximation. At least one test to be performed in each 5km.	Not required if the accuracy level from SS-1 and SS-2 output satisfies the project scope.	0.5 < Øg ≤ 0.6	Geotechnical design parameters based on exploratory boring information.	- Preliminary foundation design. - Preliminary foundation type distribution (up to ±30% variation) along the transmission line route.

	SS-3b	Sample collection in SS-3a and laboratory test.	Not required for nonaggressive soil.	-	-	- Durability design parameters.
Planning	PS-1	Desktop and reconnaissance survey	Not required if completed in scoping phase.	-	-	- Determine the extent and scope of the geotechnical investigations required for next stages.
	PS-2a	Shallow and/ or deep exploratory boring depending on the foundation depth approximation. At least one test to be performed in each 1km.	Not required if SS-3 output satisfies the project scope. Not required if PS-2b has been carried out.	0.6 < Øg ≤ 0.7 If Øg = 0.7, poorest geotechnical design parameters shall be considered.	Geotechnical design parameters based on exploratory boring information.	- Geotechnical design parameters for the detailed foundation design. - Detailed foundation type distribution (up to ±20% variation) along the transmission line route. - Determining potential construction constraints. - Identify, estimate and evaluate cost benefits of additional geotechnical investigations to be carried out during execution phase.
	PS-2b	In-situ subsurface tests (SPT or CPT) in conjunction with shallow and/ or deep exploratory boring or additional DCP tests. At least one test to be performed in each 1km.	Not required if SS-3 output satisfies the project scope.	0.65 < Øg ≤ 0.7 If Øg = 0.7, poorest geotechnical design parameters shall be considered unless ES-1 has been carried out.	Geotechnical design parameters based on in-situ subsurface test and laboratory test information.	
	PS-2c	Sample collection and laboratory tests.	Not required for non-aggressive soil or if SS-3b data is sufficient.	-	-	Detailed durability design parameters.

Execution	ES-1	Additional in-situ subsurface tests (SPT or CPT) or shallow and/ or deep exploratory boring at selected line section to refine foundation type selection. At least one test including a borehole to be performed at each structure location.	Not required if the level of accuracy in foundation type distribution achieved at planning phase is proven satisfactory.	0.7 < Øg ≤ 0.8 If Øg = 0.8, poorest geotechnical design parameters shall be considered.	-	- Detailed foundation type distribution along selected transmission line section.
	ES-2	Rock sample collection and laboratory tests (rotary coring).	Not required if rock properties are evaluated in PS-2c.			- Rock strength.
	ES-3a	Soil compaction verifications using DCP, PSP. At least one test (up to 300mm drive length between 20%-80% of buried depth) to be performed at each tower leg and >132kV pole locations; and first 10 installed poles and 10% minimum for balance of a ≤132kV pole line or section worked on.	Foundation testings carried out in accordance with Western Power's internal document or if soil is not suitable for DCP, PSP and ES-3b has been carried out.	-	-	- Compaction level achieved, signed off by site supervisor.

	ES-3b	Backfill compaction and density test. At least one test to be performed at each structure location when the strength of foundation is reliance upon the compaction level of the backfill.		-	-	- Suitability and compaction level of insitu or imported backfill signed off by site supervisor.
	ES-3c	Foundation Tests in accordance with Western Power's internal document.	Øg < 0.65 in poor soil, unsupervised work, unknown soil. Øg < 0.75 for all other cases without foundation tests.	0.75 - 0.9	Proof strength at test location. Maximum 90 percentile strength at similar locations.	- Test report and recommendation by suitably qualified geotechnical engineer(s).

Note:

[1] Table 6.3 of AS/NZS 7000-2016 states Øg = 0.5 to 0.8 for foundations relying on strength of soil. Øg for weight of soil shall be selected based on Table 3.2. Øg for foundation relying on load relief shall be selected based on Table 3.3. All geotechnical strength factors higher than the proposed range (up to a maximum value of 0.9 with foundation test) shall be signed off by a geotechnical engineer experienced in soil investigations and design, then submitted for approval by Western Power.

Table 3.2: Geotechnical Strength Factor for Weight of Soil

Load Type	Soil Type	Geotechnical Strength Factor (øg)
Static uplift	In-situ or uncontrolled fill	0.8
	Compacted and tested stable backfill	0.9
Static compression	All	1.1
Dynamic vertical	All	0.8-1.3

Table 3.3: Geotechnical Strength Factor for Foundation Relying on Load Relief

Load Type	Soil Type	Geotechnical Strength Factor (øg)
Overturning	In-situ or uncontrolled fill	0.8 (medium soil assumed) 1.0 (poor soil assumed)
	Compacted and tested stable backfill	1.0

4. Desktop Study and Reconnaissance Survey

4.1 Introduction

The preliminary investigation shall consist of collecting existing data relating to local and subsurface conditions, and conducting a geotechnical field reconnaissance of the proposed transmission asset.

This initial appraisal shall form the basis of the geotechnical model of the transmission asset and shall establish the potential foundation types for the support structures.

4.2 Desktop Study

The Geological Survey of Western Australia (GSWA) publishes reports, maps, and state-of-the-art database documenting the geology of Western Australia.

The Information from GSWA along with the available previous geotechnical investigation reports shall be used for desktop study.

4.3 Reconnaissance Survey

The reconnaissance survey shall identify potential site conditions at the support sites and verify the information obtained from the desktop study. The survey may be conducted with the aid of dynamic cone penetrometer or Perth sand penetrometer tests.

The preliminary soil and rock classifications shall comply with Tables 9, 10 and 19 of AS 1726.

5. Exploratory Boring

5.1 Introduction

The exploratory boring shall be used for the following purposes:

- visual classification of soil or rock
- moisture content and level of ground water

The above information shall provide the geotechnical design parameters for preliminary or detailed foundation design and foundation type distribution with the accuracy level as detailed in Section 2 - Geotechnical Investigation Methodologies.

Disturbed or undisturbed soil samples collected during exploratory boring shall be used for laboratory testing.

5.2 Types of Exploratory Boring

The acceptable types of exploratory borings are as follows:

Table 5.1: Types of Exploratory Boring

Exploratory Boring	Exploration Method	Suitable Soil Type	Suitable Sample Type Collection	Achievable Depth
Shallow exploratory boring	Trial pit	Dry Sand Dry Clay Low to medium strength rock	Disturbed	Maximum 4 to 5m.
	Window sampler	Sand Clay	Disturbed	Maximum 8 to 10m
Deep exploratory boring	Rotary wash boring	Sand Clay	Disturbed Undisturbed	Approximate 60m
	Rotary coring	Rock	Disturbed Undisturbed	Approximate 60m
	Power auger drilling	Sand Clay	Disturbed	Approximate 30m

5.3 Location

The locations shall be along the line route outside the substation boundary where subsurface interpretation is difficult from the available desktop-based data.

Exploratory boring shall also be required at locations with early refusal of SPT/ CPT due to the presence of rock.

6. In-Situ Subsurface Test

In general, in-situ subsurface penetration tests are suitable for soil with little or no rock. The location of tests shall be as close as possible to the structure position (existing or new as applicable).

The in-situ tests in conjunction with laboratory test results shall be used to determine the geotechnical design parameters and to develop the foundation type distribution with the accuracy level described in Table 3.1.

The acceptable test methods are described in the table below.

Table 6.1: Types of In-situ Subsurface Test

Item	SPT	CPT
Scope	To determine the standard penetration resistance at different intervals To obtain the split-barrel samples (“disturbed”) for soil identification purposes	An alternative to SPT in particular for cohesive soil to determine the static cone penetration resistance of a soil as continuous subsurface records
Locations	Where sub-surface materials are sand without the presence of clay or silt	Where sub-surface materials are not pure cohesionless soil (i.e. where sand with fine grained particles like clay or silts may present)
Reference standards	AS 1289.6.3.1: Soil strength and consolidation tests— Determination of the penetration resistance of a soil—Standard penetration test. AS 1289.1.2.1: Sampling and preparation of soils—Disturbed samples—Standard method	AS 1289.6.5.1: Soil strength and consolidation tests— Determination of the static cone penetration resistance of a soil—Field test using a mechanical and electrical cone or friction-cone penetrometer

For replacement of existing 132kV or lower voltages pole support structures, a dynamic cone penetrometer (DCP) or a Perth sand penetrometer (PSP) test in accordance with AS 1289.6.3.2 and AS 1289.6.3.3 respectively may be used in place of a standard or static cone penetration test at locations with medium or better soil (refer Table L2 AS/NZS 7000). In this case, DCP or PSP test shall be carried out at all pole locations.

DCP or PSP may also be used in conjunction with SPT for a section of the pole line with consistent soil profile and when only the soil internal friction angle is required to determine the footing rotation of a 132kV or lower voltages pole line (refer to Transmission Line Foundation Design Standard[2]).

The number of DCP verifications tests shall be increased for foundation or line sections with inconsistent backfill compaction (refer Table 3.1 Phase ES-3). The required compaction level and type shall be specified to suit intended foundation performance level (i.e. rigid or non-rigid) base on the anticipated soil characteristics. The compaction test shall be carried out at locations where DCP test cannot be conducted (i.e. rocky terrain).

When the strength of foundation is reliant upon the compaction level of the backfill, it shall be compacted in 150-300 mm layers using 596 kJ/m3 effort, supervised and signed off by a qualified work supervisor and tested successfully in accordance with AS 1289.5.1.1 and AS 1289.5.8.4. To reduce the number of compaction tests, DCP or PSP may be used to verify similarly compacted and tested backfill of line sections within similar geological profile.

[2] Refer to Western Power’s internal document

Foundation design shall be revised based on in-situ soil characteristics as required in accordance with Transmission Line Foundation Design Standard[3].

7. Depth of Exploratory Boring or In-Situ Test

The minimum depth of investigation shall be as per following table.

Table 7.1: Recommended Depth of Exploration

Foundation Type	Recommended Depth of Exploration
Mass concrete foundation	2x Anticipated foundation depth
Raft foundation	Anticipated depth + 1.5 x anticipated width
Bored concrete foundation	Anticipated depth + 2x anticipated diameter or 10m minimum For location with competent underlying rock, 2x anticipated diameter into the rock mass
Steel pile foundation	1.5x Anticipated depth or 15m minimum
Note: (1) For location with soft underlying stratum, the target depth shall be increased past the soft stratum.	

8. Laboratory Test

8.1 Introduction

Laboratory tests provide site specific geotechnical and durability parameters for foundation design. These tests also provide appropriateness of the "in situ" test result interpretations.

Reference shall be made to Standards Australia handbook "HB 106- Soil testing" for detailed testing qualitative and quantitative requirements.

8.2 Sampling

8.2.1 Undisturbed Samples

Undisturbed samples shall be collected for laboratory testing where the soil characteristics are governed by the fine grain particles i.e. clay or silt. Undisturbed samples in medium to stiff cohesive soils shall be obtained using a thin walled sampler. In order to reduce the wall friction, suitable precautions, such as oiling the surfaces shall be required.

In soft clays and silky clays, with water standing in the casing pipe, piston sampler shall be used to collect undisturbed samples in the presence of expert supervision. Accurate measurements of the sampling depth,

[3] Refer to Western Power's internal document

dimensions of sampler, stroke and length of sample recovery shall be recorded. After the sampler is pushed to the required depth, the cylinder and piston system shall be drawn up together, preventing disturbance and changes in moisture content of the sample.

At least three samples per geological topography shall be required.

8.2.2 Disturbed Samples

Disturbed samples shall be collected for laboratory testing where the soil characteristics are governed by the coarse grain particles i.e. sand.

The number of samples shall not be less than 2 for each layer of soil profile under consideration.

When SPT is used to collect "split barrel" samples, these shall be collected at intervals of approximately every 2-4m at each test location.

8.2.3 Rock Coring

Rock coring by air core drilling techniques in weak rock and diamond core drilling in strong rock shall be required where investigation of the bedrock is necessary.

At least one sample per geological topography shall be required.

8.2.4 Groundwater Samples

Where groundwater is present within anticipated foundation depth, samples shall be taken from each borehole to do chemical analysis.

Representative ground water samples shall be collected when first encountered in boreholes and before the addition of water to aid boring or drilling.

Chemical analysis of water samples shall include determination of pH value, turbidity, sulphate and chloride contents, presence of organic material and suspended solids. Chemical preservatives may be added to the sample for cases as specified in the test methods.

8.3 Testing

The laboratory tests on collected soil samples shall conform to the following table:

Table 8.1: List of Laboratory Tests

Soil Type	Sample Type	Test
Sand with fine particles (<0.075 mm) less than 12%	Disturbed	1. Particle Size Distribution (with hydrometer analysis on one sample) 2. Unit weight Additional for substations: 3. Relative density 4. Moisture content 5. Oedometer test (coefficient of compressibility) Where pavement is required: 6. California bearing ratio (pavement analysis)
All other soil types	Undisturbed	1. Particle Size Distribution (with hydrometer analysis) 2. Atterberg limit 3. Unit weight 4. Unconfined Compression Strength 5. Moisture content Additional for substations: 6. Void ratio 7. Oedometer test (coefficient of compressibility) Where pavement is required: 8. California bearing ratio (pavement analysis)
Rock	Rock coring	Point load index (AS 4133.4.1)
All types	Groundwater/ disturbed soil sample	Chemical Test (Chloride and Sulphate in soil as well as pH in soil and groundwater)

9. Special Hazards/Constraints

The geotechnical investigation shall identify any hazards listed in the following table:

Table 9.1: Special Hazards

Geological Region	Special Hazards	Example
Hilly terrain, water catchment zones, mining sites, steep slopping ground	Land stability	• Areas of landslip. • Mining and quarrying. • Earth tectonic faults lines. • Soft ground, e.g. peat or alluvium. • Potential natural cavities. • Aquifers • Areas of seismic activity. • Steep slopes. • Unstable rock cliffs.
	Flood	• Sites near sea flood zone. • Sites near major river and overland flood zone.
Loose saturated cohesionless soil	Liquefaction	Sand area at earthquake prone zones.
Any region	Presence of asbestos, hazardous waste or material.	• Presence of organic soil. • Peat slides.
	Presence of rock	Shallow very high strength rock requiring extensive excavation.
	Highly compressible or expansive soil.	Soil susceptible to large time or moisture dependent settlement.

In presence of the above mentioned hazards/ constrains, the extent and type of geotechnical investigation shall be customised to determine appropriate engineering design & durability parameters and the extent of civil works.