Asset Lifecycle – Guidance Note

CIVIL AND STRUCTURAL

# Factors of safety for slope stability analysis

## Problem statement

Water and wastewater pipelines are often positioned in sloping ground. As part of the design, a stability analysis of the slopes is required to:

1) Determine the likelihood of slope failure based on the angle and geological properties of the slope; and
2) Validate the preservation of assets in the event of slope failure.

Currently, the design approach and criteria for **slope stability assessment** are not explicitly stated in Watercare's (WSL) standard *DP-07: Design principles for transmission water and wastewater* pipeline systems (2020).

DP-07 refers to the *American Lifelines Alliance Seismic Guidelines for Water Pipelines* (ALA, 2005) and *Underground Utilities – Seismic Assessment And Design Guidelines* (Opus, 2017) with some modifications and although *Part A, Section 5.2.1* of *DP-07* introduces Design Safety Factors (DSF) for various pipe function classes, there is no definition of DSF in the standard. As highlighted in *Table 1* below, some factors have been interpreted to be the equivalent of the minimum Factors of Safety (FoS) against slope instability and have thus been followed as criteria for slope assessment. This interpretation has led to FoS being significantly different from industry practice and has impacted the performance requirements of new pipelines by being either too conservative or inadequate.

***Table 1:*** *Design Safety Factors for Different Pipe Function Classes (reproduction of the table in Part A, Section 5.2.1 of DP-07).*

| Pipe function class | | Description | Design Safety Factors | | | | Seismic return period factor (NZS1170) $R_u$ |
|---|---|---|---|---|---|---|---|
| | | | Peak ground acceleration | Liquefaction /subsidence | Landslide/ lateral movement | Surface loading | |
| 1 | Low | Pipework in the local network area that service areas of no or limited economic impact. Post event repairs can be extended for a significant time. | 1 | 1 | 1 | 1.2 | 0.75 |
| 2 | Moderate | Common pipework in the Transmission networks, or Local Network mains larger than 150mm diameter, that if lost would result in unsatisfactory service disruption for 12 to 24 hours causing moderate economic impact. | 1.5 | 1.2 | 1.2 | 1.2 | 1.3 |
| 3 | Critical | Pipelines servicing larger numbers of customers (>10,000 people) that if lost causes significant economic impact or substantial hazard to human life, the natural environment and properties. | 1.8 | 1.35 | 1.6 | 1.5 | 1.8 |
| 4 | Essential lifeline | Pipelines that are essential to maintain service post natural disaster or man-made mishap and are intended to remain in service. | 2.3 | 1.5 | 2.6 | 2 | 1.8 |

Design Safety Factors that have been interpreted as the equivalent of the minimum Factors of Safety against slope instability in a static case

Design Safety Factors that have been interpreted as the equivalent of the minimum Factors of Safety against slope instability in a seismic case



Watercare

This Guidance Note **clarifies the design FoS for slope stability assessments of pipelines and how slope stability should be considered when evaluating the pipeline position.**

The geotechnical specialist should use commonly accepted analysis methods (e.g., limit equilibrium analysis or finite element analysis) and apply sound engineering judgement regarding geotechnical assumptions, such as soil behaviour, loading conditions and drainage conditions (drained/undrained), for project-specific slope stability analysis.

## Design factors of safety for slope stability assessment

**The DSF values in *Part A, Section 5.2.1* of *DP-07* should not be interpreted and used as target FoS values in slope stability assessment, as they are associated with design seismic displacements and are not intended for slope stability assessment.** The application of DSF is clarified in the guidance note – *Seismic Displacement for Pipeline Design (ESF-500-GDN-302)*.

The **minimum acceptable factors of safety for slope stability assessment** are presented in *Table 2*. These minimum requirements have been adopted by Auckland Council (2023) and should be followed by engineers and developers for all new pipeline projects.

***Table 2**: Minimum FOS for slope stability assessment*

| Load Case | Minimum FoS |
|---|---|
| Long term static - normal groundwater [(a)] | 1.5 |
| Short term static - worst credible groundwater [(b)] | 1.3 |
| Seismic - pseudo-static seismic loading using Ultimate Limit State (ULS) Peak Ground Acceleration (PGA) | 1.0, or<br>**FoS < 1.0** with **seismic permanent ground displacements** are considered to achieve required pipeline performance. Refer to *Guidance Note – Seismic Displacement for Pipeline Design (ESF-500-GDN-302).* |

**Notes for Table 2**:

a. This refers to the typical annual high groundwater level during winter, which may persist for an extended period (months), the design reflecting this.
b. This represents the highest peak groundwater level that typically occurs for short, transient periods (days or weeks). However, if a lower groundwater level presents a more critical condition, this scenario should be considered the worst-case and the design adjusted accordingly.

## Pipeline design within or near a slope

**Wherever practicable, conservative design approaches should prevail, including pipelines located outside the influence of a potentially unstable slope**. *Figure 1* illustrates how a pipeline can be positioned within a slope. Zone A indicates a slope zone that cannot achieve the minimum FoS shown in *Table 2* for a given load case. Pipelines are expected to be located within Zone B, where the minimum FoS can be met for all of the design load cases. This implies that the pipeline will fall outside of the area prone to slipping when considering the angle of the slope, adhesion properties of the ground, and applying a FoS.

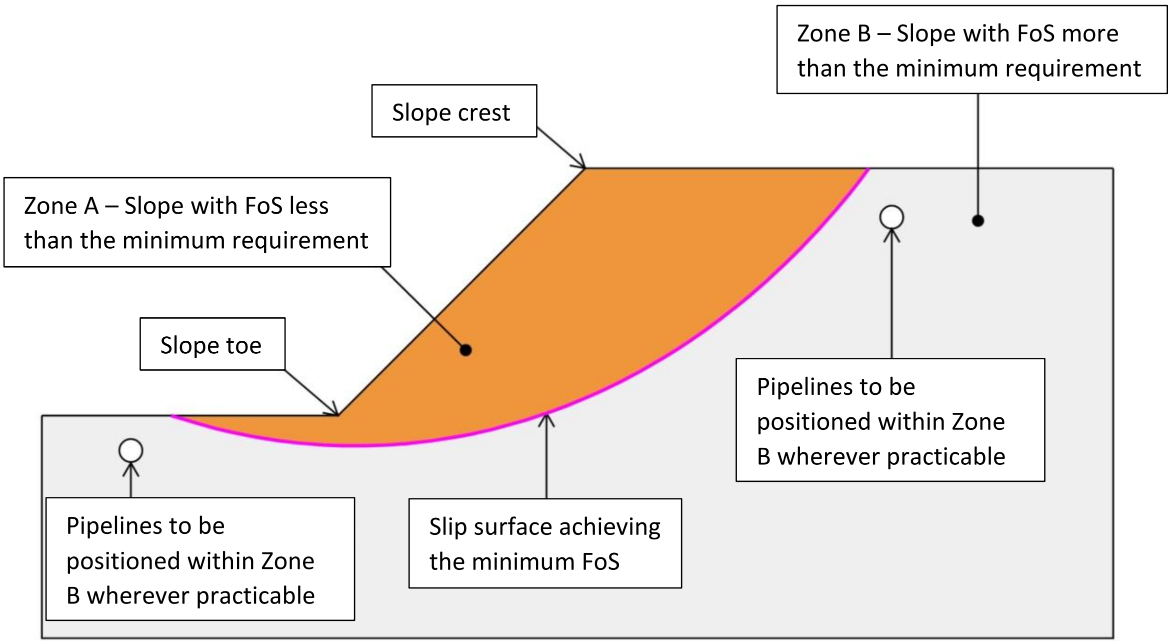


***Figure 1**: Pipeline Location within a Slope (a cross-section view)*

If it is not possible to avoid a potentially unstable slope, the designer should explore structural options to **eliminate or at least reduce the potential for pipeline damage** due to slope movement, thereby achieving the necessary **resilient** outcome.

## References


1. American Lifeline Alliance (ALA). (2005). *Seismic Guideline for Water Pipelines.* Oakland, California, United States of America: American Lifeline Alliance.
2. Auckland Council. (2023). *The Auckland Code of Practice for Land Development and Subdivision Chapter 2: Earthworks and Geotechnical.* Auckland: Auckland Council.
3. Opus. (2017). *Underground Utilities - Seismic Assessment and Design Guidelines* (1st ed.). Wellington, New Zealand: Opus International Consultants Ltd.
4. Sydney Water. (2022). *Technical Specification - Civil CPDMS0023* (10th ed.). Sydney, NSW, Australia: Sydney Water.
5. Waka Kotahi. (2022). *Bridge Manual (SP/M/022) Third Edition, Amendment 4.* Wellington, New Zealand: Waka Kotahi NZ Transport Agency.
6. Watercare. (2020). *Design Principles for Transmission Water and Wastewater Pipeline Systems (DP-07).* Auckland: Watercare.
7. WSAA. (2012). *Water Supply Code of Australia WSA 03: 2011-3.1 Melbourne Retail Water Agencies Edition* (2nd ed.). Sydney, NSW, Australia: Water Services Association of Australia Limited .