

UKOPA

United Kingdom Onshore Pipeline Operators' Association

Good Practice Guide

Managing Pipelines Subject to Ground Movement

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The guidance in this document represents what is considered by UKOPA to represent current UK pipeline industry good practice within the defined scope of the document. All requirements should be considered guidance and should not be considered obligatory against the judgement of the Pipeline Owner/Operator. Where new and better techniques are developed and proved, they should be adopted without waiting for modifications to the guidance in this document

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EXECUTIVE SUMMARY

This UKOPA good practice guide (GPG) has been developed by the UKOPA Pipeline Integrity Working Group to provide guidance on the management of pipelines subject to ground movement. The guidance within the document is applicable to all buried pipelines operated by the UKOPA member companies.

Pipelines are long life, linear assets which are routed on third party land over a distance of several kilometres. The topography and ground conditions can vary considerably along the route, and localised ground movement can occur during pipeline operation. Ground movement has the potential to cause external loading on pipelines which can result in significant axial and bending stresses, leading to failure. The safe management of pipelines subject to ground movement is an important element of the operator's pipeline integrity management strategy.

A primary requirement is the identification of ground movement which may impact on an operating pipeline, inducing high stresses in the pipeline and resulting in possible failure. The prediction and measurement of ground displacement requires specialist expertise, and the analysis of the effects of ground movement on pipelines may require the application of finite element techniques to model the nonlinear soil and pipeline behaviour. These activities are site and pipeline specific, and when required, involve expert resources.

The document provides advice on the identification of locations susceptible to ground movement with the potential to cause damage to pipelines, and the requirements for the safe management of such pipelines including reducing loading on the pipeline, monitoring ground movement and pipeline strain.

1 OBJECTIVES

The objectives of this GPG are to provide advice to pipeline operators on the identification of locations which are susceptible to ground movement with the potential to cause damage to pipelines, and the requirements for the safe management of such pipelines including reducing loading on the pipeline, monitoring ground movement and pipeline strain.

2 INTRODUCTION

2.1 Background

Pipelines are long life, linear assets which are routed on third party land over a distance of several kilometres. The topography and ground conditions can vary considerably along the route, and localised ground movement can occur during pipeline operation.

Ground movement has the potential to apply high external loading to pipelines, generating high axial and bending stresses which may result in failure. Controlling the threat to pipeline integrity posed by potential ground movement is therefore a key requirement of the operator's pipeline integrity management strategy. In addition, if ground movement occurs, it is necessary to monitor and measure the movement, assess its impact on the pipeline, reduce pipeline loading, and implement remedial actions. These activities require specialist resources and time for their implementation. In many cases continued operation of the pipeline during the investigation and evaluation will be required.

2.2 Management of Safety and Integrity

The Pipelines Safety Regulations 1996 [1], which are enacted under the Health and Safety at Work etc. Act 1974 [2], place duties on the pipeline operator to ensure the safe management and operation of pipelines and the associated installations. The legislation is goal setting, and therefore requires that the operator identifies the hazards and manages risks appropriately.

Ground movement may occur for a number of reasons, examples are:

- Land sliding.
- Rock falls and debris flows.
- Subsidence.
- Erosion.
- Fault displacement and soil liquefaction in earthquakes.
- Changes in the ground water table.
- Differential soil settlement.
- Frost heave and thaw settlement.

Risk management requirements for geological hazards are given in ISO 20074 [3]. This GPG gives recommendations for the management of geological hazard risks in the operation and maintenance of pipelines based on the guidance provided in published standards.

2.3 Scope

This GPG provides guidance on the safe management of pipelines subject to ground movement.

It addresses:

1. Risk assessment.
2. Identification of locations on the pipeline route which are susceptible to ground movement.
3. Advice on reducing loading applied to the pipeline.
4. Requirements for measuring and monitoring ground movement.
5. Mitigation and repair.

2.4 Application

The guidance in this document is applicable to all buried pipelines operated by the UKOPA member companies.

Within this document:

Shall: indicates a mandatory requirement

Should: indicates good practice and is the preferred option

3 RISK ASSESSMENT

Locations identified as susceptible to ground movement should undergo a risk assessment to determine appropriate actions. These actions could include measuring and monitoring ground movement, implementing mitigation and repair options, through to diverting/rerouting the pipeline.

The risk assessment process should include:

1. **Hazard assessment** - identifying hazards and estimating their magnitude and probability.
2. **Consequences assessment** - evaluating the credible consequences of the identified hazards.
3. **Risk assessment** - combining the hazard and consequence assessment with a cost benefit analysis to guide decisions on appropriate actions.

ISO 20074 [3] specifies requirements and provides recommendations on managing geological hazard risks, including ground movement, throughout the pipeline lifecycle. IGEM/TD/2 [4] and PD 8010-3 [5] provide guidance on the application of risk assessment, including the risk of failure due to ground movement.

The risk assessment should consider areas of pipeline with reduced wall thickness and/or defects interacting with any ground movement hazard.

4 LOCATIONS SUSCEPTIBLE TO GROUND MOVEMENT

Locations which are susceptible to ground movement are identified in the geological survey carried out for pipeline routing, and in any site-specific ground condition assessments carried out in detailed design and construction. The value and availability of this data depends upon the age of the pipeline, and for older pipelines this may not be available. Typically, ground movement which occurs during operation is detected through pipeline surveillance. Identification of ground movement through surveillance is considered in Section 5.1, and by in-line inspection in Section 5.2. In addition, the British Geological Survey (BGS) provides a GeoSure dataset [6] as a geographic information system (GIS) layer for landslide susceptibility zones, which can be licensed to overlay with pipeline GIS data to identify specific locations of landslide susceptibility. The use of the BGS GeoSure dataset is considered in Section 5.3.

4.1 Identification of Ground Movement Through Surveillance

Aerial surveillance, particularly where aerial photographs are taken, is a practical and efficient means of detecting the occurrence of ground movement, as changes to the ground surface can be identified. Displacement of normally fixed aboveground infrastructure and fauna such as pylons, telegraph poles, marker posts, and/or trees can be used to indicate ground movement. However, ground movement can initiate through small changes over a period of time, so areas which may be susceptible to ground movement should be identified for specific observation during aerial survey, supplemented through vantage point surveys and line walking as appropriate.

Geotechnical specialists experienced in identification and assessment of ground movement can be used to inform the hazard assessment.

Locations where geological hazards exist which may cause ground movement and external loading on a pipeline include:

- Earthquake fault zones.
- Medium and large river crossings.
- Karst collapse (underground caves/caverns, sinkholes formed in areas of soluble rock).
- Unstable soils subject to liquefaction (including peat which is also subject to washout).
- High and steep slopes.
- Debris flows.
- Mined, quarried areas.

The potential for ground movement or loss of ground support at such locations is likely to be exacerbated by periods of abnormally heavy rainfall and flooding. A checklist summarising the hazards and features which may be observed during surveillance and the pipeline vulnerability to be considered is given in Table 1. Photographic examples of ground movement provided by UKOPA members are included in Appendix 1.

Hazard	Observed Features	Criteria	Pipeline Vulnerability
Land slide	Steep slope, indications of surface run-off erosion, waterlogged soil, ground fissures/tension cracks, displacement of surface features/vegetation	Average gradient of slope 30° – 45°	Pipeline traversing slope subject to bending and axial stress, aligned with slope subject to axial tension and compression
Debris flow/rockfall	Large longitudinal slope, adjacent rockfalls and loose soil/rock material, recent heavy rain, obstructed water flow, surface fissures/fractures in upper mass		Loss of support, external load, stone impact damage
River/gully erosion	Evidence of river bed undercutting, river bank collapse or slope erosion.	Riverbed undercutting exceeds 1 m Slump block stones greater than 0.5 m diameter	
Slope erosion	Slope surface comprised of exposed soil, lack of vegetation. Soil type – loam/sand, slope surface shows erosion gullies	Changes observed within last year	External loading and large displacement
Soil liquefaction/collapse/salinization	Surface shows significant sedimentation, collapse or uplift, evidence of recent subsidence features or washout	Bead shaped collapse pits, subsurface erosion caves.	
Frost heave and thaw settlement	Uplift of ground, subsequent settlement on thawing	Uneven mounds and settlement due to formation and melting of ice lens	External loading and large displacement
Subsidence	Surface settlement/collapse, continuous fissure, ground water pumping in action	Limestone or dolomite bedrock present within 30 m of surface	Pipeline located in or within 200 m
Earthquake	Area identified on UK seismic hazard map	Peak ground acceleration on rock exceeds 0.1 g	External loading

Table 1: Checklist for identification of ground movement during surveillance

4.2 Identification of Ground Movement Through In-line Inspection

Inertial mapping units (IMUs) included in in-line inspection tools generate accurate three-dimensional co-ordinates for the precise location of identified features. The IMU data can be used to calculate pipeline curvature. By assuming an original pipe geometry profile, which is typically straight, the calculated curvature can be used to calculate strain and displacement. Comparison of data sets recorded sequentially at different times, can then be used to determine the change in curvature and displacement of the pipeline due to ground movement. It must be noted that to use this approach to assess ground movement, accurate analysis of a minimum of two sets of high-resolution data is required for comparison.

4.3 BGS GeoSure Dataset

A major study of UK natural landslides was commissioned by the Department of the Environment (DOE) in the 1980's. The study considered the known inland and coastal natural landslides across the UK mainland and produced a database of 8,835 landslides. The work was published in 1994.

The DOE landslide database was subsequently transferred to the BGS for management, development and extension. The database currently holds over 17,000 entries and is continually updated as new records are made available.

The BGS has developed a landslide susceptibility classification which is part of the GeoSure suite of UK geohazards. The GeoSure classification for landslide susceptibility is based on a five-tier ranking: E (high), D, C, B, and A (very low). The BGS GeoSure classes are given in Table 2.

GeoSure Class	Description
E	Slope instability problems almost certainly present and may be active
D	Slope instability problems are probably present or have occurred in the past
C	Slope instability problems may be present or anticipated
B	Slope instability problems are not likely to occur but consideration to potential problems of adjacent areas impacting on a site should always be considered
A	Slope instability problems are not thought to occur but consideration to potential problems of adjacent areas impacting on the site should always be considered

Table 2: BGS GeoSure classes

Classes E, D and C are associated with conditions conducive to landslide and in combination cover ~10% of the landmass area. Landslides are recorded in all the susceptibility classes from an average density of ~6/km² in Class E to ~0.02/km² in Class A. Approximately 50% of all recorded landslides occur within low susceptibility areas (A and B), but the likelihood of occurrence and the severity will vary significantly according to the susceptibility class.

The GeoSure zoning has been developed over a 25 m x 25 m grid resolution. The indicative spatial extents of the different landslide susceptibility levels in Great Britain are given in Table 3.

Class	Spatial Extent in Great Britain (%)	Notes
E	~0.2	10% prone to land sliding
D	~1.1	
C	~8.5	
B	~81.6	90% not prone to land sliding
A	~8.7	

Table 3: Spatial extent of landslide susceptibility levels in Great Britain

BGS provides the GeoSure dataset as a location specific GIS layer for landslide susceptibility zones. This can be licensed to overlay with pipeline GIS data to identify specific locations of landslide susceptibility along the pipeline route.

A study carried out for the UK gas industry to investigate the ground movement hazard to the high pressure gas transmission system following pipeline failures due to ground movement found that for the then ~16,000 km of pipelines operated by British Gas, ~2.2% of the system was at risk of slope instability, ~1.25% was at marginal risk of slope instability, and ~0.91% was at risk from other geological hazards. This indicates that the major cause (i.e. 80%) of ground movement is due to slope instability.

Use of the BGS GeoSure dataset provides an effective and efficient means of identifying locations susceptible to the major cause ground movement for large pipeline networks, removing the need for the detailed surveillance observations listed in Table 1. Susceptible locations found using the BGS GeoSure dataset should be subject to site specific surveillance to identify any changes which may indicate the start of ground movement due to slope instability.

5 REDUCING LOADING DUE TO GROUND MOVEMENT

Following the identification of ground movement, actions to limit the impact on the pipeline should be considered. Depending upon the type of ground movement which has occurred, options may include:

1. Working with the landowner/occupier to stop any work which has resulted in ground movement and/or reduce access to the affected location.
2. Carry out drainage work to reduce washout if required.
3. Carry out ground reinforcement works.

Techniques which can be used to reduce pipeline stress caused by ground movement while the situation is assessed include:

1. Excavating and exposing the affected pipeline section(s) to remove the applied loading.
2. Where the ground movement is perpendicular to the pipeline, opening a trench parallel to the pipeline.
3. Surrounding the pipe with low friction backfill materials.

Note that remedial action, particularly excavation and exposing operations, need to be carefully planned considering the results of strain monitoring and structural modelling simulations. The excavation must be controlled through careful monitoring, as ground movement can induce significant strain levels in the pipeline which, if relieved quickly, can result in significant displacement and buckling.

6 MEASURING AND MONITORING

IGEM/TD/1 [7] includes ground movement as a potential threat to pipeline integrity and requires that it be considered when assessing risks and defining appropriate risk control measures.

PD 8010-4 [8] requires regular surveillance of the pipeline route to detect any changes, including ground movement. If changes are identified, remedial or mitigation measures must be implemented as necessary.

6.1 Ground Movement

The method of ground or pipe monitoring is generally dependent on the stress levels predicted and/or the criticality of the pipeline. For non-critical pipelines or where the stress increase is predicted to be relatively low, simple level monitoring only is required. If the pipeline is critical or the stress increase is relatively large, then a more comprehensive type of monitoring is required.

Monitoring methods include:

- Level monitoring.
- Electronic Distance Measurement (EDM) monitoring.
- Global Positioning System (GPS) spatial positioning.
- Borehole inclinometers.

The survey approach should include measurement of the level, axial and lateral displacement, and slope inclination.

Level monitoring can be carried out in the ground, on the uncovered pipeline, or on above ground pipework or equipment, as an exercise on its own or in conjunction with axial and lateral displacement monitoring. The level of accuracy should be +/- 0.2 to 0.4 mm per kilometre.

Axial and lateral displacement monitoring should be carried out using a 'Total Station' Instrument or GPS. Repeatable accuracy of not less than +/-10 mm is acceptable. The vertical accuracy of GPS measurements is less than the horizontal accuracy, and its use may be limited where there are trees, buildings, etc. which block the satellite signals. In practice a combination of GPS and Total Station instruments may be required.

Inclinometer measurements are required where slope failure is a major concern. Borehole inclinometers are used to monitor slopes and landslips to detect zones of movement and establish whether movement is constant, accelerating or responding to remedial measures. An inclinometer provides information on slope stability by measuring variation in movement with depth and identifying whether a slip surface exists. Inclinometer readings should be taken daily, and action should be taken when a predetermined trigger reading is obtained.

In order to obtain repeatable accuracy, ground monitoring points must be installed. The extent of the pipeline likely to be affected by ground movement must be taken into account. The frequency of monitoring should be set according to the observed rate of change in ground movement.

Monitoring projects will vary in their size, complexity and nature and the suitability of equipment and methods should be considered prior to each project. Method statements detailing the survey equipment and procedure to be followed should be prepared.

In locations where the soil is of low stiffness or where soil liquefaction may occur, it may be necessary to monitor the movement of the pipeline rather than the ground. In such cases, the pipe surface can be accessed using tubes. To ensure repeatability, it will be necessary to install a locator point on the pipeline to ensure measurements are taken at the same position.

Note that monitoring cannot reliably or promptly detect sudden ground movement, so the frequency of monitoring and supplementary surveillance must consider the potential for sudden movement, and the occurrence of conditions which may prompt this (heavy rainfall, sudden temperature changes). Where the requirement for ground monitoring and surveying is identified, specialist advice should be sought from the BGS or a competent engineering consultancy.

6.2 Pipeline Strain Measurement

Strain measurements provide direct measurement of the strain changes in the pipeline. Strain measurements may be used in conjunction with residual strain measurement (RSM) which provides a datum stress measurement and allow the total strain the pipeline to be assessed. The use of strain gauges should be considered when the expected level of stress due to ground movement exceeds an equivalent stress of 45% of specified minimum yield stress (SMYS) or 50% of the maximum value allowed by the pipeline standard (normally 90% SMYS).

A minimum of two sets of strain gauge arrays, spaced at an appropriate axial distance apart, should be installed on the pipeline affected by ground movement at the location of the maximum predicted stresses. Each strain gauge array should consist of circumferentially spaced strain gauges to enable axial and bending components of incremental strain to be identified.

Strain measurements can be obtained using vibrating wire strain gauges or foil gauges. Both methods will only measure stress/strain changes in the pipeline not the total stress state in the pipeline. Vibrating wire strain gauges are more robust than foil gauges and are recommended for longer term measurements. Foil gauges are more suitable when fast measurements are needed. Vibrating wire strain gauges are welded (preferred) or glued to the pipeline, foil gauges are glued to the pipeline.

A thermocouple or other temperature measuring instrument (thermistor) must be attached to the pipeline using a suitable adhesive, so that thermal strain changes can be considered. Vibrating wire strain gauges can be fitted with thermistors which can record the temperature at the gauge location.

Strain gauges should be viewed as a means of providing a warning that a landslide is directly affecting pipeline. There is the potential that gauges will exceed their limit range before strain limits to compromise structural integrity are reached. Monitoring of strain gauges must account for the normal pipeline operating condition changes.

6.3 Use of Remote Sensing Imagery and Photography

The efficiency of an investigation of ground movement and its impact on a pipeline can be improved greatly by using remote sensing imagery, such as LiDAR (light detection and ranging) and aerial photographs. These techniques provide greater refinement and accuracy in identifying of the area affected by ground movement. The use of drones allows remote sensing imagery and aerial photography to be captured from the same fixed location on subsequent surveys facilitating imagery comparison.

7 MITIGATION AND REPAIR

Mitigation and repair methods should be carried out in accordance with pipeline standards and operator procedures.

In cases where the ground movement presents a short-term hazard only, excavation and exposure or, depending on the alignment of the pipeline with the ground movement, opening a trench parallel to the pipeline to remove the loading on the pipeline may provide the required mitigation. Where the threat is considered to be long term, permanent mitigation or repair is required.

Mitigation measures include dewatering of the soil using surface and subsurface drainage systems, slope stabilisation, backfill replacement with material to reduce load transfer to the pipeline, and controlling slope erosion through the use of geotextile materials, netting, planting light vegetation.

Repair methods include:

1. Applying stress relieving cuts and installing expansion units or sliding joints in areas of restricted access.
2. Installing pipeline repair sleeves.
3. Cut out and replacement of pipeline sections with pipe of thicker wall and higher material grade.

Note methods 2 and 3 are effective for local scour and erosion threats. Based on the ground movement risk assessment and mitigation options available, diverting or rerouting the pipeline may be the preferred solution.

8 REFERENCES

- [1] "Pipeline Safety Regulations 1996," Statutory Instrument 825/1996, 11 April 1996.
- [2] "Health and Safety at Work etc. Act 1974," CHAPTER 37, 31 July 1974.
- [3] International Organization for Standardization, "Petroleum and natural gas industry — Pipeline transportation systems — Geological hazard risk management for onshore pipeline," ISO 20074 First Edition, July 2019.
- [4] Institution of Gas Engineers and Managers, "Assessing the risks from high pressure Natural Gas pipelines," IGEN/TD/2 Edition 3 with Amendments, October 2024.
- [5] The British Standards Institution, "Pipeline systems – Part 3: Steel pipelines on land – Guide to the application of pipeline risk assessment to proposed developments in the vicinity of major accident hazard pipelines containing flammables – Supplement to PD 8010-1:2004," PD 8010-3:2009+A1, July 2013.
- [6] British Geological Survey, "BGS GeoSure," [Online]. Available: <https://www.bgs.ac.uk/datasets/geosure/>. [Accessed September 2024].
- [7] Institution of Gas Engineers and Managers, "Steel pipelines for high pressure gas transmission," IGEN/TD/1 Edition 6, October 2021.
- [8] British Standards Institution, "Steel pipelines on land and subsea pipelines - Code of Practice for Integrity Management," PD 8010-4:2012, July 2012.

APPENDIX A EXAMPLES OF GROUND MOVEMENT

A.1 Land Sliding



A.2 Soil Liquefaction



A.3 Subsidence



A.4 Quarrying

