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Petroleum and natural gas industry — Pipeline transportation systems — Geological hazard risk management for onshore pipeline

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 2, *Pipeline transportation systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is used by pipeline operators and designers for the implementation and improvement of geohazard risk management of onshore pipelines.

It is used for the orderly and effective identification, assessment and mitigation of geohazards threatening the integrity or safety of the pipeline, and to reduce the potential for risks and accident loss. This document is intended to address geohazards along the pipeline and right-of-way (RoW).

Petroleum and natural gas industry — Pipeline transportation systems — Geological hazard risk management for onshore pipeline

1 Scope

This document specifies requirements and gives recommendations on the management of geohazard risks during the pipeline design, construction and operational periods.

This document is applicable to all operators and pipelines (existing and proposed/under construction).

This document applies to onshore gathering and transmission pipelines used in the petroleum and natural gas industries.

NOTE This document is not applicable to piping and pipelines within well-defined plants and facilities, such as pump or compressor stations, processing facilities or refineries. It is assumed that the facility site as a whole will be subject to a separate geohazard assessment to evaluate applicable natural and man-made hazards. Nevertheless, this document can provide useful guidance for assessing the geohazard threat to facilities, including the pipelines within the facility.

This document is applicable to all reasonable and credible natural hazards induced by natural forces and hazards induced by human activity that manifest similarly to natural hazards collectively referred to as "geological hazards" or "geohazards", or through industry as attributed to "natural forces". Geohazards covered by this document include, but are not limited to (not given in order of significance):

— mass wasting processes, including landslides, lateral spreads, rockfalls, debris flows, avalanches, and similar processes whether naturally occurring or anthropogenic;

— land subsidence and/or sinkhole formation, whether naturally occurring such as from dissolution of salt or carbonate rock formations (karst formation) or human caused, such as from underground mining or withdrawal of subsurface fluids such as groundwater and oil and gas;

— seismic hazards, such as ground shaking, fault rupture, liquefaction, flow failures and lateral spreading or associated secondary effects, such as seismically triggered landslides;

— volcanic hazards, such as lahars, pyroclastic flows, lava flows, dam break, and volcanically induced seismicity (excluding ashfall), where such hazards can be reasonably predicted;

— hydrologic processes, such as flooding, vertical scour of river bottoms, channel migration and bank erosion, channel avulsion, rapid lake drainage;

— permafrost/periglacial processes and geothermal effects, such as thermal degradation, frost heave or thaw settlement, thermal erosion, thermokarst;

— surface (overland), trench backfill, or earthwork fill erosion;

— expansion or collapsing processes caused by expansive and collapsible soils, such as glaciomarine clays, collapsible loess, etc.

This document is not applicable to atmospheric/environmental effects, such as the following:

— high winds induced from hurricanes and tornadoes and similar storms, except where such events are reasonably predictable and will induce geohazards such as landslides, erosion, etc.;

— lightning;

— forest or brush fires;

— ashfall from volcanic eruptions.

Furthermore, this document is not applicable to cascading events, where one remote event leads to a chain of events that eventually induces a geohazard near the pipeline. It is only applicable to geohazards that directly affect the pipeline or RoW.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
construction phase
period where the pipeline is physically constructed encompassing all activities from RoW clearing, to commissioning and RoW clean-up/reinstatement

3.1.2
detailed design phase
period consisting of detailed design, which can include but is not limited to detailed hydraulic studies, mechanical design of the pipeline, stress analysis, design of RoW, full characterization of all identified geohazards, construction and logistics planning, and supply management

3.1.3
dynamic management
process that covers the pipeline's full life cycle, which can be implemented when a new hazard is identified or an existing hazard changed

3.1.4
geohazard inventory
list of all identified geohazards which can be maintained, enhanced or decreased throughout the life of the pipeline project

Note 1 to entry: Ideally, the inventory would be computer based and linked to a Geographic Information System (GIS).

3.1.5
geohazard susceptibility
geological or environmental conditions that might allow a geohazard event to occur

Note 1 to entry: A geohazard event can be natural or man-made occurrence that induces an integrity or safety threat to the pipeline or RoW.

3.1.6
geologically sensitive area
area potentially prone to geohazards

EXAMPLE Such areas include seismic fault zones or active faults, medium and large rivers, high and steep slopes, debris flows corridors, landslide prone topography, areas prone to karst collapse, mined-out areas.

3.1.7
hydrologic process
process associated with flowing water, i.e. river and stream processes

3.1.8
individual pipeline geohazard
specific geohazard that can impact the pipeline

3.1.9
land subsidence
sinking or gradual downward settling of the earth's surface with relatively little horizontal movement

Note 1 to entry: It can be caused by karst processes, collapsible or dispersive soils, piping erosion, upward migration of underground mining works, or other processes.

3.1.10
long-term management
management activities for *pipeline geohazards* (3.1.15) through monitoring and periodic re-evaluation of threat levels from geohazards

3.1.11
mass wasting process
general term for the dislodgement and gravity-driven downslope movement or transport of soil and rock material

3.1.12
operation and maintenance phase
period in pipeline lifecycle during which hydrocarbon product fills the pipeline and is transported through the pipeline, and the pipeline operator addresses issues related to pipeline and RoW maintenance and integrity

3.1.13
operator
person or organization which owns or operates a pipeline system or facilities and which is responsible for the operation and integrity of the pipeline system

3.1.14
pipeline failure consequence
impact or loss caused directly or indirectly by leakage, damage or reduced performance of a pipeline subject to geohazards

EXAMPLE Social and environmental impact, loss of life and property, negative impact on corporate reputation, and economic loss.

Note 1 to entry: This includes individual pipeline geohazard and regional pipeline geohazard.

3.1.15
pipeline geohazard
geological process or phenomenon that have the potential to cause damage to a pipeline or RoW

3.1.16
pipeline geohazard risk
combination of *geohazard susceptibility* (3.1.5), *pipeline vulnerability* (3.1.22) and *pipeline failure consequence* (3.1.14)

3.1.17
pipeline geohazard risk assessment
process of determining whether *pipeline geohazard risks* (3.1.16) are acceptable or require mitigation or an intervention

3.1.18
pipeline geohazard risk identification
process of discovery, characterization and description of credible and probable geohazards that can impact the pipeline or RoW

3.1.19
pipeline geohazard risk management
coordinated activity for guiding and coping with issues related to *pipeline geohazard risk* (3.1.16)

3.1.20
pipeline geohazard risk management program
set of processes and procedures for guiding operating companies or *operators* (3.1.13) to carry out *pipeline geohazard risk management* (3.1.19)

3.1.21
pipeline geohazard risk mitigation
process of selecting and implementing a geohazard risk countermeasure or intervention to reduce the probability of a negative event or reduce the consequences of a negative event that can impact the pipeline or RoW

3.1.22
pipeline vulnerability
conditional likelihood of a pipeline being subject to damage due to a geohazard, given a geohazard occurs and impacts the pipeline, which is an estimate of how resistant it is to damage caused by geohazards

3.1.23
preliminary engineering and route selection phase
initial period in the pipeline lifecycle during which basic design work is completed, including but not limited to route study and selection, preliminary design of the pipeline, early planning for logistics, supply management and regulatory planning and submissions

3.1.24
regional pipeline geohazard
group or cluster of existing and potential geohazards located within a defined geographic area

3.1.25
right-of-way
corridor of land within which the pipeline operator has the right to conduct activities in accordance with the agreement of the land owner

[SOURCE: ISO 13623:2017, 3.1.19]

3.1.26
seismic hazard
hazard occurring as a result of an earthquake

3.1.27
subject matter expert
SME
practitioner experienced with evaluating and managing geohazards

Note 1 to entry: The qualifications for a subject matter expert vary by location but they generally include a degree in geology, geomorphology, hydrogeology, geotechnical engineering, geological engineering, civil engineering, or related degree and at least five years of practical experience working with geohazards.

3.2 Abbreviated terms

GIS Geographic Information System

ILI In-Line Inspection

LiDAR Light Detection and Ranging

PGMP Pipeline Geohazard Risk Management Program

RoW Right-of-way

4 Pipeline geohazard risk management program

4.1 Key principles

A PGMP is a set of practices and procedures used to systematically identify, evaluate, and manage geohazards for the purposes of reducing the risk of damage to a pipeline system to an acceptable level. A PGMP is operated for the entire lifespan of the pipeline from conception and design, to construction, operation, and until the pipeline system is decommissioned. Thus, the PGMP should be designed and implemented in such a way that critical information will be maintained and accessible for the lifetime of the pipeline.

Because a variety of different groups participate in the design, construction and operation of a pipeline, overall ownership of the PGMP rests with the operator. The operator shall designate an individual or organization (the “PGMP team”) to administer the PGMP during and between the different phases. The PGMP team may be the operator’s personnel or a qualified third party entrusted by the operator. In case of replacement of one organization by another, a proper handover of geohazard risk management duties shall be ensured. When the geohazard risk management is assigned to a third party, the operator shall be continuously and intimately engaged with the third party to ensure that the interests and needs of the operator and all stakeholders are being adequately addressed and protected.

It is recommended that geohazard risk management throughout the life of a pipeline be carried out by the same organization, which can be either an operator, or a third party entrusted by them.

Dynamic management of pipeline geohazards is required and newly identified geohazards may be included in said management. Geohazards included in dynamic management are referred to as risk management objects.

Where a PGMP is needed, operators shall establish and maintain a PGMP for the life of the asset. Operator shall update the PGMP during the life of the asset as and when conditions warrant.

All work associated with the geohazard risk identification, assessment and mitigation of the pipeline shall be carried out by qualified personnel. SMEs shall be consulted as necessary throughout all stages and phases of the pipeline lifecycle.

PGMP activities shall be documented. Geohazards might change over time, and changes in the PGMP shall be documented over time, to ensure that the most current data and assessments are identified. Out-of-date assessments may be archived.

4.2 Requirements for a PGMP

The PGMP informs an operator of how to design, construct and operate the pipeline in a safe, environmentally responsible and reliable manner.

The PGMP covers the phases of preliminary engineering and route selection, detailed design, construction, as well as operation and maintenance. It is recommended to conduct geohazard risk management as a discrete element of the pipeline design phase, beginning in the earliest phases of design.

Geohazard risks to a pipeline, and thus the need and scope of a PGMP, varies from pipeline to pipeline, due to a number of natural and human-induced factors. Geohazard risk might be higher for pipelines operated in areas of

a) steep terrain,

b) active tectonics,

c) high precipitation,

d) soluble bedrock,

e) high seismicity,

f) geologically young terrain,

g) significant natural resource exploitation/extraction,

h) landslide prone geology,

i) volcanism,

j) active shallow mining,

k) significant river crossings, and

l) geothermal variability such as permafrost.

For example, a short pipeline in a flat, tectonically stable region with minimal rainfall might have a relatively low geohazard risk. In this case, the operator might demonstrate that a PGMP is not needed. Conversely a long pipeline with a 50-year service life, in a remote, steep, tectonically active tropical region would likely have a relatively high geohazard risk. In this case, the operator would very likely establish a PGMP.

Because of the broad variation in geohazard risk between pipelines, an operator is required to assess geohazard risk of existing and future pipelines and determine whether a PGMP is necessary.

If an operator concludes that a PGMP is not necessary for a particular pipeline or section of pipeline, the conclusion shall be documented. The documentation shall be a report titled:

Demonstration that Geohazard Management Program is not Required for [name of pipeline].

It shall include, without limitation, a discussion of the items listed in 4.2 a) to l) with an explanation why the geohazard risks are of such a low level that a PGMP is not needed. The report shall be prepared in consultation with suitable SMEs with appropriate experience in the region and type of geology in which the pipeline is, or will be installed.

If an operator concludes that a PGMP is necessary, the operator shall establish a PGMP team to design and implement the appropriate PGMP, beginning at the earliest phases of project development.

4.3 Elements of a PGMP

4.3.1 General

To prevent and reduce risks caused by geohazards, the PGMP shall be carried out throughout the life of a pipeline under the guidance of the PGMP team. The PGMP covers four interlinked processes:

— **identification** of potential geohazards;

— **evaluation** of the severity of the geohazards;

— **mitigation** of the threat from the geohazards;

— **long-term management** of geohazards through monitoring and periodic re-evaluation of threat levels from geohazards.

The four processes are needed to varying degrees throughout the life of the pipeline.

To illustrate the application of the four processes, this document considers four phases of pipeline life:

— preliminary engineering and route selection;

— detailed design;

— construction;

— operation and maintenance.

Each phase is discussed below, with an illustration of the four processes within each phase.

A typical PGMP follows the flowchart in Figure 1. The PGMP process shall occur in parallel with consideration of other constraints, such as economics and societal.

4.3.2 Preliminary engineering and route selection phase

In this phase, the effects of geohazards shall be fully considered to meet the requirements of route selection. Because the most effective mitigation of geohazards is avoidance, this phase represents an important opportunity for the operator to reduce the overall geohazard risk of the project.

Annex A provides guidelines for route selection in consideration of geohazards.

During this phase, the PGMP shall follow the principles of identification, evaluation, mitigation and long-term management:

— **Identification**: Establish regional understanding of geohazards and determine whether regional geohazard threat level requires further development of a PGMP. For the initial corridor alternatives, severe geohazards and geologically sensitive areas, such as seismic fault zones or active faults, medium and large rivers, high and steep slopes, debris flows corridors, landslide prone topography, areas prone to karst collapse, mined-out areas should be identified. Acquire regional and local remote sensing data sets, supplement with ground investigation if warranted. Light Detection and Ranging (LiDAR) data combined with expert interpretation have proven to be an extremely valuable tool in identifying geohazards during this phase.

— **Evaluation**: Classify geohazards along the proposed corridors according to severity of their threat to the proposed pipeline. Some geohazards might be found to be sufficiently severe that they create critical conditions and could cause a candidate corridor to be removed from consideration. Other geohazards pose less severe risk. The locations, footprints and severity of the geohazards shall be assembled in a GIS database, and shall form the geohazard inventory (5.2) that will exist for the life of the project.

— **Mitigation**: The primary mitigation of geohazards at this phase is avoidance. An important responsibility of the PGMP team at this phase is the unambiguous assessment and presentation of geohazards and risks to the broader project team. Quantification of geohazard impacts on design, construction and operations is helpful to fully define the risks. The selection of the final corridor shall consider the impacts of geohazards, balanced against other design, construction and operational considerations. At this stage, the operator may also consider other mitigations, e.g. strain-based design of the pipe.

— **Long-term management**: Because no asset yet exists, long-term management of geohazards at this stage consists of developing the geohazard inventory and associated GIS database, and passing it to the detailed design phase.

The recommended implementation procedures in this phase are:

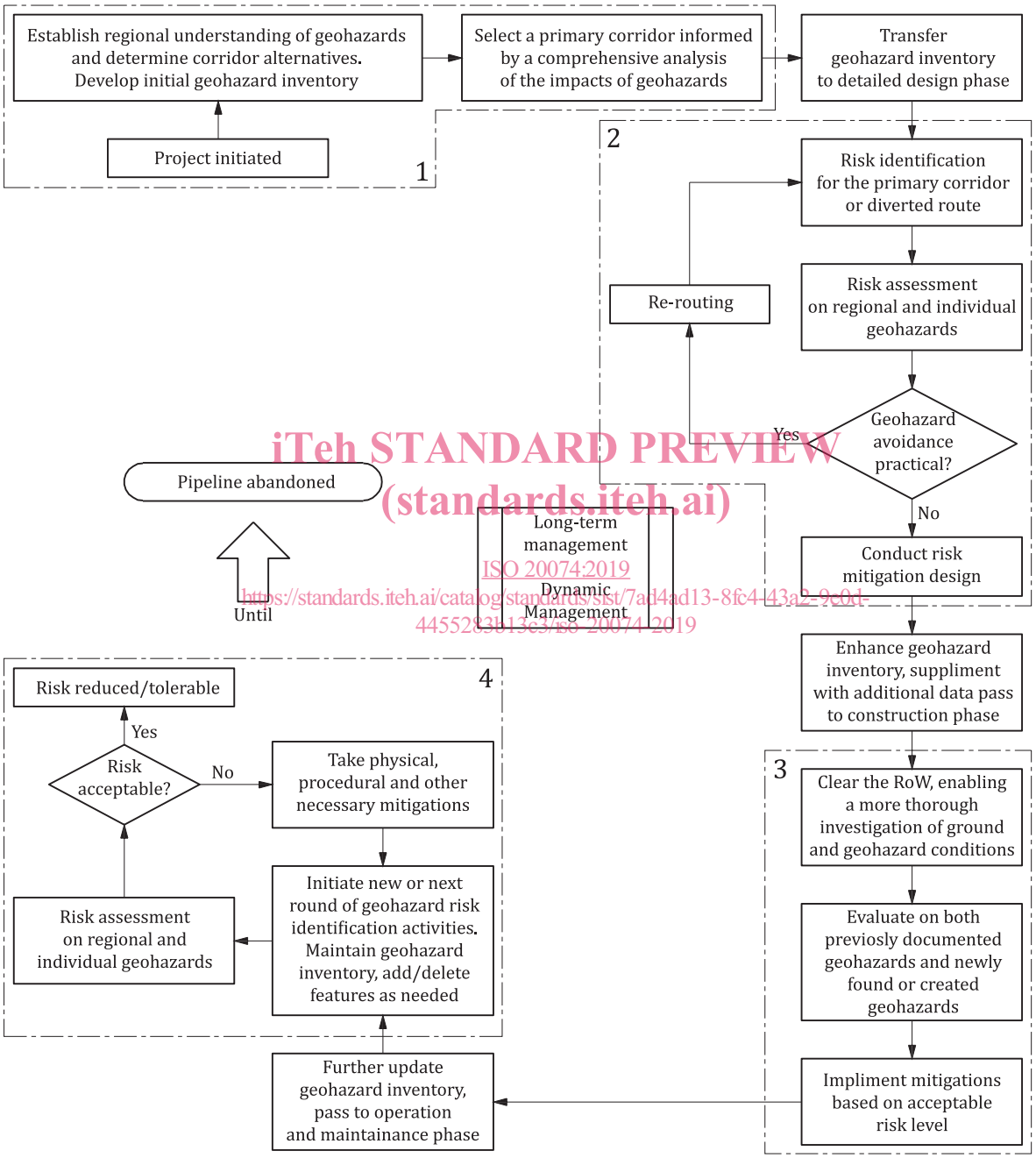
a) Establish regional understanding of geohazards and determine corridor alternatives.

b) Select a primary corridor.

c) For the primary corridor, perform regional geohazard susceptibility assessment (6.3). If warranted, individual geohazard risk assessments (6.4) might be necessary for specific locations.

d) Following selection of the primary corridor, the detailed design phases may begin.

NOTE Considerable pipeline design work, such as pipeline hydraulic studies, construction method studies, logistics and supply assessments and other activities are also being performed in this phase.



Key

1 preliminary engineering and route selection phase
2 detailed design phase
3 construction phase
4 operation and maintenance phase

Figure 1 — A PGMP flowchart

4.3.3 Detailed design phase

Detailed design may be conducted by an entity other than the operator. Compared to the previous phase, this phase typically involves a larger project team, more resources, increased ability and complexity of field works, and increased definition of project objectives. All of these activities can benefit the PGMP.

The PGMP shall again follow the four primary principles:

— **Identification**: Identification will begin with the geohazard inventory developed during the previous phase, and enhance the inventory with additional investigation, both remote sensing and ground-based. Consideration should be given to both the proposed primary pipeline corridor, as well as potential re-routes, ancillary and temporary facilities such as quarries, camps and access roads that might be required for pipeline construction.

— **Evaluation**: Existing items in the geohazard inventory shall be re-classified as new data become available, and all additional geohazard items shall be classified. Field and remote data gathering programs shall be designed in part to enable this evaluation. Remote and on-ground monitoring of geohazards may also commence during this phase. Inclinometers may be installed at ground movement locations, and monitoring plans developed. Rainfall and riverflow gauges may also be installed as access to the site improves. Evaluation of geohazard risks specifically to construction, including off-RoW impacts, shall be evaluated by the PGMP team in collaboration with the project's execution specialists.

— **Mitigation**: The primary mitigation of geohazard risk remains avoidance. In this phase, re-routing shall be used to avoid geohazards, balanced with other project objectives such as constructability, cost, environmental and stakeholder considerations. During this phase, other on-RoW mitigations, such as reduced footprint (narrow RoW), ground reinforcement and soil drains, may also be developed. Consideration shall also be given to incorporating mitigations such as strain-based design and geotechnical and integrity monitoring into the design. Adequate seismic design shall be considered for pipelines crossing seismic fault zones or active faults. References [6], [9], [10], [18], [19], [20] and [21] provide guidance for the seismic design of pipeline.

— **Long-term management:** Long-term management of geohazards at this stage consists of further developing the geohazard inventory and associated GIS database, and passing it to the construction phase. Locations and data from monitoring locations, as well plans for RoW and pipe mitigations, shall also be passed to the construction phase.

Note that

— pipeline geohazard risk management requirements shall be regarded as one of the bases for optimizing pipeline design scheme and making decisions, along with other pipeline design factors determined in the preliminary engineering and route selection phase,

— each identified geohazard shall be assessed to determine its impact on pipeline and environmental integrity, and

— mitigation shall be proposed for geohazards that have an unacceptable or unmitigated impact.

The recommended implementation procedures in this phase are:

a) Start risk identification for the primary corridor selected in the preliminary engineering and route selection phase or alternative corridors proposed by design department or as a result of public/stakeholder consultations.

b) Perform risk assessment on regional and individual geohazards.

c) Repeat steps a), and b) above until all identified geohazards have an acceptable level of risk, achieved through re-routing or application of appropriate mitigations.

d) Prepare PGMP interface with constructor. If detailed design and construction are performed by the same entity, this will be an internal interface.