PIPELINE SAFETY

Geohazard Management in Difficult Terrain

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Geohazards and Pipeline Safety

Geohazards can affect pipeline safety during:
- Construction – safety of personnel
- Operations - pipeline integrity and safety of third parties (public)

A stable RoW provides a safe working platform on which to construct a pipeline and maximizes potential for long term integrity during the operating life of the pipeline.
What are Geohazards?

“Geohazards are geological features and processes that present severe threats to humans, property and the natural environment.”

Geohazards affecting pipelines:

• Landslides and mudslides
• Rivers
• Karst
• Seismic induced geohazards such as:
  • Surface rupturing faults
  • Liquefaction
  • Lateral Spreading

Landslides and rivers are the overwhelming components of operating project geohazard risks.
Process to Reduce Geohazard Risk

Reducing geohazard risks to acceptable levels requires a series of activities at all stages of a Project.

These activities include:

• Desktop assessment, satellite and LiDAR interpretation
• Terrain evaluation and ground truthing
• Robust route assurance process including:
  • Detailed geohazard studies
  • Constraints mapping
  • Geotechnical surveys, boreholes, soundings, test pits, geophysics etc.
  • Construction engineering studies, excavatability and RoW access assessments, detailed geohazard mitigation studies etc.
• Stability assessments during construction
• Monitoring and maintenance during operations
Geohazard Avoidance During Routing

The primary mitigation to address geohazard risk is avoidance, however this is not always possible in difficult and mountainous terrain.

- Small terrain features (<1 km) such as landslides and mudslides are typically easier to avoid
- Larger terrain features (>1 km) such as landslide complexes, liquefaction prone areas and karst areas are more difficult to avoid
- Linear features such as rivers and fault crossings tend to dissect a pipeline route and are also difficult to avoid, therefore the crossing points are optimised.
Pipeline routing is a process of “corridor narrowing” typically starting at a regional level (10km corridor), narrowing down to 500m, then 100m and finally the RoW.

Each stage includes data gathering to support decisions during the narrowing process.

Data gathering starts with high level desk top assessments of key “no go areas” e.g. national parks and finishes with detailed field surveys to identify small constraints e.g. ecological habitats and cultural heritage sites to support route optimisation.
Typical Routing Constraints

- Ideal pipeline route is the shortest distance (straight line) from A to B
- Reality is that the pipeline will need to avoid areas where impacts cannot be effectively mitigated and managed either during construction or operations
Landslide Features

Typical geology comprises ophiolites, flysch (interbedded sandstones and mudstones) and limestone in a complex tectonic relationship.
Overall Constraints Map - example
Residual Geohazard Mitigation

Geohazards that could not be avoided during route selection need to be mitigated during detailed design and construction:

- Engineering mitigation is provided at specific known locations:
  - River crossings
  - Fault crossings
  - Liquefaction and lateral spreading
- Engineering mitigation using geotechnical “tool boxes”, the application of typical stability enhancement designs to deal with unforeseen ground conditions.
- RoW stability assessments during construction
- Operations monitoring and maintenance plan
River Crossings

- Robust river crossing designs now include the following:
  - Design flows include 1:200 year flood events
  - Fluvial morphology assessments to determine lateral channel migration risk (used to determine set back distances)
  - Detailed scour analysis
  - Construction windows targeted for low flow conditions to minimise flood risk during installation
  - Trenchless technology utilised where ground conditions are suitable
River Morphology – Lateral Channel Migration (1)

Aerial photos show extent of channel migration between 2001 and 2007.

Active river channel width at selected crossing point has increased from 200m in 2001 to 371m in 2007.
River Morphology – Lateral Channel Migration (2)
Pipelines Exposed by Scour and Lateral Channel Migration

Remedial work to both crossings included building out the river banks to create a false island combined with river training works.

Both crossings have been out flanked following a flood event due to inadequate set back distances.

No allowance made for lateral channel migration.
Pipelines Exposed by Scour and Lateral Channel Migration

River morphology and scour assessments during detailed design mitigate these risks
River Crossings
Traditional “Open Cut” Method

- Deep excavations (>10m), especially at the tie-in points
- Removal of buoyancy devices require personnel to enter the water

- Flooding risk is always present
- Wet trenches open for extended periods
- Significant earth moving involving large heavy equipment for long periods
River Crossings – Trenchless Technology

Safety benefits of Horizontal Direction Drilling:

- No exposure to flood risk
- Avoids trench entry associated with traditional open cut methods
- Eliminates the requirement for deep excavations at tie-ins
Fault Crossing Construction

Pipeline crossing is designed to provide flexibility during a surface rupture.

Design elements include:
- Trapezoidal trench
- Pipe wrapped in non-woven geotextile
- None-consolidating, free draining granular backfill
- Geotextile wrap of the trench to prevent ingress of fines and over time
Geohazard Mitigation During Construction

- Inevitably geohazard avoidance in difficult terrain leads to routing pipelines on narrow ridge crests with steep slopes.

- Factors affecting safety during pipeline construction can be summarised as follows:
  - Steep slopes
  - Trench entry
  - Narrow ridge crests
  - Row Access
  - Maintaining RoW stability

Maintaining a stable RoW throughout construction is one of the key steps to assure long term integrity of the pipeline.
Steep Slopes – Using Winches

- Working equipment is anchored
- Allows standard construction techniques to be utilised
- Requires experienced operators and supervision
Steep Slopes – Winching and Securing Pipe

Side secured using winch cable
Pipe secured using rope to prevent swinging
Steep Slopes – Use of Teleferic Cable Cranes

Benefits:
Minimum disturbance ensures stability is maintained
Use of specialist equipment on steep slopes (spider excavators)
No requirement for heavy equipment on the steep slopes
Steep Slopes – Use of Teleferic Cable Crane

Benefits:
Reduced RoW and minimal disturbance ensures stable working platform on steep slopes
Minimise entry into trench:
• Sand bags – traditional approach, trench entry required
• PU foam – modern application, installation can be performed outside the trench
Steep Slope – Trench Erosion Protection

High Density Poly Urethane Foam
Trench Breakers
Steep Slope - Multiple RoW Access Points

- Minimises transportation on steep slopes
- Reduces distances personnel need to travel on RoW
- Minimises interfaces between personnel and heavy construction equipment
Steep Slopes – Special Section Example (1)

- Working equipment is anchored
- Trench excavation and RoW preparation performed at the same time using standard excavation techniques
- Pipe installation and welding performed directly into the trench
- Requires experienced operators and supervision
Steep Slopes – Special Section Example (2)
Landslide Avoidance - Trenchless Crossing Beneath Failure Plane

- Tunneling head reception pit
- Stream diversion
- Tunneling head thrust pit
RoW Stabilisation – Application of Geotechnical Tool Boxes
Geotechnical Tool Boxes – Horizontal Drains

Failure occurred in a side cut during RoW preparation.
Geotechnical Tool Boxes – Pre-fabricated Drainage Systems

3rd Tirana Gas Pipelines Safety Workshop

Gasification of Albania builds safety capacity
Stability Assessments - Temporary Storage of Excavated Material

Pipeline avoided a landslide, however surcharge from spoil storage triggered a failure.

In geohazard sensitive terrain, stability assessments of areas identified for spoil storage are essential to prevent reactivation of existing landslides or initiation of first time failures.
Gasification of Albania builds safety capacity

Thank You