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Minimize Pipeline Installation Risks in Geohazard Zones

The United States is second only to Japan in economic damages resulting from natural disasters. Proper pipeline installation is critical to mitigate damage in areas prone to natural hazards. **BY GREG EVEN AND MICHAEL PORTER**

NATURAL HAZARDS in the United States cause hundreds of deaths and cost billions of dollars in disaster aid, disruption of commerce, and destruction of homes and critical infrastructure. Although the number of fatalities from natural hazards has declined in recent years, property damage has increased.

PIPELINE INSTALLATION

Underground installation of water pipelines in locations susceptible to landslides, settlement, and other geohazards has significant risks. Geohazards are geological or hydrological processes that pose a threat to people and their property. Geohazards can exist as short- or long-term phenomena or can be localized or regional. Geohazards mentioned in this article are long-term, localized phenomena.

Historically, constructing pipelines that traversed a geohazard zone entailed selecting the best horizontal and vertical alignment to avoid such hazards. However, doing so has become increasingly difficult because alignment selection is often restricted by urban congestion, an inability to obtain easements, a lack of common utility corridors, environmental restrictions, land-use incompatibility, public opposition, or significant realignment costs.

With the exception of sudden, catastrophic slope failures, many geohazards—such as slope creep, settlement and subsidence, transitions between dissimilar soils, or expansive soils—can be safely mitigated. Identifying the most appropriate mitigation strategy must be based on specific hazard scenarios and recommendations from a certified geologist or geotechnical engineer. However, using rigid welded sections with joints designed to relieve stress and strain caused by ground movement can be effective in localized situations.

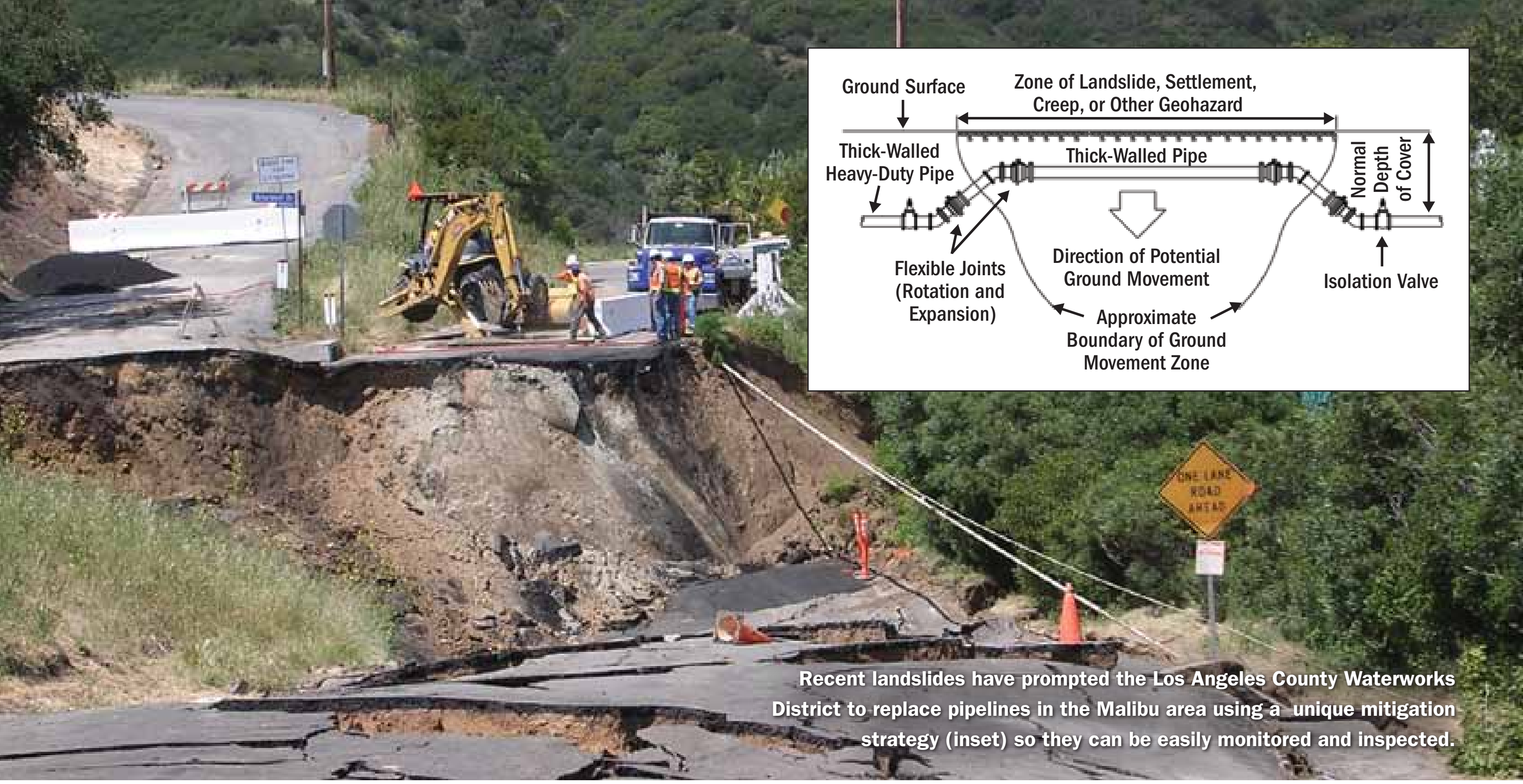
Although pipeline ruptures resulting from ground movement cause more environmental and economic damage than other hazards, the pipeline industry has focused primarily on pipeline problems that occur more frequently, such as those

Geohazard Risk Management (GRM)

GRM can be implemented in five phases.

Phase I: Overview Assessment	Evaluate hazards present, review incident data to calibrate risk models, and screen hazard exposure over broad segments of the facility.
Phase II: Detailed Hazard Inventory and Rating	Compile an inventory of geohazards and characterize their attributes using various data sources, including engineering and as-built reports.
Phase III: Detailed Investigation	Based on budget, target reliability, or risk tolerance, prioritize sites. Conduct a detailed investigation to estimate reliability, consequence of failure, and risk, as well as to develop conceptual options.
Phase IV: Risk Evaluation and Control	When risk drivers and costs are known, develop mitigation and risk-reduction alternatives for all sites. The results can be used as a basis for allocating annual maintenance mitigation budgets that maximize geohazard risk reduction and can be integrated into a systemwide risk assessment for overall corporate decision analysis.
Phase V: Action, Monitoring, and Re-evaluation	Apply preferred risk-control options, including actions to decrease geohazard potential, reduce system vulnerability if a hazard occurs, or minimize failure consequence. Implement a procedure to monitor the effects of the risk-control measures.

Source: Estimating the Influence of Natural Hazards on Pipeline Risk and Systems Reliability, International Pipeline Conference (IPC), IPC 2004 Proceedings, American Society of Mechanical Engineers



Recent landslides have prompted the Los Angeles County Waterworks District to replace pipelines in the Malibu area using a unique mitigation strategy (inset) so they can be easily monitored and inspected.

PHOTOGRAPH/DIAGRAM: LOS ANGELES COUNTY DEPARTMENT OF PUBLIC WORKS

caused by third-party excavation, corrosion, material defects, and operator error. In the United States, the average cost of property damage resulting from typical pipeline failure caused by ground movement is $430,000, more than twice the amount caused by other hazard types.

RISK MANAGEMENT

Geohazard risk management (GRM) is a proven method for mitigating geohazards and asset risks. GRM helps

- identify and characterize geohazards.
- estimate the influence of geohazards on pipeline reliability and risk.
- evaluate if the estimated reliability or risk is acceptable.
- implement ways to improve reliability or control risk and to monitor the effects of those actions.

GRM's five-phase approach is illustrated in the table on page 18. Potential damage caused by land movement, compared with other hazards, usually occurs in distinct areas that have been previously identified in geotechnical reports as risk zones. Such reports are usually prepared before a pipeline is designed or installed.

For example, in Malibu, Calif., the Los Angeles County Waterworks Districts have experienced a significant number of water main breaks caused by land movement, primarily landslides. Within the last five years, costs associated with landslide-caused main breaks include pipeline repair work, road damage repair, slope stabilization, claims processing, settlement payouts, and other mitigation costs. The average per-incident cost of four recent landslide incidents was $450,000, which is slightly higher than the national average. As a result, a replacement pipeline is often installed aboveground so it can be easily monitored and frequently inspected. Unfortunately, this solution introduces new considerations, such as aesthetic impacts, road access obstructions, vehicle collision hazards, and increased maintenance necessitated by exposure to the elements.

Alternatively, utilities can implement GRM phases during project design. In Phases I–III, geohazard risks can be identified, characterized, quantified, and assessed. In Phases IV and V, an alternative not often used in water systems can be implemented as follows:

- Design flexible joints that allow pipe rotation and elongation near landslide boundaries or the settlement interface.
- Design slack in the pipeline to allow large lateral and horizontal movements.
- Strengthen pipeline segment rigidity and moment-of-force capacity
  - within the zones of uniform movement (middle of the mass with potential for movement) and
  - outside the zone of potential movement.

This mitigation strategy, illustrated in the inset diagram above, has been used for belowground and aboveground installations in Malibu. In one installation, a large section of roadway along a pipeline alignment was built in poorly compacted fill that resulted in a landslide. After the slope failed, instead of excavating the debris field, workers reconstructed the roadway on top of the slide material. Consequently, the roadway has experienced ongoing settlement and creep. In lieu of aboveground installation, a pipeline was constructed via cut and cover through the geohazard zone. Flexible joints were installed on both sides of the geohazard boundaries to allow for significant pipeline rotation and elongation throughout the zone. In the seven years since installation, the pipeline hasn't experienced any leaks.

CONSTANT VIGILANCE

Because the consequences of water main ruptures caused by land movement are significant, it's important to properly identify geohazards, determine their potential effects, design effective mitigation measures, and continually monitor pipeline integrity. Proper GRM provides considerable return on investment of time and resources dedicated to project planning, investigation, and design. In addition, proper *in-situ* mitigation strategies, such as those used in Malibu, can significantly reduce pipeline rupture or leak risks.