“Pipeline Landslide Hazards: Due Diligence”

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HOME SAFE

EVERY DAY

Agenda

- Federal Design Requirements
- Landslide Classification
- Risk Management for New Pipelines
  - Desktop Study
  - Field reconnaissance
  - Routing
  - Geotechnical evaluation
- Takeaways

Federal Regulation

- Natural Gas and hazardous liquids pipelines are required to be designed to resist external loads including those that may be imposed by geological forces.
- 49 CFR 192.03 (natural gas pipelines)
- 49 CFR 195.110 (liquids pipelines)

2019 PHMSA Advisory Bulletin

- Pipeline Safety: Potential for Damage to Pipeline Facilities Caused by Earth Movement and Other Geological Hazards

Landslide Classification

Landslide Definition

- In simple terms:
  - A landslide is defined as a downslope movement of soil or rock material.
  - A landslide can be classified by the following characteristics:
    - Activity level
    - Type of Movement
    - Material that is moving (earth, mud, rock, debris)

Causes of Landslides

- **Water – surface water, groundwater, rain, snow melt, drainage pattern changes**
- Slope steepness
- Geology – material strength and rock discontinuities
- Excavation and Fill Placement
  - Eroding or cutting the slope or toe
  - Loading or filling the crown or slope
  - Poorly compacted fill slopes
- Wildfire (more erosion and less infiltration)
- Man-induced vibrations
- Volcanic and earthquake activity

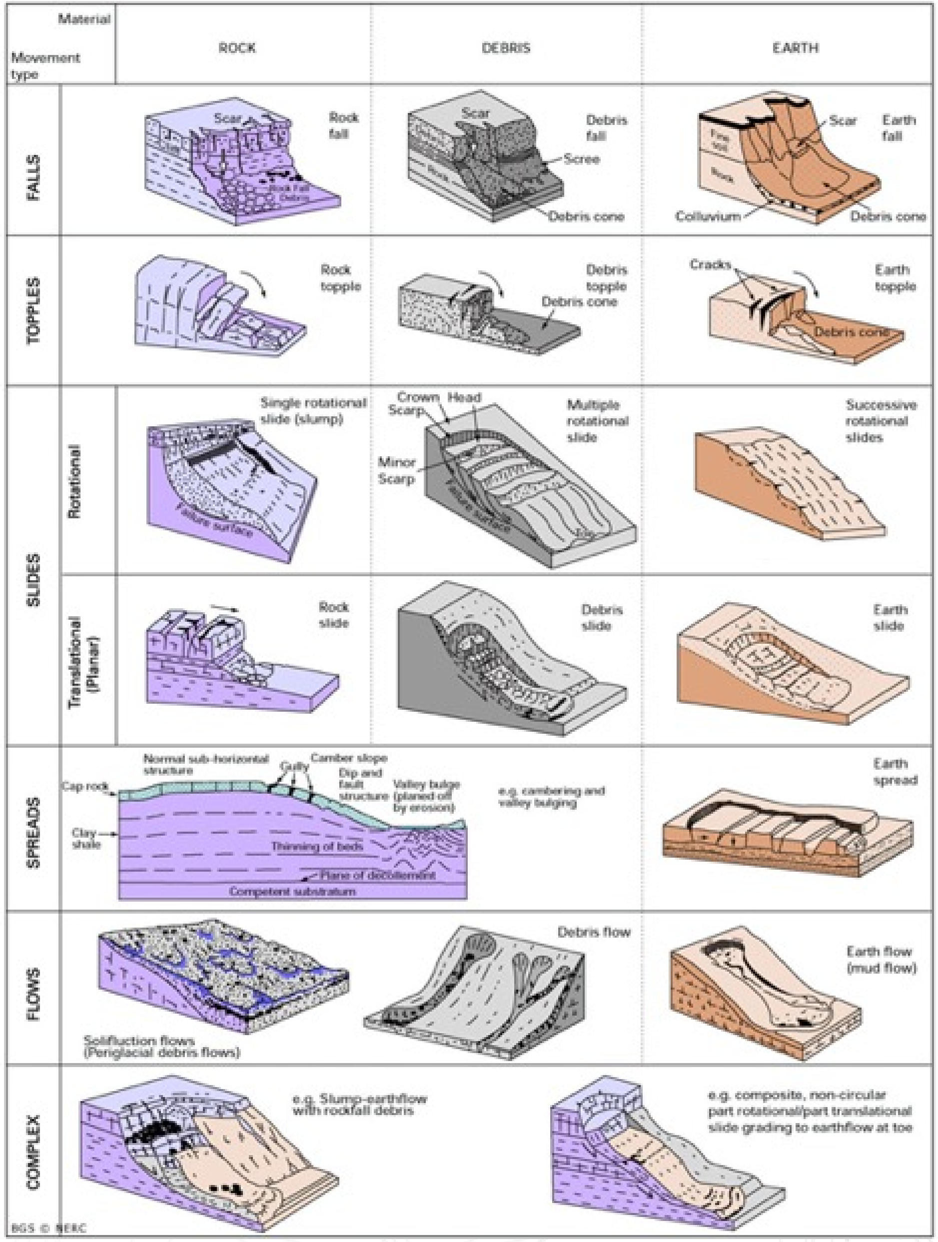
Landslide State of Activity

- Active/Recent: <50 yrs
- Dormant-Young: 50 to 500 yrs
- Dormant-Mature: 500 to 5,000 yrs
- Ancient/Relict: > 5,000 yrs

*Modified from McCalpin, 1984

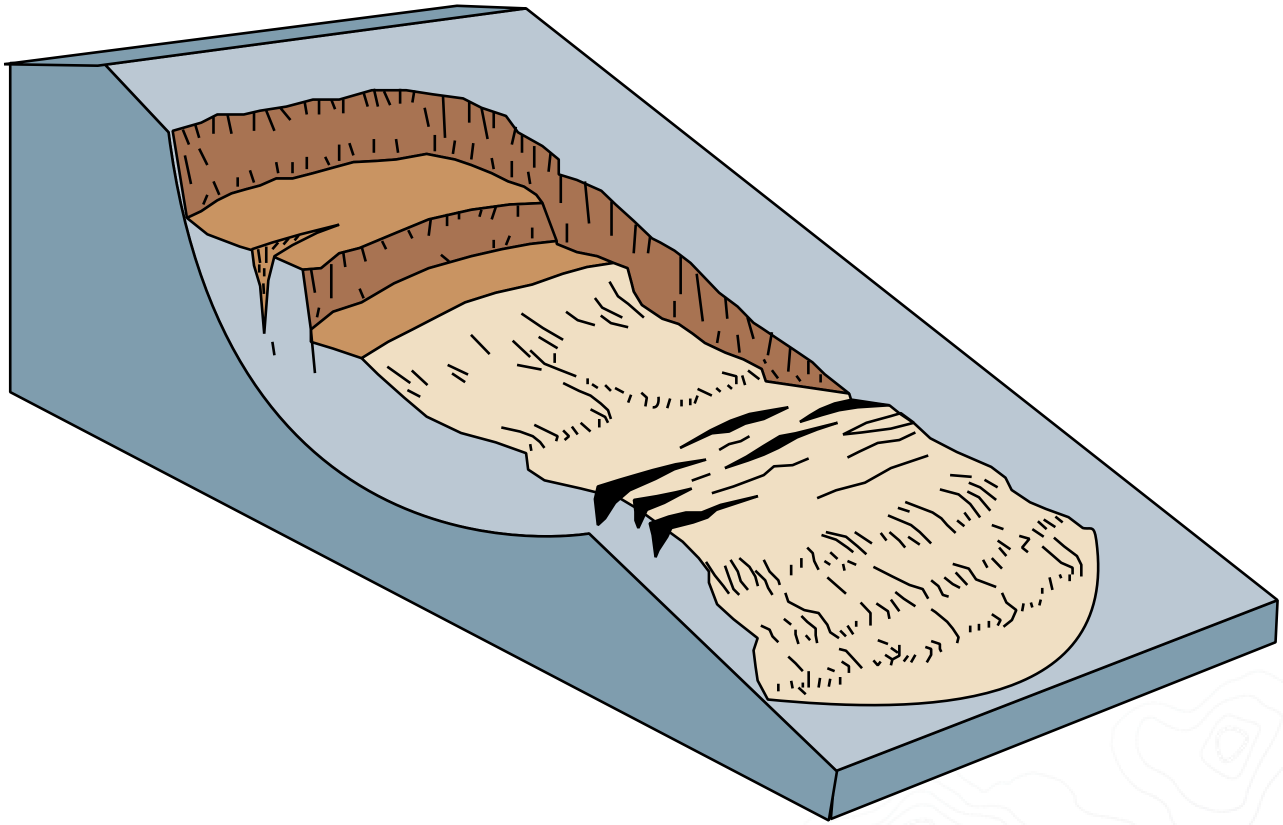
Types of Landslides

- Falls and Topples
- Slides
  - Rotational Slides
  - Translational Slides
- Spreads
- Flows
- Avalanches
- Complex failures

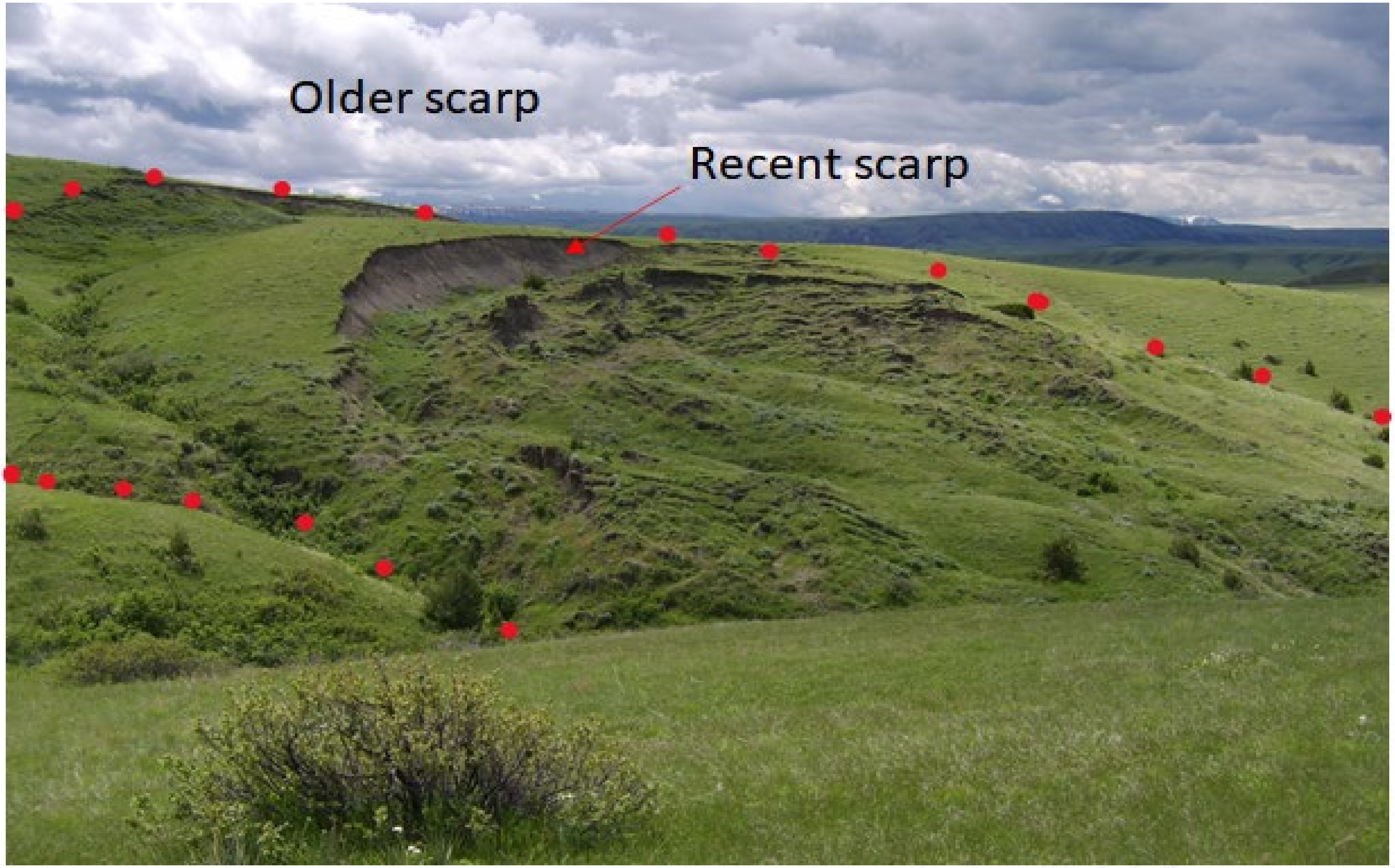


Varnes, 1978

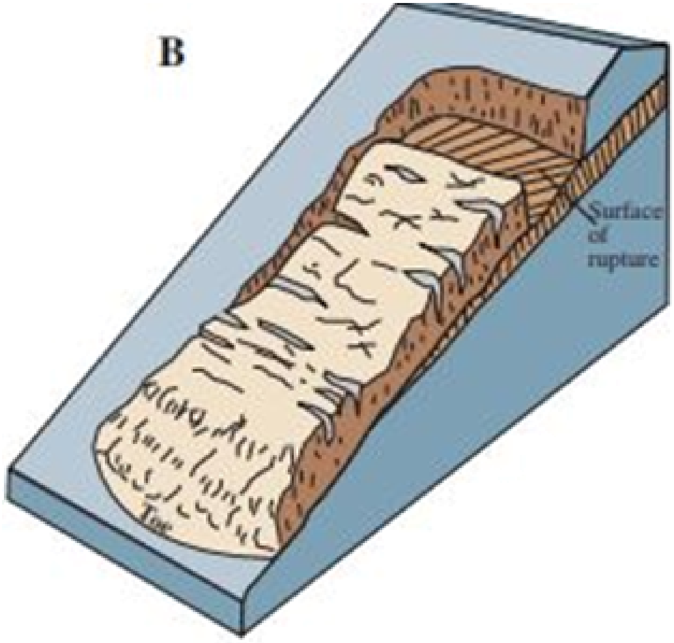
Rotational Slide



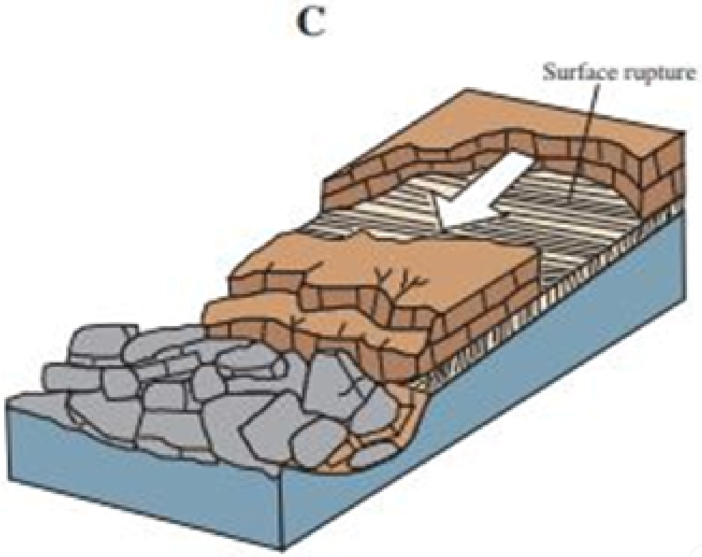
Rotational Landslide



Translational Slide



Soil

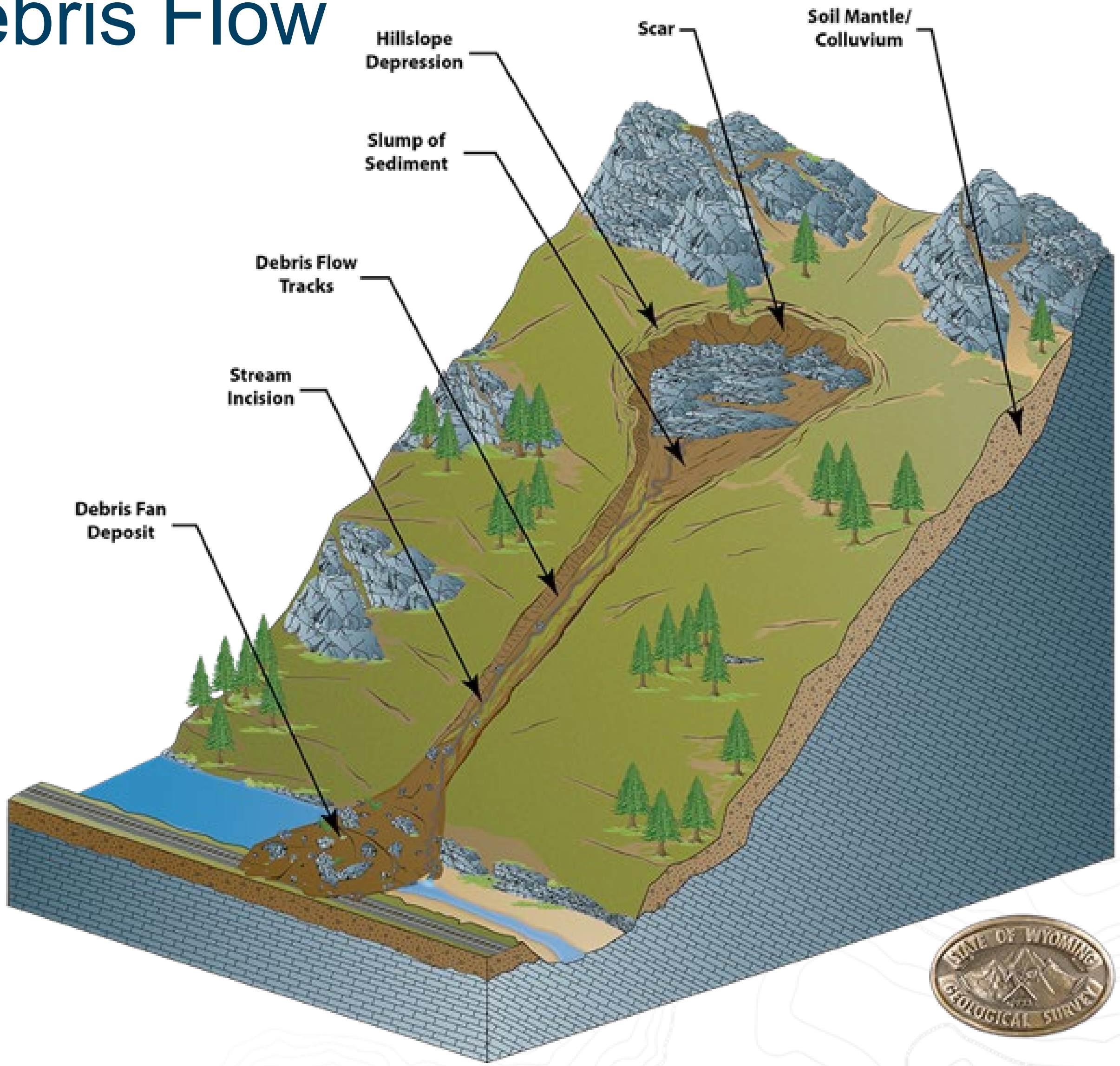


Rock

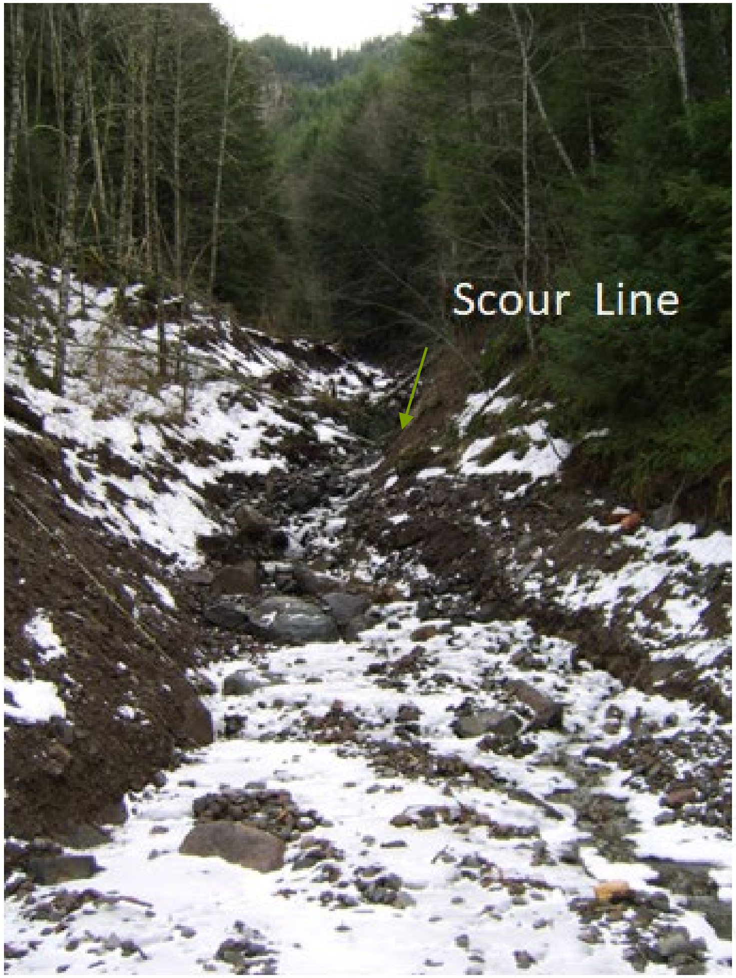
Translational Landslide (Soil)

Translational Landslide (Rock)

Debris Flow


Hillslope Depression
Scar
Soil Mantle/ Colluvium
Slump of Sediment
Debris Flow Tracks
Stream Incision
Debris Fan Deposit

Debris Flow



Complex Landslide

Landslide Hazards – Risks to Pipelines

- Induced strain on pipeline
  - Pipeline rupture (can occur from compression and from tensional forces)
  - Pipeline bending
- Loss of ground support under pipeline
  - Can exceed maximum allowable free span length
- Impacts to pipeline from debris flows
  - Dents, gouges and scrapes to coating

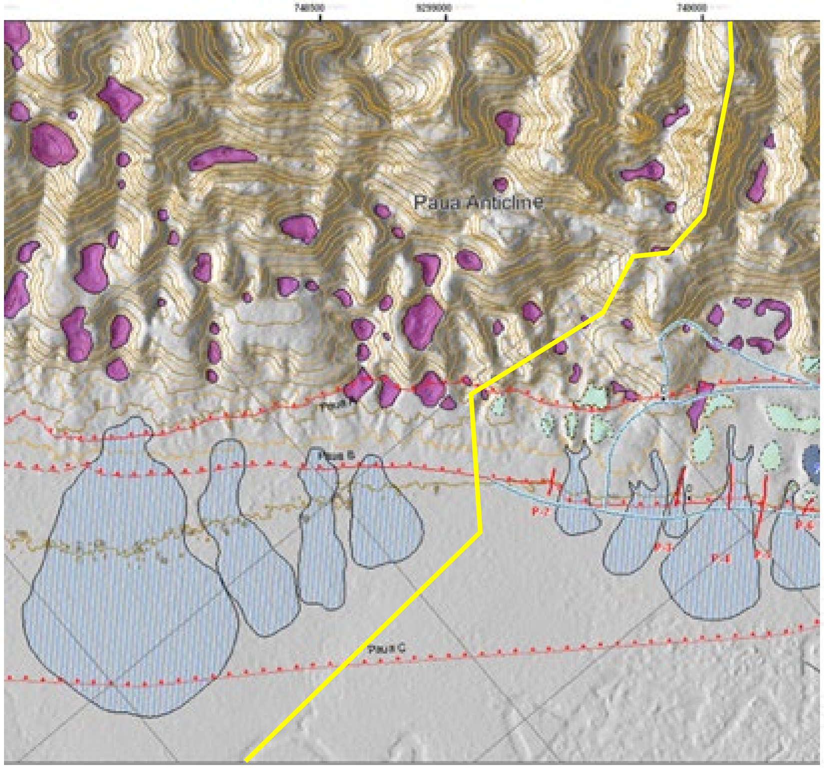
Large Deep-Seated/Native Slopes

Constructed Slopes

Risk Management for New Pipelines

Geotechnical Scope

- Desktop Study
- Field Reconnaissance
- Routing Analysis
- Geotechnical Evaluation
- Design/Construction Specifications



PHMSA Bulletin

- Main takeaways:
  - Identify areas surrounding the pipeline that may be prone to large earth movement
  - Utilize geotechnical engineers during design, construction and ongoing operations of a pipeline system
  - Develop design, construction and monitoring plans and procedures for each identified location
  - Monitoring plans

threats the operator has identified for each pipeline segment. If an operator determines there is a threat to the pipeline, such as outside force damage (*e.g.*, earth movement, floods), the operator must take steps to prevent a failure and to minimize the consequences of a failure under these regulations.

PHMSA is aware of recent earth movement and other geological-related incidents/accidents and safety-related conditions throughout the county, particularly in the eastern portion of the United States. Seven of the more notable events are briefly described below:

- On October 21, 2016, a pipeline release of over 1,238 barrels of gasoline spilled into the Loyalsock Creek in Lycoming County, Pennsylvania. The release was caused by extreme localized flooding and soil erosion.
- On December 5, 2016, approximately 12,615 barrels of crude oil was released into Ash Coulee Creek in Billings County, North Dakota. The metallurgical and root cause failure analysis indicated the failure was caused by compressive and bending forces due to a landslide impacting the pipeline. The landslide was the result of excessive moisture within the hillside creating unstable soil conditions.
- On April 30, 2018, a pipeline failure occurred in a remote mountainous region of Marshall County, West Virginia resulting in the release of 2,658 barrels of propane. The failure and subsequent release was caused by lateral movement of the 8-inch intrastate pipeline due to earth movement along the right-of-way.
- On June 7, 2018, a rupture occurred on a 36-inch pipeline located in a rural, mountainous area near Moundsville, West Virginia, resulting in the release of approximately 165,000 MCF of natural gas. The failed sections of the pipeline were sent to a metallurgical laboratory to determine the probable cause behind the failure of the pipeline. According to the analysis, the cause of the rupture was due to earth movement on the right-of-way due to a single overload event. Overloading of the pipeline likely resulted from a series of lateral displacements with accompanying bending.
- On January 9, 2018, a failure occurred on a 22-inch transmission pipeline in Montecito California. The incident resulted in a fire and explosion and the release of an estimated 12,000 MFC of natural gas within a Class 3 location.[1] It is believed that heavy rains and localized flooding contributed to the incident. Automated safety equipment designed to stop the flow of gas to the effected segment activated to shut off gas flow to the damaged segment of pipeline.
- On January 31, 2018, a portion of a pipeline experienced an in-service rupture near the city of Summerfield, Ohio. The rupture of the 24-inch interstate pipeline resulted in the release of approximately 23,500 MCF of natural gas in a rural forested area. A root cause analysis concluded that the girth weld failure was caused by axial stress due to movement of the pipe that exceeded the cross-sectional tensile strength of the net section weld zone surrounding the crack initiation location. This determination is supported by metallurgical analysis, strain capacity evaluation and geotechnical findings.
- On January 29, 2019, a pipeline ruptured near the town of Lumberport in Harrison County, West Virginia. The rupture was located at a girth weld of an elbow on the 12-inch interstate pipeline. The root cause investigation concluded that a landslide about 150 yards from the rupture moved the pipeline approximately 10 feet from its original location causing excessive stress on the pipe resulting in the rupture.

II. Advisory Bulletin (ADB–2019–02)

To: Owners and Operators of Gas and Hazardous Liquid Pipeline Systems.

Subject: Potential Damage to Pipeline Facilities Caused by External Loads Imposed by Earth Movement and Other Geologic Hazards on and Adjacent to Pipeline Right-of-Way Corridors.

Advisory: All owners and operators of gas and hazardous liquid pipelines are reminded that earth movement, particularly in variable, steep, and rugged terrain and with varied geological subsurface conditions, can pose a threat to the integrity of a pipeline if those threats are not mitigated. Pipeline operators should consider taking the following actions to ensure pipeline safety:

1. Identify areas surrounding the pipeline that may be prone to large earth movement, including but not limited to slope instability, subsidence, frost heave, soil settlement, erosion, earthquakes, and other dynamic geologic conditions that may pose a safety risk.
2. Utilize geotechnical engineers during the design, construction, and ongoing operations of a pipeline system to ensure that sufficient information is available to avoid or minimize the impact of earth movement on the integrity of the pipeline system. At a minimum, this should include soil strength characteristics, ground and surface water conditions, propensity for erosion or scour of underlying soils, and the propensity of earthquakes or frost heave.
3. Develop design, construction, and monitoring plans and procedures for each identified location, based on the site-specific hazards identified. When constructing new pipelines, develop and implement procedures for pipe and girth weld designs to increase their effectiveness for taking loads, either stresses or strains, exerted from pipe movement in areas where geological subsurface conditions and movement are a hazard to the pipeline integrity.
4. Monitoring plans may include:
   - Ensuring during construction of new pipelines that excavators do not steepen, load (including changing the groundwater levels) or undercut slopes which may cause excessive ground movement during construction or after operations commence.
   - Conducting periodic visits and site inspections; increased patrolling may be necessary due to potential hazards identified and existing/pending weather conditions. Right-of-way patrol staff must be trained on how to detect and report to appropriate staff the conditions that may lead to or exhibit ground movement.
   - Identifying geodetic monitoring points (*i.e.*, survey bench marks) to track potential ground movement;
   - Installing slope inclinometers to track ground movement at depth which may otherwise not be detectable during ROW patrols;
   - Installing standpipe piezometers to track changes in groundwater conditions that may affect slope stability;
   - Evaluating the accumulation of strain in the pipeline by installing strain gauges on the pipeline.
   - Conducting stress/strain analysis utilizing in-line inspection tools equipped with Inertia Mapping Unit technology and High Resolution Deformation in-line inspection for pipe bending and denting from movement.
   - Utilizing aerial mapping light detection and ranging or other technology to track changes in ground conditions.
5. Develop mitigation measures to remediate the identified locations.
6. Mitigation measures should be based on site-specific conditions and may include:
   - Re-routing the pipeline right-of-way prior to construction to avoid areas prone to large ground movement such as unstable slope areas, earthquake fault zones, permafrost movement, or scour.

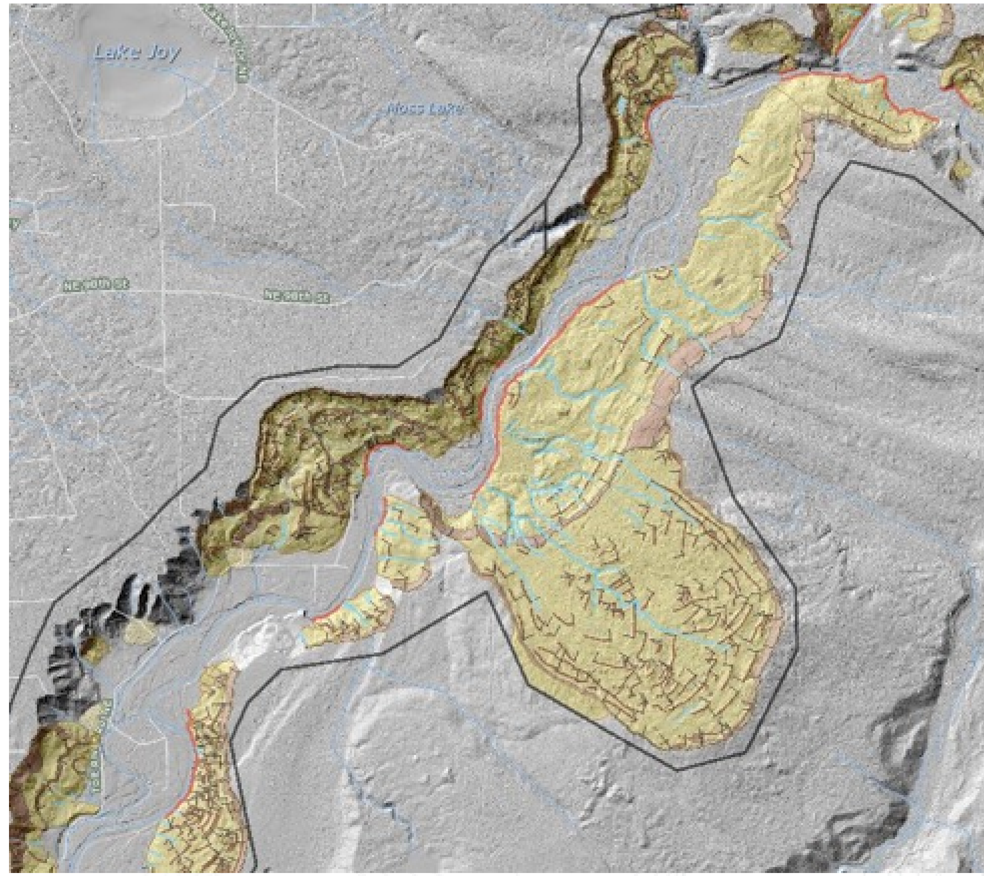
[1] *See* 49 CFR 192.5(b)(3) (defining Class 3 locations).

Desktop Study

- Review published geologic information
- Interpretation of aerial imagery and remote sensing
  - Google Earth and aerial photos (stereo and time series)
  - LiDAR (Light Detection and Ranging)
  - Drone imagery
  - Satellite imagery
  - InSAR

Published Geologic Information

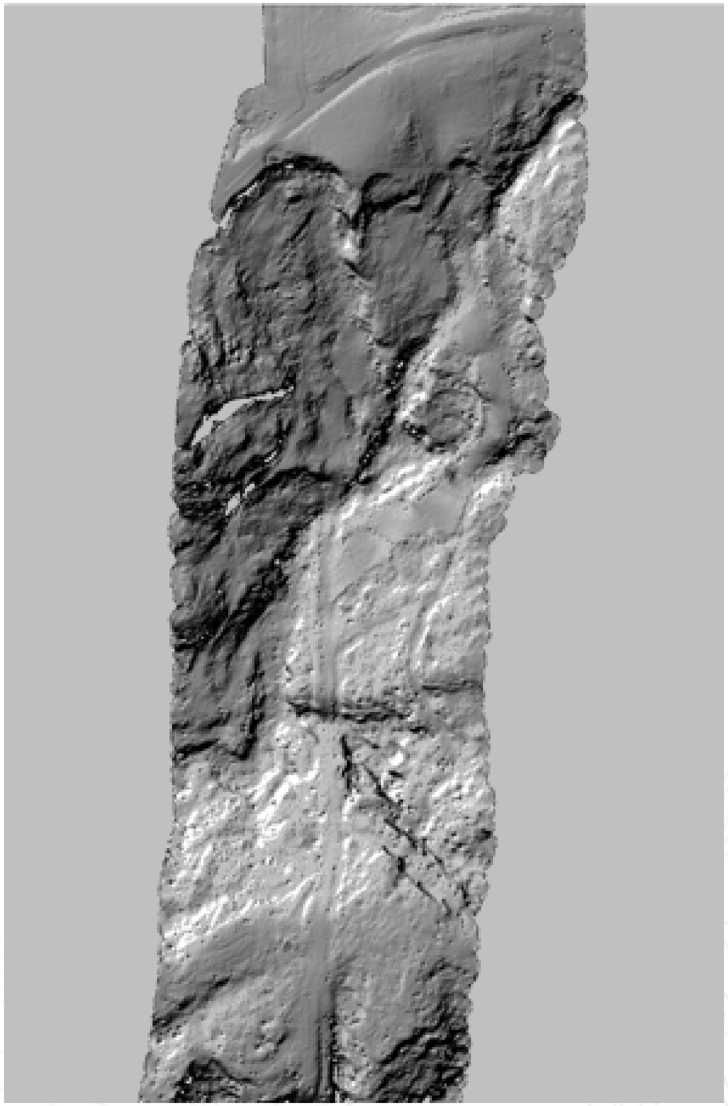
- Geologic Maps
- Geologic Hazard and Landslide Mapping
- Published articles



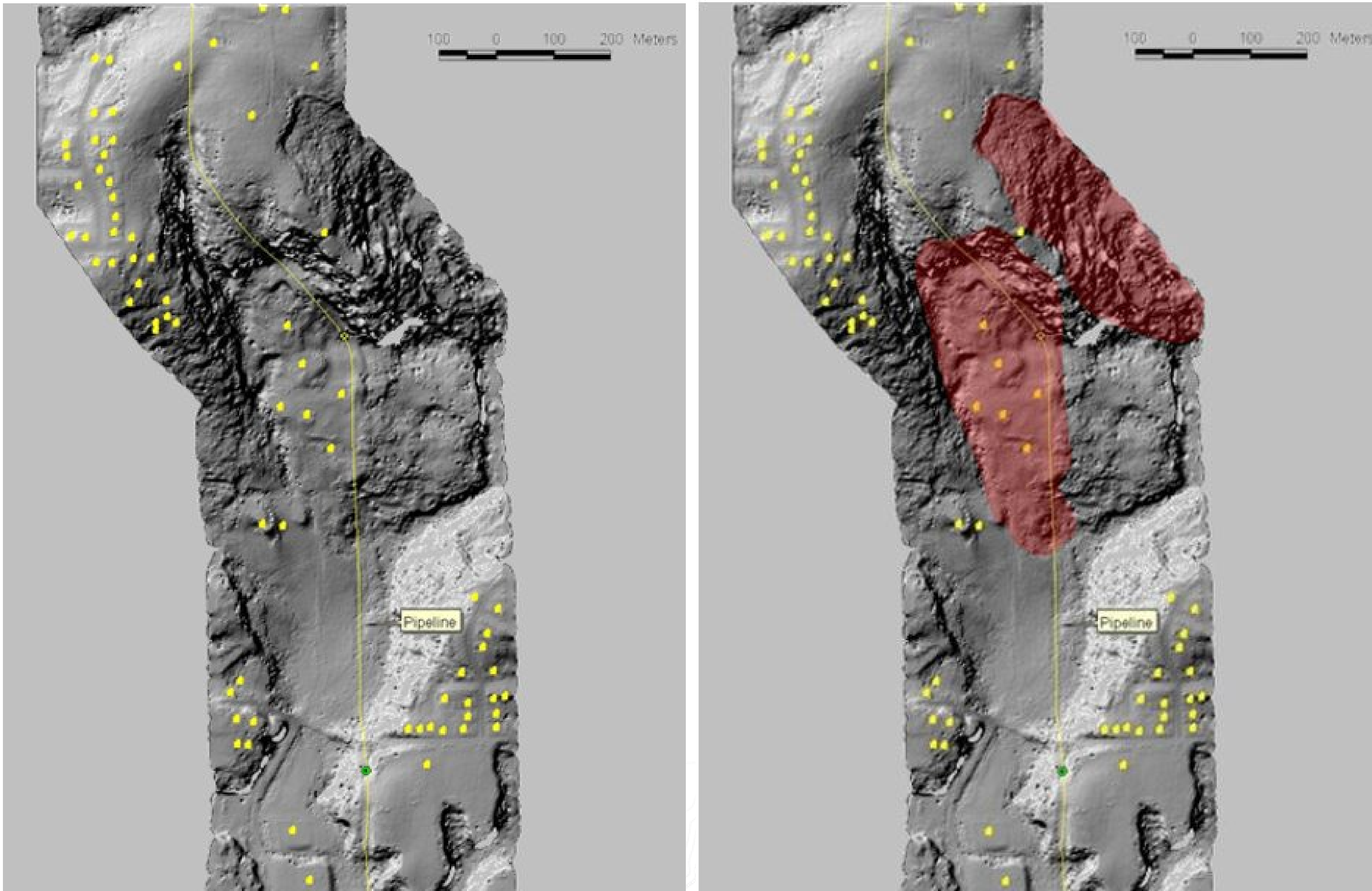
Historical Aerial Photograph Review

LiDAR

- High-resolution ground surface elevation data for use in hazard mapping, routing and geotechnical design
- Ability to process out vegetation and buildings
- Relatively inexpensive to perform site- or route-specific surveys
- Publicly available for many states (quality varies)

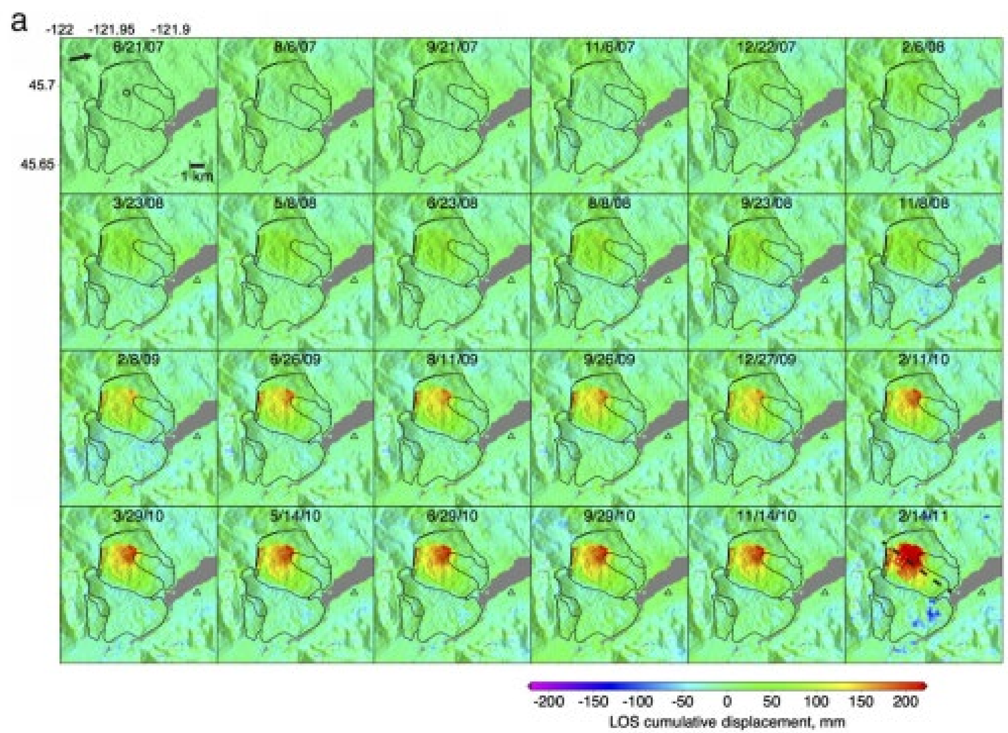


Historic Landslide – LiDAR



InSAR

- Technique for mapping ground deformation using radar images collected from satellites
- Product is a deformation time-series
- Pipeline corridors can be assessed relatively quickly as part of an initial geologic hazards study or long-term monitoring technique (early warning system)



X. Tong, D. Schmidt / Remote Sensing of Environment 186 (2016) 405–415

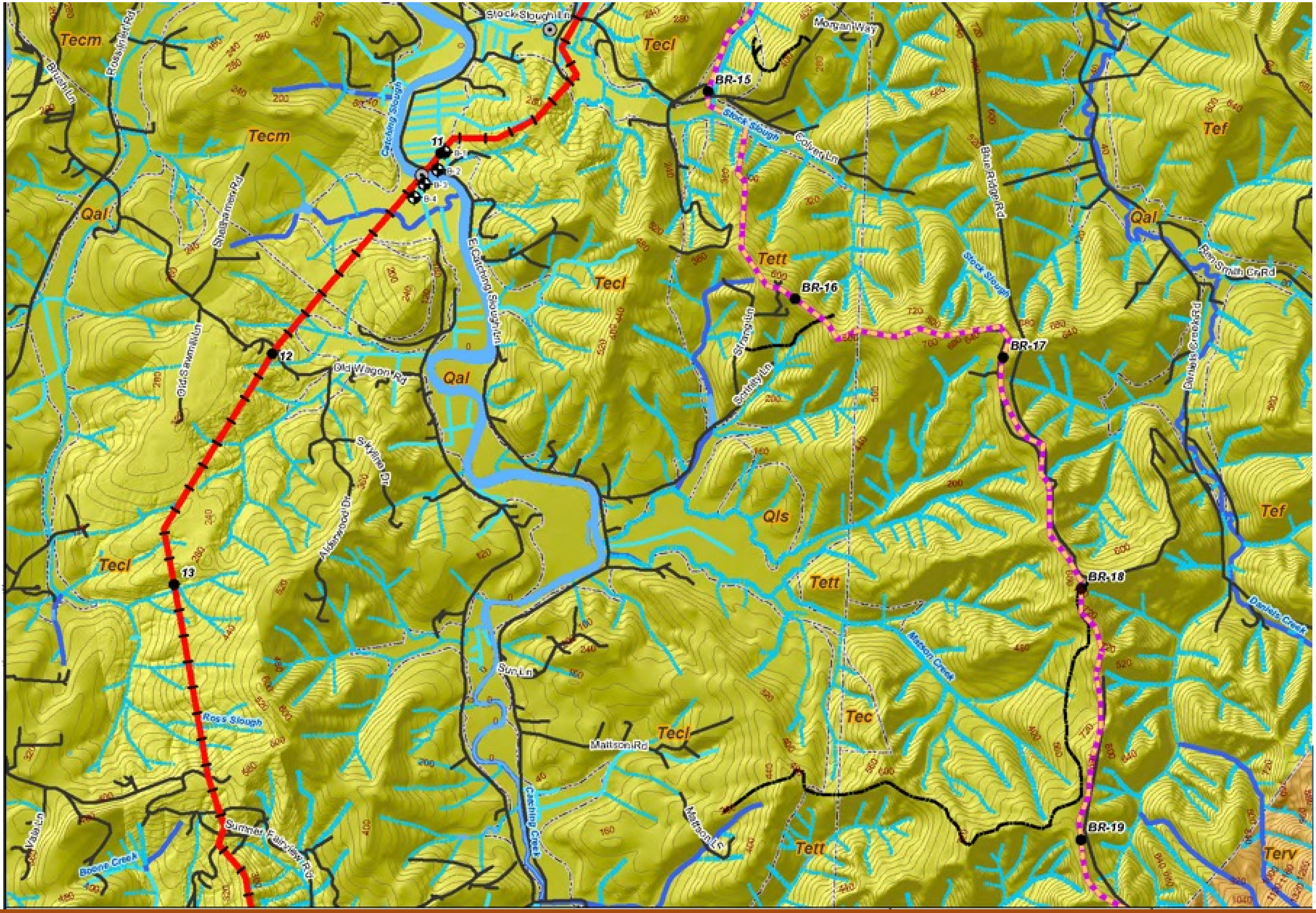
Field Reconnaissance

- Confirm findings of the desktop study in the field
- Assess the activity level and risk to the pipeline from landslide hazards

Routing

- Avoiding known/mapped landslide hazard areas
- Minimize sidehill orientation
- Orient with fall line of slope
- Follow ridge lines

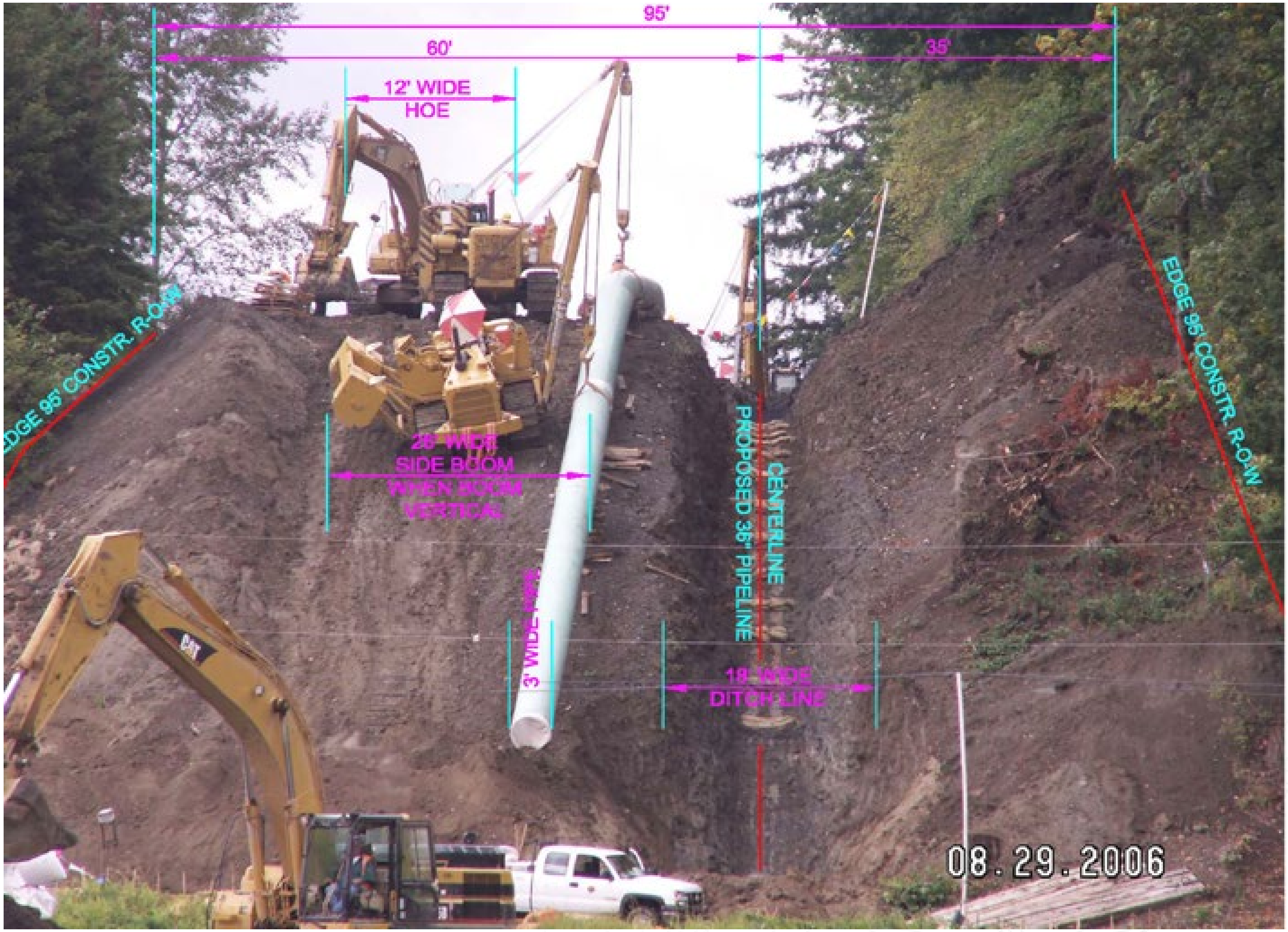
Routing Comparison



Geotechnical Considerations

- Pipeline Orientation
- Water management
- Fill slope construction
- Slope gradient

Sidehill Orientation

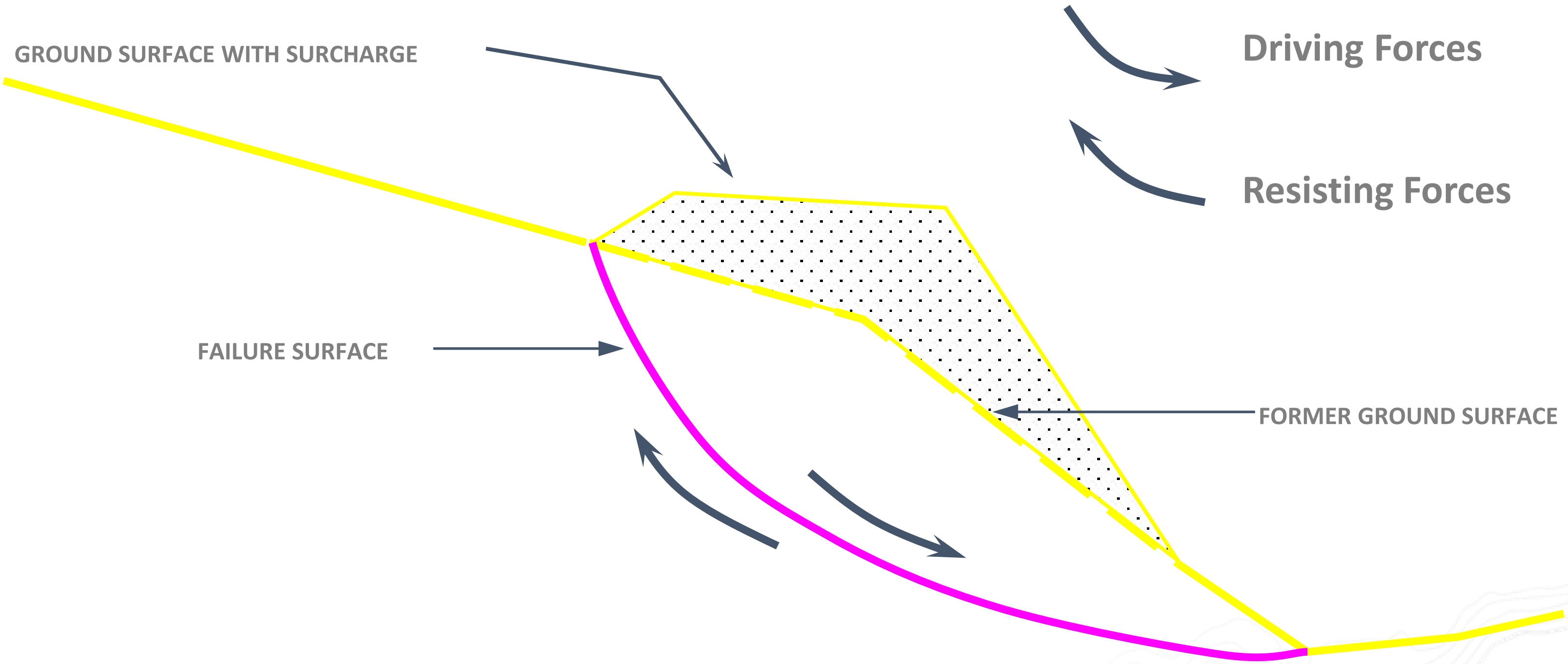


If geotechnical controls are inadequate…

Water Management

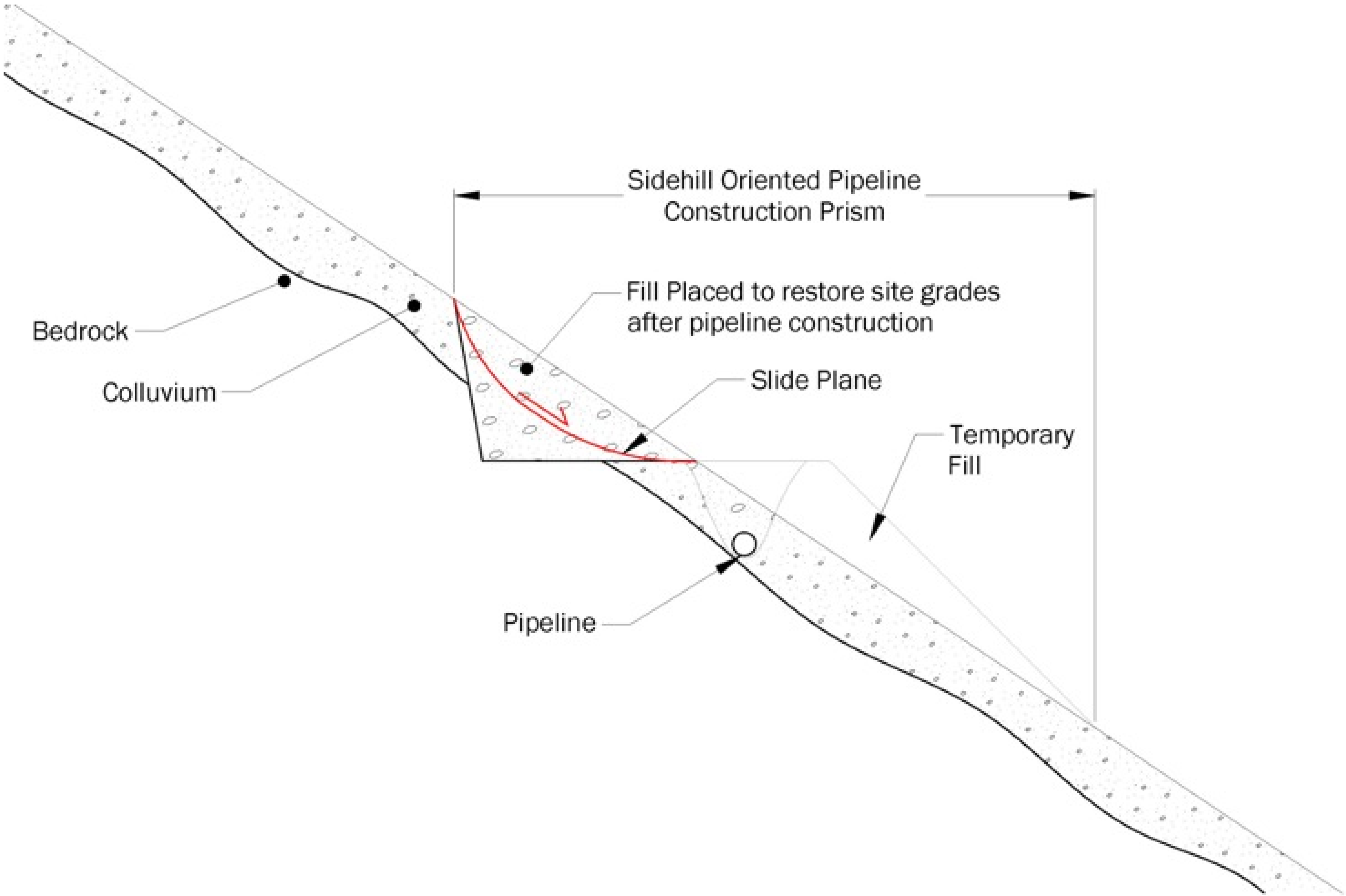
Roads, ROWs, and pipeline trench can capture, concentrate and divert water.

Temporary Fill Surcharge

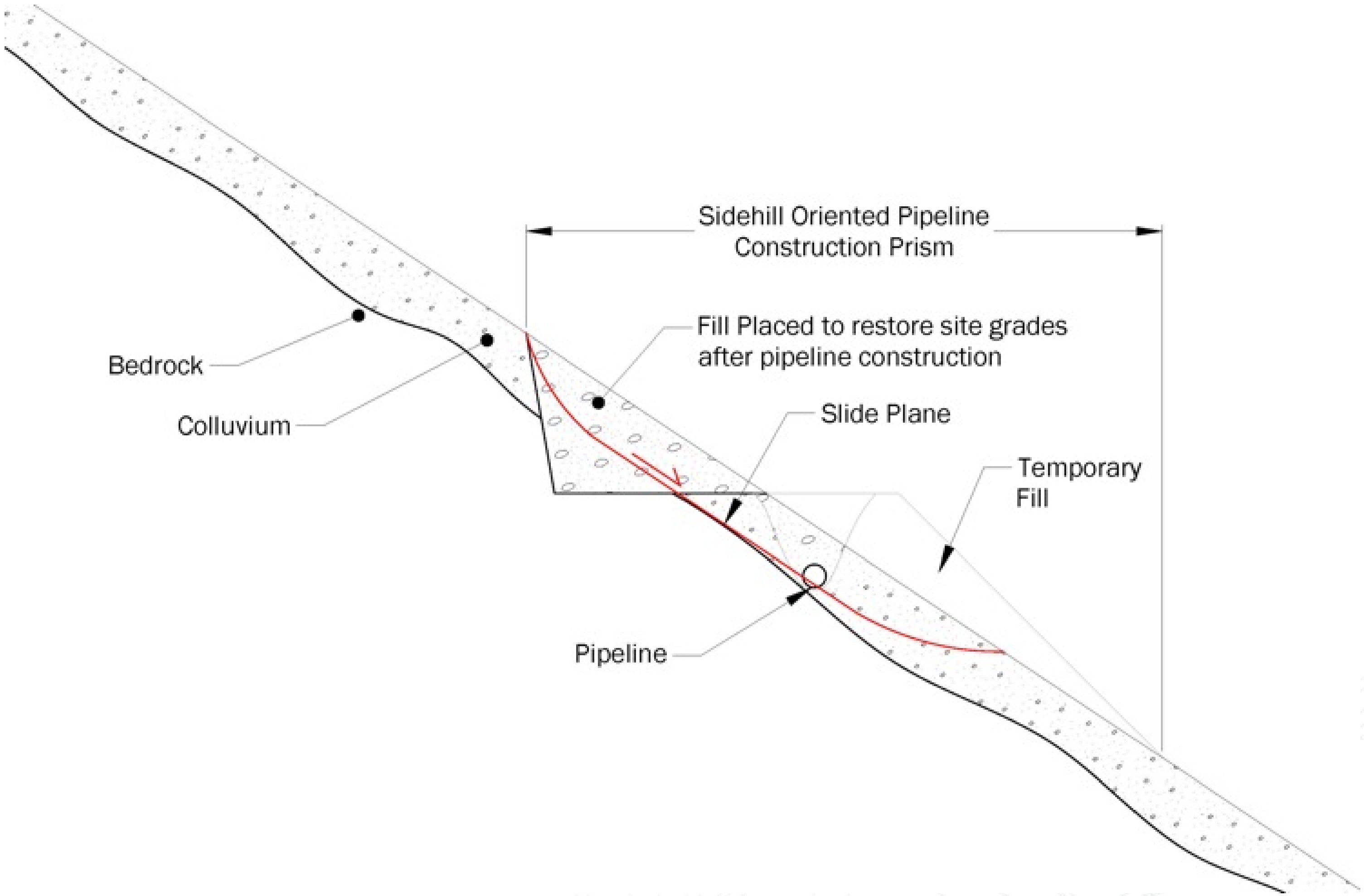


SURCHARGE LOADS SLOPE CREST: DRIVING FORCES ARE INCREASED

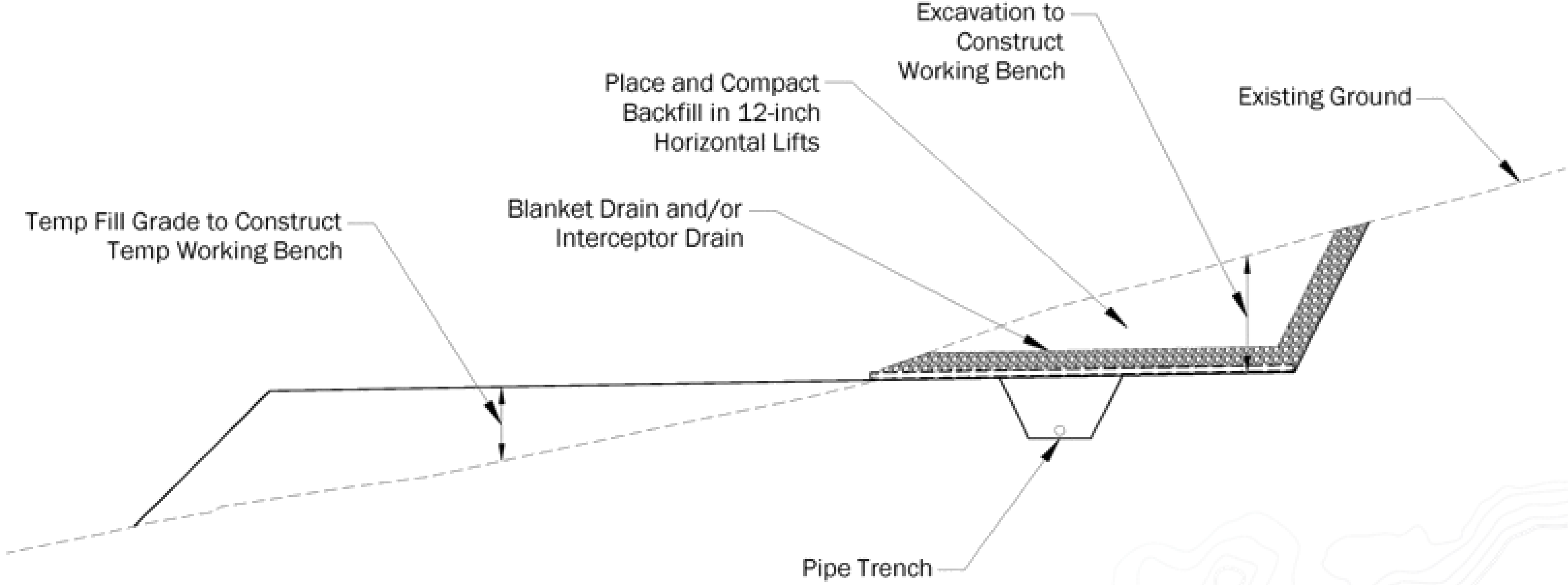
Permanent Fill Slopes



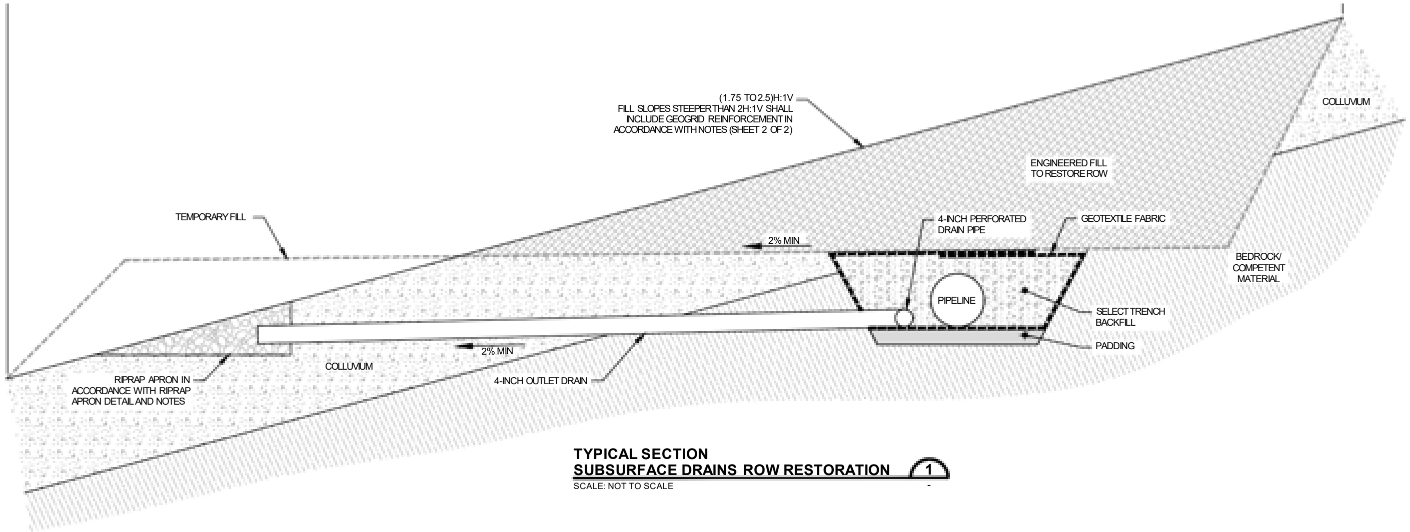
Permanent Fill Slopes



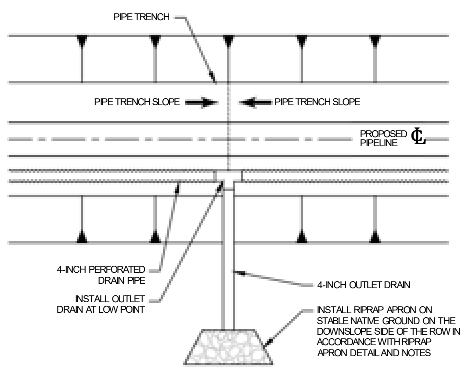
Geotechnical Risk Reduction Measures



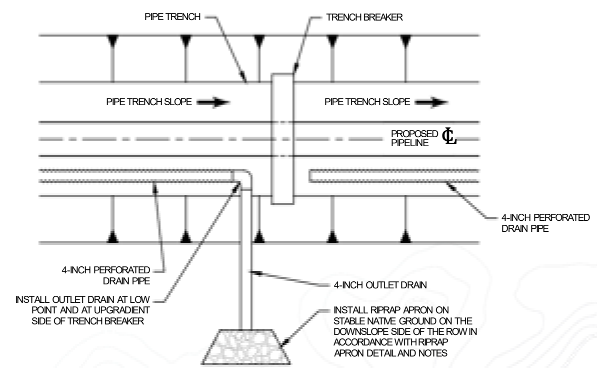
Subsurface Trench Drains



TYPICAL SECTION
SUBSURFACE DRAINS ROW RESTORATION 1
SCALE: NOT TO SCALE



PLAN VIEW - BLEEDER DRAIN
AT TRENCH LOWPOINT 2
SCALE: NOT TO SCALE



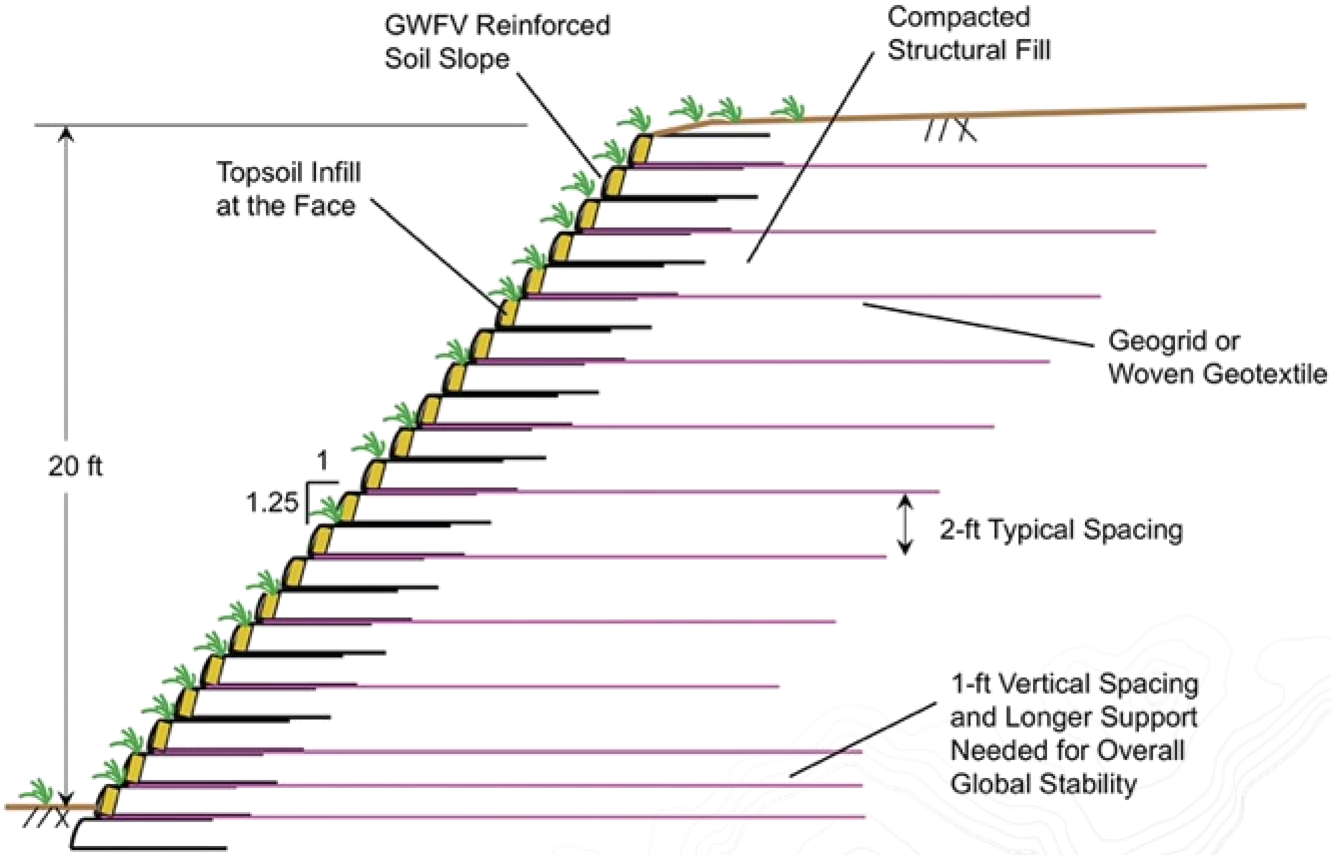
PLAN VIEW - BLEEDER DRAIN
WITH SLOPED PIPE TRENCH 3
SCALE: NOT TO SCALE

DRAFT SUBMITTAL - NOT FOR CONSTRUCTION

Fill Compaction

- Compaction Specifications and Nuclear Densometer
- Visual Observation, Proof Rolling, Probing
- Moisture Control- Lime Amendment
- Mechanically Stabilized Earth

Reinforced Fill Slope



Most Important Takeaways

- Upfront due diligence
- Proper earthwork construction and drainage controls
- Preventative measures = cost savings

Questions?

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