LANDSLIDE MITIGATION
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"There are landslides we fix and there are those we name." Most landslides are slow-moving and therefore do not present the potential for catastrophic conditions. Where landslide conditions are known or suspected, mitigation may need to be undertaken. In general, risks to new and existing facilities are greater than normal when constructing in suspected landslide terrain. There are many examples where construction has either caused reactivation of sliding or has been victim of renewed slide activity. In situations where landslides occur unexpectedly and impact facilities, emergency responses and repairs may be required. There are different approaches to dealing with landslides, depending on needs, risks and available funds. Stabilization measures to fully remediate landslides according to the standard of practice often take time to investigate, design and construct and can become expensive, particularly for large/deep slides. The standard of practice includes selecting a suitable Factor of Safety (margin of stability). Significant stabilization measures might be required to protect critical facilities such as dams, expensive structures and primary highway routes. However, there are situations where full stabilization is impractical (due to size of landslide, excessive cost, and environmental and ownership restrictions). There are alternative mitigation options available for situations where some risk-taking may be acceptable to owners and affected jurisdictions. In either case, owners/jurisdictions and their design professionals have the responsibility to safeguard users of the property and protect the public from death or injury. The challenge is to develop an optimal treatment that is cost-effective and achieves stability, based on a reasonable level of study, sound scientific understanding and qualified landslide experience.

Level of Mitigation

When facilities are planned in suspected or known landslide areas, the risks should be evaluated to determine whether satisfactory stability can be achieved through mitigation or stabilization measures. Landslide areas could be designated "no-build" zones or "open spaces" to avoid possible impacts. This approach is known as "Avoidance." Jurisdictions and owners could consider whether potential landslide risks would be acceptable and apply mitigations to improve stability to adequate levels.

A "Do Nothing" approach might be the least expensive but should be based on an adequate understanding of the risks and potential consequences. In addition, monitoring of the landslide would be prudent to confirm the acceptability of the approach and to warn if changing conditions warrant a different approach. A "Do Nothing" approach could require that maintenance be performed when damages create unacceptable conditions for use of the property or facility.

The "Maintenance" approach is often used to reopen a facility (i.e., by removing debris, patching cracks, restoring structural support, etc.) and hopefully to provide immediate improvement in slide stability. Sometimes, the immediate maintenance does not stop the landslide and the problem reoccurs.

"Selective Stabilization" is an approach where only a portion of the landslide is stabilized in order to protect a facility, and the remainder of the slide is left in its marginally-stable or unstable condition. For example, roads that are located in the upper portions of slides could be improved by stabilizing only the upper portion of the slide mass that it rests on. The unmitigated portion of the slide is left undeveloped unless it too receives adequate stabilization.

"Marginal Stabilization" is an approach where, due to the large size of a slide and/or high cost of standard stabilization, a lower 'margin of stability' could be considered in an attempt to reduce the hazard level. If a "Marginal Stabilization" approach is adopted, mitigation measures could be applied in phases until the desired reduction in movement is accomplished, which is usually accompanied with instrument monitoring to verify the improvement achieved.

"Conventional Stabilization," or "Full Remediation," utilizes higher levels of stability margin that are intended to account for uncertainties and potential errors in modeling the slide and foreseeable future conditions. The intent of the conventional design stability margins is to reduce the risk of landslide reactivation or localized instabilities and the risk to the public. There are cases where this approach does not result in financially feasible solutions and, therefore, other mitigation approaches are considered.

Design Approaches

It is difficult to predict the level of stability that exists in ground suspected of past landslide movement even with the application of geological investigations and geotechnical engineering. Geotechnical evaluations are more reliable when dealing with known active slides since key parameters can be more reasonably back-calculated. Therefore, different stability margin criteria apply depending on ground/landslide characteristics, amount and quality of relevant subsurface data, uncertainties in the subsurface model (geometric conditions and material properties), pore-water conditions acting on the slip surface, and reasonably foreseeable future conditions.

The design of mitigation measures for small non-critical applications can be based on precedent, experience and judgment. An example is constructing a rock inlay to replace small slumps. Larger and more complex landslides and those potentially causing impacts to life or property are often designed using numerical analyses. The latter design method includes limit-equilibrium stability analyses and deformation analyses. The stability margin can be calculated as a Factor of Safety (FS), which is often used to express the level of calculated stability.

The level of FS that is considered adequate can vary depending on several issues, such as: 1) potential impact to life and property, 2) criticality of facility, 3) extent and reliability of subsurface conditions and parameters/properties for analysis 4) design life, 5) cost, 6) level of acceptable risk (consequences if landslide is reactivated), 7) jurisdictional requirements/regulations, and 8) the ability to predict future adverse conditions. For small landslides, a remediation factor of safety in the 1.2 to 1.5 range is typically used, assuming adequate investigation, instrumentation and back-analysis. For comparison, the Factor of Safety commonly used for designing earthwork where no landslide conditions exist is typically 1.5 because soil properties cannot be back-analyzed and greater uncertainties exist in the analysis model. Lower FS criteria are considered for large landslides and "marginal stabilization" when the cost of standard design methods are exorbitant and the owner can accept greater levels of risk. When constructing in ancient landslide terrain, the level of existing stability is usually marginal (FS < 1.2) and mitigation measures should be designed to avoid any reduction in stability and preferably to increase the FS. The landslide analyst should confirm that the proposed mitigation sufficiently contains a safety margin that accounts for potential uncertainties and errors in the model and analyses and also accounts for foreseeable future conditions and events.

For analysis to be reliable, a geologic model should first be determined that fully addresses the most probable causative factors for the landslide assuming existing and anticipated future conditions. Back-analysis is extremely important to establish reasonable parameters for design of mitigation measures and should be performed with few exceptions. The use of back-analysis allows the use of lower (less conservative) stability margins or FS criteria.

The level of stability can be difficult to predict for landslide areas that appear to be inactive, therefore analyses should assume marginal stability, which implies an existing Factor of Safety that is close to unity (using the Original Profile Analysis procedure, refer to Cornforth 2005). The goal should be to restore any decreases in stability caused by construction and to preferably provide an increase in stability, depending on the level of improvement considered appropriate for the type of facility. The foregoing approach is more realistic and safer than utilizing factors of safety based on potentially unconservative laboratory-tested shear strengths that often lead to unrealistically high estimates of stability. Soil properties above or below the shear zone can vary dramatically from the properties within the shear zone. Representative samples are difficult to obtain and usually are not sufficient for landslide testing . Laboratory shear tests generally produce an overestimation of the true residual shear strength because of non-representative materials or incorrect test procedures. Standard direct shear tests on remolded soils often result in strengths that are between the peak and residual levels that are difficult to interpret and correlate. Therefore, using a back-analyzed marginal-stability model (Original Profile Analysis) is recommended.

The analysis of mitigation methods should include all potential failure cases in addition to the existing failure geometry. For example, toe buttresses are sized to resist the existing failure surface by interrupting it with higher strength materials (rockfill); however, the slide mass might instead opt to daylight upslope of the buttress because there may be weak materials in that area. Therefore, the landslide may need to be stabilized with a series of mitigation measures in order to provide sufficient stability for all applicable cases. Each cross section model should be checked for reasonableness to confirm that assumed parameters are consistent with the appropriate landslide model that is based on "marginal stability" conditions.

Sensitivity analyses should be performed to evaluate the impact of various subsurface assumptions and to model extreme events such as seismic and significant groundwater elevation due to unusual precipitation and snow pack thaw. Lower stability margin criteria can be applied when considering unusual/extreme events.

Mitigation Methods

Mitigation options can be categorized based on the way each measure improves stability. While a "Do Nothing" option can be acceptable for maintaining facilities affected by inactive or creeping landslides, such an approach does not increase the level of stability and may eventually require maintenance to repair damaged facilities. Where new construction is planned, mitigation would be appropriate to reduce the risks to acceptable levels. There are three main categories to improve stability: 1) avoidance, 2) reduction of driving forces, and 3) increasing resistance. The design should determine which of the mitigation method options are appropriate and cost-effective for a particular landslide.

Avoidance can include "no-build" designations in the area of and surrounding the landslide, relocation of planned facilities, and bridging over landslide areas. "No-build" designations help to reduce risks to jurisdictions, property owners and the public. The objective is to construct new facilities in locations where no landslide risks exist or have been adequately stabilized. Roads and utilities can be routed across landslides on bridges with sufficiently long spans to avoid contact with any portion of the slide mass and adjacent marginal areas.

Reduction of driving forces can include removal of weight from the upper portions of landslides and drainage of water and groundwater flowing into the landslides. Unloading can be accomplished by excavating the amount of slide material to sufficiently improve the margin of stability. Another means of unloading is to remove the upper part of the slide mass and replace it with lighter-weight materials to support the facility. Reduction of driving forces can also be taken to the extreme by removing the entire landslide mass and forming stable slopes in adjacent ground. Drainage of groundwater near the head of slide areas reduces driving forces by decreasing seepage forces and total weights of soil in the driving portion. The use of surface drainage systems, impermeable covers, and hydrophilic plants can help to reduce infiltration. However, biostabilization methods are more appropriate for erosion control rather than landslide mitigation.

Increasing resistance can include improvement of soil shear strengths, buttressing, restraint/reinforcement, and dewatering. Shear strengths can be improved by replacing portions of the shear zone material with stronger materials, such as buttresses and shear keys. Buttresses, gravity walls and berms constructed in the toe area of a landslide can add positive weight that increases the net shear resistance, and the amount of benefit achieved would be influenced by the strength of the material in the shear zone (slip surface). Dewatering using drainage systems can reduce buoyancy and result in improved resistance along the shear zone, provided that the drainage systems can effectively reduce groundwater pressures on the shear zone. More expensive structural alternatives could be considered when there are special constraints or when the risks and consequences of failure are significant. Structural methods of adding resistive forces include retaining walls, ground anchors and shear piles. The concept of using chemical injection and grouting methods to improve shear strength has been recognized, but such methods typically do not achieve uniform or significant improvement.

Examples of the various mitigation methods will be described in the presentation.

<u>Selection of Mitigation System</u>

The selection of appropriate mitigation measures should be based on an assessment of risk, uncertainty, possible consequences, constructability, environmental impacts and costs. A final mitigation approach usually consists of a creative combination of several methods.

Environmental constraints and requirements can influence the selection and overall design of mitigation measures. For example, a toe buttress might not be permissible if the toe of a landslide is in a river, lake or wetland. Mitigation measures may need to comply with aesthetic requirements of parks and scenic areas.

When selecting a specific mitigation or stabilization method, it is best keep it simple (KISS principle) to match the capabilities of contractors and the availability of materials. Constructability and construction requirements should be evaluated, including sequencing, temporary support, and protection of nearby property, facilities, utilities, traffic and the public. Construction can be further complicated if slide movements are occurring or can be triggered by excavations, grading and changes in water conditions. The possible unstable conditions that can be caused or encountered during construction should be identified and potential solutions determined. Timing of construction could be an issue, particularly to avoid periods when groundwater conditions are adverse and when ground movements are significant.

In difficult and constrained situations, it might be necessary to use structural solutions, which could increase the complexity of construction. Structural systems require special design and sequencing to account for possible slide movement during construction and to provide sufficient capacity in each structural member that will not be exceeded at any time during or after construction. In many cases, weak and clayey soils exist in landslides that could creep when loaded, and could be a factor in design of foundations and anchors.

The mere act of constructing mitigation measures does not always stop ground movements immediately. Often, cracks caused by landsliding leave voids in the ground that could take time to compress or fill-in. Mitigation measures often rely on movement of the slide mass to mobilize new resistive forces. Following mitigation, slide movements tend to slow down prior to stopping and could take years to reach final stability. Where on-going movement is anticipated, the selected option must be capable of accommodating such movements.

The maintenance requirements associated with each mitigation option should be considered to understand the potential long-term impacts and costs. This includes identifying procedures, equipment, frequency and level of effort that would be required for maintenance and the consequences when such maintenance is not performed. Another consideration is to evaluate whether the mitigation measure will experience a reduction in effectiveness over time due to potential damage, weakening, plugging, vandalism, or due to indirect effects of nearby development and activities.

Implementation

Additional property and/or easements may be required for some of the mitigation measures. This may be necessary to accommodate construction access and installation of large mitigation elements, as well as to protect mitigation measures from being altered. In addition, access may be required for long-term maintenance. Property and/or easements can also be obtained to prevent new construction on surrounding property that could potentially decrease landslide stability.

To protect the level of stability of a landslide or mitigated area from not being decreased over time, it would be prudent to place conditions on properties in the landslide area to prevent changes that could potentially cause landslide reactivation, partial reactivation or further instability. The area of concern would extend a reasonable distance uphill and downslope of the landslide area, which could be determined by stability analyses.

The involvement of a geotechnical professional during construction is critical to the success of mitigation measures because most investigations are unable to reveal all problem conditions during the design phase. The approach should be to continue the geotechnical engineering of the mitigations during construction in order to identify and adapt to new subsurface information, as well as to identify the suitability of the contractor’s methods.

Instrumentation monitoring during construction can be used to identify risks and potential harm by determining whether landslide movements are occurring, the rates of movement and the depths/extent of sliding. Excavations or fills could temporarily reduce stability as mitigations are being constructed. If potentially harmful movements are detected, construction procedures and designs might need to be modified.. Monitoring of instruments is also valuable after construction to identify whether ground movements have ceased or to warn of reactivated movements.

Summary

There are a variety of ways to deal with landslides, depending on the degree of the landslide hazard as well as legal, social, environmental, geotechnical and economic factors. These options include “Avoidance,” “Do Nothing,” “Maintenance,” and “Selective Stabilization” approaches as well as “Conventional” stabilizations. Fortunately there are many techniques available to improve stability. However, there is usually no standard rule-of-thumb solution because formulation of mitigation measures is often unique for each site and requires proper technical evaluation of causative factors. The level of stability that should be attained through mitigation is often misunderstood and can be a controversial topic. Investigations are often inadequate and there is poor understanding about landslide conditions. Stability margins and design approaches are also not well understood by practitioners. Fortunately, principles and guidance exist for developing adequate criteria and selecting appropriate design methods. Geotechnical landslide experience and judgment are necessary for evaluating the potential risks and consequences and for formulating recommendations and mitigation measures that would be acceptable to owners and affected jurisdictions.

References

Recommended references describing landslide mitigation measures include:

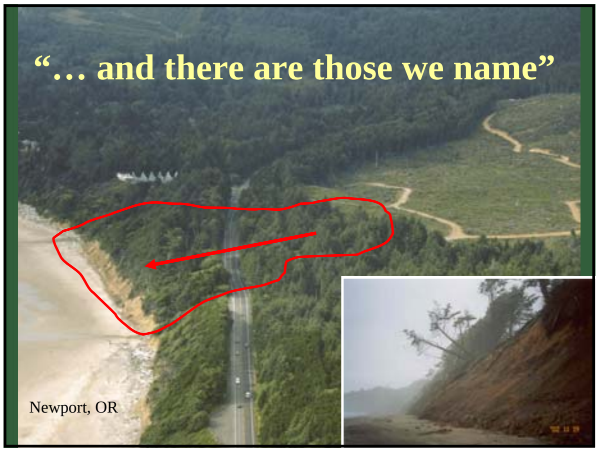
- Cornforth, D, “Landslides In Practice, Investigation, Analysis, and Remedial/Preventative Options in Soils,” Wiley, 2005.
- Duncan, J.M., and Wright, S.G, “Soil Strength and Slope Stability,” Wiley, 2005.
- TRB, “Landslides: Investigation and Mitigation,” Special Report 247, Transportation Research Board, 1996. (Various contributing authors)
- FHWA, “Advanced Technology for Soil Slope Stability,” FHWA-SA-94-005, U.S. Department of Transportation, 1994. (Primary authors: Abrahamson, Boyce, Lee, and Sharma)
- FHWA, “Highway and Slope Maintenance and Slide Restoration Workshop Manual,” FHWA-RT-88-040, U.S. Department of Transportation, 1988. (Primary authors: Hopkins, Allen, Deen, and Grayson)
- US Forest Service, “Slope Stability Reference Guide for National Forests in the United States,” Volume III, EM-7170-13, US Department of Agriculture, 1994.

I-80, Utah

George Machan

“There are landslides we fix,

I-80, Utah



Newport, OR

Outline

- Level of Mitigation
- Design Approaches
- Mitigation Methods
- Constructability
- Long-term performance and maintenance
- Selection of Mitigation System
- Implementation
- Examples

Level of Mitigation

Why should all landslides not be mitigated to the same level?

Examples:

- No Build or Avoidance
- Do Nothing
- Maintenance Approach
- Selective Stabilization
- Marginal Stabilization
- Conventional Stabilization

Design Approach

- Before starting design:
  - perform adequate geologic studies and investigations
  - Perform proper lab tests
  - Monitor instruments to get reliable info on slide geometry (movement depths and corresponding groundwater pressures)
- Design by <u>precedence</u> could be applicable for small slides (i.e., local cut slope and fill slope instabilities)
- Slides that require <u>analysis</u> include those that impact facilities and can potentially cause harm or damage.

Analysis

- For slides that require analysis:
  - Perform appropriate analyses and verify that the landslide model is without flaw
  - Input the shear zone geometry based on investigation (don't use canned "failure surfaces" and search routines)
  - Check all reasonably possible failure hypotheses
- Effective Stress analysis – preferable (if groundwater pressures are known)
- Total stress analysis – when groundwater information is uncertain
  - and when groundwater will not affect final solution

LANDSLIDE TECHNOLOGY

Existing Factor of Safety

- How is existing Factor of Safety (FS) determined?
- Back-analysis is a "must" for landslide applications
  - Most landslides are marginally stable, no matter how old
  - Back-calculated shear strengths: more reliable than lab tests
  - Only one strength parameter (ϕ' or c)
- Assume FS = 1.0 as a starting point (even if stability level is slightly higher)
- Sensitivity Analyses to confirm model and properties
- Don't be misled by calculations of unrealistically high FS (input geometry, strengths, groundwater could be incorrect)

LANDSLIDE TECHNOLOGY

Stability Margin

What factors influence selection of Stability Margin?

- Size of landslide
- Criticality and importance of facility
- Degree of uncertainty of subsurface data/model
- Level of risk-taking
- Potential consequences
- Back-calculated shear strength
- Short-term conditions
- Extreme & rare loads/conditions

LANDSLIDE TECHNOLOGY

Stability Margin – landslide size

- Size of landslide (w/ adequate investigation)
  - Small to Very Small — FS > 1.35 – 1.5
  - Medium — FS > 1.25
  - Large to Very Large — FS > 1.2 - 1.15

LANDSLIDE TECHNOLOGY

Analysis Issues?

- Check various potential failure modes when applying and sizing mitigation measures
- Failure surfaces along:
  - residual shear zone
  - Undisturbed soil ("First time shear")
- What if drainage is a mitigation measure - what analysis to be used? What dangers?

LANDSLIDE TECHNOLOGY

Mitigation Methods

- Avoidance
- Reduction of Driving Forces
- Increasing Resistance

LANDSLIDE TECHNOLOGY

Constructability

- Simplicity
- Sequencing
- Temporary support of exposed landslide
- Protection of nearby facilities
- Availability of materials and equipment
- Accommodation of slide movement during construction

Long-term Performance

- Long-term performance objectives met?
- Maintenance requirements?
- Ability of having maintenance performed
  - Resources
  - Funding
- Consequence of future slide movement on selected mitigation measure?

Selection of Mitigation System

- Determine which methods provide dependable Stability Margin at reasonable cost
- Selection should be based on assessment of Stability Margin, risk, uncertainty, possible consequences, constructability, environmental impacts, short-term and long-term performance, costs

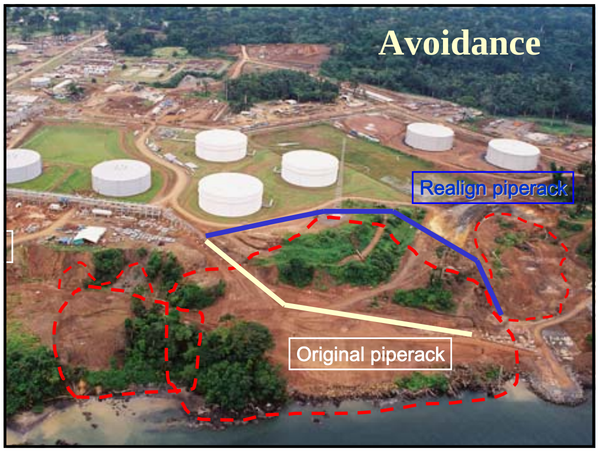
Implementation

- Property and easements; Access
- Permits; Environmental stewardship
- Provide protection to prevent disturbance to mitigation measures & instruments
- Involve a competent landslide expert to oversee design, monitoring and construction

Examples of Mitigation Concepts

Avoidance options

- Leave landslide alone (nature preserve, park)
- Span over landslide without touching (bridge)
- Construct around perimeter of landslide
- Avoid actions that potentially decrease ground stability



Bridge to avoid Landslide

West Africa

LANDSLIDE TECHNOLOGY

Reduction of Driving Forces

- Unload material from upper part of slide
  - Remove material
  - Replace soils with light-weight material
- Intercept surface water and groundwater

LANDSLIDE TECHNOLOGY

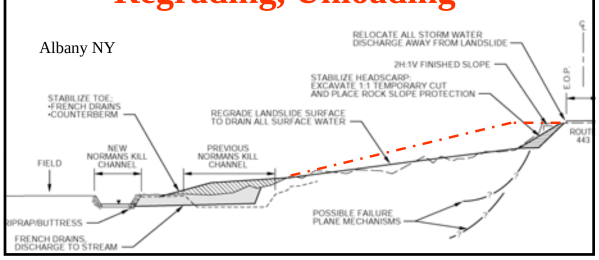
Albany NY

Nature flattens slopes,
… sometimes to our dismay !!!

LANDSLIDE TECHNOLOGY

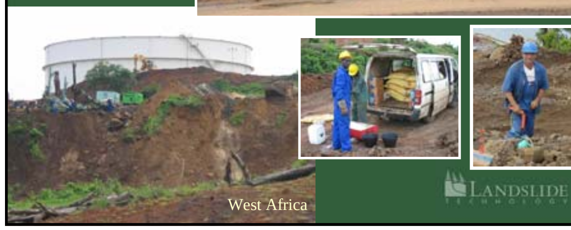
Regrading, Unloading

Albany NY



Slide Unloading

blasting to
remove huge
boulders



West Africa

LANDSLIDE TECHNOLOGY

Lightweight Fill

- Shredded tires
- Wood chips

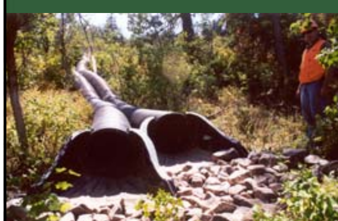
Oregon DOT

Geofoam light-weight fill

Albany NY

Interceptor Ditches and Culverts

Snowbasin



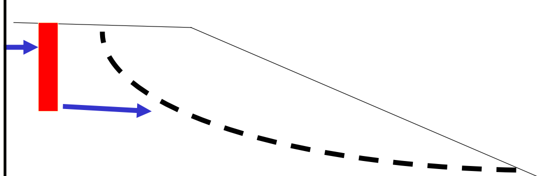
Interceptor Ditches

West Africa

& Dewatering Wells

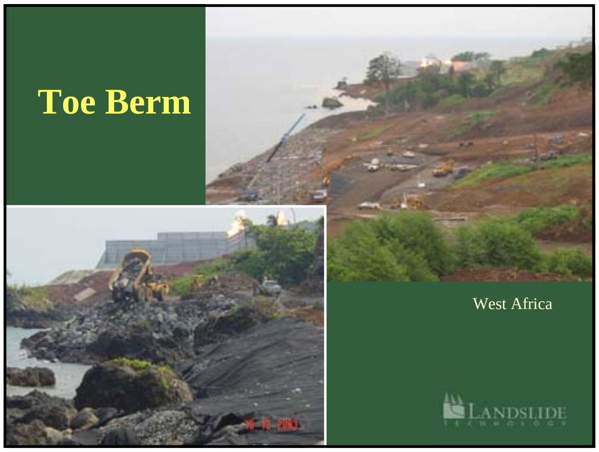
Drainage Trench

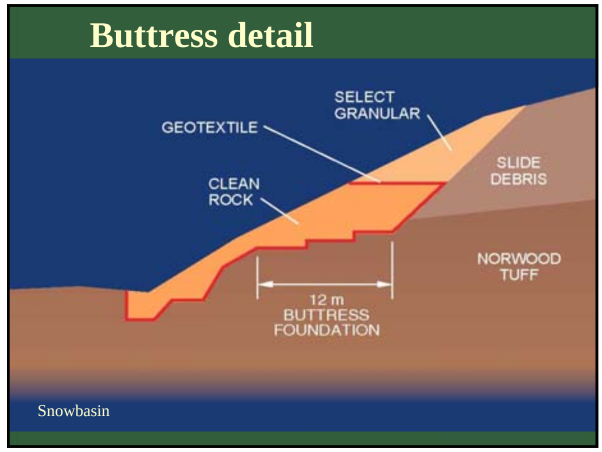
- intercept groundwater to reduce seepage

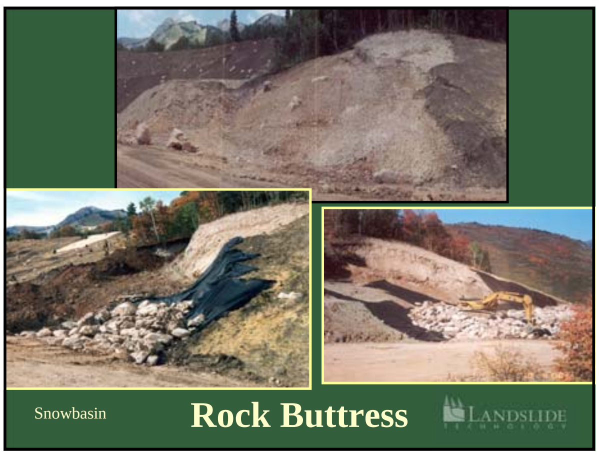


Increasing Resistance

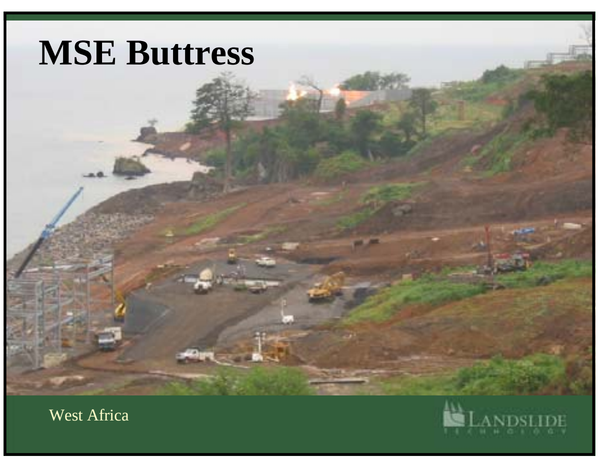
- Toe berm or gravity wall
- Buttress
- Increase shear strength in basal shear zone
  (shear keys, dewatering, chemical alteration, freezing)
- Structural reinforcement
  (ground anchors, shear piles, geogrids)

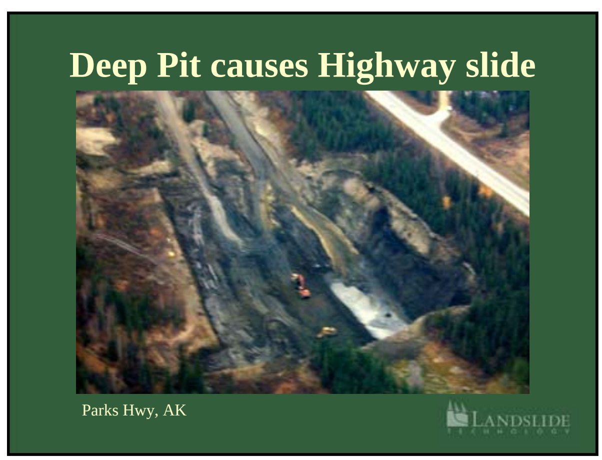

Toe Berm
West Africa
LANDSLIDE

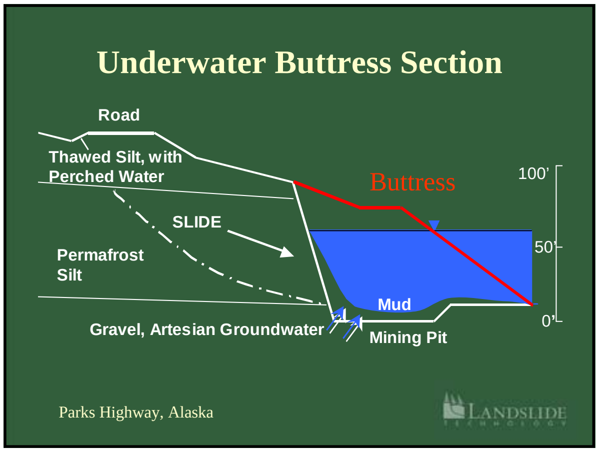

Buttress detail
SELECT GRANULAR
GEOTEXTILE
SLIDE DEBRIS
CLEAN ROCK
NORWOOD TUFF
12 m BUTTRESS FOUNDATION
Snowbasin

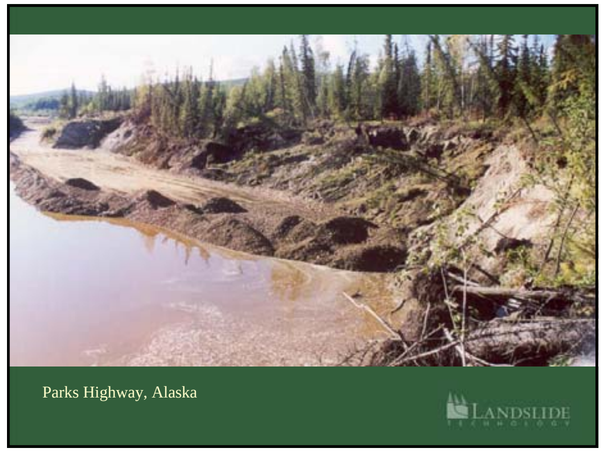

Snowbasin
Rock Buttress
LANDSLIDE

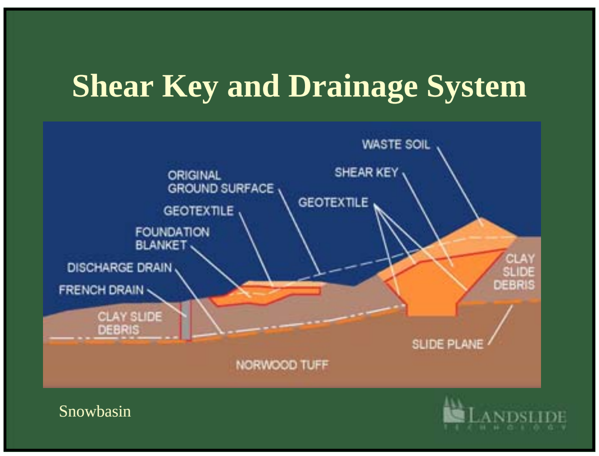

Finished buttress
Snowbasin
LANDSLIDE


MSE Buttress
West Africa
LANDSLIDE

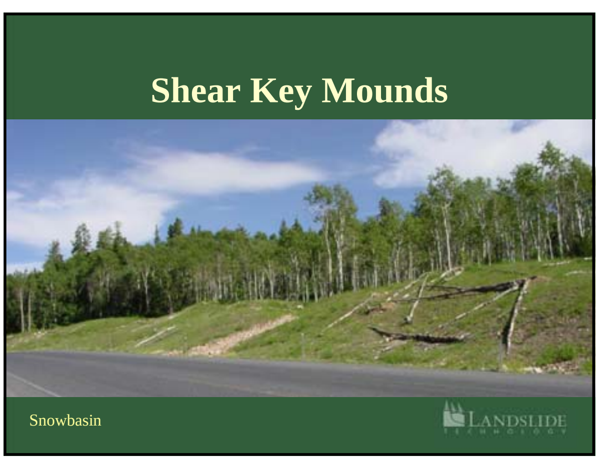

Deep Pit causes Highway slide
Parks Hwy, AK
LANDSLIDE

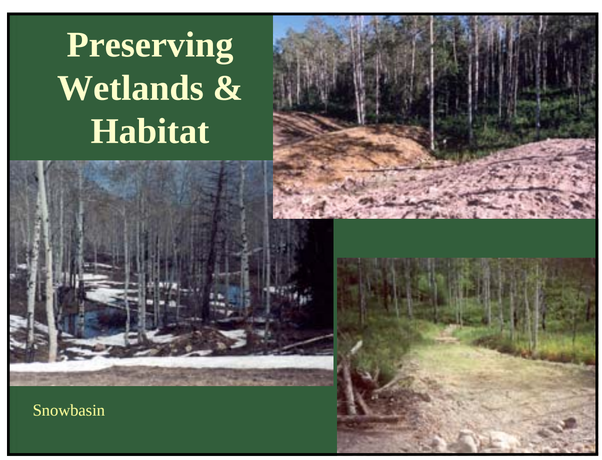

Underwater Buttress Section
Road
Thawed Silt, with Perched Water
SLIDE
Permafrost Silt
Gravel, Artesian Groundwater
Buttress
Mud
Mining Pit
100'
50'
0'
Parks Highway, Alaska


Parks Highway, Alaska

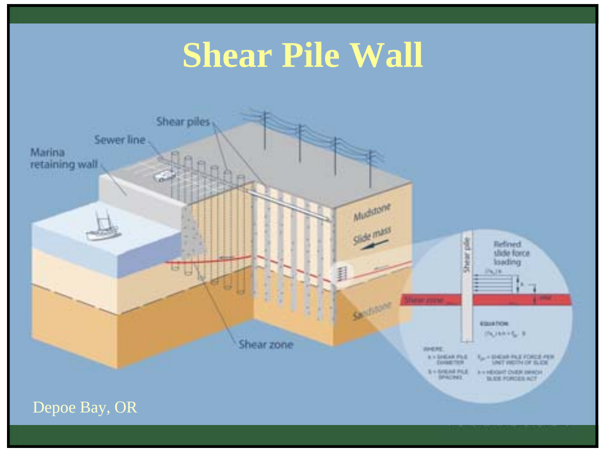

Shear Key and Drainage System
WASTE SOIL
ORIGINAL GROUND SURFACE
SHEAR KEY
GEOTEXTILE
GEOTEXTILE
FOUNDATION BLANKET
DISCHARGE DRAIN
FRENCH DRAIN
CLAY SLIDE DEBRIS
CLAY SLIDE DEBRIS
SLIDE PLANE
NORWOOD TUFF
Snowbasin


Shear key construction
Snowbasin

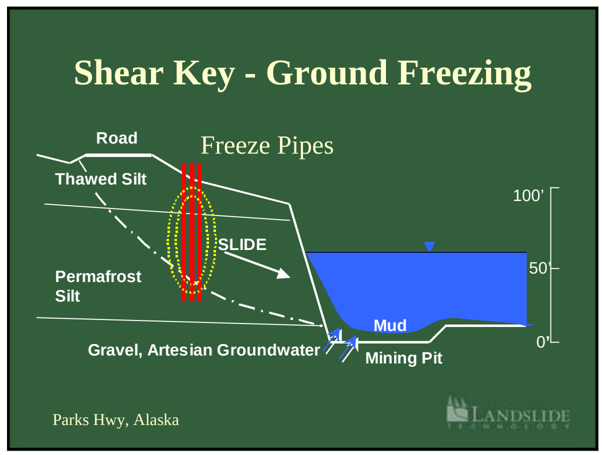

Shear Key Mounds
Snowbasin

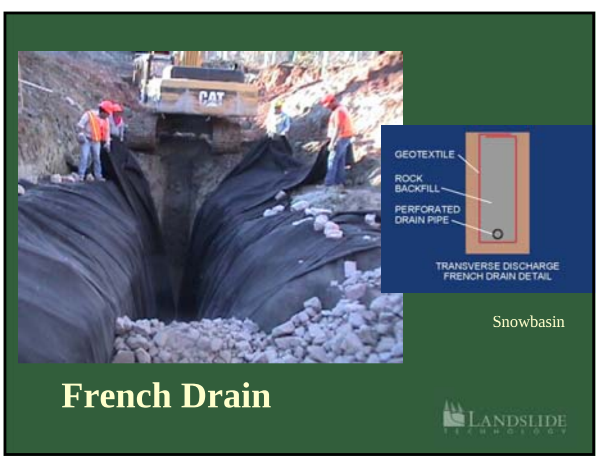

Preserving Wetlands & Habitat
Snowbasin

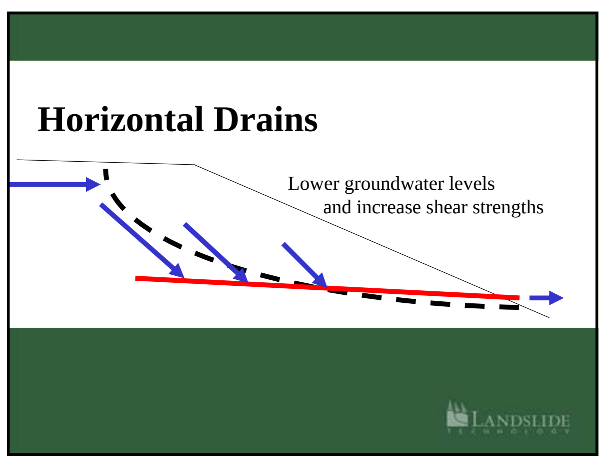

Slide impacting Dock
Active landslide limits
Shear pile wall
Depoe Bay, OR


Shear Pile Wall
Shear piles
Sewer line
Marina retaining wall
Mudstone
Slide mass
Sandstone
Shear zone
Refined slide force loading
Depoe Bay, OR


Steel reinforcement for Shear piles
3' dia
Depoe Bay, OR


Shear Key - Ground Freezing
Road
Freeze Pipes
Thawed Silt
100'
SLIDE
50'
Permafrost Silt
Mud
0'
Gravel, Artesian Groundwater
Mining Pit
Parks Hwy, Alaska


GEOTEXTILE
ROCK BACKFILL
PERFORATED DRAIN PIPE
TRANSVERSE DISCHARGE FRENCH DRAIN DETAIL
Snowbasin
French Drain


Horizontal Drains
Lower groundwater levels
and increase shear strengths

Horizontal Drains

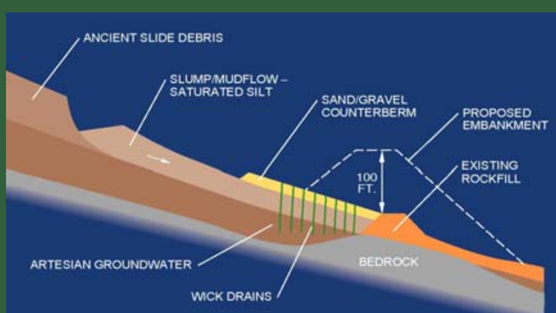
Oregon

West Africa

Special Horizontal Drain Systems

Snowbasin

Artesian Pressure Relief Drains



Bonners Ferry, Idaho

Wick Drains

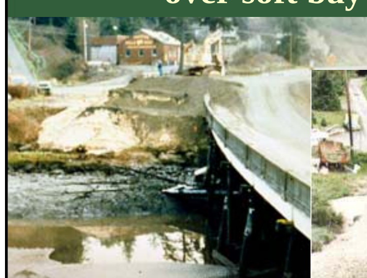
to stabilize slide mass

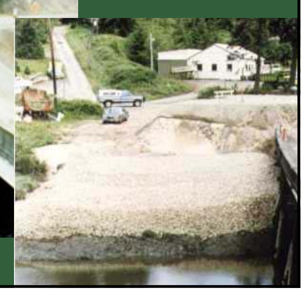
Bonners Ferry, Idaho

Seepage Control Berm

Bonners Ferry, Idaho

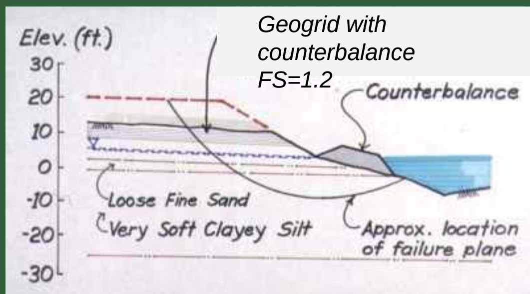
Unstable embankment over soft bay mud





SR-42, Oregon

Geogrid Reinforcement



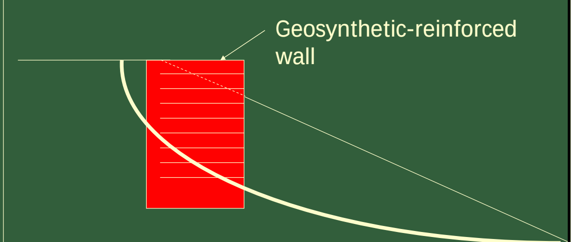
SR-42, Oregon

LANDSLIDE TECHNOLOGY

Retaining Structures – Selective Stabilization

- Restrain upper portion of slide
- Lower portion is free to move
  - or stabilized with additional mitigation

LANDSLIDE TECHNOLOGY



Wall at top of slide

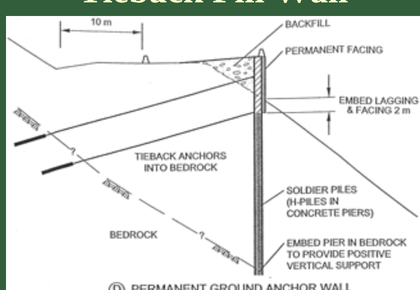
LANDSLIDE TECHNOLOGY

Shallow Slides and Creep

Glenn Hwy, AK

LANDSLIDE TECHNOLOGY

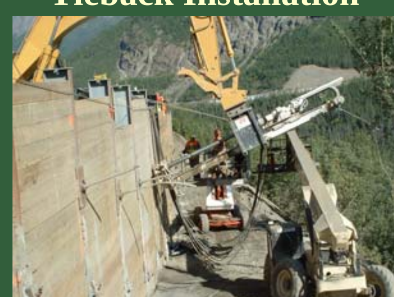
Tieback Fill Wall



Glenn Hwy, AK

LANDSLIDE TECHNOLOGY

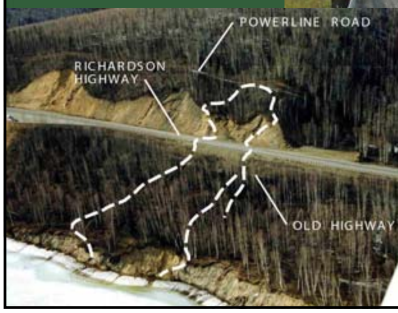
Tieback Installation



Glenn Hwy, AK

LANDSLIDE TECHNOLOGY

Ground Anchors



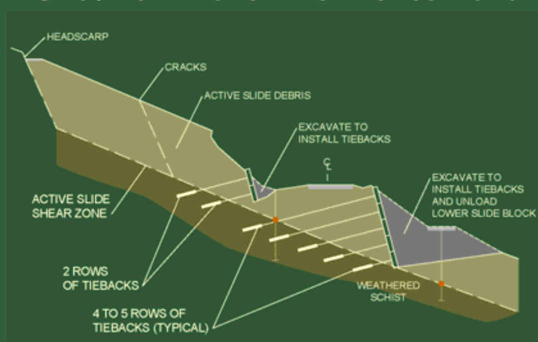
Richardson Hwy, Alaska

Slide Stabilization Analyses

- Anchor the Upper Block
  - FS = 1.05 during construction
  - FS = 1.25 long-term
- Anchor the Middle Block supporting roadway
- Lower Slide Stability

Richardson Hwy, Alaska

Ground Anchor Reinforcement



Richardson Hwy, Alaska

Both Rows complete, Upper Wall

Richardson Hwy, Alaska

Richardson Hwy, Alaska

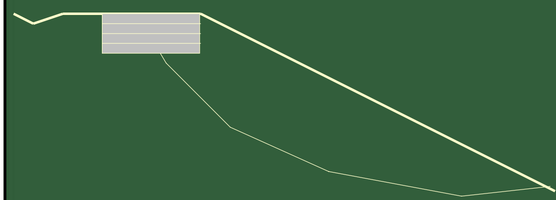
Backfilling Lower Wall

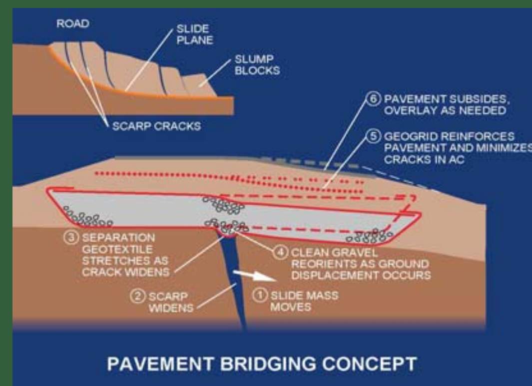
Repairing pavements over landslide scarps

Parks Highway Alaska

Deep Patch

Fabric Wall or MSE



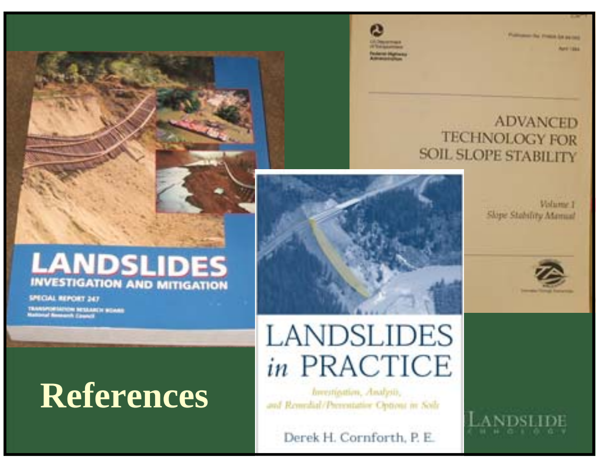


Design of Mitigations: Summary

- Proper investigation - develop correct model
- Addressing the existing stability level
- Determining the min. Stability Margin criterion
- Solution must account for slide conditions & trigger mechanism
- Understanding the consequences of the selected mitigation methods for the specific landslide and matching the owner's needs and capabilities
- Balancing variables such as risk, cost & performance

Summary (cont'd)

- Combination of mitigation concepts?
- Creative and effective use of materials, products, & technology
- Integrating Geotechnical landslide experience and judgment
- Follow through and check performance



References

Dinner time ?