Geological Constraints on Road Design and Use:

Building Roads that Fit the Landscape

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Primary Environmental Constraints on Road Design and Use

- Topography
- Water
- Geology

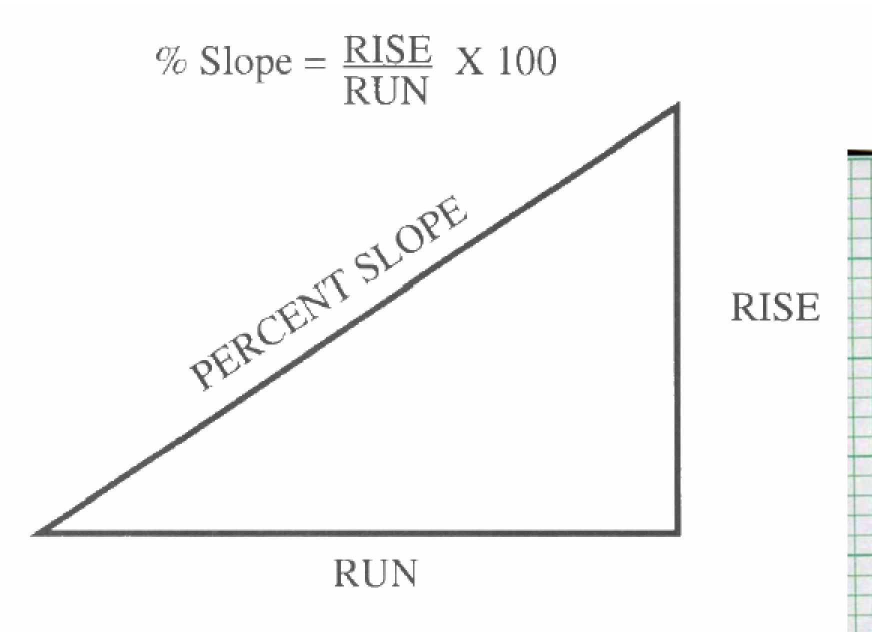
Road Design can be Adjusted for Environmental Constraints

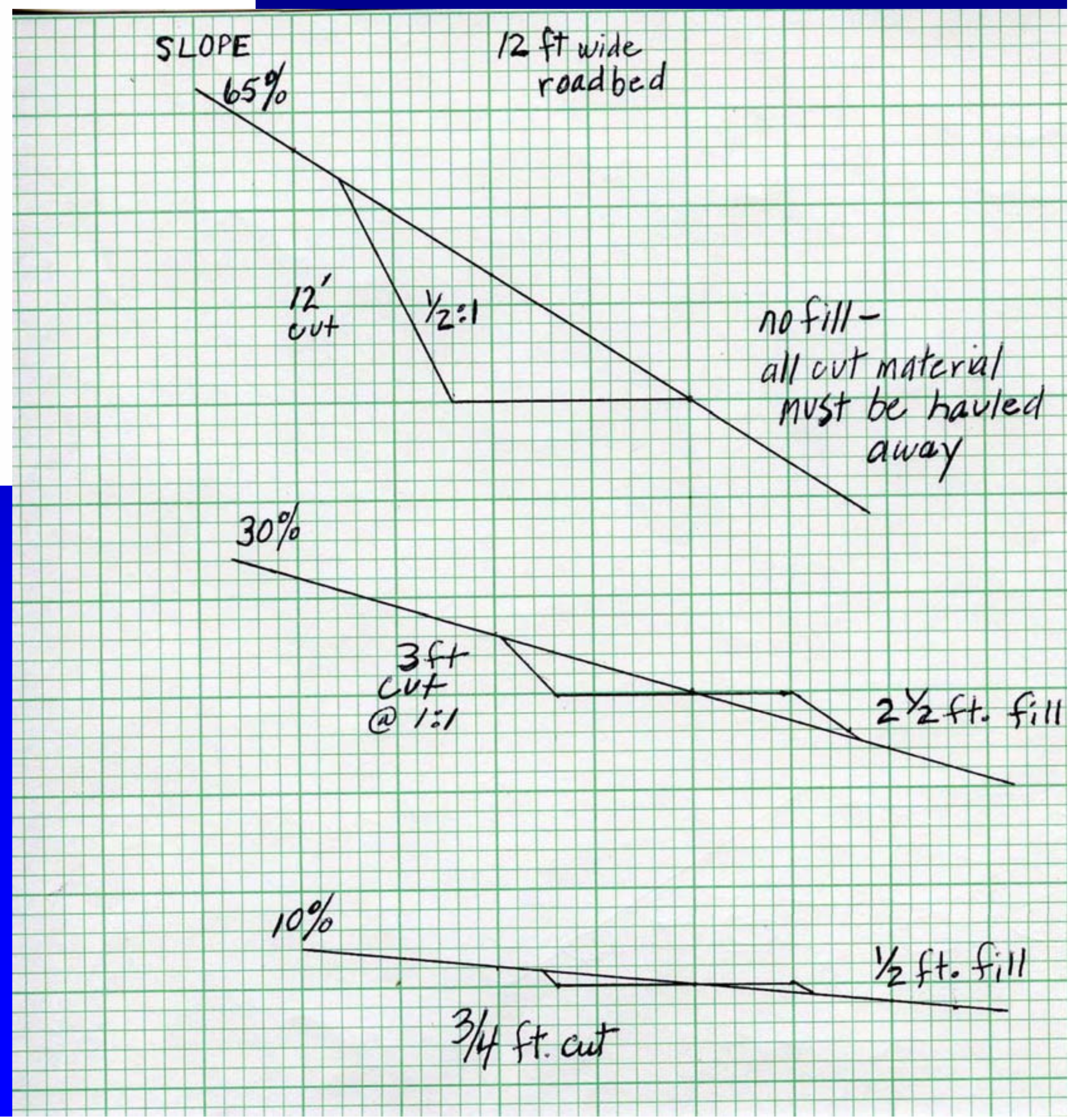
- Good Design can mitigate difficult environmental conditions.
- Poor Design can negate favorable environment conditions.

Good Road Design

- Gentle Road Grades less than 10% are much easier to use and maintain, and are much more forgiving if something goes wrong.
- “Hydrologically Invisible” is the goal. Get water across the road as soon as possible. Less inside ditch; more cross drains, more outsloping

Figure 2 – Calculation of Percent (%) Slope



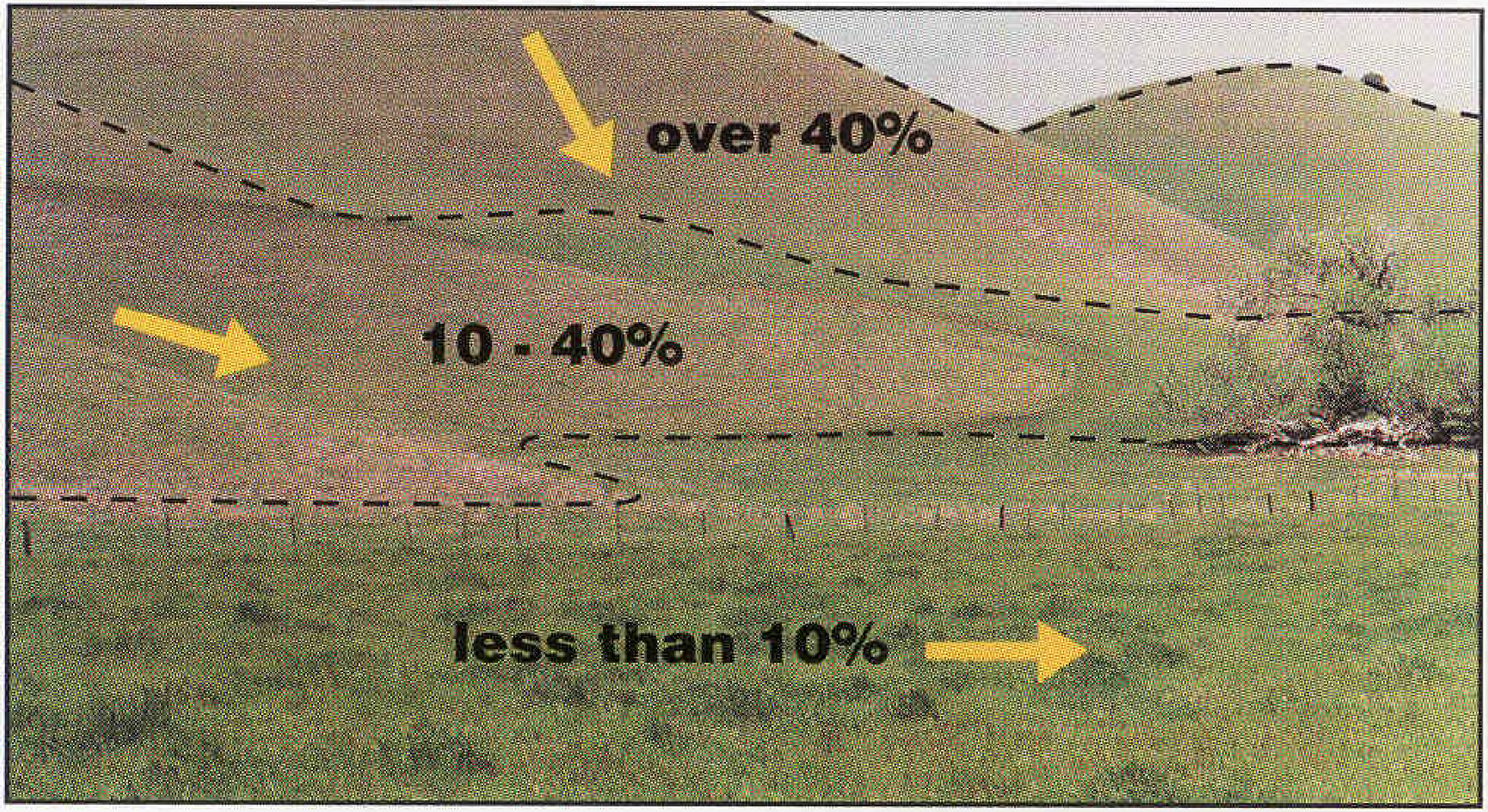


Topography

- Steep slopes (> 40 %) and flat (<10%) low-level areas are difficult
- Gentle slopes (10 to 40 % are preferable –

  Gentle slopes minimize:
  – Road grade (road steepness)
  – Excavation and fill volumes

  Examples of gentle slopes
  - Toe slopes
  - Topographic benches
  - Ridge and hill tops



Wildland Solutions, 1999

Topography

- Gentle slopes:
  - Minimize road grade (steepness)
    - Reduces potential for
      - Erosion of roadbed
      - Stream diversion at watercourse crossings
    - While allowing road surface to drain downslope

Steep road grades

+

surface water

=

<u>EROSION</u>

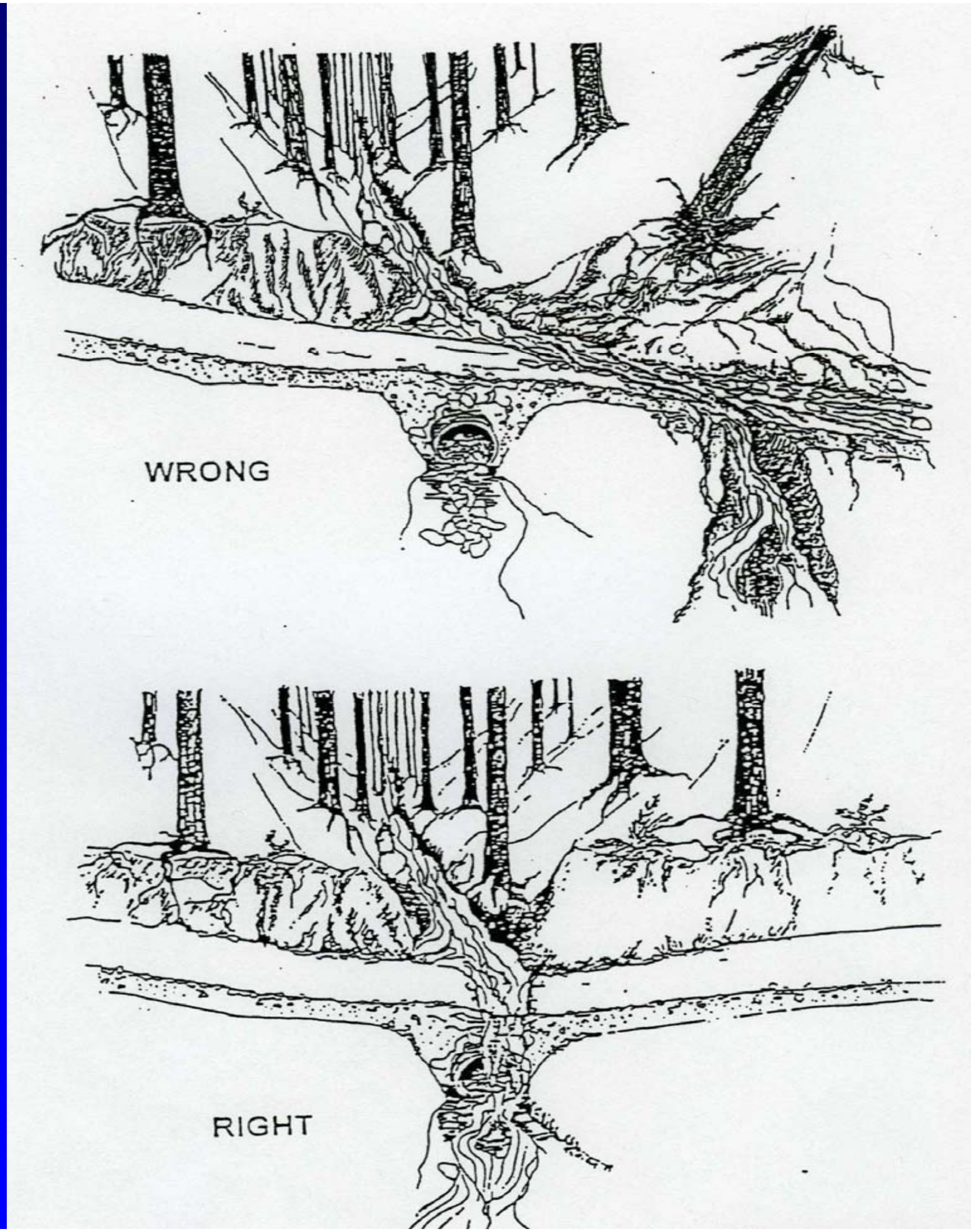
Steep road grades

+

watercourse crossing

=

<u>high stream-diversion potential</u>



Horizontal grades (hard to drain)

+

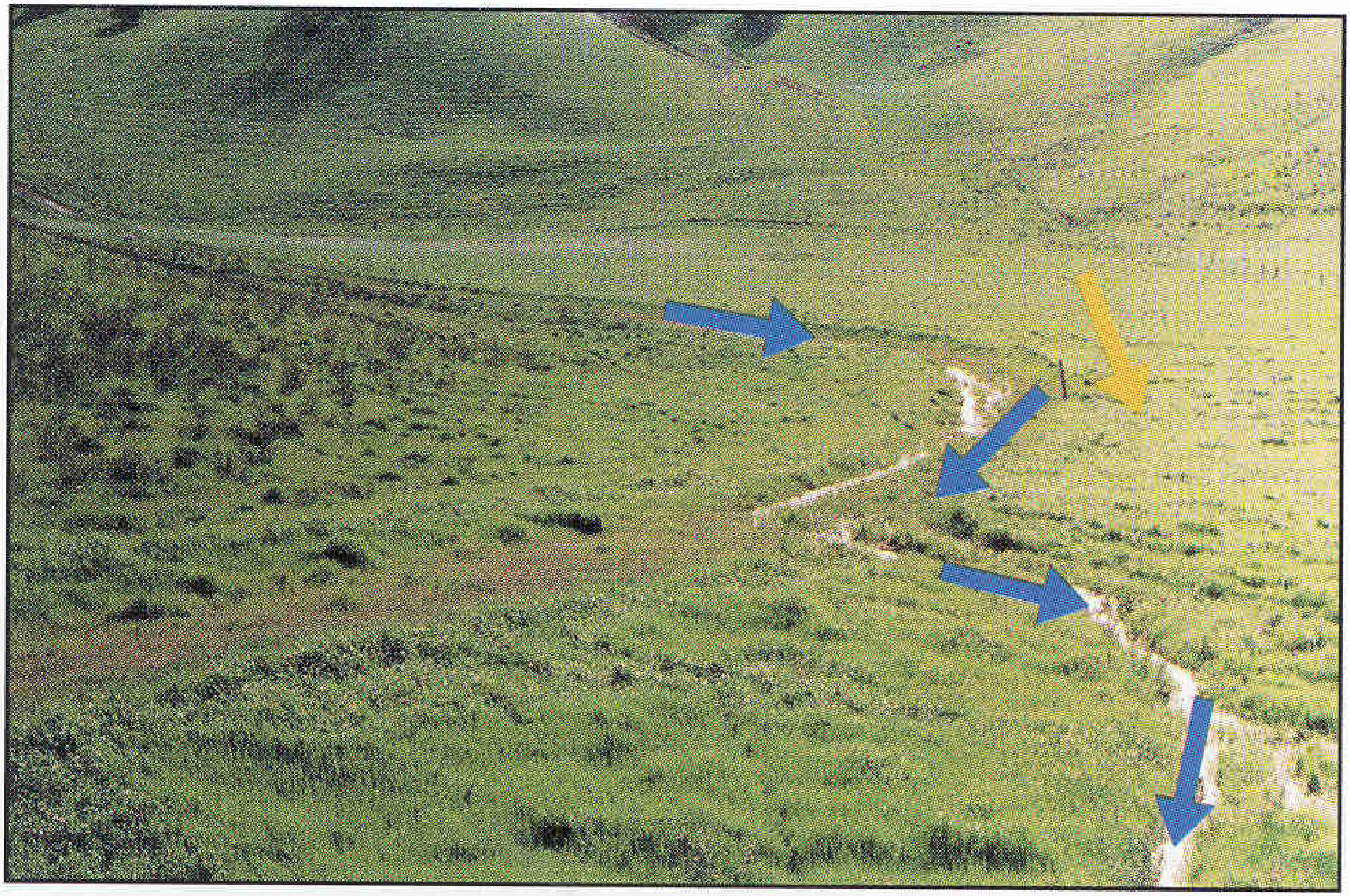
surface water

=

WET

road prism

Problem *Road in drainage bottom – cannot drain*



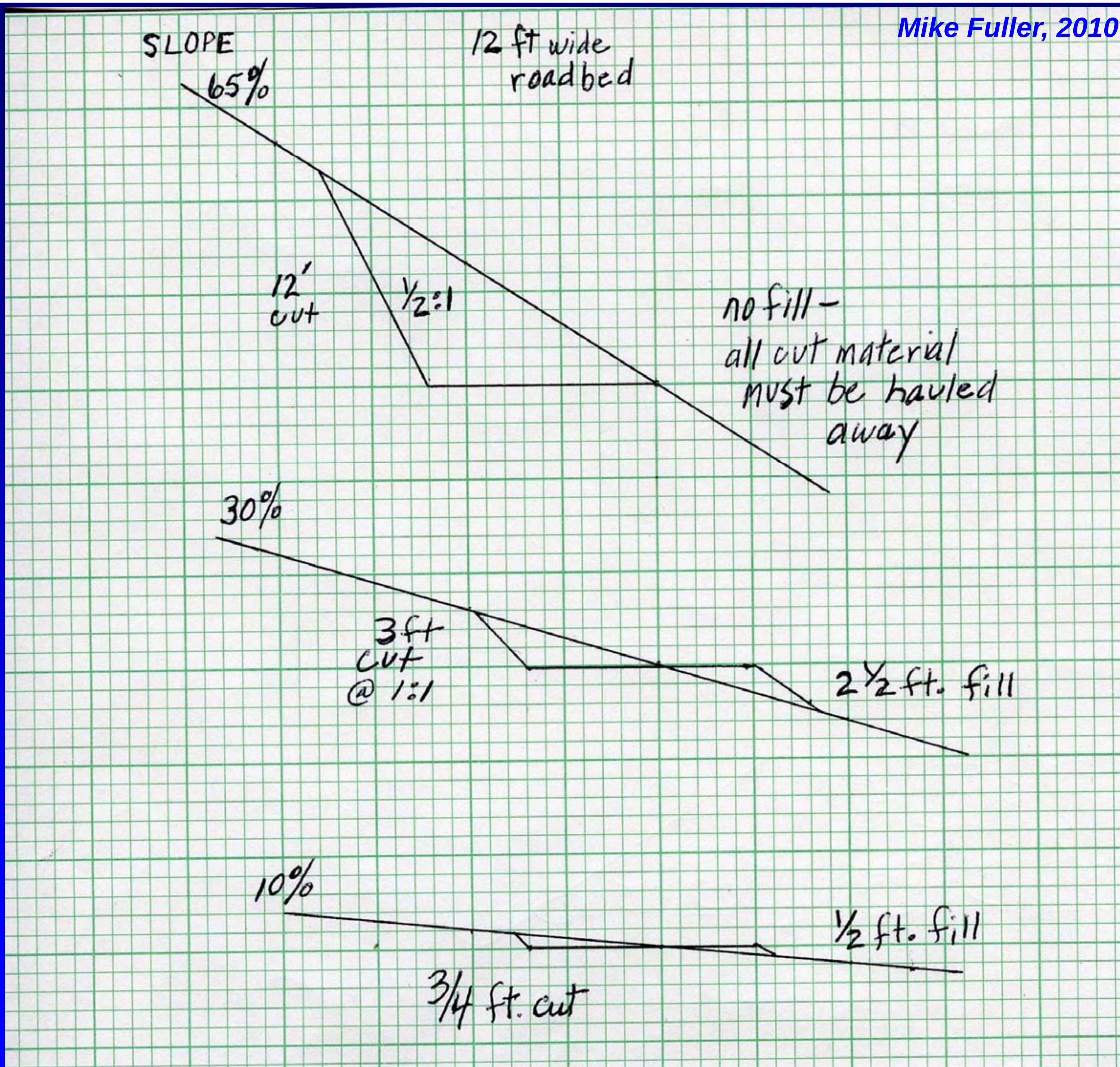
Wildland Solutions, 1999

Solution: *Reroute road to adjacent low-angle toe slope and outslope road*

Wildland Solutions, 1999

Topography

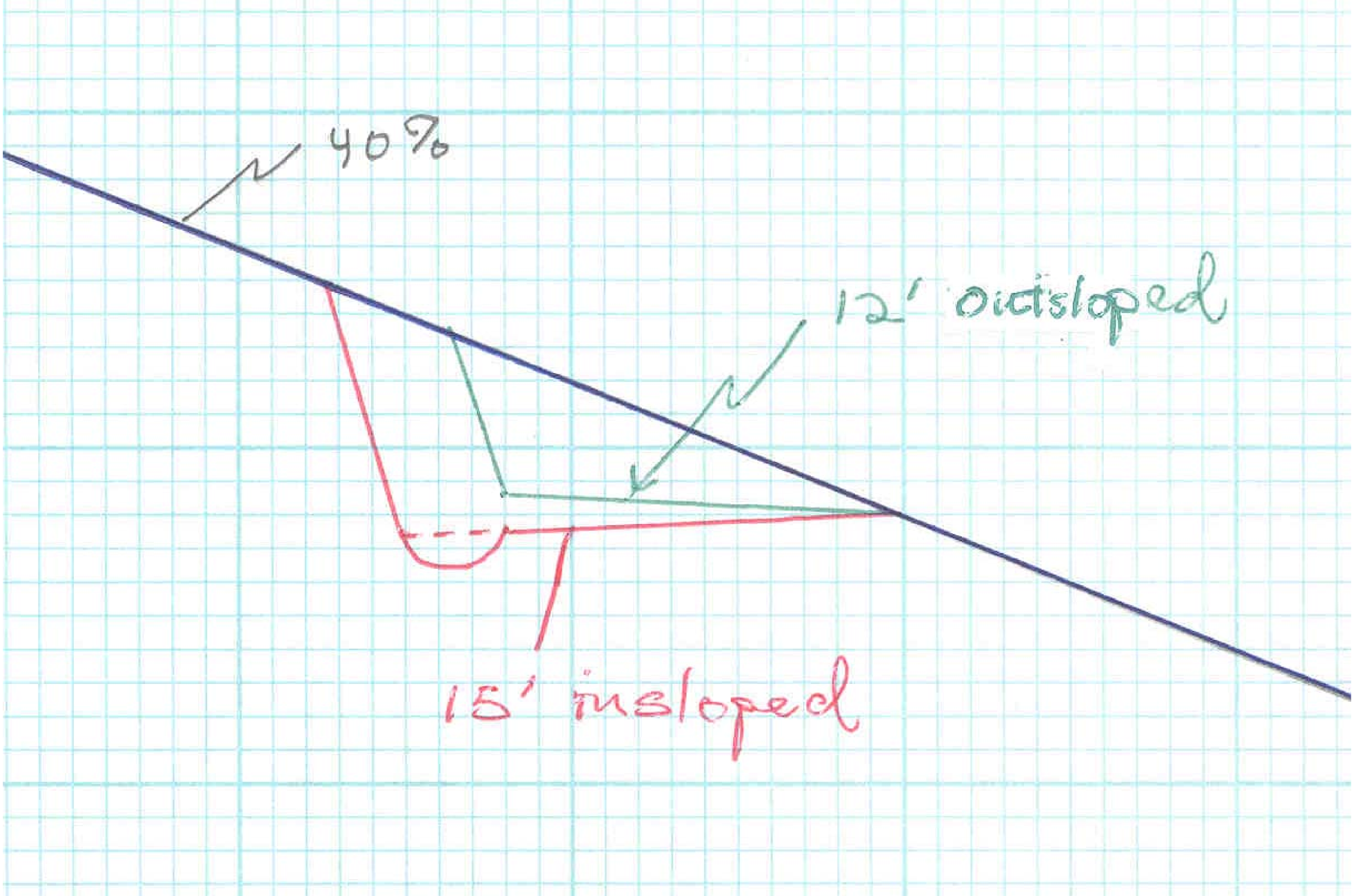
- Gentle side slopes minimize:
  - Excavation and fill
    - Shorter and less steep
      - Cutslopes
      - Fillslopes
    - Less likelihood of
      - Cutslope failure
      - Fillslope failure


Mike Fuller, 2010
SLOPE
65%
12 ft wide
roadbed
12'
cut
½:1
no fill –
all cut material
must be hauled
away
30%
3 ft
cut
@ 1:1
2½ ft. fill
10%
½ ft. fill
¾ ft. cut


Oversteep (near vertical) cutslope
Cut failure
Uncontrolled water
Fill failure in oversteep or uncompacted fill material
Loose sidecast fill on a steep slope

Road Design

- Outsloped roads (versus insloped w ditches):
  – Drain better
  – Shorter cutslope (≈1/3 shorter)
  – Less spoils from excavation (>50% less)


40%
12' outsloped
15' insloped

Water

- Streams
- Wet areas

Water

- Streams

  Stay away from except to cross

  (Pete Cafferata will discuss stream crossings July 2)

  - Road effects on streams

  - Stream effects on roads

Road Effects on Streams

- Can Increase Sediment Discharge to Streams
- Can Increase Stream Peak Flow – Flood Crest
- Road effects reduced by increasing distance between road and stream (buffer effects)

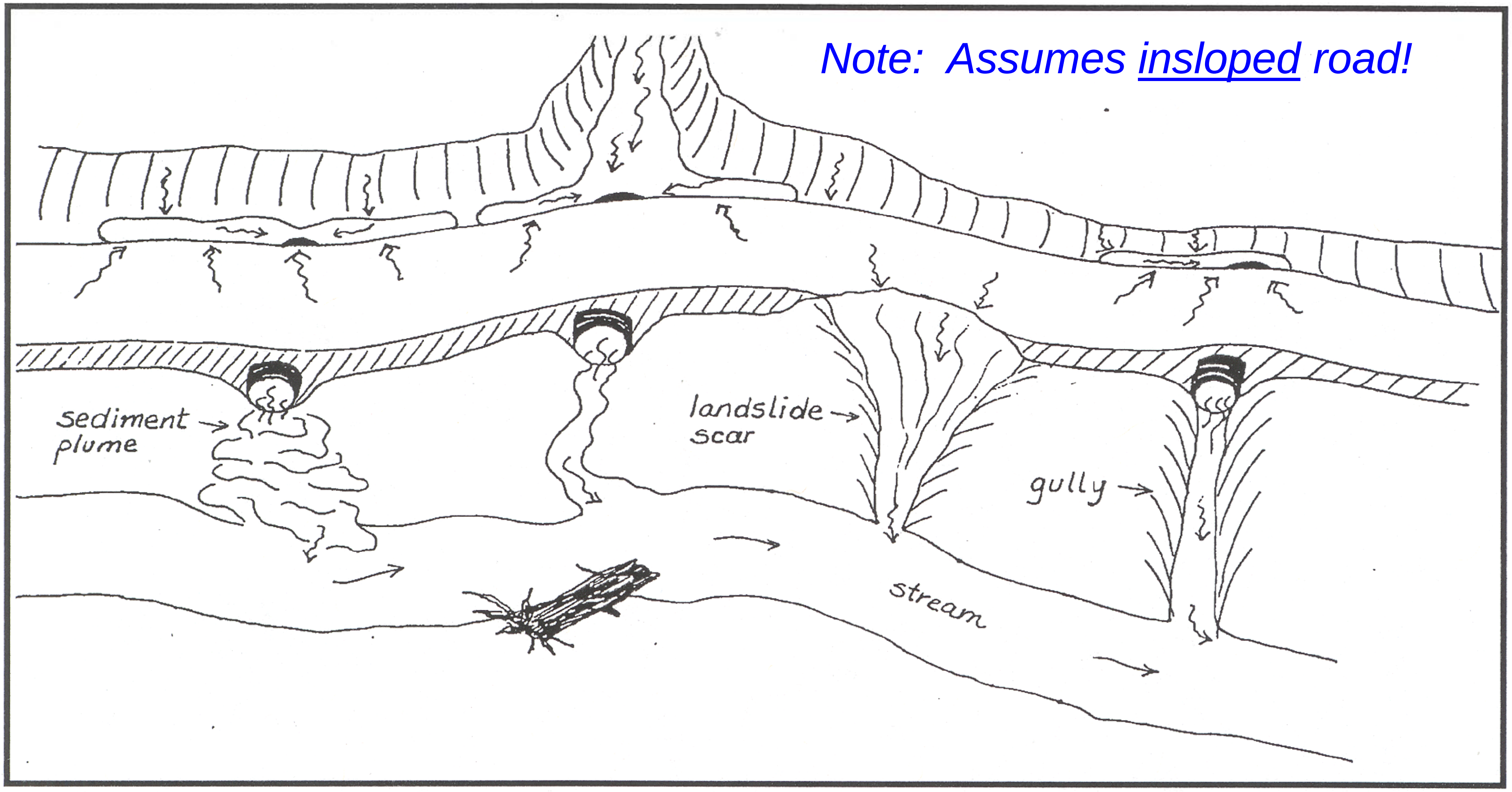


Figure 1-2. How roads can be connected to streams.

Road Effects on Streams

Stream peak flows increased by

- *Runoff from compacted road surface, cutslope, fillslope.*
- *Interception of shallow groundwater by cutslope.*

*How subsurface water comes off hillslopes***

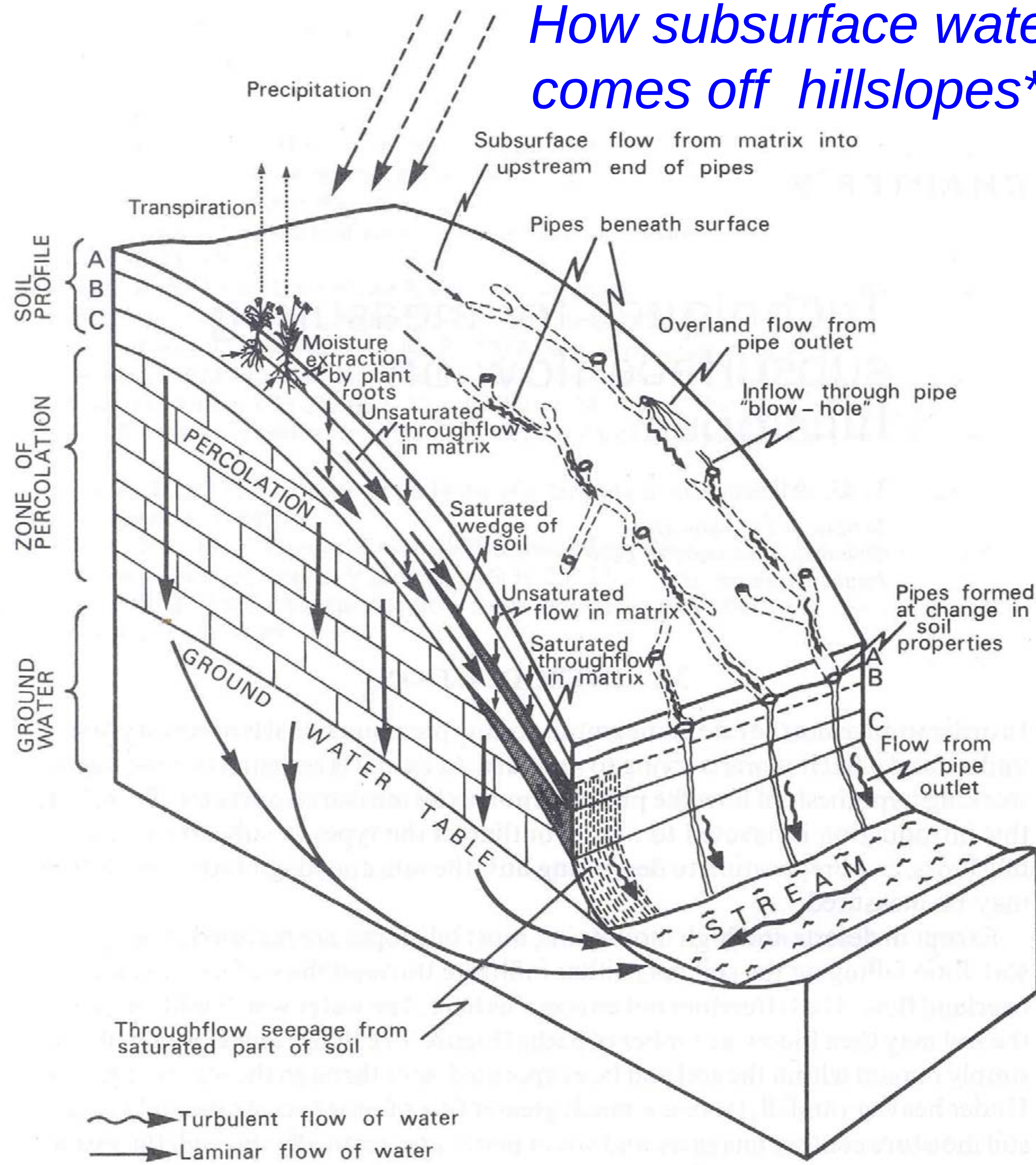


Figure 3.1 Flow routes followed by subsurface runoff on hillslopes

Atkinson, 1978

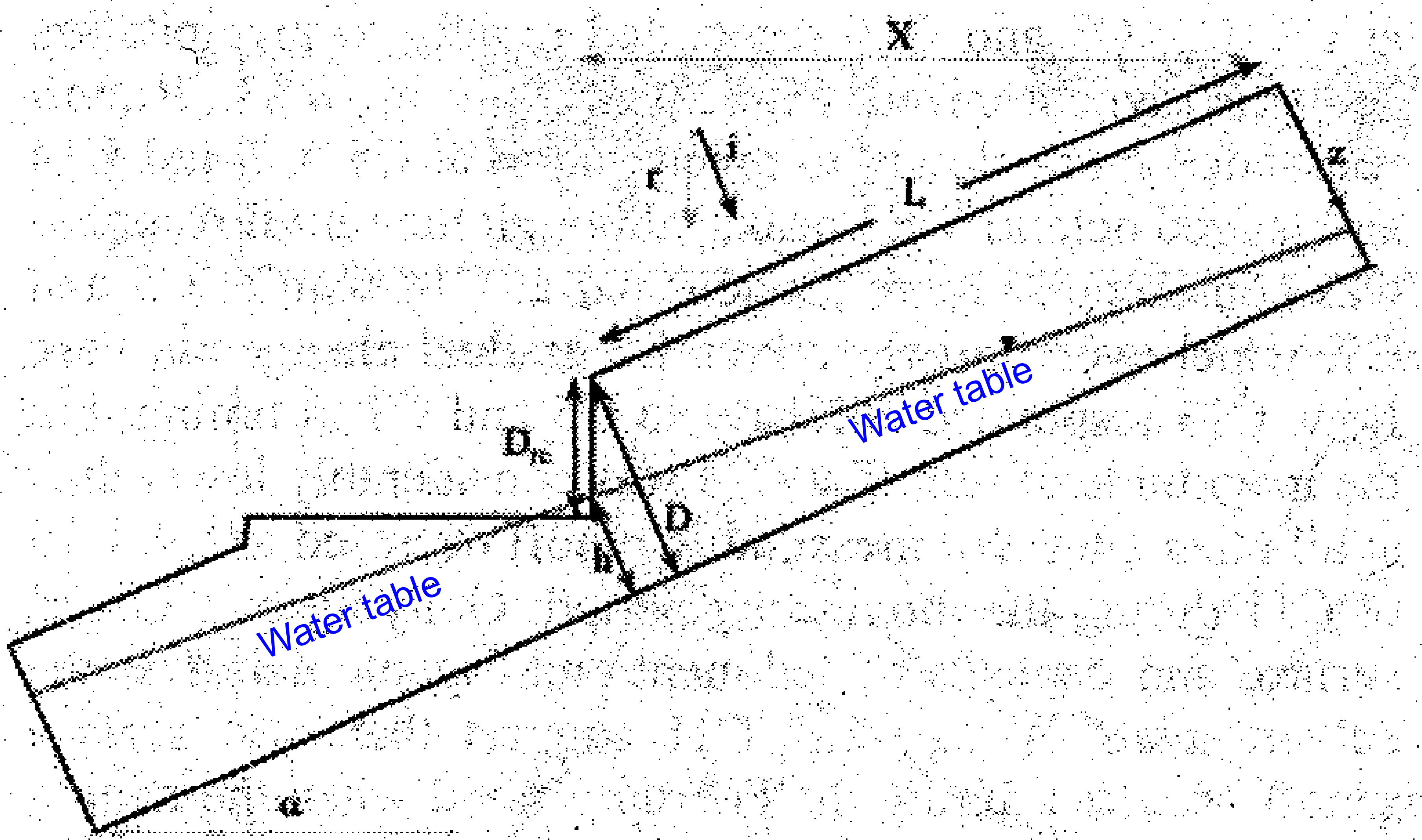
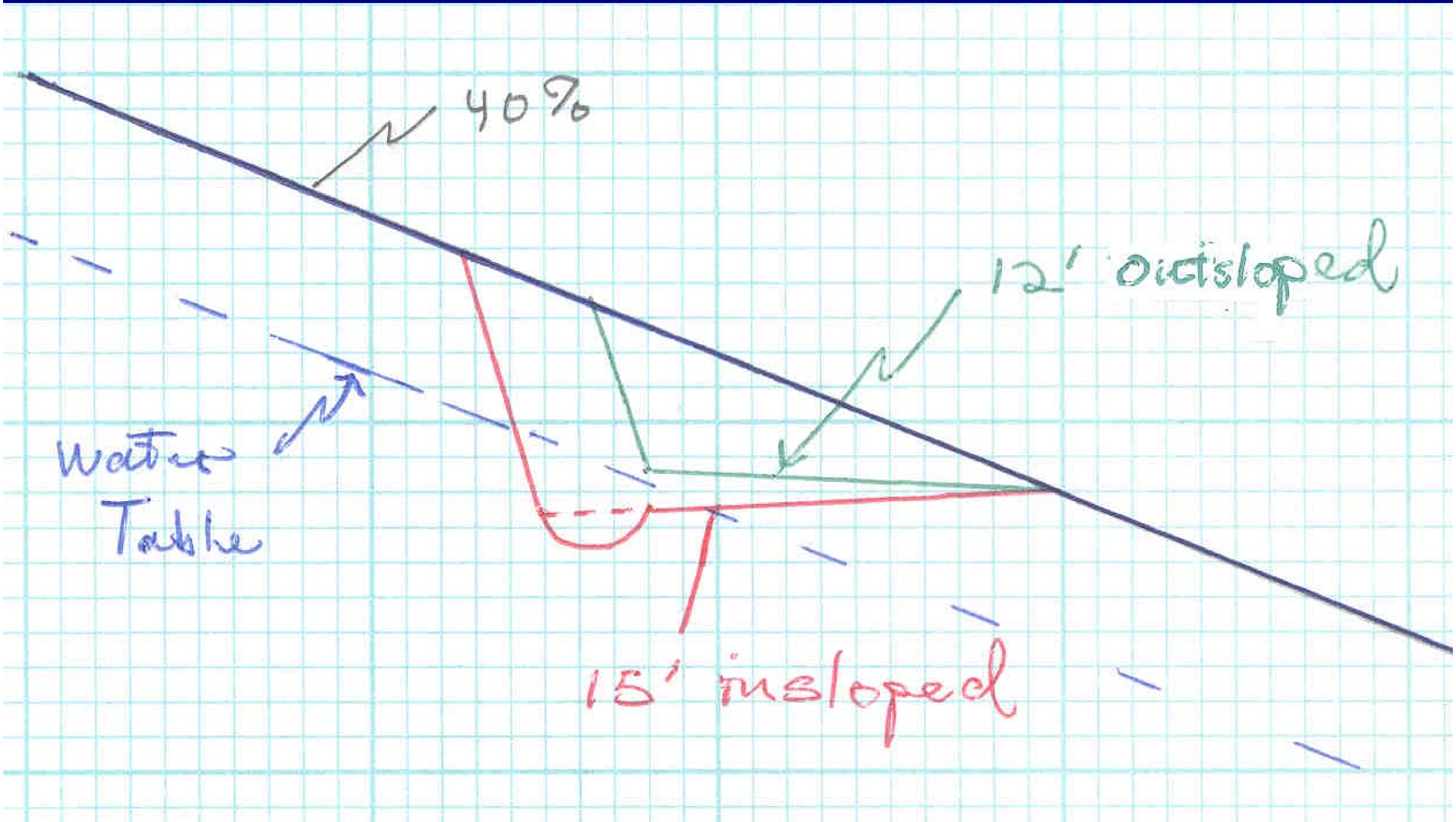


Figure 3. Schematic diagram illustrating the interaction of the hillslope water table with the road cut and parameters used in calculations.

Road Effects on Streams

- Interception of shallow groundwater minimized by:
  - Smaller road width
  - Outsloping
    - Eliminates inner ditch,
    - Narrows the road width
    - Raises inside edge of road

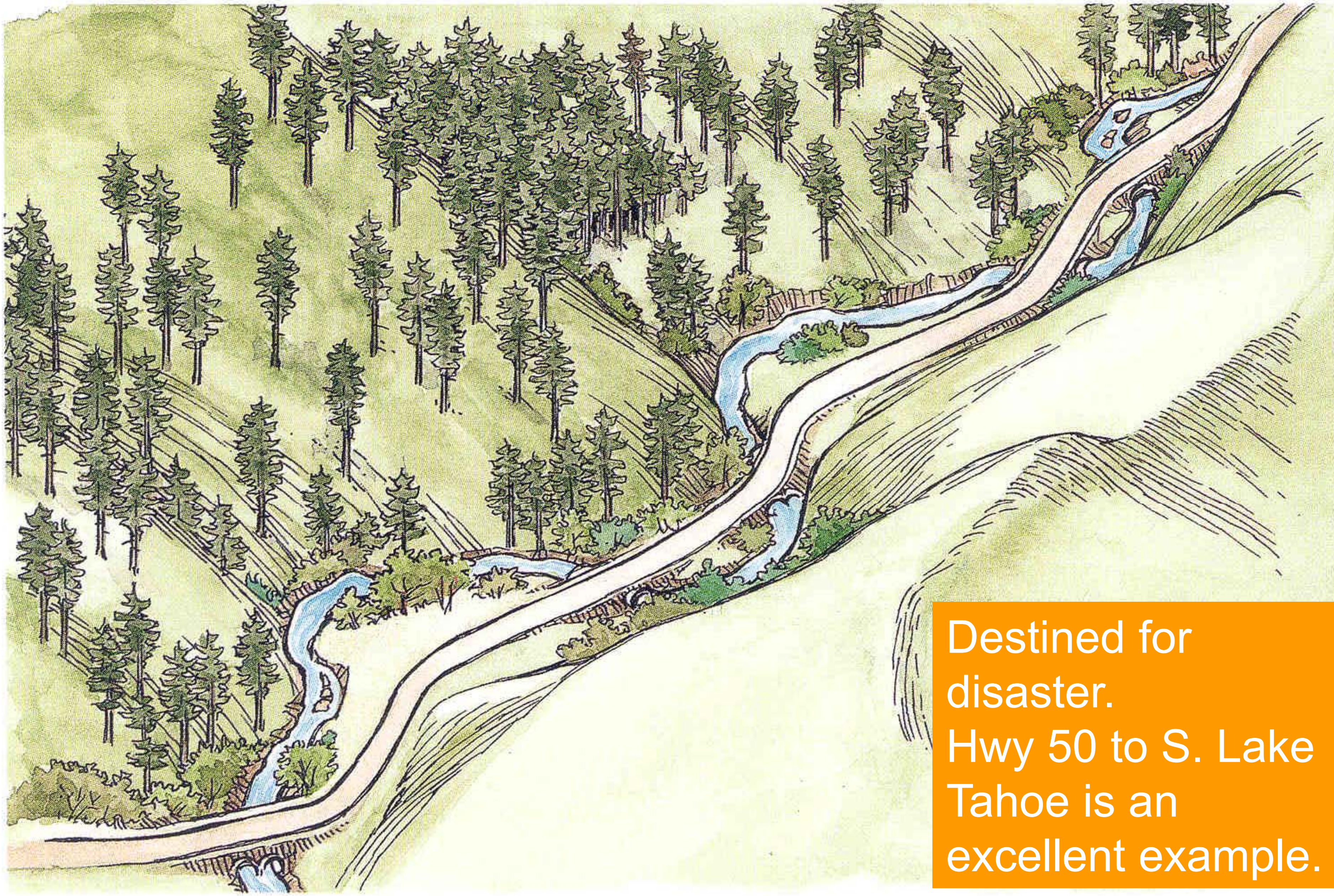

40%
12' outsloped
Water Table
15' insloped

Stream Effects on Roads

- Inner gorges along streams
  - Unstable
  - Poor location for roads (unstable, too close to stream)
- Road located near valley bottom must cross tributary streams.
- Lateral erosion may erode roadway if located close to stream.

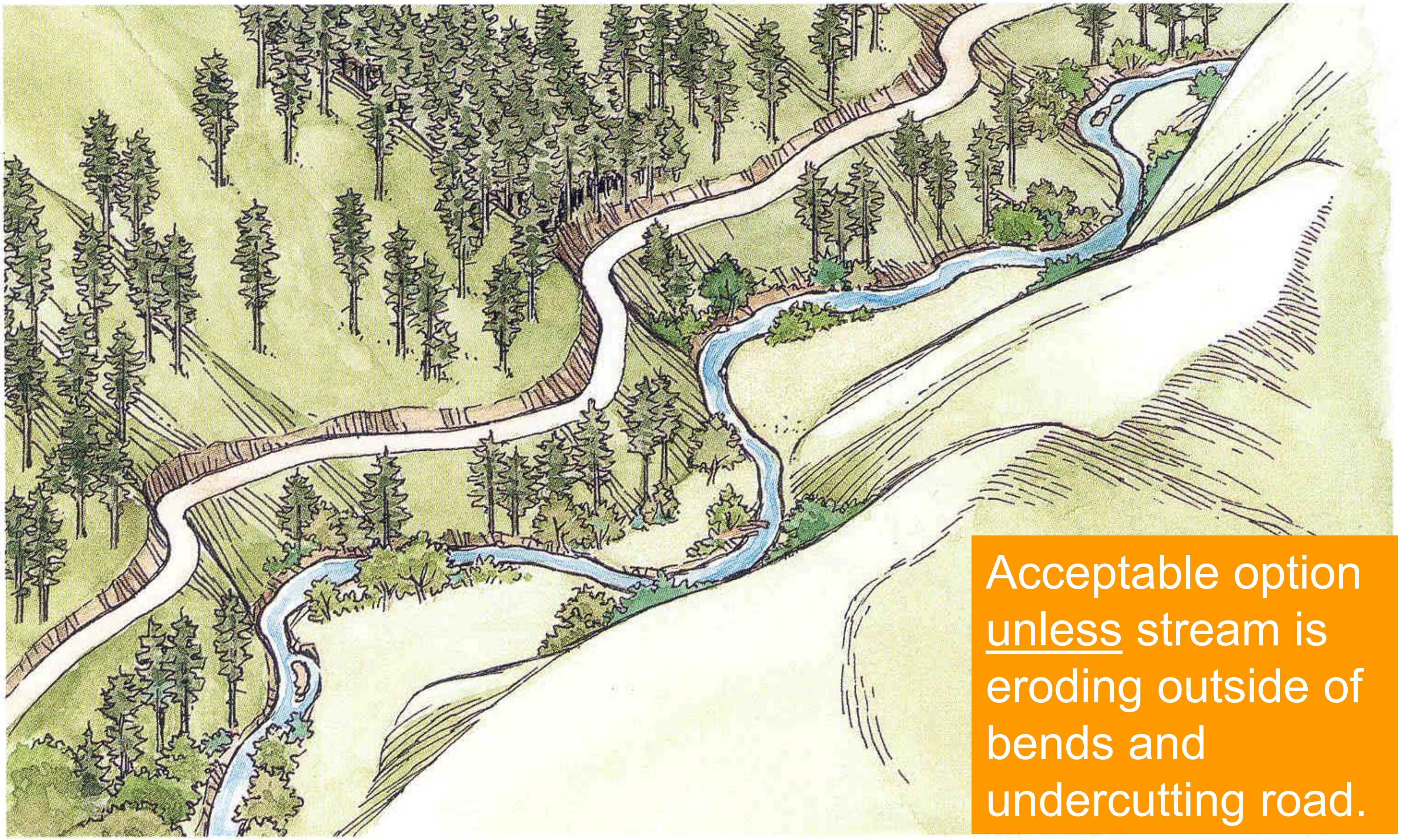
Keep roads away from streams!


Inner Gorge



Destined for disaster. Hwy 50 to S. Lake Tahoe is an excellent example.

Oregon Forest Resources Institute, 2002



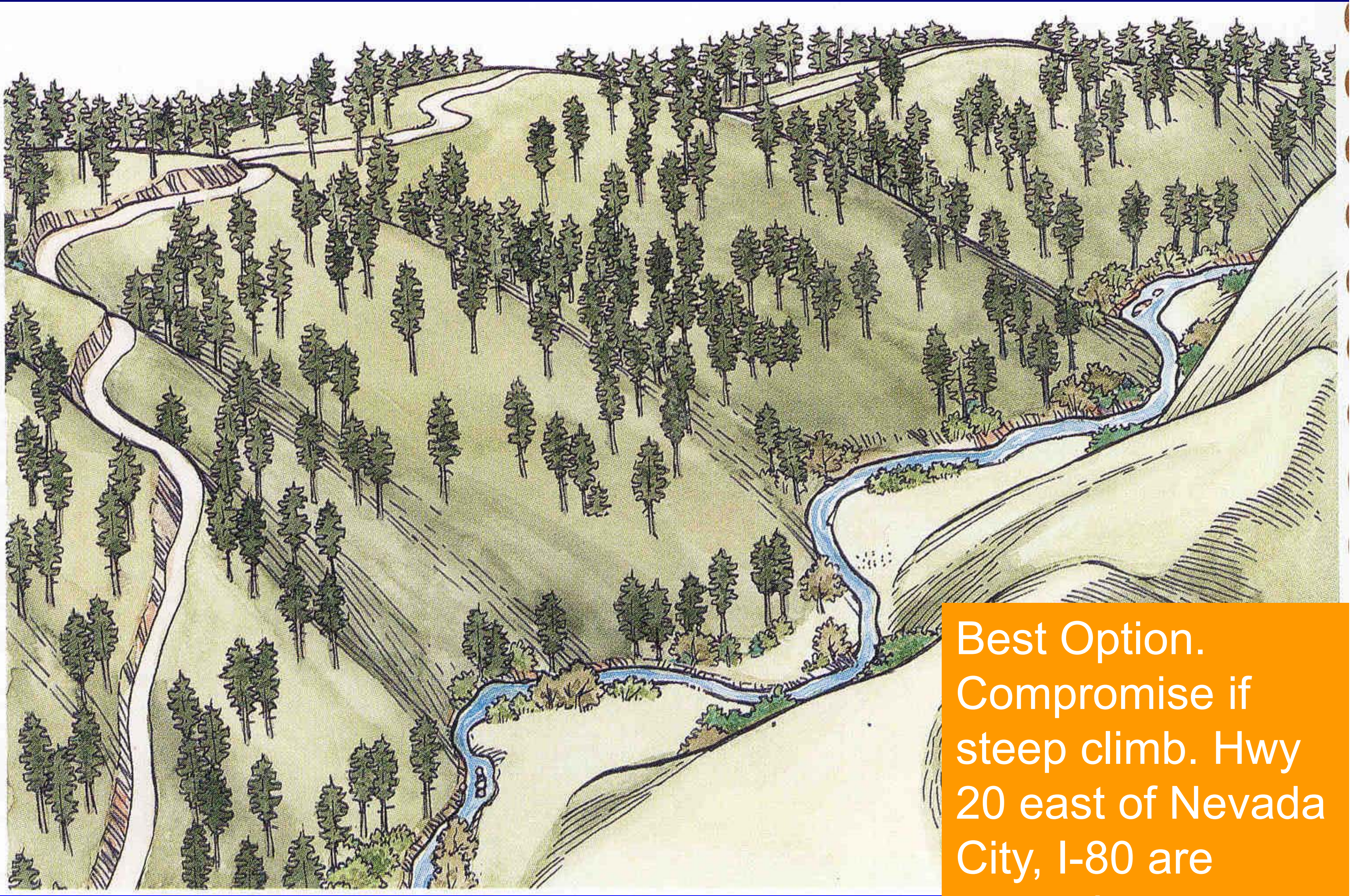
Acceptable option unless stream is eroding outside of bends and undercutting road.

Oregon Forest Resources Institute, 2002

Road failure caused by stream undercutting

Stream Effects on Roads

- Best to locate roads up on ridge tops if possible – away from potential adverse effects of the stream.



Best Option. Compromise if steep climb. Hwy 20 east of Nevada City, I-80 are examples.

Oregon Forest Resources Institute, 2002

Stream Effects on Roads

- Crossings *(Pete Cafferata will discuss July 2)*
  - ➢Expensive to install, maintain
  - ➢Failure potential

Best to avoid stream crossings if possible!

Wet Areas

How to Identify –

- Water present on ground surface
- Water-loving plants (horsetail, maple, dogwood, etc.) = hydrophytes
- Green areas when all else is dried up

Wet Areas

Problems –

- Possible surface drainage across road and sediment to streams
- Seepage into road prism

(Don Lindsay will address road drainage July 2)

- Soft soils and road substrate

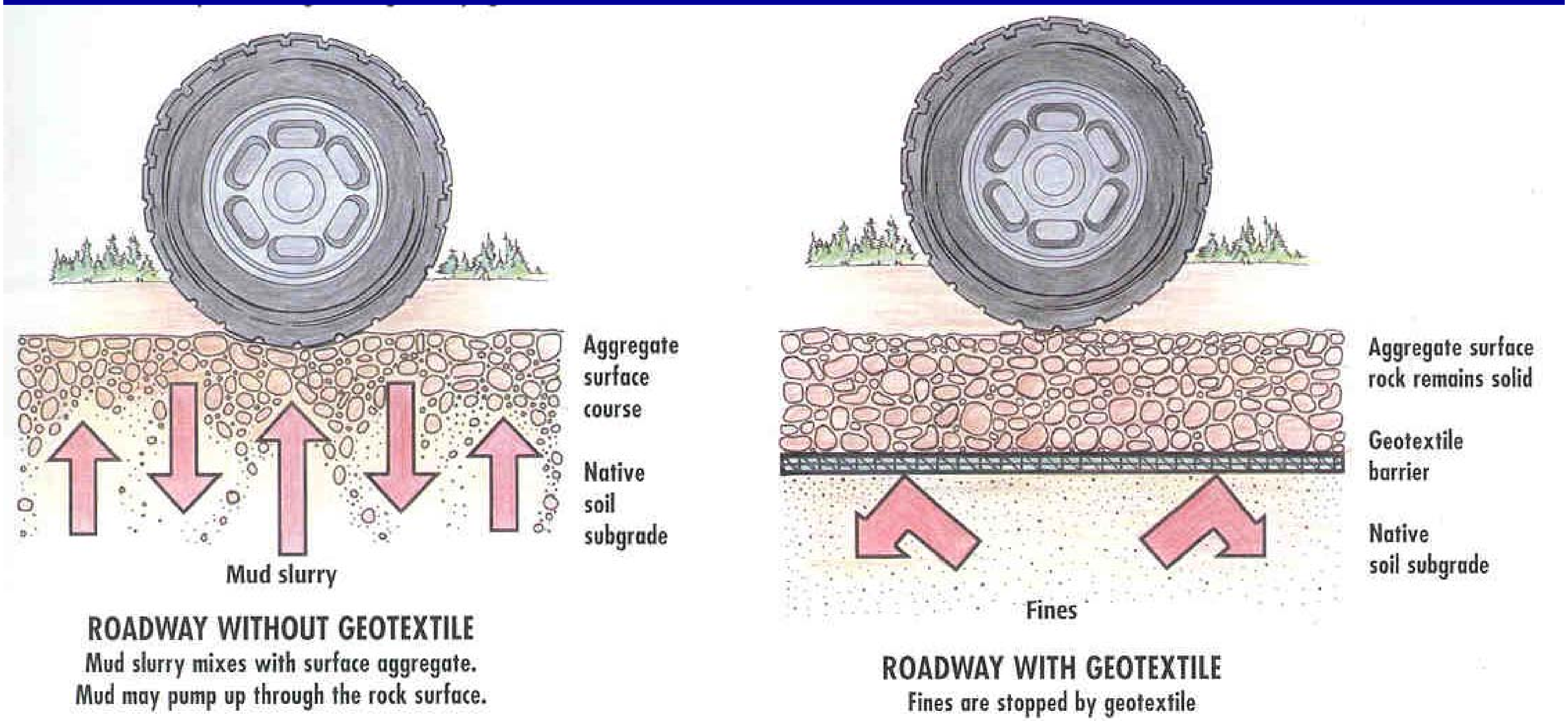
Results in rutting

Wet Areas

Mitigations –

- Avoid wet areas if possible
- Drain wet areas *(Don Lindsay will address July 2)*
- Use Geotextile as a separator on soft soils

Use Geotextile as a separator

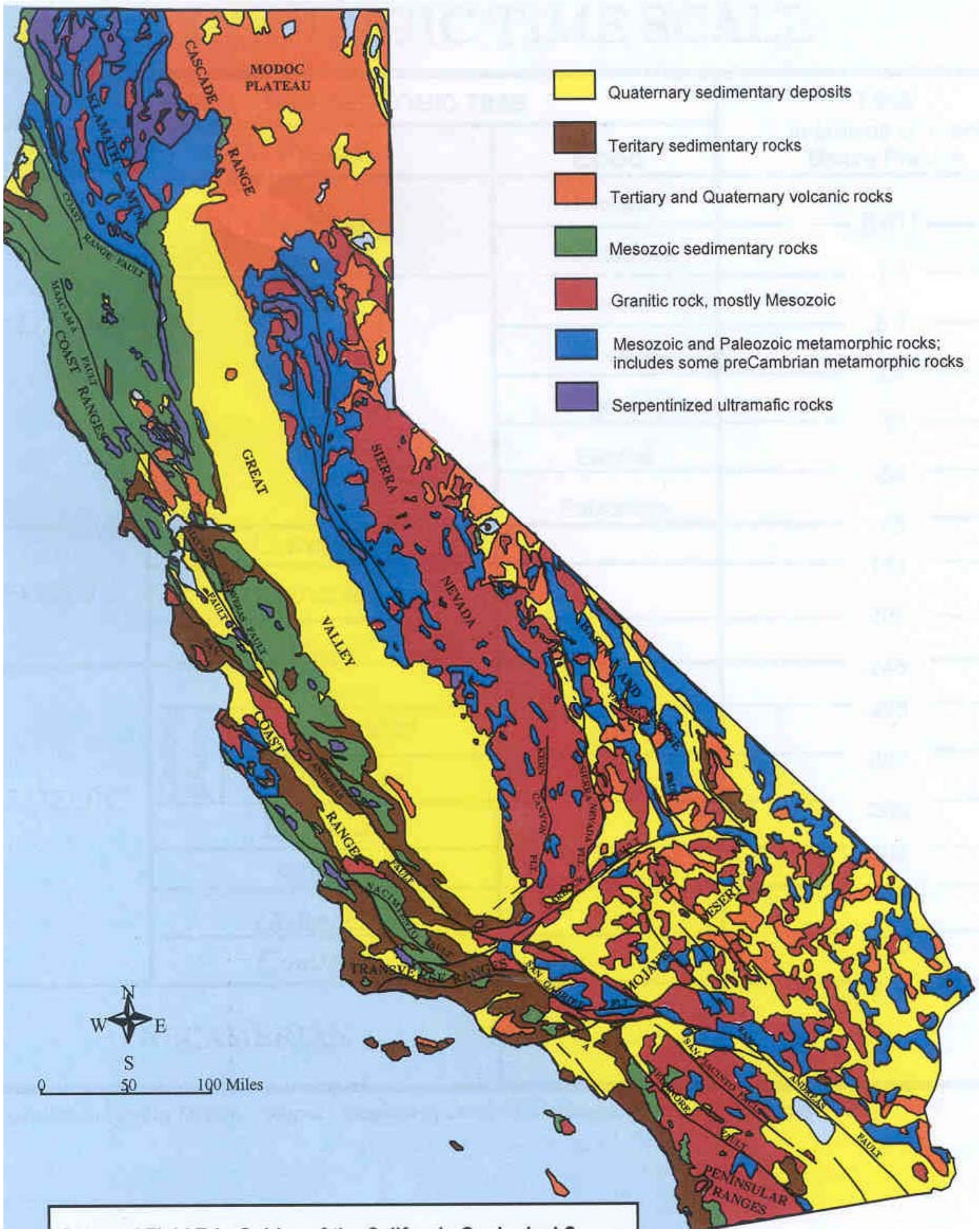


Geotextiles are used to reinforce subgrades by spreading the load over a larger area. This reduces the chance of settling and failure. It also allows road construction over wet areas, reducing the need to remove unsuitable roadbed material.

Questions?

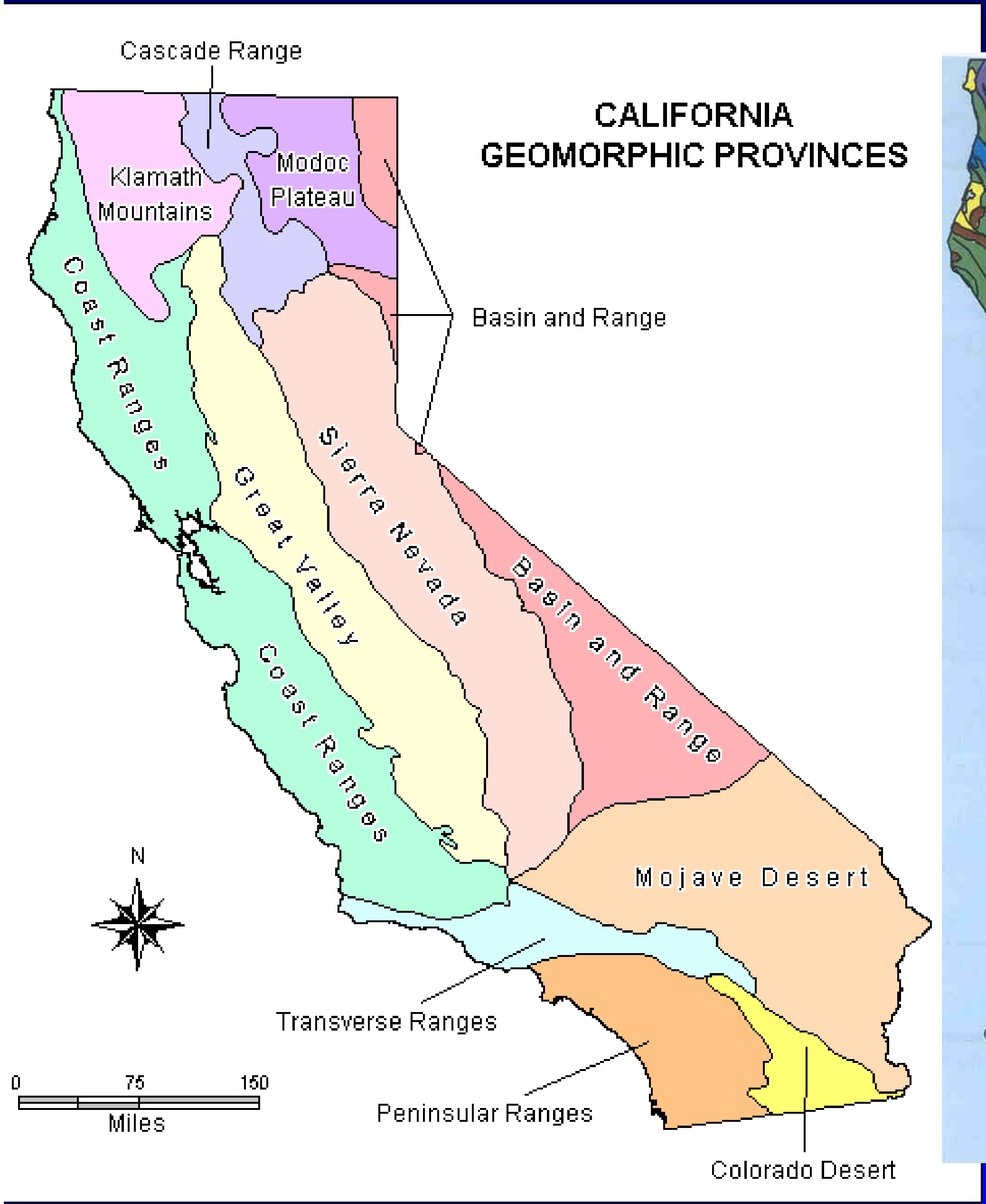
Geology

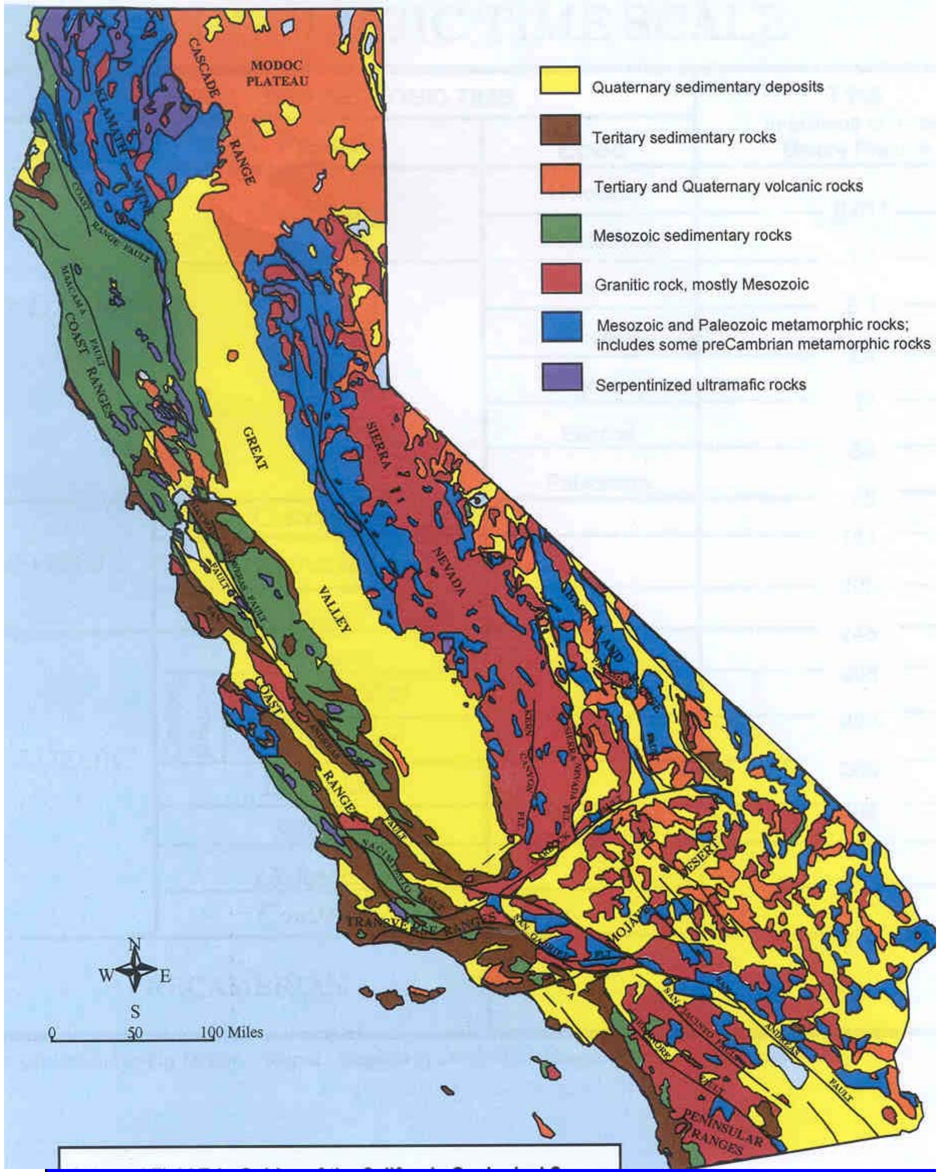
- Geology of California
- Road problems resulting from geology



Geologic Time Scale	
Era or Period	**Age** *(Millions of Years Before Present (Ma])*
Quaternary	Present day to 1.6 Ma
Tertiary	1.6 Ma to 65 Ma
Mesozoic	65 Ma to 245 Ma
Paleozoic	245 to 570 Ma
Precambrian	Older than 570 Ma

Generalized Geologic Map of California


CALIFORNIA
GEOMORPHIC PROVINCES
Cascade Range
Klamath Mountains
Modoc Plateau
Basin and Range
Coast Ranges
Great Valley
Sierra Nevada
Basin and Range
Coast Ranges
Mojave Desert
Transverse Ranges
Peninsular Ranges
Colorado Desert
N
0
75
150
Miles


Quaternary sedimentary deposits
Teritary sedimentary rocks
Tertiary and Quaternary volcanic rocks
Mesozoic sedimentary rocks
Granitic rock, mostly Mesozoic
Mesozoic and Paleozoic metamorphic rocks; includes some preCambrian metamorphic rocks
Serpentinized ultramafic rocks
MODOC PLATEAU
CASCADE RANGE
GREAT VALLEY
SIERRA NEVADA
N
W
E
S
0
50
100 Miles

- Geologic information available through California Geological Survey (CGS) at :

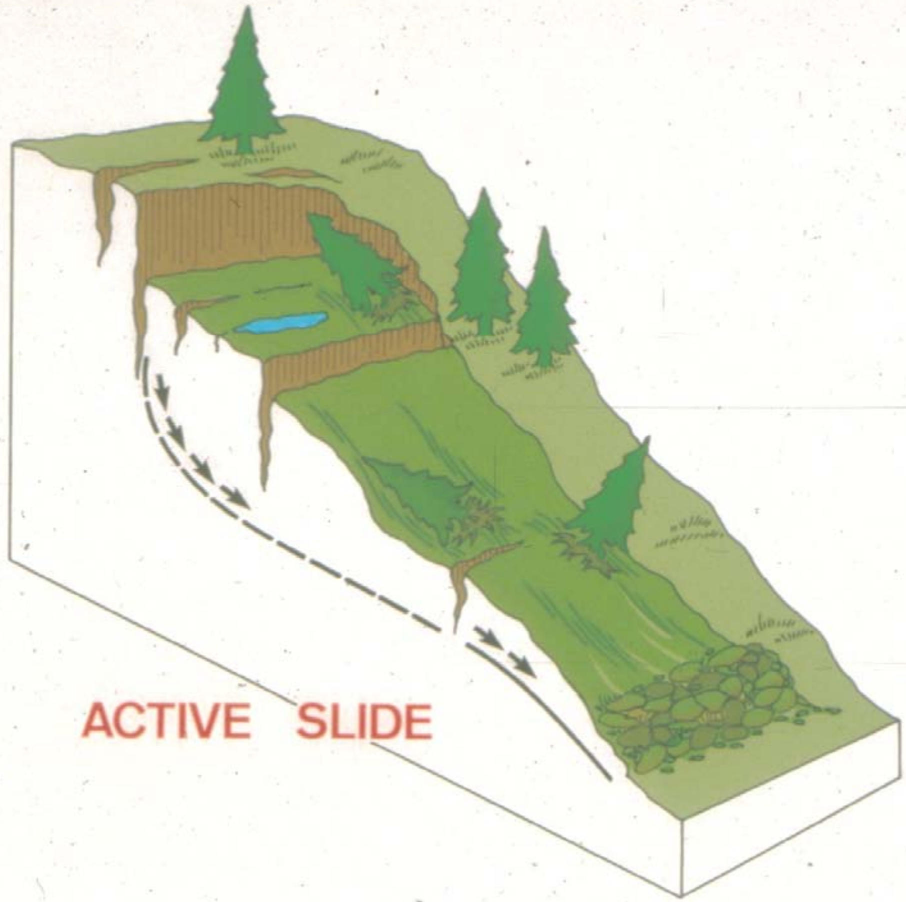
http://www.conservation.ca.gov/CGS/Pages/Index.aspx

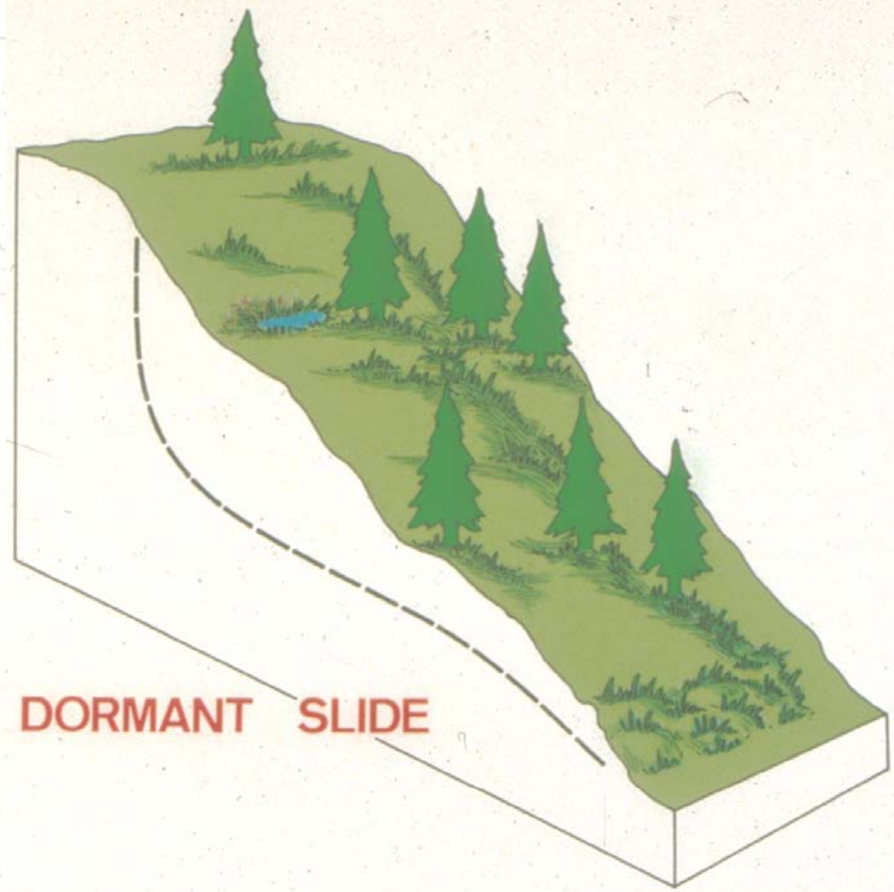
Geology

- Problems resulting from geology
  - Unstable soils (landslides)
  - Rockslides, rock fall
  - Erodible soils (esp. DG soils)
  - Asbestos-bearing rock units

Unstable area characteristics

- Tension cracks and headwall scarps
- Leaning, jackstrawed, or split trees are common
- Trees with excessive sweep
- Evidence of impaired groundwater movement
  - Sag ponds, springs, patches of wet ground, hydrophytic (water-loving) vegetation
- Short irregular surface drainages begin and end on the slope
- Hummocky topography
  - Rolling bumpy ground
  - Frequent topographic benches
  - Frequent closed depressions


ACTIVE SLIDE


DORMANT SLIDE

Arc-shaped cracks in sidecast fill are evidence of a landslide starting to move

Geology

- Unstable areas
  - Types of slides
    - Deep-seated (rotational) *(cohesive, clay-rich soils)*

      Relatively thick slide body (often includes bedrock)

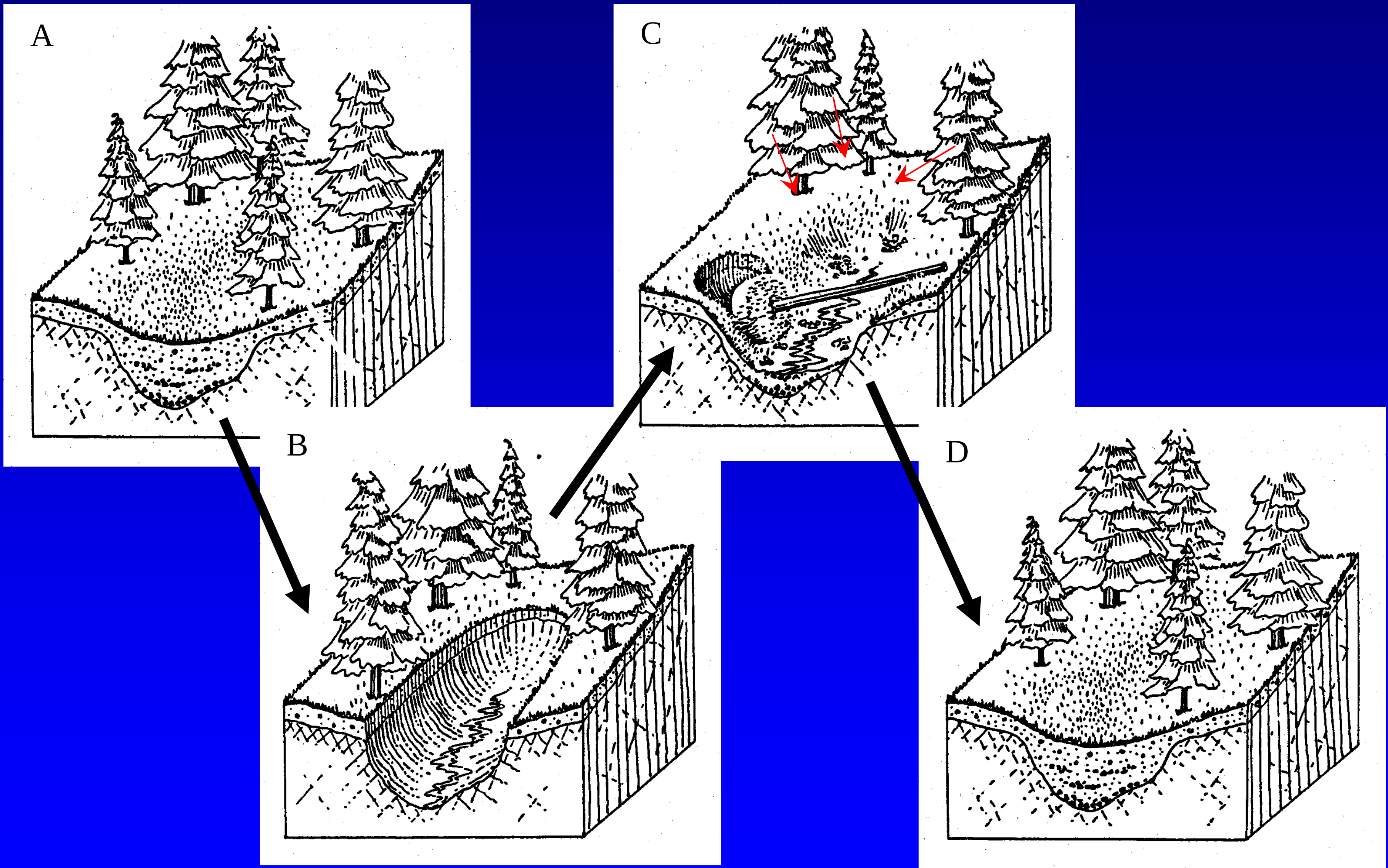
    - Shallow-seated (debris slides, flows, torrents) *(non-cohesive, clay-poor soils)*

      Relatively thin slide body (usually only regolith over bedrock)

Deep-Seated Landslide

Shallow-Seated Landslide

Colluvial Hollows



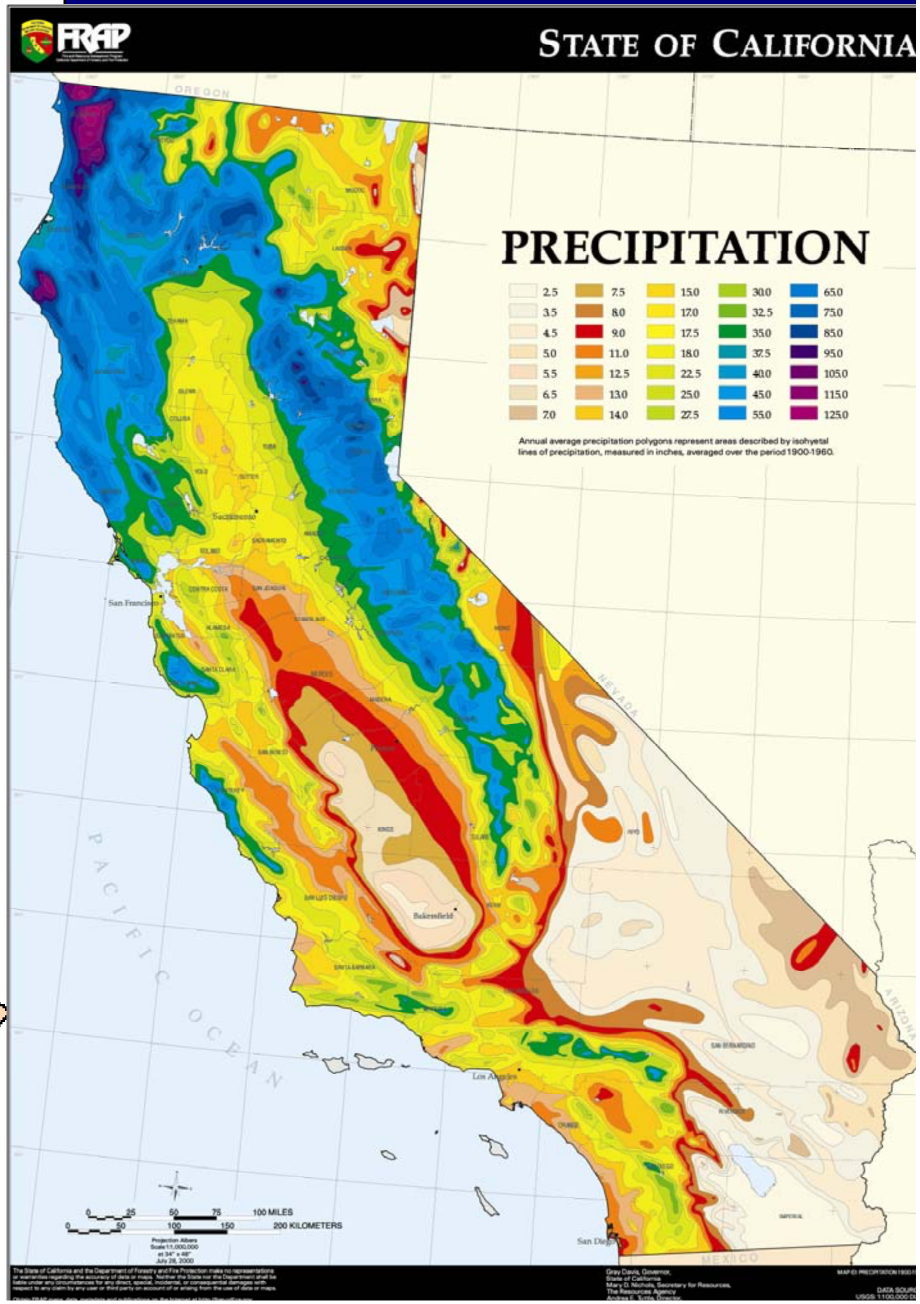
Geology

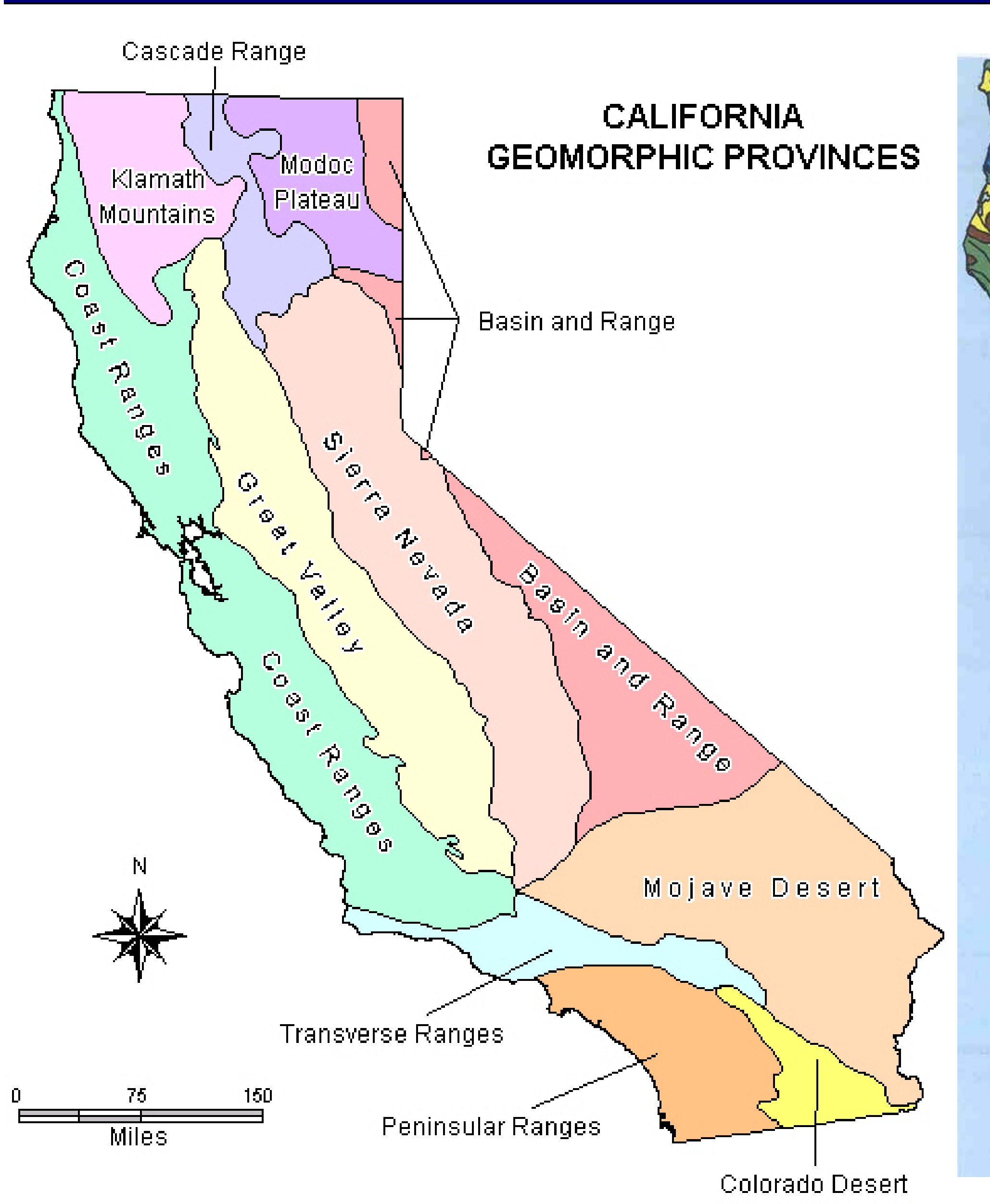
- Unstable areas – typically associated with:
  - Steep slopes – result from
    - Tectonic uplift (mountain-building),
    - Subsequent erosion and valley incision
  - Water
    - weakens substrate
    - reduces slide-resisting forces thru buoyancy effects

Geology

- Unstable areas associated with:
  - Certain Rock types and associations:
    - Clays, and rocks that weather to clay
    - Colluvium in hollows; poorly consolidated rocks
    - Slippery rocks (phyllites, mica schists, serpentinite)
    - High-permeability rocks over low-permeability rocks
    - Fault zones (weak, sheared, often clay-like rocks, permeability difference)
  - Bad areas
    - Areas of groundwater convergence (bottom of swales)
    - Areas of groundwater discharge, esp. at toes of slopes (e.g., inner gorges of streams)

Water is important!!

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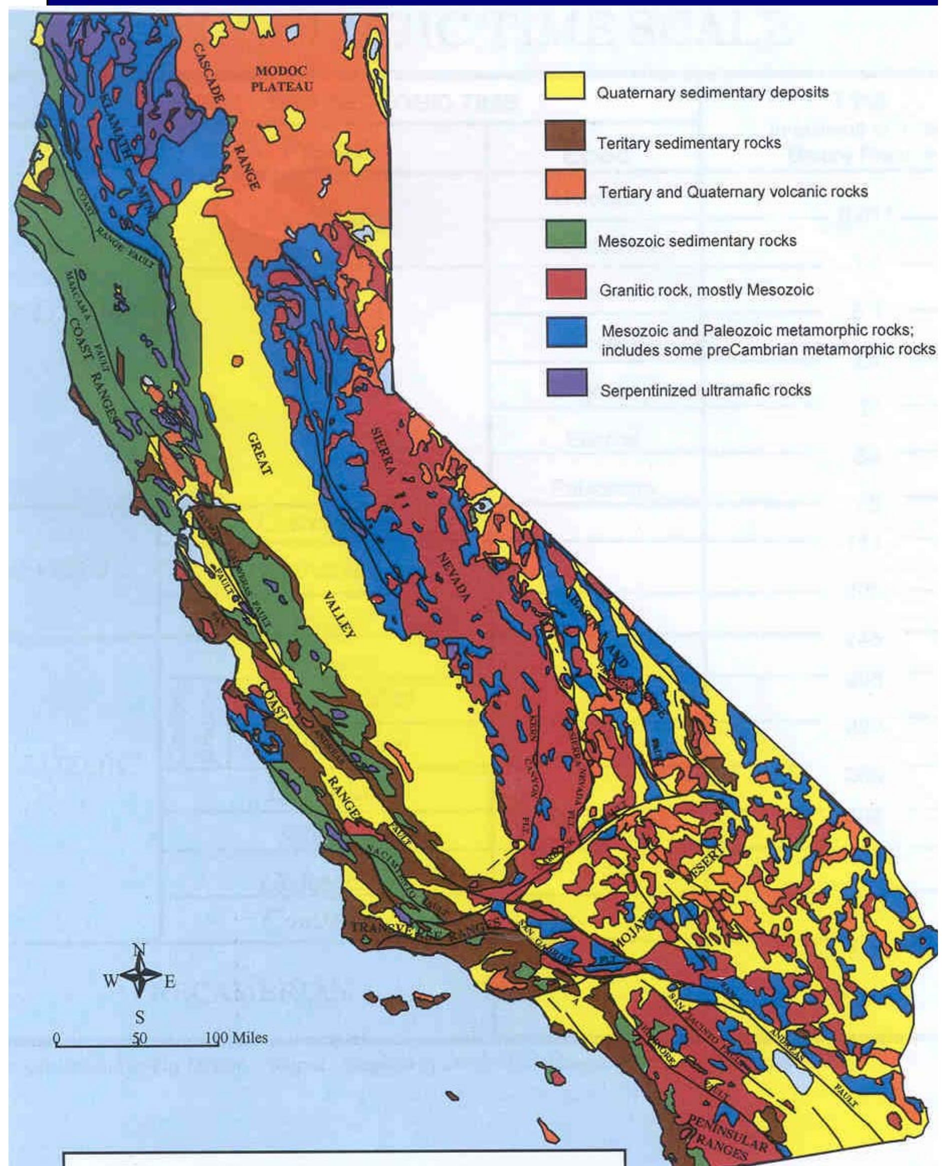
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PENINSULAR RANGES
N
W
E
S
0
50
100 Miles

Geology

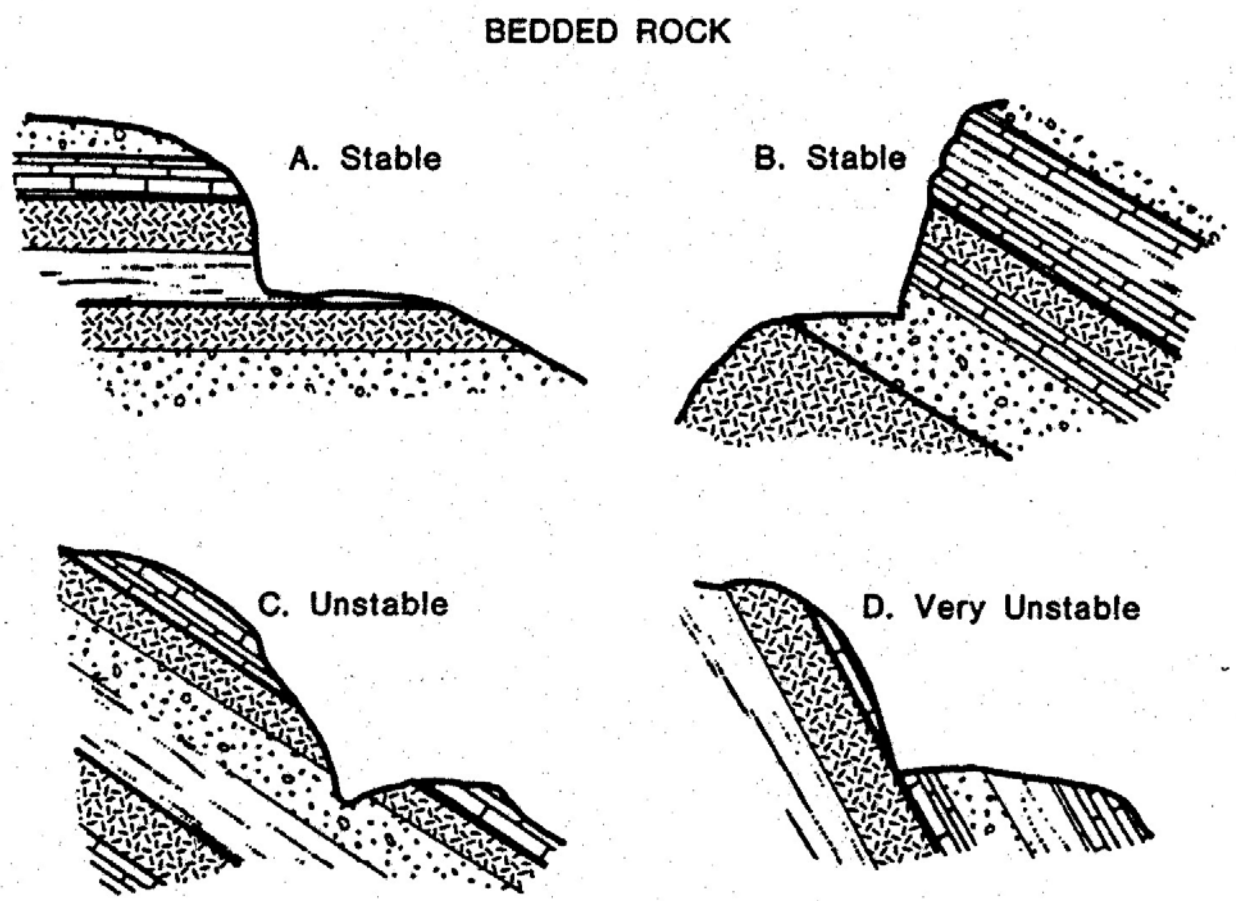
- Examples of rocks in California associated w unstable areas
  - <u>Young, relatively unconsolidated rocks</u>
    - Colluvium *(esp. in hollows)*
    - Young sedimentary rocks on steep slopes
  - Melange rocks *(melange = French for "mixture")*
    - Franciscan Formation in Coast Ranges
    - Rattlesnake Creek Terrane in Klamath Mountains
  - Ultramafic rocks (typically serpentinized) and serpentinite *(purple on geologic map)*
  - Mica schists (Klamath Mtns)
  - Volcanic mudflow cap over less permeable granitic and metamorphic bedrock in Sierra

Geology

- Unstable-area mitigation
  - **Avoid if at all possible**
  - Do not:
    - Excavate toe *(reduces slide-resisting forces)*
    - Load head *(increases slide-driving forces)*
    - Concentrate water onto or into the slide

Rock Slides

- Tilted planar features in bedrock
  - Tilted beds
  - Tilted foliation
  - Tilted rock-jointing
- Hazard dependant on <u>rock hardness</u>



Source: Washington State DOE Report # 82-5, Handbook for Forest Roads, November 1982

Geology

- Erodible soils
  - Sandy and silty soils
    (<u>especially</u> decomposed granite [DG] soils)
  - How to identify
    - Field test
    - Soil Survey – available from
      - NRCS – soil surveys on the Internet at: USFS Forest Service

Decomposed granite soils

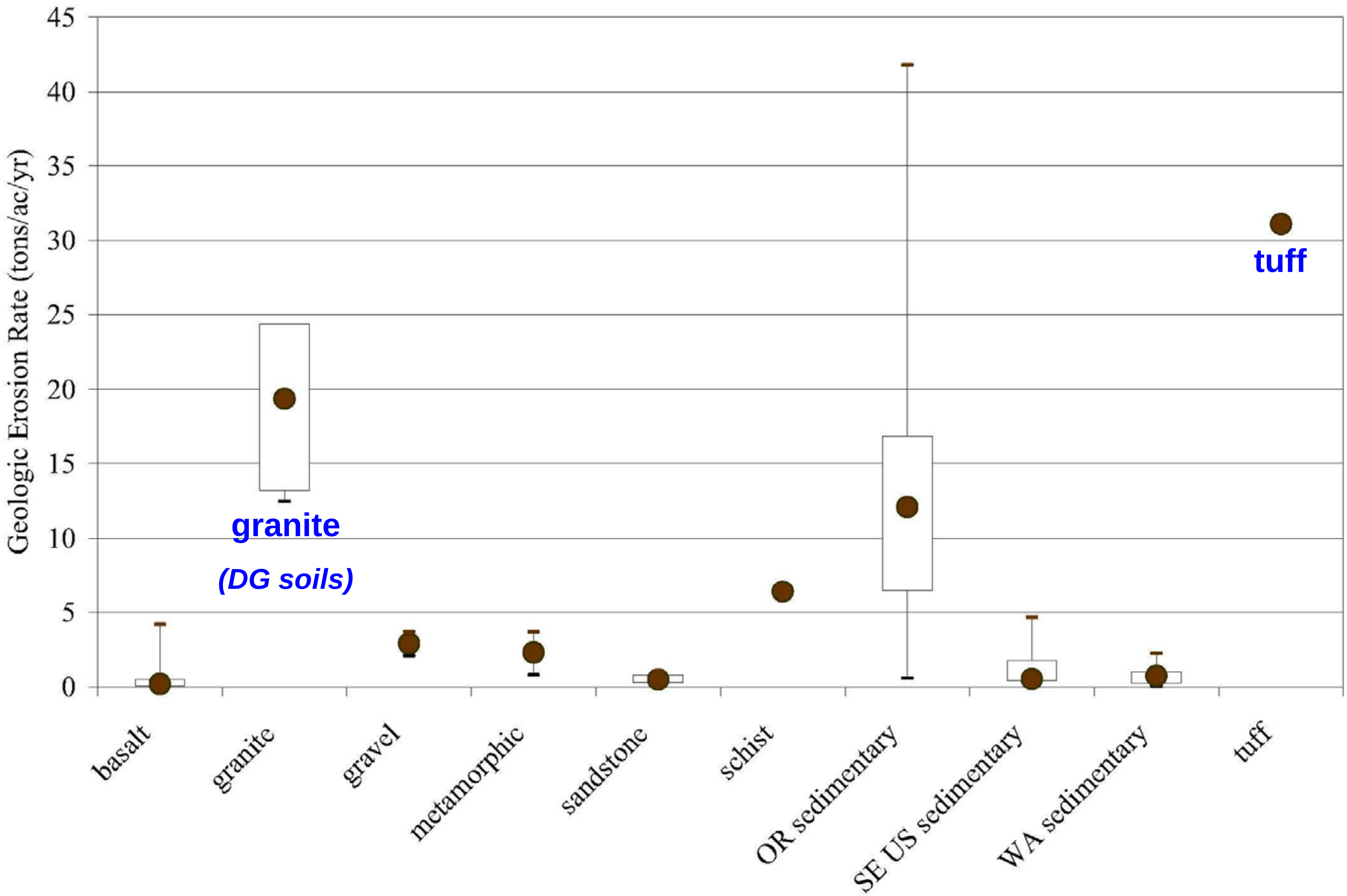
C. The interior of the granite outcrop consists of hard igneous rock, with light-colored feldspar and quartz, and dark biotite.

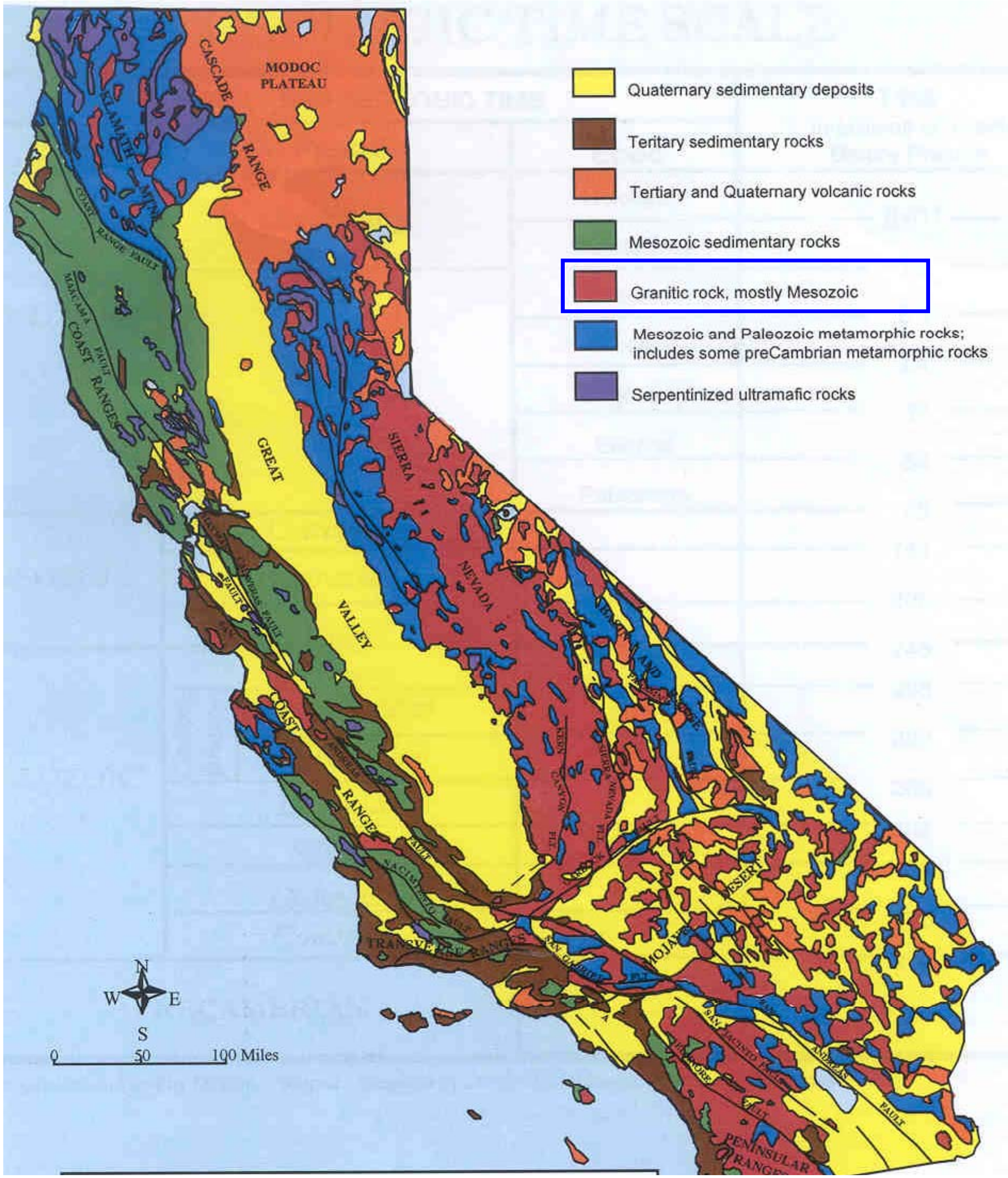
D. The outer part of the outcrop is crumbly granite, notably browner than the interior sample and with less biotite.

E. Fragments that accumulated at the base of the outcrop are almost entirely quartz and feldspar, coated in fine brown dust.

Washington Road Surface Erosion Model *(Dube et al., 2004)*

Figure A-1. Geologic Erosion Rates Calculated from Road Erosion Measurements.





DG soils

- Not so much an issue in High Sierra where soils removed by glaciation
- Larger issue in:
  - Granitic glacial deposits
  - Deeply-weathered non-glaciated granitic rocks

Geology

- Erodible soils
  - Sandy and silty soils *(especially decomposed granite [DG] soils of the Shasta Bally batholith and associated intrusions)*
  - How to identify
    - Field tests for soil textures
    - Soil Survey – available from
      - NRCS – soil surveys on the Internet at: *(http://websoilsurvey.nrcs.usda.gov/app/)*
      - USFS Forest Service

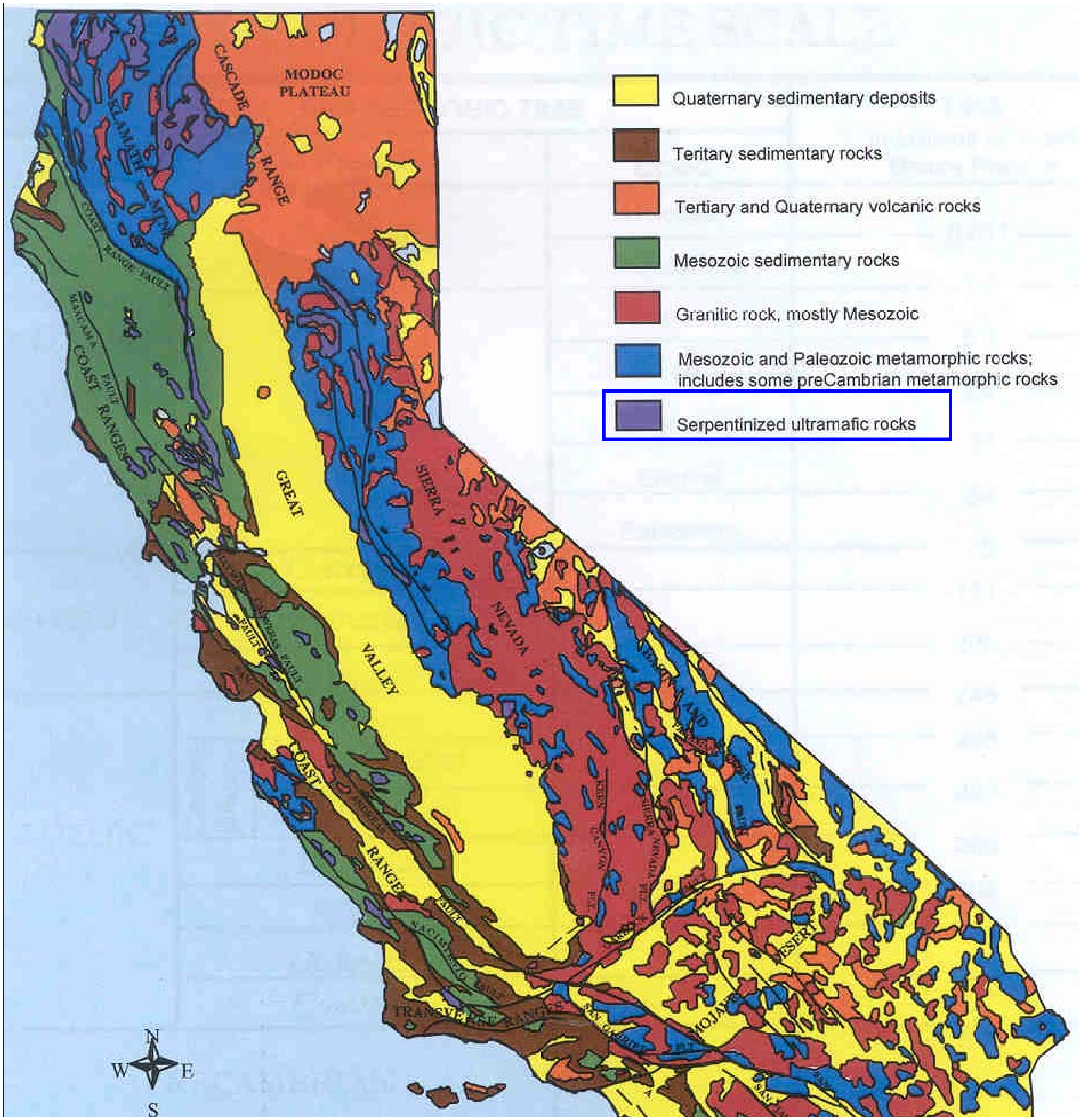
Geology

- Mitigating erodible soils
  - Keep road gradient gentle
  - **Get water off the road!**
    - Outslope the road
    - Frequent water breaks *(Rolling dips, Waterbars)*
  - **Rock the road!**
  - Avoid draining water over unvegetated cutslopes
  - For DG soils, see CAL FIRE guidance document: ***Recommended Mitigation Measures for Timber Operations in Decomposed Granite Soils***

    Available on the Internet at:
    http://www.fire.ca.gov/resource_mgt/downloads/DGSoilsMits.pdf

Hazardous asbestos dust

- Asbestos-bearing rock units
  (Contain naturally occurring asbestos [NOA])
  - Occur in ultramafic rocks and soils
  - Concerns and effects
  - How to identify
    - Geology maps
    - Rock descriptions
    - See CGS site
      (http://www.conservation.ca.gov/cgs/minerals/hazardous_minerals/asbestos/Pages/Index.aspx)
  - Mitigation
    - Keep soil damp to avoid dust during construction



Ultramafic rocks and asbestos

The End

Questions?

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