Topic 11: Landslides, Mass Movements and Mass Wasting

short videos are test material!

test #3 today, due by midnight
topics 8-10, HW1
late submission not eligible for extra credit

HW#3 due tomorrow
late submissions not eligible for extra/bonus credit

discussion session (TAs): 4 pm York 3030

office hour (Laske): 5 pm Zoom

What is a Mass Movement ?

MASS MOVEMENT
downward movement of mass
✧slope failure
✧collapse of structure beneath

MASS WASTING
more general term including
✧deforestation
✧soil erosion

in U.S.
✧$1.5 B in damages/year
✧25 fatalities/year

compared to earthquakes and volcanoes:
huge anthropogenic component through
- building on unstable ground despite better information
- actually triggering mass movements (at all scales)

Classical Mass Movements – Hong Kong

NATURAL:
- ✧climate
  (HK: humid/sub-tropical; typhoons)
- ✧elevation

HUMAN:
- ✧urban development
- ✧population pressure
- ✧building in unstable environment

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Hong Kong Stacked Apartments in Quarry Bay
source: wikipedia

Understanding Mass Movements- Yungay

31 May 1970 Yungay, Peru
* Nevado Huascaran > 6,400 m
* ice cap
* Mw 7.7 EQ triggered debris/mudflow
* 18,000 fatalities
* recurring hazard (1962: 4,000)!!

NATURAL:
✧climate
✧elevation
✧plate tectonics/EQs

HUMAN:
✧building in unstable environment

Understanding Mass Movements

22 September 2013
* Hurricane Ingrid/Gulf of Mexico
* Hurricane Manuel/East Pacific
* mudslides in Guerrero
-> more than 190 fatalities

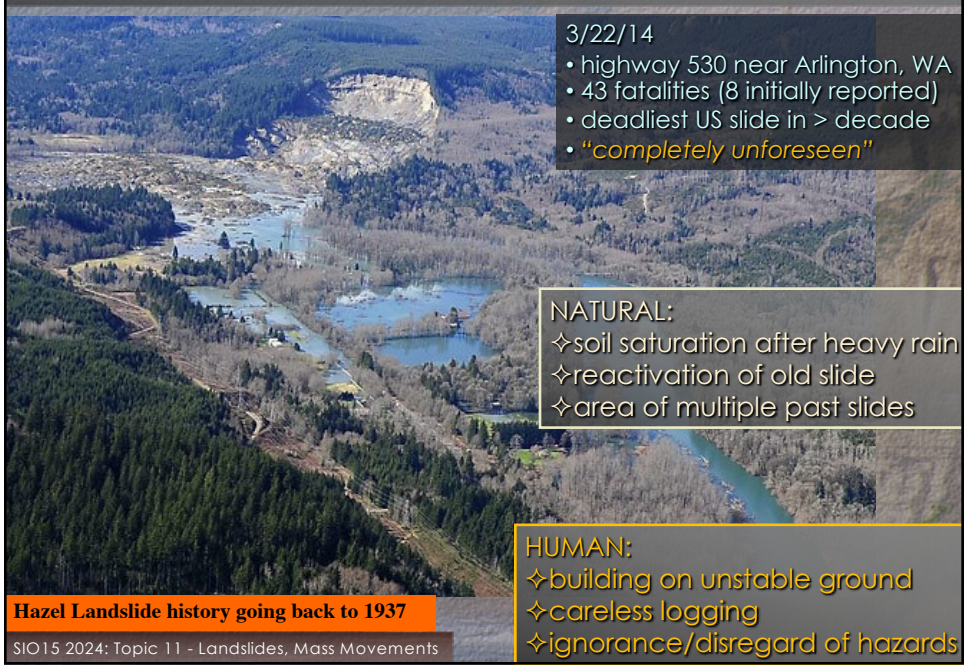
NATURAL:
✧climate
heavy rain from hurricane

source: CNN

Hurricane Manuel hits Mexico

HUMAN:
✧little warning in remote areas
✧tourism in Acapulco affected (10 years before Hurricane Otis)

Mass Movements 2014: the Oso Mudslide



3/22/14
- highway 530 near Arlington, WA
- 43 fatalities (8 initially reported)
- deadliest US slide in > decade
- *"completely unforeseen"*

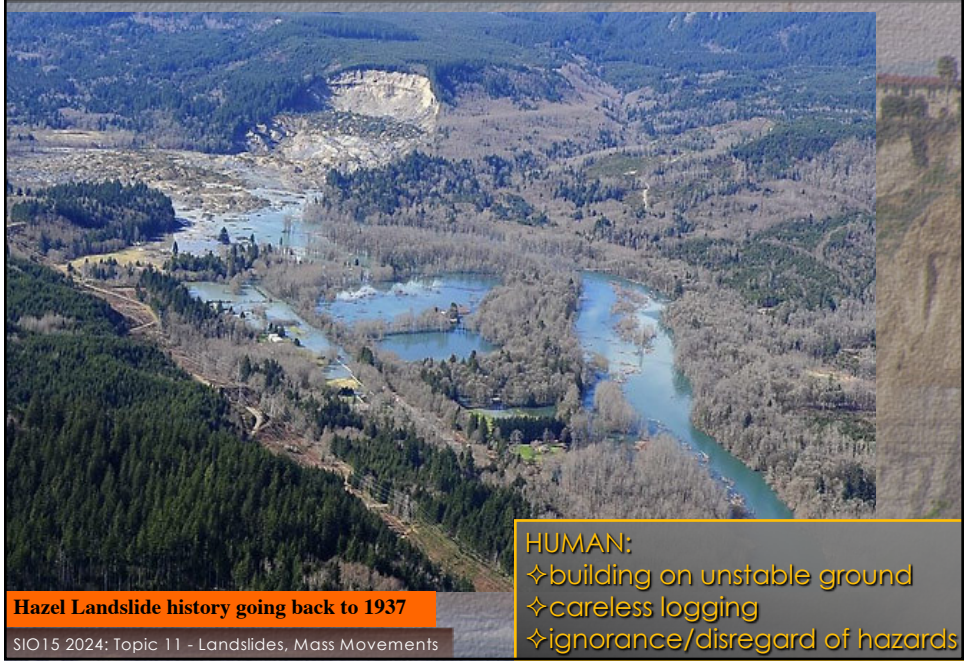
NATURAL:
- ✧soil saturation after heavy rain
- ✧reactivation of old slide
- ✧area of multiple past slides

HUMAN:
- ✧building on unstable ground
- ✧careless logging
- ✧ignorance/disregard of hazards

Hazel Landslide history going back to 1937

SIO15 2024: Topic 11 - Landslides, Mass Movements

Mass Movements 2014: the Oso Mudslide



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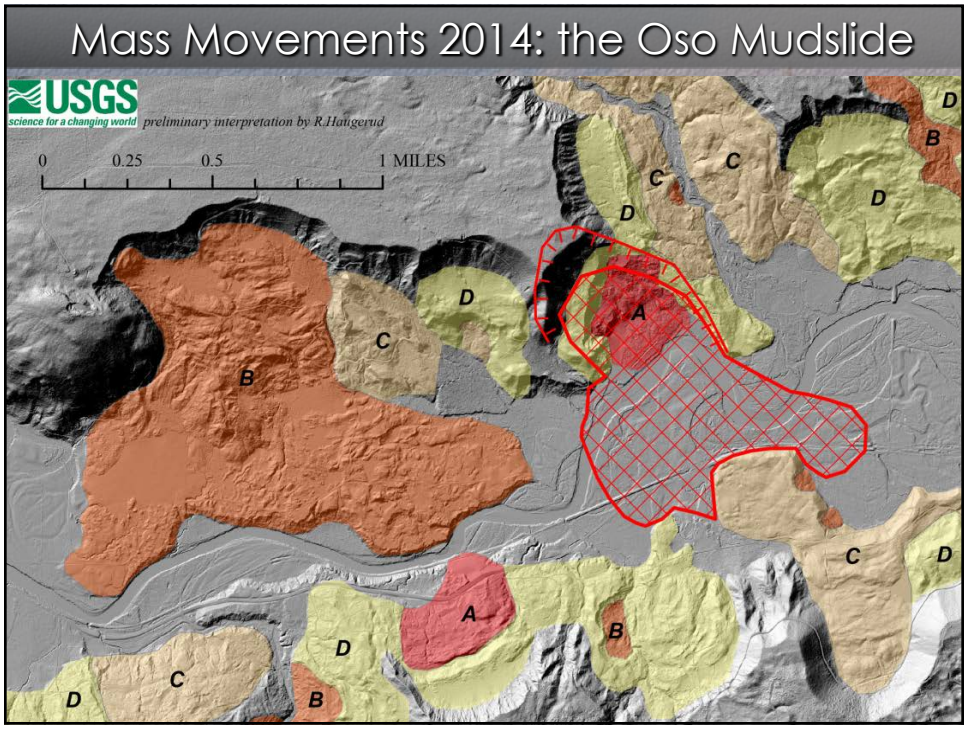
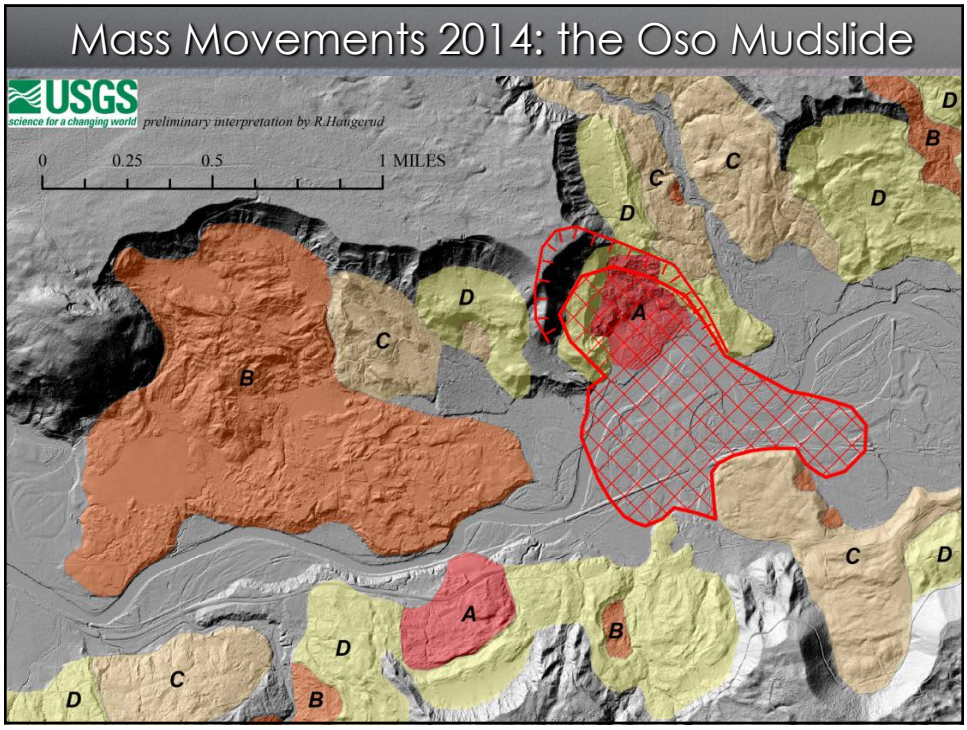

Mass Movements 2014: the Oso Mudslide
USGS
science for a changing world
preliminary interpretation by R.Haugerud
0 0.25 0.5 1 MILES
A
B
C
D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A
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C
D

9 Jan, 2018 – Montecito/Santa Barbara

second-deadliest US mass movement in modern times

source: Wikipedia

12/4 2017 – 1/12/2018 Thomas fire
282,000 acres burned (largest in modern Cali history, until Aug 2018)
21 fatalities from mudflow Jan 2018

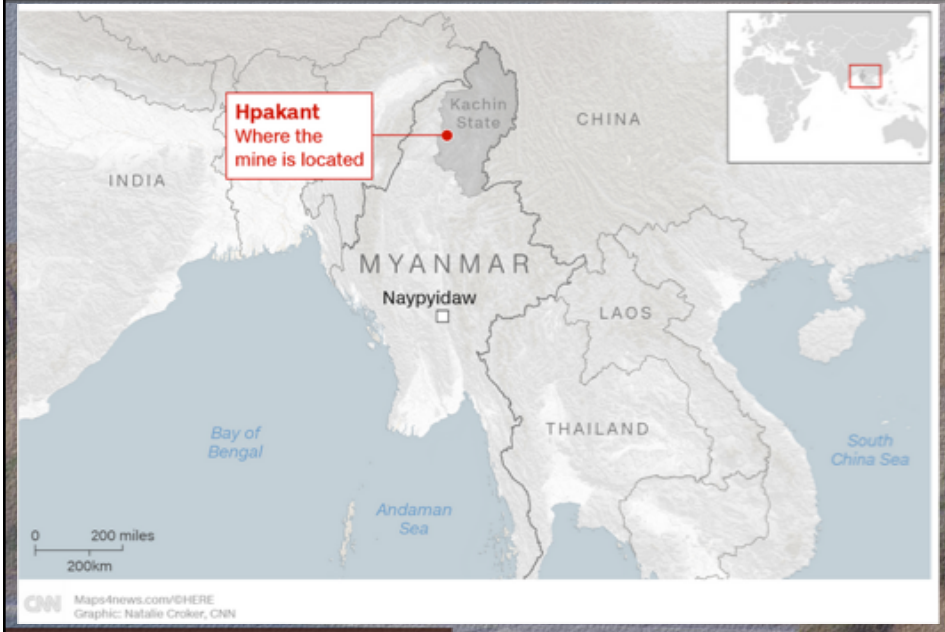
Recent Deadly Mass Movements

Date	Name	# Fatalities	Comment
30 Jul 2024	Wayanad,Kerala, India	443+	multiple slides in Wayanad district
24 May 2024	Enga, Papua N.G.	160-2000	buried 6 villages
6 Feb 2024	Maco, Philippines	92	after heavy rain
22 Jan 2024	Liangshui, China	44	steep clifftop
20 Nov 2023	Wrangell, AK	6	slide buried a family
16 Dec 2022	Batang Kali, Malaysia	31	unlicensed campsites in high-risk area
26 Nov 2022	Ischia, Italy	12	after heavy rain
23 Nov 2022	Palmeira de Faro, Portugal	2	after excavation of unstable rock
29 Oct 2022	Maguindanao, Philippines	63	Tropical Storm Nalgae
30 Jun 2022	Manipur, India	58	
15 Feb 2022	Petropolis, Brazil	231	
3 Jul 2021	Atami, Japan	27	after heavy rain
30 Dec 2020	Gjerdrum, Norway	10	in 'high-risk' zone
7 Aug 2020	Pettimudi, Kerala, India	66+	after heavy rain
2 Jul 2020	Hpakant jade mine, Myanmar	175+	after heavy rain
4-23 Dec 2019	Cibitoke, Burundi	41+	unseasonably heavy rain
9 Aug 2019	Mottama, Myanmar	70	torrential rain
28 Jul 2019	Hpakant jade mine, Myanmar	14	
22 Apr 2019	Hpakant jade mine, Myanmar	57	
22 Dec 2018	Anak Krakatau, Indonesia	426	tsunami from submarine landslide
9 Jan 2018	Montecito, SoCal	20	heavy rain during Thomas fire
14 Aug 2017	Freetown, Sierra Leone	1141+	particularly wet rainy season
24 Jun 2017	Xinmo, Sichuan, SW China	10	after rainy season
17 Jun 2017	Karrat Fjord, Greenland	4	from tsunami, locally 90-100m tall
12 Jun 2017	Bangladesh	152	worst in country's history
2 Apr 2017	Mocoa, Colombia	329+	weather-related
21 Nov 2015	Hpakant jade mine, Myanmar	113	man-made waste pile collapsed
13 Nov 2015	Zhejiang, China	38	

Hpakant 15 Aug
32+ dead
(Aljazeera/CNN/Reuters)

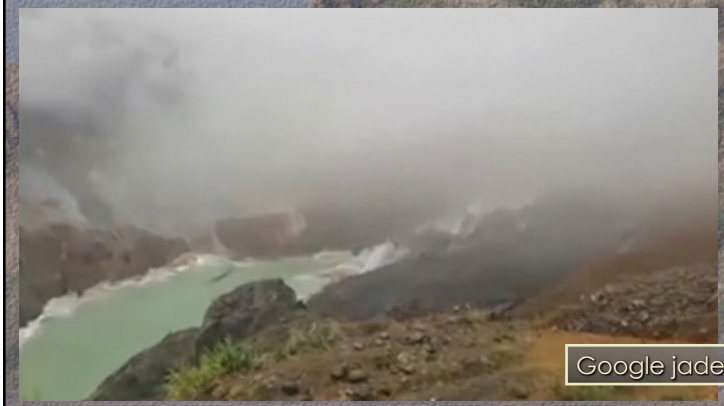
Hpakant:
* 4 out of 28 most deadly recent landslides
* 4 in 5 years

07/02/20 – Jade Mine Myanmar



07/02/20 – Jade Mine Myanmar

https://www.bbc.com/news/av/world-asia-53260841/myanmar-jade-mine-landslide-captured-on-video



Google jade mine disaster

07/02/20 – Jade Mine Myanmar

- > 162 dead (175+ as of 2024)
- True toll likely unknown
- Heavy rain
- Unstable waste pile collapsed

Source: BBC, NPR, Aljazeera

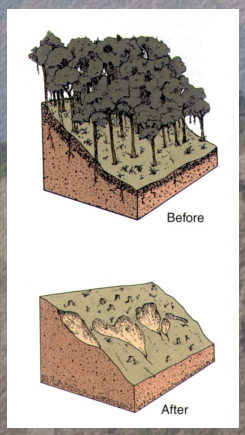
07/02/20 – Jade Mine Myanmar

"one of the worst accidents to hit the treacherous industry"

- Billion-dollar industry
- reckless, irresponsible mining
- Large-scale, illegal
- poor 'freelance' miners

Source: BBC, NPR, Aljazeera

Deforestation and Mass Wasting



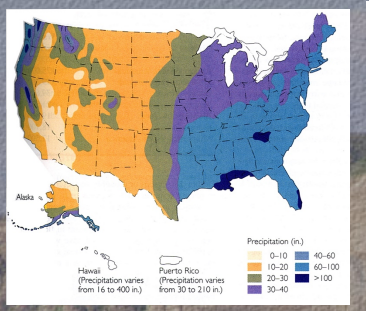
NATURAL:
- ✧climate
- ✧tropical rainforest has poor soil

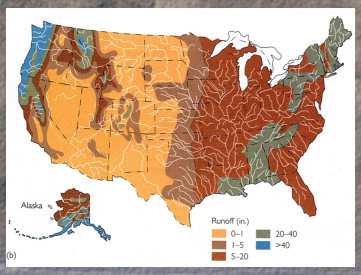
HUMAN:
- ✧deforestation

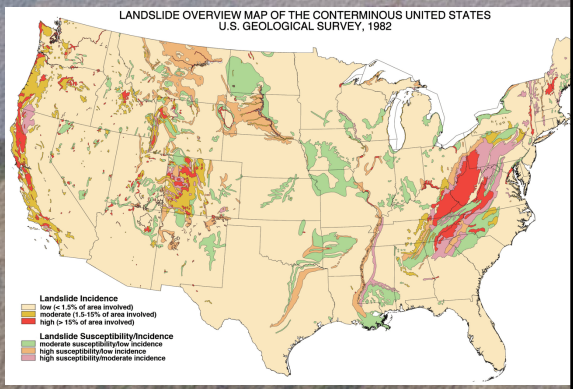
Tropical Rainforest particularly problematic

Tropical Soil:
- thin humus layer
- fast decay
- soil takes long time to form

Mass Movements in the U.S.





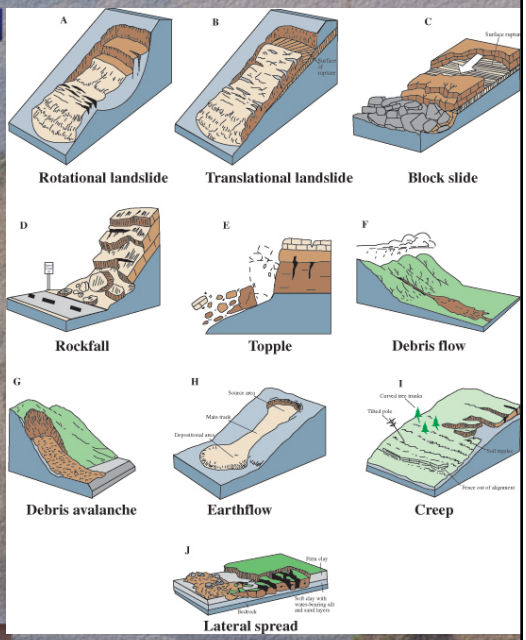


areas of high precipitation
areas of steep slopes
areas of high runoff
large, meandering rivers

Types of Mass Movements (e.g. USGS)

USGS
many different
categories

Fig. 8.18

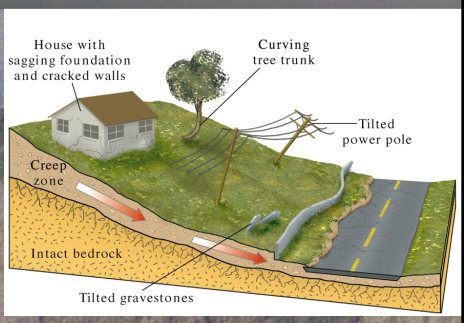


Classification may include:
- which material
- how much water is involved
- how a material moves
- speed of movement
- type of environment

CREEP

too slow to watch but telltale signs
- ✧titled poles, fences, gravestones
- ✧cracked walls
- ✧bent tree trunks
- ✧covered roadsides

Gilman Dr., Feb 2005

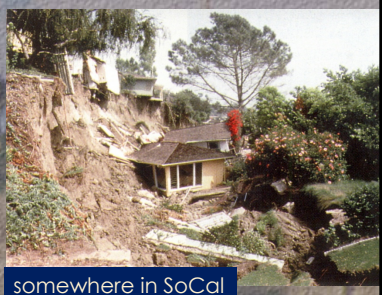


Types of Mass Movements

SLIDES
all sizes, speeds at mm/day to m/min
moves down slope as whole
translational

SLUMPS
all sizes, speeds at mm/day to m/min
rotates in place as whole
rotational

Basic Features of Slope Failure



somewhere in SoCal

top: head scarp/tear-away zone
bottom: toe/pile-up zone
glide horizon/surface of weakness

middle: transverse cracks

Mt. Soledad, Oct 13, 07

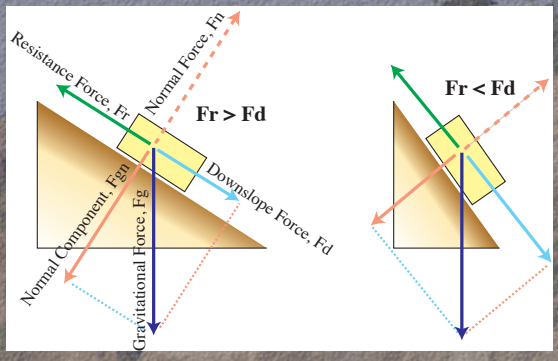
see Chapter 2

The Role of Gravity

short video 8a

✧pull of gravity downslope -> Fd
✧resistance force due to friction -> Fr

GLIDE HORIZON
surface between
unstable mass and solid ground



NATURAL:
earthquakes lower Fr

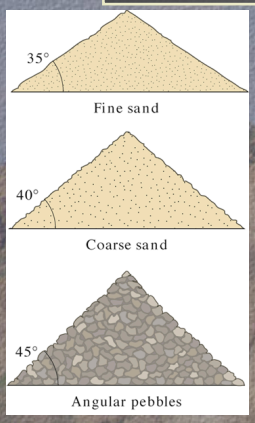
HUMAN:
✧vibrations
✧heavy traffic

✧Fr > Fd -> mass stays put
✧Fr < Fd -> mass slides down

GRADIENT
vertical/horizontal
(dz/dx)

The Angle of Repose

✧maximum angle a pile can retain without disintegrating
✧depends on grain properties (size, roundness, cohesion)



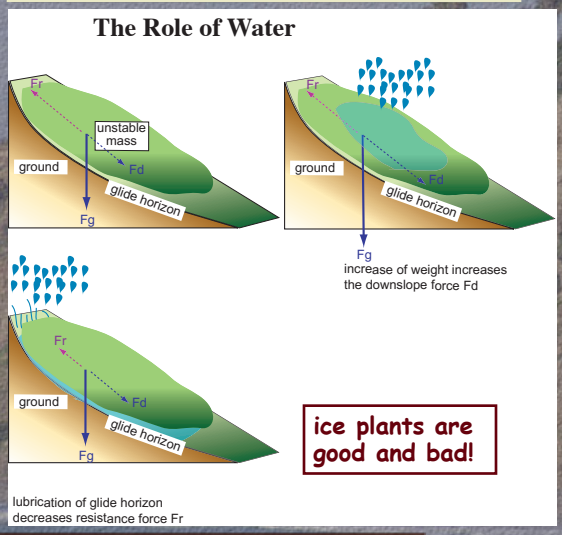
Sunset Crater, AZ (cinder cone)

source: volcano.und.edu

WATER
✧a little: adds cohesion, may increase angle of repose (sand castle)
✧a lot: reduces friction, accelerates erosion

The Role of Water

✧pull of gravity downslope -> Fd
✧resistance force due to friction -> Fr

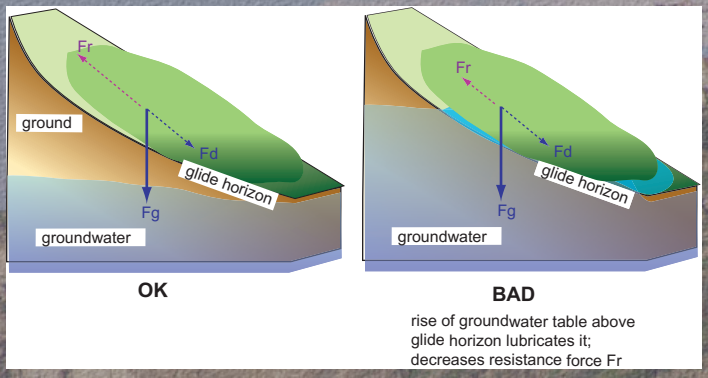


ice plants are good and bad!

NATURAL: rain
✧adds mass
✧reduces frictions

HUMAN:
✧irrigation
✧failing pipes
✧leaky pools

The Role of Groundwater



ok:
water table below glide horizon

bad:
water table above glide horizon

NATURAL:
long rain
tectonic changes

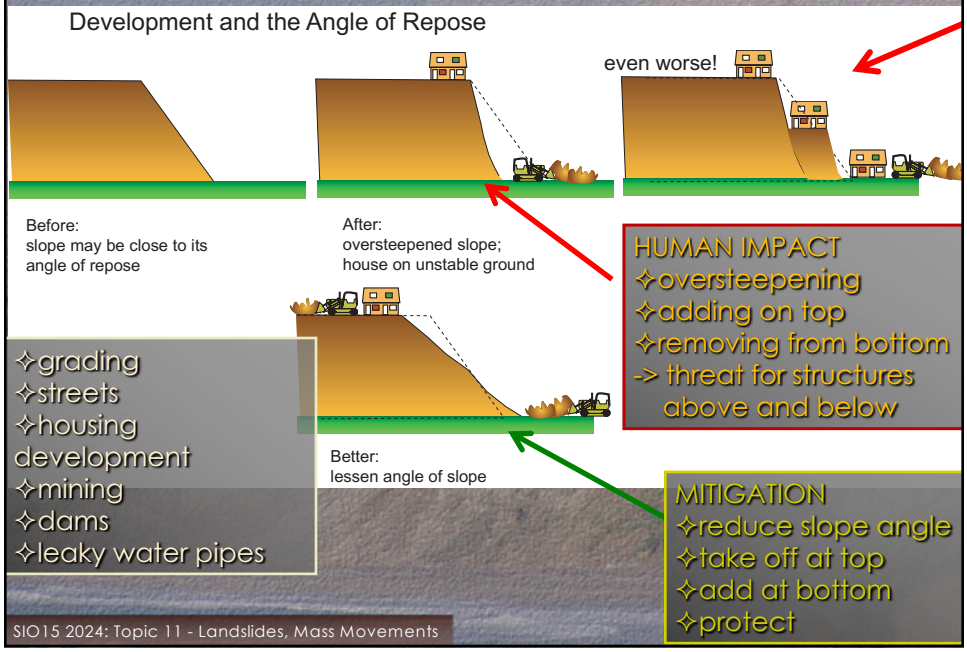
HUMAN:
excessive irrigation

Triggers of Mass Movement

contributing factors
- ✧preexisting instability
- ✧plate tectonics
- ✧rain
- ✧rising groundwater table
- ✧earthquakes
- ✧thawing of frozen ground/large change in T

- ✧human construction (roads, houses, grading, dams)
- ✧mining
- ✧irrigation
- ✧excess water withdrawal
- ✧traffic
- ✧deforestation

… and how humans mess with it



HUMAN IMPACT
- ✧oversteepening
- ✧adding on top
- ✧removing from bottom

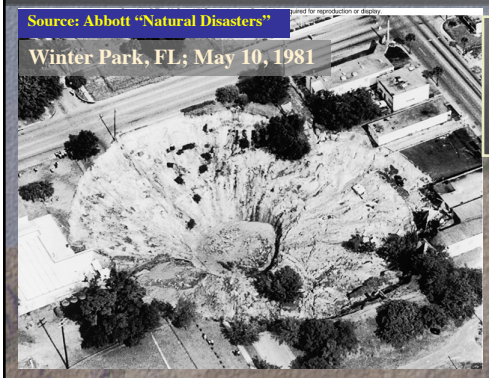
-> threat for structures above and below

- ✧grading
- ✧streets
- ✧housing development
- ✧mining
- ✧dams
- ✧leaky water pipes

MITIGATION
- ✧reduce slope angle
- ✧take off at top
- ✧add at bottom
- ✧protect

Subsidence – Slow or Sudden Sinking of Surface

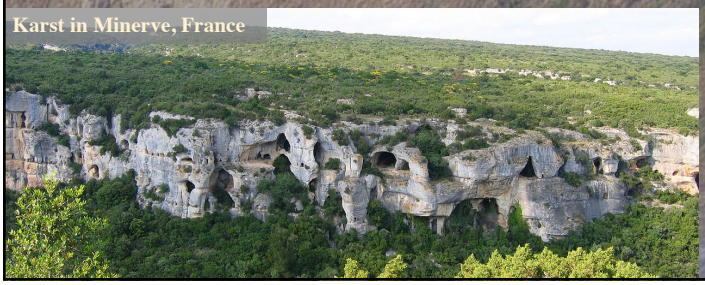
Source: Abbott "Natural Disasters"



Winter Park, FL; May 10, 1981

- collapse in karst (limestone) region
- carbonate dissolves on water
  - → underground caves
  - → sinkholes

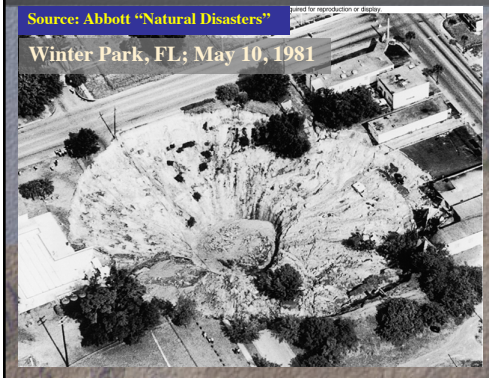
NATURAL CAUSES:
subsurface weathering
drought



Karst in Minerve, France

Sinkholes

Source: Abbott "Natural Disasters"



Winter Park, FL; May 10, 1981

HUMAN CAUSES:
excess g.w. withdrawal

- excess irrigation
- failing pipes
- leaking pools

-> subsurface weathering
-> collapse

Karst in Minerve, France

Sinkholes - Mining

underground coal mining, CO -> underground cavities -> sinkholes

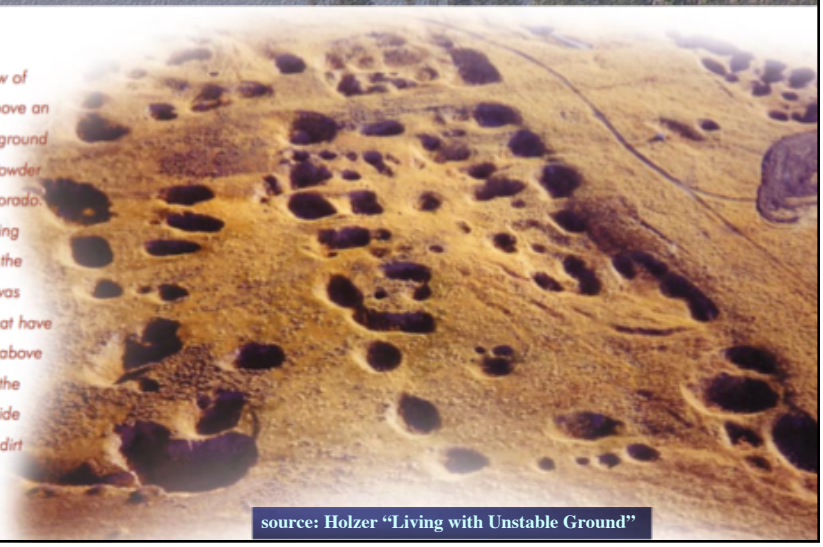


Fig. 34. Aerial view of subsidence pits above an abandoned underground coal mine in the Powder River Basin of Colorado. Collapse is occurring above "rooms" in the mine where coal was removed. Areas that have not collapsed are above the pillars of coal the miners left to provide support. Note the dirt road for scale.

source: Holzer "Living with Unstable Ground"

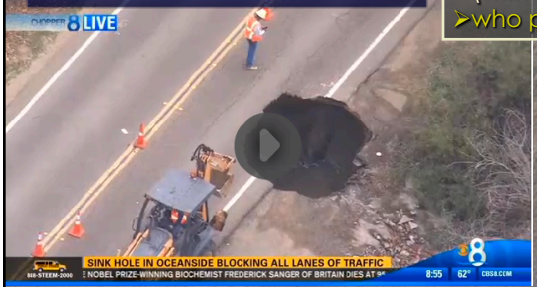
Local Sinkholes

Point Loma, San Diego; 19 Oct 2005

Genessee Ave near UCSD; 06 Oct 2011

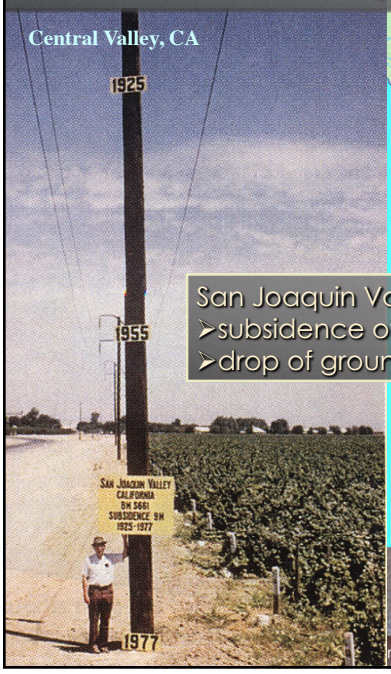
- failing underground water infrastructure
- U.S.: 10-30% water unaccounted for (with 30% in cities)
- who pays for repairs?

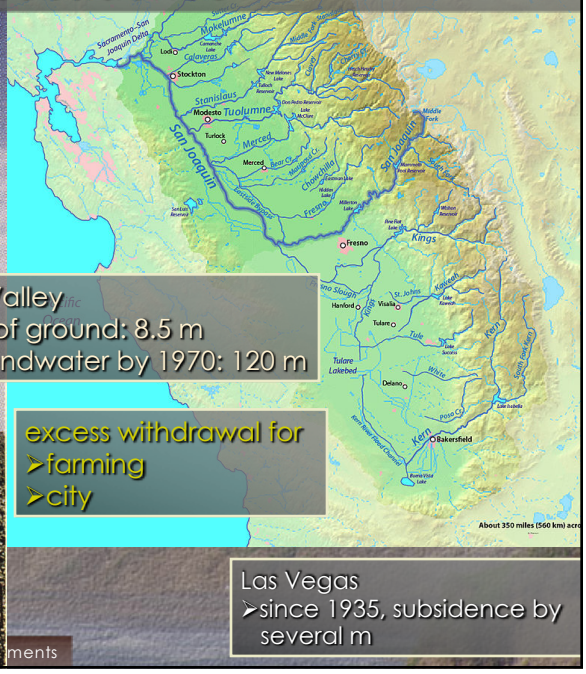
16 Oct 2014: Sinkhole in Oceanside



14 Sep 2017: 20-ft deep; I-8

Subsidence





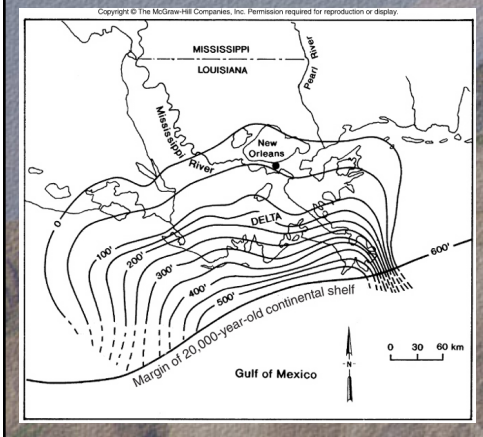
San Joaquin Valley
- subsidence of ground: 8.5 m
- drop of groundwater by 1970: 120 m

excess withdrawal for
- farming
- city

Las Vegas
- since 1935, subsidence by several m

ments

Subsidence

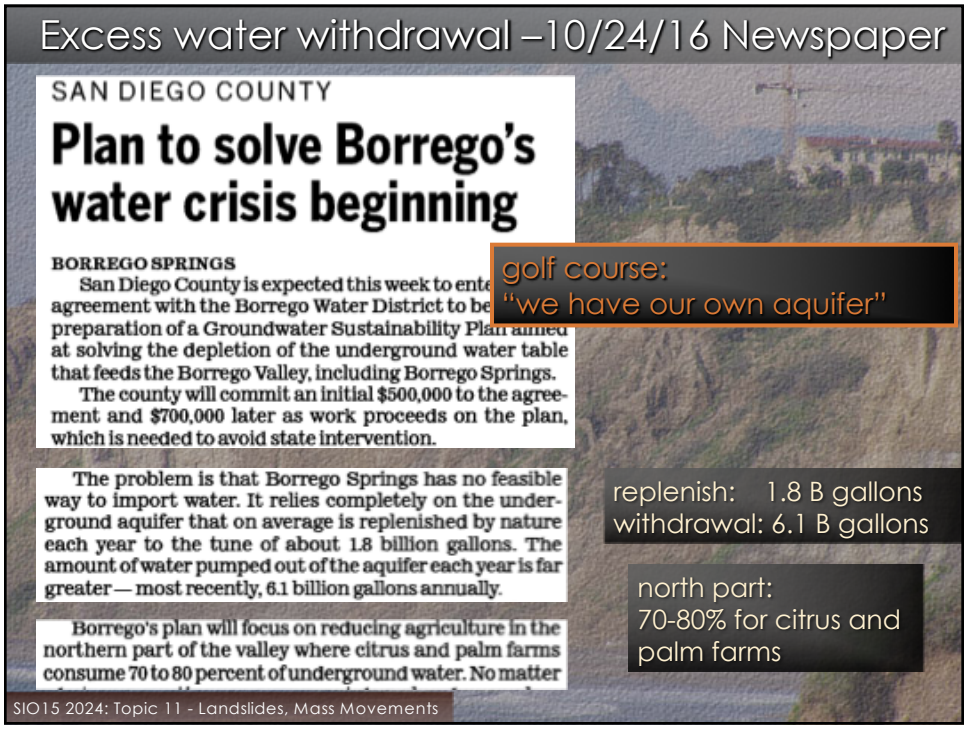


Delta subsidence in last 20,000 years

compaction of sediments
- New Orleans sunk 3 m in last 50 yrs
- 45% below sea level

HUMAN CAUSES:
- excess withdrawal (oil, water)
- dredging and canals prevent natural supply of sediments

Excess water withdrawal –10/24/16 Newspaper



SAN DIEGO COUNTY

Plan to solve Borrego's water crisis beginning

BORREGO SPRINGS

San Diego County is expected this week to ente
agreement with the Borrego Water District to be
preparation of a Groundwater Sustainability Plan aimed
at solving the depletion of the underground water table
that feeds the Borrego Valley, including Borrego Springs.

The county will commit an initial $500,000 to the agreement and $700,000 later as work proceeds on the plan, which is needed to avoid state intervention.

The problem is that Borrego Springs has no feasible way to import water. It relies completely on the underground aquifer that on average is replenished by nature each year to the tune of about 1.8 billion gallons. The amount of water pumped out of the aquifer each year is far greater — most recently, 6.1 billion gallons annually.

Borrego's plan will focus on reducing agriculture in the northern part of the valley where citrus and palm farms consume 70 to 80 percent of underground water. No matter

golf course:
"we have our own aquifer"

replenish: 1.8 B gallons
withdrawal: 6.1 B gallons

north part:
70-80% for citrus and palm farms