ASDSO

A Tragedy in the Italian Alps (50th Anniversary)

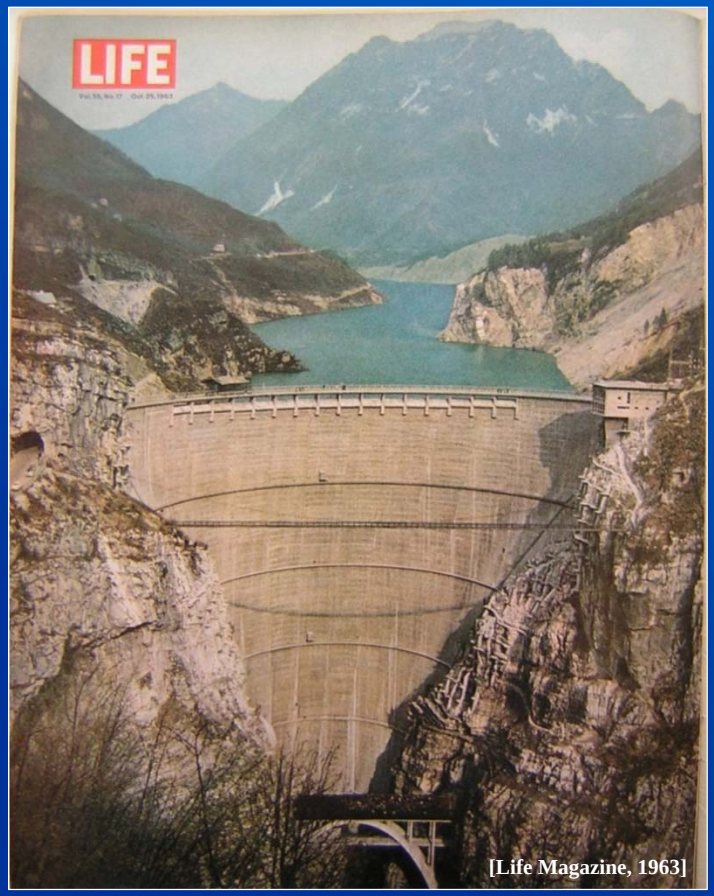
VAJONT DAM

Lee Mauney, Wayne Graham
Bureau of Reclamation

DECADE DAM FAILURE SERIES
ASDSO

Presentation Outline

- Not focused on landslide
- Previous Research
- Timeline
- Warning
- Consequences
- Newsreel Footage (2.5 minutes)



Previous Research

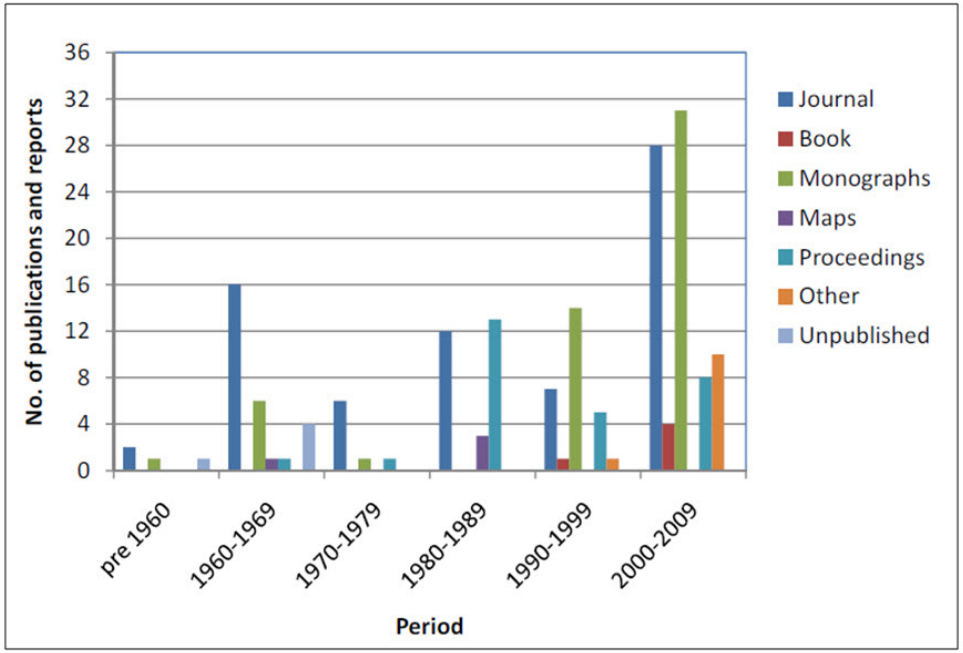
- Hendron and Patton [1985] noted, “It is likely that more information has been published and more analyses have been made of the (Vajont) data than for any other slide in the world.”
- …”the Vajont rockslide event is often regarded as a milestone in rock slope stability studies, and it has also been considered as the starting point for the development of modern rock mechanics and rock engineering” [Paronuzzi and Bolla, 2012]

Additional areas of research pertaining to Vajont Dam.

Area of Research	Results	References
Response/Warning and Evacuation	Very little warning time	Quarantelli, 1979
Computer Modeling of Flood Inundation	2-D and 3-D models of reservoir and landslide generated wave	Tagliavini et al., 2008 Bosa and Petti, 2010
Politics and Prosecution of Engineers	Engineers charged with manslaughter	Ross, 1984
Psychological/ aftermath of tragedy	Long-term psychological effects on survivors	Zaette et al., 2001

Previous Research

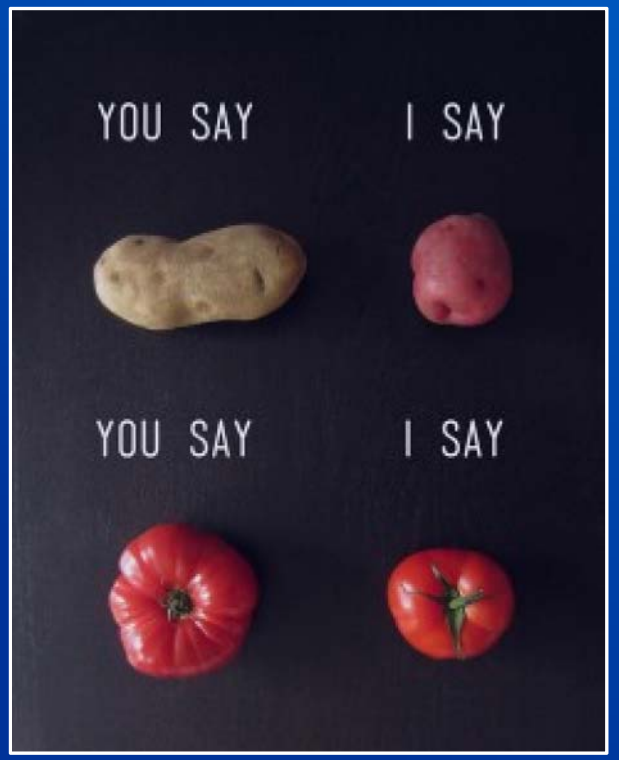
- An extensive database of published and unpublished data established in 2010, and is available online.
- Relatively high production immediately after the landslide
- 1980–1999 international conference on the (Vajont) landslide
- Most of the documentation have been produced recently



Chronology of the documentation on the Vajont landslide [Superchi et al., 2010].

Tomayto tomahto…

- ‘Vajont’ Dam or ‘Vaiont’ Dam?
- For consistency, ‘Vajont Dam’ is used according to current Italian toponymy.



Background

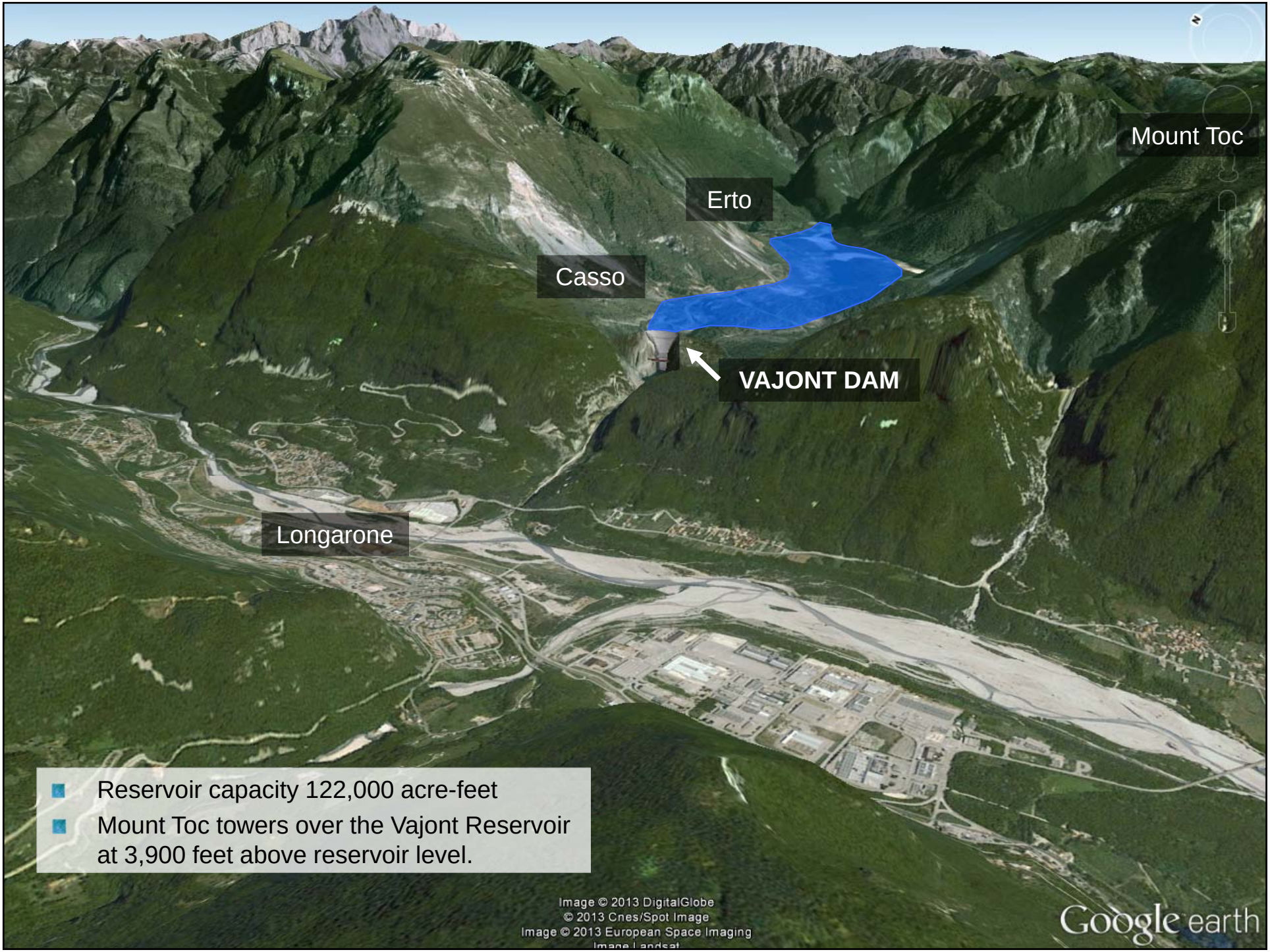
- Compared with historic dam incident case studies, Vajont is unique in many aspects, including:
  - Vajont Dam did not fail and remains one of the highest dams in the world,
  - The scale of the 1963 landslide and resultant flood wave are unprecedented,
  - Resultant flooding from the landslide reached Longarone almost immediately,
  - The fatality rate is among the highest recorded dam failure or dam incident,
  - Voluminous research has been conducted on the Vajont landslide and surrounding geology.

Selected dam incidents within the last 100 years.

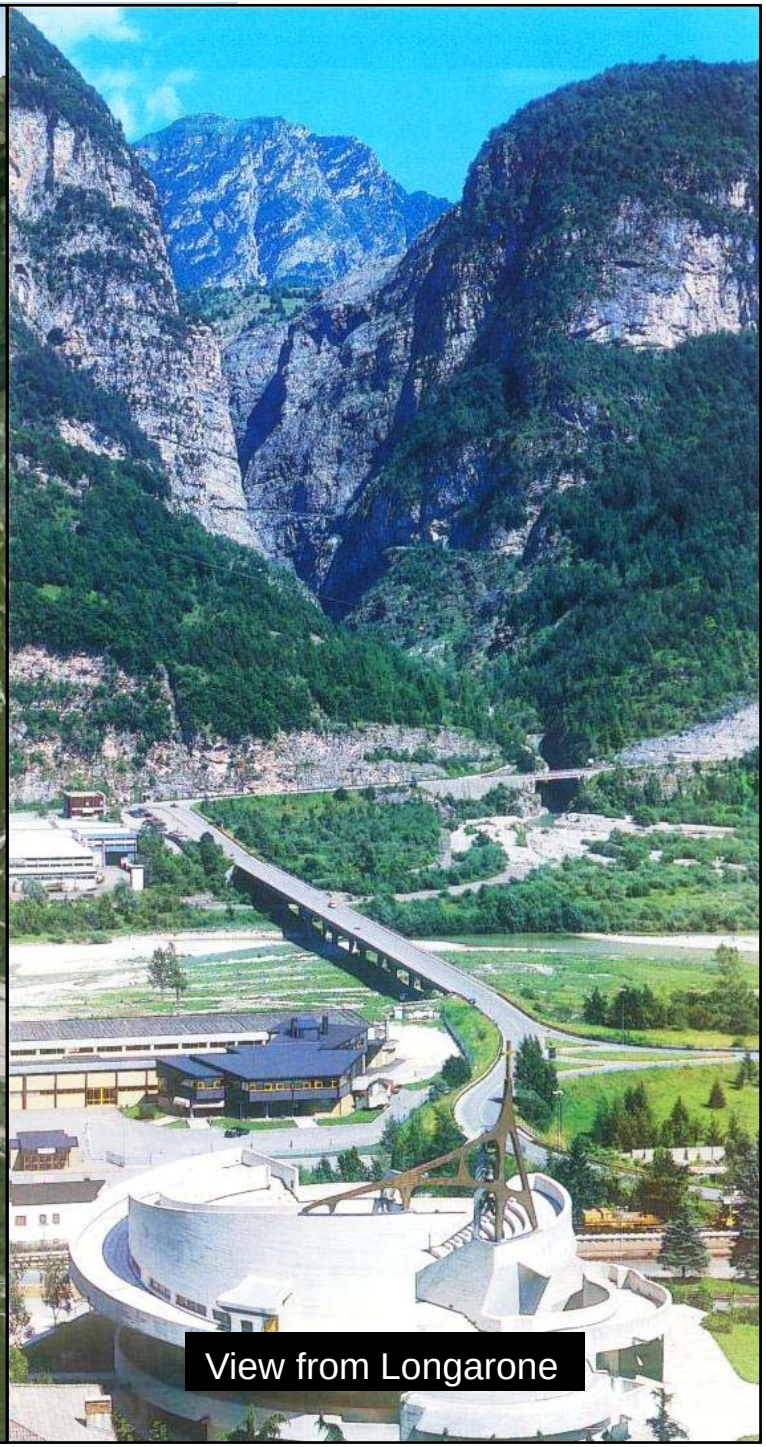
Dam Incident	Year	Location	Estimated Deaths	Description
Vajont Dam Landslide	1963	Italy	2,600	Landslide into Reservoir
St. Francis Dam Failure	1928	USA	420 to 600+	Geological Instability
Malpasset Dam Failure	1959	France	423 to 550	Extended period of rainfall
Gleno Dam Failure	1923	Italy	356	Construction Flaws
Vega de Tera Dam Failure	1959	Spain	144	Hydrologically Induced Static Failure

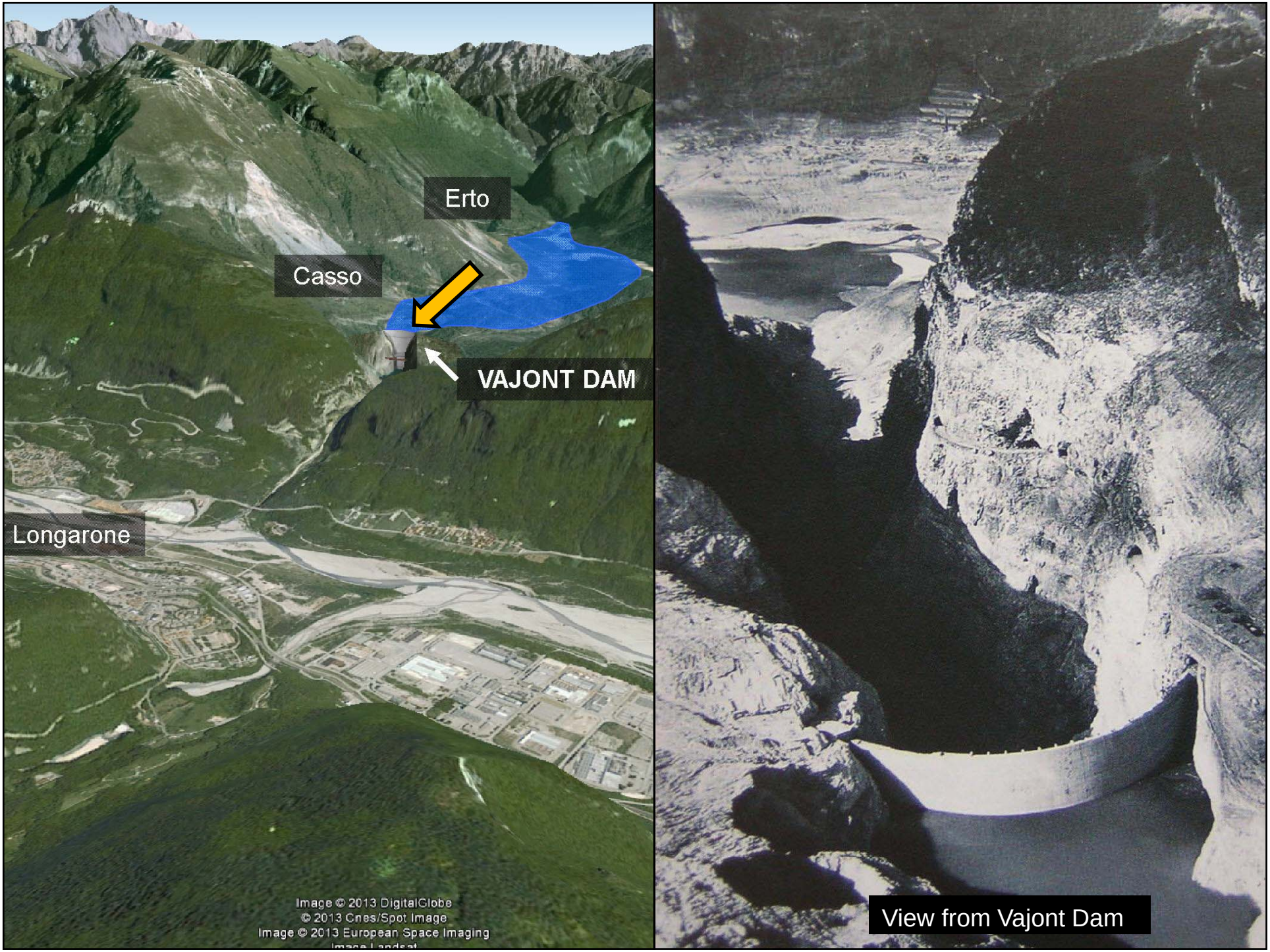
Location

- Vajont Dam is on the Vajont River, a tributary of the Piave River, just upstream of Longarone, in northeast Italy.
- Longarone is approximately 62 miles north of Venice, Italy.

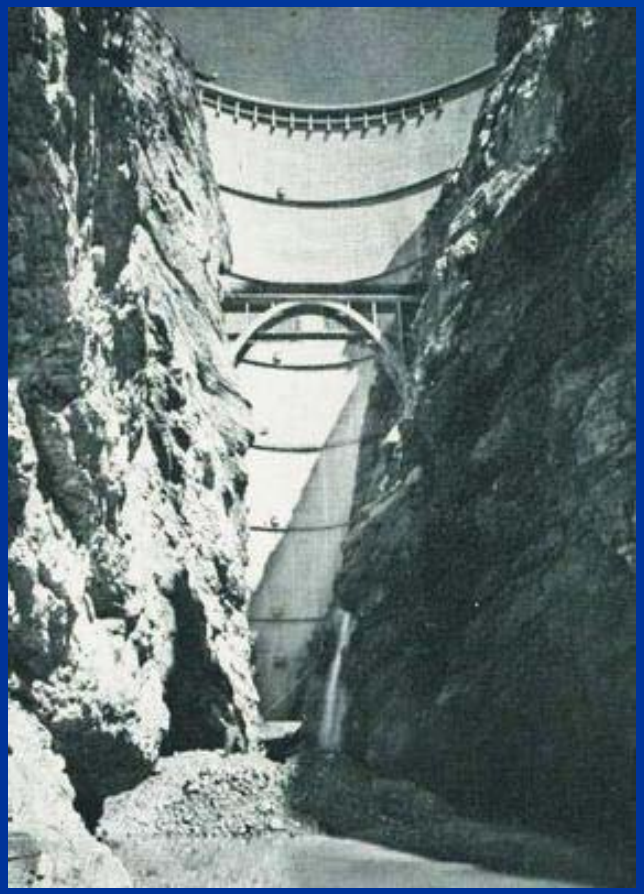

Mount Toc
Erto
Casso
VAJONT DAM
Longarone
Reservoir capacity 122,000 acre-feet
Mount Toc towers over the Vajont Reservoir at 3,900 feet above reservoir level.
Image © 2013 DigitalGlobe
© 2013 Cnes/Spot Image
Image © 2013 European Space Imaging
Google earth


Erto
Casso
VAJONT DAM
Longarone
Image © 2013 DigitalGlobe
© 2013 Cnes/Spot Image
Image © 2013 European Space Imaging

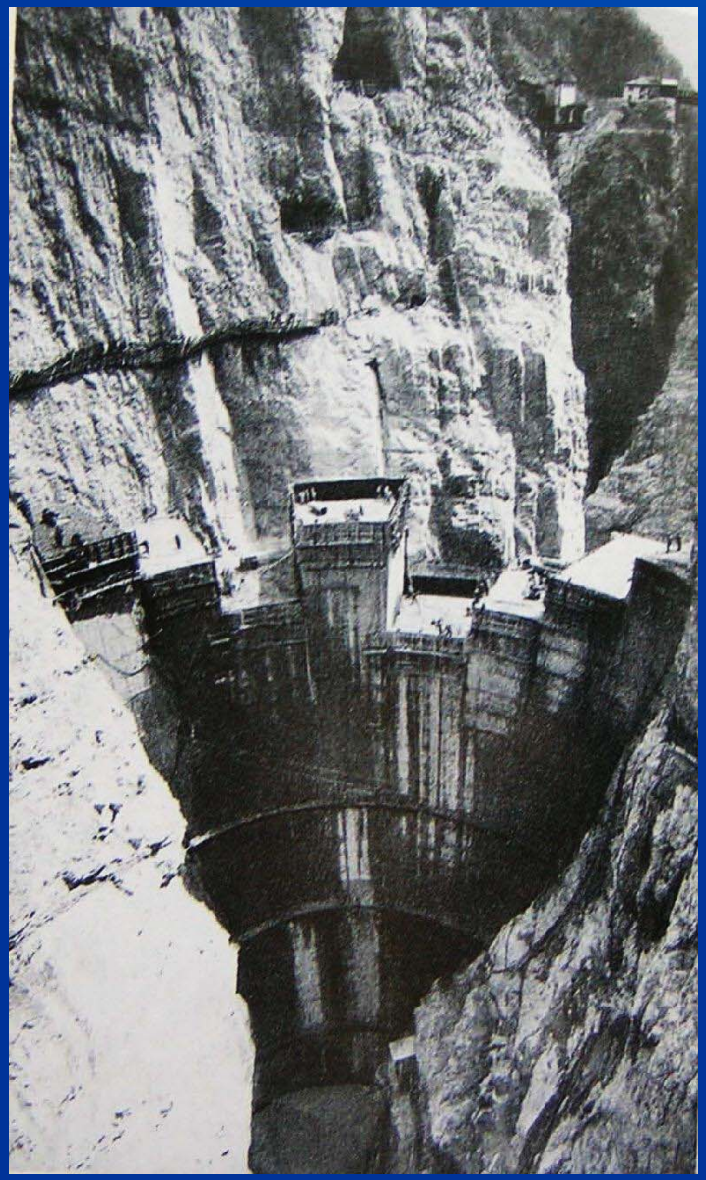

View from Longarone


Erto
Casso
VAJONT DAM
Longarone
Image © 2013 DigitalGlobe
© 2013 Cnes/Spot Image
Image © 2013 European Space Imaging
View from Vajont Dam

Vajont Dam



- 860 feet high
- Double-curved, thin-arch dam
- Constructed for hydro-electric power generation



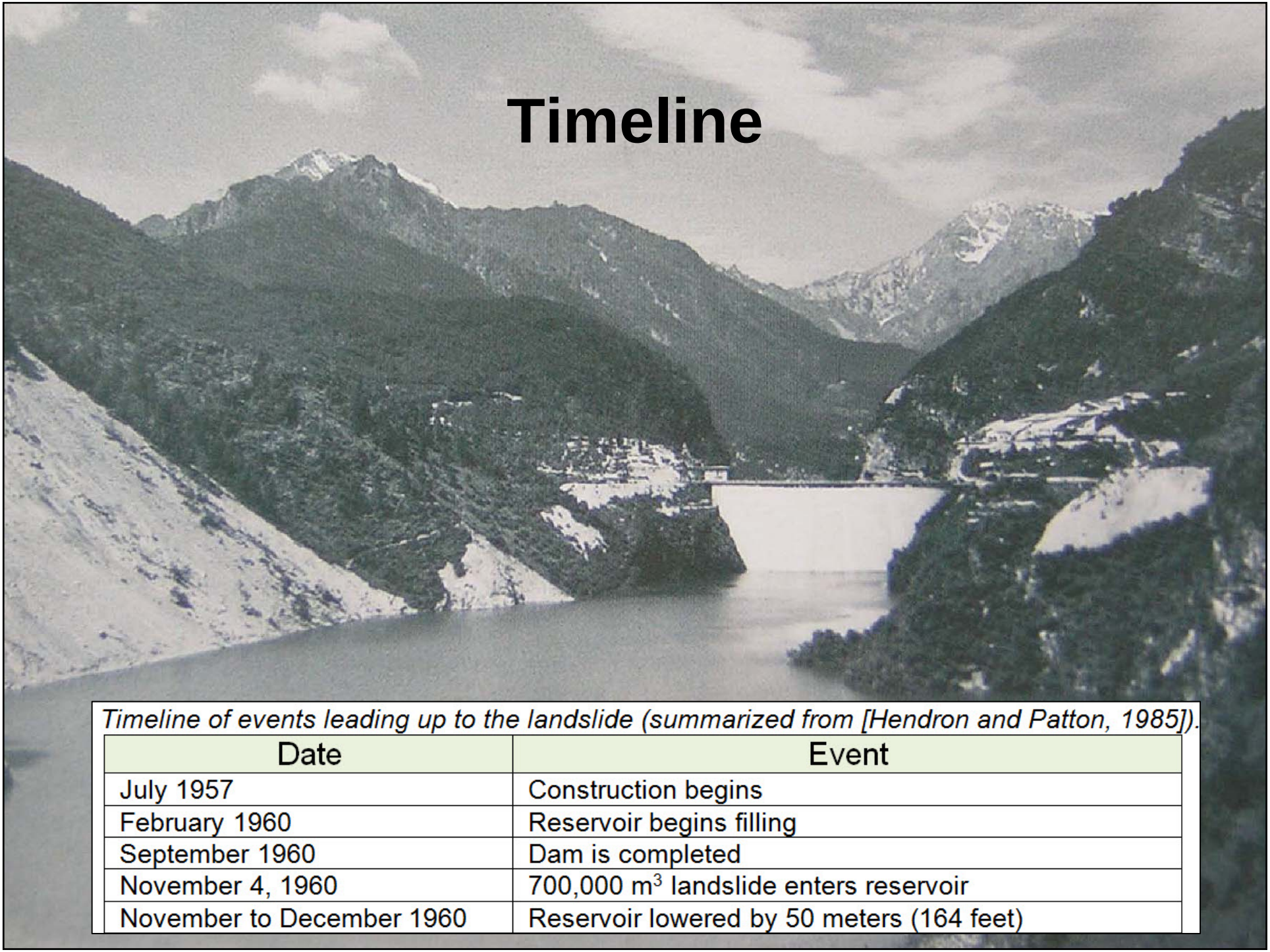
Construction

- Construction began in July 1957
- Reservoir began filling in February 1960.
- A local newspaper published article suggesting recurrent landslides make a disaster likely. Shortly after, legal action was taken for spreading false news and disturbing the peace.
- Residents were assured of safety, but they continued to distrust the stability of Mount Toc, even nicknaming it, “the mountain that walks.”

Vajont Dam

DECADE DAM FAILURE SERIES
ASDSO

Timeline



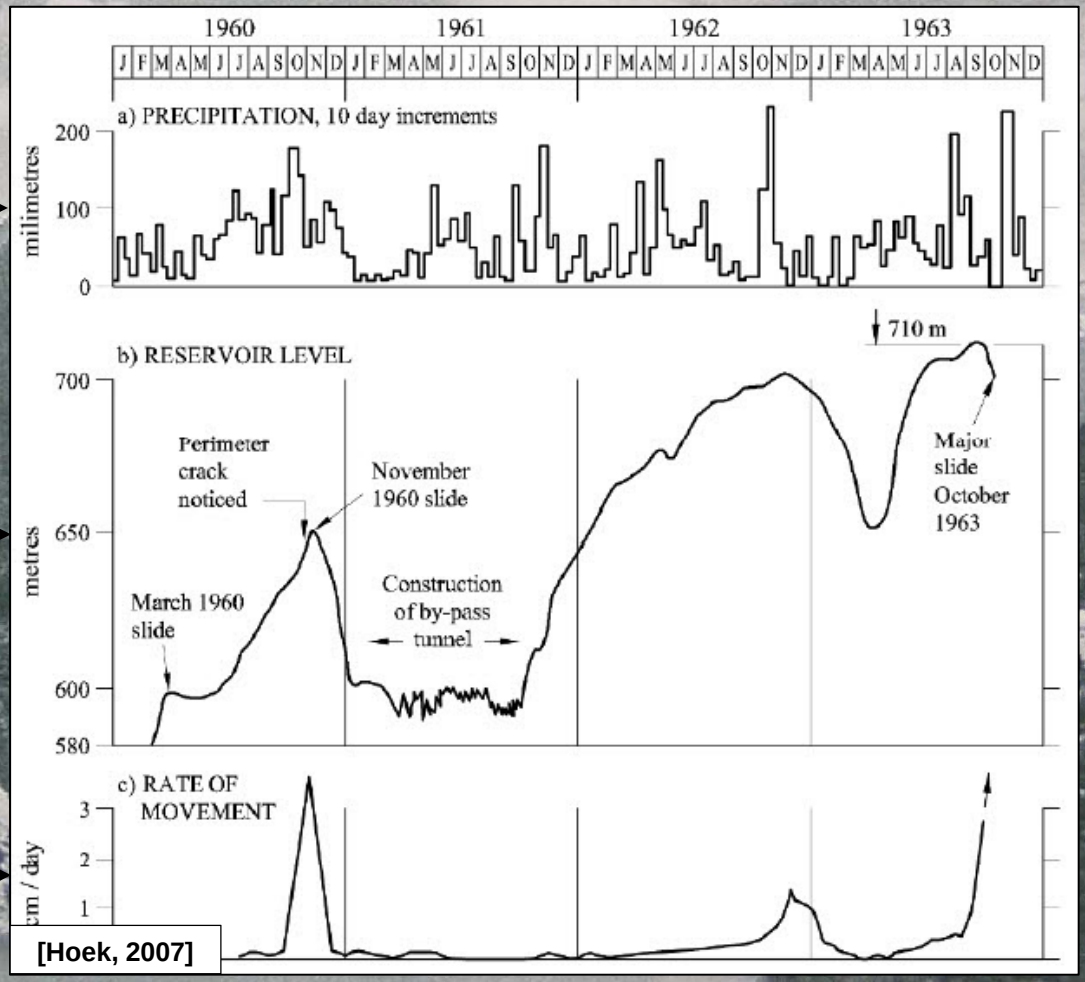
Timeline of events leading up to the landslide (summarized from [Hendron and Patton, 1985]).

Date	Event
July 1957	Construction begins
February 1960	Reservoir begins filling
September 1960	Dam is completed
November 4, 1960	700,000 m^3 landslide enters reservoir
November to December 1960	Reservoir lowered by 50 meters (164 feet)

Precipitation

Reservoir Level

Rate of Movement

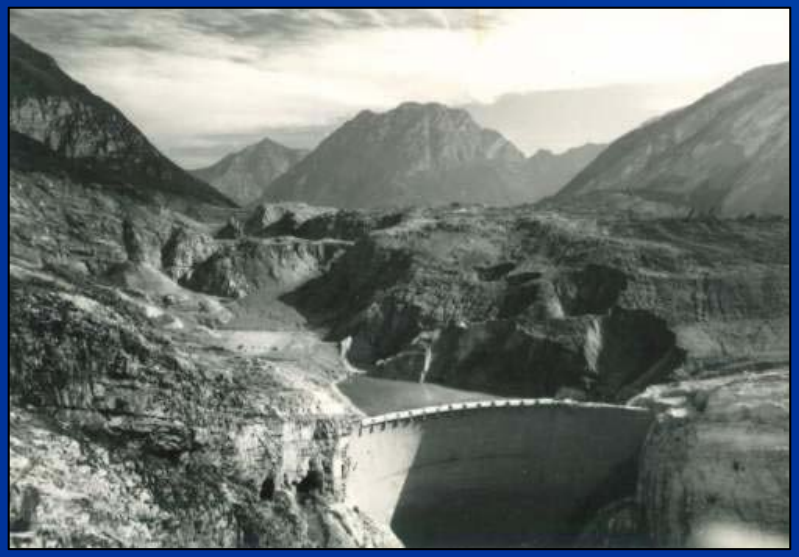


[Hoek, 2007]

Timeline of events leading up to the landslide (summarized from [Hendron and Patton, 1985]).

Date	Event
July 1957	Construction begins
February 1960	Reservoir begins filling
September 1960	Dam is completed
November 4, 1960	700,000 m^3 landslide enters reservoir
November to December 1960	Reservoir lowered by 50 meters (164 feet)
February to October 1961	Bypass tunnel constructed
September 1963	Reservoir at highest level ever
October 9, 1963	Landslide enters reservoir (10:39 p.m.)

Warning



- Some warnings were issued prior to the Vajont landslide, however they were not effective.
- Officials thought the reservoir was drawn down enough to not cause harm, but they grossly underestimated the resultant size of the landslide.
- Warnings were not issued in sufficient time for downstream residents to evacuate, and if they were, very few people heeded the warnings.

[Paronuzzi, 2012

Vajont Dam

Landslide

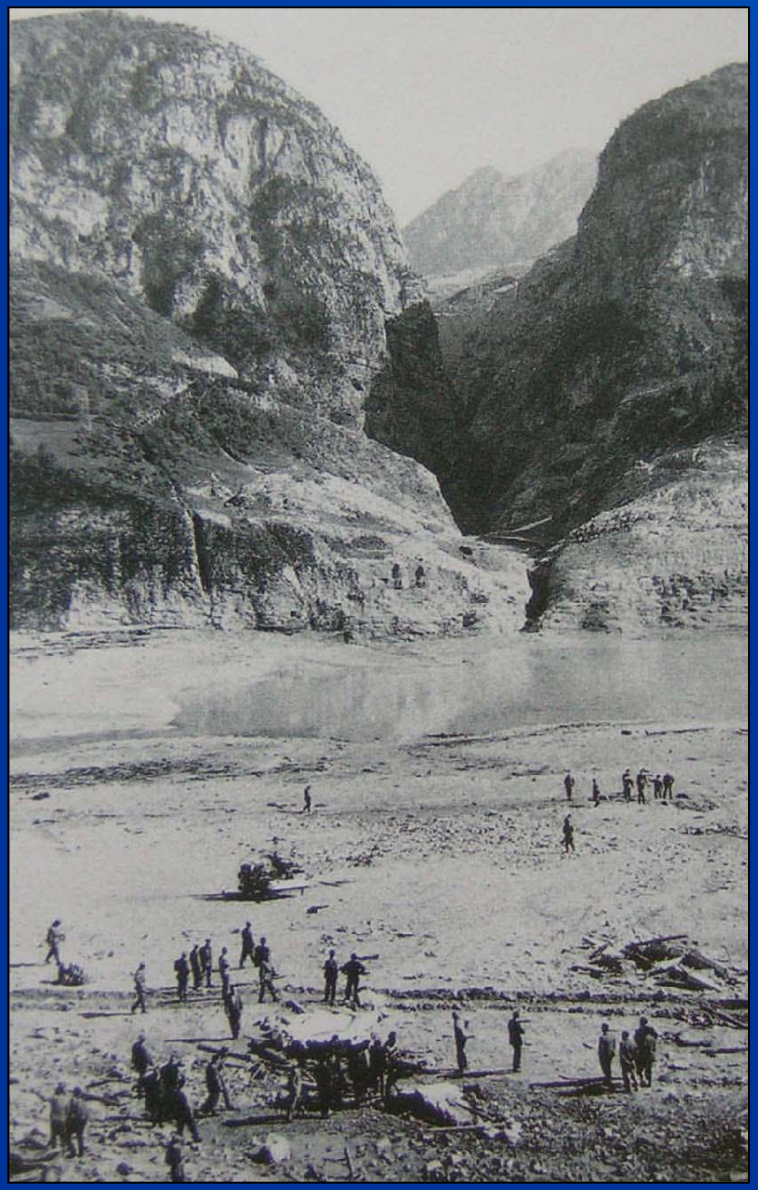
- Vajont is considered the most disastrous rockslide ever to occur in Europe.
- The event created strong earth tremors, recorded as far away as Vienna and Brussels.
- Enormous mass estimated at up to 300 million m^3 of earth and debris
- Slid into the Vajont reservoir in less than 45 seconds

Vajont Dam

Landslide

- Reservoir volume 93,000 acre-feet at time of slide
- The volume of the slide was about twice the volume of water impounded behind Vajont Dam.
- Updraft of air rocks and water climbed canyon wall ~ 850 feet above the reservoir.
- Waves of water over abutments > 300 feet above dam crest.

[Genevois, 2005]



Evacuation

- The water arrived in Longarone at 10:43 pm, (~4 minutes after the landslide)
- The wave was over 230 feet high
- Residents that were able to evacuate, escaped on foot.
- There was extensive onsite monitoring at the dam when the landslide occurred, with 20 technical personnel in the control center on the left abutment, all of which perished.

Consequences

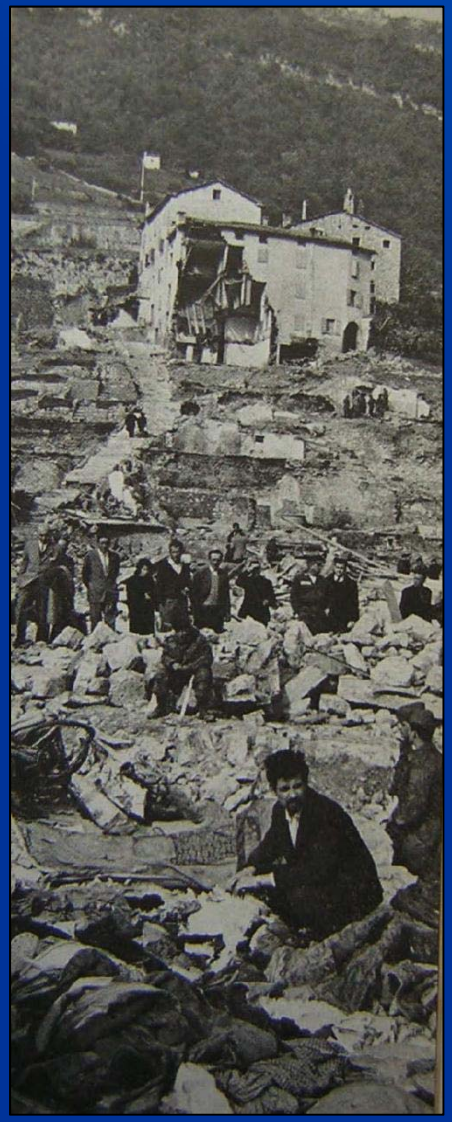
- 2,600 total fatalities and many injured.
- Five downstream towns were destroyed including Longarone, Pirago, Rivalta, Villanova, and Fae.
- Fatality rate of 94% in Longarone
  (1,269 of 1,328)
- 158 fatalities at Erto and Casso
- Consequences are unique in scale, with extremely high fatality rates caused by very deep and fast moving flood waters.

Vajont Dam

DECADE DAM FAILURE SERIES
ASDSO

AFTER THE DELUGE. The townsite of Longarone is demolished almost as though it never existed. Beyond the old woman, and across the river valley where the search for the dead goes on, is the gorge from which, only hours earlier, the 300-foot-high wall of water had spilled. Of the 2,300 who were in the town of Longarone at the time of the disaster, fewer than 200 lived to see it in ruins.

[Life Magazine, 1964]



Bias

- Landslide was over 400 times larger than the previous landslide, three years prior
- It is common for people to revert to recent, observed history.

Vajont Dam

Discussion

- Officials did not recognize the magnitude of the danger or the scale of a possible landslide at Vajont
- Even those most familiar with the facility, including engineers who worked at the dam site did not seem to understand the risks.
- General hesitation to warn and evacuate people before an outcome is certain.

- Even if officials and engineers understood the risk associated with a landslide, there were few ways to remediate the situation, outside of removing the dam completely or evacuating Longarone indefinitely.

Discussion

- Surprisingly, the Vajont Dam structure had little damage, even though subjected to a force estimated at 4 million tons from the combined slide and overtopping wave, far in excess of design pressures.
- Lesson: Hazards can exist at dams, even if a structure is considered safe and does not fail.

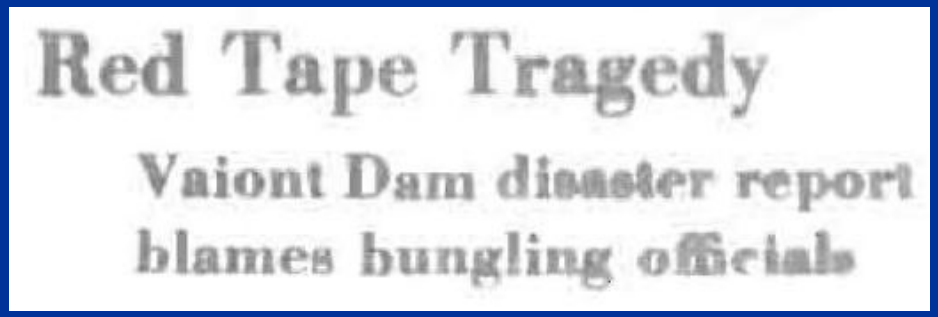
Discussion

- The Italian Government appointed technical board to review the circumstances leading up to the slide and establish responsibility for actions.
- The report cited a lack of coordination between the technical and governmental officials
- Eleven Italian engineers were later charged with manslaughter for not taking action to minimize risks.

Vaiont Dam Engineers Are Blamed

Responsibility for the 1963 Vaiont Dam disaster, which killed over 2,000 persons, has been charged to 11 Italian engineers by the public prosecutor of Belluno, Italy. Nine of them may face trial.

men were aware of a slide of over 1 million cu yd that took place in 1960 during a test filling of the reservoir to El. 2,133. That movement was more than was expected, but, the prosecutor says, the two continued test fillings, and con-



Red Tape Tragedy

Vaiont Dam disaster report blames bungling officials

Discussion


AT FAULT?

In 2009, an earthquake devastated the Italian city of L'Aquila and killed more than 300 people. Now, scientists are on trial for manslaughter.

- Italy, even fifty years later…

On April 6, 2009, a magnitude 6.3 earthquake killed over 300 people.

Prior to the devastating earthquake, the area experienced low-level tremors, known as seismic swarms, for several months. Just days before the earthquake occurred, a commission convened to discuss the potential for a major earthquake. In press interviews before and after the meeting, members of the committee said that the situation was "certainly normal" and posed "no danger." When prompted by a journalist who said, "So we should have a nice glass of wine," one committee member replied, "Absolutely." In the end, six Italian scientists were convicted of manslaughter for not adequately warning of the pending earthquake. Although the courts were publically criticized for the ruling, the case highlights issues that public officials face in understanding and communicating risk of disasters, particularly in Italy.

Thank You!