Mitigating Volcanic Hazards Through Geophysical Monitoring and Research

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Mitigating Volcanic Hazards

Monitoring informs Research

Research informs Monitoring Strategies
The Mount Rainier hazard assessment and map were the first geology-based volcano assessment in modern times.
Rainier Lahar Hazards

- 9 large lahars have reached now-populated areas in last 5600 years
- > 90,000 people live in Rainier lahar hazard zones (Diefenbach et al., 2015)
August 13, 2015, debris flow (Tahoma Creek)
Mount Rainier Lahars: Research

Orting – built on ~520-year-old lahar deposits
Mount Rainier Lahars: Research

Pat Pringle, WA DNR
Mount Rainier Lahars: Research

Rainier Lahar Hazards

• 9 large lahars have reached now-populated areas in last 5600 years

• > 90,000 people live in Rainier lahar hazard zones (Diefenbach et al., 2015)

• 8 lahars associated with eruptions; 1 was not (Electron, 1501 A.D.)

• Half associated with large landslides
Mount Rainier Lahars: Research

Reid et al. (2001), Finn et al (2001) – area of instability on west flank
260 M m$^3$ debris avalanche in least-stable source region

“D-Claw” simulations of collapse-driven lahars courtesy of Dick Iverson and David George (USGS-CVO)
Map view D-Claw simulation of 260 million m$^3$ lahar originating in least-stable source region, Mount Rainier

$t = 2$ minutes

Mount Rainier Lahars: Research

Ashford

Nisqually entrance

Iverson and George, in prep
Mount Rainier Lahars: Research

Map view D-Claw simulation of 260 million m$^3$ lahar originating in least-stable source region, Mount Rainier

$t = 10$ minutes

Iverson and George, in prep
Map view D-Claw simulation of 260 million m$^3$ lahar originating in least-stable source region, Mount Rainier

t = 20 minutes
Mount Rainier Lahars: Research

Map view D-Claw simulation of 260 million m$^3$ lahar originating in least-stable source region, Mount Rainier

$t = 60$ minutes
Mount Rainier Lahars: Research

- Most likely scenario: Large lahar will occur during unrest/eruption
- Mitigation strategy – install really good real-time monitoring network to detect earliest signs of unrest
Mount Rainier – Current monitoring network

- First station installed 1963, 2nd in 1972
- Three installed by CVO in 2007-2008
- PNSN-CVO network: 9 stations w/in 20 km
- Also 7 CGPS stations
What is a “good” monitoring network?

2008 USGS report

- 10 co-authors from USGS and academia.
- Identified phenomena that had given early warning at at least one volcano.
- Determined instrumentation levels to enable detection of phenomena.
- Recommendations:
  - 12-20 broadband seismometers
  - 12-20 continuous GPS
  - Several infrasound
  - All within 20 km of volcano

Moran et al., 2008
Mount Rainier – Volcano monitoring
St. Andrews Rock, Rainier, 11,000’
Mount Rainier Seismicity

1985-2017 “good” locations (>4 P picks, < 150° gap)

New stations installed
Mount Rainier – Tomography Model

- Low velocities aren’t low enough for sedimentary lithologies
- Low velocities aren’t high enough for igneous lithologies
- Igneous rock + partial melt?

*Moran et al., 2000*
Mount Rainier – Conceptual Model

Moran et al., 2000
Mount Rainier – Sept 20-22, 2009, swarm

- ~1000 quakes in 3 days (~100 located by PNSN)
- Most significant swarm since monitoring began
- Cause == ??

Shelly et al., 2013
Mount Rainier – Sept 20-22, 2009, swarm

- Event migration front: ~1 m²/sec
- Rate consistent with fluid flow (too fast for magma)

Rainier Challenge: Convert to monitoring tool

1) Need good seismic network
2) Need to do template ID and relocation in near real-time.

Shelly et al., 2013
Mount Rainier – Volcano monitoring

- Less likely (but still possible) scenario: Large lahar occurs due to spontaneous landslide

- Mitigation strategy: Install lahar detection system to warn communities downstream

- Goal #1: Detect large lahar within minutes to give downstream communities 20-60 minutes of warning.

- Goal #2: NO FALSE ALARMS
Detect Large Moving Landslides

Mount Meager landslide, 2010

Allstadt et al., 2015
Detect Large Moving Landslides

Allstadt et al., 2015
Detect Large Moving Landslides

Landslide force time history

Allstadt et al., 2015
Detect Large Moving Landslides

Rainier Challenge: Convert to monitoring tool

1) Need good network of broadband seismometers
2) Need to determine force time-history in real time

*Refer to Figure 8 for the timing and Figure 11 for the location of points a–e.*

Allstadt et al., 2015
Detect Lahars & Track Flow Front Position

- Seismometers have to be close to drainages to record lahars
- Need multiple stations to be sure (no false alarms)

August 13, 2015 debris flow
Detect Lahars & Track Flow Front Position

Volcan Villarrica 2015 eruption

Johnson et al., 2015
Detect Lahars & Track Flow Front Position

Rainier Challenge: Convert to monitoring tool

1) Lahar only detected on one of six infrasound arrays – need to install a lot to make this reliable
2) Flow-front position only tracked for 5 minutes
3) Need to do beam-forming and semblance analysis in real time
Mount Rainier Lahars: Monitoring

Mount Rainier Lahar Detection System, 1998
Mount Rainier Monitoring: 2022

- ~35 broadband seismometers
- ~15 3-/6-component infrasound arrays
- ~10 webcams
- ~15 tripwires
Mitigating Volcanic Hazards

Monitoring begets Research

Research informs Monitoring Strategies
Mitigating Volcanic Hazards

- Monitoring
- Research
- Community Preparedness
Community Preparedness: The Reason It’s Important

Armero, Colombia – 1985 lahar, 
~20,000 dead
Community Preparedness: Response Plans

Produced by WA EMD, WA DNR, Pierce County & other counties, USGS, land managers, etc.
Community Preparedness: Outreach

- Policy Makers and Planners
- News & social media
- Hazards products
- Education Resources

Images:
1. Group of people working at a table with maps and papers.
2. Person presenting in front of a map.
3. A sign indicating an evacuation route.
4. Brochure titled "Living with a Volcano in Your Backyard".
5. Map showing volcanic activity and evacuation routes.