Earthquake Monitoring
Trans-Alaska Pipeline System (TAPS)

Sterling Strait
Earthquake Protection Program Coordinator
2002 M7.9 Denali Earthquake

Denali Fault Crossing
18-ft Lateral Displacement
Trans-Alaska Pipeline System

800-mile (1287-km) Route
Aboveground: 420 miles (676 km)
Belowground: 376 miles (605 km)
Refrigerated burial: 4 miles (6 km)
Trans-Alaska Pipeline System

Facilities
Originally 12 pump stations (now 4)
Valdez Terminal (2 berths, 18 tanks - 500 K bbl)
176 mainline block values, mostly remote)
Trans-Alaska Pipeline System

Traversing Three Mountain Ranges
- Atigun Pass: 4,739 feet
- Isabel Pass: 3,420 feet
- Thompson Pass: 2,812 feet
Trans-Alaska Pipeline System

Crossing 500+ Rivers & Streams
- Yukon River
- Tanana River
- 11 more aerial crossings
Trans-Alaska Pipeline System

Epically Remote Arctic Region
Limited Infrastructure
Difficult to Respond Quickly
Trans-Alaska Pipeline System

Built Across High Seismic Zones
Crosses Three Active Faults
Repeated History of M8+ Events

Valdez AK, 1964
Anchorage AK, 1964
TAPS Earthquake Engineering

Step One: Proper Seismic Design
TAPS Designed to Survive Earthquakes
Critical Equipment is Seismically Qualified

Dr. Newmark (left) and Dr. Hall (right) consulted on TAPS seismic design criteria
TAPS Earthquake Monitoring

Step Two: Seismic Monitoring & Response Planning

- Was that an earthquake?
- How big was it?
- Where was it?
- Challenge: 800 miles to monitor

- Challenge: remote system control

- Where is the impact the worst?
- Do I need to shutdown the pipeline?

- Which facilities were impacted?

- Challenge: recovering from a damaging event

- Where should I deploy responders?
- Is any equipment damaged?

- Challenge: responding to remote locations
TAPS Earthquake Monitoring

TAPS Earthquake Monitoring System

1. Field Seismic Sensors
2. Operations Control Center (OCC) Earthquake Alarms
3. Earthquake Response Management System

Useful for owners of remote infrastructure under constant control
Useful for any infrastructure owner
TAPS Earthquake Monitoring

Field Seismic Sensors
- Seismic Sensor stations installed at 11 TAPS facilities
  - Strong-Motion and Broadband borehole instruments
- Constantly monitoring for ground motion
- Partnered with UAF Alaska Earthquake Center
- Redundant communications network

Strong-Motion Sensor
Broadband Sensor
TAPS Earthquake Monitoring

OCC Earthquake Alarms

- Provides real-time alerts to OCC Controllers
- Redundant servers monitor seismic stations
- Automatic event alarms trigger in TAPS control center
  - Pre-set PGA trigger thresholds
  - Event confirmation by Alaska Earthquake Center

TAPS is operated remotely from the Operations Control Center (OCC) in Anchorage
TAPS Earthquake Monitoring

Earthquake Response Management System (EQRMS)

- Automatic earthquake alerts - email & text messaging
- Identifies facilities at risk for damage
- Guides event recovery
TAPS Earthquake Monitoring

Earthquake Event Alerts

- Automatically generated for significant earthquakes near TAPS
- Distributed to operations, emergency responders, engineering, and others

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**Email Alert**

**EQRMS Alert**
Alyeska Earthquake Monitoring System

**Earthquake Notification - ACTUAL Event - Magnitude 6.4**

An earthquake has been detected in the vicinity of TAPS. The Alyeska EQRMS system has automatically generated this message to provide you with immediate information on this event. This message is for information only.

If this event is significant enough to impact TAPS then additional messages will be transmitted regarding potential impacts to TAPS facilities and inspection priorities.

For more detail on this event please visit the [USGS Event Page](#).

**Earthquake Details**

<table>
<thead>
<tr>
<th>Map</th>
<th>ID</th>
<th>Time</th>
<th>Mag</th>
<th>Lat</th>
<th>Lon</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image_url" alt="Map Image" /></td>
<td>ak20076877</td>
<td>2018-09-12 06:58:55</td>
<td>6.4</td>
<td>69.725</td>
<td>145.136</td>
<td>73km SW of Kaktovik, Alaska</td>
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</table>

**Text Alert**

Mon, Dec 10, 12:32 PM

(1/2) EQRMS ALERT! MAG: 7 TIME: 2018-11-30 08:29:29 LAT: 61.3234 LON: -149.9234 LOCATION: 7 miles NW of Elmendorf POC_ShakeCast@alyeska-pipeline.com (2/2) AFB ID: ak20419010

[Links to USGS event page for more detail](#)
TAPS Earthquake Monitoring

Facility Impact Alerts

- 2nd alert generated if earthquake is potentially damaging
- Guides post-earthquake damage inspections
- Prioritizes response effort

Summary of Potential Impacts: MAINLINE_INTEGRITY

- Total number of facilities analyzed: 114
- Summary by impact rank:
  - High: 3
    - High impact potential
    - Conduct Inspection ASAP
  - Medium-High: 14
    - Medium-High impact potential
    - Conduct Inspection within 8 hours
  - Medium: 40
    - Medium impact potential
    - Conduct Inspection within 48 hours
  - Low: 38
    - Low impact potential
    - Conduct Inspection within 2 weeks
  - Below Threshold: 19
    - No impact potential
    - No action required

List of Potentially Impacted Facilities: MAINLINE_INTEGRITY

MAINLINE_INTEGRITY presented in the table below are sorted in order of impact potential. The list includes up to the top 200 facilities in the area of shaking. The complete list can be found in the attached file 'exposure.csv'.

<table>
<thead>
<tr>
<th>MAINLINE_INTEGRITY</th>
<th>Ep. Distance (km)</th>
<th>Impact Potential</th>
<th>PGA</th>
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<tbody>
<tr>
<td>MAINLINE_B/G - MP 800</td>
<td>156.9</td>
<td>High</td>
<td>34.32</td>
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<tr>
<td>MAINLINE_B/G - MP 760</td>
<td>123.01</td>
<td>High</td>
<td>25.28</td>
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<td>MAINLINE_B/G - MP 710</td>
<td>69.61</td>
<td>High</td>
<td>16.73</td>
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<td>MAINLINE_B/G - MP 795</td>
<td>215.69</td>
<td>Medium-High</td>
<td>22.81</td>
</tr>
</tbody>
</table>
TAPS Earthquake Monitoring

USGS ShakeMaps and ShakeCast

- Alerts generated using ShakeCast
- TAPS Facility Database includes:
  - Pipeline at 5-mile increments
  - Facilities
  - Bridges
  - Geohazards
- Fragilities based on seismic design criteria
TAPS Earthquake Response

Post-Earthquake Damage Assessments

- Rapid Assessment – Completed immediately by onsite personnel
- Detailed Assessment – In-depth inspection by engineering team
- Base on ATC-20 procedure
- Inspection checklists pre-deployed to each facility
TAPS Earthquake Response

Rapid Damage Assessments

- Focus on building safety and process safety
TAPS Earthquake Response

Detailed Damage Assessments

- Methodical inspection of structures and equipment
- Looking for minor damage requiring repair

![Post-Earthquake Field Review Checklist](image-url)
Earthquake Response Scenario

2018 M7.1 Anchorage Earthquake

- Earthquake detected at multiple seismic stations
- PGA at pipeline below threshold for OCC Alarm – pipeline shutdown as precaution
- EQRMS issued alerts within 5 minutes of event
- Rapid damage assessments and mainline survey completed
- Impacted facilities assessed prior for damage
- Pipeline restarted after 8 hours
TAPS Earthquake Monitoring

- Field Seismic Sensors
- Control System Earthquake Alarms
- Earthquake Response Management System
  - Automatic Alerts
  - Damage Assessment Checklists
Avoiding/Reducing Shutdown Impacts

Recommendations for Infrastructure Owners

- Planning is critical minimizing impacts of an earthquake
- Understand requirements for ‘return-to-service’
- Plan for the low and medium-impact events; not just the high-impact
- Build redundancy into response planning
- Use ShakeCast to obtain rapid situational awareness
- Build a relationship with the operator of your regional seismic network
- Earthquake monitoring is not a substitute for good design – build it right the first time
Earthquake Monitoring
Trans-Alaska Pipeline System (TAPS)

Thanks!
Earthquake Monitoring
Trans-Alaska Pipeline System (TAPS)

References:


