

**3/22/11  
PRESENTATION  
ALASKA  
TSUNAMI  
MODELING AND  
EMERGENCY  
PREPAREDNESS**

<TARGET><BILL></BILL><SUBJECT>3-22-11 PRESENTATION  
ALASKA TSUNAMI MODELING AND EMERGENCY  
PREPAREDNESS</SUBJECT><COMM>SCRA27</COMM></TARGET>

## EARTHQUAKE BREIFING

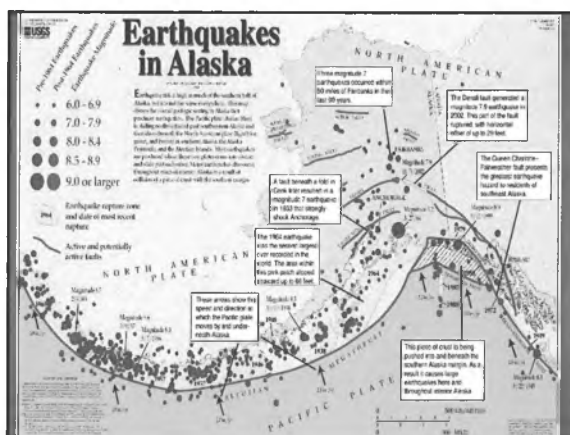
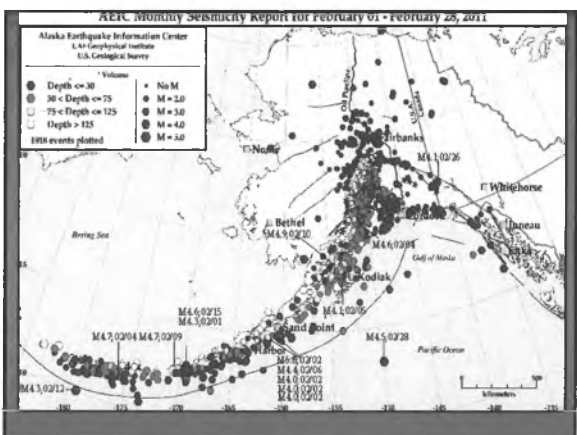
Dr. John L. Ahoc, Ph.D., Sc.D.  
March 22, 2011



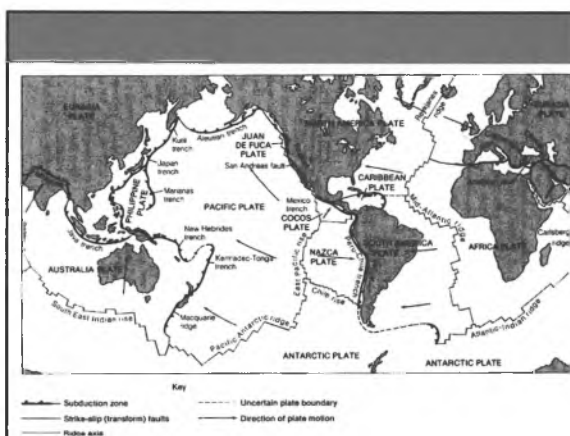
**Presentation to: Alaska Senate Community and Regional Affairs Committee**

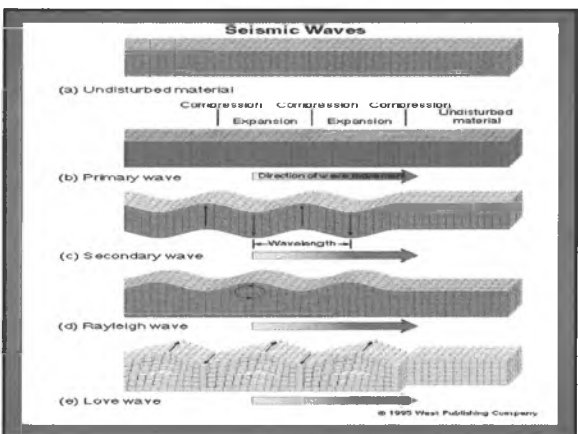
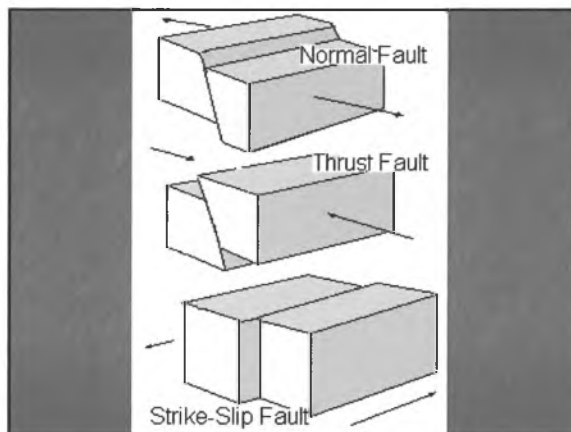
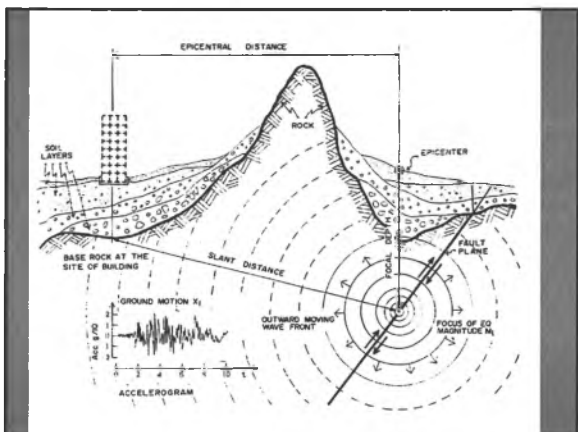
## DISCUSSION TOPICS

- Terms and Facts
- Damage Causes
- Research Projects
- Alaska Seismic Hazards Safety Commission
- Questions (with possible answers)



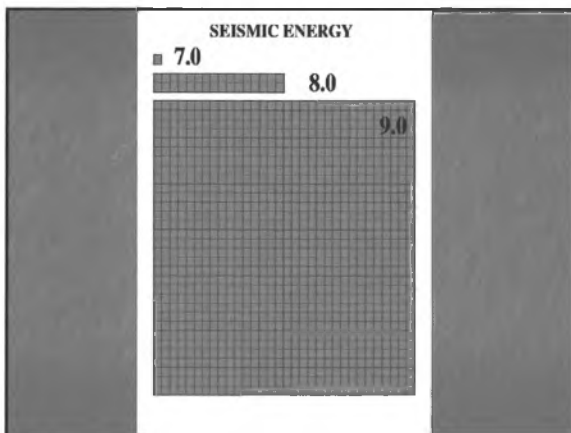
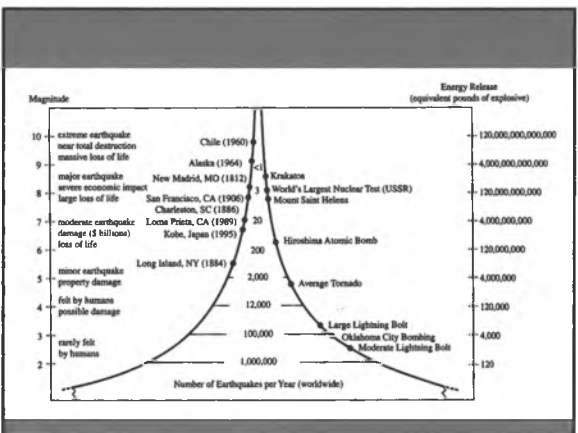
## Earthquake Terms and Facts

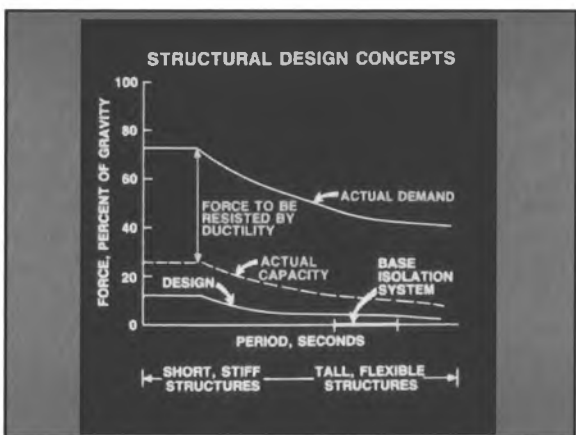
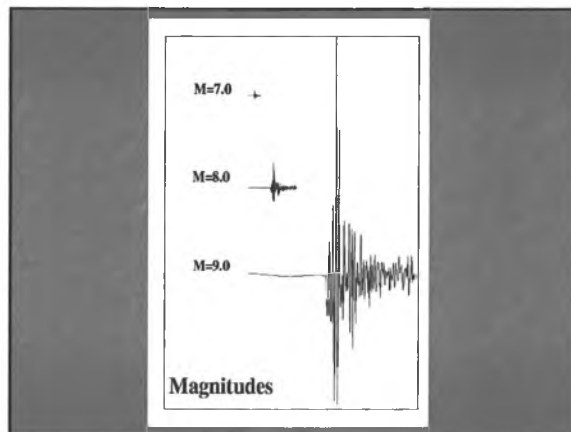
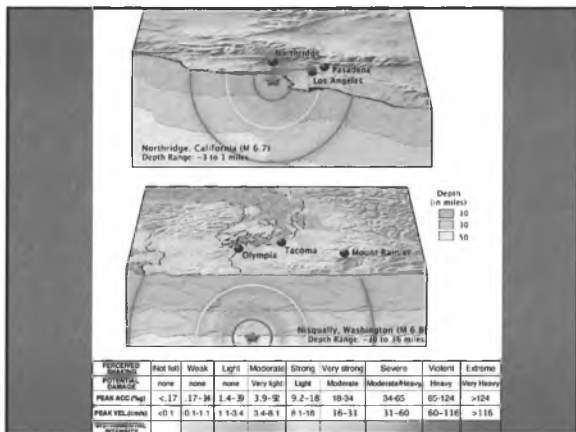




### Hazard vs Risk

- Seismic Hazard
  - The expected occurrence of a future seismic event
- Seismic Risk
  - The expected consequences of a future seismic event





### Cause of Damage

- Tsunami
- Ground Failure
- Ground Rupture
- Ground Shaking



### Ground Failure

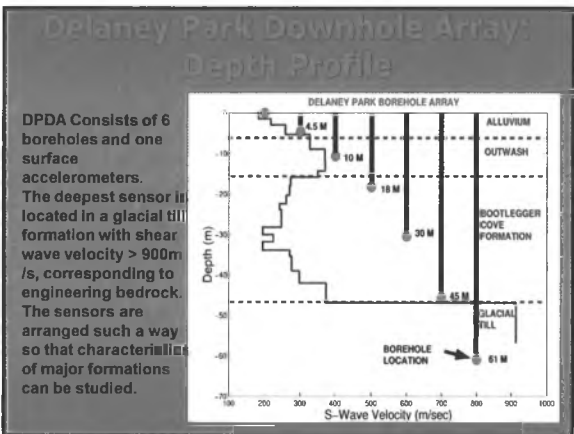
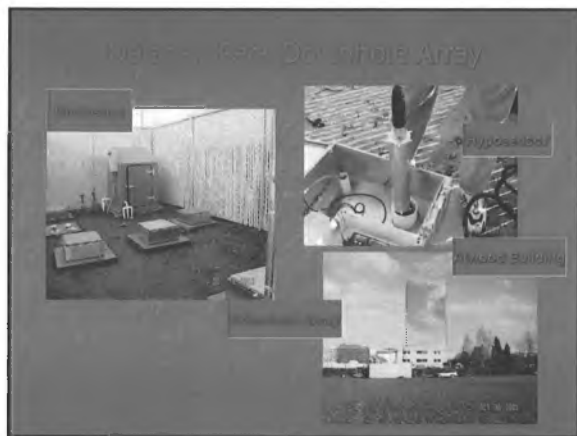


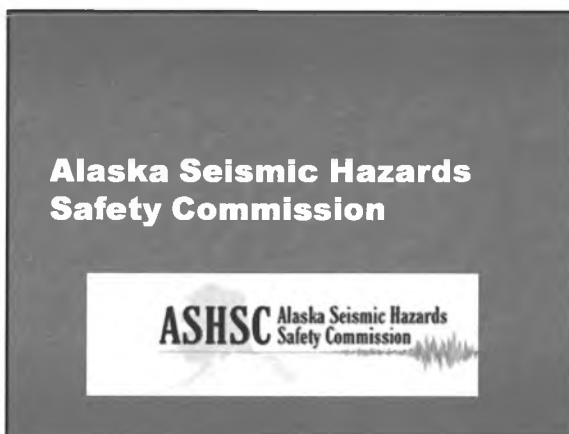
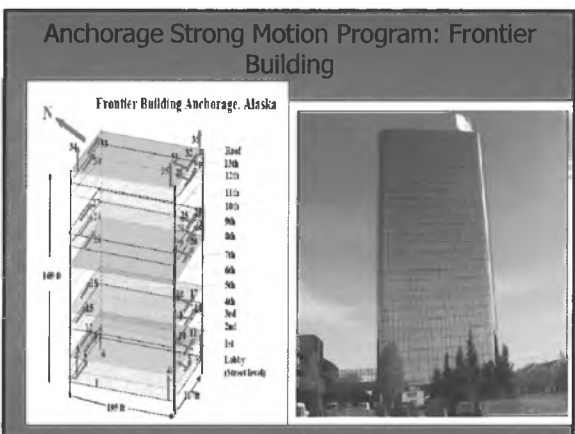
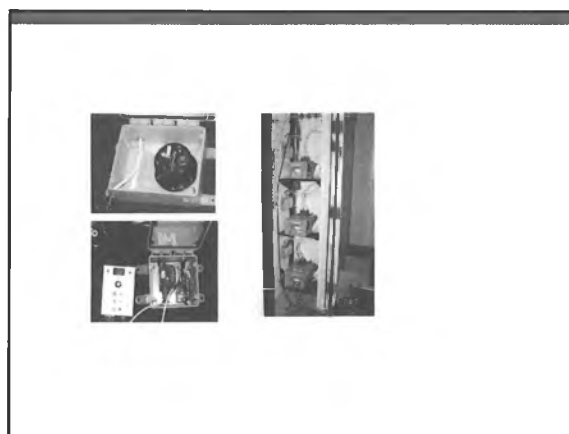
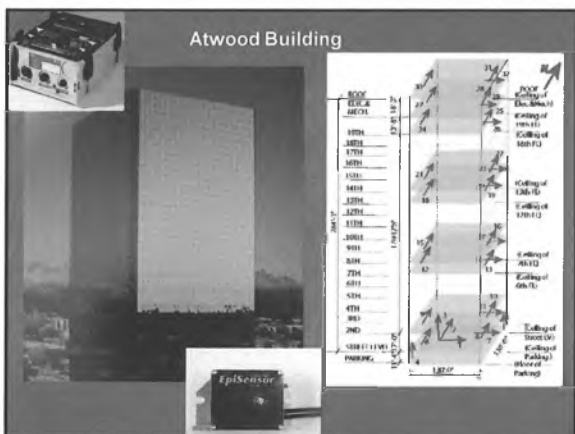
### Liquefaction



### Ground Shaking







### Membership

- **Dr. John L. Aho, Chair**
- **Laura Kelly, P.E., Vice-chair**
- **Dan Mahalak**
- **Dr. Roger Hansen,**
- **Dr. Gary Carver**
- **Rich Koehler**
- **Gayle White**
- **Gay Dunham**
- **Dave Miller**
- **Mark Roberts**

ASHSC Alaska Seismic Hazards Safety Commission

### Powers & Duties

1. Recommend seismic risk mitigation goals & priorities
2. Recommend needed research, mapping, and monitoring programs
3. Offer advice on coordinating disaster preparedness
4. Review practices for recovery & reconstruction
5. Recommend improvements to mitigate losses from future events
6. Gather, analyze, & disseminate information
7. Establish working relationships with public and private agencies
8. Review warnings & suggest appropriate responses
9. Review proposed seismic notifications
10. Recommend issuance of notifications
11. Give appropriate response advice

ASHSC Alaska Seismic Hazards Safety Commission



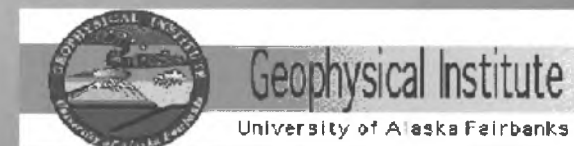
# **ALASKA TSUNAMI MODELING & EMERGENCY PREPAREDNESS**

**Mike O'Hare**  
Deputy Director

**State of Alaska**  
**Division of Homeland Security and Emergency Management**

Testimony to House/Senate C&RA      March 22, 2011

# Our Partners



# Distant Threat



**TSUNAMI HAZARD  
 BY COMMUNITY  
 (DISTANT SOURCES ONLY)**

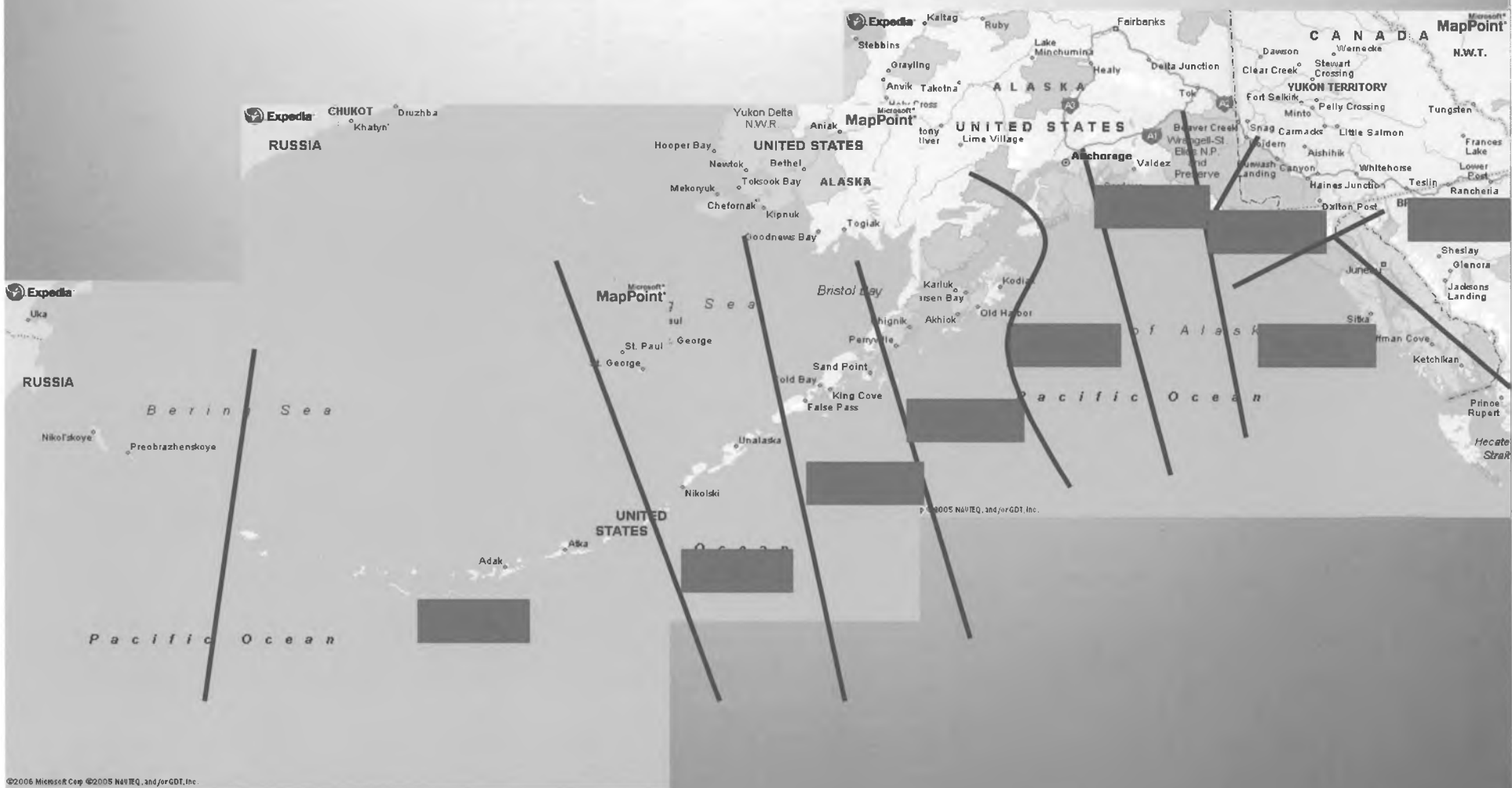
- High
- Moderate
- Low
- None or negligible







# Community Notification Call Map



**Zone B Includes:**

Nikolski: 907-576-2204/2202/2239

Contacted: \_\_\_\_\_

St. Paul: 907-546-3130/3132

Contacted: \_\_\_\_\_

St. George: 907-859-2263/2418/2415

Contacted: \_\_\_\_\_

Unalaska / Dutch Harbor: 907-581-1233

Contacted: \_\_\_\_\_



B e r i n g S e a

Bristol Bay

Gulf of Alaska

P a c i f i c O c e a n

**Zone A**

Previous Page

**Zone B**

**Zone C**

Next Page

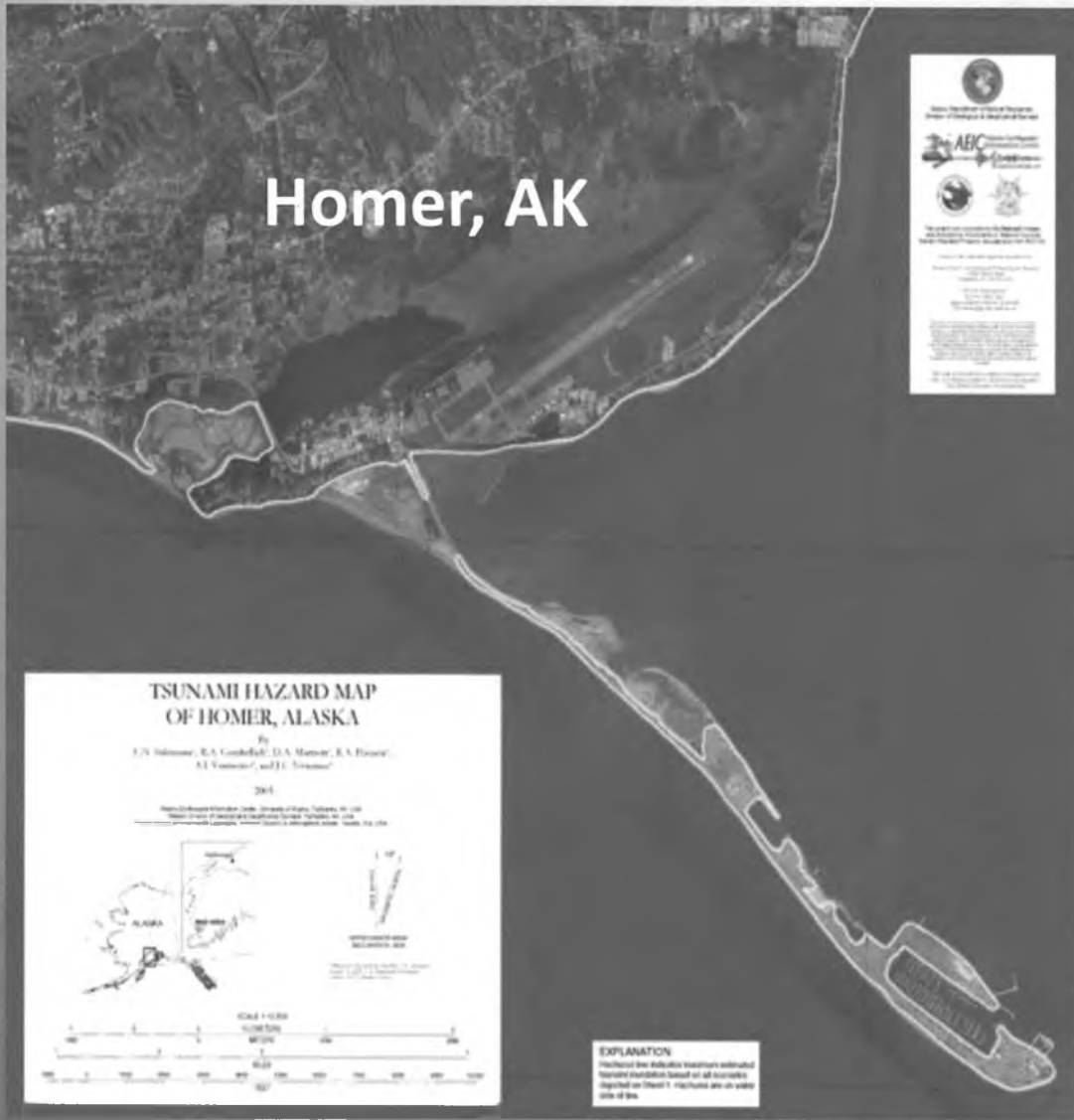
**TSUNAMI NOTIFICATION CALL**



# Inundation Maps UAF / GI



Geophysical Institute  
University of Alaska Fairbanks



# Hazard Mapping



**AK DGGS**

# Warning Sirens

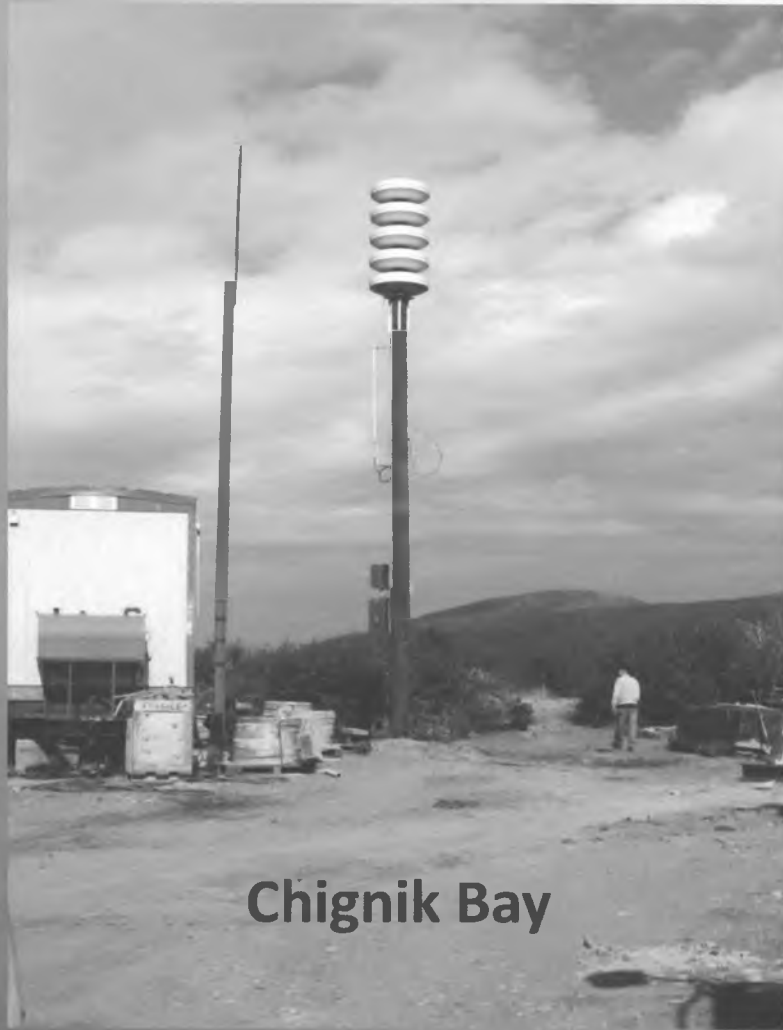


**King Cove**



**Sand Point**

# Warning Sirens



**Chignik Bay**

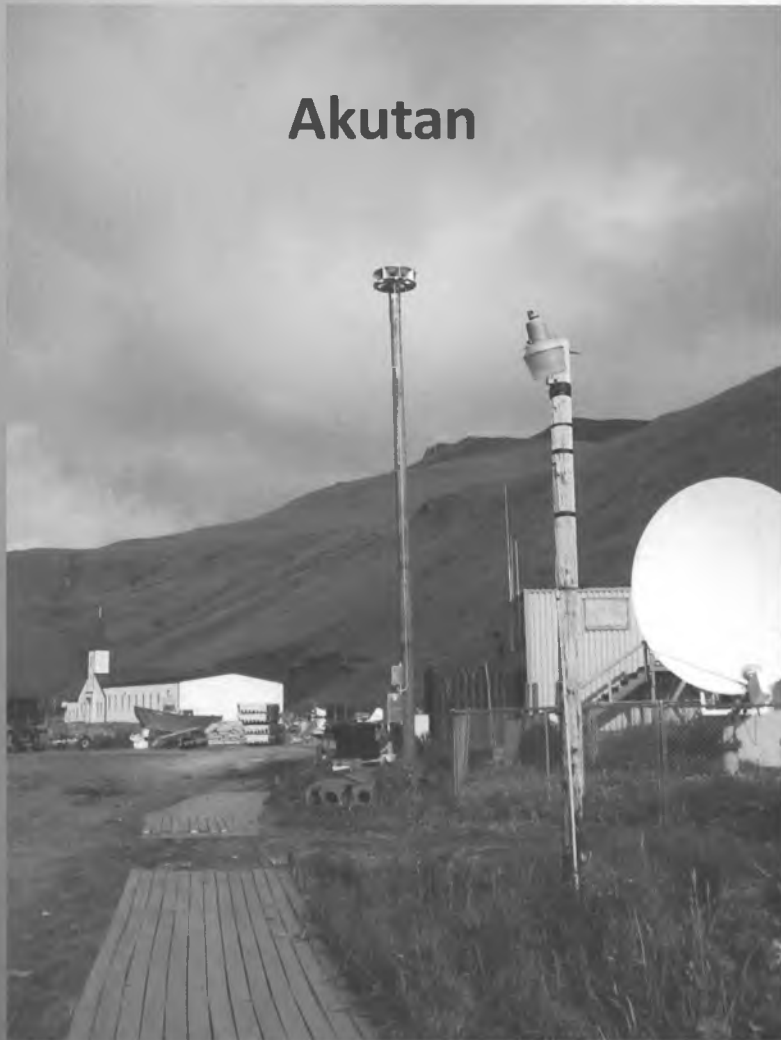


**Perryville**

# Warning Sirens



## Akutan



## Ouzinkie



# Warning Sirens



**Atka**

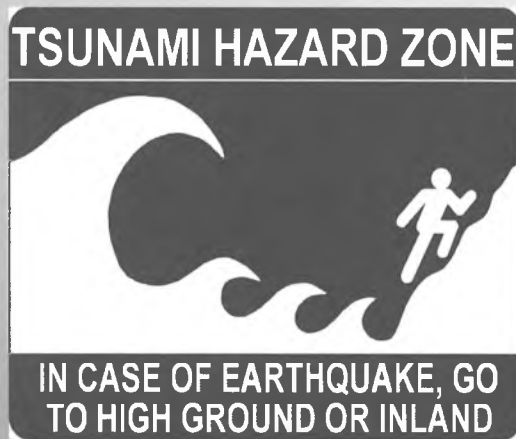


**Nikolski**



## Kenai Peninsula Borough Mobile Siren

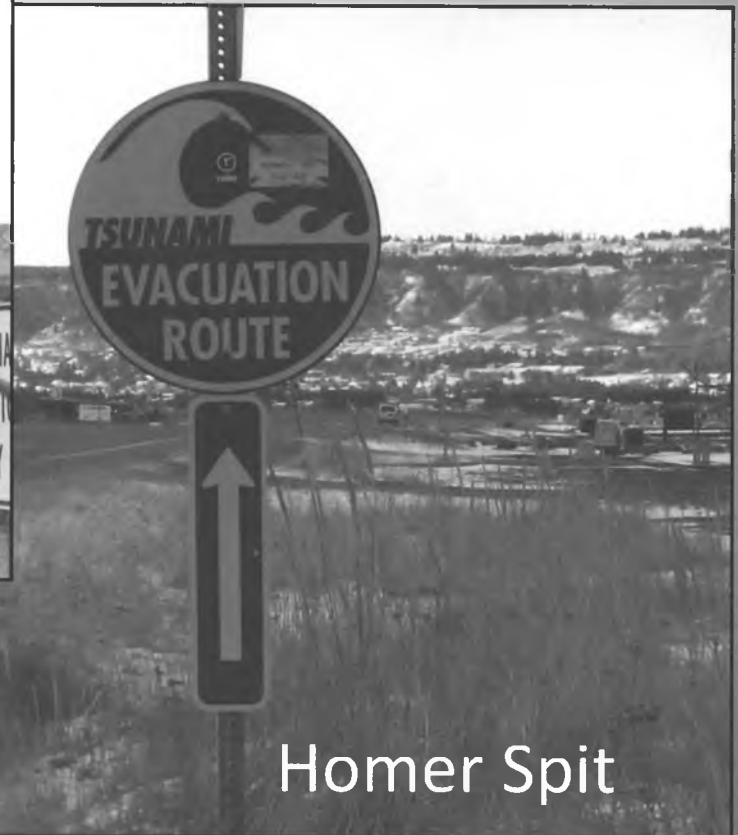
# Tsunami Sign Program



# Tsunami Signs



Homer Terminal



Homer Spit

# Tsunami Signs



Sand Point Harbor

# Outreach and Education



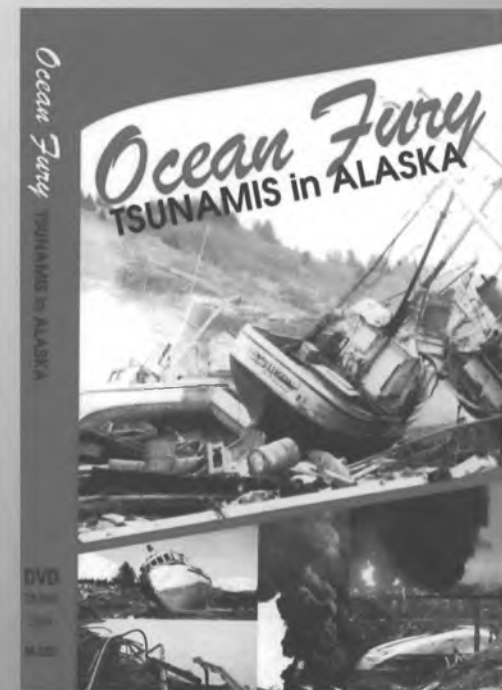
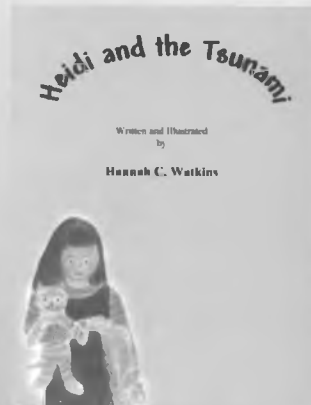
## “Quake Cabin”

- Quake Cabin increases tsunami and earthquake focused outreach initiatives throughout Alaska
- Distribute outreach materials
- Teach mitigation methods
- Simulates 5.0 magnitude
- Used at public and private events
- Schools & businesses
- State fairs & safety events





# Outreach Products





*An educated and aware public  
with a plan of action will have  
the ability to adapt to the  
situation and respond  
accordingly.*



# Valdez 1964



State of

Alaska

Department of Military  
and Veterans Affairs

Homeland Security &  
Emergency Management



# Hazards / Threats



- Earthquakes
- Floods
- Volcanoes
- HAZMAT
- Severe Storms
- Tsunamis
- Wildland Fires
- Avalanches
- Terrorism
- Pandemic Flu
- Other

# Partnerships



## Local Communities

### State of Alaska

Department of Military and Veterans Affairs  
Alaska National Guard  
Division of Homeland Security and  
Emergency Management  
Department of Public Safety  
Alaska State Troopers  
Department of Health and Social Services  
Department of Environmental Conservation  
Department of Transportation  
Port of Anchorage  
Department of Corrections  
UAF Unmanned Aerial Systems  
Alaska Railroad

### Other Organizations

AK Partnership for Infrastructure Protection (APIP)  
Amateur Radio Emergency Services (ARES)  
Civil Air Patrol  
American Red Cross

### Alaska-Based DOD

Joint Task Force – Alaska (JTF-AK)  
Alaskan NORAD Region (ANR)  
US Army Alaska (USARAK)  
US Army Garrison Alaska (USAG-AK)  
US Army Garrison Ft Wainwright (USAG-FWA)  
Bassett Army Community Hospital (BACH)  
US Army Garrison Ft Greely (USAG-FGA)  
3rd Wing (3WG)  
US Army Corps of Engineers – Alaska (USACE-AK)

### External DOD

FEMA Region 10 DCE

### Other Federal

Department of Homeland Security  
USCG District 17  
FEMA Region 10  
TSA  
Department of Justice  
US Attorney  
Department of Transportation  
FAA

State of  
**Alaska**  
Department of Military  
and Veterans Affairs  
Homeland Security &  
Emergency Management



Questions?

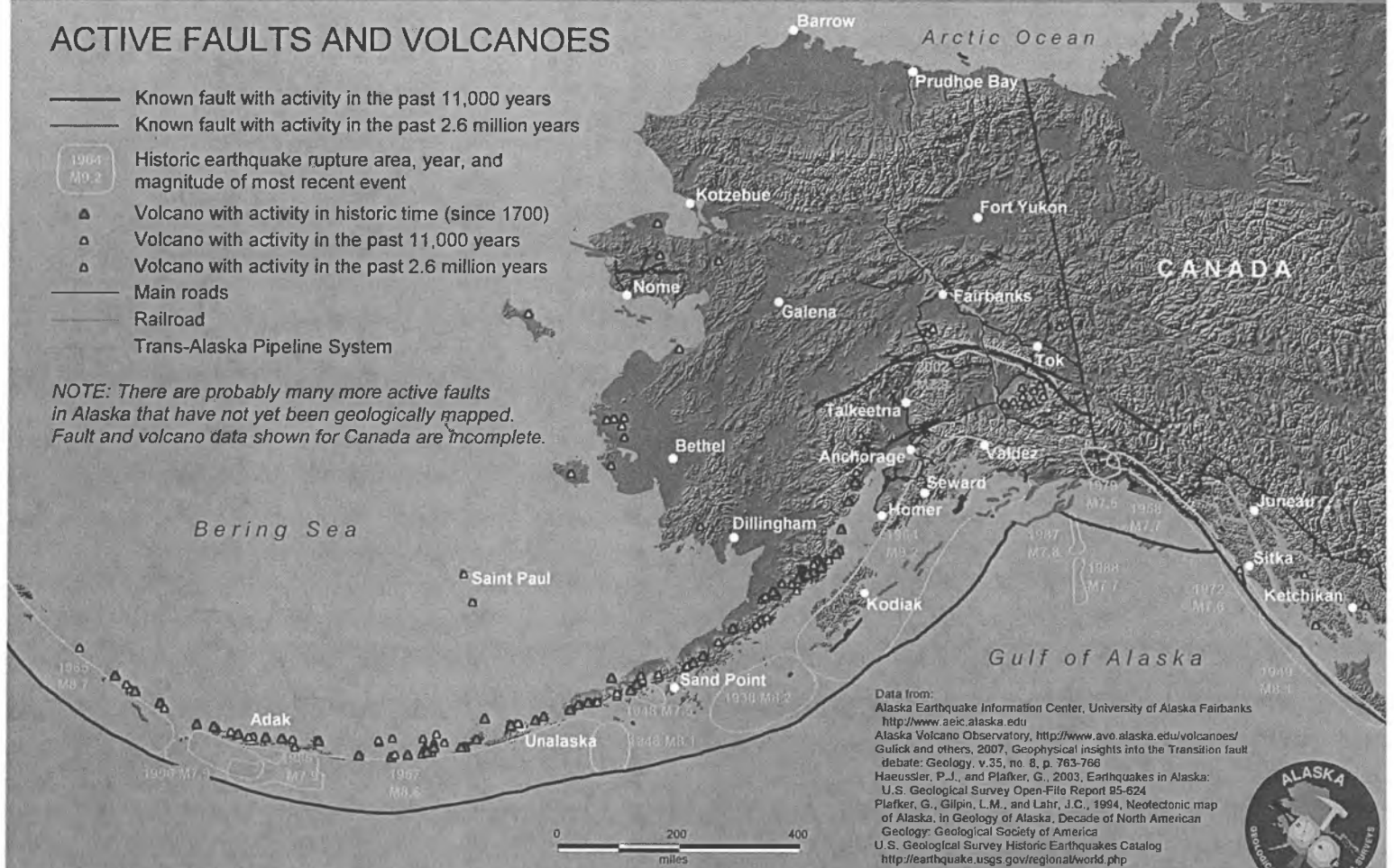
[www.ready.alaska.gov](http://www.ready.alaska.gov)

# ALASKA

## ACTIVE FAULTS AND VOLCANOES

- Known fault with activity in the past 11,000 years
- Known fault with activity in the past 2.6 million years
- 1964 M9.2  
Historic earthquake rupture area, year, and magnitude of most recent event
- ▲ Volcano with activity in historic time (since 1700)
- △ Volcano with activity in the past 11,000 years
- △ Volcano with activity in the past 2.6 million years
- Main roads
- Railroad
- Trans-Alaska Pipeline System

NOTE: There are probably many more active faults in Alaska that have not yet been geologically mapped. Fault and volcano data shown for Canada are incomplete.



Data from:  
 Alaska Earthquake Information Center, University of Alaska Fairbanks  
<http://www.aEIC.alaska.edu>  
 Alaska Volcano Observatory, <http://www.avo.alaska.edu/volcanoes/>  
 Gulick and others, 2007, Geophysical insights into the Transition fault debate: Geology, v.35, no. 8, p. 763-766  
 Haessler, P.J., and Plafker, G., 2003, Earthquakes in Alaska: U.S. Geological Survey Open-File Report 03-624  
 Plafker, G., Gilpin, L.M., and Lahr, J.C., 1994, Neotectonic map of Alaska, in Geology of Alaska, Decade of North American Geology: Geological Society of America  
 U.S. Geological Survey Historic Earthquakes Catalog  
<http://earthquake.usgs.gov/regional/world.php>



Division of Geological & Geophysical Surveys

## ACTIVE FAULTS AND VOLCANOES IN ALASKA

Eleven percent of the world's recorded earthquakes have occurred in Alaska, including seven of the ten largest in the United States and three of the ten largest in the world. About 2,000 earthquakes are recorded in Alaska every month.

Since 1900, Alaska has had an average of:

- A "great" earthquake (magnitude 8 or larger) every 13 to 15 years
- A magnitude 7 to 8 earthquake every 1 to 2 years
- About 6 magnitude 6 to 7 earthquakes per year
- About 50 magnitude 5 to 6 earthquakes per year
- About 340 magnitude 4 to 5 earthquakes per year

This map shows faults that have been active in historic time or show geologic evidence of activity during the past 11,000 years (Holocene), and faults that show evidence of activity during approximately the preceding 2.6 million years (Pleistocene). Rupture area boundaries delineate the approximate extent of the initial epicenter and aftershocks of large earthquakes recorded since 1900. Considering the high rate of seismicity in Alaska, with earthquakes occurring in most areas of the state, there are probably many more active faults that have not yet been geologically mapped.

Alaska has more than 50 volcanoes that have been active during historic time (since about 1700). These volcanoes in Alaska make up well over three-quarters of U.S. volcanoes that have erupted in the past two hundred years. An additional ~90 volcanoes in Alaska show evidence of activity during the Holocene or Pleistocene epochs.

DGGS- and University of Alaska-affiliated web sites about earthquake and volcano hazards in Alaska:

**Alaska Seismic Hazards Safety Commission**  
<http://seismic.alaska.gov>

**Alaska Volcano Observatory**  
<http://avo.alaska.edu>

**Alaska Earthquake Information Center**  
<http://www.aeic.alaska.edu>



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Map and graphics by Rod Combellick, revised October 2010



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# TSUNAMI INUNDATION MAPS OF SEWARD AND NORTHERN RESURRECTION BAY, ALASKA

by

E.N. Suleimani, D.J. Nicolsky, D.A. West, R.A. Combellick, and R.A. Hansen



**Published by**  
STATE OF ALASKA

DEPARTMENT OF NATURAL RESOURCES  
DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS  
2010



# **Report of Investigations 2010-1**

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by

E.N. Suleimani, D.J. Nicolsky, D.A. West, R.A. Combellick, and R.A. Hansen

2010

This DGGS Report of Investigations is a final report of scientific research.  
It has received technical review and may be cited as an agency publication.



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# Tsunami inundation maps of Seward and northern Resurrection Bay, Alaska

by

E.N. Suleimani<sup>1</sup>, D.J. Nicolsky<sup>1</sup>, D.A. West<sup>1</sup>, R.A. Combellick<sup>2</sup>, and R.A. Hansen<sup>1</sup>

## Abstract

The purpose of this study is to evaluate tsunami hazard for the community of Seward and northern Resurrection Bay area, Alaska. This report will provide guidance to local emergency managers in tsunami hazard assessment. We used a numerical modeling method to estimate the extent of inundation by tsunami waves generated from earthquake and landslide sources. Our tsunami scenarios included a repeat of the tsunami of the 1964 Great Alaska Earthquake, as well as tsunami waves generated by two hypothetical Yakataga Gap earthquakes in northeastern Gulf of Alaska, hypothetical earthquakes in Prince William Sound and Kodiak asperities of the 1964 rupture, and local underwater landslides in Resurrection Bay. Results of numerical modeling combined with historical observations in the region are intended to help local emergency officials with evacuation planning and public education for reducing future tsunami risk.

## INTRODUCTION

Alaska has the greatest earthquake and tsunami potential among the U.S. states. Figure 1 shows one of the most seismically active regions of the state, where the Pacific Plate is subducting under the North American Plate. This subduction zone, known as the Alaska–Aleutian megathrust zone, makes the adjacent coastal areas especially hazardous with regard to tsunami exposure. The coseismic crustal movements that characterize this area have a high potential for producing vertical sea floor displacements, which are highly tsunamigenic. Historic tsunamis that were generated by earthquakes on the Alaska–Aleutian subduction zone have resulted in widespread damage and loss of life along the Alaskan Pacific coast and other exposed locations around the Pacific Ocean. Large seismic events occurring in the vicinity of the Alaska Peninsula, Aleutian Islands, and Gulf of Alaska have a very high potential for generating both local and Pacific-wide tsunamis. Tsunamis originating in Alaska can travel across the Pacific Ocean and impact coastal areas hours after they are generated. However, these waves are considered to be a near-field hazard for Alaska, and can reach Alaskan coastal communities within minutes of the earthquake. Therefore, saving lives and property depends on how well a community is prepared, which makes it essential to estimate the potential flooding of the coastal zone in the case of a local or distant tsunami.

On March 27, 1964, the Prince William Sound area of Alaska was struck by the largest earthquake ever recorded in North America. This magnitude  $M_w 9.2$  megathrust earthquake generated the most destructive historic tsunami in Alaska and, farther south, impacted

the west coast of the United States and Canada. Of the 131 fatalities associated with this earthquake, 122 were caused by tsunami waves (Lander, 1996). Although tragic, the number of deaths was fortunately far smaller than in the case of the 2004 Indian Ocean tsunami due to low population density on the Alaska coast. In addition to the major tectonic tsunami that was generated by displacement of the ocean floor between the trench and the coastline, more than 20 local tsunamis were generated by submarine and subaerial landslides in coastal Alaska. Local tsunamis caused most of the damage and accounted for 76 percent of tsunami fatalities. Also, they arrived almost immediately after the shaking was felt, leaving no time for warning or evacuation. The community of Seward in Resurrection Bay (fig. 2) suffered from the combined effects of local landslide-generated waves and the major tectonic tsunami that propagated from the main earthquake rupture zone in the Gulf of Alaska. The earthquake triggered a series of slope failures offshore of Seward, which resulted in landsliding of part of the coastline into the water, along with the loss of the port facilities. The town sustained great damage, and 12 people perished due to the tsunamis. During a future earthquake, underwater slides could be triggered almost instantaneously and tsunami waves could arrive without warning, as they did in 1964. Local tsunamis were responsible for most of the damage in Seward during the 1964 earthquake, thus the future potential of similar events must be evaluated for comprehensive inundation mapping.

To help mitigate the risk that earthquakes and tsunamis pose to Alaska coastal communities, the Alaska

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Tsunami Mapping Team (ATMT) was created. It consists of personnel with the Geophysical Institute (GI) of the University of Alaska Fairbanks and the Alaska Division of Geological & Geophysical Surveys (DGGs). The ATMT participates in the National Tsunami Hazard Mitigation Program (NTHMP) by evaluating and mapping potential inundation of selected parts of the Alaska coastline using numerical modeling of tsunami wave dynamics. The communities are selected for inundation modeling in coordination with the Alaska Division of Homeland Security and Emergency Management (DHSEM) with consideration for location, infrastructure, availability and quality of bathymetric and topographic data, and community involvement.

The production of tsunami evacuation maps consists of several stages. First, we construct hypothetical tsunami scenarios on the basis of the parameters of potential underwater earthquakes and landslides. Next, we perform model simulations for each of the source scenarios. The results are compared with any observations from historical tsunamis in the region, if such data exist. Finally, numerical results and historical observations are combined to develop a realistic “worst case” inundation

line for every community on a map. This inundation line encompasses the maximum extent of flooding based on model simulations of all source scenarios and historical observations, and becomes a basis for local tsunami hazard planning and creation of evacuation maps.

The Seward and Resurrection Bay tsunami inundation maps described in this report represent the results of the ongoing effort of state and federal agencies to produce inundation maps for many Alaska coastal communities.

In this report, we generally provide both metric and English units of measure. However, where we quote existing data, we report the data in the original units of measure without conversion. To convert kilometers to miles, multiply by 0.6214.

## PROJECT BACKGROUND: REGIONAL AND HISTORICAL CONTEXT

### SETTING

The town of Seward is near the northwestern corner of Resurrection Bay, about 200 km south of Anchorage (fig. 2). During the construction of the Alaska Railroad

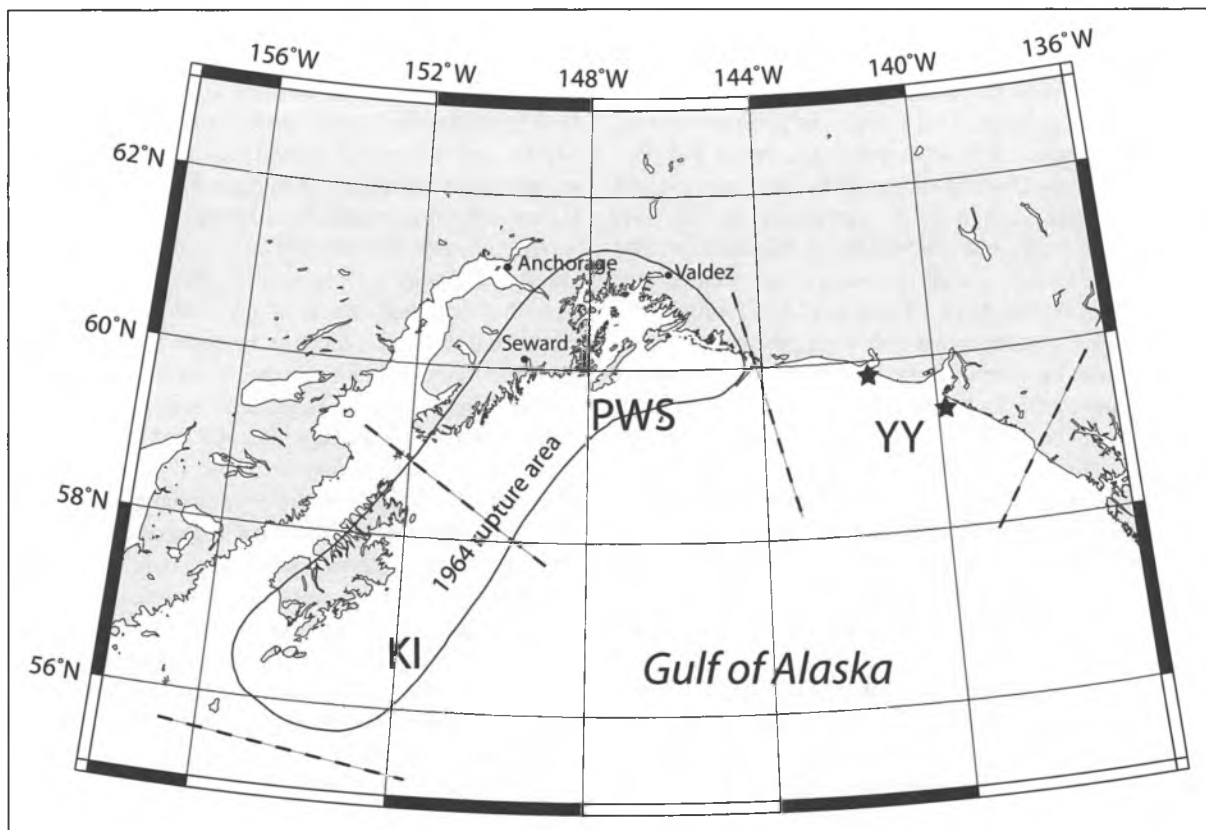


Figure 1. Map of southcentral Alaska with rupture zone of the 1964 Great Alaska Earthquake and segments of the Alaska-Aleutian megathrust: the Prince William Sound (PWS), the Kodiak Island (KI) and the Yakutat-Yakutat (YY) segments. Stars indicate epicenters of two earthquakes of September 1899.

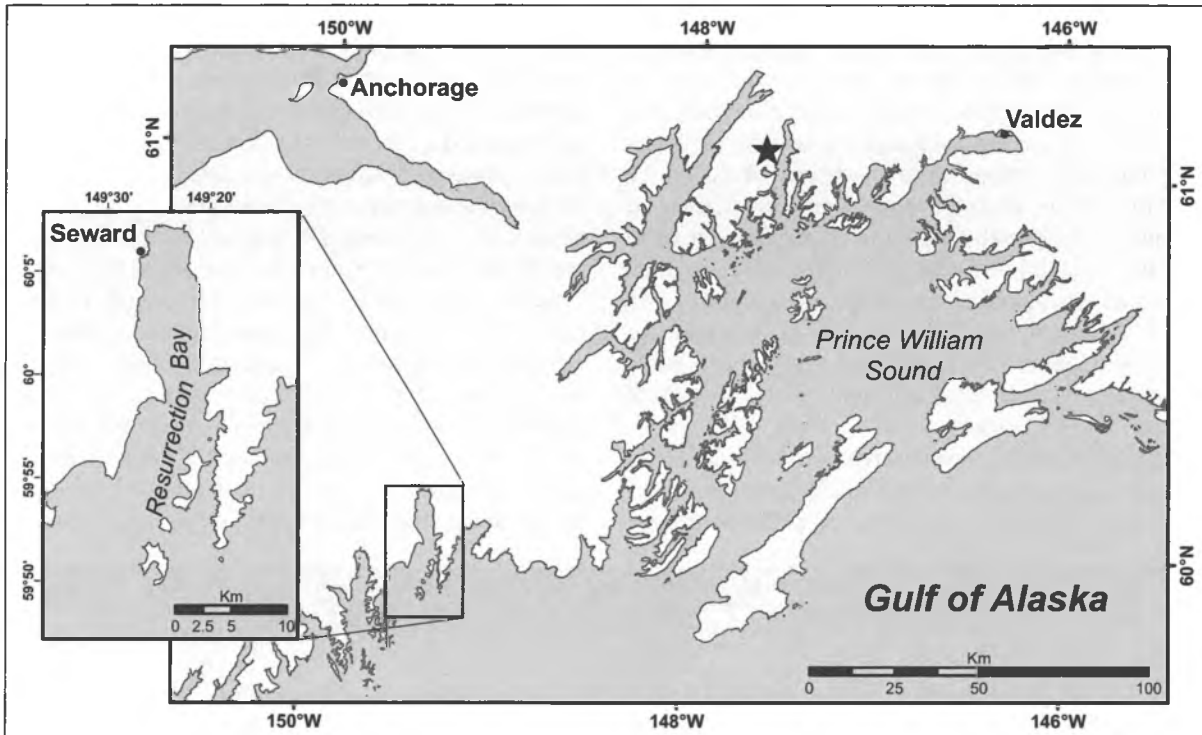


Figure 2. Location of Seward in Resurrection Bay. Star indicates initial epicenter of the 1964 Great Alaska Earthquake.

between 1915 and 1923, Seward became an ocean terminus and supply center for interior Alaska. The economy of Seward has long been dominated by transportation and supply services. At the time of the 1964 earthquake, the economy of Seward was based on shipping, and was heavily dependent on the city's railroad, harbor, and port operations. Seward was severely impacted by the 1964 earthquake and tsunami waves. The loss of harbor facilities from the earthquake and resultant offshore slope failures near the Seward waterfront devastated the economic base of the town (Lemke, 1967).

Seward has grown considerably since the 1964 earthquake. Its economy is more diversified and includes tourism, commercial fishing, and fish processing, as well as oil and gas development. Still, much of the economic activity and infrastructure is located on or near the coast, ports, and harbors. As an ice-free harbor, Seward is an important supply center for Interior Alaska and a port for the state ferry system. Every year, more than 320,000 cruise ship passengers visit the port city (Alaska Division of Community Advocacy, 2005). Figure 3 presents a sequence of Seward photos, taken before and after the 1964 tsunami, and then recently, in 2005. The red line indicates the maximum extent of inundation caused by the 1964 tsunami waves. The bottom image makes it clear that much of the economic and industrial base has been rebuilt in the area inundated by the 1964 tsunami.

Seward is built mostly on the alluvial fan of Lowell Creek. Lowell Point, Tonsina Point, and the area at the

mouth of Fourth of July Creek (fig. 4) are also alluvial fans that extend into the bay as fan deltas (Lemke, 1967). The entire head of Resurrection Bay is a fjord-head delta, formed by Resurrection River. Haeussler and others (2007) use the term 'bathtub' to describe a flat depression in the middle of the bay extending north to south (fig. 4). The deepest part of the bathtub is approximately 300 m below sea level. Prior to the 1964 earthquake, the average offshore slopes in the vicinity of Seward ranged from 10 to 20 degrees, decreasing to 5 degrees at the depth of about 200 m (Lemke, 1967). Today, that same area has an average slope of about 25 degrees (Lee and others, 2006). A natural barrier formed by Caines Head and a glacial sill divide the bay into two deep basins, separated by a narrow 'neck' with maximum depth above the sill at 195 m. This sill inhibits sediment transport by tidal currents to the southern part of the bay (Haeussler and others, 2007). Our study focuses on the northern basin of Resurrection Bay, north of the sill area (fig. 4).

### TSUNAMI WAVES IN RESURRECTION BAY, ALASKA, ON MARCH 27, 1964

The  $M_w$ 9.2 Alaska earthquake of March 27, 1964, at Seward was characterized by strong ground motion that lasted 3–4 minutes. During the shaking, a section of the waterfront slid into the bay, taking with it docks and other harbor facilities. At the same time, fuel tanks fractured and oil ignited. Both local, landslide-generated waves

and distant, tectonically generated waves inundated the Seward shoreline and caused tremendous damage (Lemke, 1967). Damage from the strong ground motion alone was minor compared to tsunami-related destruction. As a result of regional tectonic deformation, the Resurrection Bay area subsided about 3.5 feet (1.1 m), which resulted in low-lying coastal areas being inundated at high tide. Thirteen people were killed and five injured in Seward as a combined result of the earthquake and tsunami waves. Eighty-six houses were totally destroyed and 269 were heavily damaged. According to Lemke (1967), the total cost to repair public and private facilities was estimated at \$22 million (\$153 million in 2009 dollars).

Several types of waves were observed in Resurrection Bay on March 27, 1964: landslide-generated waves, a tectonic tsunami wave train, and probably seiches

(Wilson and Tørum, 1968), all resulting in a complicated wave pattern. The Seward tide gauge was positioned on a dock that collapsed into the bay as a result of massive submarine slope failures. The instrument was heavily damaged, and the record was lost. Although the sequence of waves was reconstructed from observations provided by eyewitnesses, there are uncertainties in the time estimates of wave arrivals (Wilson and Tørum, 1968). An initial drawdown of water was observed at the Seward waterfront about 30 seconds after the ground started to shake. At the same time, fuel tanks ruptured, leaked, and subsequently exploded; the tanks slid into the bay, and the receding water was covered with burning oil. The highest wave at Seward was about 6–8 m high, observed about 1.5–2 minutes after the shaking began. The tectonic tsunami wave, covered with burning oil, came into the bay about 25 minutes after the earthquake, spanning



*Figure 3. Imagery of downtown Seward: top – aerial photo taken before the earthquake of March 27, 1964 (photo by the U.S. Army Corps of Engineers, mosaic by the USGS); middle – aerial photo taken one day after the earthquake of March 27, 1964 (photo by the U.S. Army Corps of Engineers, mosaic by the USGS); bottom – a recent satellite image of Seward (Digital Globe, 2005). Red line indicates the maximum extent of inundation caused by the 1964 tsunami waves.*

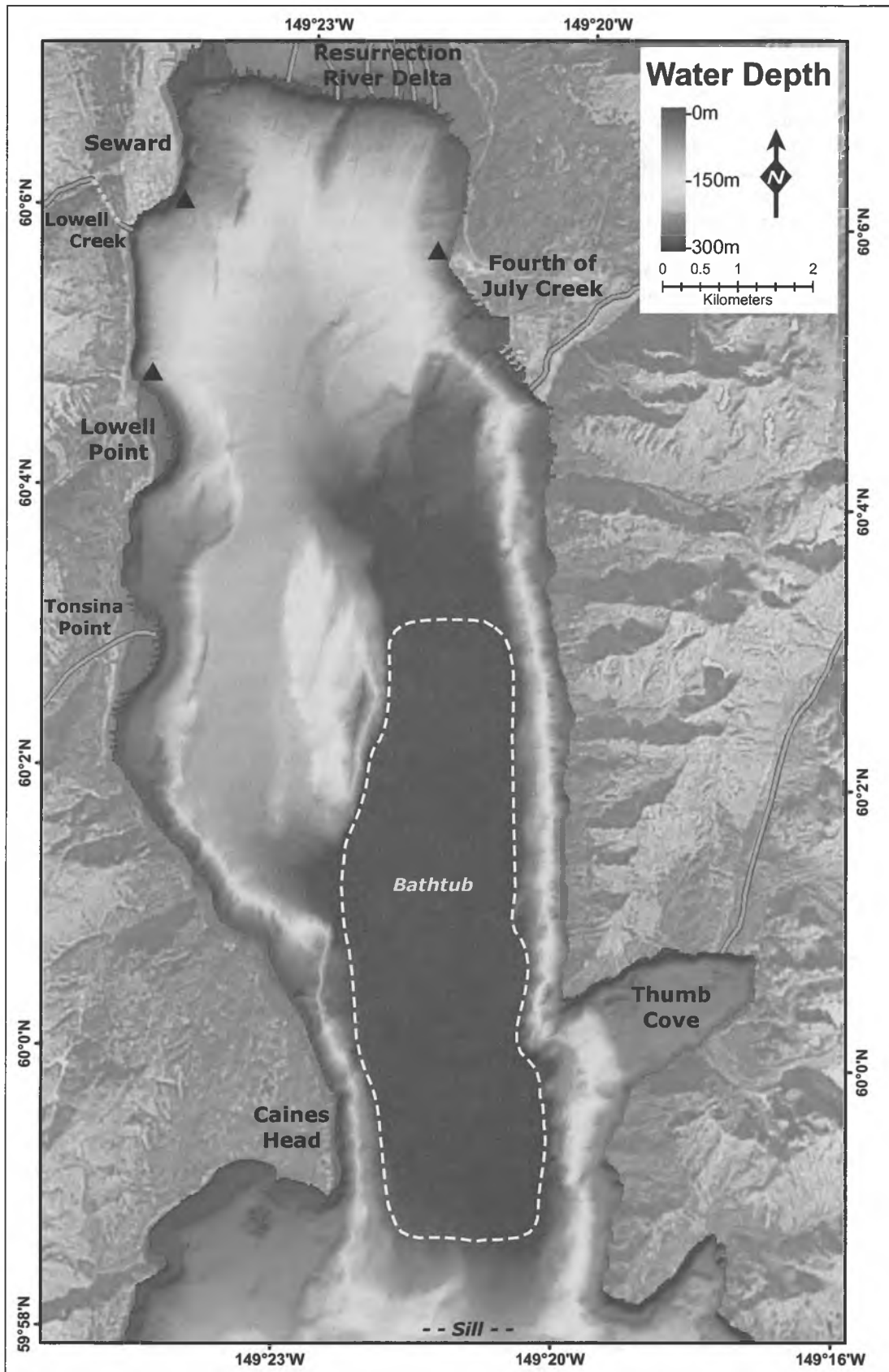


Figure 4. Bathymetry of Resurrection Bay, showing major fan deltas and creeks.

the entire width of the bay (Wilson and Tørum, 1968). This wave was similar in height to the initial landslide-generated waves but extended farther inland toward the river delta at the head of the bay than the local waves. Lemke (1967) summarized results of geologic investigations that were conducted in the Resurrection Bay area following the earthquake, and delineated the maximum observed tsunami inundation in downtown Seward and at the head of Resurrection Bay (fig. 5). The maximum inundation line at the city of Seward represents the combined effects from both the local landslide-generated waves and the major tectonic tsunami, while the observations of maximum runup at the head of the bay delineate the area that was flooded only by seismically generated waves.

Several researchers conducted geologic investigations in the Resurrection Bay area right after the earthquake (Lemke, 1967; Wilson and Tørum, 1968; Plafker and others, 1969; Shannon and Hilts, 1973). From these studies, it was concluded that strong ground motion during the earthquake caused several submarine slope failures along the Seward waterfront and other areas in upper Resurrection Bay. Hampton and others (2002) described the triggering mechanism as dynamic forces imposed by large seismic accelerations that added to the downslope component of the gravitational force on the steep slopes of the Lowell Creek and Resurrection River deltas. Hampton and others (2002) note that the stability of the sediment was also decreased by the low tidal level at the time of the earthquake, and by the rapid drawdown of water following the initial slope failure, which prevented the pore water from draining from the sediment quickly enough to maintain hydrostatic stability. The underwater slope failures generated large waves that were observed during ground shaking (Wilson and Tørum, 1968). The major factors that contributed to the total volume and aerial extent of the slide material were the long duration of ground motion (3 to 4 min), the configuration of underwater slopes, and the type of sediment forming these slopes—unconsolidated and fine-grained materials (Lemke, 1967). Hampton and others (1996) added that high artesian pressure within aquifers of the delta, combined with the extra load caused by waterfront artificial fill and shoreline development, also contributed to the slope failures. The authors summarized all the environmental loads in Resurrection Bay and concluded that although it was a unique combination of conditions, most of them had been documented separately during slope failures in other fjords.

## REGIONAL SEISMOTECTONICS

Resurrection Bay occupies an area of very high seismic activity in southcentral Alaska (fig. 1). Tectonic regime is dominated by the convergence of the Pacific and North American plates, which interact along the

Aleutian Megathrust (Page and others, 1991). The convergence rate is approximately 56 mm/yr (2.2 in/yr) (DeMets and others, 1990). Resurrection Bay is close to the northeast end of the Aleutian Megathrust, where the megathrust is strongly coupled and has a shallow dip angle of about 7 degrees. This zone has the potential to produce some of the largest earthquakes in the world, as demonstrated by the magnitude  $M_w$  9.2 Great Alaska Earthquake of 1964 (fig. 1). These plate motions also have the potential to drive significant seismicity in both the overriding plate and the subducting slab (Doser and Brown, 2001).

Freymueller and others (2000) used GPS measurements of the crustal motions to study the deformation of the region and model the plate interactions. They found that under the eastern portion of the Kenai Peninsula and in Prince William Sound, the plates are nearly completely locked, while under the western portion of the Kenai Peninsula the plates are freely slipping. This correlates with Doser and Brown's (2001) findings that the central and southern Kenai Peninsula has been seismically quiet at the  $M_w > 5$  level since the 1964 event, while the Prince William Sound area has continued to have seismic activity similar to that occurring before the 1964 earthquake.

Figure 6 plots seismicity in southcentral Alaska with locations taken from the Alaska Earthquake Information Center catalog. The events with moment magnitude less than 6 are shown as small dots and color-coded according to depth, and the red box indicates the location of the region of interest. Prior to installation of the seismic network in Alaska in the early 1970s, only relatively larger events were reliably located ( $M > \approx 6$ ). After installation of the network, events of much smaller sizes were regularly located.

Shennan and others (2008) presented geologic evidence of six prehistoric great earthquakes in the Kenai Peninsula area of southcentral Alaska in the past 4,000 years (seven including 1964), based on radiocarbon ages of tidal marsh deposits at Girdwood. Their evidence indicates that recurrence intervals for great earthquakes in this area range from a minimum of 180–720 years to a maximum of 790–920 years. On the basis of all published paleoseismic data for the region, Carver and Plafker (2008) calculated that the average median recurrence interval for great earthquakes in the Prince William Sound segment of the eastern Aleutian seismic zone over this period is 589 years.

According to the segmentation model of Nishenko and Jacob (1990), southcentral Alaska includes three segments of the megathrust: the Yakataga–Yakutat (YY), Prince William Sound (PWS), and Kodiak Island (KI) segments (fig. 1). The YY segment at the eastern end of the megathrust represents a complex collision zone where the Yakutat microplate moves northwest toward

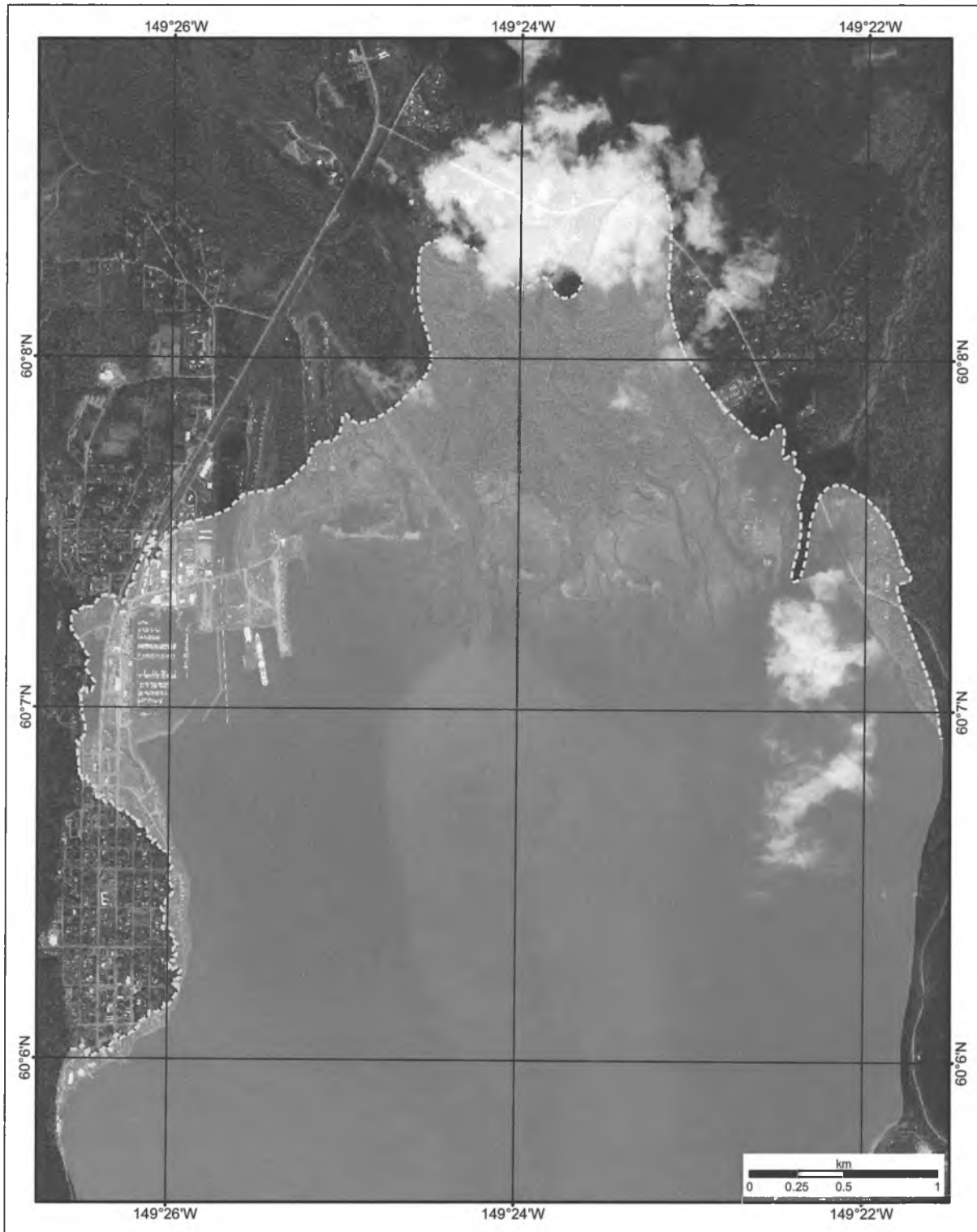


Figure 5. Maximum observed tsunami runup in downtown Seward and at the head of Resurrection Bay in 1964 (from Lemke, 1967).

central Alaska at 48 mm/yr (Carver and Plafker, 2008). This segment translates the predominantly strike-slip motion east of it to shallow-dipping subduction to the west (Nishenko and Jacob, 1990). The interaction between the Yakutat block and the Pacific and North American plates is complex and not well characterized. The southern and eastern boundaries of the Yakutat block are well defined, but a collection of distributed fold and thrust zones, splay faults, and regions of mountain

building complicates the northern and western edges of the block. Plafker and Thatcher (2008) reevaluated the mechanisms of the two great Yakutat Bay earthquakes of September 1899 (fig. 1) and showed that coseismic deformation was mostly uplift and onshore, which explained the absence of tsunami in the Gulf of Alaska. There were several local tsunamis observed in bays and fjords that were triggered by submarine slides and collapses of glacier walls. Plafker and Thatcher (2008)

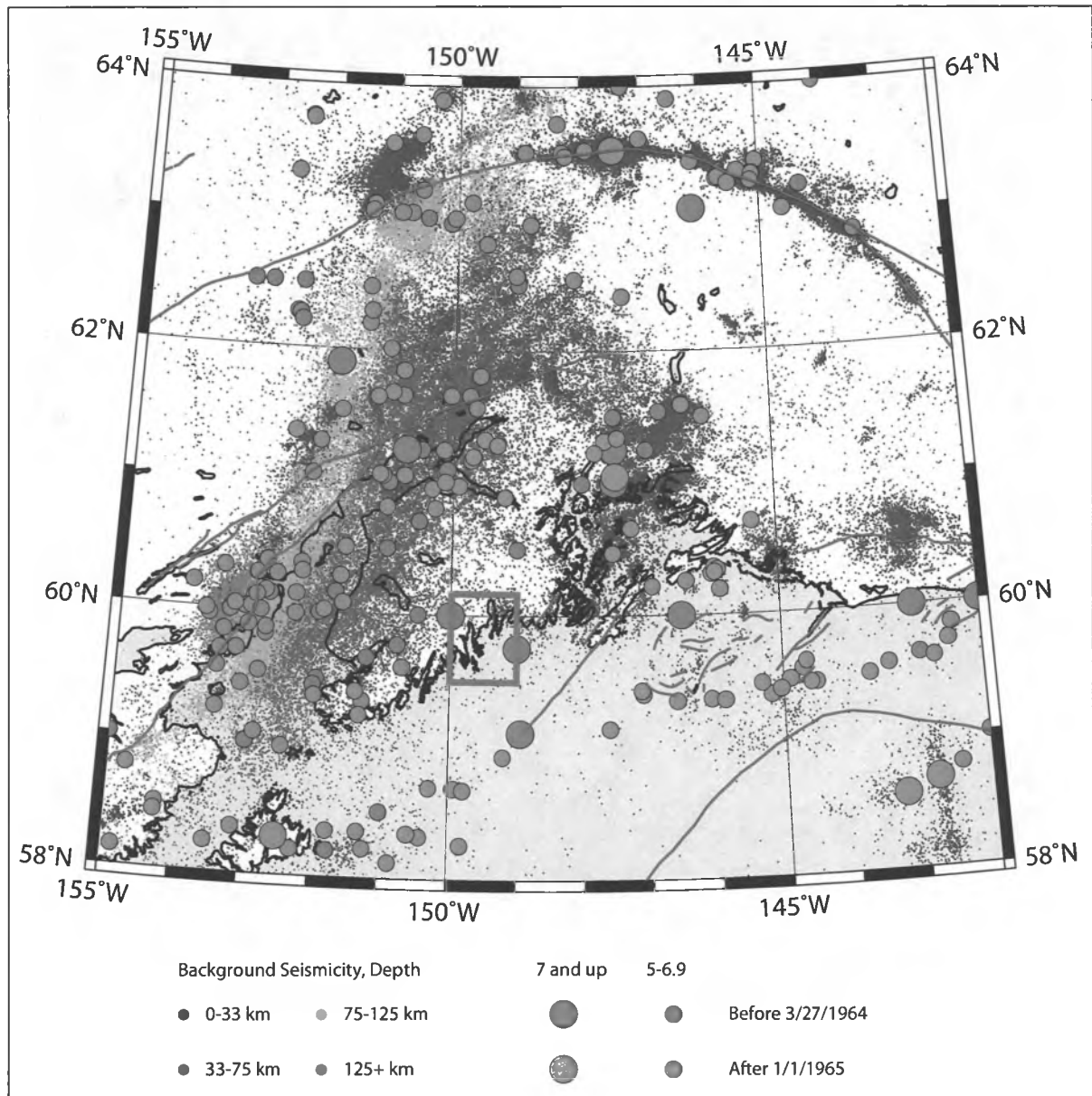


Figure 6. Earthquakes in southcentral Alaska, from the Alaska Earthquake Information Center catalog. The red rectangle delineates the computational grid of 8-arc-second resolution surrounding Resurrection Bay. Small dots correspond to earthquakes with magnitude less than 5. Large circles show significant earthquakes (magnitude 5 and greater) before (purple) and after (light blue) the Great Alaska Earthquake of March 27, 1964. The main shock and aftershocks of this event are not included in the plot.

concluded that the 1899 earthquake sequence most likely did not fill the offshore portion of the Yakataga seismic gap between the 1964 rupture area and the focal area of the 1899 earthquakes. This finding suggests that the YY segment has a high potential for a future tsunamigenic earthquake.

In the paleoseismic study of regional land subsidence at Kenai Peninsula sites, Hamilton and Shennan (2005) estimated coseismic subsidence during the 1964 earthquake and two earlier events. It was shown that the earthquake dated to ~1500–1400 cal. yr BP produced more than two times the subsidence caused by the 1964 earthquake. By comparing the Kenai Peninsula sites with other sites around Cook Inlet, the authors found that each of the three great earthquakes in the study had a unique pattern of coseismic subsidence. This result demonstrates that understanding the most recent great earthquake in the area is not sufficient for comprehensive tsunami hazard assessment in southcentral Alaska, and detailed studies of multiple great earthquakes are required. The recent work by Shennan and others (2008) tests the hypothesis that in some seismic cycles megathrust segments can combine, as proposed in the segmentation model by Nishenko and Jacob (1990), and produce earthquakes greater than any in the recorded history. The paper presents paleoseismic evidence that earthquakes ~900 and ~1,500 yr BP simultaneously ruptured three adjacent segments of the Aleutian Megathrust: the PWS and KI segments, and the Yakutat microplate (the YY segment). The rupture area of these earthquakes was calculated to be 23,000 km<sup>2</sup> greater than that of the 1964 earthquake, with a 15 percent increase in seismic moment. The authors suggested that increase in seismic moment is less significant than increased tsunami potential of this multi-segment rupture, due to coseismic uplift over a large area of shallow continental shelf off the Yakataga coast. We built a hypothetical tsunami source function for the extended rupture and performed a numerical modeling experiment to estimate the impact of tsunami waves generated by this event at Seward. The source function and modeling results are described in section 4 of "Methodology and data."

## LANDSLIDE TSUNAMI HAZARD IN RESURRECTION BAY

Resurrection Bay is a deep glacial fjord, typical of many in southcentral and southeastern Alaska. Kulikov and others (1998) analyzed tsunami catalog data for the North Pacific coast and showed that this region has a long recorded history of tsunami waves generated by submarine and subaerial landslides, avalanches, and rockfalls. The authors also found that, in the majority of cases, tectonic tsunamis that arrive in bays and fjords from the open ocean have relatively small amplitudes,

but a great number of local landslide-generated tsunamis have much larger wave amplitudes. For example, as a result of the 1964 earthquake, about 20 local submarine and subaerial landslide tsunamis were generated in Alaska (Lander, 1996). Following the earthquake, Seward was the only place hit by both landslide-generated tsunamis and a major tectonic tsunami (Haeussler and others, 2007), while several other communities experienced only locally generated waves (Plafker and others, 1969). Kulikov and others (1998) also noted that, due to the sparse population of the area, the actual number of historical landslide tsunami events is unknown, and probably much greater than the number of events observed or recorded. Bornhold and others (2001) addressed the problem of estimation of hazard from landslide-generated tsunami waves for the coast of Alaska and British Columbia. They outlined specific features of long-term prediction of landslide-generated tsunamis at selected sites, and developed an approach for estimating tsunami hazard. The long-term approach consists of two steps: (1) analysis of historical events and verification of model results with runup observations at the site, and (2) numerical simulation of hypothetical tsunami scenarios. Although for many communities historical observations do not exist, Seward is an exception. The effects of the 1964 earthquake and tsunami waves in Resurrection Bay, including wave amplitudes and extent of inundation, are well documented (Lemke, 1967; Wilson and Tørum, 1968) and are ideal for numerical modeling studies.

Tsunamis caused by submarine slope failures are a serious hazard in glacial fjords of coastal Alaska where rapidly deposited sediments accumulate on steep underwater slopes (Lee and others, 2006). Bornhold and others (2001) identify earthquakes, extreme low tides, and construction activities in ports and harbors as the most common triggering mechanisms for underwater slope failures. Estimation of landslide tsunami risk for a coastal community requires assessment of locations of potential underwater failures using high-resolution bathymetry, actual physical parameters of the underwater materials, and an adequate numerical model. The most probable locations of unstable sediment bodies in Resurrection Bay are the underwater slopes of the Resurrection River delta, and abnormally steep submarine slopes located elsewhere in the bay (Lee and others, 2006).

Engineering studies conducted after the 1964 earthquake (Lemke, 1967; Coulter and Migliaccio, 1966; Shannon and Hilt, 1973) showed that additional on-shore and submarine landslides can be expected along the Seward waterfront in the event of another large earthquake, and that sediment from the Resurrection River and smaller creeks will continue to accumulate on underwater slopes of Resurrection Bay. These studies also concluded that underwater slope failures have not

improved slope stability, meaning that the same slopes could fail again during a large earthquake. Moreover, some of the streams draining into Resurrection Bay, such as Lowell Creek and Fourth of July Creek, have been rerouted by humans. These creeks are now depositing sediments in new locations, which may lead to new unstable sediment accumulations and future submarine slides.

The recent results of sediment chemistry monitoring in Port Valdez, located in a glacial fjord setting similar to that of Resurrection Bay (fig. 2), demonstrated high sediment accumulation rates of about 1.5 cm/yr at the head of the fjord (Savoie and others, 2006). Sediment could be released not only by the ground shaking due to an earthquake, but also by other triggering events, such as extreme low tide conditions and construction activities. Because short-term prediction of landslide tsunamis is not practical for tsunami hazard assessment (Bornhold and others, 2001), we will use the long-term approach for estimating local tsunami hazard at Seward. The most essential components of this approach are numerical modeling of historical landslide tsunami events, and simulation of future hypothetical underwater slope failures.

## METHODOLOGY AND DATA

### GRID DEVELOPMENT AND DATA SOURCES

To support inundation modeling of coastal areas in Alaska, we use a series of nested telescoping grids, or digital elevation models (DEMs), as input layers for tsunami inundation modeling and mapping. These grids of increasing resolution allow us to propagate waves, generated by both distant and local sources, to Resurrection Bay. In order to propagate a wave from its source to various coastal locations we use embedded grids, placing a large, coarse grid in deep water and coupling it with smaller, finer grids in shallow water areas. This embedding technique allows us to dramatically increase resolution in the area where inundation calculations are

performed, and save computational resources by using lower resolution grids in the deep ocean region. The extent of each grid used for Seward mapping is shown in figure 7 and table 1. The coarsest resolution 2-arc-minute grid (see table 1 for grid spacing) spans the Gulf of Alaska, while the highest resolution 15 m grid is restricted to upper Resurrection Bay. This grid is used for Seward inundation mapping; it also includes Lowell Point and Fourth of July Point (fig. 4). In this grid, the seamlessly combined bathymetric and topographic data allow for calculation of tsunami inundation of previously dry land.

The grids used for modeling were gathered from three sources:

**15-m Grid:** This “high resolution” grid contains bathymetric and topographic data merged into one DEM. It was developed by Labay and Haeussler (2008) from the following input surveys:

- Low-altitude LIDAR (Light Detection and Ranging) topography collected for the Kenai Watershed Forum in 2006
- U.S. Army Corps of Engineers (USACE) harbor soundings for the Seward City Marina and surroundings collected in 2006
- Multibeam bathymetric surveys of Resurrection Bay, conducted by NOAA’s National Ocean Service (NOS) in 2001

Survey data were first adjusted to a common Mean High Water vertical datum before being combined into one ESRI point feature class. Where available, the more recent USACE harbor data were used in place of 2001 NOS survey data to represent the significant reconstruction of the harbor infrastructure between 2001 and 2006. Significant gaps between the survey areas were then filled in using interpolation routines. Topographic data in this grid are a combination of the 2006 LIDAR collection in the northern part of the bay, and the 10-m USGS DEM in the rest of the area, which was not covered by

*Table 1. Nested grids used in the model to compute propagation of tsunami waves generated in the Gulf of Alaska to the city of Seward. The 15-m grid is used to compute the inundation.*

| Resolution     | Spacing along longitude at 60°N | Spacing along latitude | West–East boundaries | North–South boundaries |
|----------------|---------------------------------|------------------------|----------------------|------------------------|
| 2 arc-minutes  | 1,850 m                         | 3,700 m                | 138°00'W – 169°00'W  | 52°00'N – 63°00'N      |
| 24 arc-seconds | 370.5 m                         | 741 m                  | 147°00'W – 155°00'W  | 55°00'N – 62°00'N      |
| 8 arc-seconds  | 123.5 m                         | 247 m                  | 149°00'W – 150°00'W  | 59°30'N – 60°10'N      |
| 3 arc-seconds  | 48.5 m                          | 97 m                   | 149°14'W – 149°37'W  | 59°42'N – 60°10'N      |
| 15 meters      | 15 m                            | 15 m                   | 149°16'W – 149°27'W  | 59°57'N – 60°09'N      |

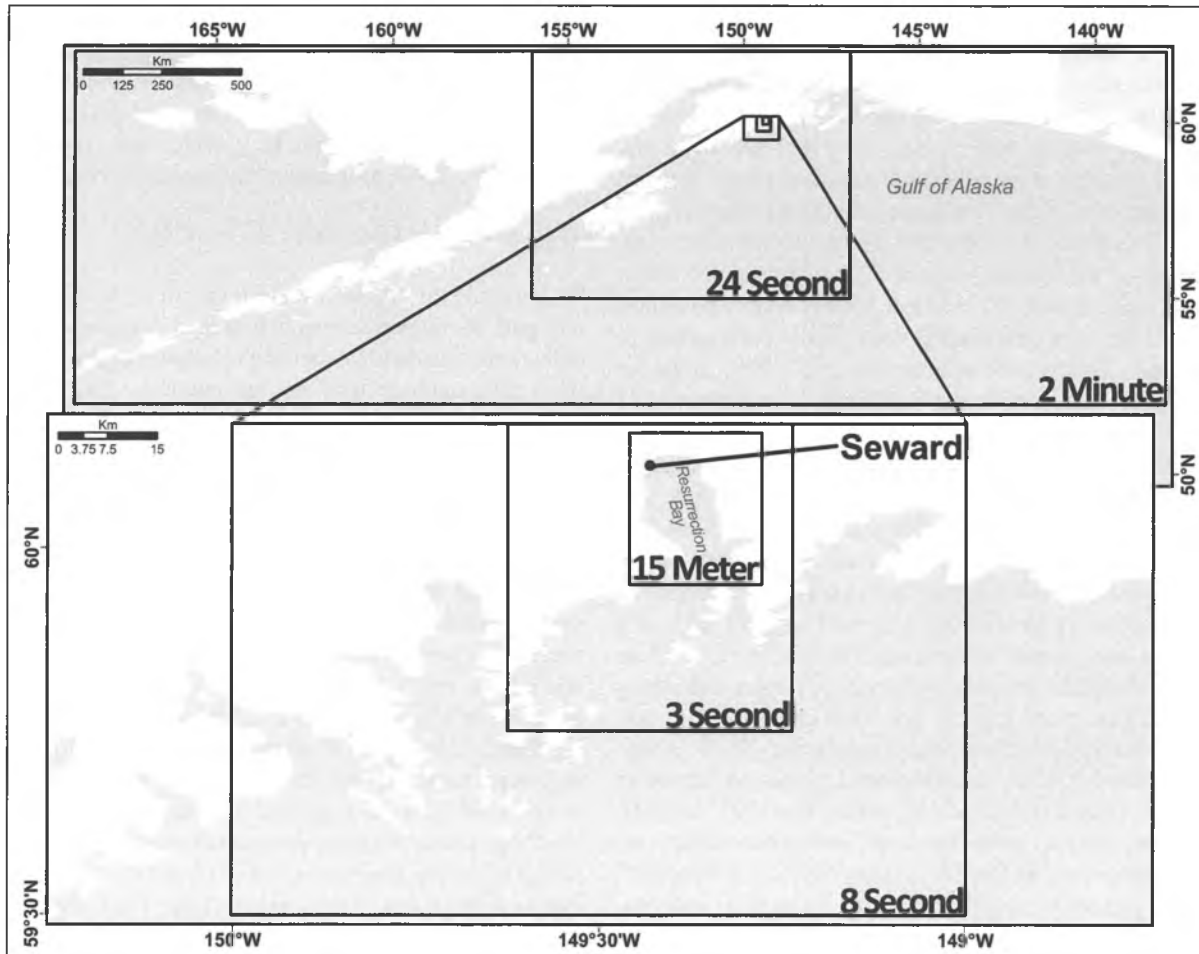


Figure 7. Telescoping embedded numerical grids for calculation of tsunami propagation and runup.

LIDAR. The northern section of the bay contains the most significant population and infrastructure centers. The resulting seamless dataset was exported and delivered in ESRI digital raster and ASCII xyz format with 15 m resolution.

**3-Arc-Second, 8-Arc-Second and 24-Arc-Second Grids:** Angie Venturato of the Pacific Marine Environmental Laboratory, National Oceanic & Atmospheric Administration (PMEL/NOAA) constructed these grids using bathymetry collected from NOS survey and chart data as well as shoreline data from USACE and Alaska Railroad surveys. These input surveys represent a variety of collection methods over a wide timescale from 1972 to 2004. Root mean squared error (RMSE) applies to systematic and random errors in the dataset and is used to define the vertical accuracy of these grids. The accuracy of bathymetric soundings is generally expected to be within 2 percent of depth.

The surveys were first converted into ESRI-compatible point data formats before depths were adjusted to

Mean High Water from their respective origin vertical datums. The surveys were then clipped to a standard shoreline vector before being merged through the creation of a triangular irregular network (TIN). This compiled TIN dataset was used to export directly from ArcView 3.2 software into ASCII xyz format.

**2-Arc-Minute Grid:** This grid was created by Robert Kamphaus of PMEL/NOAA. Bathymetry for the Gulf of Alaska level extent was extracted directly from the publicly available ETOPO2 data set (NOAA, National Geophysical Data Center).

One of the challenges in near-field modeling of tsunami waves generated by a historic earthquake is to account for coseismic and post-seismic tectonic land changes, and also for a difference between the datum of the numerical grid and the stage of tide at the time of the earthquake. The high-resolution numerical grid of combined bathymetry and topography data for Resurrection Bay by Labay and Haeussler (2008) was referenced to the tidal datum of Mean High Water (MHW). Accord-

ing to observations (Lemke, 1967), tide was low at the time of the main shock. Low tide was one of the major factors that contributed to the large scale of landsliding, but at the same time helped to lessen the amount of damage from the first tectonic wave that arrived on low tide. Figure 8 is a predicted water-level plot at Seward on the day of the earthquake, obtained from NOAA tide calculator. It shows that the first tectonic wave arrived on the local minimum of the tidal curve, which corresponds to 0.175 m below Mean Lower Low Water (MLLW). The time mark 20:00 actually corresponds to 7 pm local time in Seward on March 27, 1964, since the State of Alaska moved to a different time zone in 1983 (one hour ahead).

Different tidal datums and tectonic land changes at Seward are demonstrated in figure 9. We call tidal range (TR) the difference between MHW and MLLW, and 'tide' is the sea level at the time of the earthquake. The landmass in the Seward area experienced coseismic subsidence (CS) of about 1.15 m (Lemke, 1967); as a result, many areas that were never flooded by tides before the earthquake are now under water. Larsen and others (2003) analyzed relative sea level changes from tide gauge records at 15 sites along the Pacific–North American plate boundary in southcentral Alaska, to determine vertical crustal motions in the period from 1937 to 2001. In several years immediately following the earthquake, the Seward site showed oscillatory uplift, and then uplift rates increased steadily thereafter. From their analysis,

the total postseismic uplift (PU) at Seward could be estimated at about 20 cm. The following equation therefore provides the relationship between the water depth in Resurrection Bay at the time of the earthquake,  $H_{EQ}$ , and the present water depth,  $H_{now}$ , which was measured in 2001 by NOAA multibeam bathymetry survey:

$$H_{EQ} = H_{now} - TR - tide - CS + PU$$

By using the adjusted vertical datum in the bathymetry grid, the numerical model will reproduce the effects of tsunami inundation occurring at Seward under conditions close to those that were present at the time of the 1964 earthquake.

### NUMERICAL MODEL OF TSUNAMI WAVE PROPAGATION AND RUNUP

Recently, NOAA published a technical memorandum that outlines major requirements for numerical models used in inundation mapping and tsunami forecasting, and describes a procedure for model evaluation (Synolakis and others, 2007). There are two major components in this process. The first is model validation, which is ensuring that the model solves equations of motion correctly by comparing model results with known solutions. This is achieved through analytical and laboratory benchmarking. The second component is model verification, which is testing the model, using observations of real events through field data benchmarking. The numerical

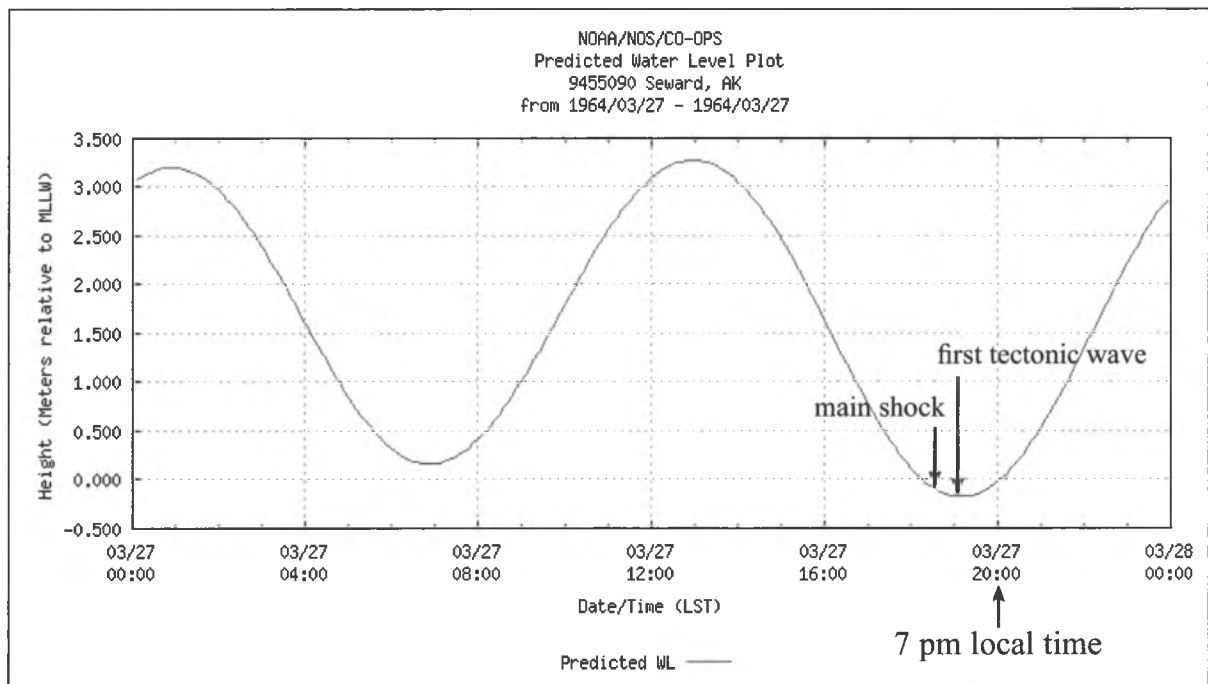


Figure 8. Predicted water level plot for Seward on March 27, 1964. Time is Local Standard Time (UTC-9); arrows indicate times of the main shock of the 1964 earthquake, and arrival of the first tectonic wave.

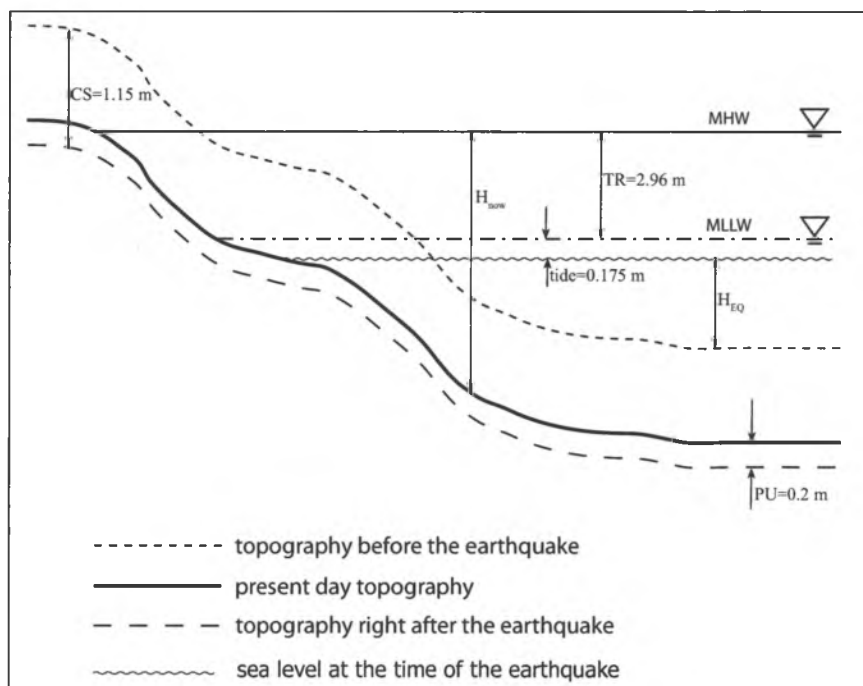


Figure 9. A diagram that relates different tidal datums and vertical tectonic land changes during and after the 1964 earthquake.

model currently used by AEIC for tsunami inundation mapping has been validated through a set of analytical benchmarks, and tested against laboratory and field data (Nicolosky and others, in press). The model solves non-linear shallow water equations using a finite-difference method on a staggered grid. For any coarse-fine pair of computational grids, we apply an explicit-in-time numerical scheme as follows. First, we compute the water flux (WF) in a coarse-resolution grid. These values of WF are used to define the WF on a boundary of the fine-resolution grid. Consequently, the sea surface height (SSH) and then the WF are calculated in the fine-resolution grid. Finally, the SSH computed in the fine-resolution grid is used to define the SSH within the area of the coarse-resolution grid that coincides with the fine grid. Despite the fact that developed nested grids decrease the total number of grid cells and preserve an accuracy of computations within certain regions of interest, real life simulations are still prohibitive if parallel computing is not implemented. We use Portable Extensible Toolkit for Scientific computation (PETSc) which provides sets of tools for the parallel numerical solution of shallow-water equations. In particular, each computational grid listed in table 1 can be subdivided between an arbitrary number of processors. The above-mentioned passing of information between WF and SSH is implemented efficiently using PETSc subroutines.

We assess hazard related to tectonic and landslide-generated tsunamis in Resurrection Bay by performing model simulations for each hypothetical earthquake and landslide source scenario. In the output of the numerical model, each of the grid points has either a value of

0 where no inundation occurs or 1 if seawater reaches the grid point at any time. The inundation line approximately follows the 0.5 contour between these 0 and 1 point values but was adjusted visually to accommodate obstacles or local variations in topography that are not represented by the DEM. Although the location of the inundation line has an accuracy of approximately plus or minus 15 m horizontally relative to the grid spacing, the true location accuracy is unknown because the lines are the result of a complex modeling process whose accuracy depends on many factors. These factors include suitability of the earthquake source model, accuracy of the bathymetric and topographic data, and the adequacy of the numerical model in representing the generation, propagation, and run-up of tsunami waves. We did not attempt to adjust the modeled inundation limits to account for these uncertainty factors.

There are several limitations of the model. It does not take into account the periodic change of sea level due to tides. We conducted all model runs using bathymetric data that correspond to Mean High Water (MHW), with the exception of numerical modeling of the 1964 tsunami for the purpose of model validation. Those runs were conducted using the stage of tide at the time of the earthquake, approximately Mean Low Water. For the generation mechanism, we modeled earthquakes and landslides as potential sources of tsunami waves. In this region it was important to include landslide tsunami sources, because underwater landslides and the resulting tsunamis caused a significant portion of the damage in Resurrection Bay during the 1964 Great Alaska Earthquake.

## NUMERICAL MODEL OF LANDSLIDE-GENERATED TSUNAMI WAVES

To simulate tsunami waves produced by multiple underwater slope failures in Resurrection Bay on March 27, 1964, we used a three-dimensional numerical model of a viscous underwater slide with full interactions between the deforming slide and the water waves that it generates. This model was initially proposed by Jiang and LeBlond (1992). Fine and others (1998) improved the model by including realistic bathymetry, and by correcting errors in the governing equations. The model's assumptions and applicability in simulating underwater mudflows are discussed by Jiang and LeBlond (1992, 1994) in their formulation of the viscous slide model. The model uses long-wave approximation for water waves and the deforming slide, which means that the wavelength is much greater than the local water depth, and the slide thickness is much smaller than the characteristic length of the slide along the slope (Jiang and LeBlond, 1994). Assier-Rzadkiewicz and others (1997) argued that the long-wave approximation could be inaccurate for steep slopes, which are slopes greater than 10 degrees. Rabinovich and others (2003) studied the validity of the long-wave approximation for slopes greater than 10 degrees and found that for a slope of 16 degrees the possible error was 8 percent, and for the maximum slope in their study (23 degrees), the possible error was 15 percent. Based on this analysis, for the average pre-earthquake offshore slopes that ranged from 10 to 20 degrees in the vicinity of Seward, the possible error introduced by a slide moving down these higher gradient slopes could be around 10 percent.

The advantage of this vertically integrated model, which includes two horizontal dimension effects, is its ability to simulate real landslide tsunami events using high-resolution numerical grids based on multibeam bathymetry data. Although model runs require the use of high-performance computing, the computational times are still reasonable. This model was successfully applied to simulate tsunami waves in Skagway Harbor, Alaska, generated by a submarine landslide on November 3, 1994 (Fine and others, 1998; Thomson and others, 2001). The results of numerical simulations were in good agreement with the tide gauge record in Skagway Harbor, one of the numerous fjords in southeastern Alaska. Rabinovich and others (2003) simulated potential underwater landslides in British Columbia fjords with settings similar to Resurrection Bay, and demonstrated that this model can be used for tsunami-hazard assessment.

## TECTONIC TSUNAMI SOURCES SOURCE FUNCTIONS OF THE 1964 TSUNAMI

The 1964 Great Alaska Earthquake generated one of the most destructive tsunamis ever observed in Alaska and the northwestern Pacific coast. This major tectonic

tsunami was generated in the trench and upper plate fold and thrust belt area of the subduction zone (Plafker and others, 2000) and affected many communities in Alaska. Both the Prince William Sound and the Kodiak Island segments ruptured in the 1964 earthquake, producing the area of surface deformation of about 285,000 km<sup>2</sup> (Plafker, 1969). Christensen and Beck (1994) demonstrated that there were two areas of high moment release, representing the two major asperities of the 1964 rupture zone: the PWS asperity with an average slip of 18 m, and the KI asperity with an average slip of 10 m. Analysis of historical earthquake data in PWS and KI segments (Nishenko and Jacob, 1990) showed that the KI segment produced both large and great earthquakes more frequently and also independently of the PWS segment.

The 1964 tsunami was studied in depth by several investigators (Plafker, 1967; Wilson and Tørum, 1968; Lemke, 1967); observed inundation patterns for a number of Alaska communities are available for model calibration. We use a displacement of the ocean surface that results from an underwater earthquake as the initial condition for calculation of tsunami propagation. The amplitude of this initial disturbance is one of the major factors that affect the runup amplitudes along the shoreline. The fault parameters required to compute sea floor deformation are location of the epicenter, area, dip, rake, strike, and amount of slip on the fault. In all model runs, the initial topography was modified to account for residual seismic deformation of land due to the earthquake. We assumed that the initial displacement of the ocean surface from the equilibrium position was equal to vertical displacement of the ocean floor due to the earthquake rupture process. The model does not take into account the propagation of the moving rupture along the fault. We assumed here that the bottom movement was instantaneous. The model propagates the initial sea surface displacement from the source to coastal locations through a set of embedded grids of increasing resolution.

In this study we used two coseismic deformation models of the 1964 earthquake (Johnson and others, 1996; Suito and Freymueller, 2009) to generate the initial sea surface disturbance caused by vertical displacements of the sea floor during the earthquake. The following abbreviations will be referenced throughout this report: JDM, for deformation model by Johnson and others (1996) and SDM, for deformation model by Suito and Freymueller (2009).

A detailed analysis of the 1964 rupture zone was presented by Johnson and others (1996) through joint inversion of far-field tsunami waveforms and geodetic data. The authors derived a detailed slip distribution for the 1964 earthquake, which has eight subfaults representing the Kodiak asperity and nine subfaults in the Prince

William Sound asperity. One subfault was assigned to represent the Patton Bay fault, although contribution of this fault to the far-field tsunami waveforms was negligible. We used the equations of Okada (1985) to calculate distribution of coseismic uplift and subsidence resulting from this slip distribution. Then we used the derived surface deformation (fig. 10) as the initial condition for the tsunami propagation model. The source function based on JDM was previously applied to calculation of 1964 tsunami inundation in Kodiak and Kachemak Bay communities. The results are described in Suleimani and others (2002, 2005).

Plafker (1967) gives a detailed description of the motion observed on the Patton Bay fault during the Great Alaska Earthquake of 1964. He provides a full report of surface rupture and fault motion, as well as several pieces of evidence suggesting that the fault continues on the ocean floor well past the region where it is currently mapped. Holdahl and Sauber (1994) applied Plafker's description to construct their model of the Patton Bay fault, which was used in an inversion of geodetic data. Johnson and others (1996) used the results of Holdahl and Sauber to augment their joint inversion of geodetic and tsunami data. These two studies used only the mapped extent of the fault, approximately 72 km,

despite significant evidence that the fault may extend much farther to the southwest.

Suito and Freymueller (2009) developed a new coseismic deformation model of the 1964 earthquake, which is based on a three-dimensional viscoelastic model, incorporating a realistic geometry with an elastic slab having very low dip angle. This coseismic model is not based on an inversion, but it resembles the recently published inversion model (Ichinose and others, 2007) and past proposed models (Holdahl and Sauber, 1994; Johnson and others, 1996; Santini and others, 2003). The main difference between JDM and SDM is that the SDM predicts slightly higher slip near the downdip end of the rupture to explain horizontal displacements. Additionally, the rupture in the SDM is assumed to occur at greater depths than in the JDM. As a result, the deeper subfaults in the SDM produce smoother variations of sea floor deformation than in the JDM. Both models use the Patton Bay fault to explain the excessive uplift at Montague Island (Plafker, 1967). It is assumed in the JDM that the extent of the splay fault was not much larger than its subaerial outcrop on Montague Island. In contrast, the SDM assumes that the Patton Bay splay fault extended much farther to the west than previously assumed by Holdahl and Sauber (1994) and Johnson

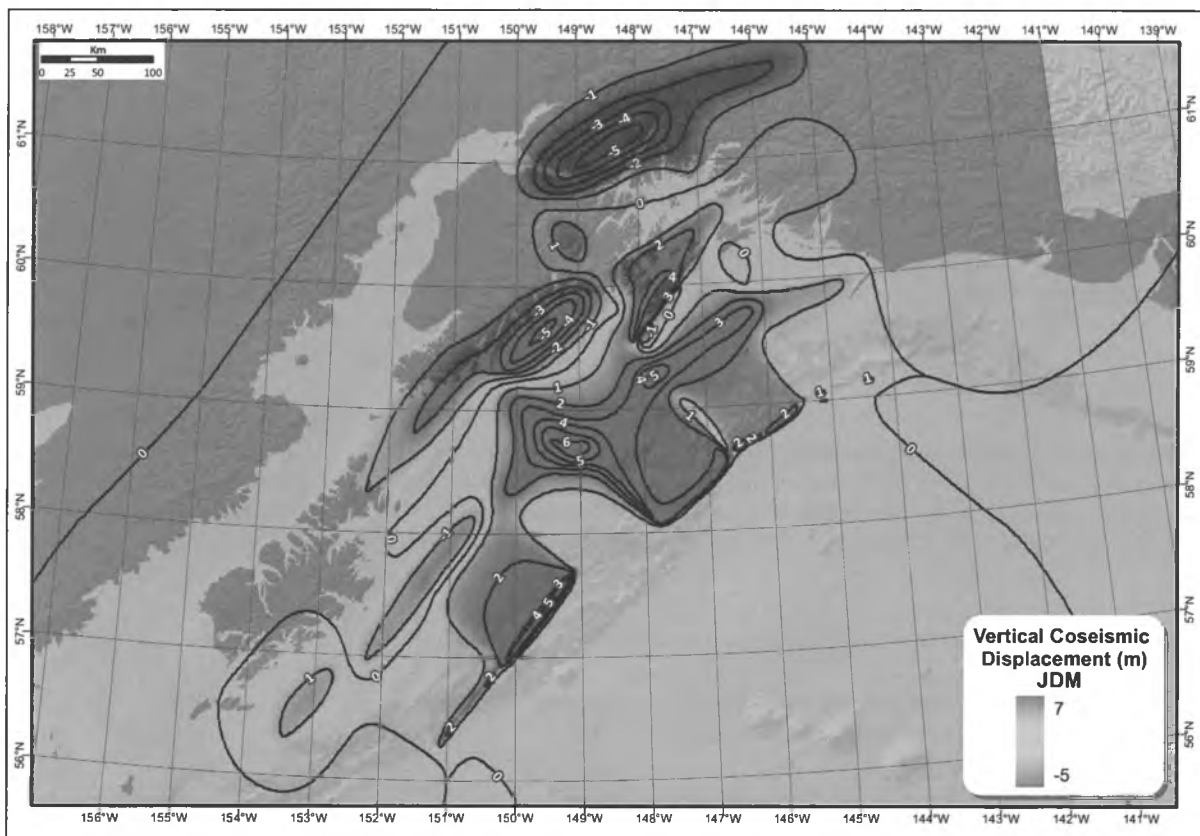


Figure 10. Source function of the 1964 tsunami based on Johnson and others (1996) (JDM).

and others (1996). Although the Patton Bay fault slipped approximately 10 m at the southwestern tip of Montague Island, there have been no comprehensive submarine surveys documenting the extent of that splay fault. Suito and Freymueller (2009), however, found that they could not fit all the GPS data accurately unless they extended the fault past the end of the Kenai Peninsula.

Results of numerical modeling of Seward inundation using the JDM source function vastly overestimate the observed 1964 inundation (see “Modeling results”, section 1), therefore we use SDM in the tsunami scenarios that represent the 1964 event.

### EXTENDED 1964 RUPTURE

A recent study by Shennan and others (2008) presents geologic evidence that the Prince William Sound and Kodiak Island segments of the 1964 rupture area and a portion of the Yakutat microplate may rupture simultaneously (see discussion in “Regional seismotectonics”). In order to evaluate whether this event would make a plausible future tsunami scenario for Seward, we have constructed a source function of the extended 1964 rupture. We applied the following constraints based on the hypothetical earthquake model of Shennan and others (2008):

- The extended source function includes three segments of the Aleutian Megathrust: the PWS, KI, and YY segments (fig. 1);
- The rupture area is about 23,000 km<sup>2</sup> greater than that of the 1964 earthquake;
- The total seismic moment is 15 percent greater than that of the 1964 earthquake;
- The new source function produces coseismic vertical uplifts along the Gulf of Alaska coastline segment between the Copper River basin and Yakataga, to match the coseismic deformation pattern to paleoseismic data (Shennan and others, 2008).

We have constructed a rupture model for the Yakataga–Yakutat segment using the constraints described above. The model consists of four subfaults with the fault parameters listed in table 2. We calculated coseismic deformations produced by this segment using Okada’s algorithm (Okada, 1985), and then superposed them

with the 1964 coseismic deformations produced by the SDM. The resulting coseismic deformation pattern for the extended 1964 rupture is shown in figure 11.

Results of numerical modeling of Seward inundation using the extended 1964 rupture model are not different from the inundation caused by the 1964 deformation model. Waves generated by the uplift of the sea floor in the area of Yakutat block arrive at Resurrection Bay much later than the wave generated in the PWS segment that arrives first and produces the maximum inundation zone.

### TECTONIC TSUNAMI SCENARIOS

**Scenario 1.** Repeat of the 1964 event: Source function based on coseismic deformation model by Suito and Freymueller (2009) (SDM).

This source function represents the entire rupture area of the 1964 earthquake, with vertical coseismic deformations derived from the SDM (fig. 12).

Christensen and Beck (1994) demonstrated that there were two areas of high moment release, representing the two major asperities of the 1964 rupture zone: the Prince William Sound asperity with an average slip of 18 m, and the Kodiak asperity with an average slip of 10 m. The results of joint inversion of tsunami and geodetic data from the 1964 earthquake (Johnson and others, 1996) support the division of the rupture zone into two different segments, the Kodiak block and the Prince William Sound (PWS) block. These zones have different recurrence intervals, with estimates of the recurrence interval for the Kodiak segment being as low as 60 years (Johnson and others, 1996). Therefore we consider these two segments of the 1964 rupture area to be separate hypothetical tsunami source scenarios. We also consider a third hypothetical event involving the rupture of the Pamplona deformation zone, which represents another source of tsunami waves capable of reaching Resurrection Bay.

**Scenario 2.** Modified 1964 event: Prince William Sound asperity of the SDM.

This source function represents the Prince William Sound asperity from the deformation model by Suito and Freymueller (2009). Vertical coseismic deformations for this scenario are shown in figure 13.

Table 2. Fault parameters for the Yakataga–Yakutat segment

| Lat<br>[deg. N] | Lon<br>[deg. W] | Depth<br>[km] | Length<br>[km] | Width<br>[km] | Strike<br>[deg.] | Dip<br>[deg.] | Rake<br>[deg.] | Slip<br>[m] |
|-----------------|-----------------|---------------|----------------|---------------|------------------|---------------|----------------|-------------|
| 59.17           | 144.12          | 1             | 50.1           | 190           | 256              | 12            | 90             | 15          |
| 59.36           | 143.23          | 3             | 51.1           | 141           | 250.4            | 10            | 90             | 15          |
| 59.54           | 142.42          | 5             | 47.8           | 114.8         | 245.8            | 6             | 90             | 15          |
| 59.94           | 141.21          | 5             | 79.7           | 99.6          | 237.8            | 8             | 90             | 15          |

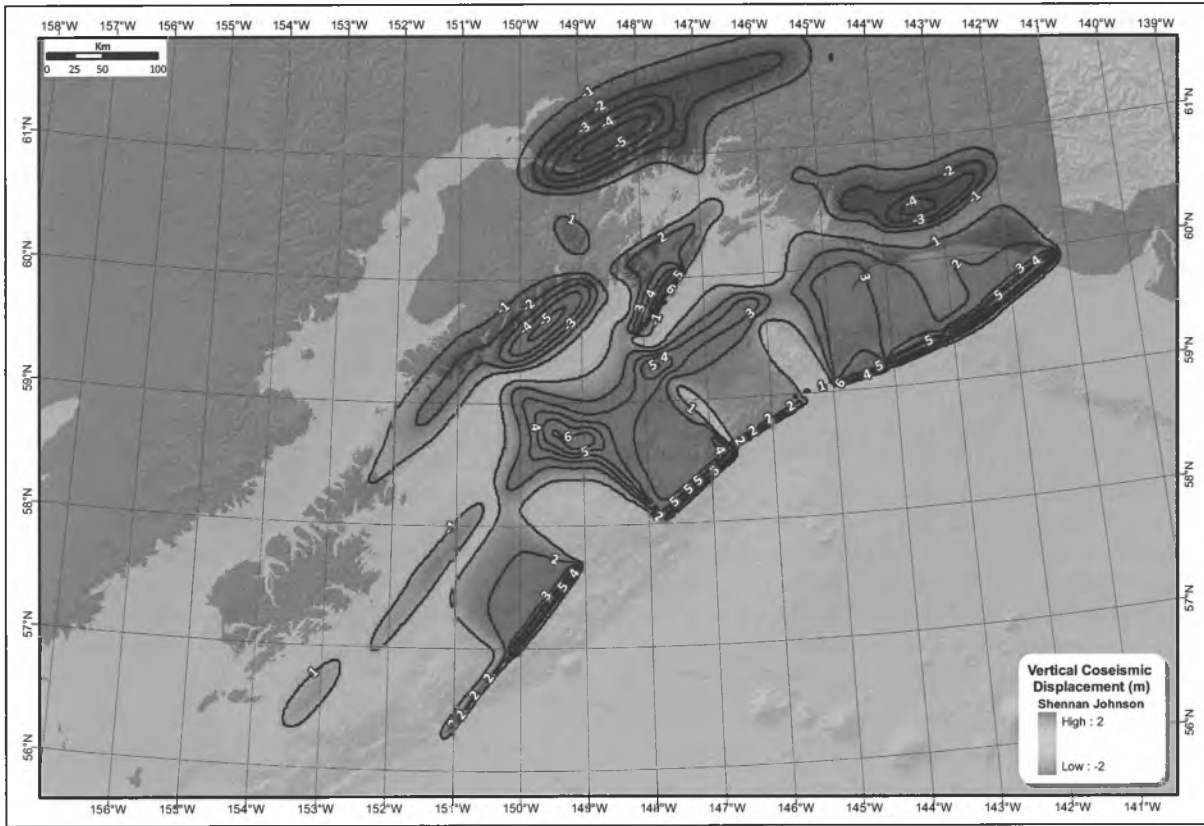


Figure 11. Vertical coseismic displacements for the extended 1964 rupture model.

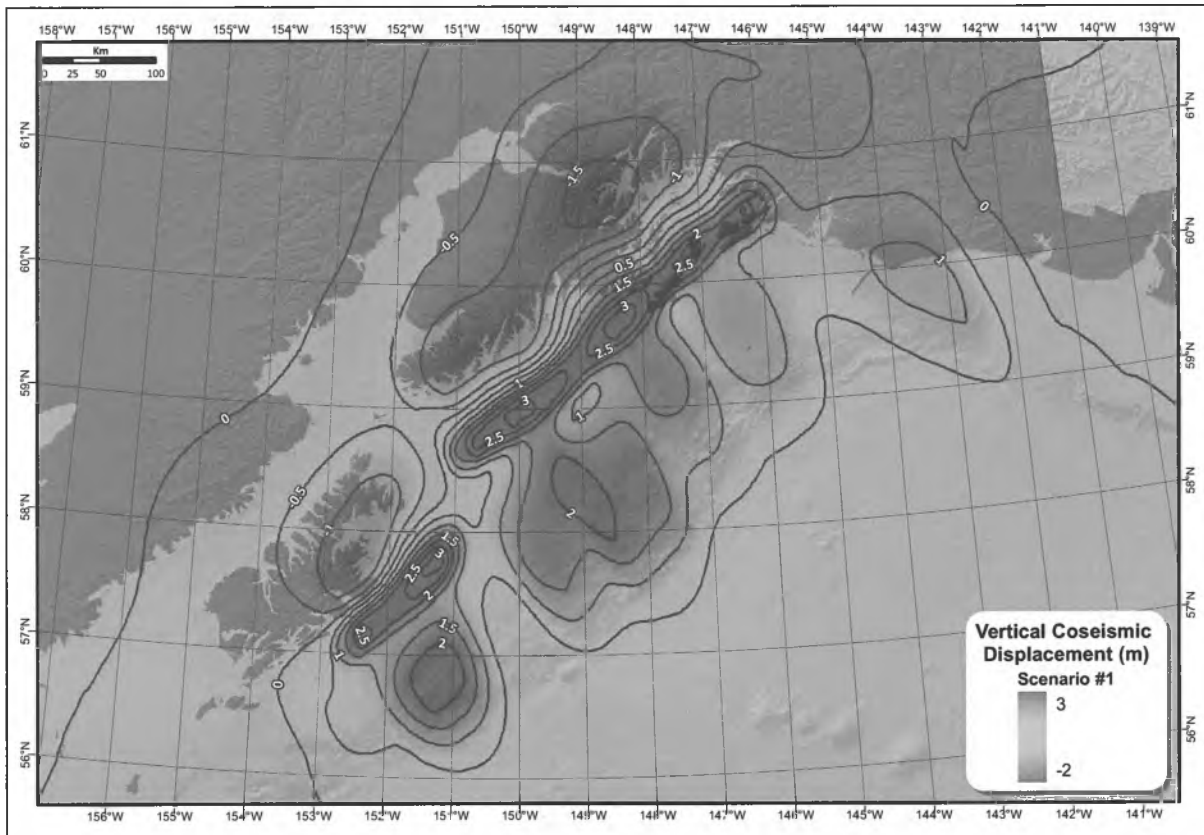


Figure 12. Scenario 1. Source function of the 1964 tsunami based on Suito and Freymueller (2008) (SDM).

**Scenario 3.** Modified 1964 event: Kodiak asperity of the SDM.

This source function represents the Kodiak asperity from the deformation model by Suito and Freymueller (2009). Vertical coseismic deformations for this scenario are shown in figure 14.

**Scenario 4.** Hypothetical event: Rupture of the Pamplona zone between the Yakutat block and the North American Plate.

This is a hypothetical earthquake that ruptures the Pamplona zone between the Malaspina fault and the Aleutian megathrust at the northwestern edge of the Yakutat block in a thrust event (fig. 15).

The Pamplona zone is a region of distributed fold and thrust features near the northwestern edge of the Yakutat block (fig. 15). There is a trend of moderate to strong historic seismicity in the area between the location of the 1979  $M_w$  7.2 St. Elias earthquake and the end of the 1964 rupture zone (shown in fig. 16). This seismic zone is aligned with the Malaspina thrust fault and is well oriented to accommodate convergence between

the Yakutat block and North American plate. Sauber and others (1997) identified this as the region most likely to rupture and fill the Yakataga seismic gap. Sauber and Molnia (2004) showed that the retreat of glaciers in the Wrangell Mountains increases the likelihood of seismic release on thrust faults in the region. We consider a hypothetical  $M_w$  ~8.8 event with fault parameters detailed in table 3. The vertical coseismic deformations for this scenario are shown in figure 17.

The Kodiak inundation mapping study (Suleimani and others, 2002) includes a scenario that represents a distant tsunami source, the Cascadia subduction zone rupture. The results of numerical modeling demonstrated that the major part of the tsunami energy will be directed west and southwest, toward Hawaii, and a very limited amount toward coastlines of Alaska. In this study, we performed numerical simulation of tsunami waves generated by a  $M_w$  9.2 earthquake in the Cascadia subduction zone. The results were consistent with those in the Kodiak report. Since this scenario produced negligible inundation at Seward, we did not include it in the list of tectonic scenarios.

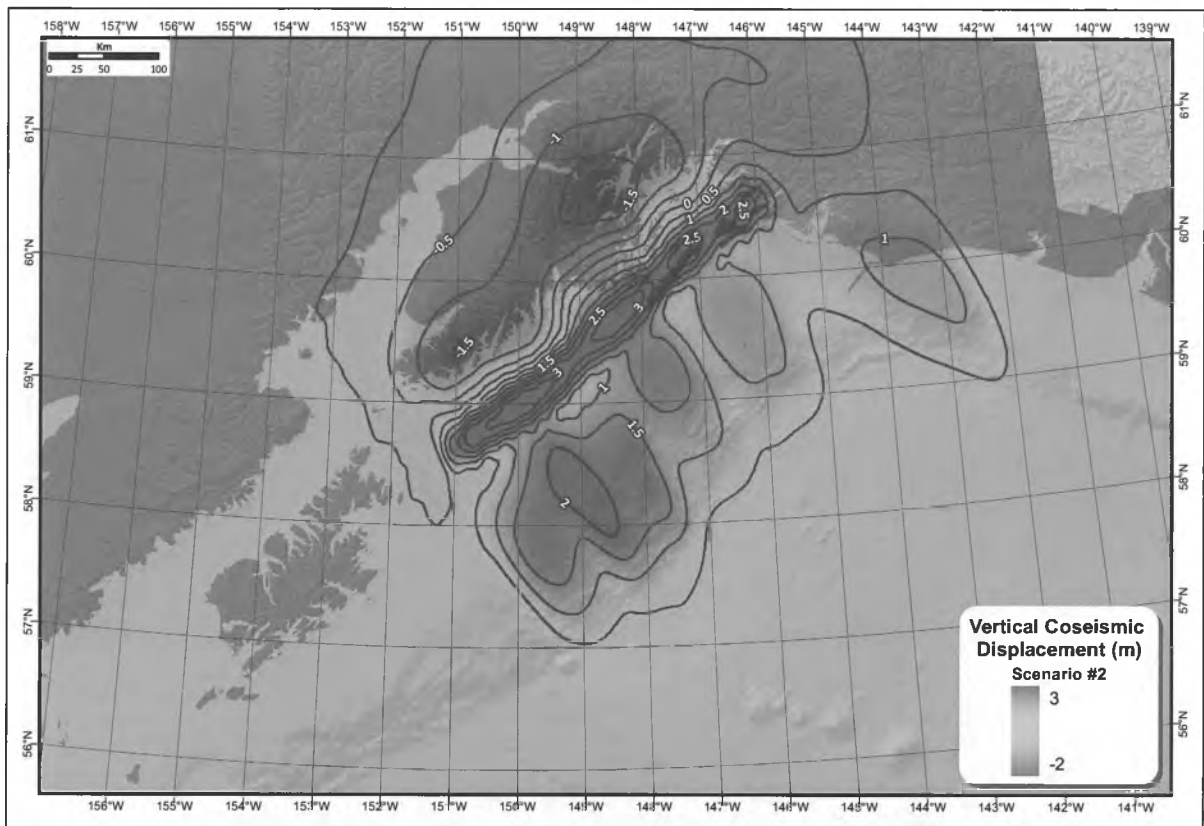


Figure 13. Scenario 2. Prince William Sound asperity of SDM.

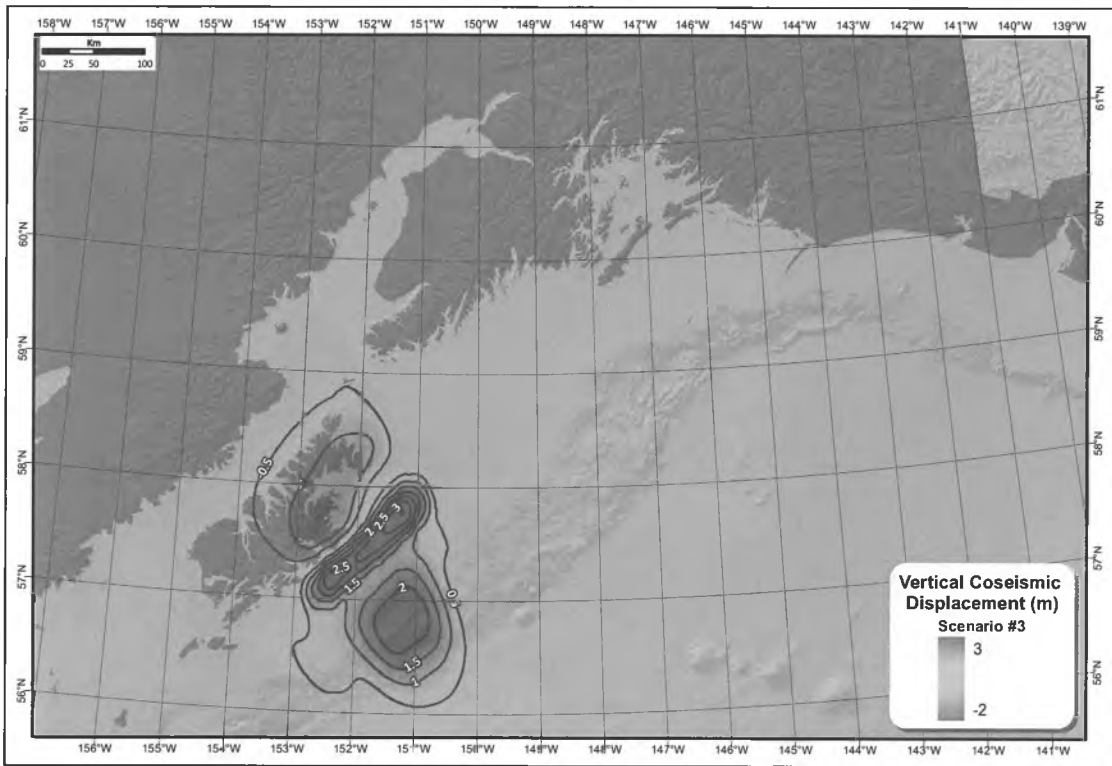


Figure 14. Scenario 3. Kodiak asperity of SDM.

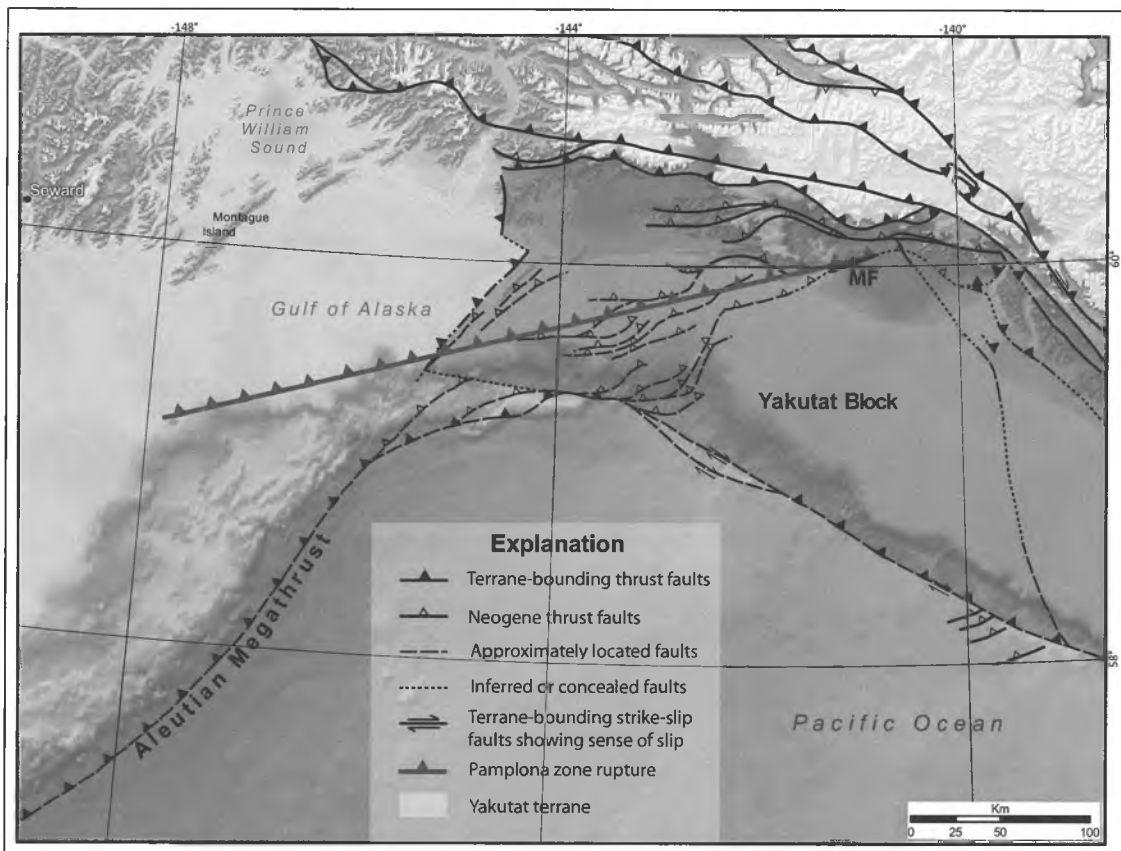


Figure 15. Geologic setting of the Yakutat block with major faults, from Plafker and Thatcher (2008). The hypothetical Pamplona zone rupture (Scenario 4) is shown by a purple line; Malaspina fault is indicated by "MF."

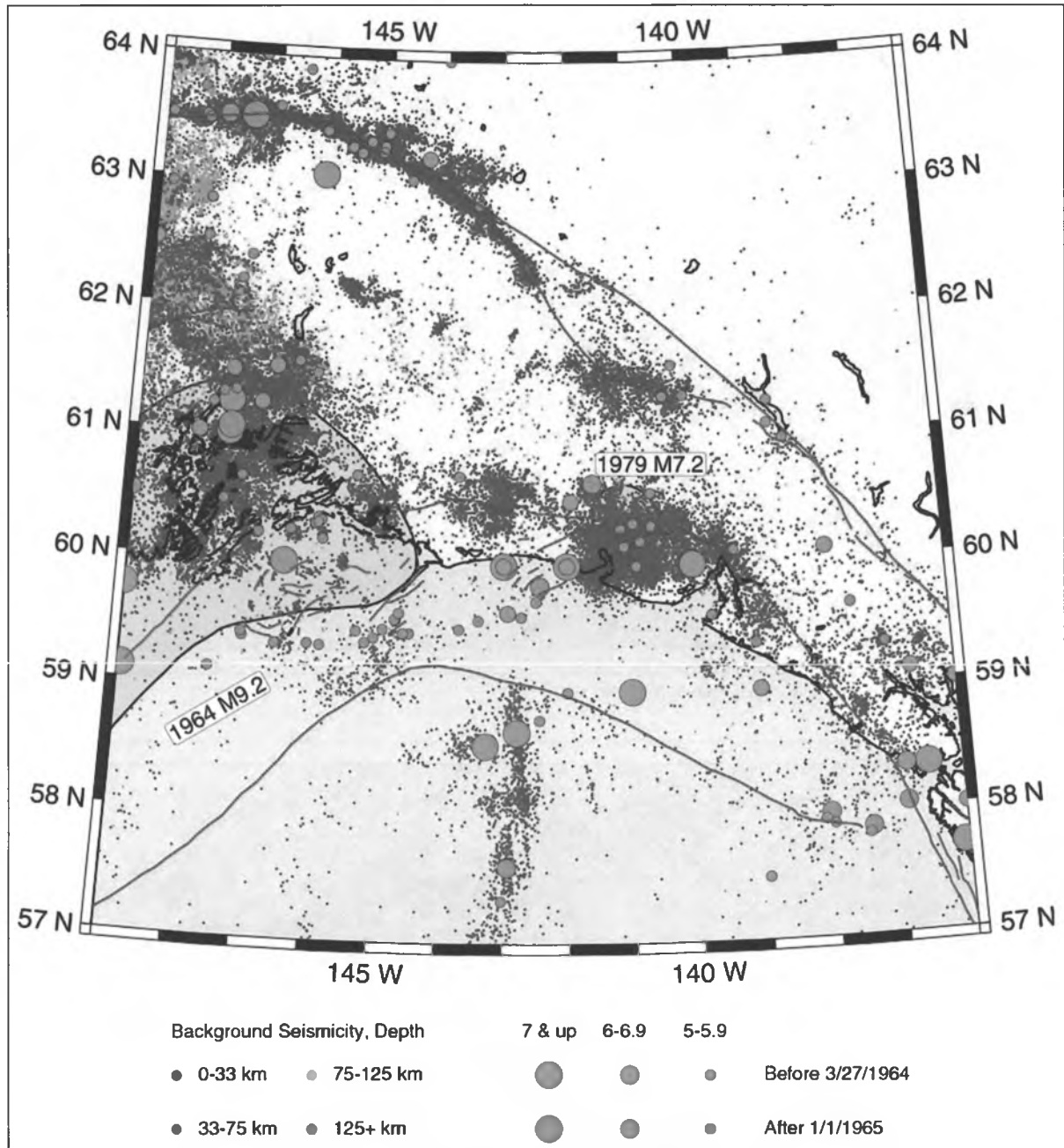


Figure 16. Earthquakes in the vicinity of the Yakutat block, from the Alaska Earthquake Information Center catalog. Major faults are shown by red lines; areas shaded in beige are rupture zones of the 1964 Great Alaska Earthquake and the 1979 earthquake. Small dots correspond to earthquakes with magnitude greater than 1 and less than 5. Large circles show significant earthquakes (magnitude 5 and greater) before (purple) and after (light blue) the great Alaska earthquake of March 27, 1964. The main shock and aftershocks of this event are not included in the plot.

Table 3. Fault parameters for scenario 4.

| Lat<br>[deg. N] | Lon<br>[deg. W] | Depth<br>[km] | Length<br>[km] | Width<br>[km] | Strike<br>[deg.] | Dip<br>[deg.] | Rake<br>[deg.] | Slip<br>[m] |
|-----------------|-----------------|---------------|----------------|---------------|------------------|---------------|----------------|-------------|
| 60.05           | 140.83          | 5             | 410            | 175           | 255              | 12            | 90             | 10          |

**LANDSLIDE TSUNAMI SOURCES  
MULTIPLE SUBMARINE SLOPE FAILURES  
IN RESURRECTION BAY DURING THE 1964  
EARTHQUAKE**

Studies by Lee and others (2006) and Haeussler and others (2007) provided analysis of pre- and post-earthquake bathymetric data and high-resolution sub-bottom profiles of Resurrection Bay and showed convincing evidence of massive submarine landsliding during the 1964 earthquake. They utilized a 2001 NOAA high-resolution multibeam bathymetric survey of Resurrection Bay to study the morphology and depth changes of the fjord bottom. A shaded relief map derived from this bathymetric data shows a variety of seafloor features related to submarine slides. Lee and others (2006) identified remains of the Seward waterfront that failed in 1964 as a result of strong ground shaking. These remains are visible as blocky debris extending offshore from Seward

for about 750 m (fig. 18). The authors also identified dispersed debris flows that correspond to failures of the Resurrection River delta, and they concluded that the 1964 earthquake could potentially have triggered different failure types simultaneously. Haeussler and others (2007) concluded that several failures initiated along the fjord walls at relatively shallow depths, and the mass flows produced by these failures transported most of the material as far as 6 to 13 km into the bathtub (see fig. 4), covering the entire basin with a flow deposit. The authors created a bathymetric difference grid that shows depth changes in the bay resulting from the 1964 slope failures. The estimated total volume of slide material is 211 million cubic meters. A map of the slide thickness, derived from the bathymetric difference grid, is shown in figure 19. The first numerical modeling study of local tsunamis in Resurrection Bay (Suleimani and others, 2009) utilized these findings and concluded

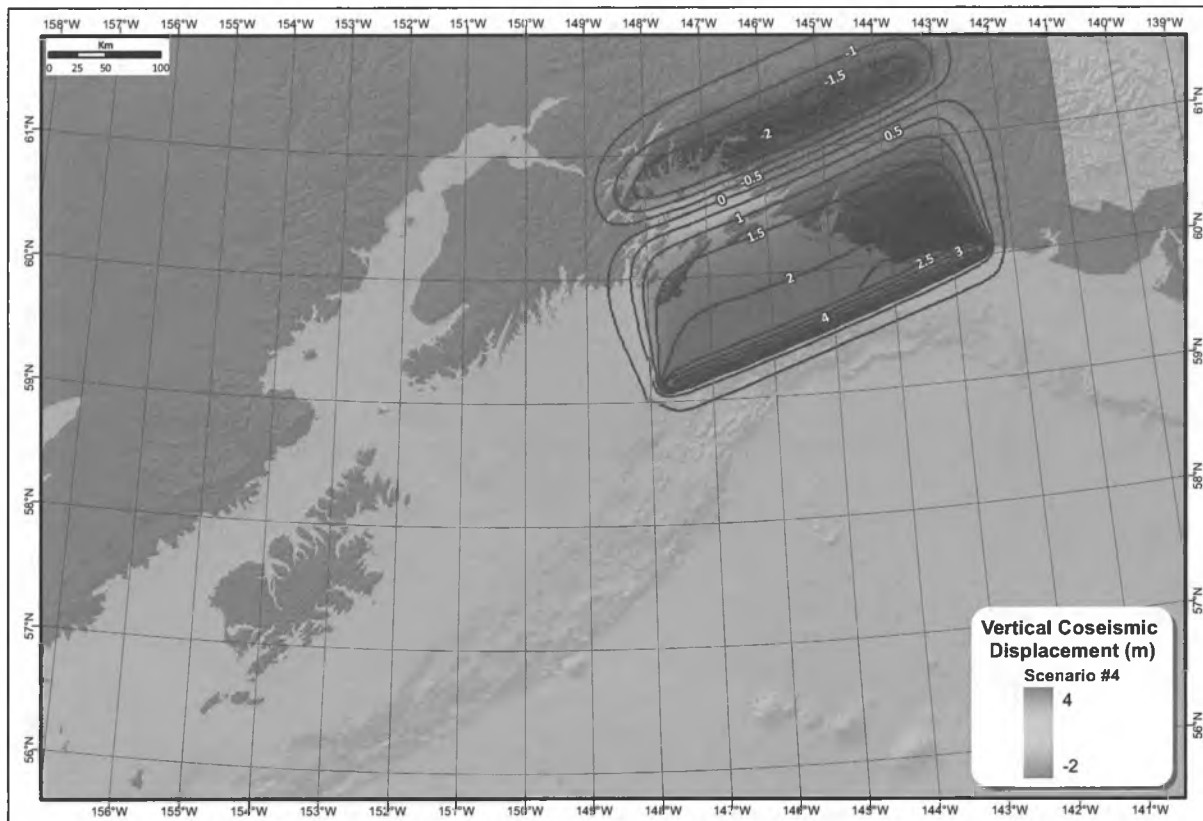


Figure 17. Scenario 4. Pamplona zone deformation model.

that the waves observed at the Seward waterfront and in several other locations in Resurrection Bay resulted from multiple submarine slope failures. Suleimani and others (2009) conducted a numerical experiment to investigate how individual underwater slides contributed to observed tsunami amplitudes in the bay. They showed that slides in the northern part of the bay were the major contributors to the tsunami amplitudes at Seward, and that the contribution from other slide complexes was negligible.

### LANDSLIDE TSUNAMI SCENARIOS

**Scenario 5.** Waves generated by three major underwater slide complexes of the 1964 earthquake – Seward downtown slide, Lowell Point slide, and Fourth of July slide.

Figure 20 shows three slide complexes in the upper bay that were the major contributors to the locally generated waves that inundated Seward (Suleimani and others, 2009). The slide thicknesses were derived by Haeussler and others (2007) from the bathymetric difference grid. This distribution of the slide material serves as an initial

condition for tsunami simulation. The total volume for these three slide complexes was approximately 80.6 million cubic meters.

**Scenario 6.** Hypothetical event: Simultaneous underwater slope failures at four locations where sediment accumulated since 1964.

The bathymetric difference grid derived by Haeussler and others (2007) shows four major areas in upper Resurrection Bay where sediment accumulated since 1964: (1) a new location of sediment deposition from the rerouted Lowell Creek; (2) and (3) accumulation areas at the fjord head delta; and (4) a new location of sediment deposition from the rerouted Fourth of July Creek (fig. 21). The total volume of sediments in all locations is approximated at 6.5 million cubic meters. We assume that the slope failures occur at the same time, and that the failure surfaces correspond to the post-earthquake bottom of Resurrection Bay. This means that the volume of the failed material will be equal to the volume of sediments accumulated after the 1964 earthquake.



Figure 18. Oblique image of Seward downtown, with offshore shaded-relief bathymetry. Dashed white lines indicate the approximate margin of debris resulting from a submarine landslide that was triggered by the 1964 earthquake.

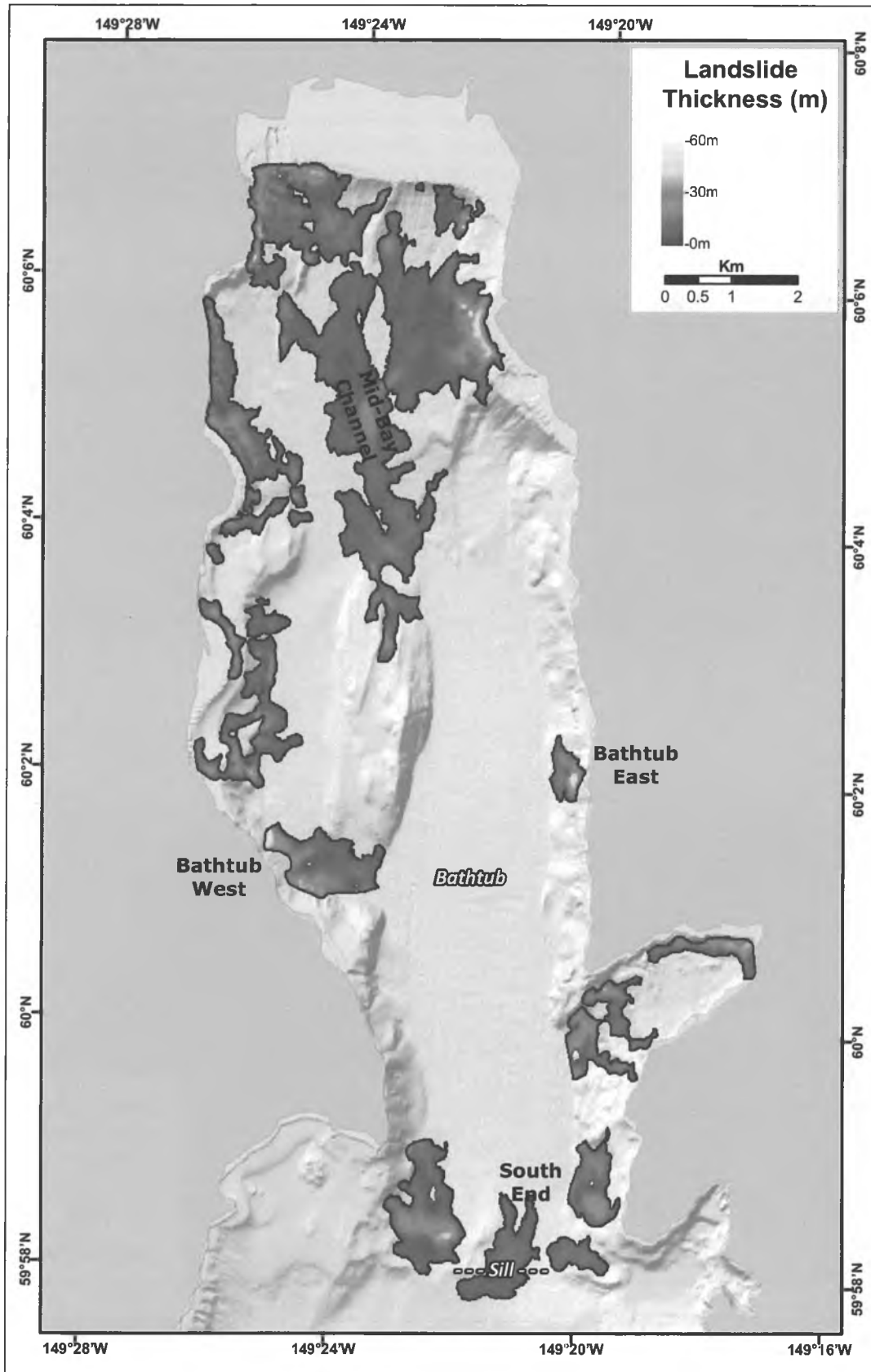
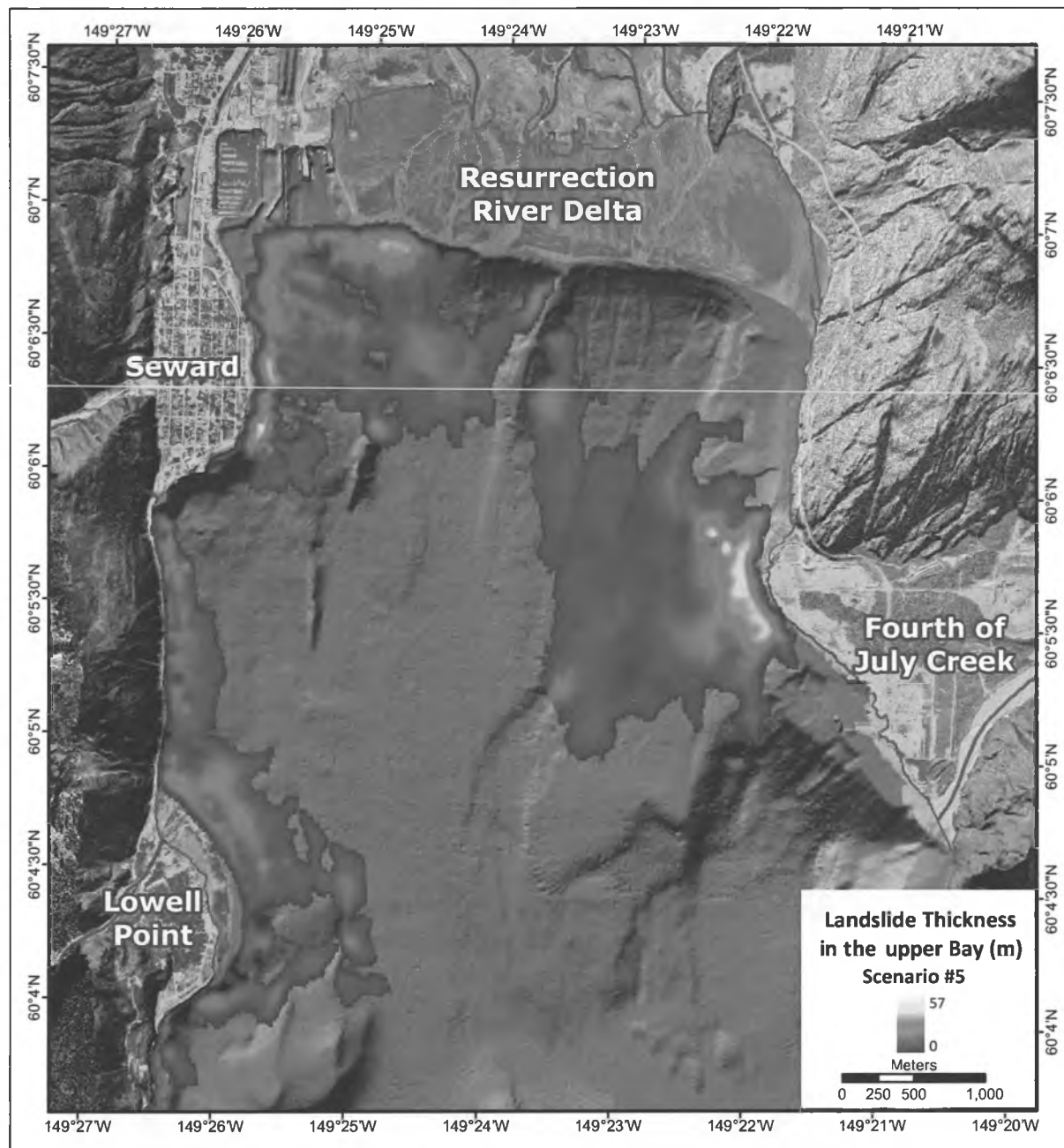


Figure 19. Distribution of initial thickness of the sliding mass.

**Scenario 7.** Hypothetical event: Simultaneous underwater slope failures at four locations where sediment accumulated since 1964, with added sediment volumes.

Recent coring surveys conducted in Resurrection Bay (Clark Alexander, oral commun.) provide information on morphology of slide deposits and on sediment accumulation rates in the fjord. One of the cores was

taken offshore at the fjord head delta front (fig. 21), and its Pb-210 and Cs-137 isotope profiles suggest that this area did not fail during the 1964 earthquake. This core also shows the highest accumulation rate among other cores in Resurrection Bay, about 2 cm per year. We base this second hypothetical landslide scenario on the same areas of sediment accumulation shown in figure 21, with an addition of extra volume of sediments that will



*Figure 20. Scenario 5. The three major slides of the 1964 earthquake-triggered massive slope failures in Resurrection Bay, which produced the greatest contribution to tsunami amplitudes at Seward. Other submarine landslides triggered in Resurrection Bay in 1964 produced negligible effects.*

be accumulated over decades. Also, future earthquakes can release lower layers of sediment that remained intact during the 1964 earthquake. Since it is not possible to predict potential failure surfaces without comprehensive slope stability analysis, we account for that additional failing mass by adding extra volume to the existing accumulated volume. This hypothetical scenario includes four slides, with the total volume approximately 100 million cubic meters.

**MODELING RESULTS**  
**NUMERICAL MODELING OF THE**  
**1964 TSUNAMI IN RESURRECTION**  
**BAY: MODEL VERIFICATION**

In this section, we compare results of inundation modeling of the 1964 tsunami in Resurrection Bay with observations collected shortly after the event. Because the source of local waves in Resurrection Bay ceased at the end of ground shaking (Wilson and Tørum, 1968),

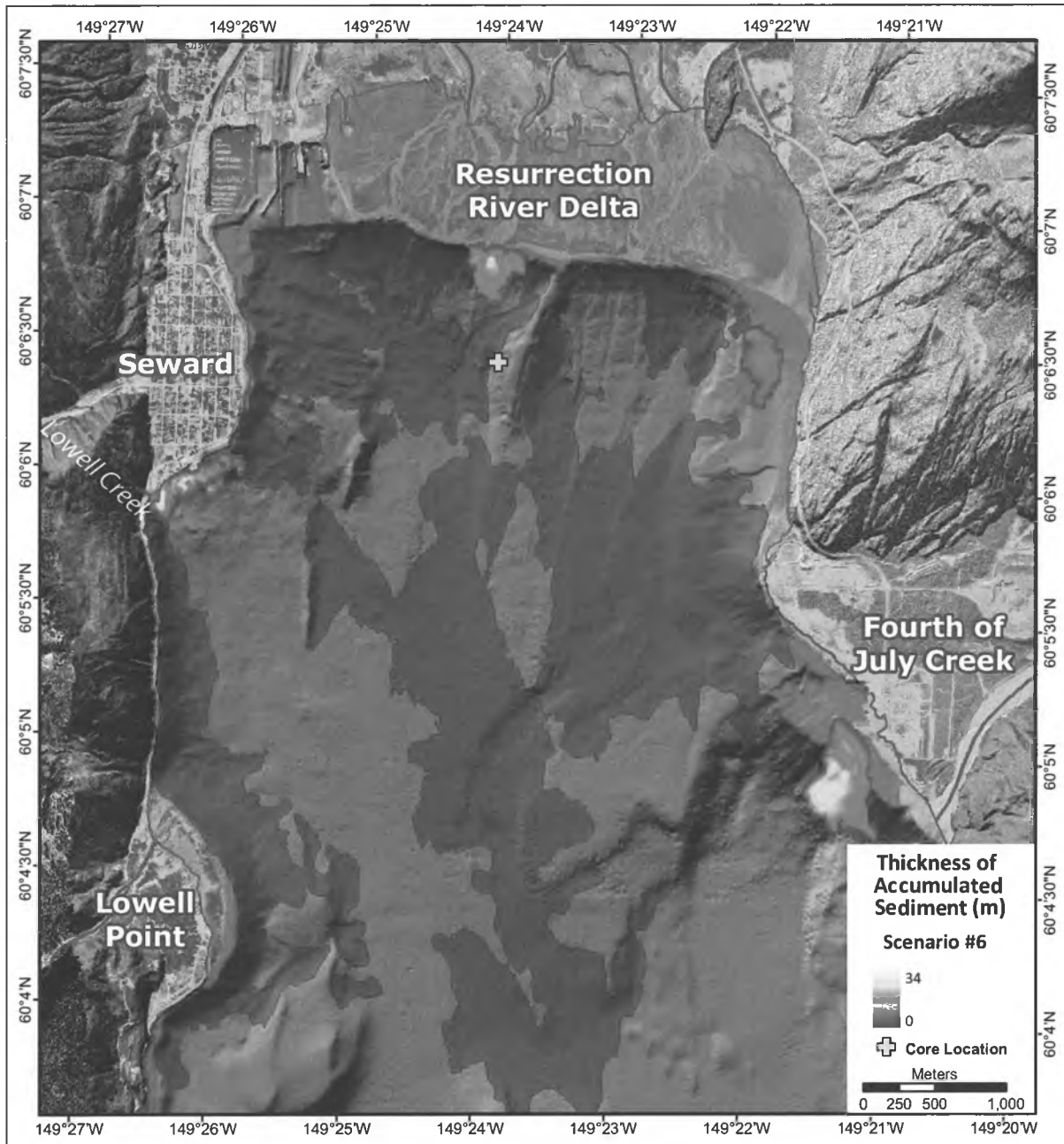


Figure 21. Scenario 6. Accumulation areas with thicknesses and location of the S2G1 core studied by Clark Alexander (oral commun.). Brown areas indicates the original positions of landslide masses released during the 1964 earthquake.

about 20 minutes before the arrival of the tectonic tsunami, we can assume that these events are independent and model them separately. The union of inundation areas computed independently for tectonic and landslide-generated waves will be compared to the observed composite inundation pattern.

The numerical grid used in inundation modeling covers the northern part of Resurrection Bay (fig. 20). We assume that the slides were initially at rest, then triggered by ground shaking at  $t = 0$ , and moved thereafter only under the force of gravity. At the southern open boundary of the grid, we specify the radiation boundary condition for the water waves. The boundary condition for the slide mass allows the slide to leave the computational domain without reflection. The moving boundary condition at the shoreline allows for wetting and drying of land. Shannon and Hilts (1973) conducted a subsurface geotechnical investigation of materials that failed in Resurrection Bay during the 1964 earthquake. They found that the density of the slide material ranged from  $2.0\text{g/cm}^3$  to  $2.11\text{g/cm}^3$ . We do not have any measurements of the slide viscosity, but sensitivity studies by Rabinovich and others (2003) demonstrated that the influence of kinematic viscosity on tsunami wave heights is small. We assume slide density of  $\rho = 2.0\text{g/cm}^3$  and slide viscosity of  $\mu = 0.05\text{m}^2/\text{s}$ . The upper and lower surfaces of the slide mass are defined by the initial slide thickness distribution (fig. 20). The slide thicknesses are added to the bathymetry values in order to define the pre-earthquake depths in Resurrection Bay. Although it is possible that individual slides were triggered at different times after the initial ground shaking, there is no independent evidence to support this hypothesis. Therefore we assume in the model that all slides start moving at the same time.

The recent numerical study by Suleimani and others (2009) confirms the observations that Seward was inundated by locally generated waves within 5 minutes of the main shock. We run numerical simulation of landslide tsunamis for 5 minutes of physical time with a time step  $\Delta t = 0.01$  seconds. The yellow line in figure 22 delineates the observed inundation area at Seward downtown. The inundation line was digitized from the U.S. Army Corps of Engineers aerial photo of Seward that was taken one day after the earthquake (Lemke, 1967). The maximum observed extent of inundation at the head of the bay is shown by a yellow line in figure 23. This line, digitized from a geologic map (Plate 1, Lemke, 1967), documents the maximum runup from one or more waves, therefore representing the composite inundation pattern. Green lines in figures 22 and 23 show calculated extent of inundation from 1964 local landslide-generated tsunami waves at Seward and at the head of the bay, respectively. The results show little inundation in the delta area at the head of the bay, and significant inundation in downtown

Seward. This can be explained by directionality of the waves that were induced by the slides (fig. 20), and by topographic changes that have occurred since 1964. Suleimani and others (2009) showed that the highest observed wave at the Seward waterfront was generated by the Fourth of July Creek slope failure. The same wave traveled as an edge wave at the head of the bay. Simulated locally generated waves did not cause much inundation in the harbor area, because the topographic data reflect the present conditions. There were significant changes to the harbor area since 1964, and the new topographic data set includes breakwaters that did not exist in 1964.

Figures 22 and 23 also show calculated extent of inundation from a tectonic tsunami. The blue line corresponds to the tectonic wave that was modeled using JDM, and the purple line corresponds to the wave modeled using SDM. The tectonic wave produced by JDM penetrates deeper inland and completely inundates the airport. These results vastly overestimate inundation of the airport area after the 1964 Great Alaska Earthquake (fig. 23). The wave associated with SDM produces an inundation zone that matches observations very well. In Seward downtown, the wave associated with JDM also penetrates deeper inland than the wave associated with SDM (fig. 22). The landslide-generated waves travel farther inland in the downtown area than the SDM-produced waves, but do not produce much inundation in the harbor area. This can be explained by the fact that the harbor area has substantially changed since 1964, and this primarily affected the modeling results for shorter wave lengths, that is, for landslide-generated waves. The union of inundation areas computed independently for tectonic and landslide-generated waves is in good agreement with observations.

## RESULTS OF HYPOTHETICAL TSUNAMI SCENARIOS

We performed numerical calculations for all scenarios described above. In every case, the initial water disturbance propagated through the set of embedded grids of increasing resolution. In a final grid of 15m resolution, where bathymetric and topographic data are combined in a continuous data set, we computed the extent of inundation using a moving boundary condition.

Sheet 1 shows inundation limits for all tectonic scenarios. Scenarios 1 and 2 (SDM and the Prince William Sound asperity of SDM) represent a source model of the 1964 earthquake and both predict high inundation. The inundation area that corresponds to the entire 1964 rupture zone coincides almost entirely with the inundation zone that corresponds to the Prince William Sound asperity alone. That allows us to conclude that the largest tectonic waves of the 1964 Alaska tsunami observed at



Figure 22. Observed 1964 inundation line (from Lemke, 1967) and calculated inundation lines from tectonic and landslide sources at Seward.



Figure 23. Observed 1964 inundation line (from Lemke, 1967) and calculated inundation lines from tectonic and landslide sources at the head of Resurrection Bay.

Seward were generated by sea floor displacements above the Prince William Sound asperity of the 1964 rupture. The numerical results for Scenarios 3 and 4 (the Kodiak asperity of SDM and the Pamplona zone rupture) predict only moderate inundation, with the Pamplona inundation zone being larger than the Kodiak zone.

Sheet 2 displays inundation lines calculated for the hypothetical landslide scenarios 5–7. The largest inundation area corresponds to a scenario that involves three major slide complexes of the 1964 slope failure. This scenario was calculated using MHW datum.

Sheet 3 shows the maximum composite calculated extent of inundation for all scenarios, and the maximum composite flow depths over dry land. For easier visual reference, on the scale for flow depths we indicated the values of 0.5 m, which approximately corresponds to knee height, and 2 m, which is just above the average person's body height. In several areas in the northeastern section of the tidal flats, the mapped 1964 inundation limit (Lemke, 1967) extends beyond the maximum estimated inundation. We did not adjust the maximum calculated inundation extent in these areas to match the 1964 limit, because the observed inundation line there obviously was not georeferenced well, crossing areas of very high elevations.

## TIME SERIES AND OTHER NUMERICAL RESULTS

To provide more accurate assessment of tsunami hazard for any particular community, we have supplemented the inundation maps with information about the calculated time history of the tsunami wave action in the region. The time of arrival of the first wave, the maximum wave amplitude, and duration of the wave action are important factors that should be considered by emergency managers during evacuation planning.

Appendix 1 contains plots of sea level and velocity time series for all scenarios at a number of locations in Resurrection Bay, shown in figure A1-1. The zero time corresponds to the epicenter origin time, and zero water level corresponds to the post-earthquake MHW level. Since velocity magnitude is calculated as water flux divided by water depth, the velocity value becomes physically meaningless when water depth is less than 10 cm. Therefore, we plot velocity values only for water depths greater than 10 cm. Also, for each scenario we provide plots of maximum flow depths in inundation areas and plots of maximum drag force. At each grid point that corresponds to initially dry land, the flow depth is computed at every time step during the tsunami propagation time interval (8 hours), and the maximum value is kept.

Tsunami flow depth is one of the important indicators of potential damage, and must be differentiated from runup height (Synolakis and Bernard, 2006). For

use in engineering applications, the flow depths must be supplemented with the momentum flux, which is proportional to the drag force (Yeh, 2006). We calculate drag force as a product of water depth and velocity squared. The plot of maximum drag force for Scenario 1 (repeat of 1964 tectonic waves, SDM) is shown in figure 24. The maximum values occur during the drawdown of the long tectonic wave, mostly affecting the boat harbor area between the jetties, and the shallow intertidal zone. Figure 25 shows drag force for Scenario 5 (repeat of 1964 landslide-generated waves). Because landslide-generated waves are shorter than tectonic waves, the maximum values occur in the generation area, where the slide starts moving down the slope.

## SOURCES OF ERRORS AND UNCERTAINTIES

The hydrodynamic model that was used to calculate tsunami propagation and runup is a nonlinear flux-formulated shallow water model (Nicolosky and others, in press). It passed the major analytical, laboratory and field benchmarks that are required for models used in production of tsunami inundation maps (Synolakis and others, 2007).

The source mechanism remains the biggest unknown in the problem of tsunami modeling. Since the initial condition for the modeling is determined by the displacement of the ocean bottom, the largest source of errors is the earthquake model. When the tsunami is generated in the vicinity of the coast, the direction of the incoming waves, their amplitudes, and times of arrival are determined by the initial displacements of the ocean surface in the source area, because the distance to the shore is too small for the waves to disperse. Therefore, the near-field inundation modeling results are especially sensitive to the fine structure of the tsunami source. The modeling process is subject to many more errors when the complexity of the source function is combined with the proximity of the coastal zone.

The 15-m resolution of the inundation modeling is limited by the resolution of the topographic and bathymetric data used for the grid construction. This resolution is high enough to describe major relief features, seawalls, jetties, and other marine structures, although very small topographic features, buildings, and other facilities cannot be accurately resolved by the existing model.

## SUMMARY

We present the results of numerical modeling of earthquake-generated tsunami waves for the Seward area and northern Resurrection Bay, Alaska. We considered several tectonic and landslide scenarios and provided an estimate of maximum credible tsunami inundation. These results are useful for state and local emergency managers to identify areas that should be evacuated in

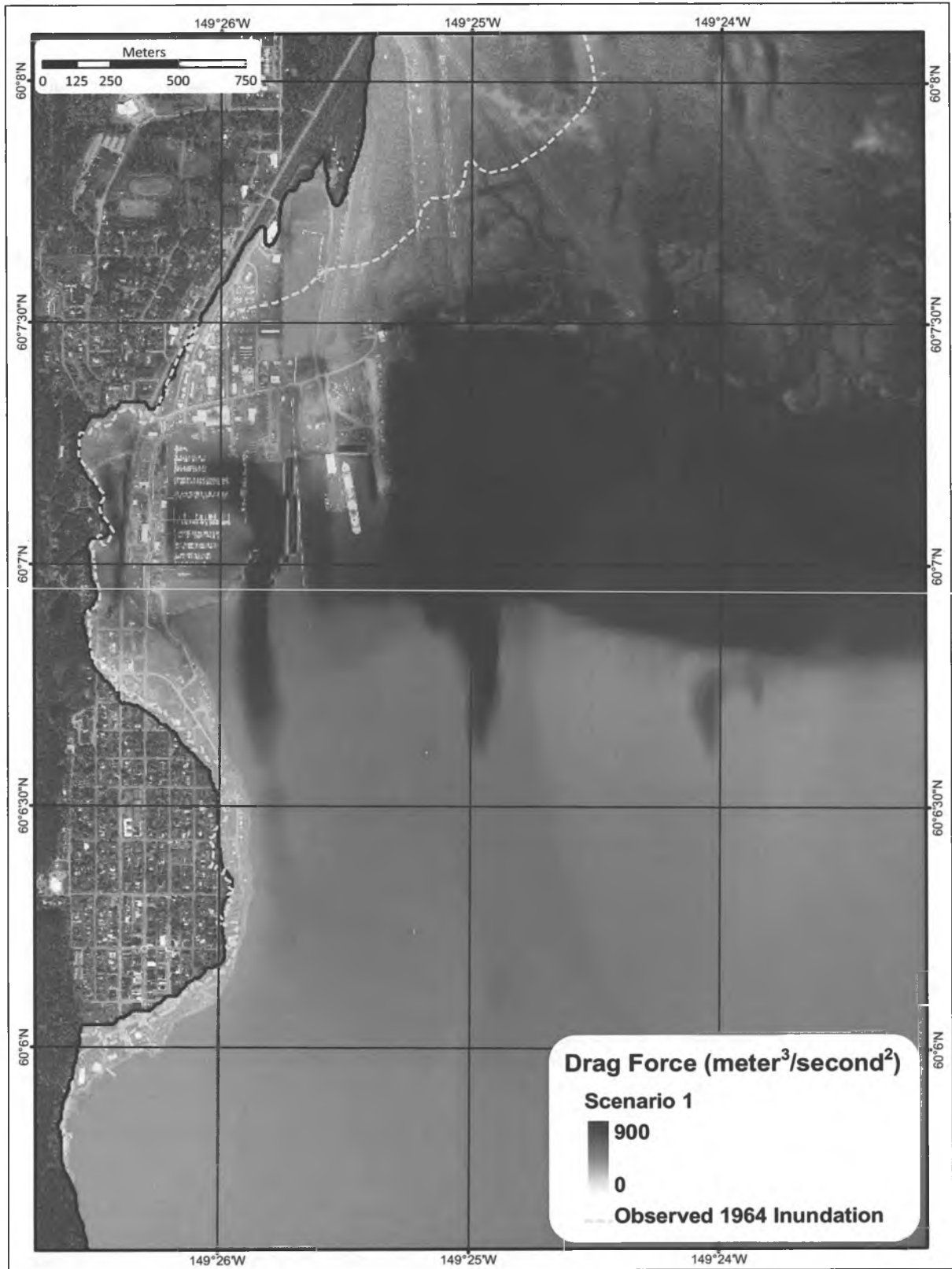


Figure 24. Maximum calculated drag force in the areas of Seward downtown, harbor, and airport for Scenario 1.

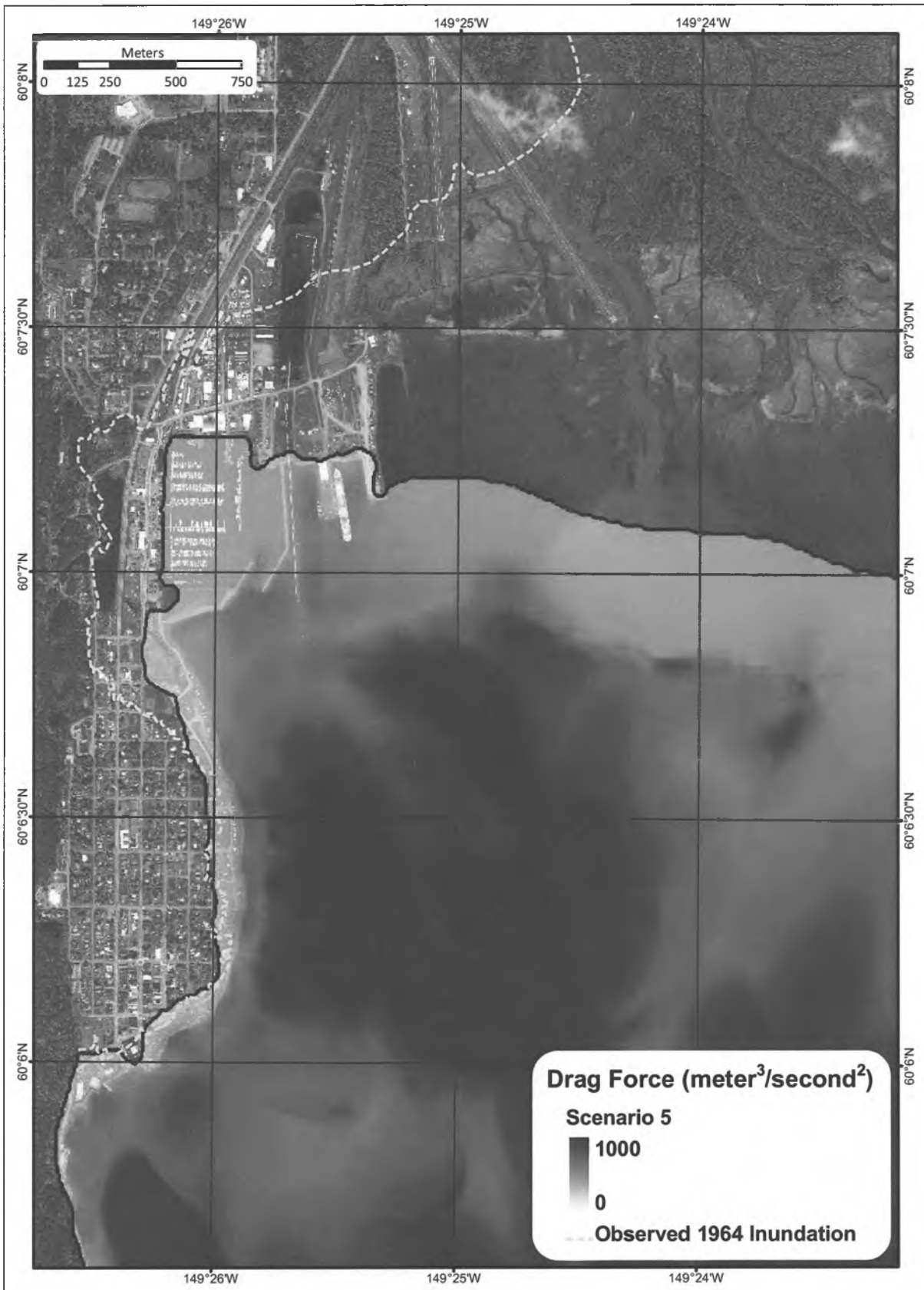


Figure 25. Maximum calculated drag force in the areas of Seward downtown, harbor, and airport for Scenario 5.

the event of a major tsunamigenic earthquake. Because of the uncertainties inherent in this type of modeling, these results are not intended for land-use regulation.

## ACKNOWLEDGMENTS

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### Appendix A

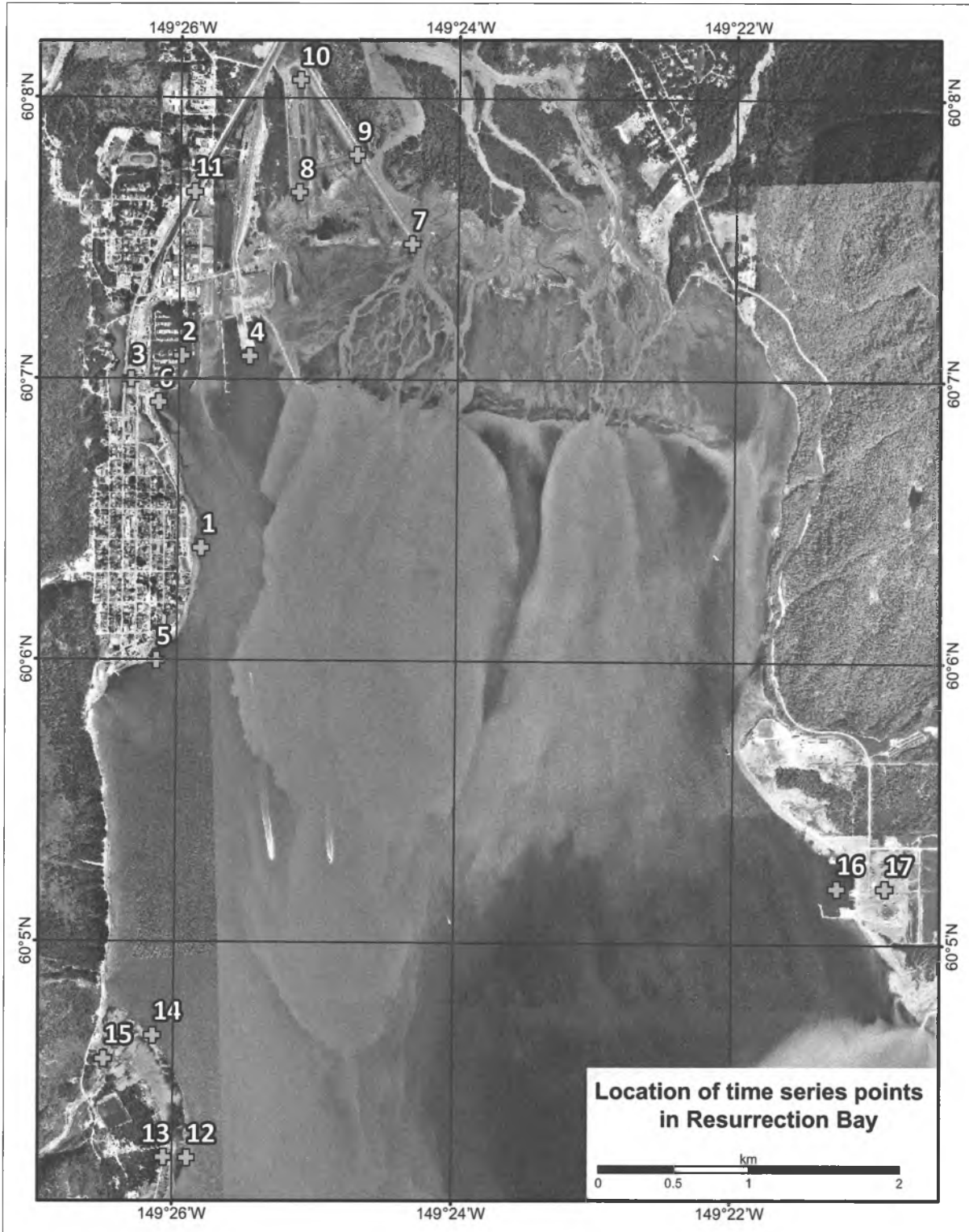
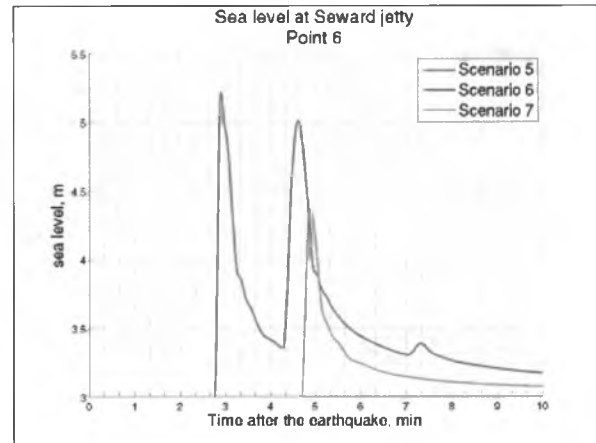
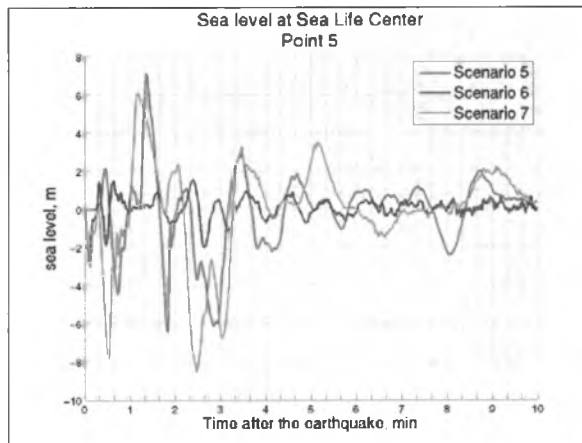
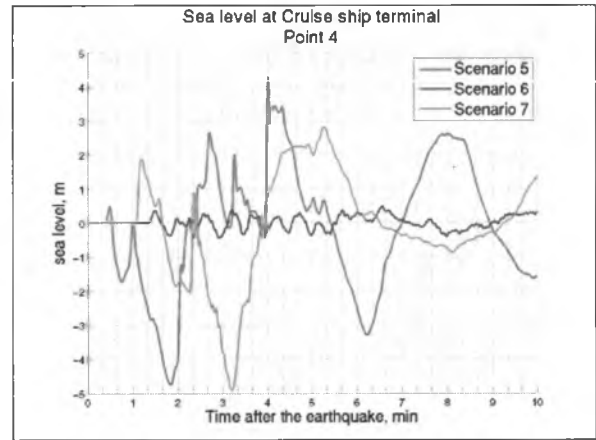
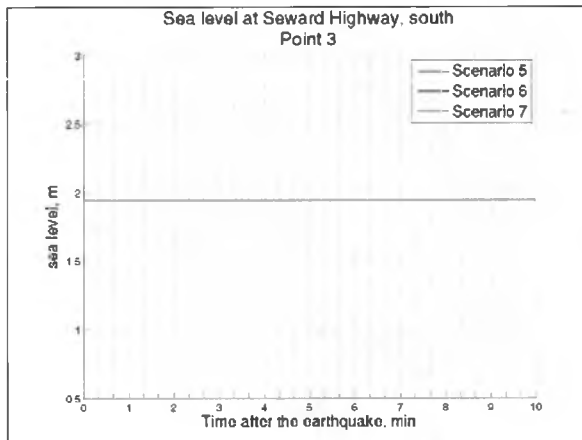
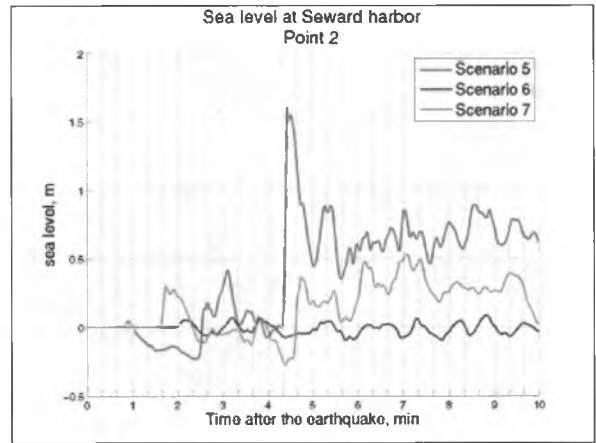
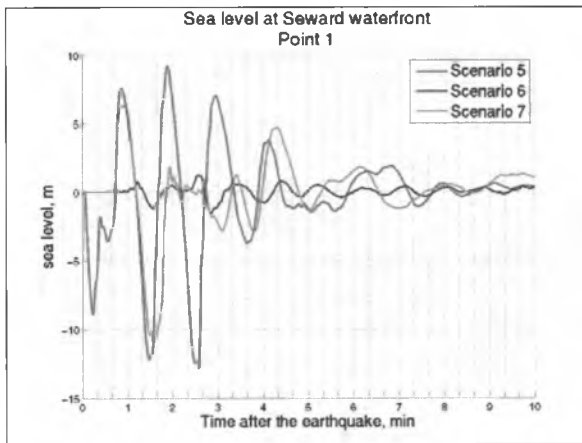
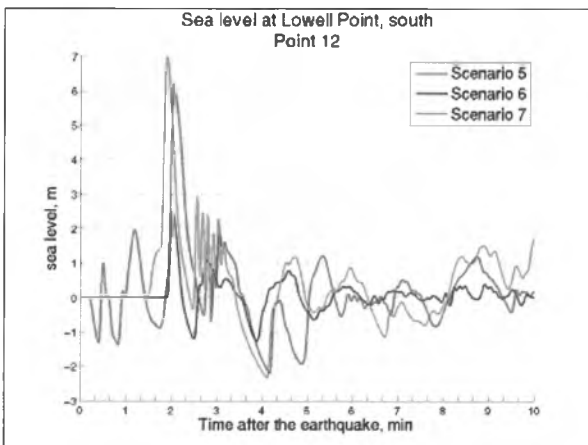
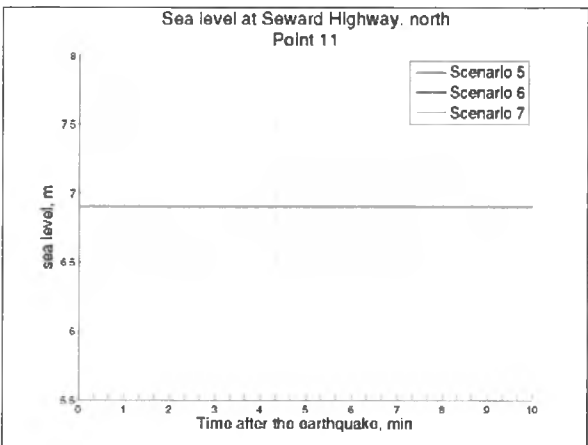
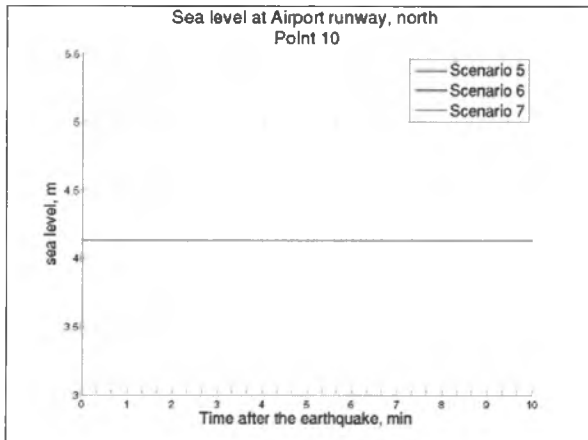
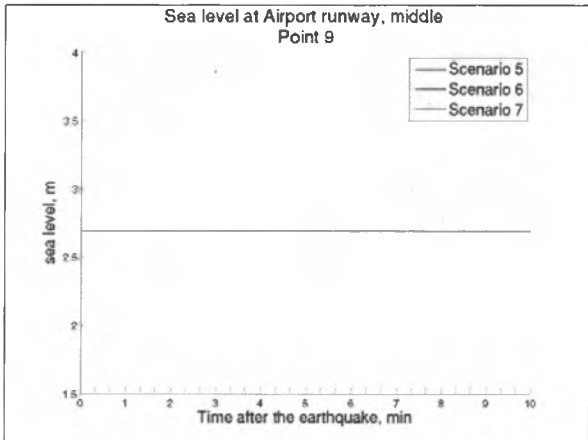
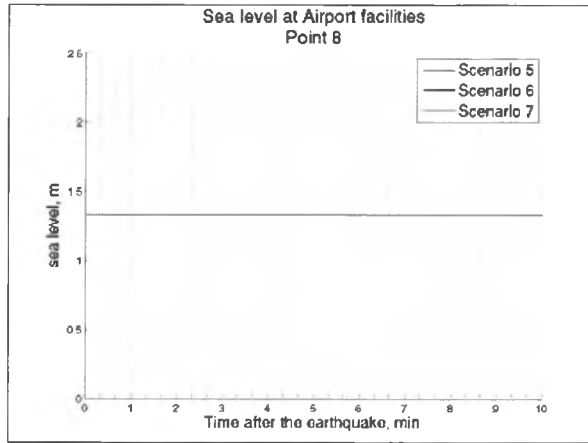
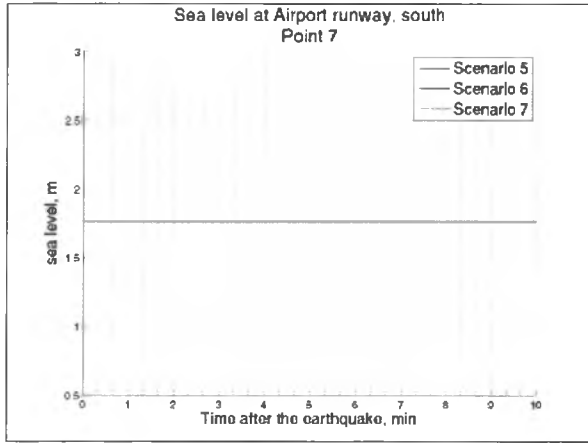
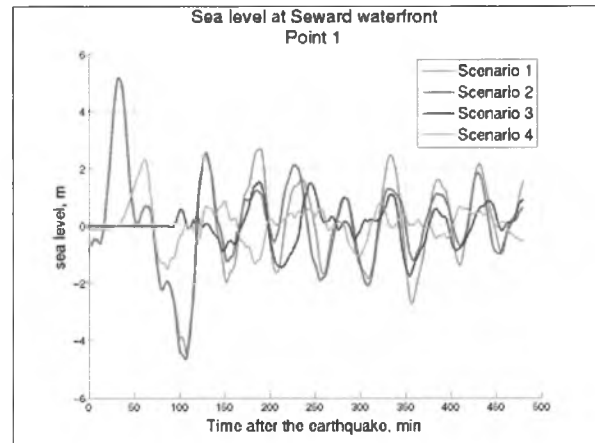
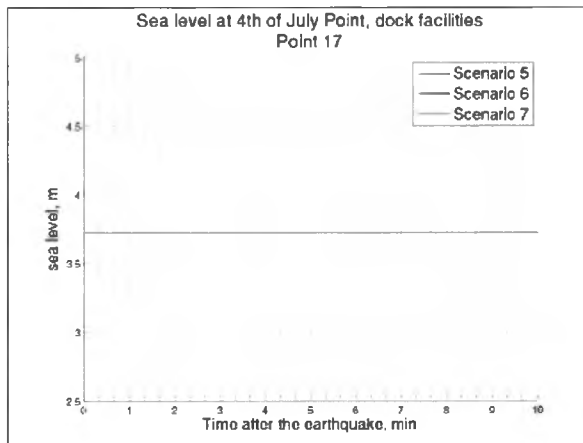
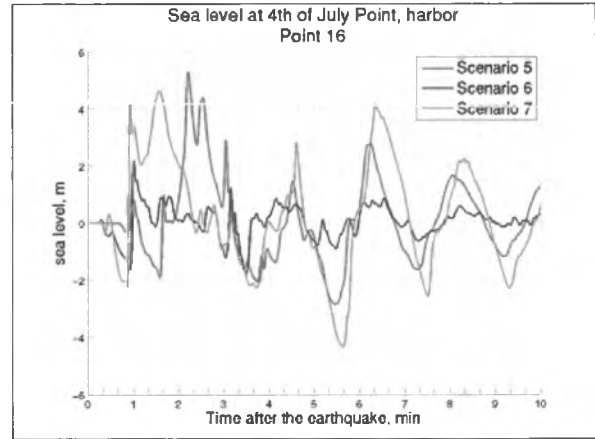
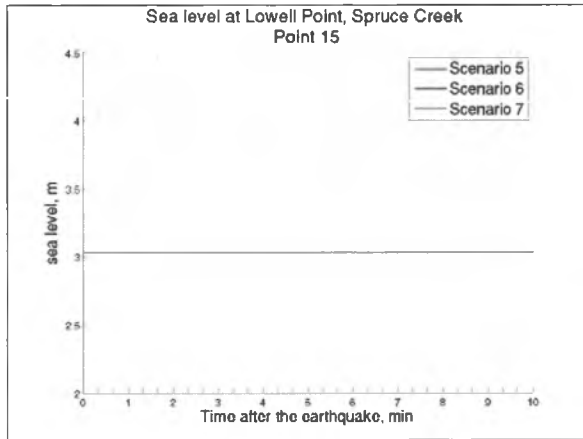
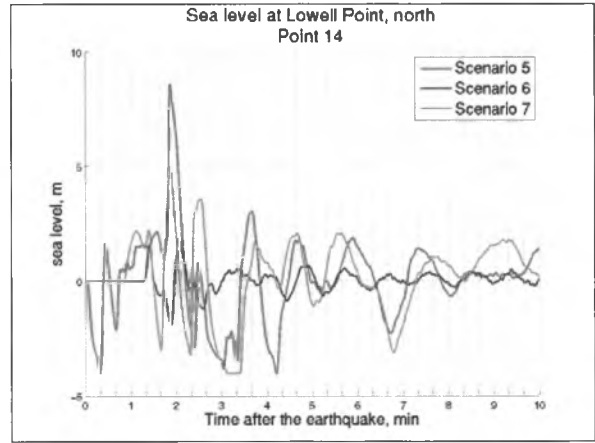
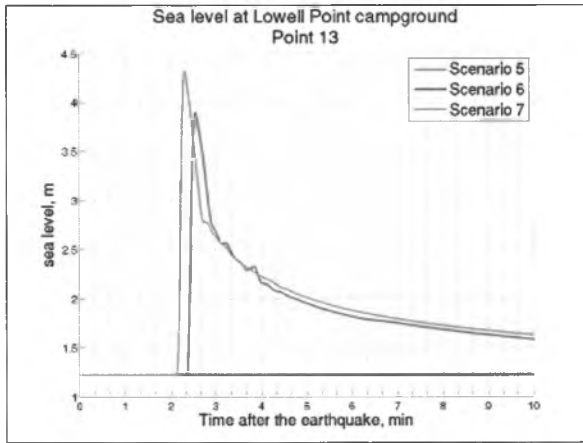
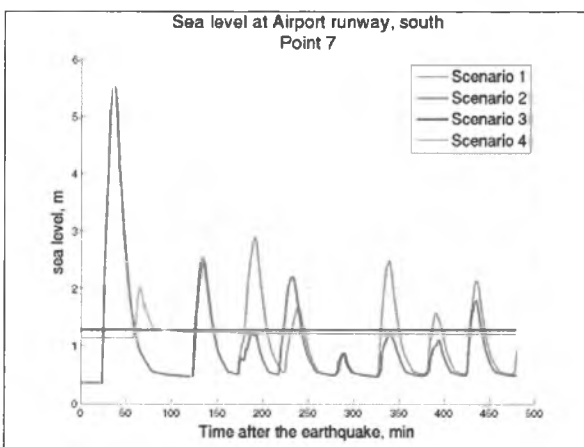
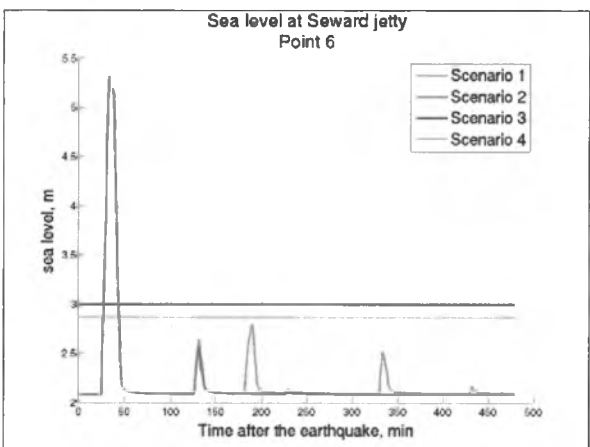
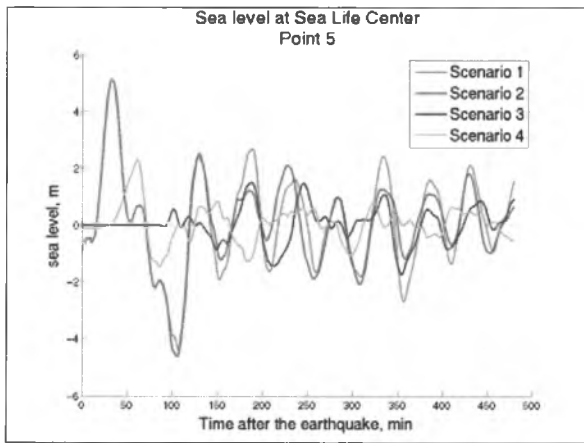
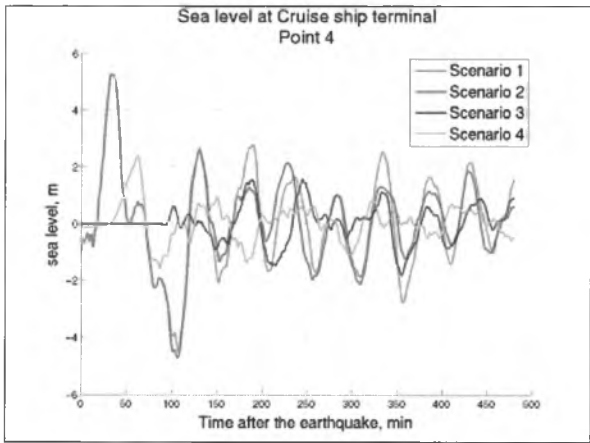
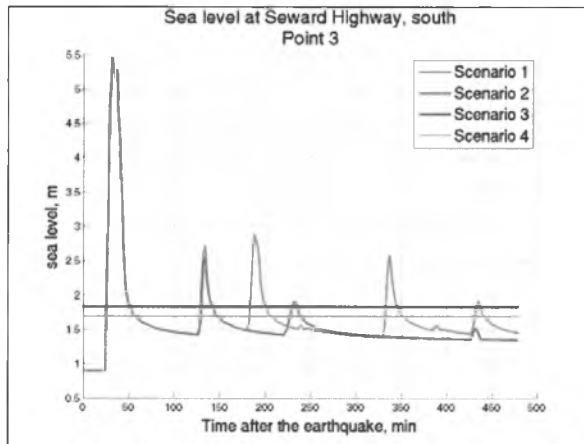
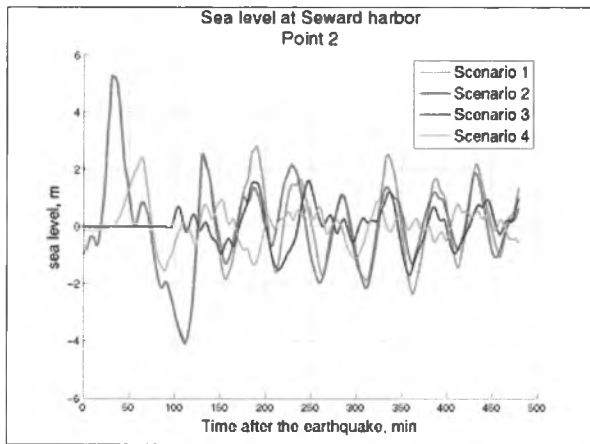


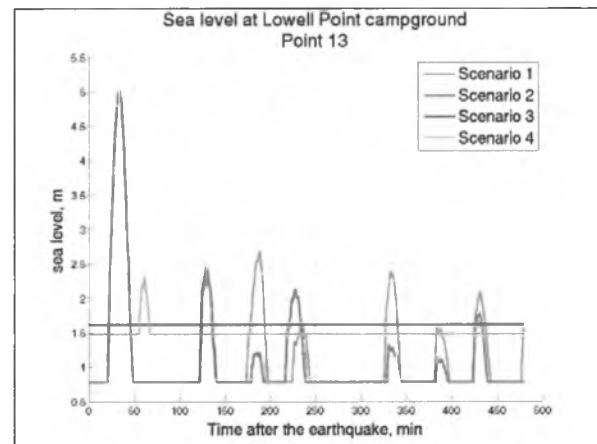
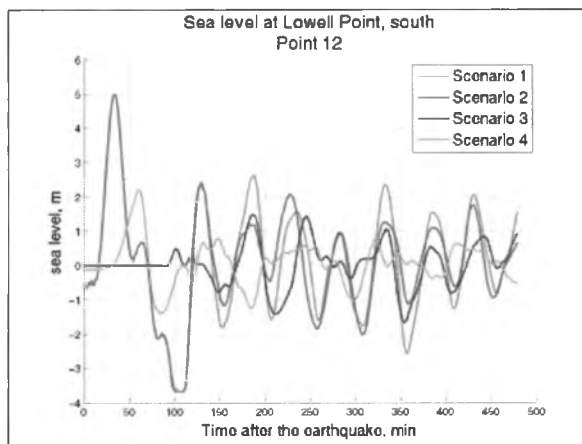
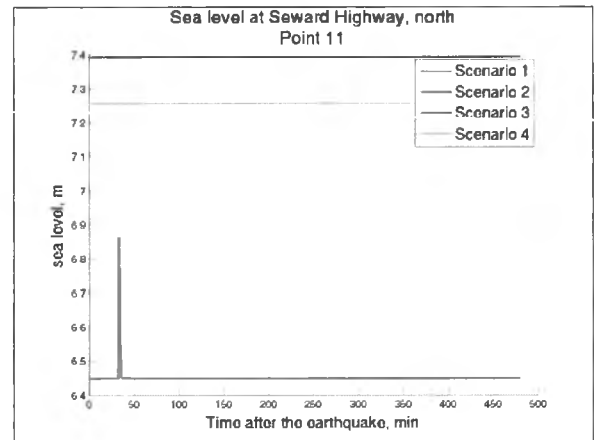
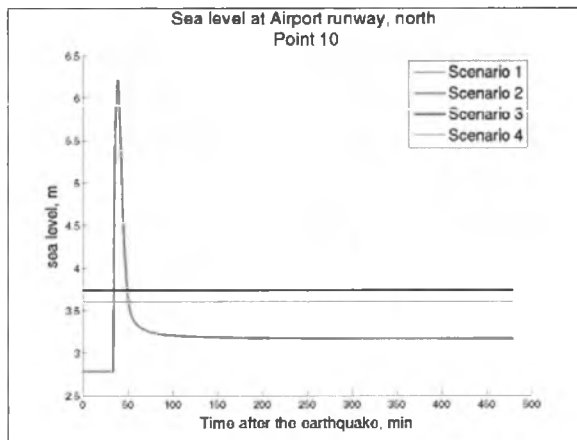
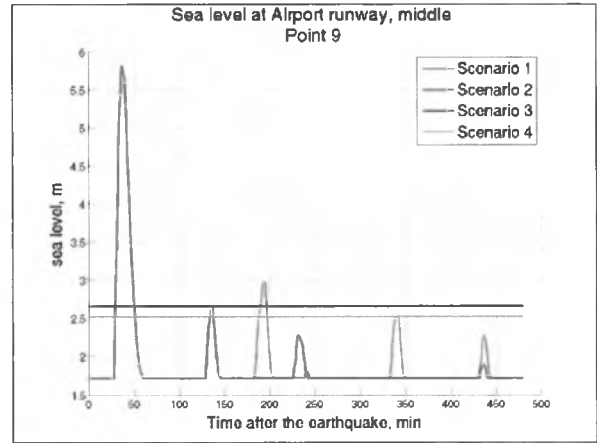
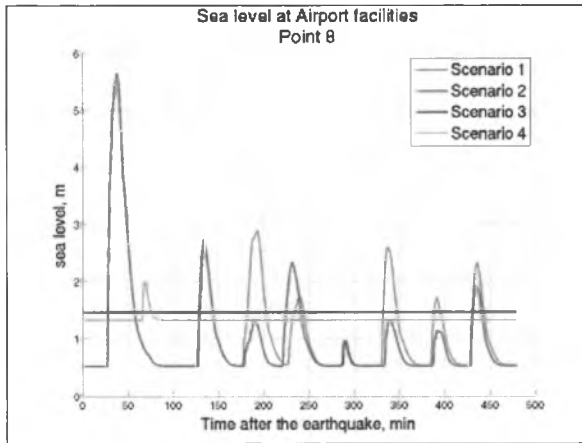
Figure A1-1. Locations of time series points.

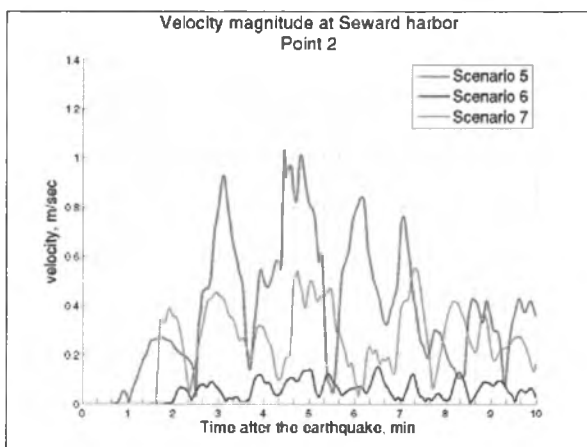
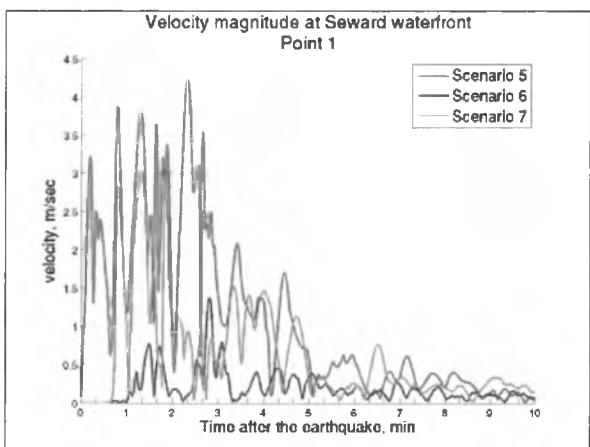
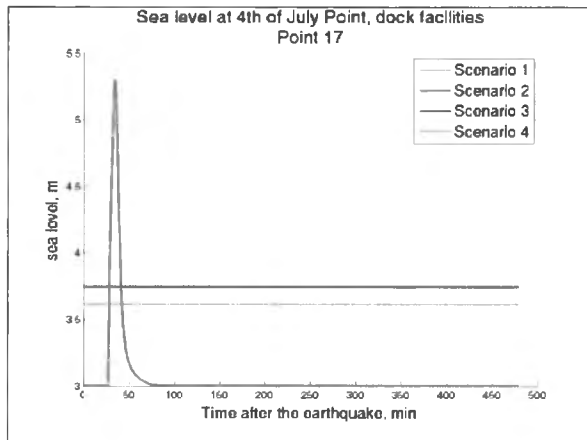
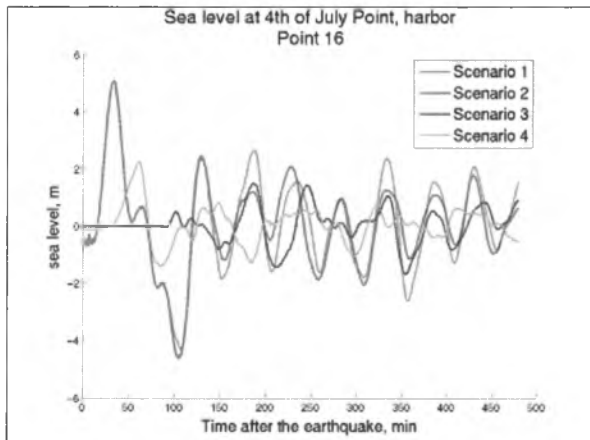
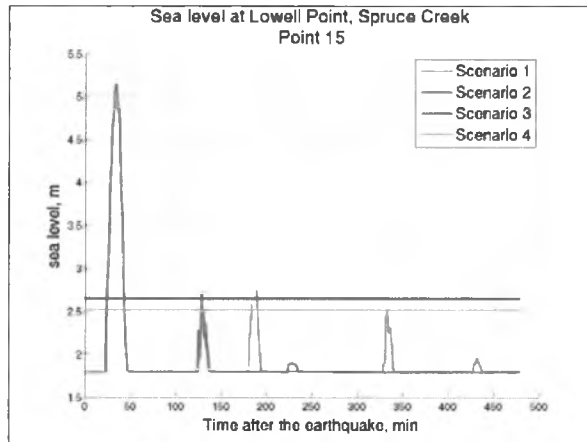
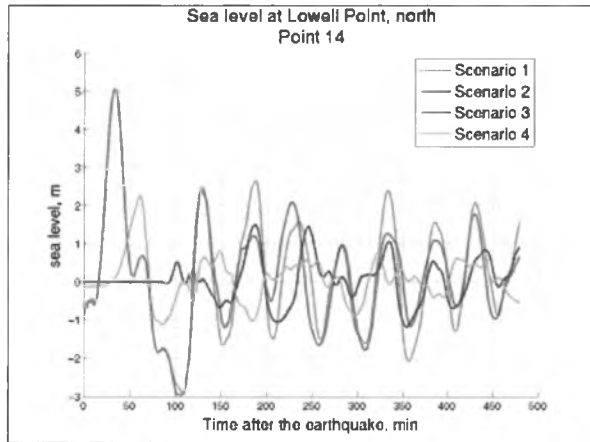


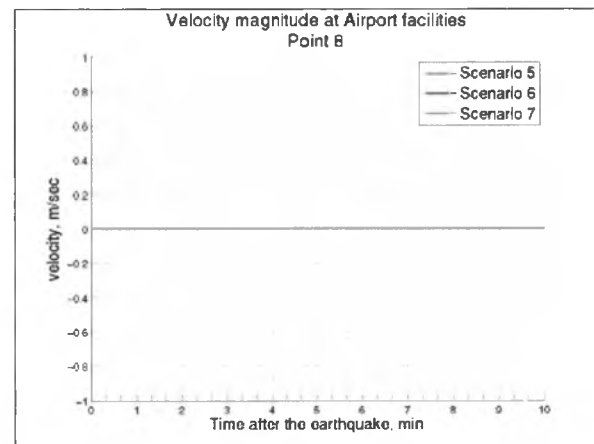
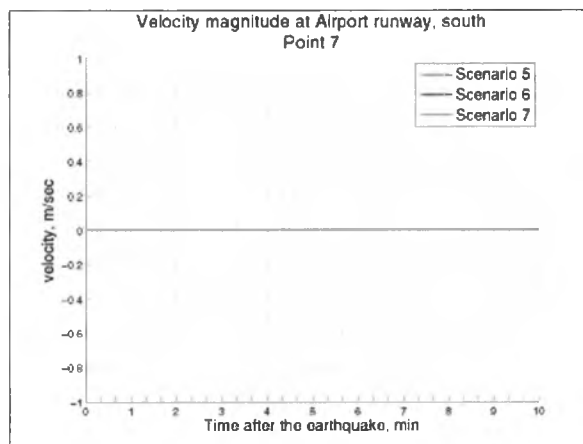
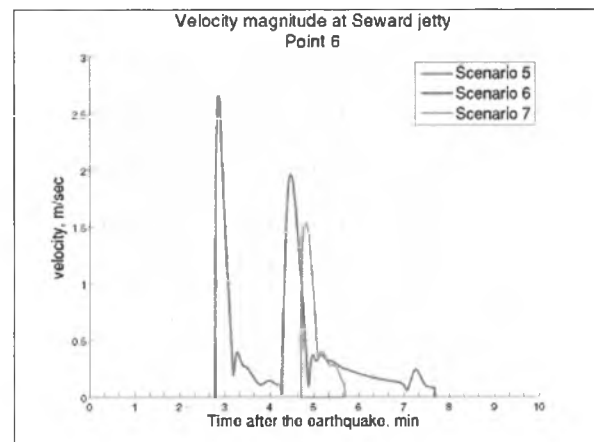
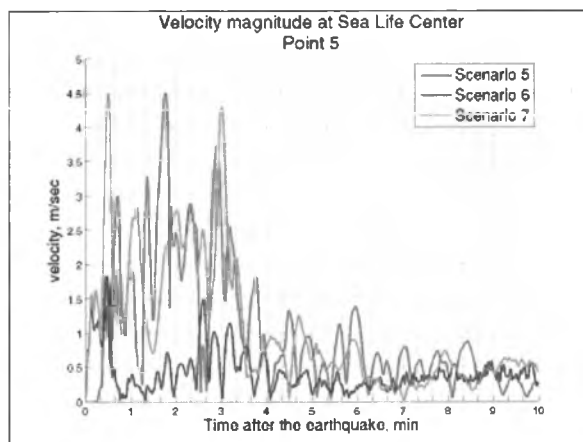
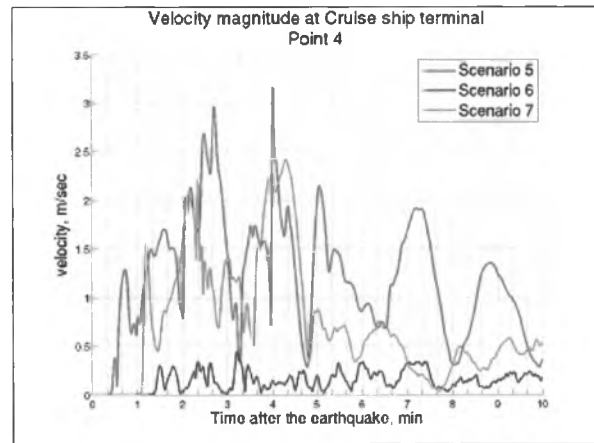
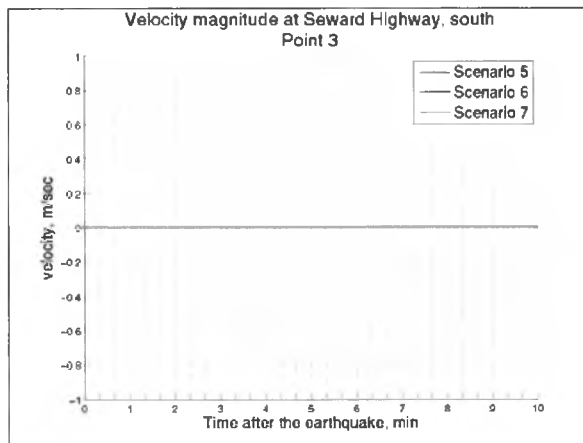


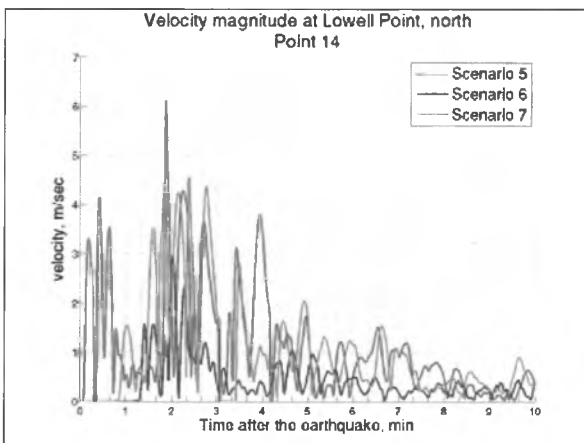
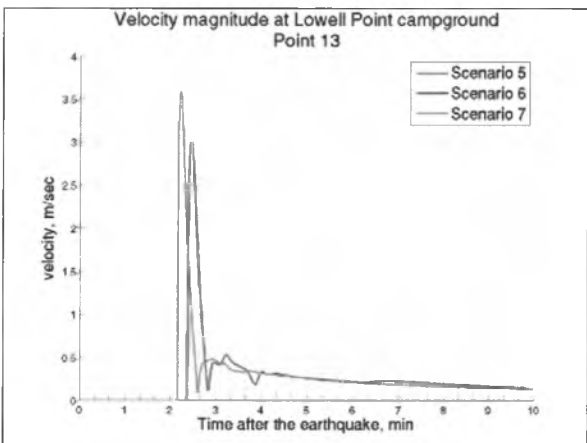
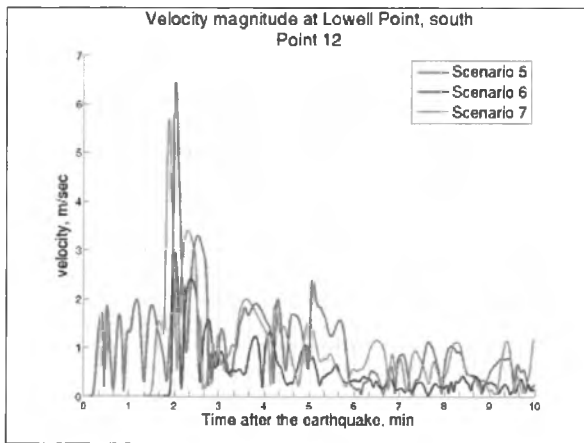
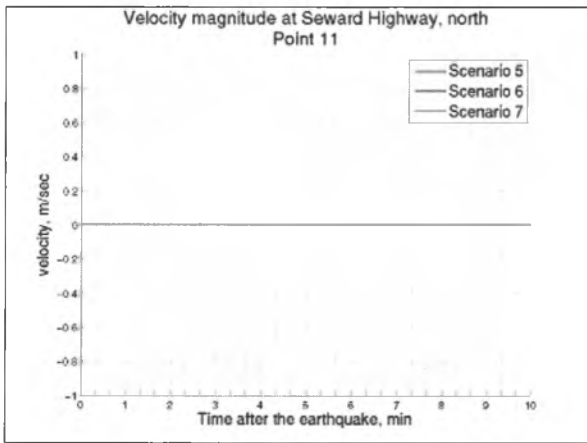
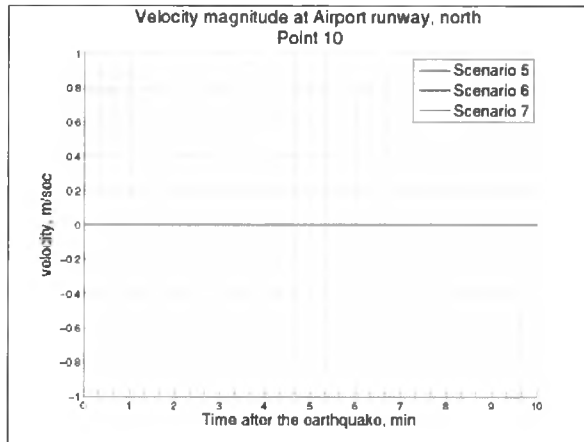
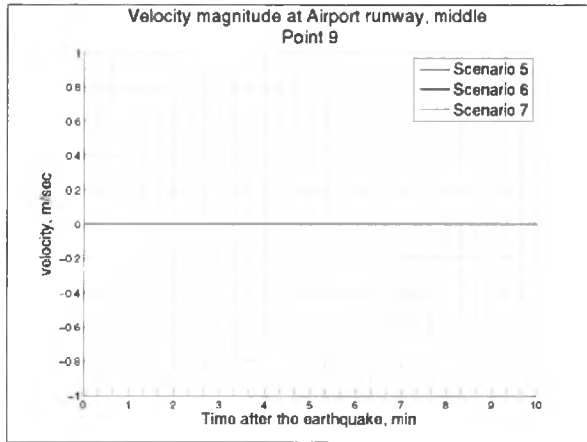


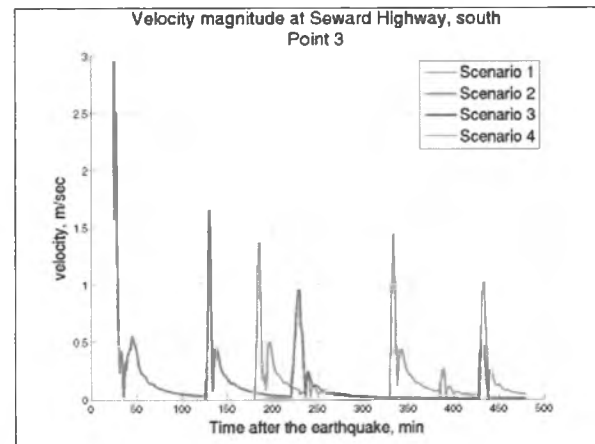
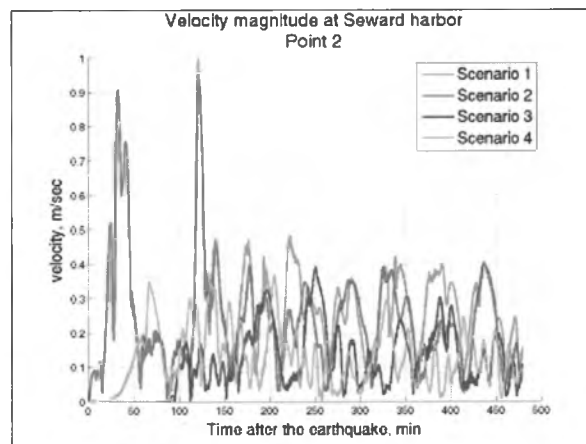
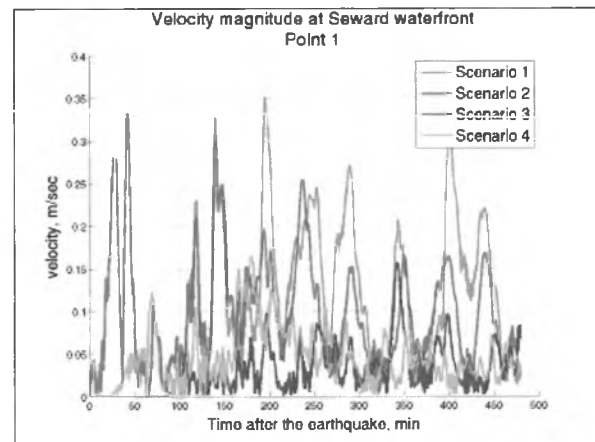
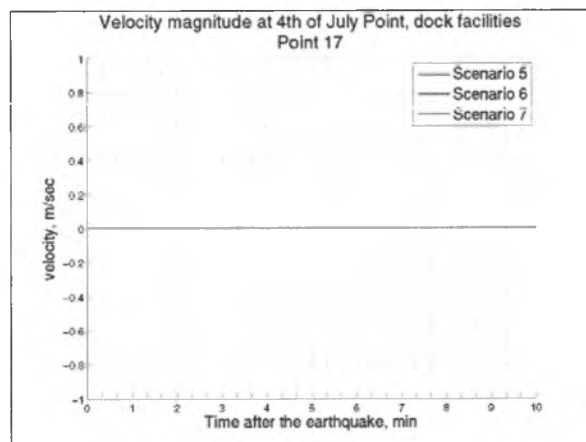
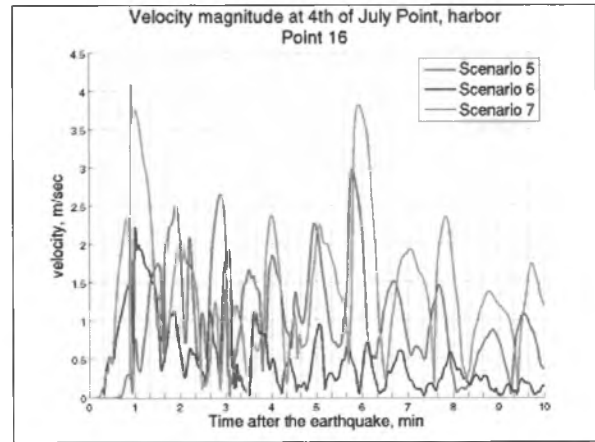
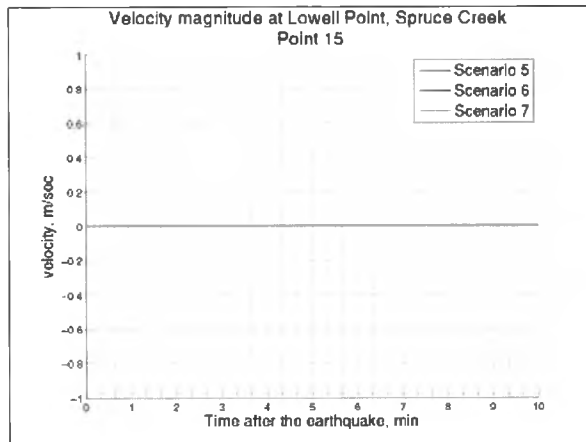


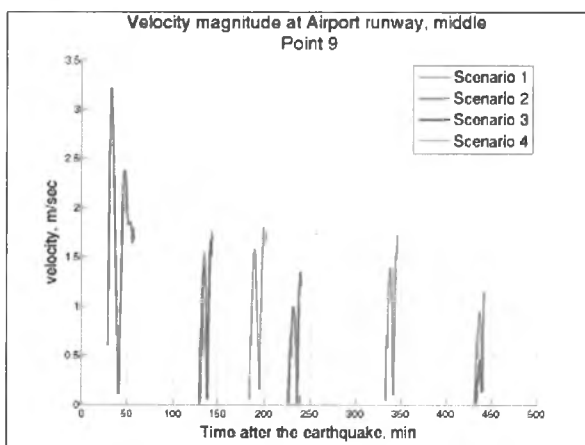
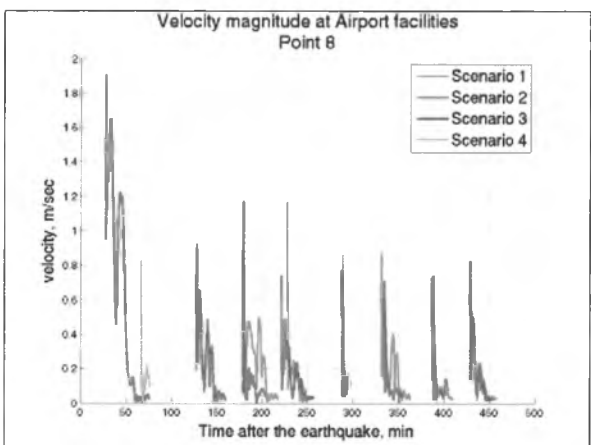
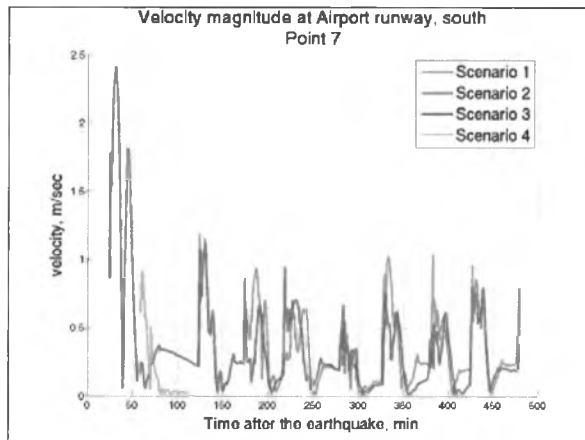
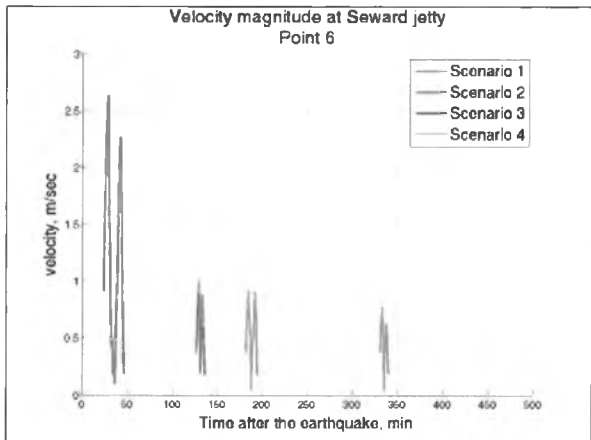
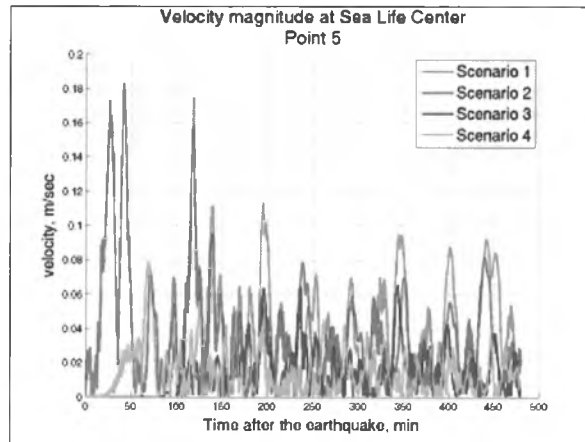
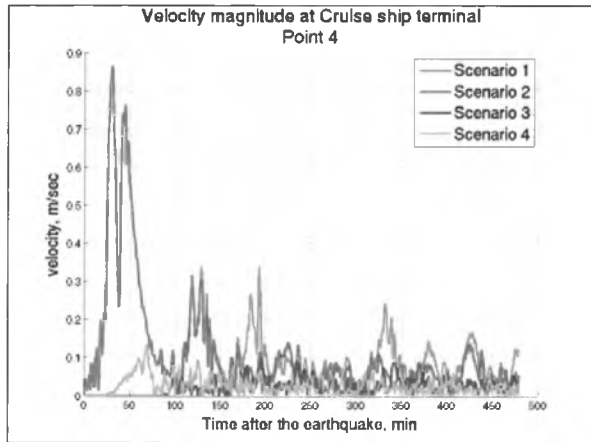


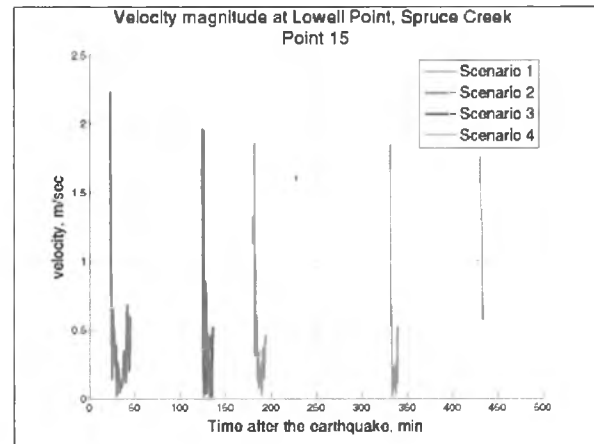
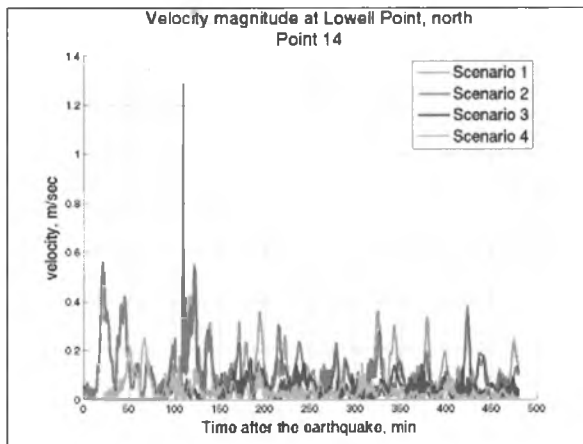
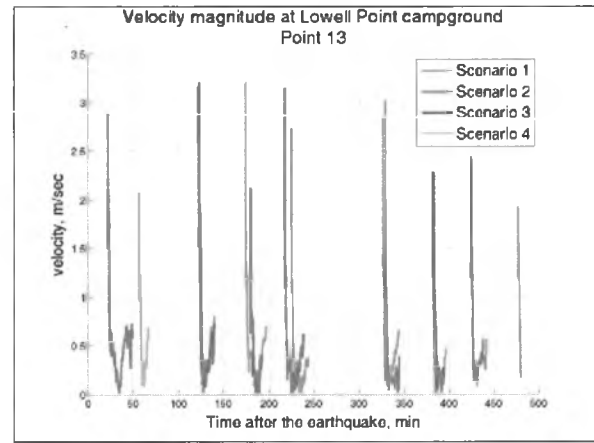
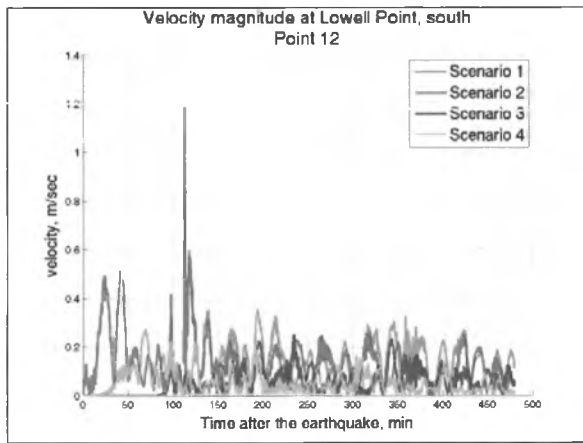
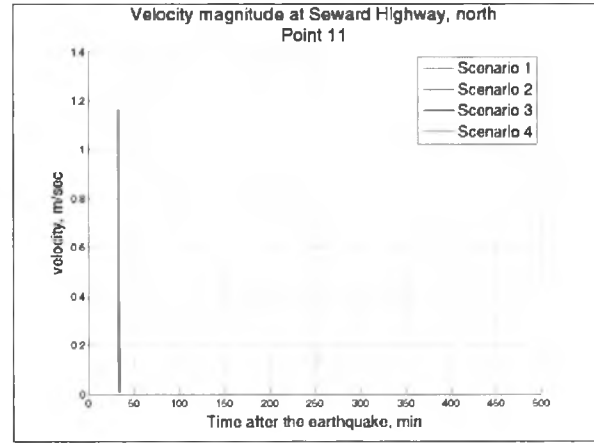
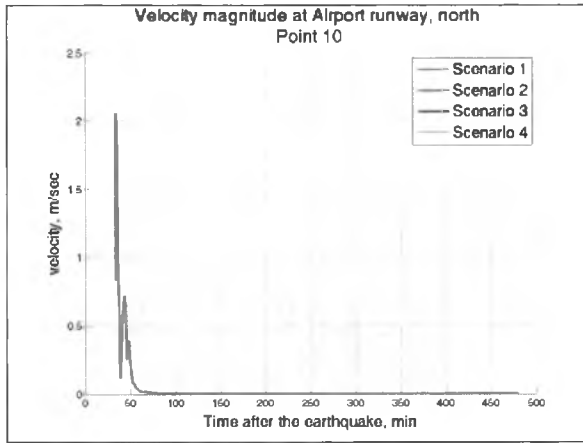


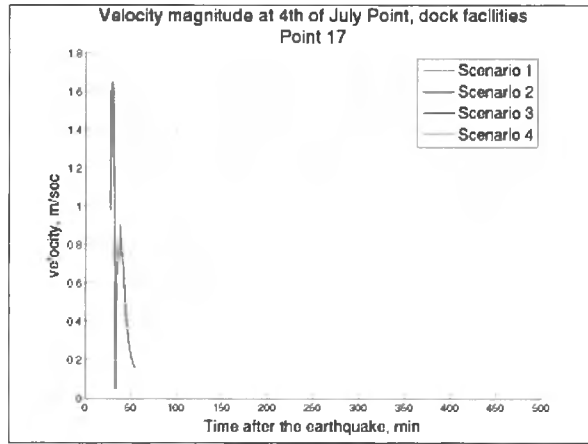
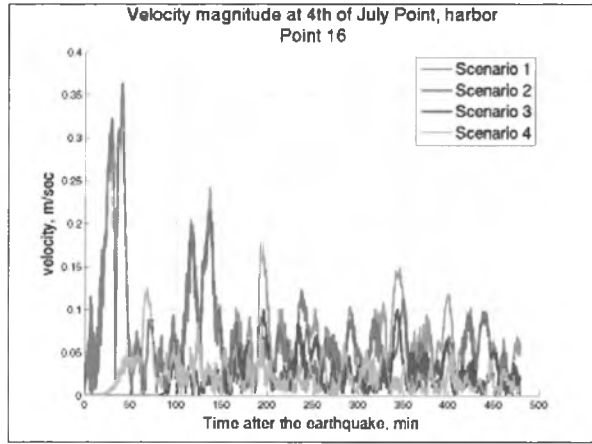














**Are you prepared for  
the next big**

# **Earthquake** **in Alaska?**

**By taking action now we can  
significantly reduce future losses  
from earthquakes.**

**What to do during and after an earthquake**

**How to prepare for an earthquake**

**Assessing your risk from earthquakes**

**Preparing for tsunamis**

**Earthquakes in Alaska**

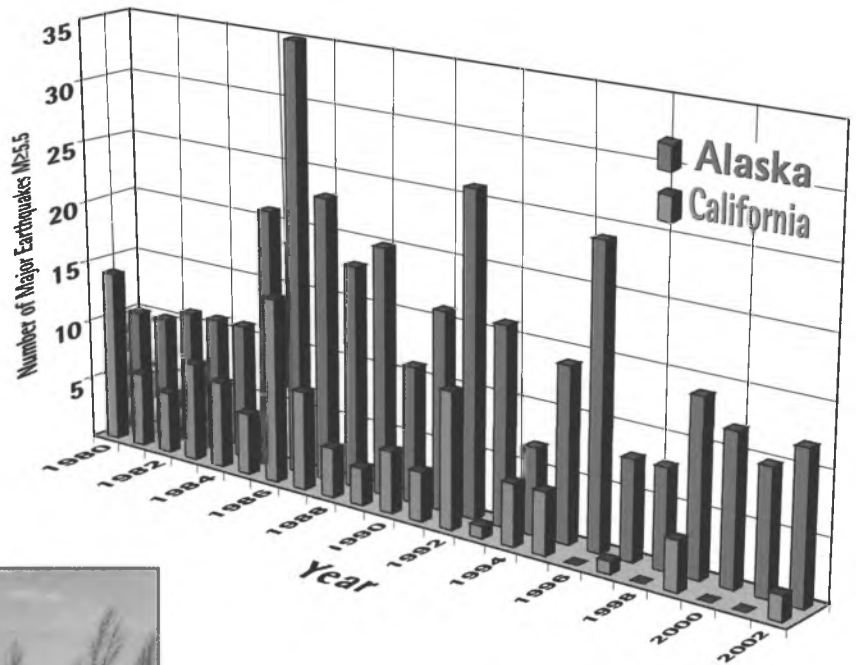
**Other sources of information**



## Why you need to prepare for the next earthquake

Scientists have long recognized that Alaska has more earthquakes than any other region of the United States and is, in fact, one of the most seismically active areas of the world. The second-largest earthquake ever recorded shook the heart of southern Alaska on March 27th, 1964.

The largest strike-slip slip earthquake in North America in almost 150 years occurred on the Denali Fault in central Alaska on November 3rd, 2002. "Great" earthquakes (larger than magnitude 8) have rocked the state on an average of once every 13 years since 1900. It is only a matter of time before another major earthquake will impact a large number of Alaskans.



Alaska has changed significantly since the damaging 1964 earthquake, and the population has more than doubled. Many new buildings are designed to withstand intense shaking, some older buildings have been reinforced, and development has been discouraged in some particularly hazardous areas.

Despite these precautions, future earthquakes may still cause damage to buildings, displace items within buildings, and disrupt the basic utilities that we take for granted. We must take every reasonable action to prepare for damaging earthquakes in order to lower these risks.

Preparedness for earthquakes and other natural disasters is both a collective and an individual responsibility. As a society we have created agencies and organizations to assess, monitor, and respond to various threats from natural disasters. The **Alaska Division of Homeland Security and Emergency Management (DHS&EM)** is responsible for providing Alaskans with earthquake preparedness information and training. The office of the Alaska State Seismologist and the **Alaska Earthquake Information Center (AEIC)**, the **UAF Geophysical Institute (UAF-GI)**, the **U.S. Geological Survey (USGS)**, the **Alaska Division of Geological & Geophysical Surveys (ADGGS)**, and the **NOAA West Coast/Alaska Tsunami Warning Center (WC/ATWC)** work together to provide data and information to the public and to local, state, and federal authorities for use in earthquake hazard mitigation and response. This alliance of agencies carries out our collective effort to understand and prepare for earthquake disasters.

As individuals, we must also take steps to prepare for earthquakes in order to protect ourselves, our loved ones and our property. By identifying the greatest hazards to our personal safety, we can set priorities for using our resources in the most effective way to reduce possible damage. By becoming aware of the hazards posed by earthquakes and by taking appropriate actions, such as those described in this pamphlet, we can drastically reduce the loss of life and property, and make Alaska a safer place to live . . . the choice is ours.

## What to do during and after an earthquake

■ **If you are indoors**, drop to the floor and take cover under a sturdy desk, table or other furniture. Hold on to it and be prepared to move with it. Hold the position until the ground stops shaking and it is safe to move. Stay clear of windows, heavy wall hangings, fireplaces, woodstoves, and heavy furniture or appliances that may fall over. Stay inside to avoid being injured by falling glass or building parts. It is difficult to stand up in a large earthquake and trying to walk would be even more difficult. Do not try to run out of the structure but instead drop, cover, and hold. Crouching against a sturdy wall with nothing above you and no windows nearby is an alternative if there is not a table to get under. If you are in a crowded area, take cover where you are. Stay calm and encourage others to do likewise.

■ **If you are outside**, get into the open, away from buildings and power lines.

■ **If you are driving**, stop if it is safe but stay inside your car. Stay away from bridges, overpasses and tunnels. Move your car as far out of the normal traffic pattern as possible. If possible, avoid stopping under trees, light posts, power lines, or signs.

■ **If you are in a mountainous area**, or near unstable slopes or cliffs, be alert for falling rock, snow, and other debris that could be loosened by the earthquake.

■ **If you are near the ocean**, move quickly to higher ground or move several hundred yards inland.

The first reaction many people have during an earthquake is to run out of a building. This increases the likelihood that you will be hit by falling objects. Most earthquake related injuries in the United States occur in this way. In a large quake, falling objects can become



*DROP*



*COVER*




*HOLD*

***DON'T RUN OUTSIDE***



projectiles that are difficult to avoid. The most serious injury sustained during the November 2002 Denali fault earthquake, occurred when a woman slipped and broke her arm while exiting her home.

**In the past it was recommended that you stand in a doorway during an earthquake. This is not the best place to go because only one person can fit in a doorway, and you won't be protected from falling and flying objects.** A woman was trapped in a doorway during the Denali fault earthquake when the door slammed shut on her hand. This not only injured her but also stopped her from taking cover from falling objects.



## Children and Earthquakes

*Earthquakes are traumatic events for all of us, but they are especially frightening for children who may be forced to leave their homes and everything that is familiar to them. A child does not usually understand such events and feels anxious, confused, and frightened. Fear is a normal reaction to any danger which threatens life or well-being. After an earthquake, a child's fears are those of recurrence, injury, death, or of being alone and separated from the rest of the family. Aftershocks can increase these fears.*

*Parents sometimes ignore the emotional needs of a child once assured of their physical safety. A child's persistent fears may generate disruptive behavior, surprising and frustrating a parent who is trying to continue with the daily family routine.*

### How a parent can help:

**Keep the family together.** This provides immediate reassurance to a child; fears of being abandoned and unprotected are alleviated.

**Reassure children** with words as well as actions. Emphasize the positive: "We are all together and nothing has happened to us," or "You don't have to worry, we will look after you."

**Encourage the child to talk.** It can also be helpful to include other family members, neighbors, and their children in a conversation about our reactions to the earthquake.

**Include the child in family activities.** There will be important concerns and things to do after an earthquake, such as checking on the damage and cleaning up broken glass and fallen furniture. Whenever possible, a child can and should be included in these activities.

At bedtime, a child may have difficulty falling asleep. They may wake up during the night or have nightmares for weeks or months after the earthquake. These situations may be dealt with by allowing the child to move into a room with another child or to sleep on a mattress in the parents' room, or simply by a parent spending a little extra time in the child's room giving reassurance.

## Safety check. Check for the following hazards

**Check for injuries:** Do not move a seriously injured person unless they are in immediate danger of further injuries.

**Gas leaks:** Shut off the main gas valve only if a leak is suspected or identified by the odor of natural gas. Wait for the gas company to turn it back on after the damage is repaired.

**Oil or propane tanks:** If you have one, check that the supports are intact and that connecting pipes and hoses are not broken.

**Downed or damaged chimneys:** Approach chimneys with caution. They may be weakened and could topple during an aftershock.

**Tsunami hazard:** If you live along the coast, be alert for news of tsunami warnings issued by the Tsunami Warning Center or local community officials. If you experience a strong earthquake, there may not be time for a warning to be issued. Move to higher ground as soon as you can, and stay there until the authorities issue an "all clear."

**Expect aftershocks:** The only time that we know earthquakes will occur is after another large earthquake. Most aftershocks are smaller than the main earthquake. Some may be large enough to do additional damage to weakened structures.

**Damaged electrical wiring:** Shut off power at the distribution panel or breaker box.

**Downed or damaged utility lines:** Stay away from downed lines even if power appears to be off.

**Fallen objects in closets and cupboards:** Displaced objects may fall when you open the door.

**Check your telephone:** Make sure each phone is on its receiver. Telephones that are off the hook tie up the telephone network unnecessarily.

**Clean up:** Clean up potentially hazardous materials and/or medicines which may have spilled.



**Use flashlights or battery-powered lanterns.**

**Do not use lighters, matches, candles, or lanterns until you are sure that there are no gas, propane or oil leaks.**



**Use your telephone only in the event of life-threatening emergencies.**



**Turn on a battery or crank-powered radio for information, damage reports, and for information on volunteering your assistance.**



**Keep streets clear for emergency vehicles. Cooperate with public safety officials.**

# How to prepare for an earthquake

Most people in Alaska will survive the next big earthquake with little loss. Some people may be severely affected. Actions you take now can reduce how much you and your family will lose.



## Practice “drop, cover, and hold” drills at home with your family, and at work.

Injuries and deaths during earthquakes are caused by falling objects and collapsing structures. Knowing how to protect yourself when the shaking starts may save your life. Show children safe areas to drop, cover and hold.

Practice counting to sixty seconds. Most earthquakes do not last that long, and it will help you to keep calm when a real earthquake strikes.

## Develop an earthquake plan at home, in your neighborhood, at school, and at work.

Determine the safest places in your home and at work. These should be

away from heavy furniture or appliances, woodstoves, fireplaces, open shelves and bookcases, and large panes of glass, pictures, or mirrors.

If the earthquake hits during the day, family members may be separated from several hours to several days. Plan ahead and select a safe place where you can reunite after the earthquake. Consider your family’s possible needs, and also select alternative locations to meet near places of work or school.



Designate an out-of-the-area telephone contact. Select a relative or friend to act as a clearinghouse for information about your family. Family members should call this contact person to report their condition and location. Make sure family members carry this number with them at all times, and that the number is known by other friends and relatives.

The most common cause of earthquake-related fires is broken gas lines. Everyone should know how to turn off the gas supply at the meter in case they smell gas after a large earthquake. Buy a special wrench that fits your gas turnoff valve and fasten it next to the valve.

Find out the policy of your local school concerning the release of children after an earthquake. Arrange with neighbors to watch out for your family and property in case you are not at home.

Make plans with your family, your neighbors, and your co-workers. Every business should have an emergency response plan.

## Pick two places to meet.

- (1) Right outside your home.
- (2) Outside your neighborhood in case you are not able to return home. Everyone must know the address and telephone number.

## Ask an out-of-state friend to be your “family contact.”

After a disaster, it’s often easier to place a long distance telephone call than a local one. Other family members should call this person and tell them where they are. Everyone must know your contact’s phone number.

## Fill out, copy, and distribute to all family members



**Family Disaster Plan**

Emergency Meeting Place \_\_\_\_\_ *outside your home*

Meeting Place \_\_\_\_\_ *outside your neighborhood* Phone \_\_\_\_\_

Address \_\_\_\_\_

Family Contact \_\_\_\_\_

Phone ( ) \_\_\_\_\_ *day* Phone ( ) \_\_\_\_\_ *evening*

## *Emergency supplies list*

*Keep enough supplies in your home to meet your needs for at least seven days. Store these items in sturdy, easy-to-carry containers such as backpacks, duffel bags, or covered trash containers. These are the basics to have on hand for any emergency:*



**Flashlights with spare batteries:** Keep a flashlight beside your bed. Do not use matches or candles after an earthquake until you are certain no gas leaks exist.

### **Hand-crank or battery-operated radio with spare batteries:**

Most telephones will be out of order or in use for emergency purposes, so radios will be your best source of information. An automobile radio is a good substitute.

**First aid kit and first aid knowledge:** Have a first aid book such as *Standard First Aid & Personal Safety* by the American Red Cross. Have members of your household take basic Red Cross first aid and CPR courses.



**Fire extinguisher:** Keep a fire extinguisher handy for small fires. Some extinguishers are only good for certain types of fires--electrical, grease, or gas. Class ABC extinguishers are designed to be used safely on any type of fire.

**Food:** It's a practical idea to keep a supply of non-perishable food on hand that can be rotated into your diet and replenished on a regular basis. Have a supply of canned or dehydrated food, powdered milk, and canned juices that is sufficient for at least seven days.

**Water:** Water should be stored in airtight containers and replaced every six months. Store at least three gallons per person. For water not treated by a commercial facility, add 16 drops or 1/4 teaspoon of household bleach per gallon of water. Stir and let stand for 30 minutes. Use bleach which has 5.25% hypochlorite as the only active ingredient, with no fragrance and soap additives. Do not store in used plastic milk containers because bacteria may be present.

**Warm clothes and blankets:** Have enough warm clothes, blankets, and sleeping bags to survive sub-zero winter temperatures. If possible store these items outside of the home so they will be accessible after a rapid evacuation.

**Special items:** Keep at least one week's supply of medications and special foods on hand that are needed for infants or for those on limited diets.



**Tools:** Have a pipe wrench and an adjustable wrench for turning off gas and water mains.



## *Emergency Broadcasts after an Earthquake*

Waiting for the dissemination of information after a disaster takes time and can prove frustrating when we want, and have come to expect, immediate and complete information. Search the radio and television channels to find stations that are able to provide information. Remember that initial news reports may be inaccurate. Don't believe everything you hear. Pay particular attention to information from a governmental source.

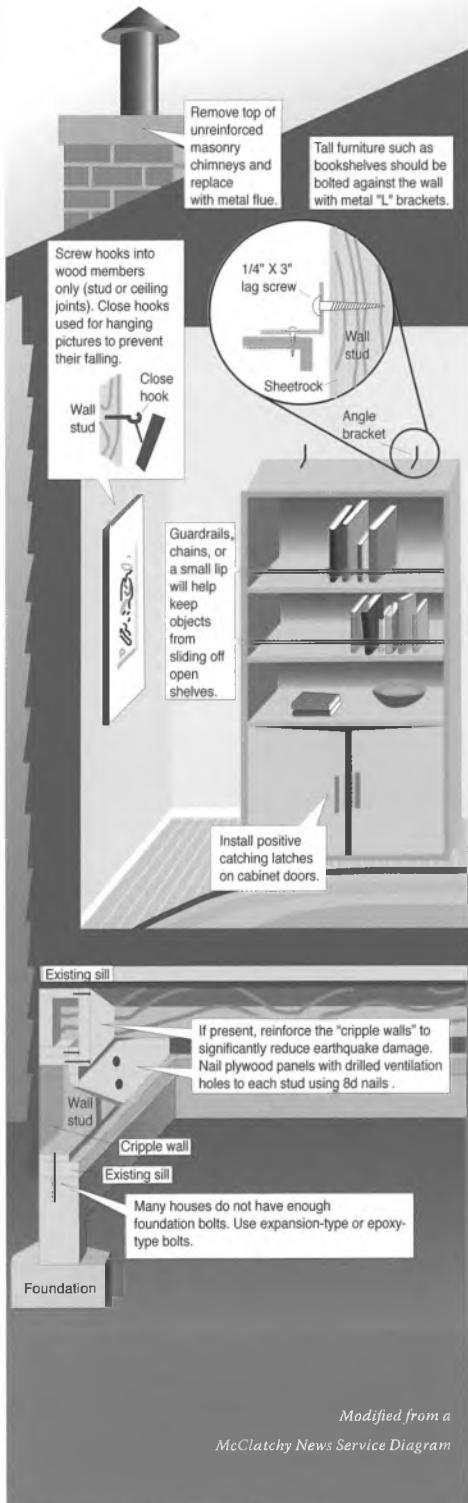
The first information about a large local earthquake may come from the **Alaska Earthquake Information Center**, the **USGS**, the **State of Alaska Department of Geological & Geophysical Surveys** or from the **West Coast/Alaska Tsunami Warning Center** (web links printed on page 23). Initial estimates of location and magnitude of an earthquake are likely to be revised as more information is analyzed.

Initial reports of damage, based primarily on eyewitness accounts, may be misleading and cause speculation. Local news-gathering capabilities may be severely hindered by the disaster, because the news media's power may be off or their news staff may be unable to communicate with their broadcast station.



## Protect your belongings

Falling objects and toppling furniture present the greatest physical danger and the biggest potential financial loss for most people. Imagine all of the contents of your kitchen cabinets falling to the floor or on your head! At home, at work, and in schools, building contents should be secured.



Modified from a  
McClatchy News Service Diagram

❑ Be sure that no heavy items, such as pictures or mirrors, can fall on your bed, where you typically spend a third of each day.

❑ Secure tall furniture and bookcases to the wall. Add lips to shelves to prevent costly items from sliding off. Be sure that adjustable shelves cannot slide off their supports.

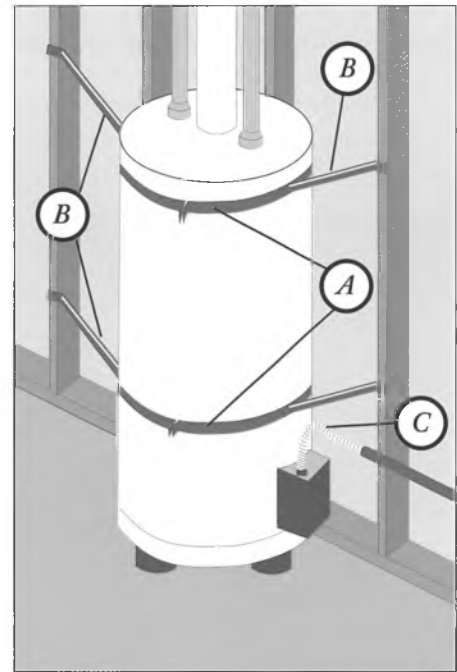
❑ Put strong latches on cabinet doors at home in your kitchen and at work in laboratories. Fasten heavy or precious items to shelves or tables. Secure file cabinets, computers, televisions, and machinery that may overturn during an earthquake.

❑ Store potentially hazardous materials such as cleaners, fertilizers, chemicals, and petroleum products in appropriate containers in sturdy cabinets that are fastened to the wall or floor.

❑ In your office, be sure heavy objects are fastened to the building structure and not just to a movable wall. Ask a carpenter or an electrician to check light fixtures and modular ceiling systems.

❑ Be sure your water heater is fastened to the wall studs and that all gas heaters and appliances are connected to the gas pipe through flexible tubing. If you use propane or heating oil, be sure the storage tank is secured against overturning and sliding.

❑ Secure your woodstove to wall or floor studs. Make sure you have a fire extinguisher close at hand.



Wrap a 1½" wide, 16-gauge-thick metal strap (A) around the top of the water heater and bolt the ends together. Do the same about 1/3 of the way up the side of the water heater. Take four lengths of EMT electrical conduit, each no longer than 30". Flatten the ends. Bolt one end to the metal strap (B). Screw the other end to a 2" by 4" stud in the wall using a 5/16" by 3" lag screw. Be sure a flexible pipe (C) is used to connect the gas supply to the heater.

❑ Check with your school officials to be sure they have taken similar precautions in your childrens' school buildings.

Many specialty earthquake fasteners are commercially produced. Check with your hardware store for products, or ask your local emergency management office for the names of products and vendors. Searching the Internet for "earthquake fasteners" will also yield many results. The web site of the **Federal Emergency Management Agency**, [www.fema.gov](http://www.fema.gov), contains much information about preparing for earthquakes. Go to the "Preparation and Prevention" section of the Library.

## Fuel tank supports and earthquakes

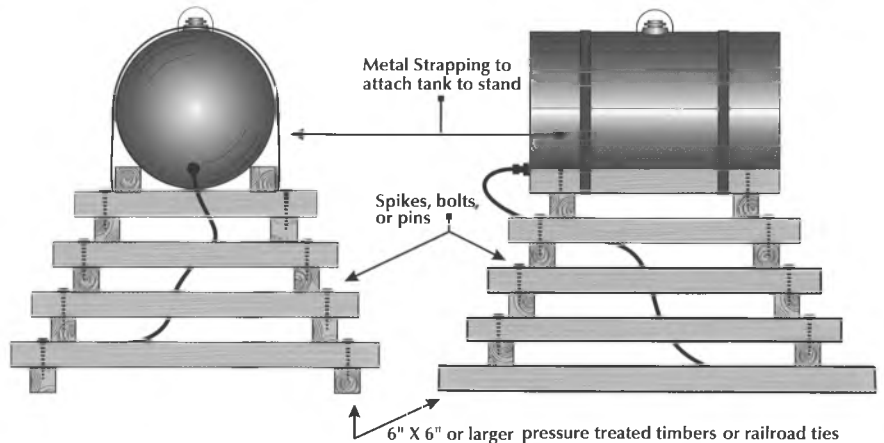
The use of raised fuel tanks, to provide gravity flow to oil heaters, is common throughout Alaska. During the Denali Fault earthquake on November 3rd, 2002, several 300 gallon fuel tanks tipped off or slid from their supports, demonstrating their vulnerability. By strengthening fuel tank supports and connectors to withstand ground shaking, the risk of damage, hazardous spills, and the loss of heating oil can be reduced. Once the structure is built, regular inspection is recommended to ensure structural integrity.



A wood support is vulnerable to damage due to deterioration or inadequate cross-bracing and fastening. It should be inspected for rot damage, and any deteriorating wood supports should be replaced. Existing wood supports with cross-bracing, or insufficient bracing, should have diagonal bracing and gussets added to strengthen the support. Utilizing wood-to-wood connecting plates, bolts, lag screws, and nails can help to reduce vulnerability, but their effectiveness is limited by the tendency of wood fibers to split and tear when subjected to large loads.

### Cradle Support

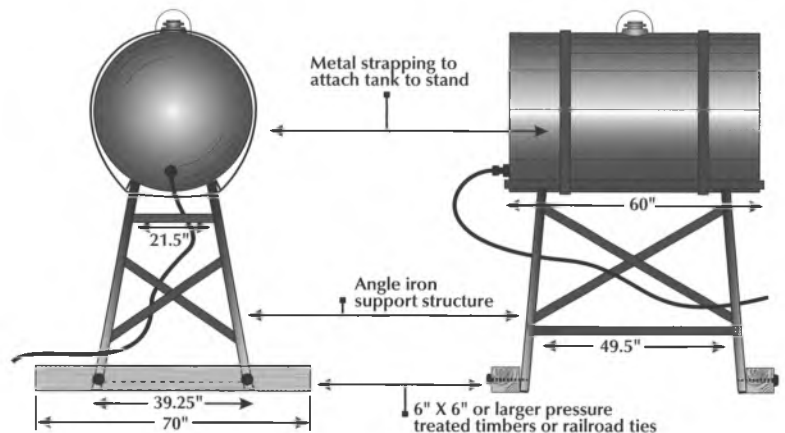
□ A timber cradle support is a safe and affordable wood support option. Strength and stability are provided by the broad base and the criss-cross stacking fashion of the timbers. The timbers need to be pressure treated and should be 6-inches by 6-inches or larger. Each layer is spiked to the one below with large spikes, pins, or bolts that are driven into pre-drilled holes to prevent splitting. The tank is strapped to the cradle with two steel bands (a special banding tool is required).



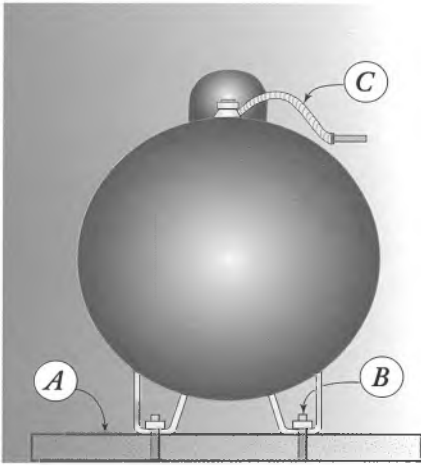
This diagram illustrates how to build a wood cradle that is likely to withstand large earthquakes. The design uses commonly available items and can be built by most people. This stand is designed to support the average size fuel tank (300 gallons) at a typical height of 4'.

### Steel Support

□ A steel support system is available when purchasing a tank from a fuel company. The steel support's angle iron construction and welded joints provide rigidity and strength to resist gravity loads and mild shaking. Steel supports with a wide footprint will have increased stability. Some steel supports may not have adequate diagonal bracing. Retrofitting may be needed to withstand strong lateral motion during an earthquake. Stability can also be improved by securely bolting the steel support to 6-inch by 6-inch pressure treated wood timbers or railroad ties on the ground. Steel banding to tie the tank to the support is another important retrofit.



This diagram illustrates how a steel tank support can be improved to withstand large earthquakes. These supports are commercially fabricated using welded angle iron, and they typically support 300 gallon tanks at heights of 3' to 5'. A wider base, and bolting the support to pressure treated timbers, provides more stability.



Mount the tank on a 6" thick concrete pad (A) using four 1/2" diameter bolts (B) imbedded a minimum of 3" into the concrete. Install a flexible hose connection (C) between the tank and the rigid supply line.

## Propane Tanks

Many residents in rural areas of Alaska use above-ground propane tanks. These tanks may move, slide, or topple during strong ground shaking. Gas leaks are frequently the cause of earthquake-related fires. The following recommendations can be followed to reduce the post-earthquake fire hazard associated with propane tanks.

### Mount the tank on a continuous concrete pad and bolt the four legs to the pad.

- Install flexible hose connections between the tank, supply line, and the entrance to your home or business.
- Clear the area of tall or heavy objects which can fall and rupture the tank or supply line.
- Keep a wrench tied on a cord near the shut-off valve and make sure that family members or employees know how to use it.
- For large tanks, seismic shut-off valves are available.

## Wood-Burning Stoves

Free-standing wood-burning stoves pose an additional risk to many in Alaska, especially in bush communities. Heavy objects such as stoves are actually more likely to move during strong ground shaking than are lighter objects. Fire codes dictate that stoves must be unsupported on all four sides,

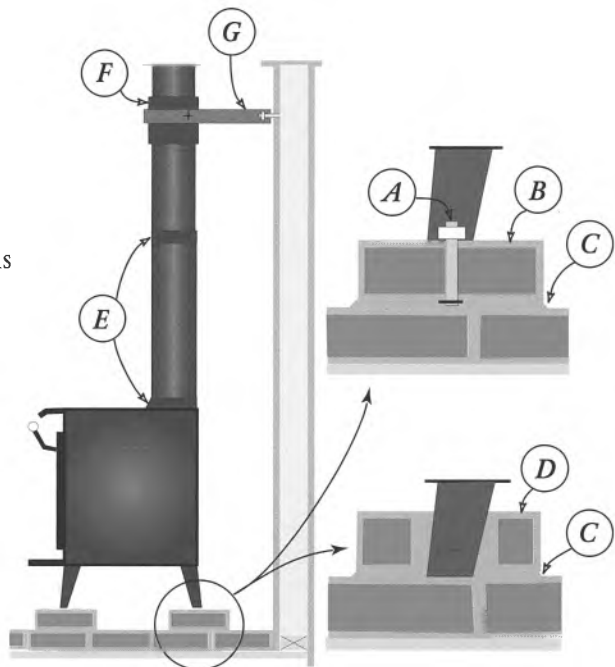
and therefore they are more vulnerable to sliding or overturning during an earthquake. If a stove were to tip and/or separate from the stove pipe, cinders or sparks might easily cause a fire in the home. To reduce the potential fire hazard following an earthquake, the stove should be anchored to the floor

and stove-pipe sections should be secured. It is important that the seismic anchors or braces do not conduct heat from the stove into the floor. Although there are many types of stoves in use, the recommendations here can be used for most installations:

### Stoves resting on a brick hearth can be anchored using bricks and mortar.

- Woodstoves resting on a concrete slab on grade can be anchored directly to the concrete.
- Stove pipes should be anchored to the flue exit, and each of the stove-pipe segments should be securely together.
- Mobile home approved units come with predrilled holes in the pedestals or legs and can be safely anchored to the underlying floor framing.

For a stove on a brick hearth, anchor the legs with a 3/8" diameter bolt (A) through a 1/2" hole to a new brick (B). Grout the new brick (B) to the hearth with 1" of new grout (C). Alternatively, build an 8" square brick pad with a grout pocket (D) at each leg. Provide at least 1" of space around each leg and fill the pocket completely with grout. Install sheet metal screws (E) at the flue exit and between the stovepipe sections. Install a radiation shield with a pipe clamp (F) braced to a wall using two tension ties (G) attached to a wall stud with 3/8" by 3" lag screws.



# Assessing your risk from earthquakes

*Earthquakes are a hazard that create risks to life and property that we must accept as part of living in Alaska. We face many other hazards in our lives and we routinely take precautions to reduce our losses from them, or to lower our risk. For example, we wear seat belts to lower the risk of injury during an automobile accident. This is an action that most people have come to accept as a reasonable precaution. Earthquake risk can also be reduced significantly by individuals, businesses, and governments when appropriate actions are taken. The basic actions described in these pages are reasonable precautions that should be taken by all residents of Alaska. Other actions such as strengthening or replacing a dangerous building, or even choosing to live in a safer building or in a safer part of your city may involve significant expense and disruption. Yet, damage to buildings and other structures is the primary cause of death, injury, and financial loss during large earthquakes.*

To decide how much action is required for protection from earthquake hazards, you must estimate your risk. Earthquake risk varies from location to location, from structure to structure, and from person to person.

## What causes Damage during an Earthquake?

**Duration of shaking.** Duration depends on how the fault breaks during the earthquake, on the distance from the rupture, and on the types and thicknesses of soils underlying the site. The strongest shaking during the 1964 earthquake lasted 3 to 4 minutes. During a magnitude 7 earthquake, the shaking may last 30 to 40 seconds. The longer buildings shake, the greater the damage.

**Strength of shaking.** Many damaging earthquakes occur within 15 miles of the Earth's surface. In this case, shaking decreases rapidly with increasing distance from the fault that produced the earthquake. In Alaska, these earthquakes are most common in central and southeastern Alaska. Deeper earthquakes are common beneath southern Alaska and the Aleutian Islands. Because of their greater depth, the shaking directly above such shocks is reduced, and the shaking decreases gradually with increasing distance from the epicenter of the earthquake.

**Type of soil.** Strength of shaking is greater on soft, thick, and wet soils. In certain soils the ground surface may settle or slide. Damage is typically less in buildings located on bedrock.

**Frequency of shaking.** Shallow earthquakes, such as those that typically occur in central and southeastern Alaska, produce more rapid shaking than deeper earthquakes, such as those in southern Alaska and the Aleutian Islands.

Buildings with a natural shaking frequency that "resonates" with the ground motion will suffer the most damage. Houses and short buildings have high resonant frequencies of shaking (1 to several shakes per second), tall buildings have low resonant frequencies (up to several seconds per shake). Thus it is possible, as occurred in Mexico City during a 1985 earthquake, for mid-height buildings to suffer great damage during a medium-frequency earthquake, while short and tall buildings survive with little or no damage.

**Type of construction.** Some existing buildings are not resistant enough to the side-to-side and up-and-down shaking common during earthquakes. Un-reinforced masonry buildings are usually the most deadly.

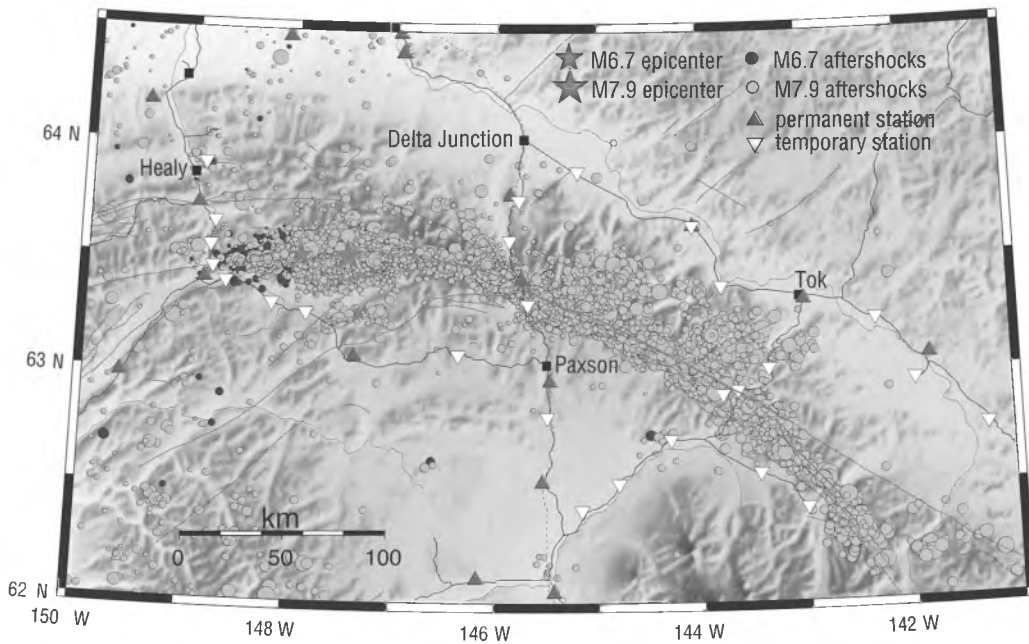


## Estimate your Risk

- Is there a risk of serious injury or even death for occupants of a specific building?
- What would be the cost of repairing or replacing a building after a large earthquake?
- What would be the cost of not being able to use a building after a large earthquake?
- What are the odds that time and money spent on preventive action today will prove cost-effective within your lifetime, and within the lifetimes of existing structures?
- If a structure will be replaced by normal development within 10 years, is strengthening it to resist earthquake damage cost-effective?
- Is such strengthening required by a governmental agency, is it economically reasonable, or is it morally necessary?

## The Uniform or International Building Code

Modern criteria for seismic design and construction have been included in the Uniform Building Code since 1973. The 2000 and later editions are termed the International Building Code, and have the most up-to-date requirements. Most large communities in Alaska have adopted either the International Building Code or the Uniform Building Code. The codes require greater strength for essential facilities and for sites on soft soil where shaking intensity is increased. The codes set minimum requirements that assure life safety but allow earthquake damage and loss of function. Owners who desire less potential damage and continued use of the building after severe earthquakes should insist on higher standards for design, construction, and inspection. Discuss with an architect or a civil or structural engineer what level of damage will be acceptable (references on page 24).

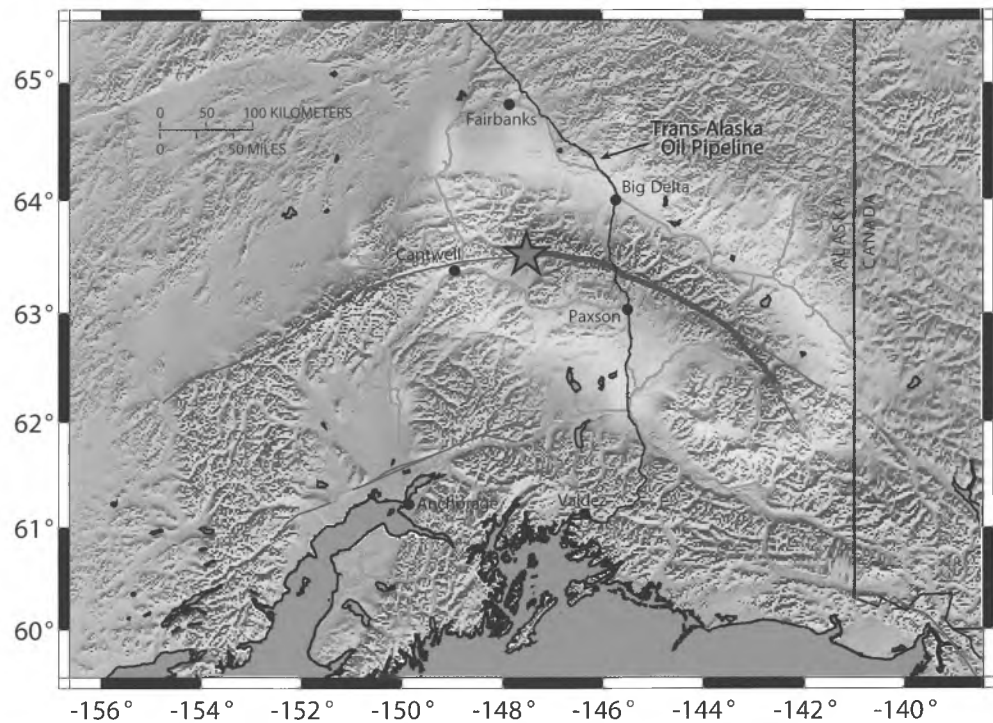


The November 3, 2002 magnitude (M) 7.9 Denali Fault earthquake was the strongest ever recorded in interior Alaska. The earthquake began in the central Alaska Range and ruptured eastward at a speed averaging about 6700 miles per hour. The M7.9 earthquake was followed by thousands of aftershocks that occurred all along the rupture zone. The main shock and aftershocks were located with high precision using a network of temporary seismic stations that was deployed by the AEIC following the M6.7 Nenana Mountain earthquake that occurred on October 23, 2002.

For more information, go online to [www.aeic.alaska.edu](http://www.aeic.alaska.edu), [www.dggs.dnr.state.ak.us](http://www.dggs.dnr.state.ak.us) and [earthquake.usgs.gov](http://earthquake.usgs.gov)

### USGS/AEIC ShakeMap

ShakeMaps show ground motion and shaking intensity in significant earthquakes. This ShakeMap was produced after the November 3rd, 2002, Denali Fault earthquake and it shows that ground shaking was strong along the Denali fault. Similar maps will be made in the future for Anchorage and Fairbanks. Maps like this one can be made for any major earthquake. They are used by federal, state, and local authorities for earthquake response and recovery, to inform the public about risk, and for preparedness exercises and disaster planning. For more information, go online to [earthquake.usgs.gov/shakemap/](http://earthquake.usgs.gov/shakemap/)

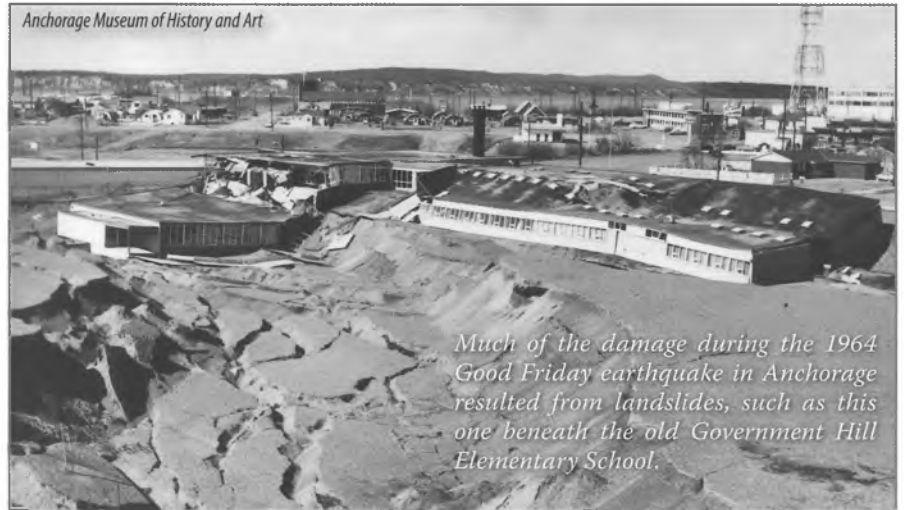


| PERCEIVED SHAKING      | Not felt | Weak   | Light | Moderate   | Strong | Very strong | Severe         | Violent | Extreme    |
|------------------------|----------|--------|-------|------------|--------|-------------|----------------|---------|------------|
| POTENTIAL DAMAGE       | none     | none   | none  | Very light | Light  | Moderate    | Moderate/Heavy | Heavy   | Very Heavy |
| INSTRUMENTAL INTENSITY | I        | II-III | IV    | V          | VI     | VII         | VIII           | IX      | X+         |

## Determine the safety of your home and school

*Most people in Alaska are safe at home if they live in a one or two-story wood-frame building. These buildings are not likely to collapse during earthquakes. The most common damage is light cracking of interior walls, cracking of masonry chimneys, and cracking and possible collapse of brick or masonry veneer on exterior walls. A cracked chimney should be inspected by a qualified professional before the woodstove or fireplace is used.*

Unfortunately, some one- or two-story wood-frame buildings can be hazardous. Buildings that are not adequately bolted to their foundation may fail at or near ground level. Adding foundation bolts and bracing cripple walls found in some older homes, can vastly reduce the earthquake risk (see page 14). Correcting these problems will vastly reduce the earthquake risk for most residents. For many homes, additional bracing of water heaters, propane tanks, or oil tanks is an important retrofit that should be completed (see pages 5, 6, and 7). Modern elementary and high school buildings have generally performed well during earthquakes, with the exceptions of the Government Hill School and West High School in Anchorage in the 1964 earthquake. The old Government Hill School was built on unstable soils and probably could not have been engineered to survive the massive landslide that occurred in



*Much of the damage during the 1964 Good Friday earthquake in Anchorage resulted from landslides, such as this one beneath the old Government Hill Elementary School.*

1964. The new Government Hill School is built on more stable soils farther from the bluff. Knowledge about proper seismic design and where to locate buildings has increased dramatically since 1964, however, older school buildings may need to be reassessed in light of modern building codes. Mobile homes, portable classrooms, and

modular buildings can slide or bounce off their foundations during earthquakes. Their supports need to be braced to resist vertical and horizontal forces. If portable classrooms are used at your local school, you should ask school officials whether they are properly braced.

## Determine the safety of other buildings you use

Buildings designed and constructed according to modern codes have generally performed very well during earthquakes. However, certain types of buildings, especially older ones, are potentially hazardous. Unreinforced brick buildings pose a particular hazard even in moderate earthquakes. Unbraced railings and walls inadequately anchored to the floors and roof can topple onto sidewalks or adjacent buildings.

Major damage often occurs in buildings with a “soft” first story. Usually, soft stories consist of an open space with stand-alone columns rather than interior walls supporting the building above. Such spaces are usually used as garages, stores, or large

offices. The first floor does not have enough strength to resist the horizontal shaking force of the upper parts of the building. Similarly, rooms added over garages of private homes or older split-level homes may not be adequately supported.

Damage to all of these types of buildings poses a threat to both life and property during earthquakes. These losses can be significantly reduced by strengthening structures before an earthquake. Investment in strengthening offices and commercial buildings will reduce structural and non-structural damage and may allow continuation of business after severe earthquakes.



*The J.C. Penny building in downtown Anchorage was heavily damaged during the 1964 Good Friday earthquake.*

## How do you locate a professional to advise you on the resistance of your building to earthquake shaking?

Civil and structural engineers and architects are trained and licensed to provide such information about structures. Geologists, foundation engineers, and geotechnical engineers are trained and licensed to evaluate the soil conditions and recommend appropriate action.

When hiring such a consultant, you are asking an experienced professional to review a potential problem and possibly to provide plans and specifications for correcting the problem. The amount of work required is not known when you hire the consultant, and thus it is important to select someone you trust, and to develop a scope of work as you proceed. A good place to start is to call a professional organization (refer to the Other Sources of Information section at the back of this pamphlet) and ask for information about the different types of work that might be required, for information about

how to select an engineer, geologist, or architect, and for a list of members in your area. Contact several firms or individuals to determine if they do the different types of work you need. Ask for information that explains the type of firms they are and that identifies others whom they have served. Check to see how satisfied other clients were. Recognize that the quality of the advice given and of the work performed, as well as the price you pay, may depend critically on the care you take in making a selection.

Become informed. Even if you do not understand the technical details, ask enough questions to understand the concepts and relative importance of the issues involved. Do not be afraid to ask questions that you fear might appear foolish. Your money is going to be expended and your life and belongings are at risk, so you have a right to understand what needs to be done and why.

For projects more complex than inspecting a single-family home, you should meet with the selected firm and discuss the options. In almost every case, there will be a number of approaches for solving any given problem. Get the consultant to explain the pros and cons of each, as well as the dollars and risks involved. Once this is done, you will have defined the work the consultant will do for you. Then a fee can be set and you can discuss how changing the work would change the fee.

State and federal agencies do not inspect individual buildings. Your local building department may be willing to inspect your building, but they are not authorized to recommend actions to be taken.



*An un-reinforced masonry building in Anchorage collapsed during the 1964 Good Friday earthquake.*

If you believe a structure that you or your family uses is hazardous and you would like to find out more or determine who you can consult, refer to the Other Sources of Information section at the back of this pamphlet. Ask the building owner what consideration has been given to seismic design and strengthening. Many civil and structural engineers and architects are trained and licensed to investigate the strength of a structure and to recommend appropriate action to reduce earthquake risk.

For single-family homes, ask a licensed engineer or architect to look at your home while you are present and to discuss the seismic issues with you. A written report, or plans and specifications for corrective action, may involve more time. You may want to ask for a seismic inspection before buying a new home.

## Earthquake Insurance

Standard homeowners insurance does not cover damage and destruction that happens as a result of an earthquake. Many people are unaware that their existing fire insurance does not cover fires caused by earthquakes. The 1989 Loma Prieta earthquake in California caused over 6 billion dollars in damage, but insured property damage accounted for only 16% of this loss. In Alaska, about 1 in 3 homeowners have purchased earthquake insurance. The most common type of earthquake insurance is normally added as an endorsement on a standard homeowner's insurance policy. Typically, there is a deductible of 10 percent of the value of the home. This means that for a home currently insured at \$200,000 you would have to pay \$20,000 in damages before the insurance company would pay anything. Separate deductibles may apply to the contents of the house and the structure. Another important coverage is temporary living expense, which pays for motel and meals if you have to move out of your home. There is usually no deductible on this coverage. The yearly cost of residential earthquake insurance is normally about \$3.00 per \$1,000 of coverage on a conventional frame home. However the rate may rise to \$13 per \$1,000 of coverage on structures with brick or masonry veneer on the outside. Clearly, the insurance industry considers homes with brick or masonry to be a greater risk in an earthquake. Thus far, homeowners insurance carriers do not consider whether the soils you live on are potentially dangerous. To find out more about earthquake insurance, ask your insurance agent.

# Earthquakes in Alaska

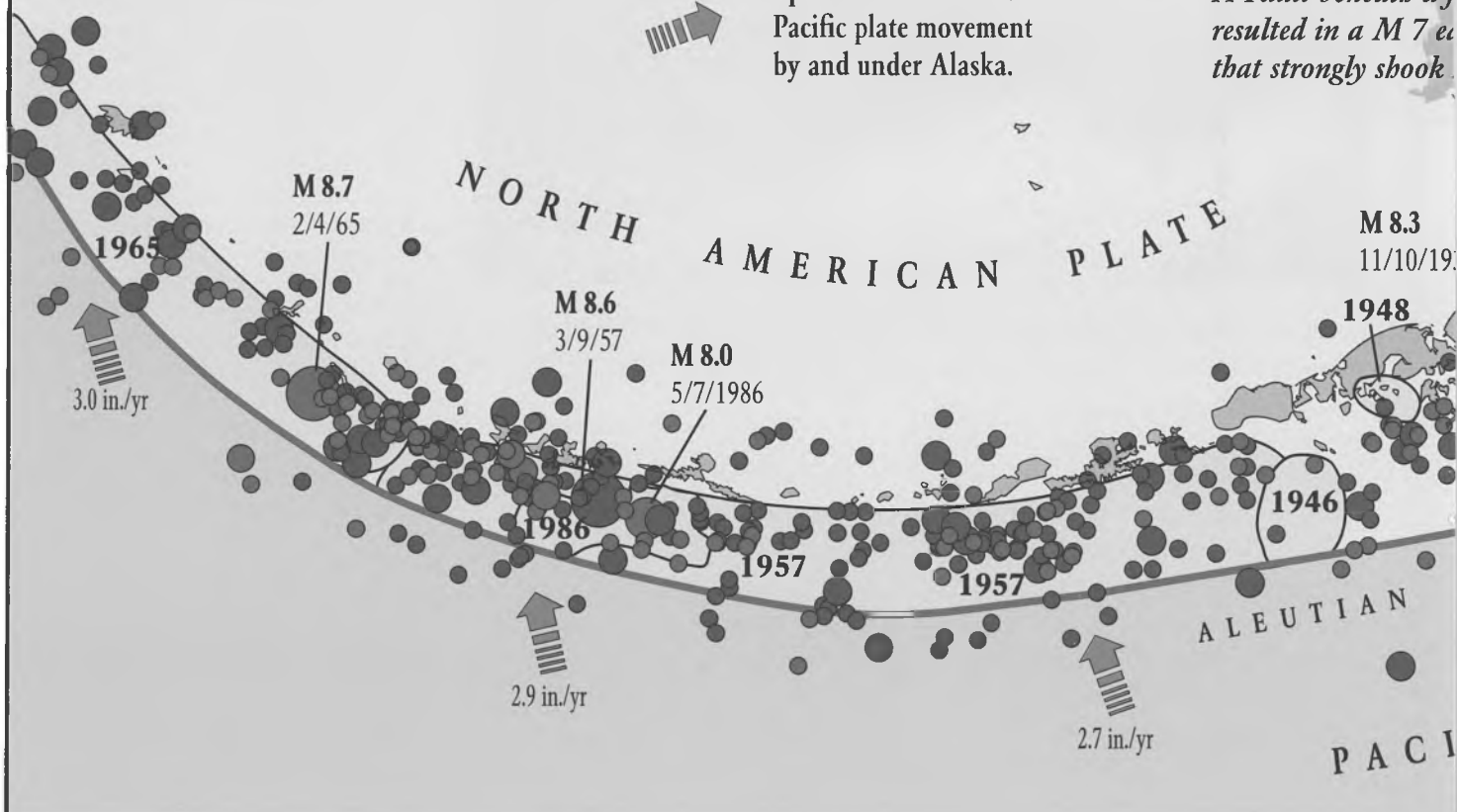
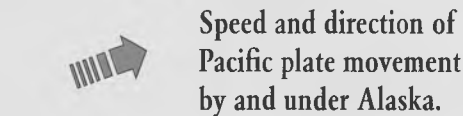
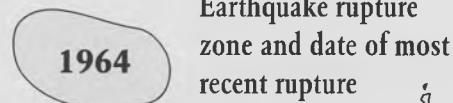
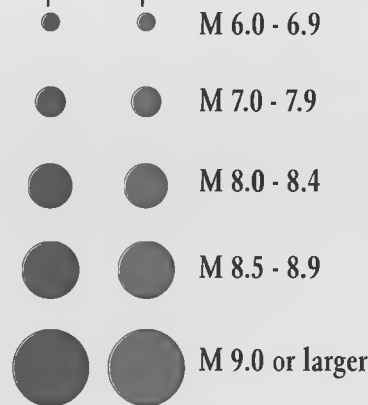
Earthquake risk is high in much of the southern half of Alaska, but it is not the same everywhere. This map shows the overall geologic setting in Alaska that produces earthquakes. The Pacific plate is sliding northwestward past southeastern Alaska and then dives beneath the North American plate in southern Alaska, the Alaska Peninsula, and the Aleutian Islands. Most earthquakes are produced where these plates come into contact and slide past each other. Major earthquakes also occur throughout much of interior Alaska as a result of collision of a piece of crust with the southern margin.

This map is modified from "Earthquakes in Alaska" by Peter Haeussler and George Plafker, U.S. Geological Survey Open File Report 95-624 <http://geopubs.wr.usgs.gov/open-file/of95-624/>

## Pre-1964 Earthquakes

## Post-1964 Earthquakes

### EQ Magnitudes (M)





## Determine if you live or work in hazardous areas

*Earthquake damage is typically concentrated in areas that can be identified in advance. The amount of shaking experienced in an earthquake can be very different in locations less than a hundred yards apart. Determine for yourself if the places where you live and work are particularly dangerous. Asking the questions on the following pages, and seeking the answers, is an excellent start.*

### Do you live where the ground can settle, slide, or shake violently?

Landslides are likely to be triggered by significant earthquakes, especially on steep slopes and in areas underlain by soft ground. During the 1964 Alaskan earthquake, much of the Turnagain Heights area of Anchorage slid toward Knik Arm because the area is underlain by a kind of soft, wet clay that is prone to sliding if shaken violently. The clay in the Anchorage area and other types of soft ground can also intensify the shaking of an earthquake.

Fortunately, most areas that can settle, slide, or shake violently can be identified before the next major earthquake. Even reasonably detailed maps give only an overview of the potential for shaking, liquefaction, landslides, faulting, and damage. To investigate a particular building site, you should consult an engineering geologist, geotechnical engineer, or a foundation engineer.

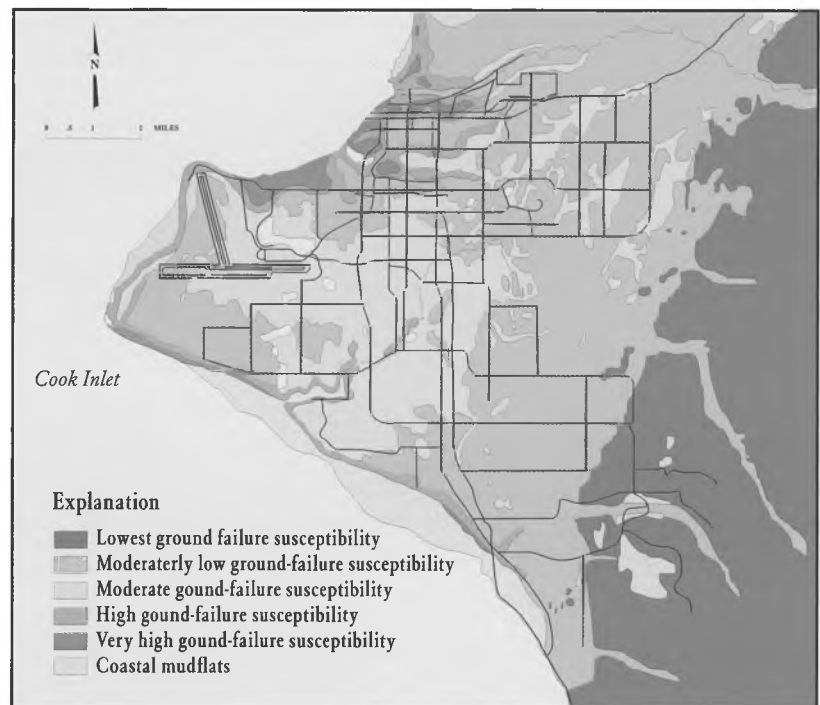
### Securing your home to your foundation

Bolting the wood frame of an older house to its concrete foundation can significantly reduce earthquake damage. Specialty foundation bolts that glue in place with epoxy are available for securing walls to foundations. These work best with older foundations since old concrete tends to be very brittle. Conventional expansion bolts may crack older concrete. Follow the manufacturer's instructions for installation.



Karl V. Steinbrunne Collection

*About 75 homes in the Turnagain Heights area of Anchorage were destroyed in 1964 by a massive landslide. This area is underlain by soil that flows like water when it is shaken.*



*This is a map of the Anchorage area showing the relative chances of earthquake-induced ground failure in different locations. If the ground "fails" during an earthquake, it will probably shake excessively, cracks may open up on the surface, and the area may be involved in a landslide. Buildings on areas with high ground-failure susceptibility may be severely damaged in future earthquakes. This map is not intended as a substitute for on-site investigations by a professional geologist or geotechnical engineer. Source: Anchorage Coastal Resources Atlas, v. 1, Anchorage Bowl available at local libraries, or online at*

*[www.dggs.dnr.state.ak.us](http://www.dggs.dnr.state.ak.us) (Publication MP32)*

## Soil Liquefaction

When loosely packed and wet sand is shaken during an earthquake, it may flow like liquid. This is called liquefaction. Anyone who has walked on a beach may have seen a small-scale version of this process. Stamp your foot in the sand near the water's edge and suddenly the area of your footprint vibrates like gelatin.

Earthquake-induced liquefaction is often accompanied by cracks in the ground surface and small eruptions of sand and water called sandblows. During the 2002 Denali Fault earthquake, people in Northway watched sand erupting 4 feet out of the ground. When a soil liquefies, it is unable to support the weight of the ground or any structures above it. Bridges and buildings may settle and tilt even though they withstood strong ground shaking. If the liquefied area is on a slope, massive landslides may result.

The Bootlegger Cove Formation is the name of a soil that underlies much of Anchorage. Liquefaction of a part of the Bootlegger Cove Formation caused much of the destruction in the Anchorage area during the 1964 earthquake, and it causes people to feel earthquakes more strongly in western Anchorage. Soils that liquefy are not limited to the Anchorage area, but are present in many low-lying parts of Alaska where soil near the surface is saturated with water.



*A sandblow that occurred in the central Alaska Range as a result of soil liquefaction from ground shaking during the November 3rd, 2002 Denali Fault Earthquake.*

## Do you live on a fault?

If you took two books, put them side-by-side, and then slid one of the books past the other, you would be imitating the process that makes earthquakes. The surface along which the two books slipped past each other is called a fault. In the Earth's crust, huge blocks of rock can move past each other along faults. When these blocks slip suddenly, an earthquake is produced. Faults are common in the Earth's crust, but only some will produce earthquakes. These are called "active faults."

Severe damage is particularly likely wherever structures are built directly on top of active faults. The 2002 Denali fault earthquake in central Alaska displaced the ground up to 29 feet from side to side. Although the earthquake offset the Trans Alaska Pipeline about 19 feet, design engineers had anticipated what would happen in such an earthquake and the pipeline survived without a single drop of oil being spilled. The location of active faults can often be determined before a major earthquake. Buildings that sit on top of, or very close to these features should be considered especially dangerous.

Many earthquake-producing faults in Alaska lie far beneath the Earth's surface. In fact, most residents of southern coastal Alaska live above a huge fault called the "Aleutian Megathrust" (see pages 12, 13 and 21). The 1964 Good Friday earthquake, and most major earthquakes in southern Alaska, are related to movement along this fault. Ground shaking caused by earthquakes on these deep faults is a more widespread hazard than the ground shaking caused by shallow faults. Nevertheless, a small earthquake close by can be just as destructive as a big earthquake farther away.

## Tsunami basics

*Tsunamis are ocean waves produced by earthquakes. The word comes from the Japanese language and means "harbor wave," because of the devastating effects these waves have had on low-lying Japanese coastal communities. Tsunamis are often incorrectly referred to as "tidal waves." Not all earthquakes produce tsunamis, but when they do, the waves may sweep ashore causing damage both locally and at places thousands of miles from the earthquake epicenter. More than 90 percent of the deaths from the 1964 earthquake were the result of tsunamis. One hundred and six Alaskans died from these waves and an additional 16 people died from tsunamis that reached California and Oregon after the event.*

Tsunamis consist of a series of waves with periods (the time between wave crests) from several minutes to an hour. These long periods cause the waves to behave differently than shorter period, wind-generated waves. Whereas wind-generated waves will break and diffuse energy offshore, tsunamis normally do not break, and arrive as a flooding wave with strong currents. For this reason, even tsunamis in the range of 3 to 6 feet in height can produce damage along shorelines. Tsunamis are not dangerous in deep water and they are rarely noticed by ships at sea. In the deep ocean, tsunamis travel at approximately 500 mph and may be only inches high. However, the same wave will slow down

and gain height dramatically as it enters shallow coastal water.

Tsunamis are produced in several ways. One way is by sudden regional uplift or subsidence of the seafloor during an earthquake. Tsunamis begun in this way can travel long distances and cause destruction thousands of miles from where the wave was generated. Underwater landslides, called slumps, are another cause of tsunamis. Destruction in Seward, Whittier, Valdez and other places in 1964 was caused by waves triggered by underwater landslides. These tsunamis are normally localized, but they are deadly because they reach the shoreline very quickly. Above-water landslides can also cause local tsunamis if

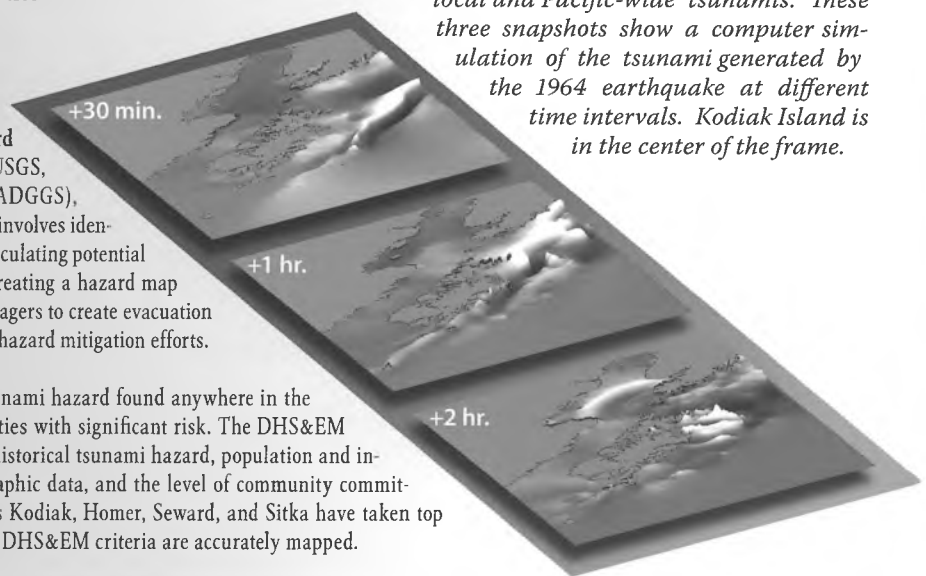
they enter a body of water. On July 9, 1958, in Lituya Bay, Alaska, a large earthquake started a giant landslide that ran into the head of the bay and generated a tsunami. The wave ran up a mountainside on the opposite side of the bay to a height of more than 1,720 feet. Two fishing vessels anchored in the bay sank and two people died. Volcanic eruptions are also capable of initiating tsunamis, especially in parts of Alaska where active volcanoes are located close to the sea. If volcanic mass flows, such as debris avalanches, lahars, or pyroclastic flows are large enough, they may initiate waves as they pass into the ocean. Although tsunami generation by these processes is relatively uncommon, under certain conditions large and damaging tsunamis can result and they do pose a threat to coastal communities in some areas of the Alaska Peninsula, the Aleutian Islands and southern Cook Inlet.

*White areas indicate tsunami crests and dark blue areas indicate depression of sea level. Tsunami simulations like this one are used to create inundation maps for Alaska's coastal communities. Seismic events that occur within the Alaska-Aleutian subduction zone have a high potential for generating both local and Pacific-wide tsunamis. These three snapshots show a computer simulation of the tsunami generated by the 1964 earthquake at different time intervals. Kodiak Island is in the center of the frame.*

### Tsunami Inundation Mapping for Alaskan Communities

The Alaska Earthquake Information Center helps Alaskan coastal communities to mitigate the risk from tsunamis by mapping the potential inundation zones for each community. This project is a part of the **National Tsunami Hazard Mitigation Program**, a cooperative effort of NOAA, the USGS, and the western coastal states of Alaska (AEIC, DHS&EM, ADGGS), Washington, Oregon, California, and Hawaii. This process involves identifying likely tsunami sources for each coastal community, calculating potential areas of inundation using a detailed computer model, and creating a hazard map and report. These products are used by local emergency managers to create evacuation plans, and for public education about tsunami risk and other hazard mitigation efforts.

Many of Alaska's coastal communities have the highest tsunami hazard found anywhere in the United States. Mapping is planned for all coastal communities with significant risk. The DHS&EM prioritizes communities for inundation mapping based on historical tsunami hazard, population and infrastructure at risk, availability of bathymetric and topographic data, and the level of community commitment to hazard mitigation. High-risk communities such as Kodiak, Homer, Seward, and Sitka have taken top priority. Work will continue until all communities meeting DHS&EM criteria are accurately mapped.



## Reducing Tsunami Damage and Danger

*Fortunately, tsunami damage can be minimized through land use planning, preparation, and evacuation. Tsunamis tend to impact the same localities over and over again. Therefore, if tsunamis have damaged an area before, they are likely to do so again. One choice is to avoid living in or using areas with significant tsunami hazard. Alternatively, communities can review land use in these areas so that no critical facilities, such as hospitals and police stations, or high occupancy buildings, such as auditoriums or schools, or petroleum-storage tanks are located where there is tsunami hazard.*

Following the shaking of the 1964 earthquake, Alaskans in coastal areas who did not feel the earthquake had little or no warning that a tsunami was on its way. As a result, the West Coast/Alaska Tsunami Warning Center was established. The WC/ATWC rapidly determines whether an earthquake in coastal Alaska may generate a tsunami, and issues a warning if necessary. After a warning is issued, people in the threatened area should immediately evacuate inland or to high ground. The WC/ATWC will issue a warning within 10 minutes after an earthquake occurs, but that is not a fast enough warning if there is a local tsunami. People near shore who feel an earthquake for 15-20 seconds or longer should heed nature's warning and quickly move to higher ground. A good rule of thumb is to move to 100' above sea level or 1 mile inland. People who are already on boats when an earthquake occurs should understand that the safest place to be is in deep water where wave energy is diffuse.

Tsunami warnings issued by the WC/ATWC are disseminated to local emergency officials and the public in Alaska by several different methods: FEMA's National Warning System, the State of Alaska Division of Homeland Security and Emergency Management, the U.S. Coast Guard, National Weather Service, the Emergency Alert System, NOAA Weather Radio, the Federal Aviation Administration, and the WC/ATWC web site – [wcatwc.arh.noaa.gov/message.shtml](http://wcatwc.arh.noaa.gov/message.shtml). During tsunami warnings, local emergency managers are responsible for conducting evacuations and notifying residents. In the event of a large tsunami, the local emergency managers are also respon-



sible for issuing the all clear notice.

The National Weather Service has developed a program known as TsunamiReady. This program provides communities with a set of guidelines to follow which enhances tsunami preparedness. If a community satisfies all the program's criteria, they are designated TsunamiReady by the NWS and the State DHS&EM. Several communities in Alaska and along the U.S. west coast have already been certified as TsunamiReady. Tsunami inundation maps are available for some coastal communities showing the areas that are at risk from tsunami waves. On the basis of these maps, emergency planners can develop evacuation plans and maps that indicate what areas should be avoided and evacuated after a major earthquake, and the routes that people should follow to reach safe ground.



*Top: Following the 1964 earthquake, tsunamis at Kodiak washed away most buildings within two blocks of the water and deposited fishing boats hundreds of feet inland. 158 houses in Kodiak were destroyed by the tsunami. Bottom: In Seward, an Alaska Railroad locomotive was overturned and swept up to 100' inland by the tsunami.*

## Tsunami safety rules

❑ A strong earthquake felt in a low-lying coastal area is a natural warning of possible immediate danger. Keep calm and quickly move to higher ground, away from the coast.

❑ Not all large earthquakes cause tsunamis, but many do. If the quake is located near or directly under the ocean, the probability of a tsunami increases. When you hear that an earthquake has occurred in the ocean or coastal region, prepare for a tsunami emergency.

❑ A tsunami is not a single wave, but a series of waves. The first wave is not necessarily the largest. Stay out of danger until an “all clear” is issued by a competent authority.

❑ Approaching tsunamis are sometimes heralded by a noticeable rise or fall of coastal water. This is nature’s tsunami warning and should be heeded.

❑ A small tsunami at one beach can be a giant a few miles away. Don’t let the modest size of one make you lose respect for all.



*Damage in Seward following the 1964 earthquake. The waterfront area, railroad yard, and petroleum storage tank facilities were devastated by the tsunami.*

❑ Sooner or later, tsunamis visit every coastline in the Pacific. All tsunamis, like hurricanes, are potentially dangerous even though they may not damage every coastline they strike.

❑ Never go down to the shore to watch for a tsunami. When you can see the wave you are too close to escape.

❑ During a tsunami emergency, your local emergency management office, police force, and other emergency organizations will work to protect your life and property. Give them your fullest cooperation.

❑ Stay tuned to your radio, marine radio, NOAA Weather Radio, or television stations during a tsunami emergency. Bulletins issued through your local emergency management office and the National Weather Service offices can save your life.

## **Tsunami Warnings**

When a large earthquake occurs near the coastline of the northern Pacific Ocean, an automated system at the West Coast/Alaska Tsunami Warning Center rapidly determines its location (epicenter) and magnitude. If the earthquake is located offshore and has a magnitude of 7 or larger it is considered large enough to generate a tsunami. A tsunami warning is then issued for a limited area near the epicenter of the earthquake. This warning is issued in Alaska through the military, Coast Guard, National Weather Service, Alaska Division of Homeland Security and Emergency Management, Federal Aviation Administration and other federal agencies. A tsunami watch is issued to adjacent areas of Alaska, Canada, and West Coast states as appropriate, alerting them to a possible tsunami threat.

If a significant tsunami is detected by instruments that measure tides near the epicenter of the earthquake, the warning will be expanded to the entire coastline of the region. If no wave was generated, the warning will be canceled. Although this will occasionally cause a warning to be issued when no wave is present, the alternative of leaving communities unaware of a potential disaster is undesirable. The West Coast/Alaska Tsunami Warning Center works closely with the other tsunami warning centers because tsunamis generated in distant parts of the Pacific Ocean, such as Japan or Chile, have also reached Alaska. A tsunami from northern Japan would take 4 hours to reach Adak Island and 8 hours to reach Kodiak, which allows Alaskans time to prepare if a watch has been issued. A tsunami travels from Peru or Chile to Kodiak in 16 to 18 hours.

## Measuring an earthquake

The energy suddenly released during an earthquake can produce a terrifying experience. The energy of the 1964 Alaska earthquake was equal to that of 63,000 Hiroshima-size atomic bombs. The size of an earthquake is commonly stated in terms of its magnitude, and the effects of an earthquake are measured by its intensity.

There are several ways that earthquake magnitude is expressed. The most famous was devised in 1934 by the late Dr. Charles F. Richter. On the Richter scale, and other magnitude scales, each whole number step represents a tenfold increase in the size of seismic waves measured on a seismograph—a machine that measures how much the ground moves in an earthquake. However, a single step on the Richter scale corresponds to a thirty fold increase in the amount of energy released in an earthquake. The news media usually refer to the size of an earth-

quake as having been measured on the Richter scale. However, a number of different scales are in common use. For example, the “moment” magnitude is now the standard for measuring large quakes. Since the late 1970s, scientists have determined that Richter magnitudes can underestimate the energy released by the largest earthquakes. As a result, the magnitude of the 1964 earthquake in Alaska, which was initially assigned a Richter magnitude of 8.4, is now considered to have had a magnitude of 9.2. The intensity of an earthquake is not measured using seismographs like Richter-scale magnitudes are, but is based upon earthquakes’ effects on man-made structures. The intensity of an earthquake can be very different in places only a hundred feet apart because the amount of shaking, and therefore the damage, depends upon the kind of soil or rock beneath a particular location.

A modified version of the Mercalli intensity scale, developed in 1902 by an Italian geologist, is often used to measure earthquake intensity. This scale ranges between Roman numerals “I,” which is rarely felt, to “XII,” which results in damage to nearly all structures. The scale is outlined in the table below.

Most residents in earthquake-prone parts of Alaska have experienced intensities up to IV. In the 1964 Alaska earthquake, there were Mercalli intensities of X near the epicenter of the quake in Prince William Sound; there were intensity VII effects in Kodiak, Homer, Seward, Valdez, Cordova, and Anchorage; there were intensity V to VI effects in Fairbanks, Fort Yukon, Yakutat, and Sitka. Regardless of how the magnitude or intensity of an earthquake is measured, any earthquake is significant if it impacts you, your family, or your community.

### Earthquake Magnitude and Intensity Scales Compared

| Earthquake Magnitude | Equivalent Energy in Weight of TNT | Equivalent Energy in Hiroshima-size Atomic Bombs | Mercalli Intensity Near the Epicenter | Human Observations                          |
|----------------------|------------------------------------|--|---------------------------------------|---|
| 4                    | 15 tons                            | 1/1000   | II-III                                | Feels like vibration from a nearby truck.   |
| 5                    | 477 tons                           | 3/100  | IV-V                                  | Small objects are upset, sleepers awaken.   |
| 6                    | 15,095 tons                        | 1  | VI-VII                                | Difficult to stand, damage to masonry.      |
| 7                    | 477,335 tons                       | 32   | VII-VIII                              | Widespread panic, some walls fall.          |
| 8                    | 15,094,673 tons                    | 1006   | IX-XI                                 | Wholesale destruction, large landslides.    |
| 9                    | 477,335,482 tons                   | 31,822   | XI-XII                                | Total damage, waves seen on ground surface. |

## History of earthquakes in Alaska

*Written records of earthquakes in Alaska extend back only to 1788, however, studies of more ancient earthquakes can give a better understanding of where they occur, how often they occur, and how large they are. Studies of recent marine and river sediment layers, buried forests and soils can reveal a record of subsidence or uplift related to major earthquakes. Past tsunamis sometimes leave recognizable sand deposits. In certain cases, tree rings can be used to estimate when an ancient earthquake occurred. Carbon 14 dating of sedimentary layers that have been offset by faults, or submerged in coastal areas during large earthquakes, can help to determine when ancient earthquakes occurred. The oral history of Alaska Natives includes legends and stories that may relate to prehistoric earthquakes.*

In Alaska, the study of ancient earthquakes, or paleoseismology, indicates that the last earthquake of comparable size to the 1964 Good Friday earthquake occurred 600 to 800 years ago. Some may conclude that because there was a major earthquake just 40 years ago that there is no longer much earthquake hazard in parts of southern Alaska. However, large earthquakes, on the order of magnitude 7 to 8, occur much more often and can be extremely devastating if they are close to population centers.

Looking at the geology of Alaska can help us to understand why there are earthquakes and where they occur.

### Why there are Earthquakes in Alaska

The surface of the Earth, also known as the crust, is made up of a dozen or so large fragments called "plates." Most of these plates are more than a thousand miles across and more than 40 miles thick. The Earth's crust has been composed of moving plates for at least four billion years, and these plates will continue to shift in the future. The movement of the plates occurs because it is hot in the middle of the Earth, and relatively cold at the surface. The Earth cools off by convecting hot mantle to the surface and releasing heat at the mid-ocean ridges where the crust is

thinnest. Hot mantle spreads away from the mid-ocean ridges and eventually cools and sinks back toward the middle of the Earth, where it is reheated before rising to the surface again. This convection cycle causes the plates to move steadily, but slowly, away from the mid-ocean ridges and past each other at rates up to 4 inches per year. Most earthquakes occur at the plate boundaries where pieces of the crust are sliding past each other, and some earthquakes are internal to plates.

These immense plates move at a steady rate, but at their edges the sliding motion is neither smooth nor constant. The motion of the plates strains or deforms the rocks at their boundaries because of friction with the neighboring plate until the rocks can no longer withstand the stress. Then, a sudden slip along a fault releases energy that causes earthquake shaking. When the plates are not slipping by each other, but are "locked" together, no earthquakes occur. Eventually enough strain will build up to cause the locked section to break and the two plates will slide past each other, causing an earthquake. The making of earthquakes is a bit like pulling a concrete block across a rough surface with a bungee cord. At first you pull on the bungee cord, it stretches out, and the block does not move. Eventually, the pull on the cord is strong enough to get the block moving, it slides

### Alaska Earthquake Statistics

Each year about 12,000 earthquakes shake the state of Alaska. That's an average of more than 30 each day!

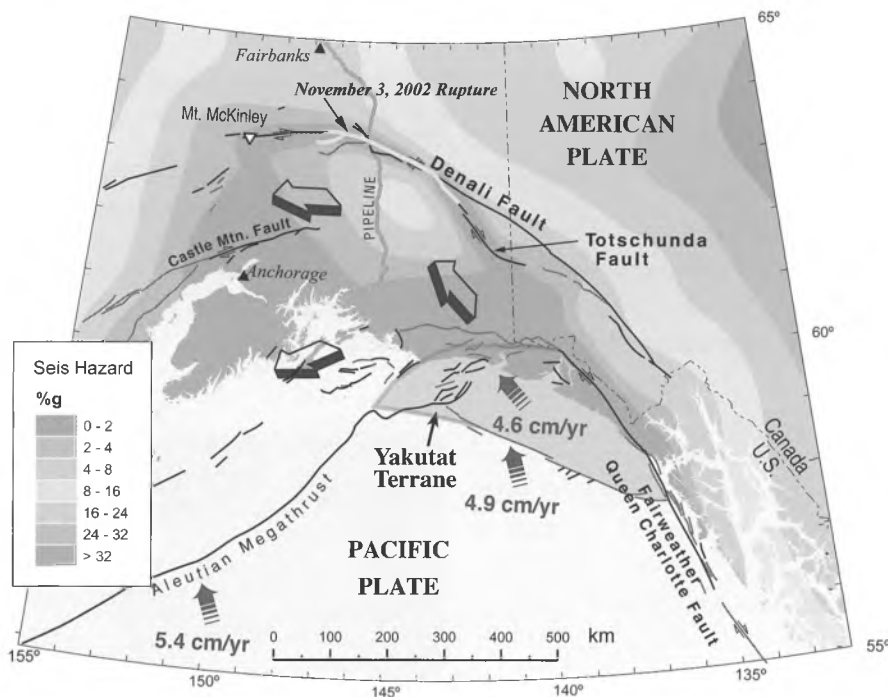
- Alaska has 11 percent of the world's recorded earthquakes.
- Alaska has more earthquakes than the rest of the United States combined.
- Three of the six largest earthquakes in the world were in Alaska.
- Seven of the ten largest earthquakes in the United States were in Alaska.

Since 1900, Alaska has had an average of:

- One magnitude 8 or larger earthquake every 13 years.
- One magnitude 7 to 8 earthquake every year.
- Six magnitude 6 to 7 earthquakes per year.
- Fortyfive magnitude 5 to 6 earthquakes per year.
- Threehundred and twenty magnitude 4 to 5 earthquakes per year.
- An average of a 1,000 earthquakes are located in Alaska each month.

forward with a jerk, and then stops. If you keep pulling, the cycle repeats itself, just like the earthquake cycle. There are a number of different regions that produce earthquakes in Alaska, and all are the result of the sliding of the Pacific plate toward the northwest, past southeastern Alaska and beneath southern Alaska.

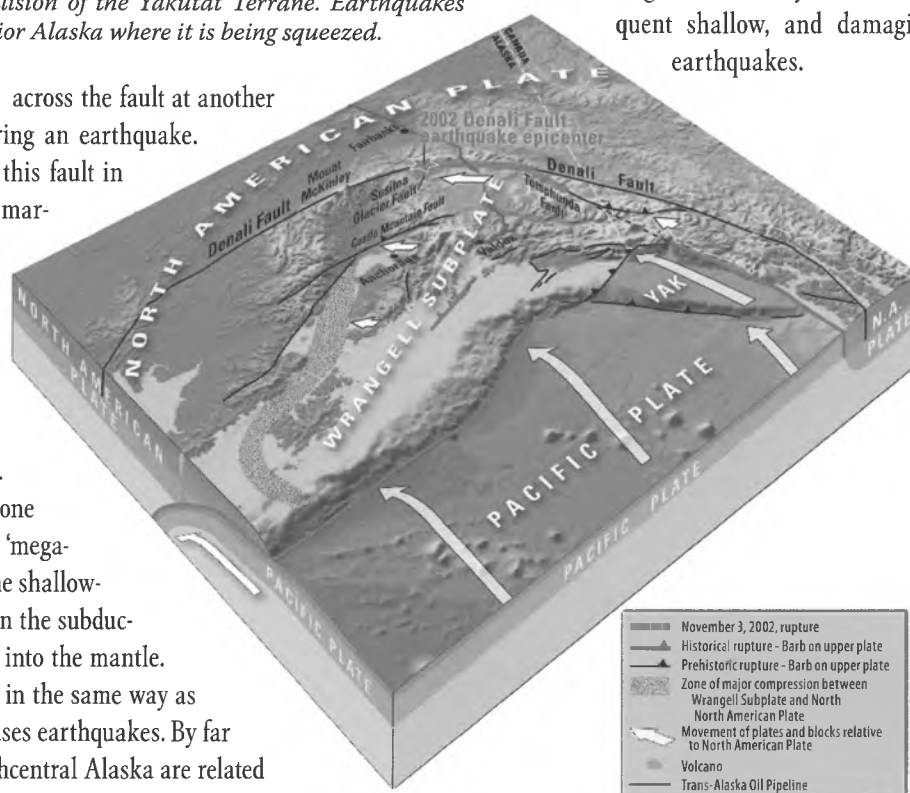
The next two figures shows where earthquakes occur in southern Alaska. The Pacific plate is located beneath the Pacific Ocean and slides past southeastern Alaska at a rate of about 2 inches per year. The main fault near southeastern Alaska, along which the plates slide past each other, is called the Queen Charlotte-Fairweather fault. It is essentially a northern continuation of the more famous San Andreas fault in California. The Queen Charlotte-Fairweather fault is a right-lateral strike-slip



**Above:** This map shows the combined seismic hazard in much of Alaska. The highest seismic hazard is shown in red, the lowest in green. The highest hazard lies along the plate margins, along the margins of the Yakutat terrane, and in zones where the Yakutat terrane collision is affecting interior Alaska. The Yakutat terrane collision is ultimately pushing up Mt. McKinley (Denali). Note: this hazard map does not portray local variations in earthquake hazard due to soil conditions. **Below:** This map shows that the plate tectonic setting of southern Alaska consists of the Pacific plate sliding past southeastern Alaska and beneath southern Alaska. The Pacific plate can be thought of as a conveyor belt. Riding on the Pacific plate is the Yakutat terrane (YAK), which is a buoyant piece of crust that is colliding with the southern Alaska margin. Interior Alaska is also being squeezed because of the collision of the Yakutat Terrane. Earthquakes occur along plate boundaries and in interior Alaska where it is being squeezed.

fault, which means that if you were looking across the fault at another person, they would move to your right during an earthquake. There was a magnitude 7.8 earthquake on this fault in 1958. The entire southern Alaska-Aleutian margin is a subduction zone where the Pacific plate is sliding to the northwest beneath the crust of southern Alaska, down into the Earth's mantle. Subduction zones produce the world's largest earthquakes, and most earthquakes felt in the Anchorage area are subduction zone earthquakes. There are several kinds of subduction zone earthquakes. The 1964 earthquake was a 'mega-thrust' earthquake related to sliding along the shallowest part of the subduction zone. Farther down the subduction zone, the Pacific plate bends downward into the mantle. The bending process cracks the Pacific plate in the same way as if you were bending a candy bar, and this causes earthquakes. By far the most commonly felt earthquakes in southcentral Alaska are related

to the sliding and bending of the Pacific plate between 18 and 60 miles beneath the earth's surface. These are called 'intraplate' earthquakes, and they can approach magnitude 7.5. The magnitude 6.8 Nisqually earthquake in Washington State in 2001 was an intraplate earthquake that caused an estimated 2 billion dollars in damage. Earthquakes in interior Alaska are caused by the collision of a piece of crust into the edge of southern Alaska. The collision is occurring near Yakutat, and thus the piece of crust is called the Yakutat terrane. The Yakutat terrane is moving quickly, at almost 2 inches per year. Earthquakes are generated at the margins of the Yakutat terrane, and further inland where the crust of Alaska is breaking in response to being shoved northward. The Denali fault is the largest of the faults in interior Alaska and it moves in response to the Yakutat terrane collision. On November 3rd, 2002, a magnitude 7.9 earthquake on the Denali fault caused more than 40 million dollars in damage. There are other faults on both sides of the Alaska Range, and in the Cook Inlet region, that may have infrequent shallow, and damaging earthquakes.



## Seismic monitoring in Alaska

*Seismic monitoring in Alaska is conducted for a variety of reasons. Foremost is the need to provide timely information to the public about the location and magnitude of significant earthquakes that may threaten life and property. Monitoring is also carried out to gather information used to improve the engineering and design of buildings for better resistance to earthquake damage. Seismic activity can also be an indication of tsunami generation (described on page 17) or volcanic activity. Monitoring is carried out on 25 of Alaska's volcanoes by the Alaska Volcano Observatory in order to detect eruptions that may pose a threat to the public.*

The Alaska Earthquake Information Center (AEIC: a partnership between the State of Alaska/UAF, USGS, and NOAA) collects all available seismic data into a single statewide network and serves as the Regional Data Center for the state. The AEIC records and processes data from a network of more than 400 seismic stations distributed across Alaska, which transmit seismic data in near-real-time to the AEIC laboratory at the Geophysical Institute in Fairbanks.

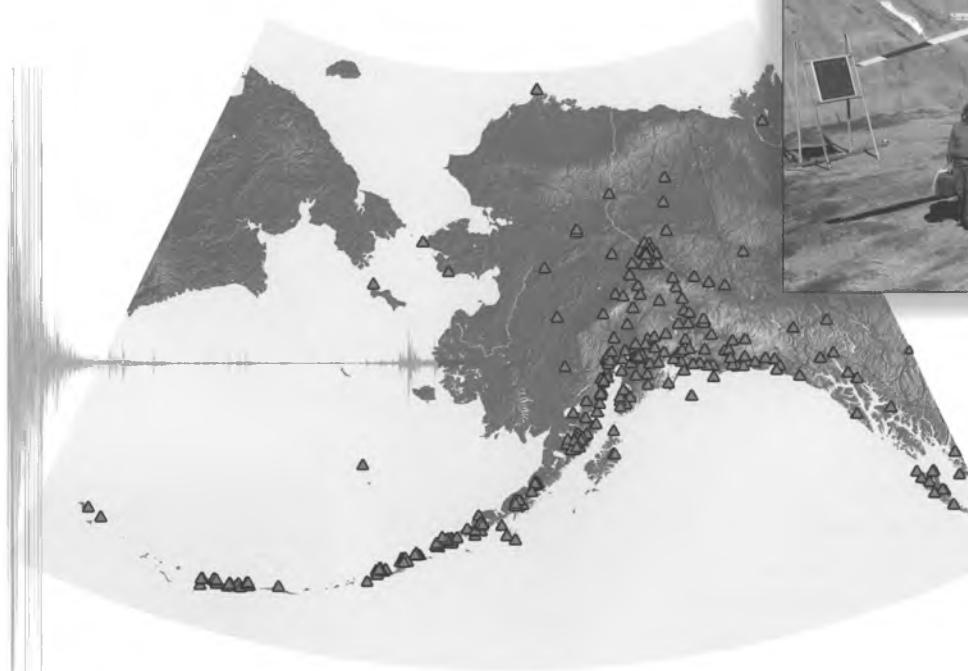
The size and location of every earthquake in Alaska (of magnitude 1.5 and larger in the mainland and magnitude 4 and larger in the Aleutian Chain) is cataloged and archived at the AEIC and made available as information releases to federal and state agencies, news organizations, and the public through the AEIC and USGS web sites. AEIC personnel analyze and report roughly 12,000 earthquakes each year and notify local, state and federal officials of the location and size of every significant earthquake (magnitude 3.5 and larger in the mainland and magnitude 5 and larger in the Aleutian Chain) within 30 minutes of occurrence. The earthquake data cataloged by the AEIC and USGS are used by scientists and government officials for a variety of purposes including research into the active tectonics of Alaska, determination of regional seismicity, and mapping of seismic hazard zones within the state.



*Alaska State Seismologist Roger Hansen analyzing seismic signals being recorded at the AEIC.*



*Above: Technician Ed Clark performing maintenance at the Chaiix Hills seismic station near Icy Bay. Left: The statewide network of seismic monitoring stations processed by the AEIC. Far Left: The seismic signal generated by the November 3rd, 2002 Denali Fault earthquake, recorded in Fairbanks.*



## Other Sources of Information

Your *local library* is a good place to start. Ask for the material referenced below. Many valuable information resources are available on the *World Wide Web*.

Internet addresses are provided in the sections below.

Look at the "*Earthquake Safety Information*" in the introductory pages of most telephone directories.

Ask your local chapter of the *American Red Cross* for pamphlets on preparedness and survival.

## **Agencies & Organizations:**

### **Alaska Earthquake Information Center, [www.aeic.alaska.edu](http://www.aeic.alaska.edu),**

Geophysical Institute, University of Alaska Fairbanks, 903 Koyukuk Dr., P.O. Box 757320, Fairbanks, AK 99775-7320, (907) 474-7320. *Provides seismic monitoring for the State of Alaska and has compilations of location, magnitude, and depth of Alaskan earthquakes.*

**Alaska Division of Geological & Geophysical Surveys, [www.dggs.dnr.state.ak.us](http://www.dggs.dnr.state.ak.us),** 3354 College Road, Fairbanks, AK 99709, (907) 451-5010. *Technical publications and maps about energy and mineral resources, geological hazards, and water resources.*

**West Coast/Alaska Tsunami Warning Center, [wcatwc.arh.noaa.gov](http://wcatwc.arh.noaa.gov),** Palmer, AK, (907) 745-4212. *Provides tsunami bulletins to coastal residents of Alaska, B.C., and the U.S. west coast for potentially tsunami-generating earthquakes in the Pacific basin.*

**Applied Technology Council, [www.atcouncil.org](http://www.atcouncil.org),** 555 Twin Dolphin Dr., #550, Redwood City, CA 94065, (650) 595-1542. *Provides technical publications for engineers, architects, and other people interested in the details of design for reducing earthquake damage to buildings and their contents.*

### **Alaska Division of Homeland Security and Emergency Management,**

**[www.ak-prepared.com](http://www.ak-prepared.com),** P.O. Box 5750, Fort Richardson, AK 99505-5750, (907) 428-7000 or (800) 478-2337. *Conducts preparedness and mitigation programs and workshops. Materials available upon request.*

**Earthquake Engineering Research Institute, [www.eeri.org](http://www.eeri.org),** 499 14th St. #320, Oakland, CA 94612-1934, (510) 451-0905, [eeeri@eeri.org](mailto:eeeri@eeri.org). *Technical information of most interest to engineers, researchers, and practicing professionals. Videotapes, annotated slide sets, and reconnaissance reports about earthquake hazard mitigation and the response of buildings, lifelines, and bridges during major earthquakes around the world. Free catalog.*

### **Federal Emergency Management Agency,**

**[www.fema.gov](http://www.fema.gov),** Region 10 (includes Alaska), 130 228th Street, SW, Bothell, WA 98021-9796, (425) 487-4604.

### **Municipality of Anchorage. Building Safety**

**Division, [www.muni.org/bsd/mainpage.cfm](http://www.muni.org/bsd/mainpage.cfm),** P.O. Box 196650, Anchorage, AK 99519-6650, (907) 343-8211. *Conducts and provides training for post-earthquake building safety evaluations.*

**U.S. Geological Survey, [www.usgs.gov](http://www.usgs.gov),** 4200 University Dr., Anchorage, AK 99567-4667, (907) 786 7011. *Publications and maps concerning earthquake hazards, faults, volcanoes, and permafrost.*

## **Additional Web Links**

[www.aeic.alaska.edu/cgi-bin/release\\_info.pl](http://www.aeic.alaska.edu/cgi-bin/release_info.pl)  
Alaska Earthquake Information Center website with list of most recent earthquakes in Alaska.

[earthquake.usgs.gov](http://earthquake.usgs.gov) - Main web page of USGS earthquake hazards program, with information about recent large earthquakes around the world.

[geopubs.wr.usgs.gov/open-file/of95-624/](http://geopubs.wr.usgs.gov/open-file/of95-624/)  
"Earthquakes in Alaska" poster of centerfold of this pamphlet.

[pasadena.wr.usgs.gov/shake/ak](http://pasadena.wr.usgs.gov/shake/ak) - "Did You Feel It?" Web site to report felt earthquakes.

[earthquake.usgs.gov/shakemap](http://earthquake.usgs.gov/shakemap) - ShakeMap website, which will have a link to Alaska when it becomes available.

[www.fema.gov/kids](http://www.fema.gov/kids) - "FEMA for Kids" website, current disaster information, preparedness, facts and figures, disaster experiences related by children, games & quizzes.

[www.fema.gov/hazards/earthquakes](http://www.fema.gov/hazards/earthquakes) - Earthquake safety and preparedness information.

[www.prh.noaa.gov/pr/ptwc/](http://www.prh.noaa.gov/pr/ptwc/) - Main web page of the Pacific Tsunami Warning Center

[wcatwc.arh.noaa.gov/tsunamiready/tready.htm](http://wcatwc.arh.noaa.gov/tsunamiready/tready.htm) - The "TsunamiReady" program of the National Weather Service



*Petroleum storage facilities at Valdez burn out of control following the 1964 Good Friday earthquake and tsunami.*

*Karl V. Steinbrugge Collection*

## American Red Cross

Anchorage (907) 646-5400 Fairbanks (907) 456-5937

Juneau (907) 463-5713 Soldotna (907) 262-4541

Wasilla (907) 357-6060

## Local Emergency Management Offices

Anchorage (907) 343-1400  
Current Emergency Information:  
(907) 343-4701  
24 hour number through  
Anchorage Fire Dispatch:  
(907) 267-4950

Fairbanks (907) 459-1481  
24 hour number:  
(907) 474-7721

Kenai (907) 262-4910

Mat-Su Valley (907) 373-8800

## Books and Materials for Children, Parents and Teachers

Age 3- 8:

**We Shake in a Quake.** By Hannah Gelman Givon, Illustrations by David Uttal, Ten Speed Press, Berkeley, 2000, 32 pages, ISBN: 1582460221

Age 9 - 12:

**Earthquake Games: Earthquakes and Volcanoes Explained by Games and Experiments.** By Matthys Levy and Christina Blatt, Illustrations by Mario George Salvadori, Marget K. McDerry (publisher), 1997, ISBN: 0689813678.

All Ages:

**Movers & Shakers** (Earthquake preparedness kit w/ video for K-12 classrooms, lesson plans for all grade levels). Free to schools, send to: Movers & Shakers, State Farm Insurance Co., Public Relations Dept. (E-8), One State Farm Plaza, Bloomington, IL 61710-0001. [www.statefarm.com/educate/moveshk.htm](http://www.statefarm.com/educate/moveshk.htm)

## Books on Geological Hazards

**Earthquakes.** By Bruce Bolt, W.H. Freeman, New York, 2003, 320 pages, ISBN: 0716719096, \$45.05

**The Citizens' Guide to Geologic Hazards.** Edward B. Nuhfer, Richard J. Proctor, and Paul H. Moser, A.I.P.G., 1993, 134 pages, ISBN: 0933637101. \$24.00, A.I.P.G., 8730 Yates Dr. #200, Westminster, CO 80031-3681, (303) 412-6205.

**Earth in Turmoil: Earthquakes, Volcanoes, and Their Impact on Humankind,** by Kerry E. Sieh and Simon LeVay, W.H. Freeman, New York, 1998, 275 pages, ISBN: 0716736519

## Engineering and Architecture Professional Societies

**Society of Professional Engineers,** ASPE Alaska Chapter, [www.myeterra.com/aspe/](http://www.myeterra.com/aspe/)

**American Institute of Architects,** AIA Alaska Chapter, P.O. Box 10-3563, Anchorage, AK 99510-3563 (907) 276-2834. [www.aiaak.org](http://www.aiaak.org)

**ASFE, The Association of Engineering Firms Practicing in the Geosciences,** 8811 Colesville Road, Suite G106, Silver Spring, MD 20910 (301) 565-2733. [www.asfe.org](http://www.asfe.org)

## Technical Reports on Regional Planning to Reduce Earthquake Risk

*The following documents are all technical in nature and are of most interest to regional planners and residents interested in regional planning.*

**Earthquake Alaska; Are we prepared?** Edited by R. Combellick, R. Head, and R. Updike, 1994, 192 pages, U.S.G.S. Open File Report 94-218. [pubs.er.usgs.gov/pubs/ofr/ofr94218](http://pubs.er.usgs.gov/pubs/ofr/ofr94218)

**Probabilistic seismic hazard maps for Alaska.** By R. Wesson, A. Frankel, C. Mueller, and S. Harmsen, 1999, Probabilistic Seismic Hazard Maps of Alaska: U.S.G.S. Open-File Report 99-36. [pubs.er.usgs.gov/pubs/ofr/ofr9936](http://pubs.er.usgs.gov/pubs/ofr/ofr9936) Updates available at: [eqhazmaps.usgs.gov](http://eqhazmaps.usgs.gov)

## Geologic-hazards mitigation in Alaska:

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## Anchorage Coastal Resources

**Atlas.** Atlas has maps of geologic hazards in the Municipality of Anchorage, including the frequently used Ground-Failure Susceptibility Map. Municipality of Anchorage, 1981-1982, v. 1-4. Available at libraries and online at: [www.dggs.dnr.state.ak.us](http://www.dggs.dnr.state.ak.us) (Publication MP32)



## Credits:

This pamphlet is based on a pamphlet that originally appeared in the Anchorage Daily News in 1994 on the 30th anniversary of the Good Friday earthquake. The concept for that booklet and much of the text came from a similar publication about the earthquake threat in San Francisco, entitled *The Next Big Earthquake in the Bay Area May Come Sooner Than You Think*, by Peter Ward, USGS. Additional material came from *On Shaky Ground: Living with Earthquakes on the North Coast*, by Lori Dengler and Kathy Moley, Humboldt State University.

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This pamphlet is meant to be instructional and to provide information that will help you understand and reduce your risk from earthquakes. The information in this publication is believed to be accurate at the time of publication. The agencies and individuals involved in the preparation and distribution of this information assume no responsibility for any damage that arises from any action that is based on information found here. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government, the State of Alaska, or any cooperating institution.



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**Back Cover:** Road damage from the Nov. 3rd, 2002 Denali Fault earthquake (**top and middle**). GI-UAF graduate student Kelly Kore installing a temporary seismic station to monitor aftershocks from the Denali Fault earthquake (**bottom**).  
**Front Cover:** Map of earthquakes in Alaska from 1898 to November 2003 (upper right). Earthquake depths: blue 0-33 km, green 33-75 km, orange 75-125 km and red 125+ km. Photograph (lower left) of damage to the Anchorage J.C. Penny building after the 1964 Good Friday earthquake.

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# Alaska Seismic Hazards Safety Commission

Report to the Governor and State Legislature  
FEBRUARY 2011



*Government Hill School in Anchorage was destroyed by a landslide triggered by the 1964 great Alaska earthquake. Because the earthquake occurred at 5:36 p.m. on Good Friday, no students were in the school and no injuries resulted. School seismic safety is a centerpiece of the Commission's policy recommendations. Photo from USGS Photo Archive.*

**ASHSC** Alaska Seismic Hazards  
Safety Commission

# ALASKA SEISMIC HAZARDS SAFETY COMMISSION

Report to the Governor and Legislature

FEBRUARY 2011

## EXECUTIVE SUMMARY

This annual report to the Governor and Legislature from the Alaska Seismic Hazards Safety Commission (ASHSC) reiterates the priority issues and goals of the Commission and identifies its 2010 accomplishments. The report updates the history and status of the Commission, identifies the current membership, lists the accomplishments to date, describes various committee functions, and presents the Commission's recommendations to improve seismic safety in Alaska.

The Federal Emergency Management Agency (FEMA) has estimated in *FEMA 366-HAZUS MH Estimated Annualized Earthquake Losses in the United States* that with its present infrastructure and policies, Alaska will have the second highest average annualized earthquake-loss ratio (ratio of average losses to infrastructure) in the country. Reducing these losses requires public commitment to earthquake-conscious siting, design, and construction. The Seismic Hazards Safety Commission is committed to addressing these issues. Earthquake-risk mitigation measures developed by similar commissions in other states have prevented hundreds of millions of dollars in losses and significant reductions in casualties when compared to other seismically active areas of the world that do not implement effective mitigation measures.

The Commission operates under the powers and duties prescribed by its enacting legislation (Appendix A) and is guided by its Charter (Appendix B) which provides a clear understanding of the Commission's roles and expectations, empowers Commission members, and provides operating guidelines agreed to by all members.

During the past year the Commission has invited numerous governmental and private organizations to give presentations describing their approaches to seismic risk mitigation. These briefings have provided the members of the Commission with opportunities to gain an understanding of current programs and various approaches to seismic risk mitigation, to identify areas of concern, and to focus initial mitigation efforts in these areas. Most of these briefings are available for viewing on the Commission website (<http://www.seismic.alaska.gov>).

The Commission's efforts in 2010 have reinforced its belief that seismic risk mitigation issues can be addressed in an economical way that will result in improving the quality of life and public safety in Alaska. The Commission presents the following policy recommendations:

### **Policy Recommendation 1:**

*Given that schools in Alaska serve not only as educational facilities but also as gathering places for the general public, and that many are designated as emergency shelters in case of a natural disaster, the Commission recommends that the State appropriate the resources necessary to identify those school facilities most at risk from earthquakes.*

### **Policy Recommendation 2:**

*The Commission recommends that all future school design, construction, and major renovation project funding include monies allotted for seismic risk mitigation tasks, to include:*

- *Seismic design by a structural engineer proficient in the design and detailing required for earthquake engineering tasks.*

- *An independent peer review of seismic design calculations and detailing by a qualified structural engineer.*
- *On-site observation of as-constructed earthquake engineering details during construction by a qualified inspector to ensure they are constructed in accordance with the contract documents.*

These and other policy recommendations continue to be addressed through the following Commission Standing Committees:

- Insurance
- Schools
- Earthquake Scenarios
- Education and Outreach
- Hazards Identification
- Response and Recovery
- Partnership

The 2010 activities of these committees are described in more detail in subsequent paragraphs.

Our basic public-policy goal areas remain unchanged from the 2008 Commission report:

- Education
- Guidance
- Assistance
- Implementation

## **INTRODUCTION**

The Alaska Seismic Hazards Safety Commission (“the Commission”) is charged by statute (AS 44.37.067; Appendix A) to recommend goals and priorities for seismic hazard mitigation to the public and private sectors; recommend policies to the Governor and the Legislature, including needed research, mapping, and monitoring programs; review the practices for recovery and reconstruction after a major earthquake; recommend improvements to mitigate losses from similar future events; and to gather, analyze, and disseminate information of general interest on seismic hazard mitigation, among other duties, to reduce the state’s vulnerability to damage from earthquakes.

The Commission consists of eleven members appointed by the Governor from the public and private sectors for three-year terms. It is administered by the Department of Natural Resources, Division of Geological & Geophysical Surveys (DGGS).

Commission members include: A representative from the University of Alaska, three representatives from local government; a representative from the Department of Natural Resources; a representative of the Division of Homeland Security and Emergency Management; a representative from an appropriate federal agency; a representative of the insurance industry; and three members of the public who are experts in the fields of geology, seismology, hydrology, geotechnical engineering, structural engineering, emergency services, or planning. Six members constitute a quorum. The Commission membership elects its own chair and vice-chair. There is no executive director, although DGGS provides administrative, travel, and publication support.

## HISTORY AND STATUS OF THE COMMISSION

In 2002, the 22nd Alaska Legislature passed, and the Governor signed into law, House Bill 53 establishing the Alaska Seismic Hazards Safety Commission with nine members. The legislation originally placed the Commission in the Office of the Governor, but in January 2003, Governor Frank Murkowski issued Executive Order Number 105 transferring the Commission to the Department of Natural Resources. Governor Murkowski appointed the first nine members to the Commission in 2005.

In 2005, the Alaska House of Representatives passed House Bill 83 (HB 83) to extend the Commission to June 30, 2008, add tsunami risks to its purview, and provide two additional Commission positions representing local government. In 2006, the Senate passed a substitute version of HB 83 including the two additional local government positions but omitting specific mention of tsunamis in the Commission's powers and duties. The Senate bill extended the Commission through June 30, 2012. The House concurred with the Senate version and Governor Murkowski signed the bill into law at a Commission meeting on June 16, 2006. Although the revised statute does not specifically include tsunami hazards in the Commission's powers and duties, the definitions in AS 44.37.069 include tsunami inundation as a seismic hazard. Consequently, the Commission addresses tsunamis in its discussions and recommendations. As a result of passage of HB 83, the Commission currently has 11 members.

The Commission first met on October 28, 2005, at which time it elected a Chair and Vice Chair, listened to briefings from the California Seismic Safety Commission and various state and local agencies in Alaska with responsibilities in earthquake-risk mitigation, and began developing goals and priorities for its activities. There were 12 meetings of the Commission through December 2006, six of which were via teleconference. Since 2006, the Commission has held eight to ten meetings annually, generally all but two of which have been via teleconference. Two-day, face-to-face meetings are held twice annually, normally in Anchorage.

The Commission published its first annual report to the Governor and Legislature on April 18, 2006, and has since published reports annually during the state Legislative sessions. A Commission website posts basic information about its mission, earthquake risk in Alaska, meeting agendas, minutes, presentations, and appropriate links. The website address is:

<http://www.seismic.alaska.gov>

## COMMISSION MEMBERSHIP

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## **EARTHQUAKE RISK IN ALASKA**

Alaska has more earthquakes than any other region of the United States and is, in fact, one of the most seismically active areas of the world. The devastating January 2010 earthquake in Haiti is a grim reminder of what can happen when a society is not prepared for the furies of nature. The second largest earthquake ever recorded occurred on the Prince William Sound portion of the Alaska–Aleutian megathrust in southern Alaska on March 27th, 1964, with a moment magnitude of 9.2. The largest on-land earthquake in North America in almost 150 years occurred on the Denali fault in central Alaska on November 3rd, 2002, with a magnitude of 7.9. In February through October, 2010, the Alaska Earthquake Information Center recorded 26,077 earthquakes, for an average of 2,900 monthly, including 270 events with magnitude 4.0 or greater, 35 events of magnitude 5.0 or greater and 8 events of magnitude 6.0 or greater. It is not possible to predict the time and location of the next big earthquake, but the active geology of Alaska guarantees that major, potentially damaging earthquakes will continue to occur. The risks to public safety and infrastructure from these future events can be greatly reduced through proper planning, design, and construction.

Alaska has changed significantly since the great 1964 earthquake. The population has more than doubled, but many new buildings are designed to prevent collapse during intense shaking. Some older buildings have been reinforced, and development has been discouraged in some particularly hazardous areas. However, despite these improvements, and because practices to reduce vulnerability to damage from earthquakes and tsunamis are not applied uniformly in regions of high risk, future earthquakes may still cause life-threatening damage to buildings, cause items within buildings to be dangerously tossed about, and disrupt the basic utilities and critical facilities that we take for granted.

In addition to the 1964 and 2002 ruptures, there are other sources of potentially damaging earthquakes in Alaska. These include the Castle Mountain fault in the lower Matanuska–Susitna valley, the Wadati–Benioff zone beneath Anchorage, the active belt of faulting and folding in northern Cook Inlet, the Fairbanks seismic zone, and the Yakataga seismic gap near Yakutat, among others. While the seismic provisions of current Alaska building codes are largely geared toward preventing collapse from the types of shaking that occurred in 1964, earthquakes on these other sources may affect structures differently, in ways that may or may not be ameliorated by the current codes.

Earthquakes of magnitudes that could cause major structural damage and injury to residents continue to occur in Alaska. The interested reader is directed to Appendix C for additional information concerning Alaska earthquake activity in 2010.

## **SOME ADDITIONAL EARTHQUAKE STATISTICS FOR ALASKA**

- Eleven percent of the world's recorded earthquakes have occurred in Alaska.
- Alaska has more frequent earthquakes than the rest of the United States combined.
- Three of the eight largest earthquakes in the world were in Alaska.
- Seven of the ten largest earthquakes in the United States were in Alaska.

Since 1900, Alaska has had an average of:

- One “great” (magnitude 8 or larger) earthquake every 13 years.
- One magnitude 7 to 8 earthquake every two years.
- Six magnitude 6 to 7 earthquakes per year.
- Fifty magnitude 5 to 6 earthquakes per year.
- Three hundred magnitude 4 to 5 earthquakes per year.
- Approximately 2,000 earthquakes recorded in Alaska each month.

It is not possible to predict the time and location of the next big earthquake, but the active geology of Alaska guarantees that major potentially damaging earthquakes will continue to occur. Scientists generally know where large earthquakes are most likely to occur, and have mapped the probable levels of ground shaking to be expected in the state (see centerfold map). With this information, as well as information on soil properties and landslide potential, it is possible to estimate earthquake risks in any given area. It is also possible to estimate the potential for earthquakes to generate tsunamis, and to model the extent to which tsunamis will inundate coastal areas.

## COMMISSION ACCOMPLISHMENTS IN 2010

The Commission’s standing committees continued to be active in 2010. Sam Kito from the Alaska Department of Education and Early Development continued to assist the Schools Committee and Joanne Bennett from the Alaska Division of Insurance has been an active participant on the Insurance Committee. Both of these individuals bring a wealth of experience to committee activities.

### 2010 accomplishments include:

1. Held five telephonic and two face-to-face (two day) meetings of the Commission.
2. Participated in the following briefings on seismic risk mitigation from the following agencies and discussed the Commission’s activities as they relate to work being accomplished elsewhere:
  - a. United States Geological Survey (USGS) Advanced National Seismic System (ANSS)
    - (1) *Up-to-date Synopsis of Alaska Seismic Network Issues*—Bill Leath/USGS
    - (2) *Future of the Strong Motion Program in Alaska*—Erol Kalkan/USGS
  - b. Alyeska Pipeline Service Company and Alaska Earthquake Information Center (AEIC)
    - (1) *Seismic Monitoring of the Alyeska Pipeline*—Jim Roddick/Alyeska, Roger Hansen/AEIC
  - c. Alaska Division of Geological & Geophysical Surveys (ADGGS)
    - (1) *Active Fault Identification in Alaska and Haiti Earthquake Briefing*—Rich Koehler/ADGGS
  - d. Oregon Department of Geology and Mineral Industries (DOGAMI)
    - (1) *Seismic Risk Mitigation in Oregon Schools*—Yumei Wang/DOGAMI
  - e. California Earthquake Authority (CEA)
    - (1) *Earthquake Insurance*—Glenn Pomeroy/CEA
  - f. West Coast and Alaska Tsunami Warning Center (WCATWC)
    - (1) *Update of WCAWTC Activities*—Bill Knight/WTCTWA
  - g. United States Geological Survey (USGS)
    - (1) *Earthquake Hazards Work in Alaska*—Peter Haeussler/USGS
  - h. Alaska Department of Natural Resources (ADNR)
    - (1) *Proposed Underground Natural Gas Storage Facility Permitting*—Tom Crafford/ADNR
  - i. Chugach Electric Association (CEA)
    - (1) *Utilities Seismic Risk Mitigation Activities*—Kevin Dunham/CEA

3. The Commission sponsored, in conjunction with the Earthquake Engineering Research Institute and the University of Alaska Anchorage School of Engineering, the Joyner Lecture presented by Art Frankel/USGS, titled *Progress and Controversy in Seismic Hazard Mapping*.
4. The Commission Chair gave 1-hour earthquake briefing presentations to each of the following organizations:
  - a. Alaska Partnership for Infrastructure Protection (APIP)
  - b. Chugach Electric Association (CEA)
  - c. Pioneers of Alaska Igloos 4 and 15
  - d. Alaskan Command and Joint Task Force-Elmendorf AFB
5. The Commission Chair prepared the training material for a 2-day Commission-sponsored course on Post-disaster Safety Assessment of Facilities, for presentation February 23–24, 2011.
6. The Commission Chair developed and facilitated a meeting of other state seismic risk mitigation agency members at the 2010 annual meeting of the Western States Seismic Policy Council (WSSPC) in Denver, Colorado. Attendees included representatives from Alaska, California, Colorado, Hawaii, Nevada, Oregon, Utah, Washington, the Federal Emergency Management Agency (FEMA), and the Western States Seismic Policy Council (WSSPC).
7. Developed and published the fifth annual report to the Governor and Legislature in January 2010.
8. The Commission began discussions with the Kodiak Island Borough concerning developing an earthquake planning scenario to be used as a tool for developing seismic risk mitigation policies and response plans.
9. Collaborated with the Alaska Board of Education and Early Development (ADEED) in developing a new capital improvement project application form for districts that specifically addresses seismic issues. Continued working with ADEED to prioritize the identification of schools at greatest seismic risk.
10. Communicated with other state seismic hazard safety commissions, including Oregon's, to identify best means for improving the seismic safety of schools. Topics included legislation, identification, prioritization, funding, and retrofit.
11. Established a link with the Division of Insurance to their publication: *2009 Homeowners Insurance Guide*, which includes a section on earthquake insurance.
12. Established a liaison with the Division of Insurance to develop a relationship to facilitate pursuit of Insurance Committee goals.
13. Exercised the procedure for convening the Commission rapidly in the event of a significant seismic event in the State to provide immediate advice to the Governor during the incident response and recovery phase. The procedure was successfully exercised during the Statewide Tsunami Warning test on March 24, 2010, and during the Statewide Alaska Shield/Northern Edge Exercise the week of April 26–30, 2010.
14. Reviewed and sent forward to the entire Commission for comment, the seismic sections of the draft State Hazard Mitigation Plan 2010 update. The seismic hazard descriptions, goals, and objectives were reviewed and revised by the entire Commission and forwarded to the State Division of Homeland Security and Emergency Management for inclusion in the FEMA-approved State plan.
15. Provided an opportunity for the Commission to review the seismic sections of community Emergency Operations Plans as requested.
16. Provided an opportunity for Commissioners to enroll in and complete the National Incident Management System (NIMS) training in Incident Command System course 100 (ICS 100) in a step to bring the Commission into accreditation with federal and State NIMS requirements.
17. Co-sponsored a training course on hospital structural and non-structural earthquake mitigation for the primary healthcare providers in Southcentral Alaska.
18. Continued to support Commission representation on the State Hazard Mitigation Advisory Committee (SHMAC) that advises the Governor's Disaster Policy Cabinet on use of State mitigation funds, policy, and planning.

## **COMMITTEE ACTIVITIES**

### **Schools Committee**

Assessing and minimizing loss due to structural instability of critical facilities in the event of a major seismic incident is a major priority of the Commission. Critical facilities of concern are schools, hospitals, clinics; fire, rescue, and police stations; plus jails and detention facilities. Other important infrastructure at potential risk also includes military bases, airports, college complexes, harbors, and utility systems (communications, electric, oil, transportation, water, and wastewater). Schools remain a major focus, however, due to the number of facilities within the state, their high occupancies, and common designation as emergency shelters (see centerfold map).

In an effort to begin mitigating earthquake risk to critical facilities, the following approaches for addressing the issue include:

- Assist in prioritizing the identification and mitigation of at-risk facilities; initially focusing on schools, due to high occupancies and common use as emergency shelters.
- Develop work plan(s) in collaboration with state and local agencies/governments.
- Advocate cost-benefit analyses for both existing and new construction.
- Identify current legislation/programs, including those adopted by other states/countries. Foster contacts with successful proponents.
- Identify pertinent code and construction requirements and potential limitations.
- Recommend improvements including policy changes, legislation, and public outreach.

The Commission believes that focusing on schools will provide the greatest potential cost/benefit to the State. Schools, especially in smaller communities, tend to be some of the most important and most heavily occupied structures. Collapse during an earthquake would not only be devastating to the occupants, but also to the recovery of a community if the structure could no longer be used for emergency shelter in Alaska's harsh climate and isolated communities. Globally, schools are becoming the main focus for prioritizing structural mitigation, especially given widespread collapses during recent earthquakes in China (2008) and Haiti (2010). Even damage to schools during past smaller U.S. earthquakes, such as the 2001 Nisqually (Seattle) Earthquake, have highlighted the need.

### **Schools Committee Activities in 2010:**

- Collaborated with the Alaska Department of Education and Early Development (ADEED) in developing a new capital improvement project application form for districts that specifically addresses seismic issues. Requirements were added to include costs to professionally assess seismic hazards, and mitigate seismic risk via investigation, design, and special construction inspections for any major project involving a school facility. The recommended changes are scheduled for implementation in 2012.
- Continued working with ADEED to prioritize identifying schools at greatest seismic risk.
- Communicated with other state seismic hazard safety commissions, including Oregon's, to identify best means for improving the seismic safety of schools. Topics included legislation, identification, prioritization, funding, and retrofit.
- Arranged for Yumei Wang, Geotechnical Engineer, Oregon Department of Geology and Mineral Industries, to speak to the Commission about Oregon's public schools and emergency facilities seismic-risk mitigation program.

**Schools Committee Plan for 2011** (see pages 16–17 for map showing public schools and earthquake hazards in Alaska):

- Continue work with ADEED to identify existing at-risk school structures and prioritize seismic mitigation.
- Maintain and foster relationships with other organizations and commissions involved with improving school seismic safety.
- Further review state policies and procedures related to constructing and maintaining critical facilities and infrastructure, with a focus on identifying and improving resiliency in the event of a major earthquake.
- Continue to seek funding to identify and retrofit critical structures at risk of damage or collapse during a major seismic event.
- Continue to advocate policy changes, legislation, and public outreach that mitigates earthquake risk.

### **Insurance Committee**

As part of the Alaska Seismic Hazard Safety Commission’s Charter, the Insurance Committee seeks to bring awareness of issues concerning availability and its importance to Alaskans through ongoing education. The committee set three goals at the outset of the year. These were:

1. Provide basic information on the ASHSC website that is easily accessible to the above audience concerning earthquake exposures, insurance availability, and personal safety measures. Consider links to other State of Alaska sites.
2. Publish an informational brochure for the public about earthquake and tsunami risks, insurance, and choice. Find venues for distributing this information.
3. Work with the Division of Insurance to provide information on hazards throughout the state, define steps that can mitigate those hazards, and assist as needed to attract additional carriers to the Alaska market who will provide affordable earthquake insurance to citizens throughout the state.

In working toward these goals, the committee this year accomplished the following:

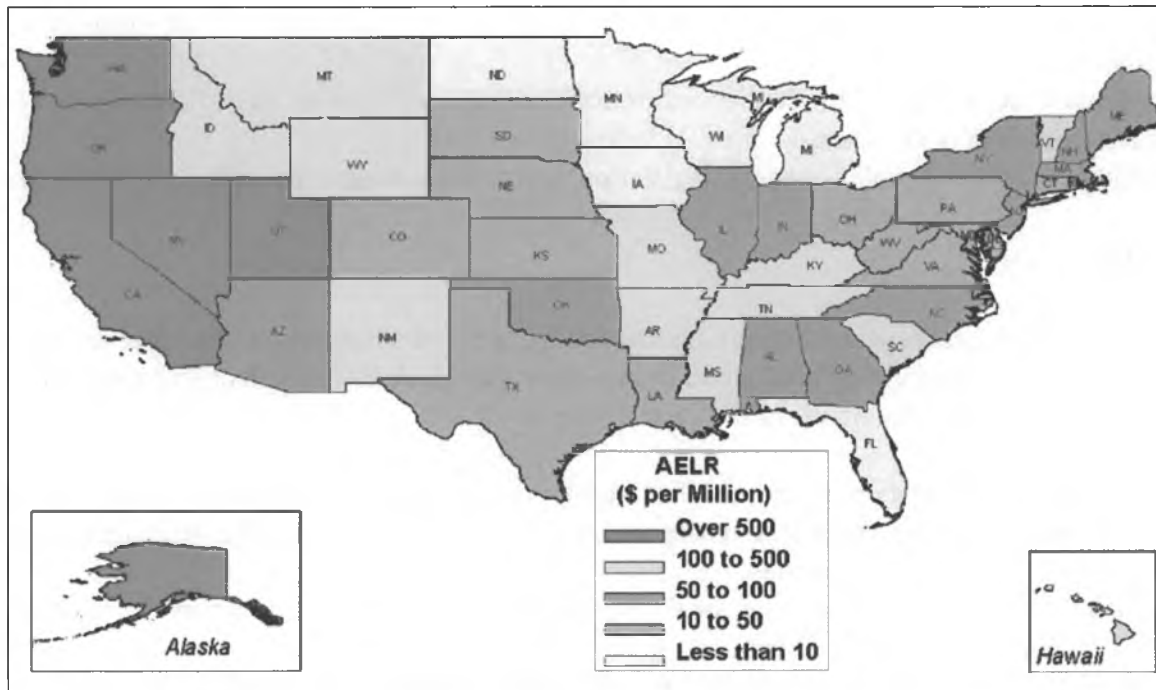
- Presented to the ASHSC a video interview of the Division of Insurance Commissioner about earthquake insurance in Alaska.
- Facilitated a presentation from Glenn Pomeroy, CEO of the California Earthquake Authority, about their unique system and how it might be adapted for Alaska.
- Established a link with the Division of Insurance to their publication, *2009 Homeowners Insurance Guide*, which includes a section on earthquake insurance.
- Established a liaison with the Division of Insurance to develop a relationship through which to pursue goals 2 and 3 in the next year.

The white paper originally written for the ASHSC website in 2006 was updated with current information about insurance in Alaska as well as effects felt from the most recent global events.

### **Earthquake Scenario Committee**

An earthquake scenario is a planning tool that helps people understand earthquakes and plan for the future. Earthquake scenarios have been used successfully in several areas of the U.S. to identify weaknesses in the

built environment as well as vulnerable interdependencies among utility and transportation systems that could result in multiple or cascading failures even if only one system fails. Communities, state and federal agencies, private industry, and emergency response organizations use scenarios as tools to increase public awareness, develop risk-reduction strategies, and plan for response and mitigation. The Western States Seismic Policy Council, in its adopted Policy Recommendation 09-1, recommends “that each member state, province, and territory establish an active program to produce Earthquake Planning Scenarios for areas with high risk of earthquake losses.”



*Projected Annualized Earthquake Loss Ratio (AELR) by State from FEMA 366 report.*

Earthquake scenarios begin by defining a hypothetical but geologically realistic earthquake suitable for the purpose of the scenario. Depending on the complexity and desired results, a scenario may describe the types and severity of shaking and ground breakage likely to result; the likely impacts to facilities, including types and extent of damage to buildings according to building type and age; and disruptions to utilities and transportation systems. A scenario may also describe secondary effects such as tsunamis, fire, and toxic materials release; estimate the numbers of deaths, injuries, and dollar value of losses by building type; and estimate the long-term business losses and socioeconomic consequences. The resulting information provides the basis for planning earthquake-response exercises, prioritizing and pre-locating response resources, and developing mitigating measures for reducing vulnerability to future earthquakes.

Developing an earthquake scenario requires assembling pertinent geologic and seismologic data for a realistic event, compiling and updating building and utility system inventory information for the affected region, assigning seismic fragilities to the building stock, and assembling current data on population demographics. Loss-estimation technology such as FEMA’s HAZUS software is often used to model the event, incorporating all the compiled data. The results are then documented in one or more reports and presentations to all interested groups. If done effectively, a scenario helps decision makers visualize specific impacts that are based on currently accepted scientific and engineering knowledge, providing a powerful tool for private industry, government officials, and the general public to develop effective mitigation policies and programs.

## **Scenario Committee Activities in 2010**

The Earthquake Scenario committee is working on ways to promote the development of scenarios that help identify and mitigate seismic risk in Alaska. During 2010, the committee performed the following tasks:

- Following its plan for 2010 as stated in the Commission's 2009 annual report, the committee worked toward promoting earthquake scenarios. In view of the limited resources likely available, the committee decided to start with relatively small, community-based scenarios that are limited in scope, such as by focusing on certain types of facilities or small areas.
- In recognition of community interest, recent successful work on school seismic safety, and support from the U.S. Coast Guard, the committee decided to promote and, to the extent possible, support development of a HAZUS Level 2 scenario for the Kodiak area.
- The committee drafted a letter, which was signed and sent by the Commission chair to the Community Development director for the Kodiak Island Borough, offering to help coordinate and oversee development of a scenario as described above.
- FEMA offered to run the HAZUS Level 2 loss estimation for Kodiak once the input data, such as earthquake source model, building inventory, and demographic data, are provided. The committee contacted FEMA to indicate its interest in helping to develop the scenario and to make it clear that the Commission will take an active role in monitoring the process and reviewing the draft products.

## **Scenario Committee Plan for 2011**

The scenario committee will help coordinate a community approach to development of an earthquake scenario for Kodiak, involving scientists, engineers, policy makers, and emergency managers, and soliciting as much volunteer support as possible. The committee will work with the Kodiak Island Borough, U.S. Coast Guard, City of Kodiak, FEMA, and other interested parties to develop the input data needed for a HAZUS Level 2 loss estimation for Kodiak and surrounding area including the Coast Guard base. In moving forward, a significant portion of the effort will be to generate interest and solicit involvement by community organizations, local professionals, and businesses. The committee will consider submitting proposals to the National Earthquake Hazard Reduction Program and Earthquake Engineering Research Institute for support in developing this scenario.

## **Hazards Identification Committee**

Seismic hazards include a number of physical phenomena generated by earthquakes that have the potential to cause damage to the state's infrastructure and compromise the safety of Alaska's residents and visitors. The most common and widespread seismic hazard is strong ground motion. Surface fault rupture, seismically triggered landslides and snow avalanches, ground failure including liquefaction, ground settlement, and subsidence, and seiches and tsunamis are also significant seismic hazards in many regions of the state. Identification and characterization of seismic hazards is fundamental to developing mitigation strategies and reducing losses from earthquakes.

The Hazards Identification committee was established to provide guidance through the Commission to the Governor, the Legislature, and the public regarding location and characteristic of the state's seismic hazards. The committee includes commission members with expertise in earthquake geology, seismicity, engineering, and seismic hazard mitigation.

The goals of the Hazards Identification Committee are to promote:

- Identification and characterization of seismic hazards in Alaska
- Definition and description of seismic risks
- Seismic risk and hazard research
- Dissemination of seismic hazard and risk information to the state and local governments, the public, business and industry, and the scientific and professional communities.

### **Hazards Identification Committee Activities in 2010**

In 2010 the Hazards Identification Committee focused its efforts on improving the understanding of Alaska's seismic hazards and the state's seismic risks. This effort included gathering information and continuing the discussion of the present state of knowledge regarding seismic sources. This effort is directed toward the development of a comprehensive overview of the seismic hazards and risks in Alaska and an approach to effectively communicate this information to private and public users.

One of the primary goals of the ASHSC is reduction of future earthquake losses in Alaska. In 2008 the commission recognized the urgent need to better understand sources of potentially damaging earthquakes in Alaska to meet this goal. In 2009 the Hazards Identification Committee encouraged the State Geologist to resurrect a previously initiated program by the Alaska Division of Geological and Geophysical Surveys (ADGGS) to develop an inventory and database of active and potentially active faults in the state and to initiate a field program aimed at evaluating fault hazards affecting infrastructure development. These efforts are now being addressed by ADGGS with the addition of a new position to their professional staff. This new addition to ADGGS's professional staff is to complete the database of active and potentially active faults in Alaska in 2011. Committee members were also active in preparing for the Association of Environmental and Engineering Geologists (AEG) annual national meeting to be held in Anchorage in September 2011.



*Denali fault displacement on Canwell Glacier.*

### **Hazards Identification Committee Plan for 2011**

To further address its goals the committee has started the development of a comprehensive white paper summarizing the present state of knowledge of the state's seismic hazards and risks. A draft of this paper is in progress and partially completed. Completion of the white paper will be one of the principal objectives of the committee in the coming year.

The chair of the Hazards Identification Committee, in collaboration with the newly hired ADGGS paleoseismologist, plan to sponsor and co-chair a technical session and symposium on seismic hazards and risks in Alaska at the Association of Environmental and Engineering Geologists (AEG) annual national meeting in Anchorage in September 2011.

## Hazards Identification Committee Challenges

One of the principal challenges to seismic hazard identification and risk definition in Alaska is the limited database and lack of a comprehensive inventory of information concerning seismic sources and their characteristics. The size of Alaska, the limited access in much of the state, and the very small community of earthquake scientists and engineers working in the state also present a significant challenge to meeting the goals of the ASHSC Hazards Identification Committee.

## Response and Recovery Committee

### Committee Activities in 2010:

- Exercised the procedure for convening the Commission rapidly in the event of a significant seismic event in the state to provide immediate advice to the Governor during the incident response and recovery phase. The procedure was successfully exercised during the Statewide Tsunami Warning test on March 24, 2010, and during the Statewide Alaska Shield/Northern Edge Exercise the week of April 26–30, 2010. A two-thirds Commission quorum was achieved in both exercise tests. The Committee also hosted a discussion of the Commission’s role in the month following a significant seismic event including draft proposed legislation and policy recommendations.

| OPERATIONAL PLANNING WORK SHEET |  |                                    |                | Denali Fault Eq  |                | 11/7        | 11/8 0700-1900                 |   |
|---------------------------------|--|------------------------------------|----------------|--|----------------|-------------|--------------------------------|---|
| DEPARTMENT OR OTHER LOCATION    | HOW MEASUREMENTS   | RESOURCES                          |                |  | EQUIPMENT      |             | PLANNING LOCATION              | PROJECT'S APPROX. DATE                            |
|                                 |  | ADCS                               | DEC            | FEMA   | Forklift       | Transponder |                                |   |
| Mestast (Denay)                 | Continue Storage Assessment<br>Fuel tank placement   | B. Nichols                         |                |  | Bar Hand Crane |             | Drilling @ 0700<br>- Report to |   |
| Slana (Gronow)                  | Continue H <sub>2</sub> O Assessment   |                                    | Staba, Johnson |  | Nichols, Opmer |             | V. Hagan afterwards            |   |
| Tetlin (Keech)                  | Damage Assessment Team<br>Red Cross - Family Service   | Cowles, W.<br>Tetlin - Jst         |                | SBA - Kiloym<br>JA B. Davis<br>PA - Anderson, Taylor                     |                |             |                                |   |
| Christo/Carhona (Gronow)        | Damage Assessment Team<br>Continue H <sub>2</sub> O Assessment                                 | John Aho<br>R. Kautsthal<br>J. Aho | Staba, Johnson | SBA - Darrington<br>JA - Claude R.<br>PA - Steve G. Smith<br>M. J. Allen |                |             |                                |   |
| Tok/Tanacross (Kurtz)           | Damage Assessment Team<br>SS / DOT/ICE   | K. Biscoe<br>D. Hudson<br>M. Macan |                | SBA - Brown, Hunt<br>EA - Jenkins<br>PA - J. Rhonda, R. Huchaj           |                |             |                                |   |
| Mineral Lakes                   | Continue Damage Assessment<br>(School Education)<br>"where" in educational time as appropriate | J. Smith<br>J. Gandy               |                |  |                |             |                                |   |
|                                 |  |                                    |                |  |                |             |                                | SE - Matt Barabell<br>Deer Support<br>Jared Skell |
|                                 |  |                                    |                |  |                |             |                                | KURTZ, RESL                                       |

Denali fault earthquake schedule for response team investigations (photo by John Aho).

- Reviewed and sent forward to the entire Commission for comment, the seismic sections of the draft State Hazard Mitigation Plan 2010 update. The seismic hazard descriptions, goals, and objectives were reviewed and revised by the entire Commission and forwarded to the State Division of Homeland Security and Emergency Management for inclusion in the FEMA-approved State plan.
- Provided an opportunity for the Commission to review the seismic sections of community Emergency Operations Plans as requested.

- Participated in the curriculum revision and training schedule for the State Post Disaster Damage Assessment (PDDA) program.
- Provided an opportunity for Commissioners to enroll in and complete the National Incident Management System (NIMS) training in Incident Command System course 100 (ICS 100) in a step to bring the Commission into accreditation with federal and State NIMS requirements.
- Co-sponsored a training course on hospital structural and non-structural earthquake risk mitigation for the primary healthcare providers in south-central Alaska.
- Continued support for Commission representation on the State Hazard Mitigation Advisory Committee (SHMAC) that advises the Governor’s Disaster Policy Cabinet on use of State mitigation funds, policy, and planning.
- Continued support for Commission representation on the Alaska Partnership for Infrastructure Protection (APIP), an Alaska Emergency Management–private sector stakeholder partnership.

#### **Planned Committee Activities in 2011:**

- Refine the Commission’s role one month and six months following a significant seismic event in the state, including draft legislation and policy recommendations that can be proposed.
- Draft a “Continuity of Operations” (COOP) plan to provide for continuing critical Commission functions in the event of an interruption of standard Commission operation.
- Provide an annual review of the seismic sections of the State Hazard Mitigation Plan goals that related to the Seismic Safety Hazards Commission.
- Co-sponsor Post Disaster Damage Assessment (PDDA) training in Anchorage in 2011.
- Co-sponsor earthquake structural and non-structural mitigation training in Fairbanks in 2011.
- Co-sponsor PDDA training in Fairbanks in 2011.
- Support planning for the 2014 anniversary of the 1964 great Alaska earthquake to include training and outreach on earthquake and tsunami emergency response.
- Continue the Commission’s availability for review of seismic sections of community emergency operations plans.
- Continue the Commission’s availability for consultation on emergency response exercises to seismic events.
- See all Commissioners successfully complete the Incident Command System (ICS) 100 course.
- Develop a post earthquake data clearinghouse process that sets in place a procedure, structure, and organization to capture—for Alaska State use—all data, photos, records, and notes produced from post earthquake investigations conducted in Alaska following a significant seismic event.
- Test the Commission’s significant earthquake incident procedure during the March 2011 tsunami warning “live code” test during Tsunami Awareness week—the week of the anniversary of the 1964 great Alaska earthquake.

#### **Education and Outreach Committee**

The committee continues to focus on developing information for the Governor’s office, Legislators, administrative agencies, local governments, local emergency planning groups, and industry groups. Activities were somewhat limited due to the Committee Chair spending much of his time outside of Alaska as a member of the Gulf Oil Spill cleanup advisory team.

## Education and Outreach Committee Activities in 2010

Activities included:

- Working with the University of Alaska Anchorage School of Engineering, the Earthquake Engineering Research Institute and Art Frankel of the USGS to have the 2010 Joyner Lecture—Progress and Controversy in Seismic Hazard Mapping—presented in Anchorage.
- Delivered earthquake briefing presentations to several public, private, and Federal agencies.
- Continued to work with the Earthquake Engineering Research Institute on sponsorship of the 2014 National Conference on Earthquake Engineering to be held in Anchorage, Alaska.



*One of the Denali fault earthquake response teams in Mentasta, Alaska (photo by John Aho).*

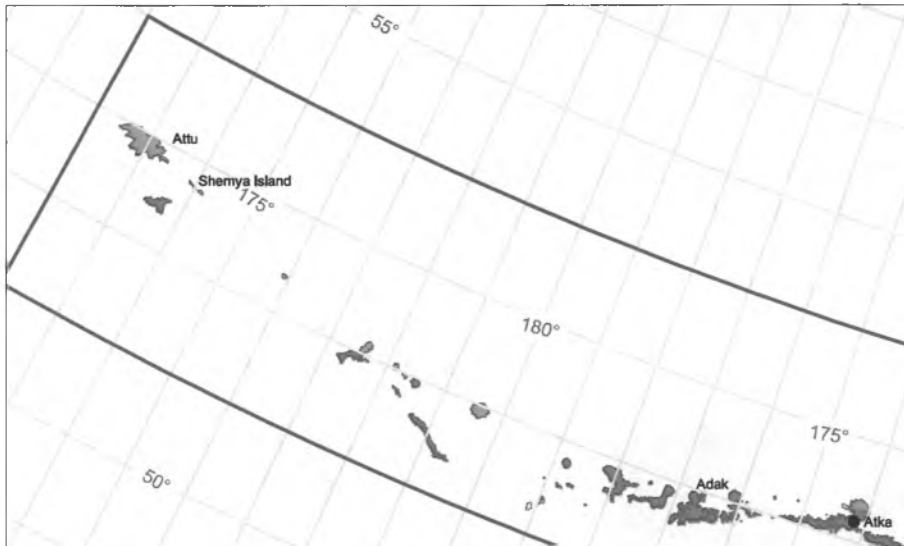
## Committee Plan for 2011

The committee will continue to address the following items:

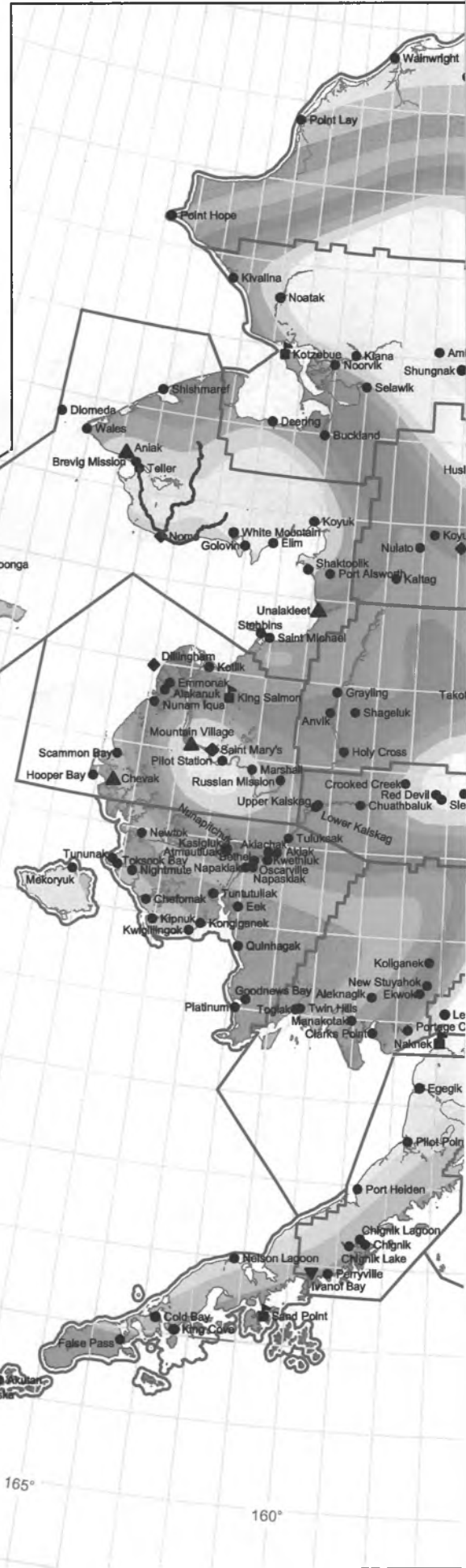
- Complete development of the Post Disaster Safety Assessment Training Program
- Present training for individuals interested in the training program noted above.
- Continue to have briefings from outside interests that are concerned with seismic risk mitigation issues.
- Continue to present earthquake briefings as requested.
- Develop an informative brochure that describes the Commission and its activities.
- Develop an Alaska Seismic Hazards Safety Commission (ASHSC) Glossary of Terms
- Work with the University of Alaska Anchorage and the Earthquake Engineering Research Institute to invite the 2011 Joyner Lecturer to Anchorage for their presentation.

## Partnership Committee

The Commission's enacting legislation charges them to "establish and maintain necessary working relationships with other public and private agencies." The purpose of the ASHSC Partnership Committee is to investigate potential relationships.



ALEUTIAN ISLANDS (CONT.)  
 - NO SCHOOLS AT PRESENT



**DATA SOURCES:**

INFORMATION COMPILED FROM THE "SEISMIC-HAZARD MAPS FOR ALASKA AND THE ALEUTIAN ISLANDS," US GEOLOGICAL SURVEY, 1999, THE "PROBABILISTIC SEISMIC HAZARD MAP OF ALASKA," US GEOLOGICAL SURVEY (OPEN FILE REPORT 99-36), THE ALASKA DEPARTMENT OF EDUCATION & EARLY DEVELOPMENT DIVISION OF SCHOOL FINANCE AND FACILITIES SCHOOL DATABASE, 2007, AND THE "ALASKA SCHOOL MAP," ALASKA DEPARTMENT OF EDUCATION AND EARLY DEVELOPMENT, REVISED 2003.

THE ACCELERATION VALUES CONTOURED ARE THE RANDOM HORIZONTAL COMPONENT. REFERENCE SITE CONDITION IS FIRM ROCK, DEFINED AS HAVING AN AVERAGE SHEAR-WAVE VELOCITY OF 760 M/SEC IN THE TOP 30 METERS, CORRESPONDING TO THE BOUNDARY BETWEEN NEHRP SITE CLASSES B AND C. IN SOME SITUATIONS, PARTICULARLY IN AREAS OF HIGH GROUND-MOTIONS (E.G. ALONG THE COAST OF SOUTHEAST ALASKA) THERE ARE DISCONTINUOUS CHAINS, OR ISLANDS, OF HIGH GROUND MOTION VALUES. THIS IS AN ARTIFACT OF THE GRID SPACING USED IN THE CALCULATIONS. IN MOST CASES THESE CHAINS SHOULD BE REPLACED WITH CONTINUOUS BANDS OF HIGH GROUND-MOTION VALUES ENCLOSING THE CHAINS.

ADDITIONAL INFORMATION, INCLUDING GRIDDED VALUES AND ARC/INFO COVERAGES USED TO MAKE THE MAPS IS AVAILABLE AT: [HTTP://EARTHQUAKE.USGS.GOV/RESEARCH/HAZMAPS/](http://earthquake.usgs.gov/research/hazmaps/). ALASKA STATE BOUNDARY, MAIN ROADS AND SCHOOL ARC/INFO COVERAGES WERE OBTAINED FROM THE ALASKA STATE GEOSPATIAL CLEARINGHOUSE AT [HTTP://WWW.ASGDC.STATE.AK.US/](http://www.asgdc.state.ak.us/) ON APRIL, 2007.

MAP PROJECTION: ALBERS EQUAL AREA CONIC, STANDARD PARALLELS 55° N AND 65° N, CENTRAL MERIDIAN 160° W.

ADEED SCH-PGA.dwg

11/15/2007 (REV. 11/24/2009)

SEE ABOVE INSET  
 FOR CONTINUED  
 COVERAGE OF THE  
 ALEUTIAN ISLANDS

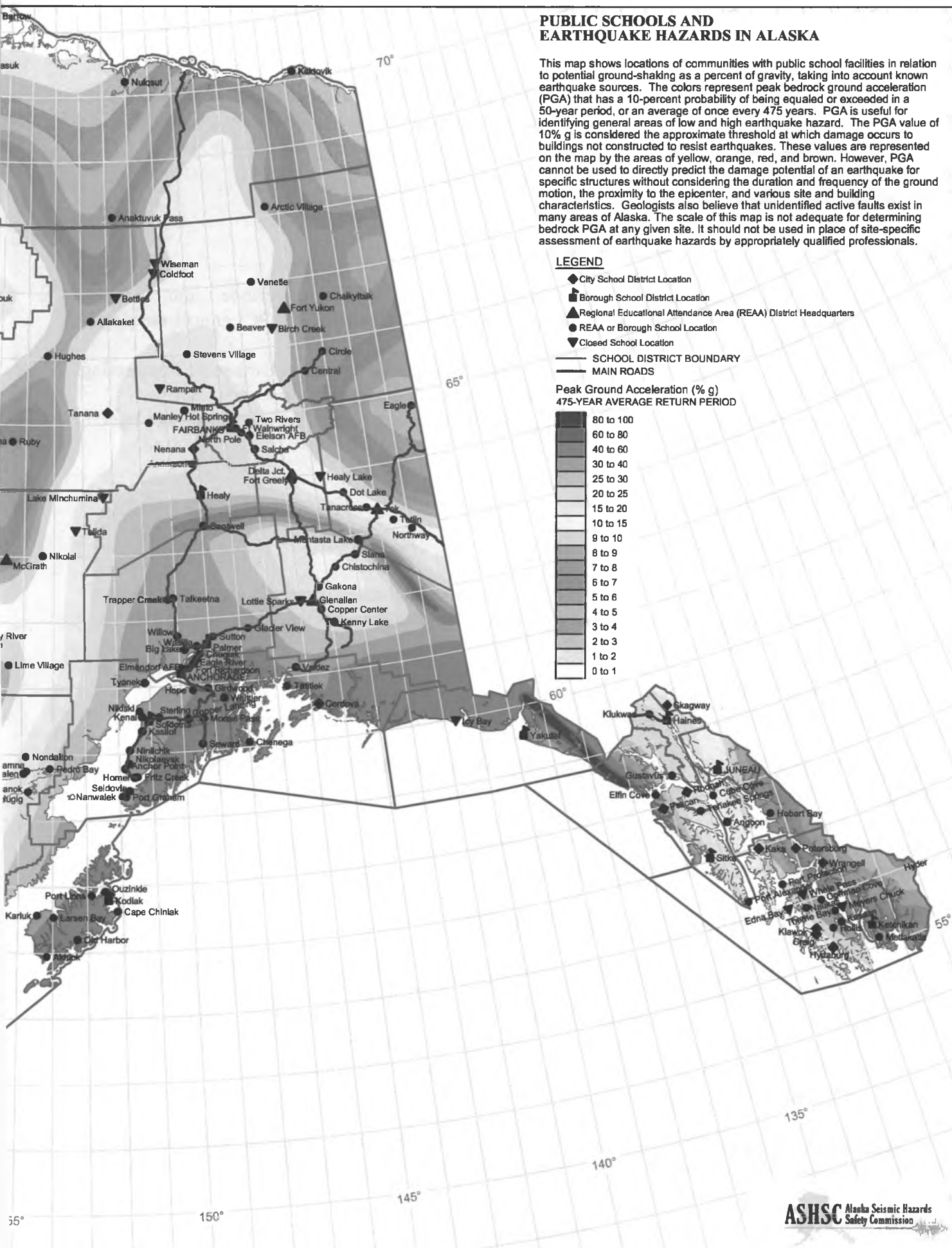
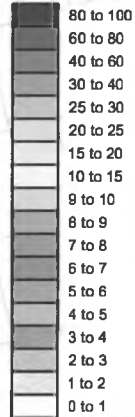
## PUBLIC SCHOOLS AND EARTHQUAKE HAZARDS IN ALASKA

This map shows locations of communities with public school facilities in relation to potential ground-shaking as a percent of gravity, taking into account known earthquake sources. The colors represent peak bedrock ground acceleration (PGA) that has a 10-percent probability of being equaled or exceeded in a 50-year period, or an average of once every 475 years. PGA is useful for identifying general areas of low and high earthquake hazard. The PGA value of 10% g is considered the approximate threshold at which damage occurs to buildings not constructed to resist earthquakes. These values are represented on the map by the areas of yellow, orange, red, and brown. However, PGA cannot be used to directly predict the damage potential of an earthquake for specific structures without considering the duration and frequency of the ground motion, the proximity to the epicenter, and various site and building characteristics. Geologists also believe that unidentified active faults exist in many areas of Alaska. The scale of this map is not adequate for determining bedrock PGA at any given site. It should not be used in place of site-specific assessment of earthquake hazards by appropriately qualified professionals.

### LEGEND

- ◆ City School District Location
- Borough School District Location
- ▲ Regional Educational Attendance Area (REAA) District Headquarters
- REAA or Borough School Location
- ▼ Closed School Location
- SCHOOL DISTRICT BOUNDARY
- MAIN ROADS

### Peak Ground Acceleration (% g) 475-YEAR AVERAGE RETURN PERIOD



The basic goals of developing partnerships are to:

- Promote combined efforts to reduce the loss of life and property
- Conduct education efforts to motivate key decision makers to reduce risks associated with earthquakes
- Foster productive connections between scientists, critical infrastructure providers, businesses, and government agencies to improve the viability of communities after an earthquake event.

### **Partnership Committee Activities in 2010**

The committee was involved in the following activities:

- The ASHSC Chair developed the agenda and facilitated a meeting of seismic commission and agency individuals at the Western States Seismic Policy Council (WSSPC) annual meeting in Denver, Colorado
- Continued to address planning aspects for the 2014 National Conference on Earthquake Engineering.
- Became actively involved in the Alaska Partnership for Infrastructure Protection (APIP).
- Through involvement in APIP, the ASHSC Chair was asked to give several earthquake briefing presentations during 2010.

### **Partnership Plan for 2011**

The following tasks will be addressed in 2011:

- Will continue to seek partnership opportunities with organizations, agencies, and public entities.
- Will make formal contact with seismic safety commissions in other areas of the United States as a follow-up to the Denver meeting identified above.
- Work will continue on the 2014 National Conference on Earthquake Engineering, expected to draw 1,000–1,500 professionals to Anchorage from around the world.
- Continue to develop relationships within the Alaska Partnership for Infrastructure Protection (APIP).

## **SEISMIC-RISK ISSUES BEING ADDRESSED BY THE ALASKA SEISMIC HAZARDS SAFETY COMMISSION**

The following issues relating to seismic risk mitigation have served as a guide to developing the path forward for the Commission and for the formation of standing committees.

### **1. Assess the Structural Stability of Critical Facilities**

**Description of the Issue:** Some existing critical buildings in the state may not be constructed in a manner to withstand future earthquake and tsunami events. A specific concern is school buildings. Hospitals, clinics, and fire, rescue, and police stations across the state are also vulnerable to failure. Also at possible risk are large Federal, State, and private complexes such as military bases, Coast Guard stations, airports, college campuses, harbors, power-generating stations, communication centers, water and waste-water treatment facilities, jails and detention facilities, pipelines, and highways and bridges.

**Importance of the Issue:** If attention is not brought to bear on this issue before a damaging earthquake or tsunami, communities in the state could see massive structural failure of important community facilities,

resulting in human casualties, economic loss, and environmental damage. Furthermore, Alaska's remote nature and extreme weather conditions can cause delays in response efforts and put displaced building occupants at severe risk from exposure. Adequate preparedness is imperative to timely rapid response and recovery from a significant seismic event.

**Benefits of Addressing the Issue:** Some private and public entities have taken important steps to improve the seismic resistance of key facilities and infrastructure. For example, prior to constructing the Trans-Alaska Pipeline System, Alyeska hired geologists and engineers to specifically address seismic hazards. The resulting design and earthquake-resistant construction prevented the spillage of any oil during the magnitude 7.9 Denali fault earthquake of November 3, 2002. The Alaska Department of Transportation & Public Facilities is undertaking a seismic retrofit program for State-owned bridges, and is focusing on upgrading bridges that provide critical access to communities. Some boroughs and cities across the State have taken the initiative to identify and begin retrofitting seismically vulnerable school buildings and other essential facilities.

Despite the newness of most construction in Alaska and implementation of modern building codes, many buildings and key parts of our infrastructure remain vulnerable due to proximity to seismic hazards, some of which are known and others of which are poorly understood. Building codes continue to change and have been significantly upgraded in the period between 1976 and 1997. The Federal Emergency Management Agency (FEMA) and earthquake consortia such as the Cascadia Regional Earthquake Workgroup (CREW) in the Pacific Northwest have long recognized that addressing the problems prior to a catastrophic event can have longstanding benefits in the future. However, building codes are often inadequately implemented and recommendations of advisory bodies are often ignored.

**How the Commission Can/Will Address the Issue:** The Commission will encourage mitigation efforts by presenting information about earthquake hazards and risk and suggesting approaches to addressing the strengthening of at-risk critical facilities. Public education must include the correct mix of information on potential damage and suggestions of effective actions to be taken.

## 2. Address the Importance of Earthquake Insurance

**Description of the Issue:** Catastrophic natural perils, particularly earthquakes, are unpredictable, relatively infrequent, and can be financially disastrous. Earthquake risk is especially difficult to insure against because insurers are unable to accumulate adequate reserves for losses of such high severity and low frequency.

**Importance of the Issue:** Insurers are unwilling to provide insurance in a market where premium rates are inadequate to create the reserves necessary to pay for damages in the event of a major earthquake. This can create a severe deficiency in availability of insurance as existing insurers withdraw from the market and new insurers are unwilling to enter.

**Benefits of Addressing the Issue:** Improved pre-loss mitigation efforts, such as retrofitting existing structures; emergency planning to speed post-loss recovery; and actuarially sound earthquake insurance rates encourage additional insurers to enter the market. This in turn improves availability of insurance products and results in more competitive premiums.

**How the Commission Can/Will Address the Issue:** The Commission can encourage development of public-private partnerships that provide education and mitigate the potential impact of future events. We will examine the seismic-hazard information needs of the insurance industry and provide recommendations for improvement.

### 3. Approaches to Seismic Risk Mitigation in Future Building Construction

**Description of the Issue:** Sustainable development entails maintaining environmental quality, improving a community's quality of life, and fostering social equity while maintaining a healthy economy. Therefore, sustainable development includes incorporating disaster resilience and mitigation into a community's decisions and actions. Building codes normally have a performance goal of life safety, which is considered a minimum safety level, but are typically the maximum level to which buildings are designed. Codes do not appropriately address the effects of ground failure or ground-shaking amplification, or provide guidance to designers and construction contractors.

**Importance of the Issue:** Communities need to know the potential earthquake risk and impacts at a structure site and should implement appropriate standards to mitigate the identified risk so new buildings are not subjected to the effects of massive ground failure and strong ground shaking.

**Benefits of Addressing the Issue:** The results of addressing the issue are more effective mitigation and an assurance that countermeasures are not only adequate but that the cost of implementation is not prohibitive.

**How the Commission Can/Will Address the Issue:** The Commission will encourage continued Federal, State, and private partnerships in updating ground-failure susceptibility mapping of Anchorage, ground shaking characterization in high-risk Alaskan communities, and determination of structural response of buildings and bridges. We will work with the technical community and the construction industry to inform, educate, and work with communities to provide guidance to improve building and land-use codes.

### 4. Response and Recovery Practices to Mitigate Future Seismic Risk

**Description of the Issue:** Communities don't have a good understanding of the costs and resources needed for response and recovery. First responders to a damaging earthquake in one of Alaska's major cities will be overwhelmed in the initial hours following the event. Damage to transportation systems will make movement of people and goods difficult. Demand for emergency shelter, food, and water will strain a community's resources. Disruptions to lifeline systems will complicate recovery.

**Importance of the Issue:** An understanding of response and recovery issues is critical to assessing the impacts to State and local resources.

**Benefits of Addressing the Issue:** Implementing effective response and recovery practices will reduce economic and social costs of recovery and will help mitigate risks from future events.

**How the Commission Can/Will Address the Issue:** The Commission will promote and assist in the development and use of "earthquake planning scenarios" to define the impact of future damaging earthquakes and will communicate lessons learned from past events to provide guidance to communities on recovery planning and preparation.

## 5. Hazard Identification and Public Education

**Description of the Issue:** A damaging earthquake has not affected a major population region in Alaska since 1964. The majority of the population is unaware of the consequences of a major seismic event. The 2002 Denali fault earthquake resulted in relatively minor damage to smaller rural communities but had little effect in larger communities such as Anchorage and Fairbanks. It was evident, during damage-assessment evaluations after the Denali fault event, that the residents of the smaller at-risk communities had little understanding of the earthquake hazard, had not implemented measures to mitigate damage, and were unprepared to respond to the consequences of damage. It is important that the population of Alaska be aware of the earthquake hazard and be informed of the measures that can be taken to mitigate risk.

**Importance of the Issue:** There is a high probability that Alaskans will experience the results of a damaging earthquake in the future. All Alaskans will be better prepared to take preventive measures ahead of time to reduce losses and casualties and to respond to the event if they are informed of, and truly understand, the hazard and the resultant risk.

**Benefits of Addressing the Issue:** An educated public has a greater potential of responding appropriately before, during, and after a damaging earthquake. Improved knowledge and public awareness of hazard and risk can change behavior and lead to more cost-effective mitigation.

**How the Commission Can/Will Address the Issue:** The Commission will examine the need for greater public investment in identification and assessment of earthquake hazards, and the most effective ways of communicating this information to the public. The Commission will examine and promote the concept of seismic resilience of communities, addressing reduced failure probabilities, reduced consequences of failure, and reduced time to recovery.

## 6. Recommended Public-policy Goals of the Commission

### a. Education

- Develop an effective public education and outreach program.
- Convey scientific and technical information from credible authorities.
- Communicate information in a manner that is understandable by the public.

### b. Guidance

- Provide advice on seismic risk mitigation and recommend policies to improve preparedness.
- Recommend goals and priorities for risk mitigation to public and private sectors.
- Recommend needed research, mapping, and monitoring programs.
- Offer advice on coordinating disaster preparedness and seismic risk mitigation.

### c. Assistance

- Review seismic- and tsunami-hazard notifications and recommend appropriate response.
- Review predictions and warnings and suggest appropriate responses.

### d. Implementation

- Establish and maintain working relationships with other private and public agencies.
- Gather, analyze, and disseminate information.
- Conduct public hearings.
- Appoint committees from Commission membership and/or external advisory committees to address risk mitigation issues.
- Accept grants, contributions, and appropriations.

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## APPENDIX A

### Alaska Seismic Hazards Safety Commission statute

#### Sec. 44.37.065. Commission established; membership.

- (a) The Alaska Seismic Hazards Safety Commission is established in the Department of Natural Resources. The Department of Natural Resources shall provide staff support to the commission.
- (b) The commission is composed of 11 members appointed by the governor for terms of three years. A vacancy is filled for the unexpired term.
- (c) The governor shall appoint to the commission
  - (1) a representative from the University of Alaska;
  - (2) three representatives, each from a local government in a separate seismically active region of the state;
  - (3) a representative from the Department of Natural Resources;
  - (4) a representative from the Department of Military and Veterans' Affairs;
  - (5) a representative from an appropriate federal agency;
  - (6) a representative of the insurance industry; and
  - (7) three members from members of the public who are expert in the fields of geology, seismology, hydrology, geotechnical engineering, structural engineering, emergency services, or planning.
- (d) The commission shall elect annually from its members a chair and vice-chair. A majority of the commission may vote to replace an officer of the commission.
- (e) Six members constitute a quorum.
- (f) Members of the Alaska Seismic Hazards Safety Commission serve without compensation but are entitled to per diem and travel expenses authorized for boards and commissions under AS 39.20.180.

#### Sec. 44.37.067. Powers and duties.

- (a) The commission shall
  - (1) recommend goals and priorities for seismic hazard mitigation to the public and private sectors;
  - (2) recommend policies to the governor and the legislature, including needed research, mapping, and monitoring programs;
  - (3) offer advice on coordinating disaster preparedness and seismic hazard mitigation activities of government at all levels, review the practices for recovery and reconstruction after a major earthquake, and recommend improvements to mitigate losses from similar future events;
  - (4) gather, analyze, and disseminate information of general interest on seismic hazard mitigation;
  - (5) establish and maintain necessary working relationships with other public and private agencies;
  - (6) review predictions and warnings issued by the federal government, research institutions, and other organizations and persons and suggest appropriate responses at the state and local levels; and
  - (7) review proposed seismic hazard notifications and supporting information from state agencies, evaluate possible socioeconomic consequences, recommend that the governor

issue formal seismic hazard notifications when appropriate, and advise state and local agencies of appropriate responses.

(b) The commission may

- (1) advise the governor and the legislature on disaster preparedness and seismic hazard mitigation and on budgets for those activities and may recommend legislation or policies to improve disaster preparedness or seismic hazard mitigation;
- (2) conduct public hearings;
- (3) appoint committees from its membership and appoint external advisory committees of ex-officio members; and
- (4) accept grants, contributions, and appropriations from public agencies, private foundations, and individuals.

Sec. 44.37.069. Definitions.

In AS 44.37.065 - 44.37.069,

- (1) “commission” means the Alaska Seismic Hazards Safety Commission;
- (2) “disaster preparedness” means establishing plans and programs for responding to and distributing funds to alleviate losses from a disaster as defined in AS 26.23.900 ;
- (3) “seismic hazard” means an earthquake-induced geologic condition that is a potential danger to life and property; in this paragraph, “geologic condition” includes strong ground shaking, landslide, avalanche, liquefaction, tsunami inundation, fault displacement, and subsidence;
- (4) “seismic hazard mitigation” or “mitigation” mean activities that prevent or alleviate the harmful effects of seismic hazards to persons and property, including identification and evaluation of the seismic hazards, assessment of the risks, and implementation of measures to reduce potential losses before a damaging event occurs;
- (5) “tsunami” means a large ocean wave produced by an earthquake, landslide, or volcanic eruption.

## Key Success Factors and Measures of Success

| Success Factor                                     | Measure   |
|--|---|
| Stakeholder Satisfaction                           | <ul style="list-style-type: none"> <li>• Facilitate Governor and Legislature understanding of seismic risk mitigation issues;</li> <li>• Meet or exceed SOA expectations;</li> <li>• Advice is sought;</li> <li>• Advice is accepted;</li> <li>• SOA endorsement; and</li> <li>• Positive feedback from staff.</li> </ul>   |
| Advocate of Risk Mitigation                        | <ul style="list-style-type: none"> <li>• Provide advocacy for seismic risk mitigation programs;</li> <li>• Create opportunities for seismic risk mitigation advocacy;</li> <li>• Become familiar with current existing programs; and</li> <li>• Develop stakeholder support.</li> </ul>   |
| Advocate Public Outreach Programs                  | <ul style="list-style-type: none"> <li>• Encourage social environment where seismic risk mitigation is accepted;</li> <li>• Examine existing programs within the State; and</li> <li>• Be available for public education presentations.</li> </ul>  |
| Promote Development of Earthquake Scenarios        | <ul style="list-style-type: none"> <li>• Complete earthquake scenarios for realistic events in high-risk areas;</li> <li>• Use scenario results to reduce earthquake risk; and</li> <li>• Seek community involvement in scenario development and application of results.</li> </ul>   |
| Facilitate Partnerships for Seismic risk Reduction | <ul style="list-style-type: none"> <li>• Identify potential partners to assist in addressing Commission goals; and</li> <li>• Involve Federal, State, municipal, and private sector in addressing goals.</li> </ul>   |
| Critical Facilities Earthquake Risk Reduction      | <ul style="list-style-type: none"> <li>• Assist in prioritizing, identifying, and mitigating risks in facilities with life safety issues;</li> <li>• Develop work plans in collaboration with State and local agencies/governments;</li> <li>• Identify current legislation/programs adopted by other states/countries;</li> <li>• Foster contacts with proponents who have had seismic risk mitigation successes;</li> <li>• Identify pertinent code and construction requirements and potential limitations; and</li> <li>• Recommend improvements including policy changes, legislation, and public outreach.</li> </ul> |
| Earthquake Insurance in Alaska                     | <ul style="list-style-type: none"> <li>• Review current trends and provide advice;</li> <li>• Review existing “white paper” and update as appropriate; and</li> <li>• Develop “pros and cons” brochure describing earthquake insurance issues.</li> </ul>   |
| Promote Seismic Hazard Identification              | <ul style="list-style-type: none"> <li>• Identification and characterization of seismic risk hazards;</li> <li>• Definition and description of seismic risks;</li> <li>• Seismic risk and hazard research; and</li> <li>• Dissemination of seismic risk and hazard information to State and local governments, the public, and industry and scientific and professional community.</li> </ul>   |

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## Charter

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### **Purpose**

*To provide a vehicle through which statewide seismic risk issues can be addressed and solutions can be proposed that will reduce life and property losses from a future damaging earthquake.*

### **Vision**

*Eliminate losses from future earthquakes and tsunamis. Promote public and government awareness of Alaska's seismic hazards and seismic risk mitigation.*

### **Mission**

*Make recommendations to the governor and legislature for reducing the State's vulnerability to seismic hazards. Advise the public and private sectors on approaches for mitigating earthquake and tsunami risk.*

#### **Act in an Advisory Capacity**

*Advise the Governor, the Legislature, and the public on Alaska's seismic hazards and risk mitigation.*

#### **Provide Information and Technical Guidance**

*Recommend studies, policies, and programs that will mitigate the risks associated with seismic hazards.*

#### **Recommend Educational Programs**

*Recommend and participate in programs that will disseminate information to government agencies and the public.*

#### **Encourage Seismic Hazards Risk Mitigation Efforts**

*Encourage efforts to address issues related to seismic hazards risk mitigation.*

*By achieving this mission, we create an opportunity to be an effective body in mitigating the potential damaging effects of major seismic events.*

### **Core Values**

- *Honesty*
- *Integrity*
- *Trust*
- *Diligence*
- *Service to the State*
- *Responsibility for One's Own work*
- *Support to Other Commission Members*
- *Commitment to Complete Accepted Assignments*
- *Provide Value to Stakeholders*
- *Be Objective and Reasonable*
- *Advocate for Seismic Risk Mitigation Efforts*
- *Recognize Exemplary Seismic Risk Mitigation Efforts*

**ENDORSEMENT**

We, the members of the Alaska Seismic Hazards Safety Commission, enthusiastically and fully endorse this Commission Charter for guiding and enhancing efforts in natural hazards risk mitigation.

**John Aho/Chair**\_\_\_\_\_

**Laura Kelly/Vice Chair**\_\_\_\_\_

**Gary Carver**\_\_\_\_\_

**David Cole**\_\_\_\_\_

**Rod Combellick**\_\_\_\_\_

**Gay Dunham**\_\_\_\_\_

**Roger Hansen**\_\_\_\_\_

**David Miller**\_\_\_\_\_

**Mark Roberts**\_\_\_\_\_

**Gayle White**\_\_\_\_\_

## APPENDIX C

### EARTHQUAKE ACTIVITY IN 2010

#### Summary Statistics for Regional/Urban Seismic Network (see figure C1)

- Total number of stations operated and/or recorded: 540
- Total number of channels recorded: 1,325
- Number of short-period (SP) stations: 283
- Number of broadband (BB) stations: 154
- Number of stations maintained and operated by network: 540
- Number of stations maintained and operated as part of ANSS: 130
- Total data volume archived (MBytes/day) 9,000

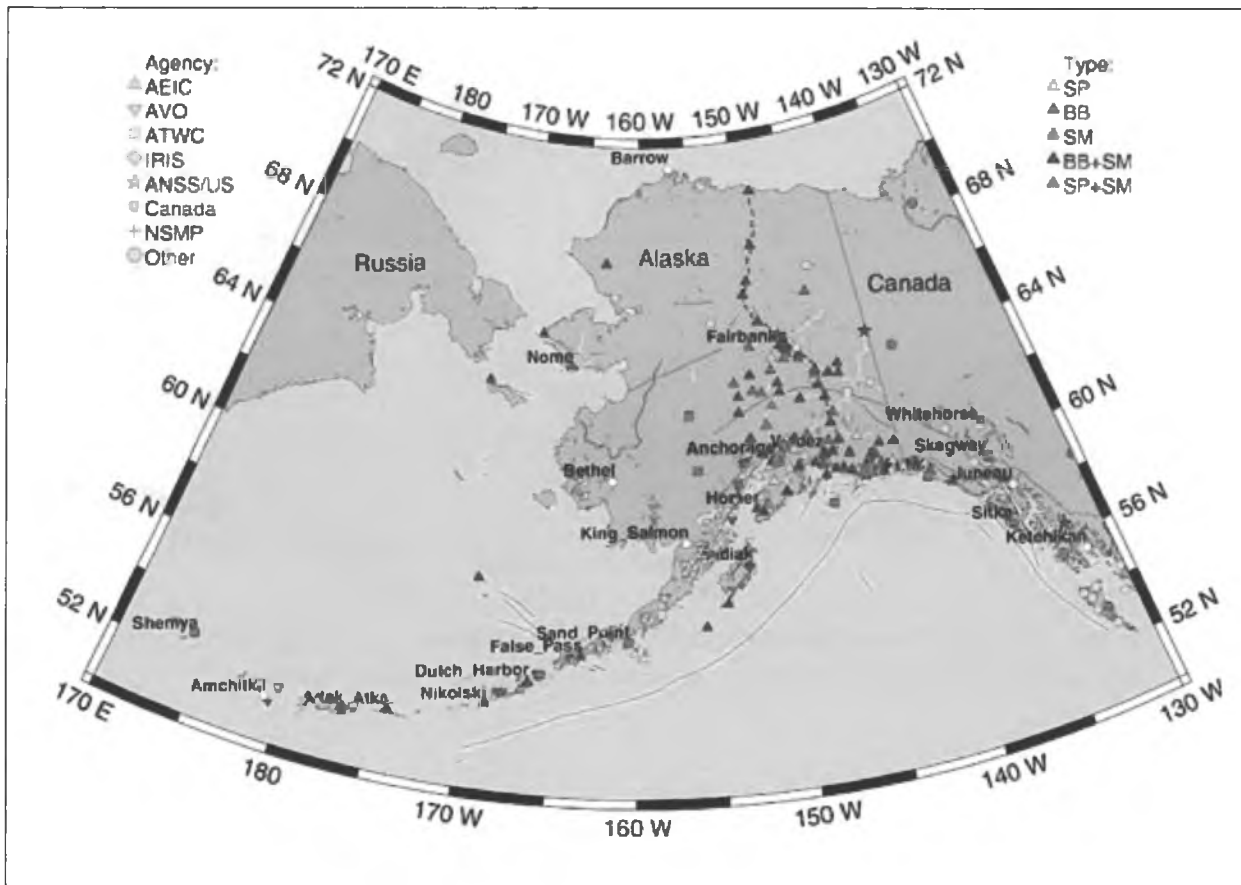


Figure C1. Seismic stations in Alaska.

## Additional Information

From February 1, 2010, through October 31, 2010, the Alaska Earthquake Information Center (AEIC) reported a total of 26,077 events within the combined seismic network (figure C2). The events range in depth from 0 to 260 km, with the deepest earthquakes located in the central Aleutian arc. The magnitude range of reported events is between -0.2 and 6.7. There were 270 events with magnitude 4.0–4.9 (~30 events per month on average); 35 events had magnitude 5.0–5.9 (~4 events per month on average); and eight events had magnitude 6.0 or above. The largest earthquakes (magnitude 6.7) occurred on July 18, 2010, in the Fox Islands region of the Aleutian Islands. The magnitude of completeness of the AEIC earthquake catalog for the reported time period is estimated to be 1.4 for the authoritative region and 2.5 for the Aleutians.

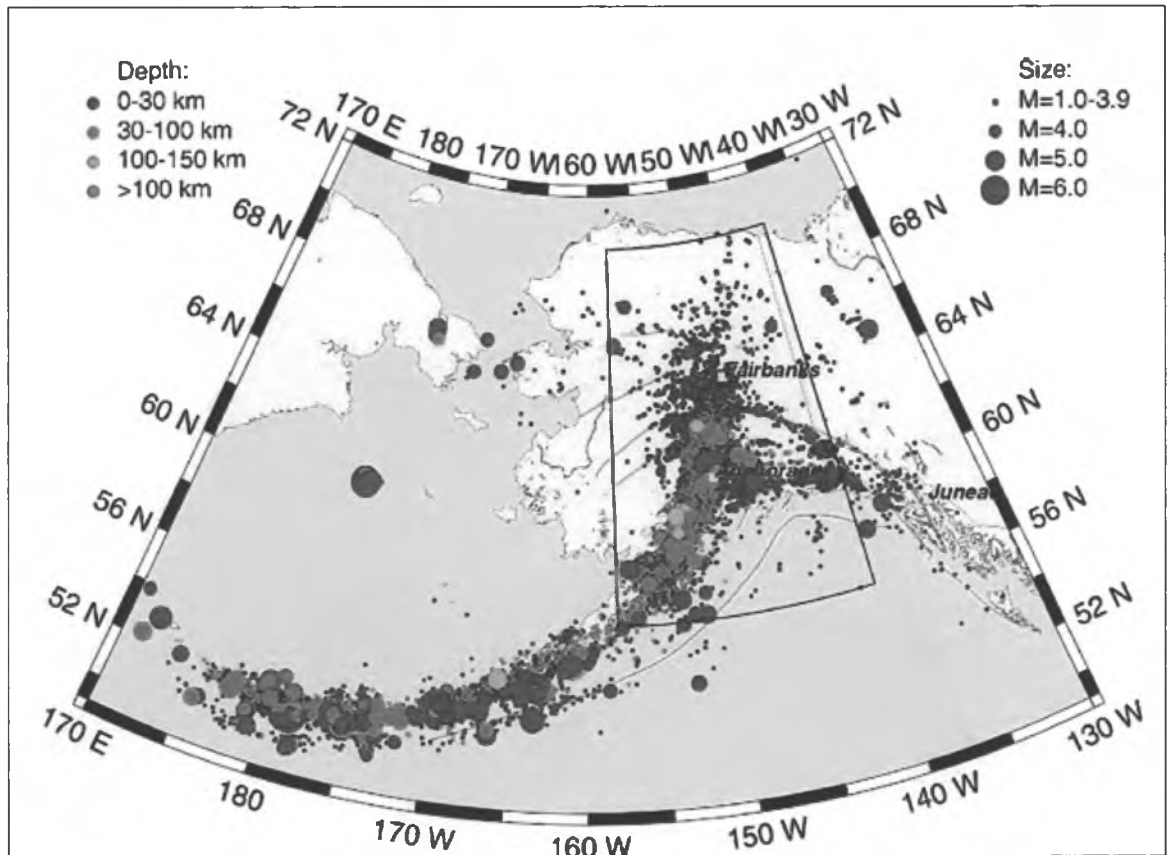
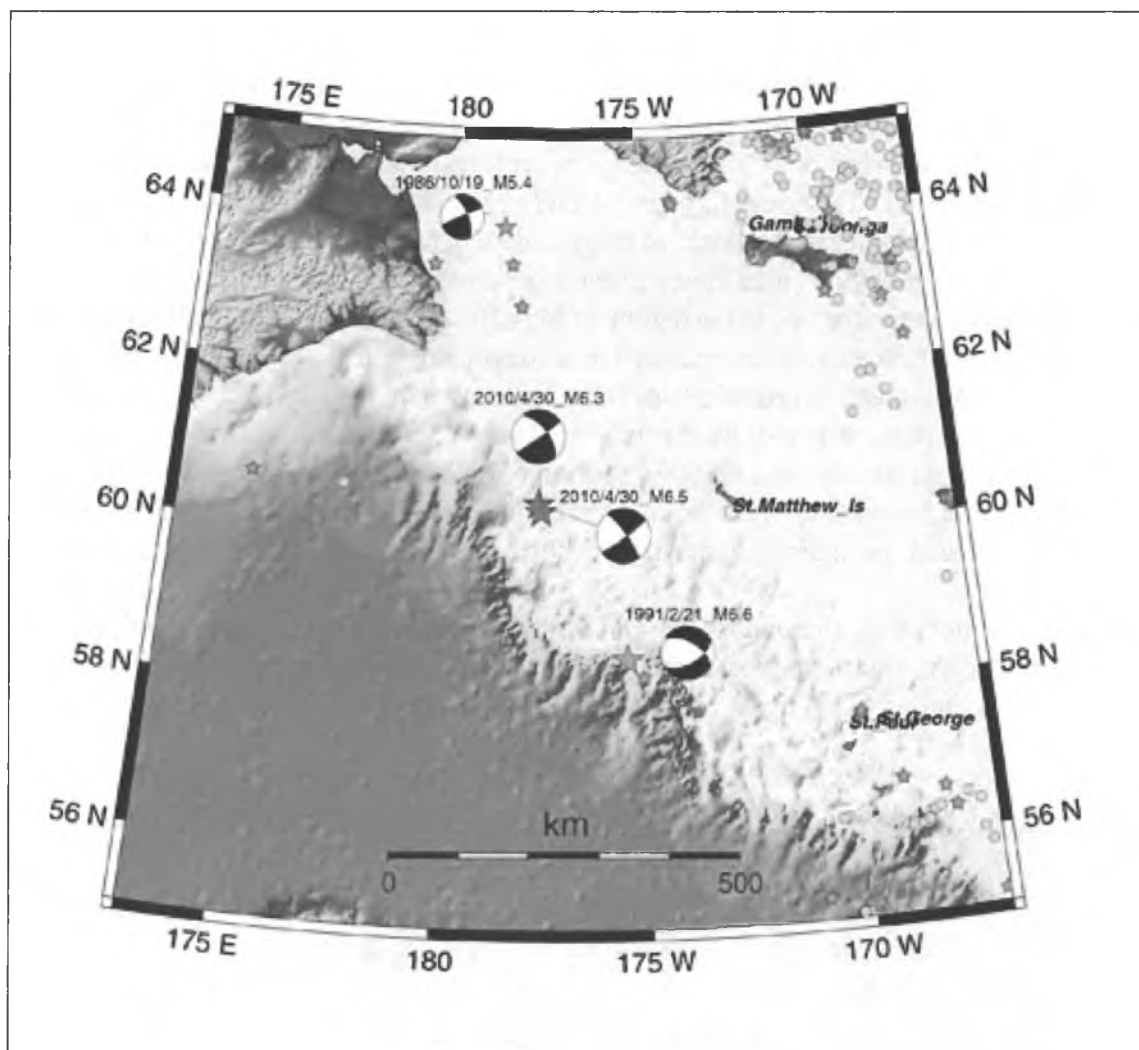


Figure C2. AEIC reported earthquakes between February 1 and October 31, 2010. The box outlines AEIC's authoritative region for earthquake submissions.

The Alaska Earthquake Information Center recorded an unusual sequence of earthquakes about 260 km (160 miles) west of St. Matthew Island that began on April 30, 2010 (figure C3). The mainshock, magnitude 6.5, occurred on April 30 at 23:11:44 UTC. It was preceded by a magnitude 4.3 foreshock, 1 minute earlier, and followed by a magnitude 6.3 aftershock, 5 minutes later. Due to the offshore location of these earthquakes, only larger events (magnitude 3.5 and greater) can be located. The nearest seismic stations are about 350 miles away, at Gambell and St. Paul. As of May 5, 2010, only 10 aftershocks have been located by AEIC. All have large location uncertainties. Both the mainshock and largest aftershock are strike-slip earthquakes.

The faulting can be associated either with the right-lateral motion on the southwest–northeast-trending fault or the left-lateral motion on the southeast–northwest-trending fault. The central region of the Bering



*Figure C3. April 30, 2010, M6.5 and M6.3 Bering Sea earthquakes*  
*yellow circles - background seismicity*  
*small orange stars - past M4.0-4.9 events*  
*medium orange stars - past M5.0-5.9 events*  
*large orange stars - past M6.0-6.9 events*  
*red stars - April 2010 events*

Sea is virtually aseismic. In the north a wide, diffuse zone of seismicity extends from western Alaska across the Bering Strait into eastern Russia. This zone is believed to mark the northern boundary of the Bering microplate. The southern edge of the Bering Sea is marked by the Aleutian Arc, where seismicity is associated with the ongoing subduction processes. In 1991, a magnitude 6.6 earthquake occurred about 210 km (150 miles) to the southeast of the April 30, 2010, earthquakes. The 1991 and 2010 earthquakes indicate north-south extension and east-west compression of the crust. The source area of the April 30, 2010, event might be structurally linked to the graben-like structure that underlies the headwall area of the Zhemchug Canyon, which is the largest submarine canyon (by volume) in the world. The structural grain of the headwall structures is northwest-southeast, parallel to the left-lateral nodal plane of the April 30 events. The right-lateral nodal plane is parallel to the crustal fabric of the hypothetical offshore continuation of the great family of northeast-southwest-trending strike-slip faults of western Alaska (Kaltag, Kobuk, Denali, etc.). If these crustal structures continue offshore, they may be the source of the April 30 earthquakes. There were no 'felt reports' for these earthquakes.

A magnitude 6.7 earthquake occurred on Saturday, July 18, 2010, at 9:56 pm AKDT (July 18, 05:56 am UTC) in the Fox Islands region of Alaska (red star farthest to left on figure C4; remaining red stars denote largest aftershocks). It was located 60 km (38 miles) west–southwest of Nikolski and 248 km (155 miles) west–southwest of Dutch Harbor. It was preceded by a magnitude 4 foreshock on July 17 at 14:44 UTC. AEIC located nearly 3,200 aftershocks through the end of July, including about 60 aftershocks with magnitudes 4.0 or greater. The largest aftershock, of magnitude 6.0, occurred on July 18 at 19:48. This is the largest event to occur in the region since the magnitude 6.5 earthquake on October 13, 2009 (yellow star). Magnitude 6.4 earthquakes occurred in the region on May 10, 2006, and December 26, 2007 (yellow stars). The 2006, 2007, and 2009 earthquakes occurred on a convergent boundary between the subducting Pacific and overriding North American crustal plates. This region, where the Pacific plate is being forced beneath the North American plate, is one of the world’s most active seismic zones. In 1957, a magnitude 8.6 Andreanof Islands earthquake ruptured a ~600-km-long portion of the plate boundary in the central Aleutian Islands. The current sequence of earthquakes is above the ruptured portion of the megathrust. The earthquake depths are shallow, indicating that they occurred in the crust of the North American plate.

Based on the waveform modeling, the mainshock and largest aftershocks are characterized by normal faulting on a north-northwest–south-southeast-oriented fault plane. The magnitude 6.7 earthquake was reported felt in Unalaska (intensity IV, light) and Dutch Harbor (intensity II, weak).

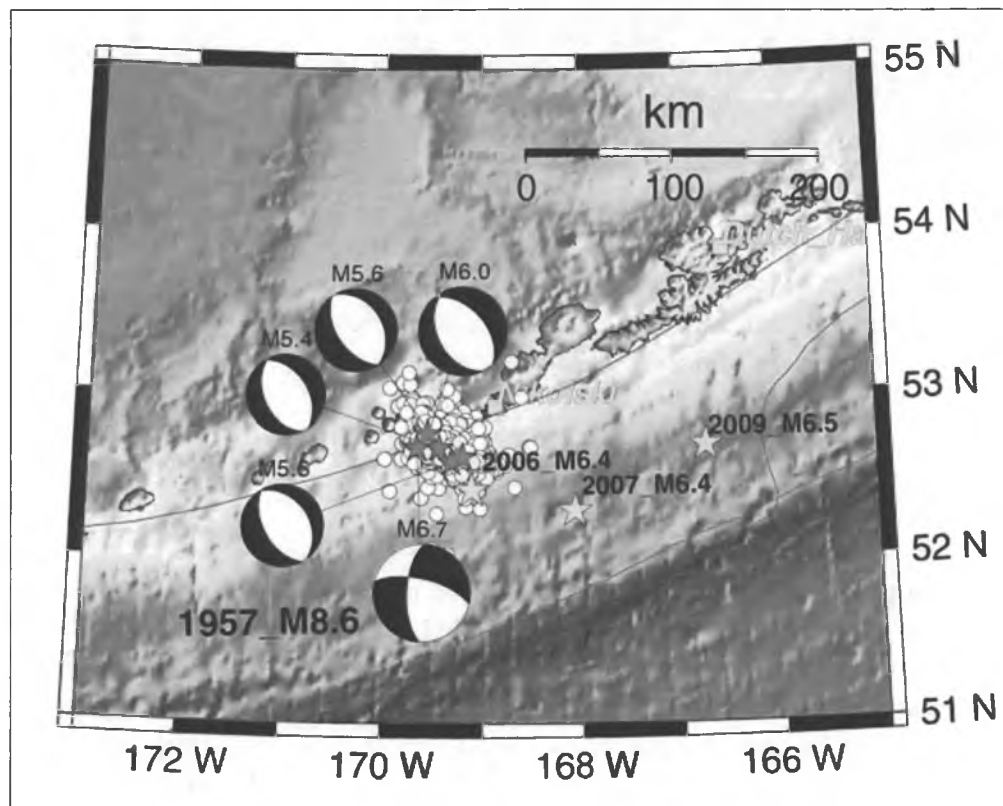


Figure C4. July 18, 2010 M6.7 Fox Islands earthquake.