Tsunami Inundation Mapping for Alaska Coastal Communities

Elena Suleimani, Dave West, Roger Hansen

Alaska Earthquake Information Center, Geophysical Institute, University of Alaska Fairbanks

Rod Combellick

Alaska Division of Geological & Geophysical Surveys

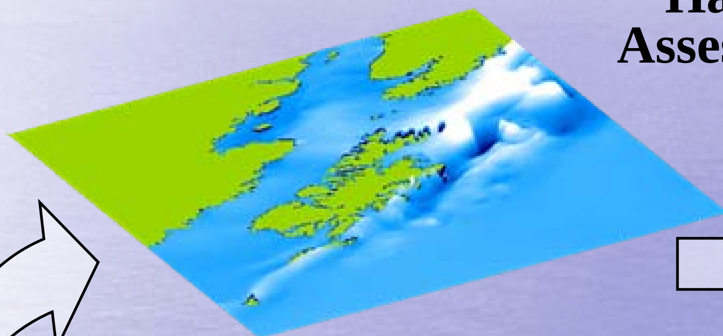
Presentation to Alaska Seismic Hazards Safety Commission

September 18, 2007

Addressing tsunami safety in Alaska

- **Alaska has the greatest tsunami potential in the United States. Many coastal communities in Alaska are at risk from tectonic and landslide-generated tsunamis.**
- **The Great Alaska earthquake of March 28, 1964, generated a major tectonic tsunami (25 fatalities) and about 20 local landslide tsunamis (81 fatalities). The effects of the 1964 tsunami are well documented.**
- **Alaska coastal rivers continue to drain nearby glaciers and to deposit sediments into the heads of the fjords at a very high rate.**
- **Comprehensive tsunami inundation mapping in Alaska requires evaluation of both tectonic and landslide tsunami potential for many coastal communities.**

How National Tsunami Hazard Mitigation Program works in Alaska



Hazard Assessment

Warning Guidance

Mitigation

Alaska Inundation Mapping Partners

Alaska Earthquake Information Center at the Geophysical Institute, UAF:

http://www.aeic.alaska.edu

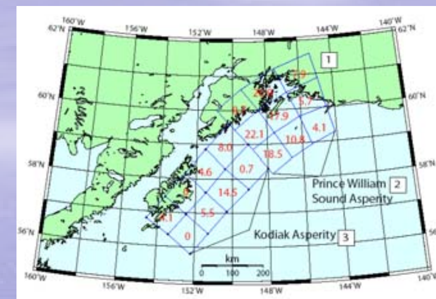
Alaska Division of Geological & Geophysical Surveys: http://wwwdggs.dnr.state.ak.us

Alaska Division of Homeland Security and Emergency Management:

http://www.ak-prepared.com

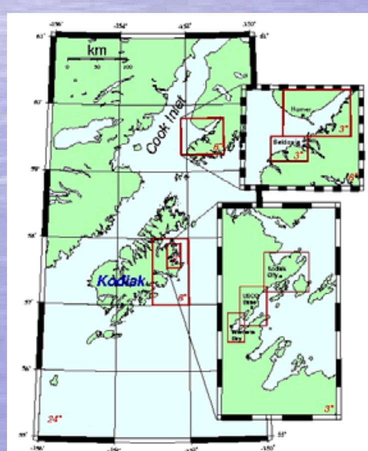
Alaska inundation mapping

Model verification with the field observations of the 1964 tsunami



Tsunami scenarios

Computer simulations



Data preparation (numerical grids)

Inundation maps and report

Specifics of Alaska inundation mapping

- Lack of adequate digital bathymetric and topographic data for many Alaskan coastal communities;
- Large changes in water depths and land elevations that are caused by the 1964 earthquake ⇨ most of the existing data do not reflect present conditions;
- Very irregular shoreline;
- Large tidal ranges;
- Lack of vertical datum and benchmark information for Alaska that is used in merging bathymetric and topographic data for inundation modeling.

Lowell Point, Resurrection Bay

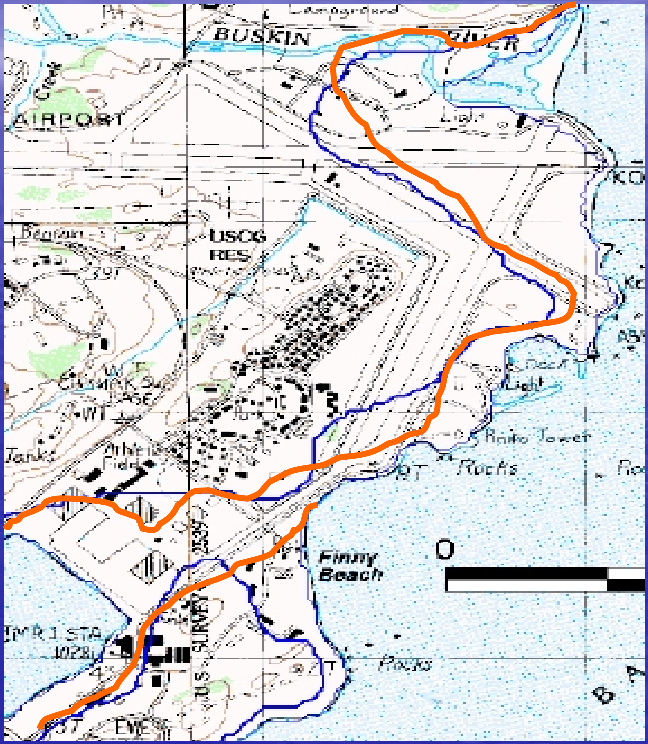
Kachemak Bay mapping: major tasks

- ☑ Identify and prioritize communities for inundation mapping: Homer and Seldovia (Alaska DHS&EM, City of Homer, Kenai Peninsula Borough);
- ☑ Identify potential tsunami sources (GI, ADGGS);
- ☑ Construct numerical grids (NOAA, GI);
- ☑ Perform and analyze inundation simulation for all scenarios (GI);
- ☑ Construct inundation maps (GI, ADGGS);
- ☑ Construct hazard maps (ADGGS, GI);
- ☑ Conduct technical review (ADGGS);
- ☑ Conduct user review (ADGGS, GI);
- ☑ Publish hazard maps and the report (ADGGS).

How the inundation map is made

Kodiak

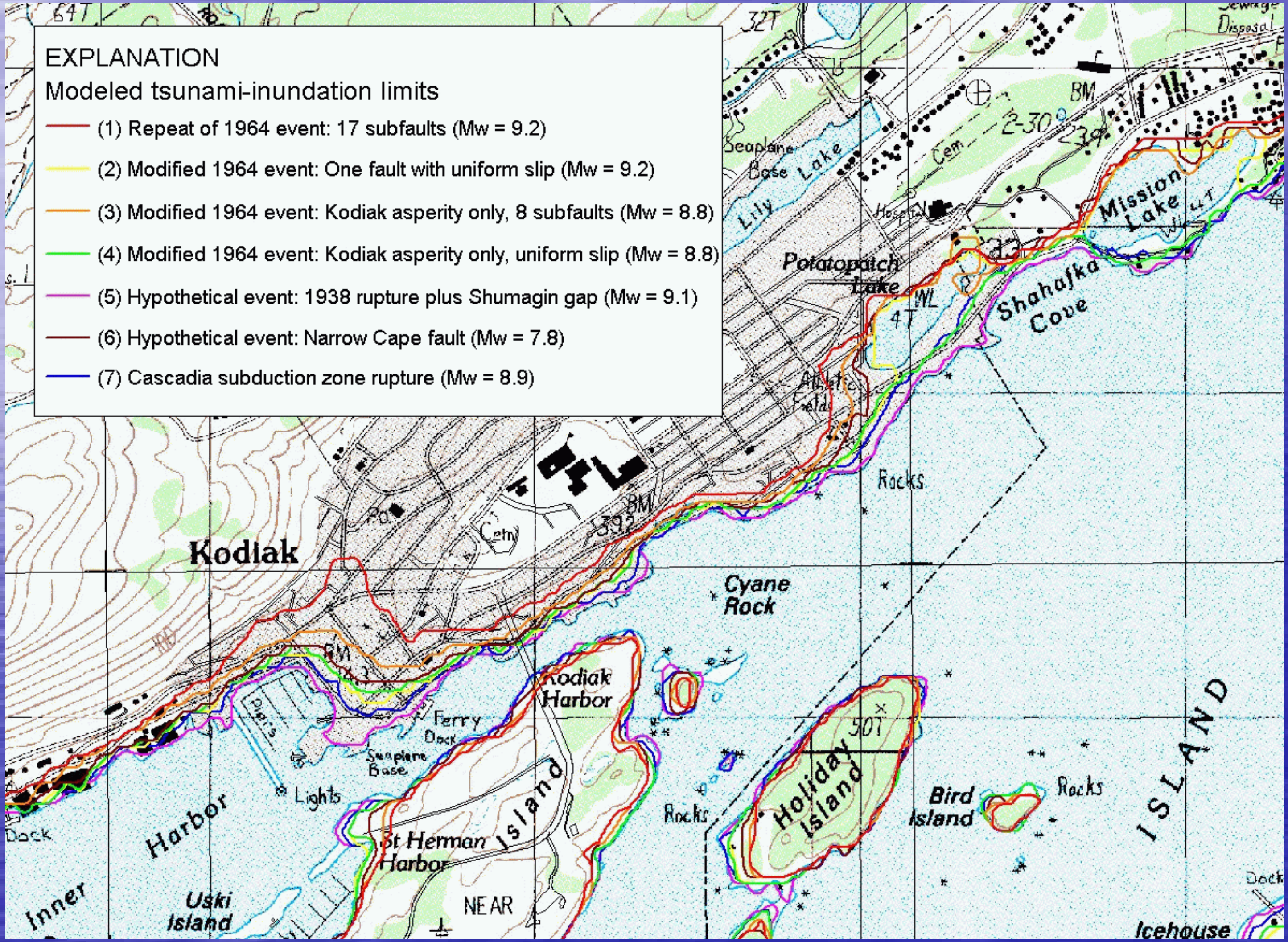
USCG



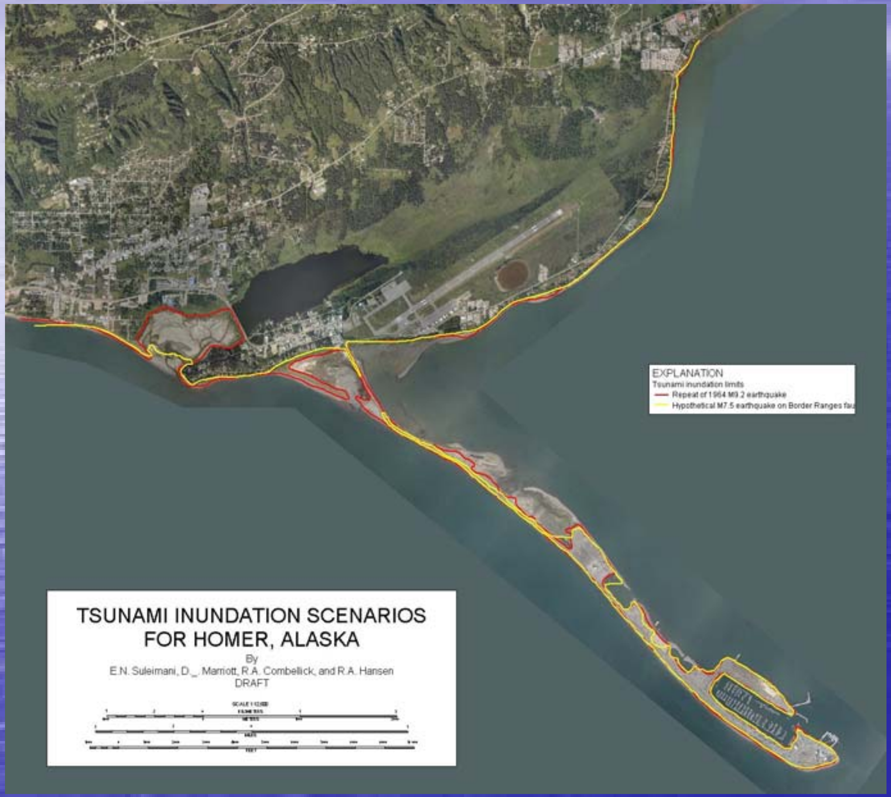
Waves inundating the Kodiak Naval Station in 1964, between 1 to 4 hours after the earthquake. *Animation by Roger Edberg (ARSC) and Elena Suleimani (GI).*

Computed and observed inundation limits at the Kodiak Naval Station

Kodiak Inundation Map



Homer and Seldovia maps

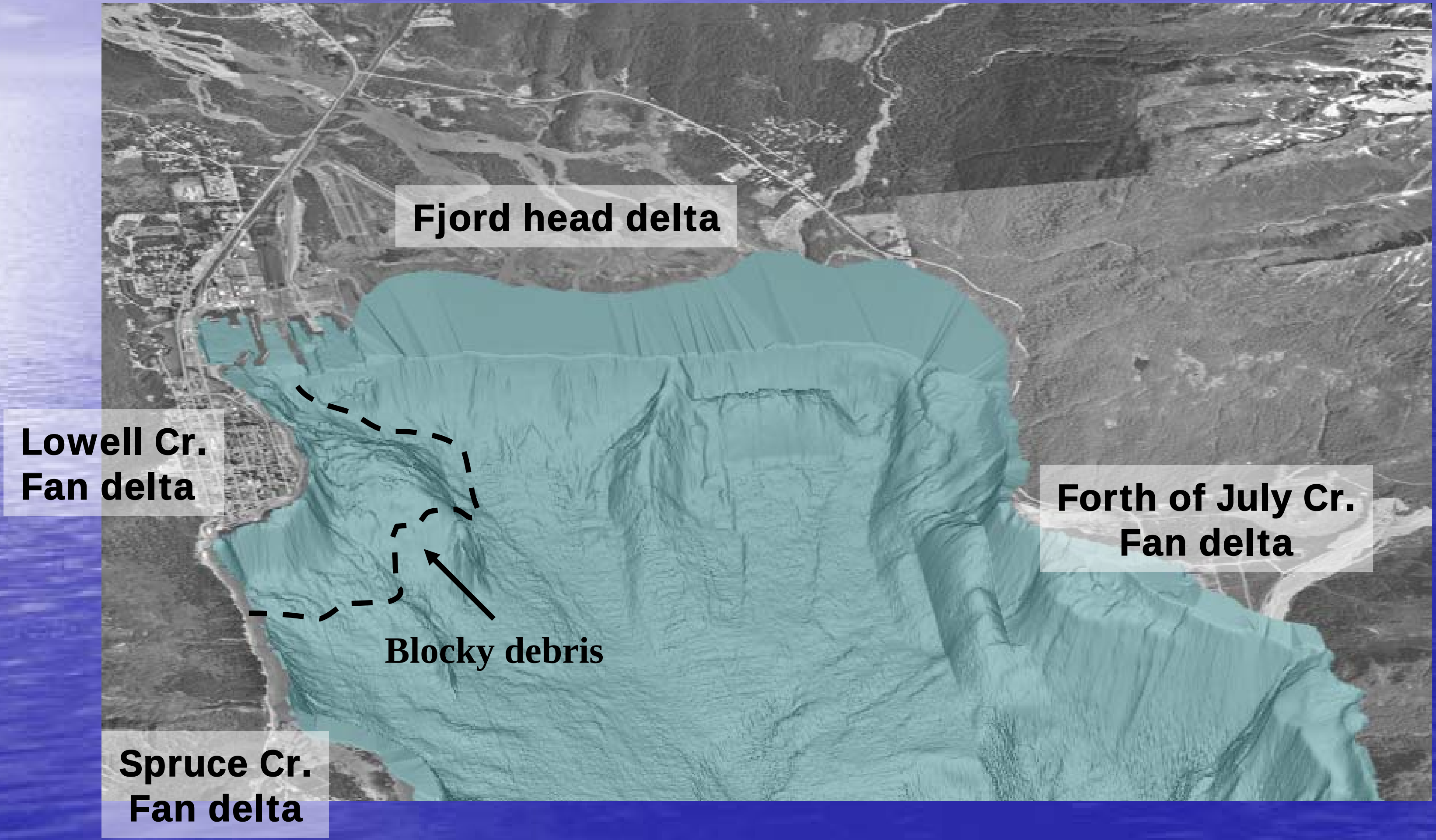


Current mapping status

- ☑ Three communities in Kodiak have been mapped: Kodiak City, USCG Base, Womens Bay
- ☑ Homer and Seldovia have been mapped
- ☐ Seward mapping is in progress
- ☐ Sitka
- ☐ Valdez
- ☐ Next one according to the **Priority List**

Seward, Resurrection Bay, Alaska

Geological setting



Seward mapping tasks

Reconstruct volumes and locations of the 1964 slides

Model submarine landslide tsunamis in combination with the major tectonic tsunami

Verify model with the field observations of the 1964 tsunami

Analyze bathymetry differences in Resurrection Bay for potential slope failures

Develop hypothetical landslide scenarios

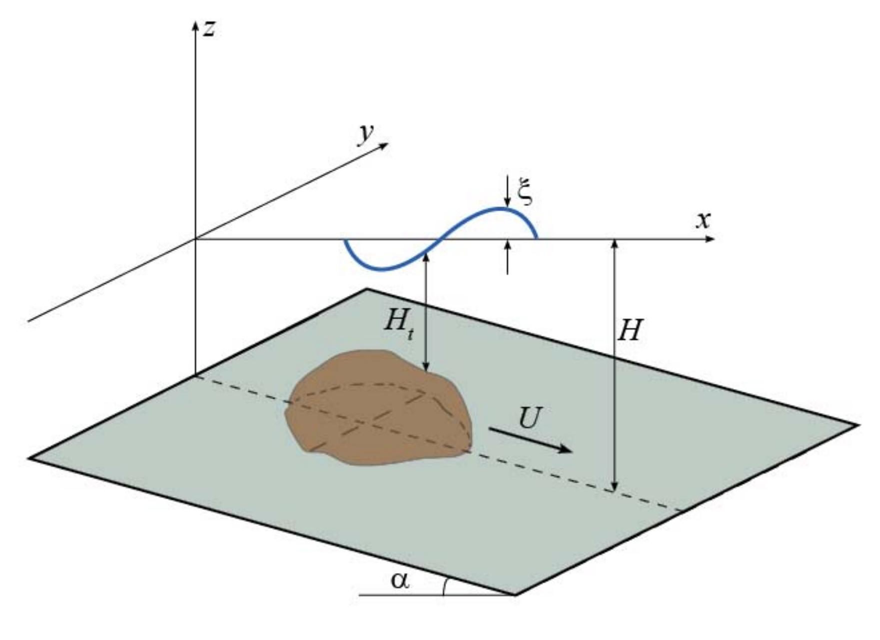
Perform sensitivity analysis for slide locations and volumes

Combine tectonic and landslide scenarios

Perform inundation calculations for all scenarios

Construct inundation maps

Landslide model

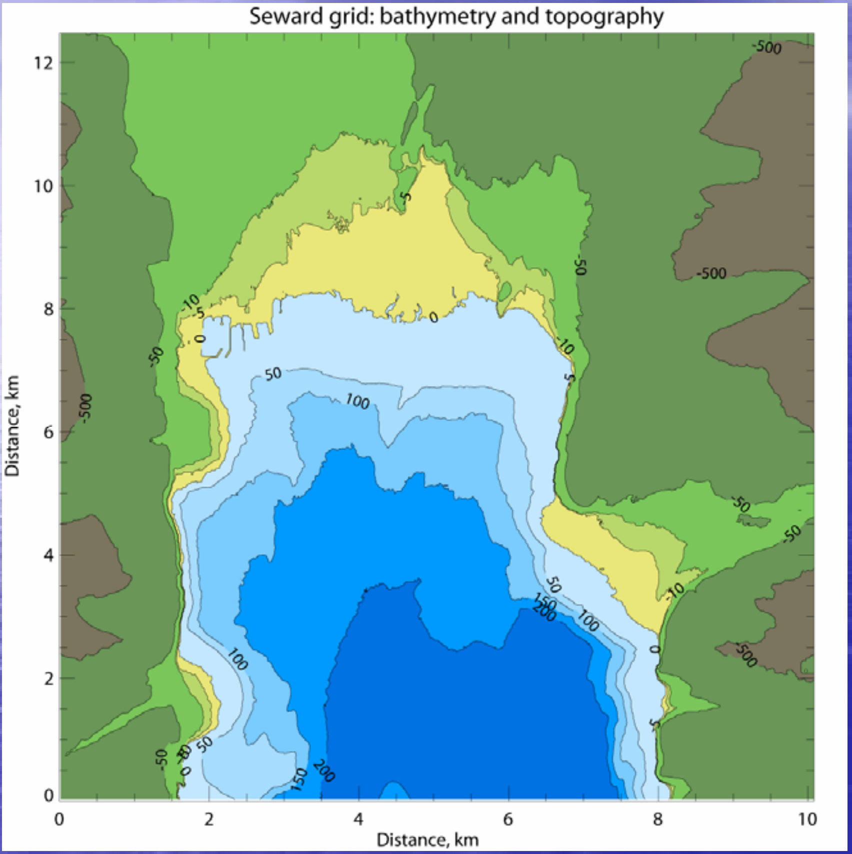


- Three-dimensional numerical model of a viscous slide with full interactions between the slide and surface waves.*
- The slide is modeled as an incompressible 3-D viscous flow. The long-wave approximation is used for both water waves and the slide.
- The equations for the slide and surface waves are solved simultaneously using a finite-difference scheme.

* 1. Jiang, L. and LeBlond, P.H.: 1994. Three-dimensional modeling of tsunami generation due to a submarine mudslide, *J. Phys. Oceanogr*. **24** (3), 559-572.

2. Fine *et al.*: 1998. Numerical modeling of landslide-generated tsunamis with application to the Skagway harbor tsunami of November 3, 1994. *Proceedings of the International Conference on Tsunamis (Paris, 1998), pp.211-223.*

Model of the Seward slide



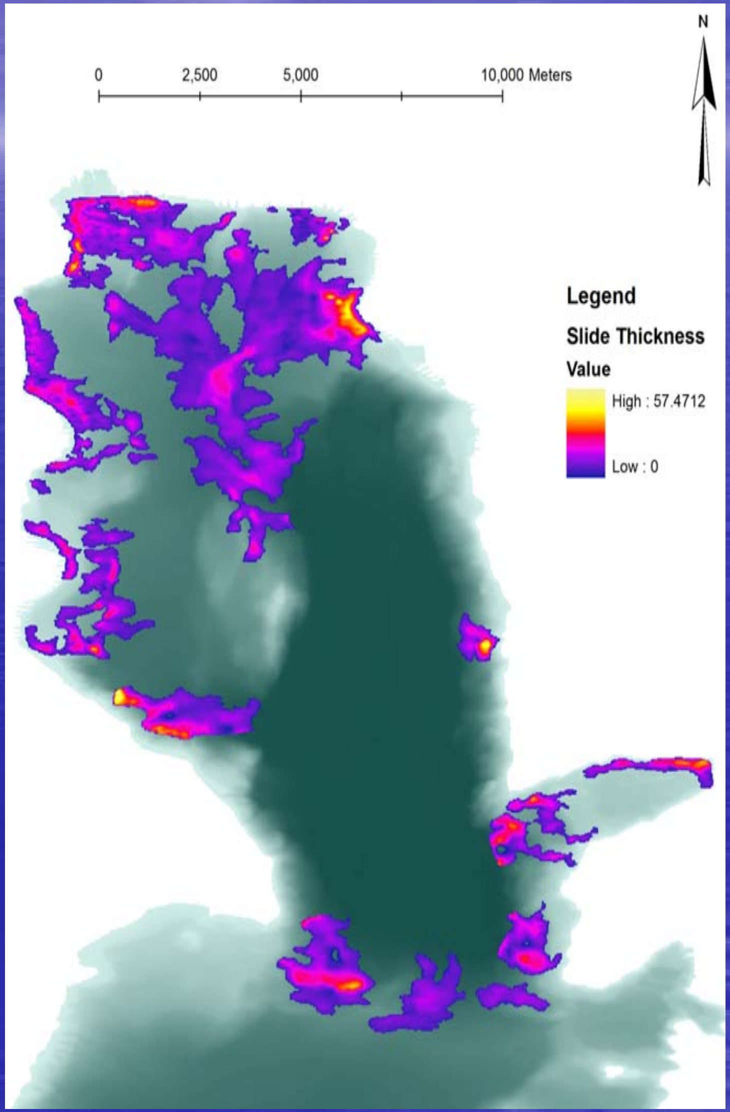
- Computational grid: 1923 x 1212 grid points with 4.5 x 9.1 m resolution.
- Slide dimensions are 680 x 1150 m, and the initial volume estimate was 15M m^3 derived from the near-shore bathymetric differences only.
- F90 code runs on IBM P690 of the Arctic Region Supercomputing Center.
- The runup component is included into the code.

slide

waves

Bathymetry data analysis

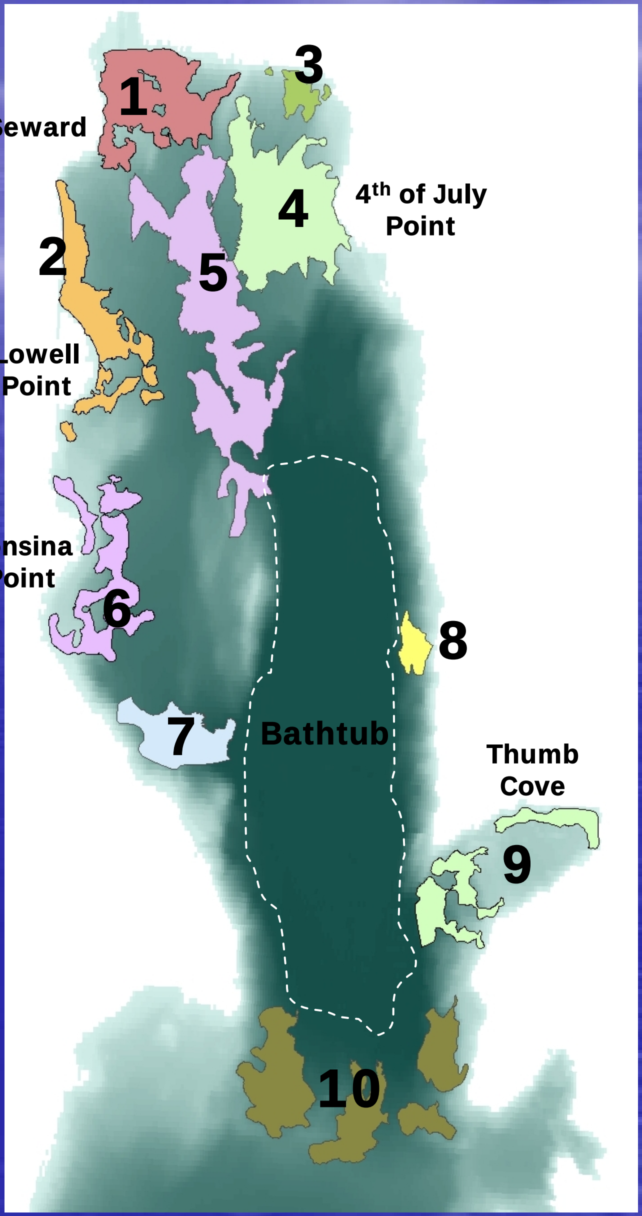
- **Data sources:**
  - **2001 NOAA multibeam survey**
  - **6906 soundings from 8 NOAA surveys, 1905-1961**
  - **10,991 soundings from 1965 survey**
  - **157 km of “chirp” high-resolution seismic reflection data**
- **The submarine failures initiated high on the fjord walls, and sediment was transported to the bathtub (6 to 13 km).**
- **The acoustically transparent unit in the bathtub is a megaturbidite deposit with the average thickness of 14 meters.**
- **Initial slide thicknesses are calculated from the bathy difference map.**



Major slide complexes and their volumes (x 10^6 m^3)

1.	Seward downtown	27.5
2.	Lowell Point	18.1
3.	Resurrection river delta	2.9
4.	4th of July Point	35.0
5.	Middle bay	40.7
6.	Tonsina Point	16.8
7.	West shore	15.3
8.	East shore	4.5
9.	Thumb Cove	16.5
10.	South slope	33.3

Total: 210.6

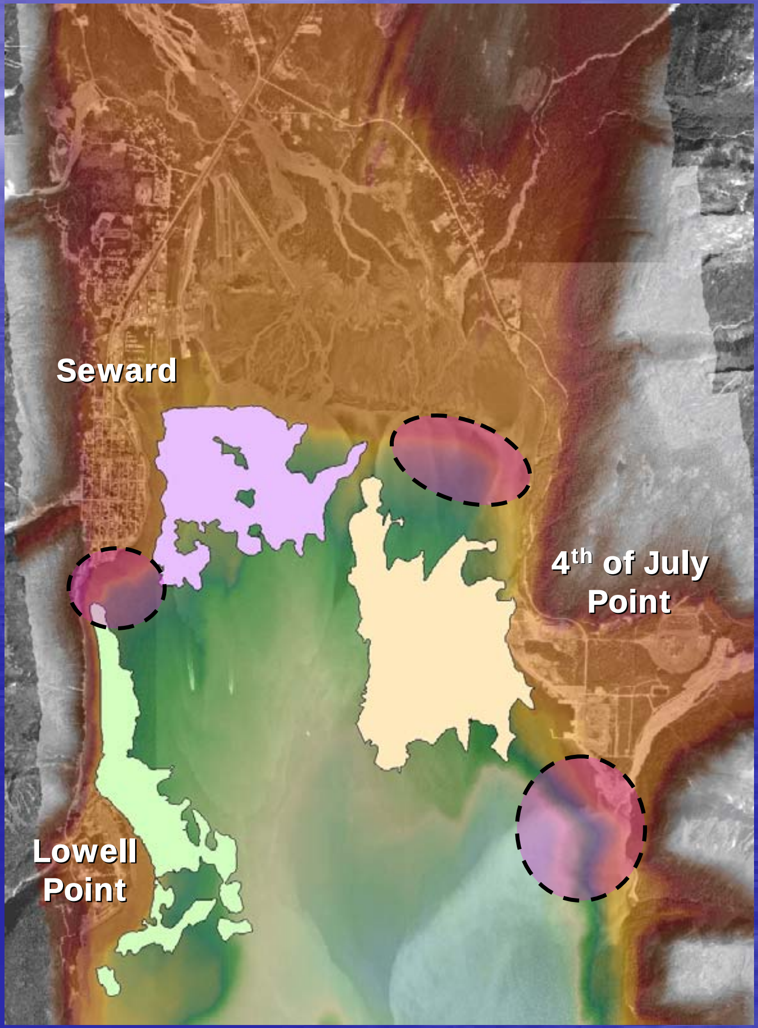


slides

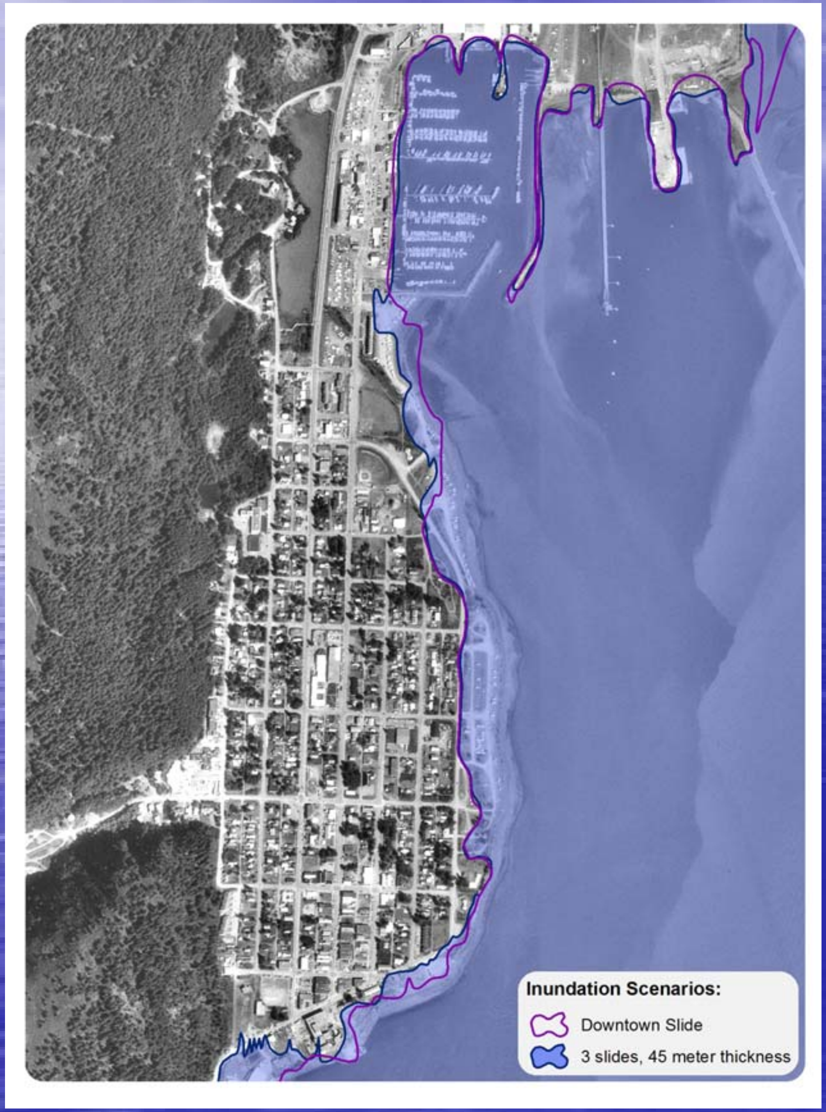
waves

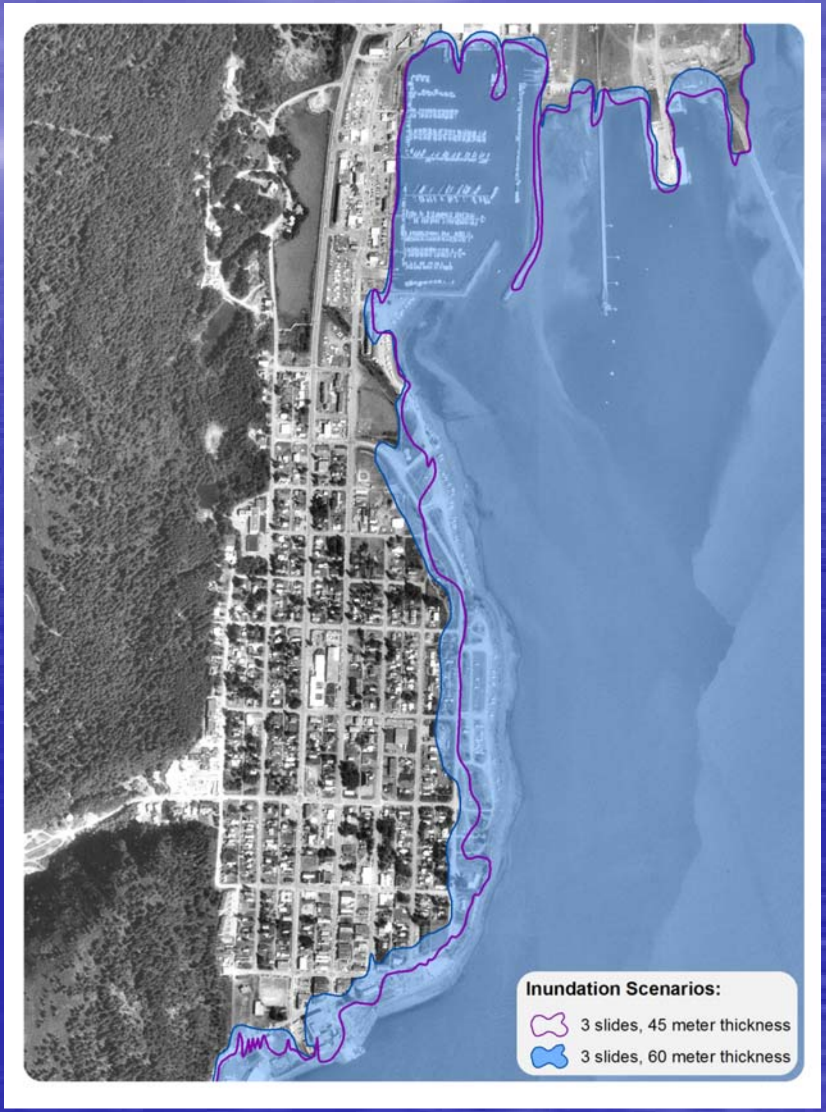
Sensitivity studies

- The computed highest wave at Seward downtown agrees very well with observations (25 ft at 1.5 – 2 min).
- By modeling the slides separately, we can estimate relative contributions of each slide to the observed wave sequence at Seward.
- This sensitivity study will help create hypothetical landslide scenarios for Seward inundation mapping.
- The bathymetry difference map (1965-2001) shows addition of significant sediment in 3 places.



Inundation maps





The way to a safer Alaska coastline

- **Tsunami safety in Alaska is addressed through a partnership between several state and federal agencies. Our goal is to improve mitigation and response to risks associated with tsunamigenic earthquakes and submarine landslides in Alaska.**
- **Landslide tsunami hazard is high in Alaska fjords. Numerical models help to identify underwater slopes most susceptible to failures, predict the effects of tsunamis, and reduce tsunami risk and loss of life.**
- **It is our responsibility to develop scenarios and models for community preparedness and tsunami education & outreach programs in Alaska coastal communities.**