HUMBOLDT-NORCAL TSUNAMI SCIENCE

FIELD GUIDE FOR MEASURING TSUNAMI

RUN-UPS AND INUNDATIONS

Tsunami Science

Humboldt and Del Norte Field Teams

http://tsu.cascadiageo.org

1st. Draft Edition - May 2014

Preface

We adopted major parts of this guide from 2nd Edition of the Hawaii Tsunami Field Guide. This document is intended solely for the use of individuals as part of the Tsunami Science Subject Matter Expert Field Teams to facilitate efficient and accurate measurements of tsunami run-ups and inundations throughout northern California. Our website is located here http://tsu.cascadiageo.org

5/12/2014

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Introduction

This guide is written to facilitate reliable and rapid measurements of run-ups and inundations by a subject matter expert field team during/following the occurrence of a tsunami. The purpose of such measurements is to: (1) better understand the effects of tsunamis, hurricanes, and storm surges; (2) better define future evacuation zones for such hazards; (3) evaluate potential tsunami, hurricane, and storm surge hazards in heretofore undeveloped or underdeveloped areas of the State; and (4) provide a data base for testing the results of theoretically computed measurements of run-up and inundation. When these observations are shared with other organizations, they can use them with a broader impact.

It is hoped that our efforts will further increase awareness of tsunami hazards and further improve the predictive capabilities of our warning system. The data acquired by the survey teams will be of critical importance in our efforts to reduce the losses associated with future tsunamis.

Survey Teams and Areas

Survey teams could consist of 2 or 3 members, preferably with at least one member having some familiarity with the region being surveyed. The spatial extent to be surveyed is highly variable, depending on the number of accessible sites and the number of measurements required. Special permission may be needed for certain areas. This may be arranged by FEMA or California Office of Emergency Services. The field teams will be advised of excluded regions/areas.

Security and Identification

To avoid inconveniencing security and rescue personnel or unnecessarily arousing concerns of residents, survey team members should, if available, wear an orange safety vest. We are attempting to develop a form of identification (to allow permission in certain locations) for field team members, but that is not yet in place. If you park your car, leave a note so people know where you went and what you are doing.

Run-Ups and Inundations

Two of the most commonly used terms in tsunami research are “run-up” and “inundation”. When a tsunami floods a coastal area, the evidence of that flooding is debris or watermarks on the ground, in trees or in other vegetation, or on man-made structures. If the debris or watermark is on the ground and there is no additional evidence of the tsunami further inland, the location of that debris or watermark is the best estimate of the limit of inland penetration of the tsunami at that point. Thus the distance from that location to the nearest shoreline is called the “Inundation Limit” (**Figure 1A**). A measurement of the height of debris or the height of a watermark on the ground relative to sea level at an inundation limit is called “Run-Up Elevation.” Obviously the tsunami “ran up” and “inundated” all of the land between the shoreline and the inundation limits. However, our primary concern is with the limits of run-ups and the limits of inundation. Strictly speaking the terms “Run-Up Limit” and “Inundation Limit” should be used, although historically the single term “run-up” has often been used to indicate either the run-up limit or wave height on land (see below).

If the evidence of a tsunami is not on the ground (e.g., seaweed in a tree or a mud line on a building), a measurement of the height of that evidence will give us the water level that existed at that location as a result of the tsunami (**Figure 1B**). This water level measurement is, strictly speaking, not

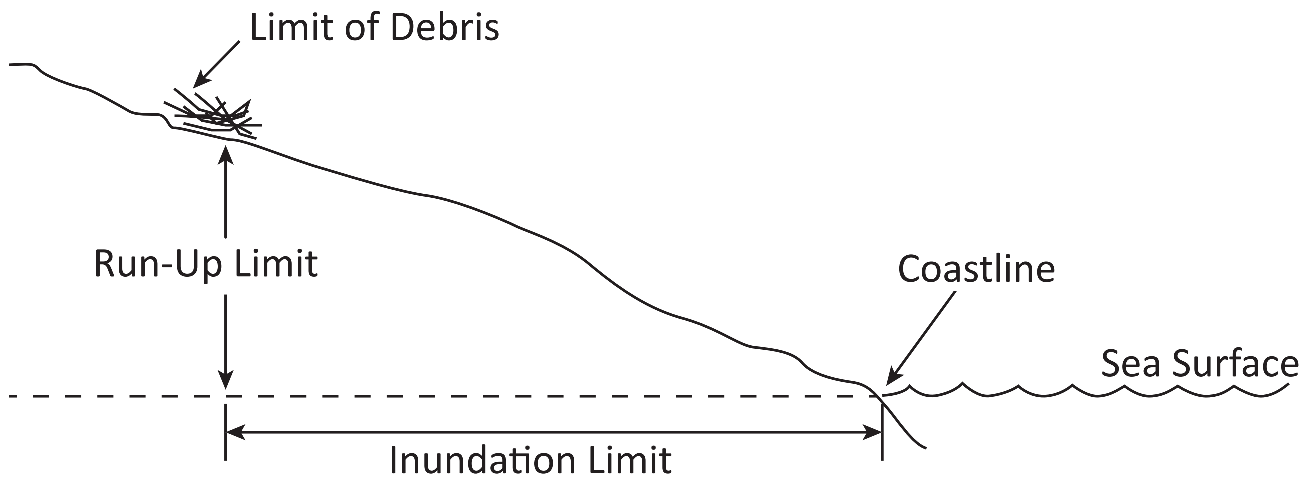


Figure 1 A. The height of the debris on the surface of the ground, measured relative to sea level, is a measure of the tsunami's run-up. The land between the shoreline and the debris line was obviously flooded or inundated by the tsunami. The debris line indicates the limit of that inundation or the maximum inland penetration of the tsunami at that location.

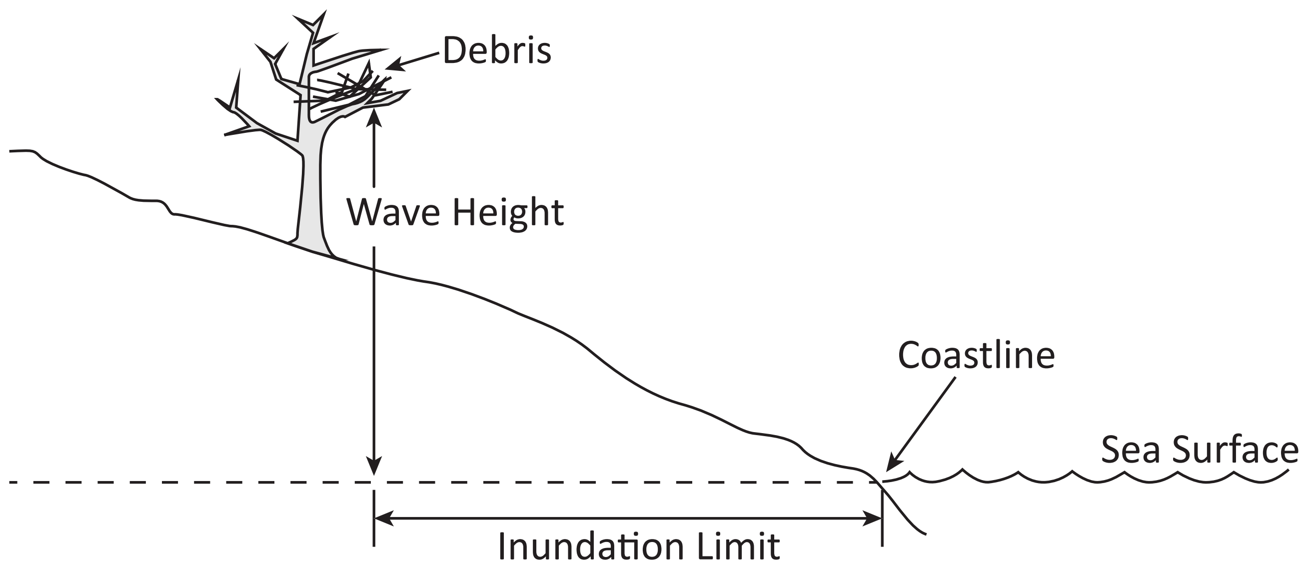


Figure 1 B. The elevation above sea level where debris is mapped in a tree is called Wave Height.

called a run-up because it is not measured at an inundation limit. Obviously, that limit was further inland. In some areas the only evidence of a tsunami may be above ground debris or watermarks. Therefore, such water level measurements may be of critical importance.

General Guidelines

Teams should search for the highest run-ups (or water levels) and furthest limits of inundation, and measure the height of debris lines or other marks above sea level, as well as the location (GPS coordinates and paced or measured distances from the shoreline) of their measurements. To permit eventual corrections to the data for tidal variations, the date and times of all readings must be noted. If there is any uncertainty in any measurement, it should be repeated if possible and notes made on the field data sheets of any uncertainties. In regions where widespread destruction has occurred, several measurements should be made. In a matter of weeks or days, important measurement sites may disappear through natural processes or human activity. With this in mind it would certainly be better to have more data.

If field maps can be prepared in advance, use them to locate your field mapping efforts. Keep in mind that the relative measures of run-up and inundation in different areas may be highly variable for different tsunamis. Ensure that notes and field maps are held consistent and that there is a way to relate the two. Locations that will be important to other organizations should include those close to power plants, electrical sub-stations, telephone exchanges, water pumping stations, waste disposal treatment facilities, schools, hotels, parks, roads, bridges, and other significant structures or sensitive areas.

Still camera photos of each measurement site and general area should be taken. If possible, prominent survivable landmarks (e.g., buildings, trees, and mountains) should be in the background of the pictures. At some locations it might be possible to mark where measurements have been taken with surveying tape or spray paint. **Voluntary or easily elicited eyewitness accounts should be documented. However, if any fatalities, injuries, or substantial losses of property have occurred in a region, overt efforts to acquire eyewitness accounts might best be abandoned.** Care must be taken to distinguish between those sites at which no effects of the tsunami were observed and sites that were not examined for evidence of the tsunami's effects. In past tsunamis both of these situations have been described by words "no observation". To avoid confusion, use "no effects observed" or "site not examined" along with GPS coordinates or geographic names. Finally, areas that you are unable to reach because of obstacles should be identified; and **no attempt should be made to take readings in inaccessible or hazardous areas.**

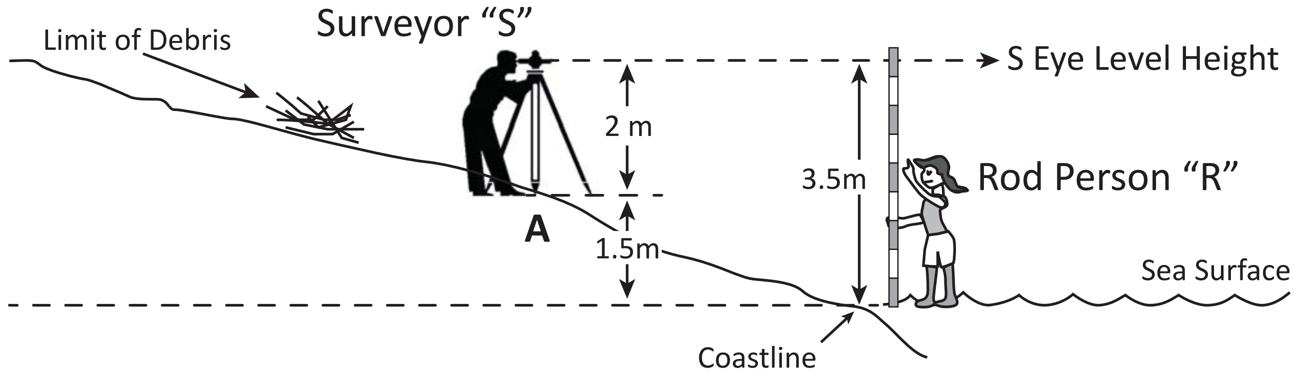
Equipment and Supplies

A listing of essential equipment, supplies, and other items follows. These should be "checked off" before beginning your survey.

- Survey rods (three 2-meter sections, two for the "Rod person" and one for the "Surveyor").
- Backpack with: the 10 essentials, GPS, Binoculars, Compass, Sighting scope/hand level, 2-way radio or cell phone, Survey Tape or Spray P aint, Digital or Video Camera, Clipboard, Watch.
- Supplies: data sheets, pens, pencils, notebook, batteries, and extra camera memory card.
- Other items: field maps and personal effects (e.g., appropriate footwear, rain coat, and trash bag).

Run-Up Measurement Techniques

Conventional surveying techniques with high degrees of accuracy are not well suited to the comprehensive and time limited measurements required for determining tsunami run-ups throughout the region. Sites may be revisited by others in some cases to make more precise measurements (eg. autolevel, RTK GPS, or total station surveys). Normal rainfall, flash floods, heavy surf, and clean-up operations can quickly destroy evidence of a tsunami's effects. Run-up measurement accuracies to within a half a meter, and inundation distance measurements of 5- to 10 meters may be more than sufficient for modeling studies and improved determinations of evacuation zones. Some simple, rapid, and sufficiently accurate methods have been developed for measuring tsunami effects using inexpensive, lightweight, and weatherproof measuring devices.



Figures 2 A, B, C. The steps involved in a typical measurement of run-up using conventional surveying and the horizon as a reference level.

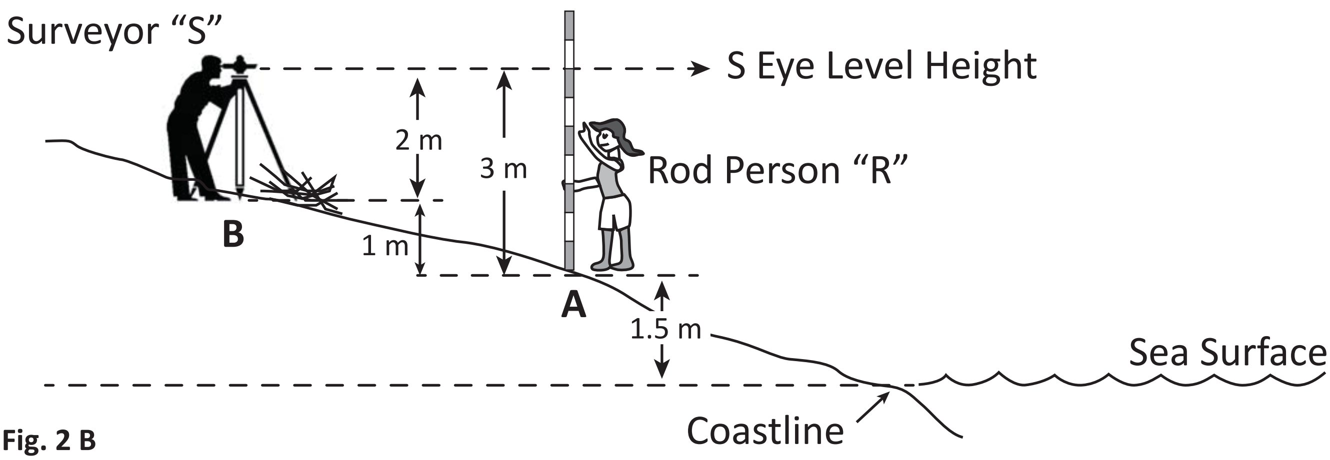


Fig. 2 B

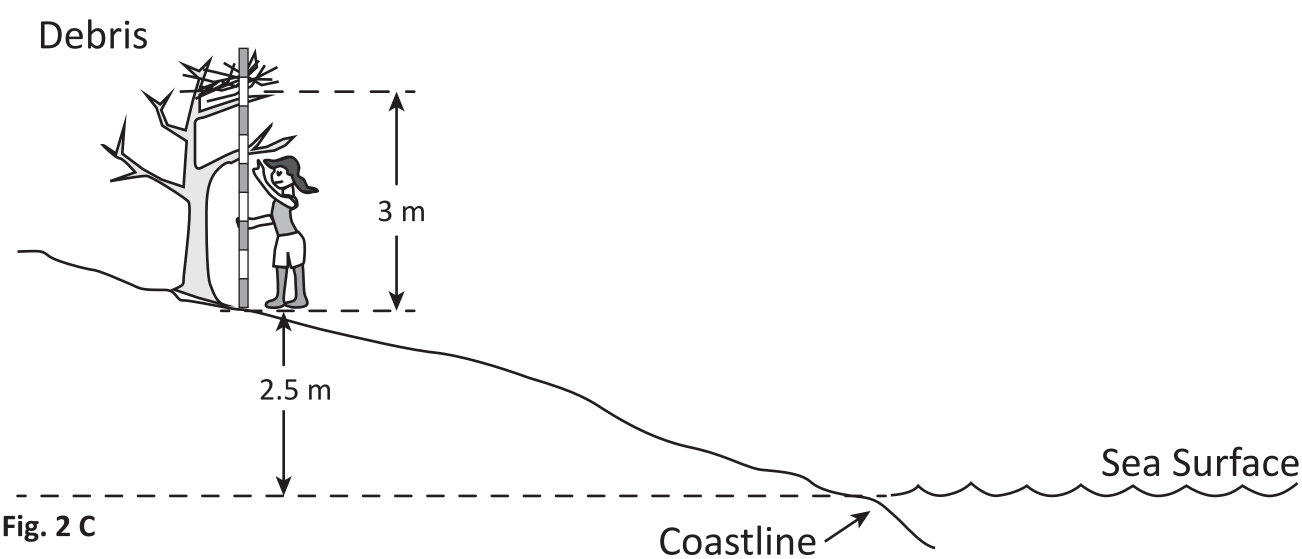


Fig. 2 C

Example Survey Method

A quick and relatively accurate method (i.e., to within the nearest foot) for measuring run-up follows. Have one team member (the "rod person"; hereafter referred to as "R") stand on the shoreline at a point where "R" is as close as possible to the normal wave action. With the rod held vertically at sea level, the other team member (the "surveyor"; hereafter referred to as "S") can move up the shore **<u>until their eye height is seen near the top of the rod</u>**. At this location ("A" in **Figure 2A**) "S" should read the height on the rod adjacent to the sea surface horizon (i.e., 3.5 m in **Figure 2A**). Inexpensive binoculars may be useful in making these readings. If "S's" eyes are 2 m above the ground, the ground at S's location is 1.5 m above sea level.

The next step is for "R" to move to the exact position where "S" was standing and again hold up the rod. "S" then moves higher up on the shore and stands at the limit of the tsunami deposited debris line (i.e., location "B" in **Figure 2B**). Again "S" reads their eye level height on the rod (i.e., 3 m in **Figure 2B**). Subtracting out the vertical distance from "S's" feet to "S's" eyes, it is determined that location B is 1 m above location "A" (i.e., 3 m minus 2 m). Therefore the tsunami deposited debris is 2.5 m above sea level (i.e., the 1.5 m measured at "A" plus the 1 m measured at "B").

If the debris line is further up the shore, this method is continued until the line is reached. If the debris had been in a tree (e.g., **Figure 2C**), it would have been necessary to measure the height of the ground below the debris line relative to sea level (i.e., the 2.5 m computed in **Fig.2C**), and then add the height of the debris above that location (i.e., the 3 m in **Figure 2C**) to get the water level that existed (i.e., the 5.5 m in **Figure 2C**) at that point.

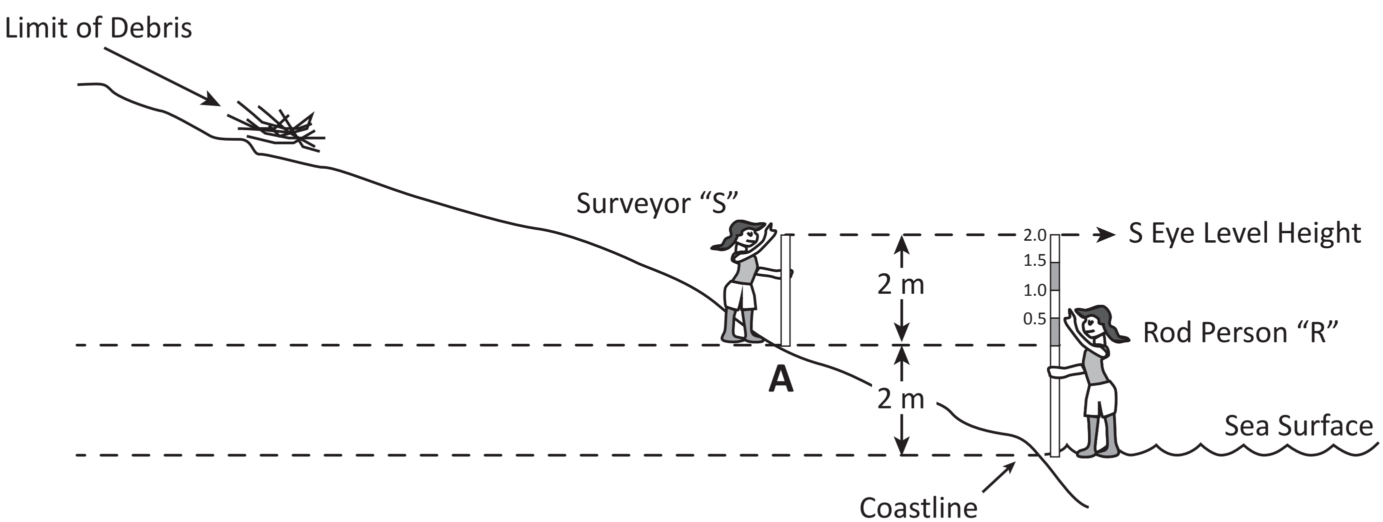
Secondary Survey Method

Now, with the understanding of this fundamental method, some additional techniques are suggested which can speed up the measurements and reduce the chance for errors. These techniques require the use of special survey rods made of two 2 meter sections of PVC pipe. The lower 2 meter section of the rod does not have to be marked. The upper section is marked from in half meter sections (or smaller, maybe 20 cm). The surveyor ("S") also has an unmarked 2 meter rod. The rod person ("R") holds the 4 meter rod up on the shoreline with the base of the rod at sea level. "S" moves up the shore (toward the debris line or water mark that is to be measured) continually sighting along the top of his (or her) 2 meter rod until the top of this rod and the top of "R's" rod line up with the sea level horizon (**Figure 3A**). At this location ("A" in **Figure 3B**) the ground level will be 2 meters above sea level.

"R" then moves to "A", and "S" moves closer to the debris line (location "B" in **Figure 3B**) until the tops of the rods again line up with the horizon.

These steps are repeated until the debris line or watermark is reached. At this point the top of the surveyor's rod and the horizon will intersect "R's" rod at a point below the top of "R's" rod (**Figure 3C**).

The run-up in meters will be this final reading plus 5 times the number of intermediate readings (in this example; 1.5 m + (2 X 2 m) = 5.5 m). "R's" rod should have a brightly colored (i.e.. orange or red) horizontal bar across its top to facilitate accurate alignment with the horizon. Under cloudy or hazy skies, a white or gray bar can be difficult to sight on a white or gray horizon. It is important to maintain a vertical alignment of the rod. The 2 meter sections are pressure fitted so that they can be easily disassembled for storage and for transport from one site to another. The accuracy of this method is estimated to provide measurements within 0.5 meter of actual values. This is more than adequate for assessing the potential destruction of future tsunamis, hurricanes, and storm surges, for improved determinations of evacuation zones for such hazards, and for testing the result of modeling studies. If the debris or watermark is in a tree or on a building, the height above the ground has to be added to get the water level that existed at that location. In these instances, the tsunami probably traveled further inland than is indicated by the debris or watermark.



Figures 3 A, B, C. A practical, short-cut method for measuring run-up.

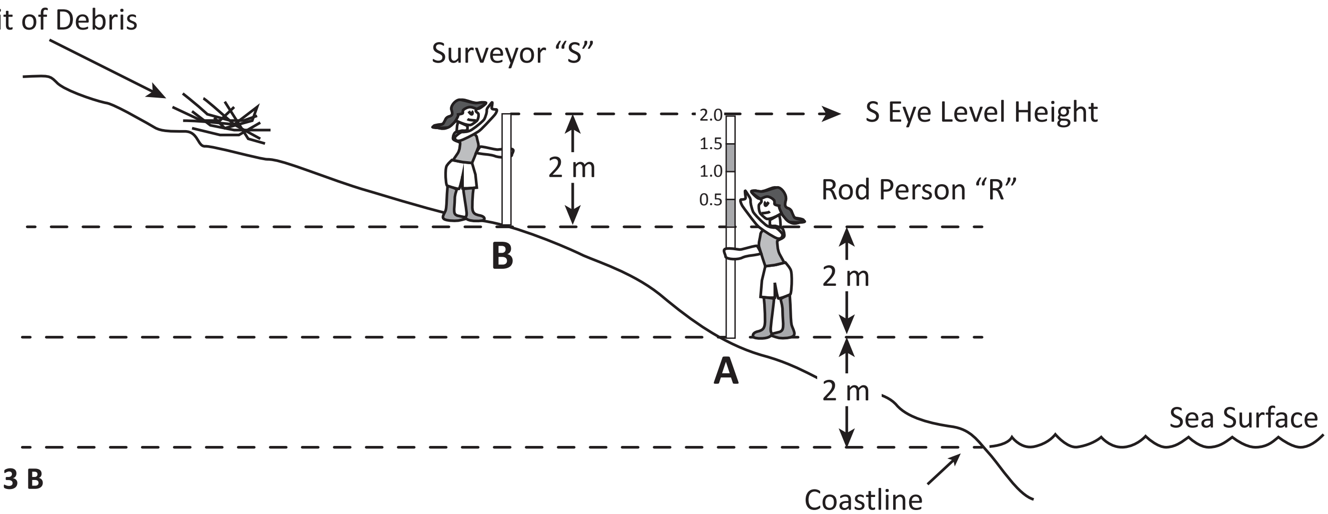


Fig. 3 B

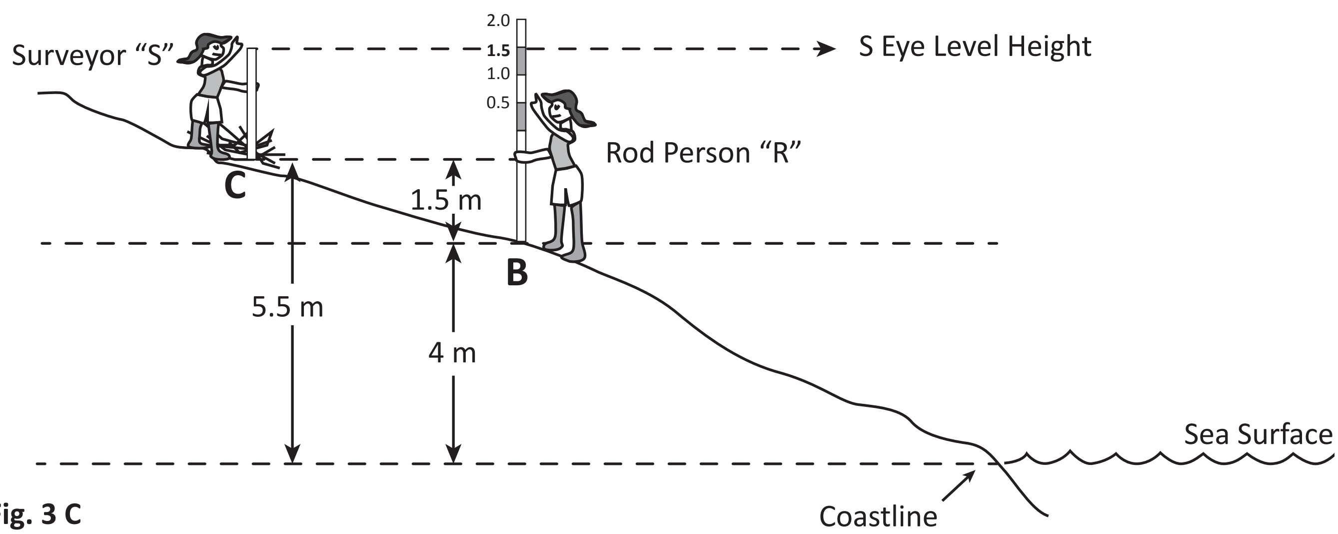


Fig. 3 C

In gently sloping shorelines with small run-ups, the horizon may not line up with the top of the rod. In this situation the run-up will be the value appearing on "R's" rod adjacent to the sea surface horizon when the horizon is sighted along the top of "S's" rod using the hand held sight level. If multiple measurements of this type are needed to reach the debris line, the run-up is the cumulative total of readings made.

An additional consideration is that the elevation of an intermediate measurement location may be lower than that of the location where "R's" rod is being held. Therefore, the bottom 2 meter section of "R's" rod should be marked so that the appropriate amount can be subtracted from the cumulative total. Also, in areas with large run-ups, an additional 2 meter section can be added to "R's" rod, so as to reduce the number of intermediate measurements. In instances where the horizon cannot be seen, an instrument known as a hand level should be used. The accuracy of some hand levels may not be as good as sightings to the horizon. **Do not use your GPS for measuring run-up heights ("altitudes"). For this type of measurement the errors** are unacceptably large.

Inundation Measurement Techniques

The inundation limit should be determined by measuring with a 100' tape, or by pacing from the shoreline closest to the debris line or watermark, and by noting the GPS coordinates of both the inundation limit and the shoreline closest to the inundation limit. GPS location accuracies are dependent on the number of satellites the instrument can "see". If GPS readings are taken next to steep cliffs or in deeply carved, narrow valleys, or near power lines errors may result. In these cases, photos of the inundation limits/debris lines including specific landmarks i.e. trees, large bushes, road signs, or big rocks, will permit later corrections of the coordinates using Google earth.

Summary of Essential Measurements

The measurements that need to be made in areas or regions of interest are:

- the highest observable water level produced by the tsunami on land relative to sea level
- the GPS coordinates of the highest water level location
- the distance to the highest water level location from the closest shoreline, if possible, as determined by measuring with a 100ft tape and noting the compass bearing, or by pacing in a straight line and noting the compass bearing
- the maximum distance that the tsunami penetrated inland as determined by pacing in a straight line, and noting the compass bearing, or measuring with a tape to the closest shoreline and noting the compass bearing
- a picture of the measurement site. The picture or pictures should have sufficient background content to facilitate a return to the site if necessary. Included in the picture or pictures should be a number (perhaps on an index card) corresponding to the number used to identify that site in the data log

In addition to the above measurements, other measures of water levels and inland flooding distances may be needed to get a better understanding of the tsunami's effects in certain areas. Certainly, in large areas of widespread devastation, several readings should be taken.

If possible, readings should be taken where measurements of prior tsunamis have been taken as indicated in the historical maps. Readings should also be made at the critical facility sites mentioned earlier under the heading "General Guidelines", or at any location the team believes to be of interest. Again, measurements should not be attempted in inaccessible or hazardous areas. Also, do not use the term "no observation". Use either "no effects observed" or "site not examined". Finally, measuring distances in a straight line to the closest shoreline may not be possible in some situations (e.g., because of debris or a meandering stream channel). In these situations the measurement should be made to the nearest accessible shoreline in a straight line noting the compass bearing.

Additional Complementary Tasks

- take photos of the debris or water marks at measurement
- mark each measurement site with distinctive surveying tape or paint
- document eyewitness accounts. Note: in areas of property loss, injuries, or fatalities these accounts should be entirely unsolicited, voluntary, and preferably, first person.
- make a sketch of the area to avoid difficulty in reoccupying the site should additional measurements be needed

An example of a completed data sheet is provided in the field back-pack and after the following discussion.

When to Measure

In the case of large tsunamis it can be a few days before the ocean gets back to normal. During this time period there will be significant fluctuations in sea level above and below the predicted tidal variations because of continuing tsunami oscillations. Measurements of run-up taken during these times may be inaccurate. In these situations it is recommended that GPS locations be noted and pictures taken of all desired run-up and inundation sites as soon as those sites are accessible. If necessary, this can be done by one person. Later, when the ocean settles down, measurements of run-up and inundation can be more accurately taken. Picture taking and site marking with tape or paint as soon as possible is important because the evidence of run-up and inundation may be destroyed by man or nature before the ocean returns to normal.

Accuracy of Measurements

We focus here on sources of error in measurements generally capable of being a few inches or more. Such errors are possible in determining sea level at the time of the first sighting to the rod. In areas with waves washing up and down the shore, estimating where to place the rod is difficult. This is especially true with steeply sloping shorelines and heavy surf. In this situation it may be necessary to study the ebb and flow of the waves on the shoreline for several minutes to find a reasonable estimate of the sea level location. Also, be aware of the possibility of sets of waves in your determinations, and avoid dangerous surf that could knock you down or sweep you into the ocean. Measurements under such circumstances should be taken at another time when the surf is smaller. Errors in the misplacement of the rod at sea level would generally be plus or minus a few inches under normal conditions, and perhaps a foot or two with larger surf. As already discussed, the "horizon assumption" would generally produce errors of only a few inches. For very large run-ups (e.g., about 50 feet) and large inundations (e.g., about 400 feet), the error would approach 1 foot (i.e., the reading of run-ups would be too small by a factor of about 1

TSUNAMI DATA LOG

Survey Team: M-2 Reading No: 11 Location Name: N. side of HANA BAY

Date: 11 Dec 2002 Time of Reading (Use Hawaiian Time): 6:32 (AM) PM

Coordinates ((GPS) preferred; note if from maps): 20°46.00'N ; 155°59.12'W

Height of Reading above Sea Level (in feet): 12.5 ft

Distance from Shoreline (in feet): 54 ft

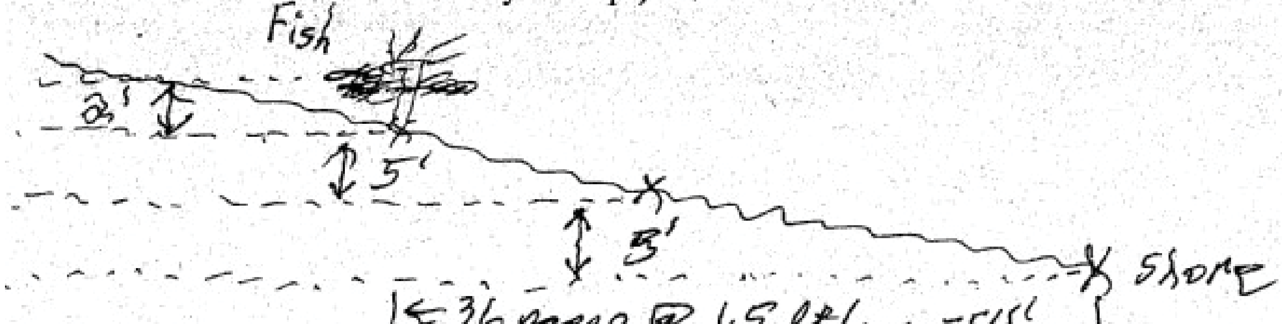
Compass Bearing to Shore: 12° E of S

Picture Taken: (Yes) No Disk or (Film Roll) No: 1 Exposure No: 13

Nature of Observation: Debris on Land (Debris in Tree) 1 Other

If "other", describe: not applicable

In this general area, does this measurement appear to be:
The highest water level? Yes No 3 (Not Yet Known) 2
The greatest distance from the shoreline? Yes (No) 3 Not Yet Known
Calculations, sketches, comments, and additional notes (be sure to place the reading number at the estimated location on your maps):



1. actually a fish and seaweed in a tree.
2. Will take other measurements in Hana Bay area.
3. Can see that debris is further inland in other areas.
Note: the stream bed area south of this location is too dangerous to get to because of debris. However, stream bed area does not appear to have greatest runup or furthest inundation in the Hana Bay area. Fisherman said third wave was largest at about 11:45 AM.

foot because true level was slightly higher on the rod than the horizon).

Another potentially significant source of error is in determinations based on debris or watermarks. The debris lines or watermarks are actually produced by a superposition of normal short period (i.e., a few seconds) waves on top of the much longer period (i.e., several minutes) tsunami waves. Other factors are the tides and knowing the time of the arrival of the largest tsunami wave. In some tsunamis, waves arriving as much as two or three hours after the first wave can be the largest. Storm surges and the large sets of waves associated with heavy surf could also give false high readings. As discussed earlier GPS accuracy may be good to within a few tens of feet if enough satellites are used, but may be much worse in shorelines adjacent to high cliffs or deeply carved and narrow valleys or near power lines Finally, with thick piles of debris, it may be difficult to determine which part of the pile is indicative of the tsunami's maximum height.

Concluding Remarks

Data gathered by the survey teams will help to reduce the human and economic losses associated with future tsunamis, hurricanes, and storm surges. For that reason everyone involved in the development of this field guide wishes to express their gratitude to the survey team volunteers on behalf of present and future residents of, and visitors to, the State of California.

Humboldt-Norcal Tsunami Science Subject Matter Expert Field Team Form Page 1

Survey Team/Names ____ Observation #: _______

Location Name: ______________________________ Date: __________________ Local Time: ______

Coordinates (GPS, field map name) ____

Geographic Location nearby: ____

Run-Up Limit (m/ft): _________________________________ relative to: _______________________

Inundation Limit (m/ft): ______________________________ relative to: _______________________

Photos:

Nature of Observation: Debris on Land Debris in Tree Other ___________________

The highest water? Yes/No/ Unknown The greatest distance from the shoreline? Yes/No/Unknown

Map/Notes:

Humboldt-Norcal Tsunami Science Subject Matter Expert Field Team Form Page 2

a. Conditions before tsunami (weather, special events, etc.)	
b. Character of tsunami	
i. Form (bore, surge, flood, breaking wave, eddies, etc.)	
ii. Number of surges, timing, which appeared to be the largest?	
iii. Suspended material (mud, sand)	
iv. Color	
c. **Inland reach of tsunami flooding**	
i. Distance from MSL line	
ii. Elevation	
iii. Locate on map/image	
d. Debris/Sediment movement and deposition (take pictures!)	
i. Type, size, and weight of debris	
ii. Composition and thickness of sediment	
iii. Distance from MSL line	
iv. Highest elevation deposited	
v. Location on map/image	
e. Erosion of beach sands/rip-rap or scour within harbors observed/ other geomorphic features	
f. **Maximum tsunami amplitudes**	
i. Amount	
ii. Where and when observed	
iii. Are there non-NOAA tide gauges?	
g. **Maximum tsunami current velocities**	
i. Amount (knots, m/s)	
ii. Where and when observed	
iii. Did boats have flow meters?	
h. **Damage (take pictures!)**	
i. Type (structures, boats, docks, infrastructure, vegetation)	
ii. Severity (minor, moderate, major)	
iii. Cause of damage (surge, buoyancy, drag, eddies, impact)	
iv. Environmental issues (broken pipes, oil spills)	
v. Location	
vi. Estimated cost	
r. Anecdotal information – every location is unique so make sure to capture this information when interviewing people or making observations	

Date: ___________ Location: _____________________ Field Personnel: _________________________________

People Interviewed (with contact information): ______ ____ _____

EMERGENCY RESPONSE QUESTIONS CHECKLIST (**BOLD** portions is most important)

a. How did they first hear about the tsunami? (media, emergency response channels, etc.)
b. **Was it clear what actions to take during Warning/Advisory? How did they learn what to do (from the message, from previous event or outreach, etc.)?**
c. **What action did they take** (no action, keep people off beach, limited access to dock and boat areas, evacuate people, evacuate vessels out of harbors)? When did they take that action?
d. **How did the public respond?**
e. When did they end their tsunami response activities and why?
f. What changes did they make when Warning was degraded to Advisory?
g. Did the event occur like they thought? How did it compare to the March 11, 2011 event?
h. **Are there any improvements that the state can make, or suggest to cities, counties, or Warning Center?**

UNESCO Field Guide Interview Template 1

Template 1 – sample interview questions adapted from IOC UNESCO 2010 Chile tsunami ITST

1. Was a tsunami, tidal wave or other unusual water wave activity along nearby coastal areas noted by you or anyone in your community near the date and time indicated on the opposite page? ☐ Yes ☐ No
   If No, please complete item 2 and return this form.

Date ____________ Time _______________ ☐ AM ☐ PM ☐ Standard Time ☐ Daylight

2. To be completed by person filling out this form

Name ____
Address ____
City ______________________________ Country ____________________________
State ______________________________ Zip Code ___________________________
Tel ______________________________ Fax ______________________________
E-mail ______________________________
Profession, gender, age____

Where were you during the earthquake and the tsunami? (a hill, a house, a boat, etc.)________
Place name (town, village, colony, topographic) ______________________(locate on maps or air photos)

TSUNAMI ALERT INFORMATION

3. Did you have knowledge/expectation that a tsunami would come? ☐ Yes ☐ No
4. If yes, but what do you know and how did you know it? ___________________
   Did you have experience of or knowledge of previous events? ____

5. Did you receive a tsunami alert, information bulletin, watch, or warning? ☐ Yes ☐ No

6. If yes, indicate type and at what time(s):

☐ Alert ______ _______________
☐ Bulletin ___ ☐ Watch ______ ☐ Warning ____

7. If yes, how did you learn of the alert, warning, bulletin, or watch? If more than one, please indicate order:

☐ Siren ☐ Radio ☐ TV ☐ Civil Defense ☐ Fire Dept
☐ Police ☐ Telephone ☐ Internet ☐ Other (explain) ____________

8. What was your response to the alert, warning, bulletin or watch? If more than one, please indicate order:

☐ Did nothing ☐ Evacuated ☐ Waited for further instructions
☐ Other (explain) ____

9. What was the response of different segments of the population (elderly, disable, minors and children, etc) ?
   ____

10. How effective were response planning, operation, and evacuations?_______________________________

11. Were there obstacles during the evacuation? ____

12. What preparedness actions had you taken well before the tsunami?______________________________

TSUNAMI WAVE OBSERVATIONS

We are interested in documenting the sea water appearance before, during, and after the tsunami (boiling, foaming, etc.).
Specifically, did the water receded or not before the first tsunami wave arrived?

Were there any sounds (noise) before or during the arrival of the tsunami and of what type?
Were there tsunami-excited seiches in semi-enclosed bays, tsunami generated bore waves traveling up-rivers, trapping, refraction or diffraction of tsunami waves around islands and edge waves along the continental shelf, coastal water piling due to intense hurricane or typhoon winds simultaneous to the arrival of the tsunami?
Were there any evidences and effects of tsunami-induced flows and currents (estimate magnitude and direction if possible).

What was the situation before the tsunami? (meteorological conditions, sea-level, light conditions, sounds or noise, etc. ____

13. Did you see unusual waves? ☐ Yes ☐ No

14. If yes, indicate the location and type of water body where you observed the wave:
☐ Open coast ☐ Bay ☐ Harbor ☐ Estuary
Location ____

15. Indicate the direction the wave came from:
☐ North ☐ South ☐ East ☐ West
16. Indicate the direction the wave went to:
☐ North ☐ South ☐ East ☐ West

17. Indicated the slope of the shore where you observed the wave:
☐ Level ☐ Gently sloping ☐ Steep ☐ Vertical

18. Were there any other natural phenomena at or near the time of the tsunami?
☐ None ☐ Earthquake ☐ Landslide ☐ Volcanic activity
☐ Other (describe) ____

19. What was the water condition before the tsunami waves arrived?
☐ Calm ☐ Ripples ☐ Swells ☐ Choppy ☐ Heavy surf ☐ Stormy

20. Describe any sounds at the time of arrival?
☐ Drum ☐ Thunder ☐ Airplane ☐ Rain ☐ Car
☐ River ☐ Train ☐ No Sound ☐ Other ____________________

21. Did the water recede before the first tsunami wave arrived? ☐ Yes ☐ No

22. Indicate the nature of the tsunami wave(s):
☐ Fast rising and falling tides ☐ Breaking waves (swell with white caps)
☐ Calm, slow flooding ☐ Like a river ☐ Wall (bore)
☐ Other ____

23. Describe any sounds or noise, or other unusual happening <u>before or during</u> the tsunami wave arrival.
____

24. How many times did the water rise (How many waves were there)? ____________________________
Local time - from clocks, TV programmes, etc. ____
How much time was there between the main earthquake shock and the tsunami wave arrival ____________
(Note that an aftershock may come between the main shock and the tsunami arrival time)
Did the water completely withdraw and came back again? ____________________________________
Were there bores, eddies in rivers or bays, or changes in water color?
What was the relative size of the waves? (which one was largest, etc.)? _________________________

Please give times and heights of the waves at your location:

	Time	Heights (feet or meters)	Location and Observation
First wave:			
Second wave:			
Third wave:			
Fourth wave:			
Fifth wave:			
Other waves:			

25. How far inland did the water travel from high-tide shoreline at your location?

☐ A few feet (up to few m) ☐ Up to 165 feet (50 m) ☐ Up to 330 feet (100 m)
☐ Up to 80 feet (25 m) ☐ Up to 245 feet (75 m) ☐ More than 330 feet (100 m)

Please provide additional descriptions.
Location and Description ____
____

TSUNAMI IMPACT AND DAMAGE

26. Describe the types of tree damage observed (if any):

☐ Small limbs broken ☐ Tree less than 2” diameter broken (5 cm)
☐ Trees from 2” to 8” diameter broken (5-20 cm) ☐ Trees greater than 8” diameter broken (20 cm)
☐ Trees uprooted ☐ Total destruction of vegetation

27. Describe effects on other types of vegetation:
____

28. Did the water move debris inland (seaward) form the shoreline?
Inland: ☐ Yes ☐ No; Seaward: ☐ Yes ☐ No
29. If yes, identify large rocks, significant debris, houses, ships, etc moved by the tsunami (and where they were before).
30. Make a drawing if necessary.

31. Indicate the predominant type of debris, how far inland (or seaward) beyond the high (low) tide shoreline the debris was moved, and the slope of the shore (i.e. level, gentle, steep):

	Slope	Distance
☐ Sand		
☐ Driftwood		
☐ Rocks to cobble size		
☐ Boulders		
☐ Other (describe) ______		

32. Were there any permanent changes in sea level after the tsunami? ☐ Yes ☐ No
What were the changes in the land surface caused by the tsunami?
Places where there was erosion? Places where it left sediment (deposits)? What did it look like before the tsunami?
Location ____
Description ____

33. Was there damage to boats of different sizes?

34. What percentage of boats were damaged in the harbour?
☐ None ☐ Few (about 5%) ☐ Many (about 50%) ☐ Most (about 75%)

35. List types of damage (moorings, types of boats) and describe how they were damaged, such as by waves, strong currents, debris (boats, pirogues).
Location ____
Description ____

STRUCTURAL DAMAGE

36. What percentage of buildings or structures were damaged by the wave in your locality?
☐ None ☐ Few (about 5%) ☐ Many (about 50%) ☐ Most (about 75%)

37. Check the approximate age of the majority of damaged buildings or structures:
☐ Built before 1945 ☐ Built between 1945 and 1965 ☐ Built between 1965 and 1980
☐ Built between 1980 and 1990 ☐ Built between 1990 and 2000 ☐ Built after 2000

38. Check the types of buildings or structures, the type of construction (wood, stone, brick, cinderblock, metal, reinforced concrete, etc), the type of foundation (pilings, cinder block, poured concrete, etc.), and the overall extent of damage
(1-Slight, 2-Moderate, 3-Severe, 4-Total):

Type:	Type of construction:	Foundation:	Damage:
☐ High-rise building	____________	____________	☐ 1 ☐ 2 ☐ 3 ☐ 4
☐ Low-rise building	____________	____________	☐ 1 ☐ 2 ☐ 3 ☐ 4
☐ Split-level houses	____________	____________	☐ 1 ☐ 2 ☐ 3 ☐ 4
☐ Single-level houses	____________	____________	☐ 1 ☐ 2 ☐ 3 ☐ 4
☐ Breakwaters	____________	____________	☐ 1 ☐ 2 ☐ 3 ☐ 4
☐ Piers	____________	____________	☐ 1 ☐ 2 ☐ 3 ☐ 4
☐ Docks	____________	____________	☐ 1 ☐ 2 ☐ 3 ☐ 4
☐ Wharfs	____________	____________	☐ 1 ☐ 2 ☐ 3 ☐ 4
☐ Light houses	____________	____________	☐ 1 ☐ 2 ☐ 3 ☐ 4
☐ Bridges	____________	____________	☐ 1 ☐ 2 ☐ 3 ☐ 4
☐ Overpasses	____________	____________	☐ 1 ☐ 2 ☐ 3 ☐ 4
☐ Dams	____________	____________	☐ 1 ☐ 2 ☐ 3 ☐ 4
☐ Railroad tracks	____________	____________	☐ 1 ☐ 2 ☐ 3 ☐ 4
☐ Roads	____________	____________	☐ 1 ☐ 2 ☐ 3 ☐ 4
☐ Other	____________	____________	☐ 1 ☐ 2 ☐ 3 ☐ 4

Describe ____

39. Describe the predominant type of ground under the majority of damaged buildings or structures:
☐ Sandy soil ☐ Marshy ☐ Fill ☐ Hard rock
☐ Clay soil ☐ Shale ☐ Don't know

40. Was the slope of the ground under these buildings or structures:
☐ Level ☐ Gently sloping ☐ Steep

41. How far away from the shoreline were the buildings or structures that were damaged?
☐ At the shoreline ☐ Less than 165 feet (50 m) ☐ Between 165-330 feet (50-100 m)
☐ Between 330-660 feet (100-200 m) ☐ More than 660 feet (200 m)

42. Do you know of any injuries or fatalities associated with the wave? ☐ Yes ☐ No
If yes, how many injuries? ____________ Fatalities? ____________
Circumstances? ____

FOR THOSE WHO WERE IN BOATS OR AT THE BEACH

43. Where were you before, during and after the event?
Please describe____

44. What did the sea surface look like? (e.g., boiling, shaking, foaming ripples or waves)
Please
describe____

45. Was there damage to the ship/boat? ☐ Yes ☐ No
Please describe ____

46. Did you notice any other phenomena? (e.g., fish behavior, light, etc.)____
____

FOR OLDER PERSONS

47. Have you experienced any other tsunamis like this one in your lifetime, at this same or another place? When? Where? Please describe such events.____
____

48. Did your parents/grandparents experience any such events?
When? Where? Please give a brief description____

49. Do you know of stories or legends of such events that have been handed down? Please describe.
____

Thank you for taking the time to fill out this information questionnaire.