Samoa Earthquake - Tsunami Reconnaissance October 22 – November 4, 2009

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The EERI-ASCE/COPRI Samoa Post Tsunami Survey team from left to right: Jennifer Irish, Jeff Brandt, Heather Lazrus, Lori Dengler, Lesley Ewing, Chris Jones.

Day 1: Thursday October 22

I'm currently sitting in the Arcata Airport enduring a fog delay on the first leg of our Samoa post-tsunami reconnaissance study. I'm leading an interdisciplinary group under the auspices of the Earthquake Engineering Research Group (EERI) of that includes an environmental scientist, an anthropologist and an emergency manger that will be working in American Samoa and Samoa over the next two weeks. We will be coordinating our efforts with a group of engineers sponsored by the American Society of Civil Engineers who will be examining the performance of port and coastal structures over the same time period as our visit.

Post tsunami field studies are important for a number of reasons. Usually the first teams to visit a tsunami-struck area are the water height specialists who measure tsunami runup (the elevation of the tsunami at the inland extent of inundation) and other water height indicators. Records of water heights such as debris lines, water marks on buildings, and debris in trees are ephemeral and these measurements are critical to calibrating numerical models of tsunami flooding such as those used to estimate California tsunami hazards. Almost as quick on the scene are scientists who study tsunami deposits – the cobbles, sands, silts and debris transported by tsunamis. The characteristics of deposits of recent tsunamis can be used to help interpret paleotsunami deposits such as those found in Crescent City and the southern parts of Humboldt Bay.

Our group is focusing on a different aspect of tsunamis – how people responded to the natural warning signs of the tsunami and how coastal structures, planning and management affected exposure. We are also going to be looking at how people responded to the natural warning of September 29 – the strong ground shaking of a magnitude 8 earthquake, and the official warning that was issued on October 7 when a large earthquake occurred in the Vanuatu Islands about 1500 miles away from Samoa.

Well there's a further fog delay – and my next connection is getting iffy. I'll keep you posted.

Day 2: Friday October 23

Courtesy of United Airlines I've had to switch to plan B. Mechanical problems delayed the San Francisco – Honolulu departure for 3.5 hours, so I missed the Pago Pago flight. Unfortunately, the Pago Pago American Samoa flights are only on Thursdays and Sundays so I'm stranded in Honolulu for three days. It won't be a complete waste – it gives me the chance to meet with folks at the International Tsunami Information Center (ITIC) who compile information on all tsunamis and also go to the Pacific Tsunami Warning Center (PTWC) and find out more about how the recent spate of warnings have gone from their perspective.

The most interesting piece of information I've gotten in the past day is an account from a family who were in a boat in Pago Pago harbor during the tsunami – courtesy of HSU alum Orion George. The most jarring part of this account to me is the failure to adequately educate people about what to do when they feel a strong earthquake near the coast. These folks should have immediately evacuated as soon as the shaking diminished enough for them to move. Instead they took the time to go on the internet! They were very fortunate – if the tsunami had been larger, they would not have survived.

"This morning (six hrs ago) we were shaken awake by an earthquake which seemed to have no end! We were aboard Gallivanter and tied side-to a big concrete dock in the heart of Pago Pago, American Samoa. And after living up & down the California coast, I knew this was no minor tremor.

After the rude awakening, Cath & I walked across the dock and chatted with a few of our fellow sailors, one of whom said that he's just done a Google search on "recent earthquakes" and said that it measured-in at 8.1 and the epicenter was only 120 miles distant.

We returned to Gallivanter and I turned on our laptop and searched the same website. Sure enough there it was... "8.1 earthquake - American Samoa - 20 minutes ago". I clicked on the "Show Map" option and noticed the epicenter was located south west of Pago Pago... which is located on the southern side of the island.

Just as I was considering the ramifications of that little fact... all hell started breaking loose! Our boat was on the move! My first reaction was to start the engine and dash up on deck to see what was going on. I witnessed the water around us was rapidly dropping! Rapidly! In a blink of an eye, we were on the bottom and the boat was falling away from the dock! Three of our big dock lines popped and we fell right over into the mud - the entire basin we had been floating in only moments ago had completely drained! People were screaming!

Next - the water came flooding back in at an even more alarming rate and the next thing I knew we were floating directly above the dock! Over the concrete slab and drifting toward a young lady we knew (from another boat) who was desperately hugging a power pole and up to her chin in

swirling water! I told Cath to cut the two remaining dock lines with our serrated bread knife and to be quick about it!

Right as I put the boat into gear, we were somehow washed back off the dock and into the basin as I advance to full throttle and we accelerated through a floating debris field of floating docks, fuel drums, sinking boats, a shipping container and a barnicle encrusted wreck all of which were spinning in the torrent of rapidly dropping sea level. It was absolute mayhem! As we steered out toward the deep water in the center of the harbor I looked over my shouder and saw what appeared to be a waterfall pouring off the dock and shore beyond. Not one of the dozen vessels remained at the dock. All were underway in a matter of seconds... with or without crews aboard.

We motored around in the middle of the harbor watching the waves of floods & ebbs while wondering about after-shocks and our fellow cruising sailors. As we passed one of our neighbors she shouted to us that her husband had been washed off the dock as they were trying to get away. She was alone and seriously concerned. Other boats broke free from their moorings and anchors in the initial seismic waves and many were driven ashore, or driven under by loose tuna boats.

After about three hours, we felt it was finally safe enough to return to the dock. All we had were lengths of old line and we were short a couple fenders. We were the first to go in and we started un-tangling lines and helping others get back along side the concrete dock. All of the store-fronts along the water are destroyed, roving mobs of kids can be seen looting, the fence around the dock is gone, every boat on stands in a nearby boatyard were washed away. Big fishing boats are now in parking lots across the street. Absolute destruction is seen everywhere along the shore.

Phones and power are down but we got back online right away and I immediately went back to the recent earthquakes website to see if things have been calming down in the center of the earth. A number of aftershocks as strong as 6.0 have been recorded over the past few hours - but thankfully no more wave action has been noticed. We've been making Skype calls to our families and letting others use the computer as well to phone home.

Online news reports say that the earthquake lasted three minutes and the highest flood rose 25 ft above normal! There are 20 confirmed deaths... including our neighbor who was swept off the dock. Most fatalities occured in and around the harbor where we live. Boats are battered and nerves are fried. One friend wound-up on his boat nearly 1000 feet away from the water after breaking from his anchor and sailing right down Main St. taking power & telephone wires down with his mast! Some people lost everything... including their lives. We came through remarkably well with only minor damage sustained to our toe rail when the dock lines parted and to our fender basket which was the only point of contact with that drifting wreck. I never felt any jarring loads while we were hurtling around above & below the concrete dock, so I believe our hull, keel & rudder suffered no damage from the wildest boat ride I've ever been on."

Day 3: Saturday October 24

The layover in Honolulu has had some positive outcomes. I was able to visit with Chip McCreery, the geophysicist in charge of PTWC and Brian Yanagi of ITIC. I first met Chip in 1997 when I was in Hawaii working on the strategic plan for the National Tsunami Hazard Mitigation Program (NTHMP). He was the director of ITIC at that time – it was a tiny office, just Chip and a part time staff person. Since then Chip moved to PTWC, the 2004 tsunami happened and both PTWC and ITIC have expanded. I had an informal discussion with Chip about what worked and what didn't work quite so well during the Samoa tsunami alerts. A fortuitous factor was that Vasily Titov, NOAA's top tsunami modeler and other members of the NOAA's Pacific Marine Environmental Laboratory's modeling program happened to be at PTWC doing a training on how to run the new

SIFT (Short-term Inundation Forecasting for Tsunamis) tsunami forecasting tool. Note - there are a lot of acronyms in the tsunami world. So they were able to assist in both the forecasts and in the discussions as the event ran its course. This was the first time SIFT was used in a fully operational manner at both tsunami warning centers. While it's a great tool – it could use a little refining to make it easier to use in an operational sense. Unlike the other forecast tools, its output doesn't automatically insert into messaging, and folks spent a lot of time writing things down on scraps of paper to later insert into messages. SIFT also creates simulations at a number of sites, producing a number of different screens and window all overlain on the same computer, making it sometimes hard to find the screen you want. But it's a huge step forward and these are minor bugs that shouldn't be too difficult to work out. When I first started working on tsunami issues, the idea of using modeling as a forecast tool dueing an actual event was unheard of. One other lesson had to do with the importance of a good PR person. Delores Clark, NOAA's long term expert Public Affairs person, was on another assignment during the tsunami event and her replacement wasn't nearly as skilled at managing the media, inadvertently letting them all into the operations core of PTWC – not a good idea have cameras and news folks intermixed with the forecasters trying to work the event. This is an important lesson – make sure the rules for back up public relations people are well spelled out.

I've know Brian Yanagi for a long time too. He was the State of Hawaii emergency services representative to the NTHMP from 1996 until 2005, lasting about 2 years longer as an NTHMP rep than I did. After the 2004 tsunami ITIC was able to expand and Brian joined ITIC director Laura Kong in international tsunami trainings and outreach efforts. I missed Laura on this trip – she is in Vanuatu at the moment. Brina took me to a viewing a the movie "The Third Wave", a documentary about a volunteer relief effort in the aftermath of the 2004 tsunami in Sri Lanka. This was the only showing at the Hawaiian International Film festival. It is the closest thing I've ever seen to putting you into the post tsunami aftermath and the volunteers who cobble together a long term relief-recovery program are inspiring. More about the movie at
http://www.thethirdwavemovie.com/Third_Wave/Welcome.html

And check out an interesting way of using Google for photos and eyewitness accounts at:
http://www.stuff.co.nz/world/2917454/Map-Tsunami-strikes-Samoa

Day 4: Sunday October 25

I'm finally under way again. Four members of our group are waiting in the Honolulu airport for the flight to Pago Pago (pronounced Pango Pango). Due to family emergencies and state bureaucracies our team has been whittled down to 6 – three engineers, an environmental scientist an anthropologist and me. The flight is boarding – hope to find a wifi hotspot tomorrow to update this.

Day 5: Monday October 26

I finally arrived in American Samoa last night – after a five hour flight where I was fortuitously seated next to a large Samoan gentleman who turned out to be the matai (chief) of the village of Leone on the western end of the island. Leone was one of the areas hardest hit by the tsunami – 11 of the 34 deaths attributed to the tsunami were in his village. He was very gracious and we had plenty of time for a long conversation about what happened in his village. He had tried to push tsunami awareness after the 2004 Indian Ocean event, but many people were apathetic. On Sept 29 many people evacuated on feeling the ground shake – there had been a number of education efforts over the past year – but many people used their vehicle and some got stuck in traffic. For a number of the victims, being very large was a liability. Some people were just too big to be able to quickly walk to higher ground.

Couldn't see much on the drive to Tisa's Barefoot Bar where we are staying. The amount of cleanup is impressive. Some damaged boats and buildings at the back of Pago Pago harbor but most of the coast looked surprisingly ok. Tisa's is on a beautiful little pocket beach with four fale (sleeping shacks) right on the beach. There was some flooding here during the tsunami but very little damage. I do plan to evacuate if a strong earthquakes hits in the night. Mosquito screens make our beds look regal. So far the trade winds have been pretty strong and I haven't noticed many insects.'

First real glance at the place was around 5 AM with day dawning. American Samoa doesn't have the big vast beaches of Hawaii, but the small beaches have pristine white sand, no people, no trash, and the Manau Island's to the east are supposed to be great for diving and snorkeling. It's a surprise to me that there little tourism here – to me this is a hands down winner over Waikiki. Very full day of meetings with officials from a variety of agencies to introduce ourselves, find out what was happening with their organizations and how we could collaborate with their efforts. First to FEMA who holds planning meetings every Monday, Wed. and Friday morning. We didn't have any official introduction, just the letters Marjory had provided us with our EERI affiliation (thanks Marjorie – they really helped). We ended up going right to the top meeting with the Federal Coordinating Officer in charge – who was surprisingly interested, genuine and supportive of what we were trying to do. Before going on this trip we had been warned that the response phase was still in full swing and to steer clear of all government agencies involved with response. The actual situation is quite different. Response was over and the recovery problems were looming large – top on the list debris removal and processing and health issues related to water supplies contaminated by damaged cess pools. Debris is a problem – tsunami debris is very dirty, generally a mix of sand, vegetation, metal and building materials. Fortunately they have adequate space for debris and the landfill and scrap metal yards are in close proximity. They try to do primary sorting of metal/no metal on site so that the debris only needs to be handled once. The traditional way of dealing with woody debris and vegetation is to burn. But much of the wood is pressure treated and the burning creates additional environmental issues.

Jeff examining truck that had been slammed into a wall in Pago Pago, American Samoa.

One of the group we met with was Joe Toland, head of the Department of Homeland Securities Geospatial Analys group – he's a whiz at GIS and space-based imaging and an alum of HSU's

international studies option in Environmental Systems masters program (he said hi to Steve Steinberg). He gave us a great number of maps and before/after space based images.

Met with the National Park folks. The park lands were barely impacted by the tsunami but park headquarters and visitor center is at the head of Pago Pago harbor where some of the highest water levels were observed. The building was destroyed along with many archeological artifacts, and all the computer data. Fortunately some of the computer data had been backed up and they were able to retrieve some data off retrieved C-drives, but some was lost. Another lesson – if its important, keep backup computer data in different locations. We spent a long time talking with the park archeologist who experienced the peak of the tsunami in Pango Plaza, one of the hardest hit areas. She is also from Leone and three of the victims were her sister-in-law and two nieces and a sister is currently in intensive care in Hawaii.

We met with territory officials in the afternoon and reconnected with the three engineers in our group. A lot of discussion on how to tackle some of the main recovery issues. Land use planning, building design requirements and cess pool – sewage treatment issues are at the top of the list. The planning team will need to present a recovery plan with recommendations soon to the territorial government and there are many touchy issues. Land ownership is complex and traditional in Samoa villages. Sewage treatment in low-lying areas is very difficult. No detailed tsunami hazard assessment has been completed here and 60 percent of residents are below the poverty line.

Final meeting of the day was with two FEMA disaster response workers. One was Jeanne Johnston, a 1946 tsunami survivor who has worked with Walt Dudley on collecting tsunami survivor stories for years and also led the State of Hawaii's tsunami program for civil defense for a few years. She sees the lack of a full hazard assessment for Samoa as a major problem and has been surprised that few NTHMP resources have been spent here outside of some Tsunami Ready funding.

Day 6: Tuesday October 27

A very full day of interviews and meetings. It rained heavily in the night – knocked out power and interrupted internet service for awhile. The rains pose a health risk. Both dengue fever and Leptisporis are on the rise because of the debris has created many pooling places for stagnant water. We were told yesterday of a man who was evacuated off island with swine flu, leptospirosis and dengue all at once. We spent the morning at the home of the park anthropologist we interviewed yesterday. Her home was right on the edge of the inundation zone and her pig sty was in it. She has a sow with 6 piglets and when she returned to her home after the tsunami, they had all survived but the sow had a high water dirt mark on it's neck. All of the piglets must have swum to survive. Her village is Leone where 11 people died – it was the single hardest hit in terms of human loss. The water heights weren't as high in Leone and the percent of damaged structures wasn't as great as in the nearby communities of Paloa (1 death) or Amenave (no deaths) where almost all structures were erased. The difference in the casualty rate is probably mainly related to the population of the village – Leone is much larger, but tomorrow we will visit Amenave and Paloa and may have more to add to the story. A number of larger buildings appeared to have little damage and we heard several stories of people surviving on the second floors. We spent some time looking at the pattern of damage in Leone. It was irregular – flattened buildings next to ones that appeared substantially undamaged. Impact appears to have played a major role . Vehicles, telephone boles, trees, boats and large containers were transported tens of meters and the size and character of impact had a major role in the severity of damage. In our cursory look, we saw little evidence of scour – just one location in central Leone where the scour was noticeable.

Leone had the largest loss of life in American Samoa.

We met with Don Vargo of the American Samoa Community College and several colleagues. Don and his research assistants have helped a number of visiting scientific teams and their translation help has been essential to getting accurate accounts from people who only speak Samoan. We had a lively discussion about what could be done to improve education efforts and institutionalize the lessons of this event. A top priority is a good tsunami hazards map for the territory. While there are a number of generic tsunami hazard zones posted, there is no information on how high or far people need to go. Over evacuation was common on September 29. With credible hazard zone maps it would be possible to create walking evacuation routes and evacuation areas. With evacuation routes, village evacuation drills could be held – maybe a good goal is the one year anniversary of the tsunami.

Today CNN released a video report of the tsunami warning system performance in the tsunami - http://edition.cnn.com/2009/WORLD/americas/10/27/asamoa.tsunami.warningsystem/
No question that there is a need to improve the warning system but I wish they had put equal emphasis on the importance of continuing to improve education efforts. A predominant theme of our visit has been how successful the education efforts of ITIC and some locals were. During September as part of National Preparedness Month activities, one of the 2004 tsunami documentaries was shown repeatedly on local television.

Day 8: Wednesday October 28

We've become acclimated to life in Alega. The sound of the waves is wonderful to sleep too – although people who experienced the tsunami find it traumatic and few people have returned to living in the harder hit coastal communities even if their home wasn't damaged.

Post event surveys are a mix of meetings, field work, interviews, dealing with set backs, and logistical planning. This morning was spent dealing with our travel plans to Samoa and getting and official ok from the Samoan government to work there. Flying from Pago Pago to Apia (a 30 minute flight) is not something you can just book online. We spent much of the morning at the airport afrranging the flight schedules for 5 people with 4 different itineraries. There are 3 carriers – one that has 5 flights a day but evidently just went out of business – their office is dark

and they don't return calls. One with pressurized cabins, AC and "large" planes that carry 30 people but they have run out of fuel and aren't flying for the next 2 days. And finally Polynesian Air which has flying culverts but is still in business and has fuel. Apparent success – we'll find out for sure tomorrow.

More logistics – calls to the director of the International Tsunami Information Center – a NOAA funded organization that now works through UNESCO to coordinate tsunami preparedness efforts throughout the world. For the first time, UNESCO has developed a protocol for visiting scientific teams responding to the Samoa tsunami event. It's important for reconnaissance teams to collaborate with in-country scientists and other researchers and government officials. Over 60 international researchers have visited Samoa since the tsunami including teams from Japan, the US, Australia and New Zealand. A team from Cambridge, England is due to arrive the day I leave. Coordination is also important to avoid duplication of efforts and build on the findings of other groups. UNESCO is also committed to making sure that these teams share their information with the host country so that they benefit from the research teams' efforts. Some groups in both this and past events have operated outside of government sanction – partly because of the need to quickly get perishable information, and sometimes because the official route can be cumbersome. In 1998 after the Papua New Guinea tsunami, I was all set to leave with a group of 5 international scientists when the PNG government pulled our permission 24 hours before the plane left. It took a month to solve the problem and in the end only 2 of us were able to go. I think we've got our bases covered this time, but one never knows.

We spent the afternoon looking at the hardest hit areas on the western end of the island and talking to survivors. Don Vargo of American Samoa Community College provided a Ford Tundra capable of making it over the steep roads and two research assistants to drive and provide translation. First to Poloa on the NW tip of the island where only one home in the coastal portion of the village survived without damage and one person died. The earthquake occurred around 6:40 AM and children were just leaving their homes to go to school. One mother tried to get her kids into a car when she saw the water withdraw. The coastal road parallels the coast and driving would have increased their exposure. Fortunately the oldest child had studied about tsunamis and insisted they run up the hill behind their house.

Church in Poloa withstood the tsunami but was flooded and filled with debris.

There were two substantial buildings in the town – a catholic church and a school – both of which were less than 2 years old. The tsunami reached to at least the first story roof level on both structures. The school was destroyed – the structural columns resisted the tsunami but all the walls were blown out. The church was structurally intact – the windows were gone and the interior contents badly damaged but by the time we visited it had been cleaned up and it will be used tomorrow when the funeral for the one tsunami victim will be held.

After Poloa, we went to Amenave, another village where almost all of the coastal buildings were destroyed. But even though the population of Amenave was larger than Paloa, no one died. The mayor of the village used his bullhorn to warn the people about a possible tsunami after he felt the earthquake. He had attended a training several months ago sponsored by the Smoan Affirs Office for all village mayors on tsunamis. Many people ignored him on his first run through the village, so he ran through again and saw the water recede. That finally triggered people to move. This seems to be a recurring theme – relatively few people were willing to act on the ground shaking alone. But seeing the water recede definitely got them moving.

Aveao Faausu Fonoti, Mayor of Amanave, showing us the bullhorn he used to notify his village that a tsunami was coming.

Day 8: Thursday October 29

Today was a change islands and countries. We flew Polynesian Airlines from Pago Pago to Apia in an 18 passenger prop plane that flew low enough to not need pressurization of air conditioning. No security screening and we can carry as many liquids on board as we wish. Checking in involves getting on a scale with all your luggage so they know the total cargo weight. I had a front row seat and there was no door to the cockpit so I could watch the pilot and the controls. We were able to

see some of the tsunami-damaged areas on the east end of Tutuila (the main populated island of American Samoa). Much of Tutuilla is steep and the damaged areas were confined to pockets of low lying villages near the mouths of coastal rivers. The flight is just over 30 minutes. We can see some of the damaged areas along the SE coast of Upolo, the more populated eastern island of Samoa. Even from afar, the damage looks more continuous than on Tutuila. Apia is located on the north side of Upolo.

As in American Samoa, first on our itinerary is to introduce ourselves to UNESCO and government officials to sanction our field effort. First is a meeting with Jan Steffan, the UNESCO science coordinator for the Pacific region and the interface between scientific teams and the Samoan government. He had spent two years in Indonesia before this assignment and had spent much time in Padang in the aftermath of the 2004 Andaman-Sumatra earthquake and tsunami. He knew several of the people I had worked with on the 2005 Sumatra post-tsunami survey. We explained the purpose of our trip and how our work was not just a repeat of the previous team efforts. He agreed that our expertise and focus would add to what had already been done and forwarded his approval to the Samoan Government. We have an appointment to meet with an official of the Department of Environment and Meteorology tomorrow morning for the final ok.

After the meeting, there wasn't much time left for work. We took a quick drive over to the south side of the island and looked at some of the areas that were hit. Samoa consists of two main islands Upolo and Savai'I both of which are larger than Tutuila. The population is more thant 2.5 times larger than American Samoa. Upolo was the hardest hit by the tsunami. Unlike Tutuila which was located nearly perpendicular to the orientation of the earthquake fault that caused the tsunami, Upolo was a little to the west of the maximum wave energy. Major damage was confined to the SE coast and no damage occurred on the north coast where Apia and the most populated part of Samoa is located. If a future tsunami generating event has a slightly different orientation, the outcome for Apia could be different. One of the major needs for both Samoa and American Samoa is a credible tsunami hazard map that addresses the likely maximum inundation for tsunami sources both nearby and elsewhere in the Pacific. It is very difficult to locate evacuation sites and evacuation routes if you don't know where the safe areas are. On September 29, many people over-evacuated, driving as high up as they could, causing traffic problems. The lack of a well defined evacuation zone also may have encouraged people to use cars to evacuate as they didn't realize that in many cases they didn't need to go far to be in a safe area. Hazard assessments are based on numerical modeling efforts, past tsunami inundation and water height measurements and, when available, paleotsunami deposits. All of this information needs to be pulled together to see if what happened on September 29 was the worst likely event here, or what might produce a greater impact.

We looked at the Coconut Beach Resort near Maninoa. This was a well-landscaped, high-class resort with a beautiful beach and spa that catered to international visitors. There were about 90 guests on September 29. The earthquake was felt strongly but no one connected the earthquake and a possible tsunami. Fortunately the nearby resort of Sinelei was run by a general manager who was more aware to the relationship between shaking and tsunamis. Sinelei had installed a siren and also practiced evacuation drills. They also had developed a protocol for evacuation events with a staff person grabbing a list of the clients. On September 29, Sinalei was able to quickly ascertain that two guests had not left their rooms and staff were able to find them and help them evacuate before the worst surge arrived. People at nearby resorts including Coconut Beach heard the alarm and all but one person was able to escape. One woman tripped while evacuating and was caught in the water. Coconut Beach also provided an interesting example of tree resistance to the force of the water. Smaller diameter trees were bent while the larger ones resisted the flow. Although Coconut Beach did not have plans for a tsunami, they did respond

quickly after the event – and were the first to arrive at the hospital, to deposit the 12 injured guests. They were quickly rebuilding and hope to be open for a limited number of guests in February – and they plan to include information about natural tsunami warnings in guest literature.

Day 9: Friday October 30

A morning meeting with the government official who has been overseeing the scientific teams. The Samoan Government, UNESCO and ITIC developed "Terms of Reference" for all research groups working in Samoa to address. We got the ok to work in the country, but were asked to focus on two of the seven tasks defined:

6. Collect information on human and community vulnerability and resilience factors at work in different places: i.e., what made a particular community resilient or vulnerable?;
7. Where possible, to map the above information.

Other tasks included mapping inundation and water levels, measuring environmental and ecosystem impacts, collecting tsunami deposits, looking at damage to structures, and recording survivor stories. We were also asked to include a government official during all of our field work. We were assigned a young meteorologist in training who had been educated in New Zealand. He was very pleasant but it did mean changing our transportation plans. We had arranged a 4 person car and Samoan guide-interpreter which worked fine for the three of us. This added an hour delay while we arranged to rent a different car for the day.

Drove back to the south side of Upolo. Passed the Robert Louis Stevenson Museum on the way. Stevenson spent the last 5 years of his life on Upolo and is buried nearby on the peak of Mt. Vaea. Our first stop is Poutasi Village where 9 people died including 3 children. All villages in Samoa consist of a swath of land the runs from the coast to higher elevations in the mountains where plantations of coconuts, bananas and other crops are grown. Most people lived in houses near the coast before the tsunami, but many had sleeping fales (open air covered platforms) and other small structures in the plantation areas. Poutasi is particularly vulnerable because a river runs behind most of the coastal houses and the only access to higher ground is along a road running parallel to the beach and a bridge near the mouth of the river.

Most of the houses in Poutasi were flattened – all that remained were the concrete slab foundations. But one house right by the beach looked practically untouched and we wondered if it had been rebuilt. Most of the people who lived near the coast have moved up to the houses and fales in the plantation area and there was almost no one in what remained of the coastal part of the village. We were lucky - the man who owned the home was working on it so we were able to get the story of what happened during the tsunami and a clue to why the house had so little damage. The man's mother lived in the home – his house was further inland. After feeling the earthquake, he ran to his mother's home because he thought "something bad might happen", and arrived just in time to see the water recede. He knew there was no time to get to high ground so he stationed his mother beneath the front porch on the landward side of the house and told her to hang on to the door and window frame. Just as he got her positioned, the first surge caught them. He was carried by the surge across the street and managed to grab a tree and climb up it. He could see his mother still hanging on to the house – the porch provided an air pocket for his mother. The second surge was larger, but she still managed to keep her position and both of them survived. The house was wood frame and only a few months old. He had added lots of cross bracing and the home was secured to the foundation. He had also reinforced the coastline in front of his house with basalt boulders. There was no coastal reinforcement on the adjacent home where erosion had undermined the structure.

Next we talked to a matai of Poutasi. He and his son were restoring the boulders around a family grave. In Samoa, relatives are buried in front of the home. It is the responsibility of the children to maintain the grave sites of their ancestors. The graves are also proof of ownership in a country where there are no deeds and titles. Throughout Poutasi and elsewhere in the damaged areas, the graves were the first structures to be cleaned and restored – and the sight of a newly whitewashed family tomb topped with bright flowers is a jarring contrast to the destroyed structures around it. The matai lost three of his grandchildren in the tsunami. The earthquake woke him up. His son, daughter and three grandchildren were getting ready to go to school and had gotten into the cab of a truck. He got into the back. The tsunami caught the truck and rolled it. The three adults survived but the children didn't. After the tsunami, some people from higher up or other villages came down to the damaged areas to help find the missing. In some cases, they also helped themselves to any belongings they found in the damaged areas. This turned out to be a recurring theme – the "gaoi" (cheater, thief), who came into damaged areas as soon as the water retreated. The matai said that no one is thinking of rebuilding right now – everyone is scared and staying up in the plantation areas. They might only have guest fales in the low areas – places for people to sit and visit during the day – and have all the residents in the plantations. The Samoan village structure has several advantages in responding to a tsunami. All of the villages have land up high, everyone in the village group and anyone in the village can use the upland land as long as the matais approve. This is the first major disaster that I have visited where there are no relief camps or shelters for the simple reason that everyone has relatives they can stay with.

Day 10: Saturday October 31

Last full day of field work in Samoa. We made an early run to the flea market to look at how the tsunami was being commemorated. Tsunami lava lavas (sarongs) and t-shirts were being sold at a brisk clip. We've seen 6 variations so far – a simple date, "I survived the tsunami", "morning of tears", "tears of sadness", "Trust in God tsunami", and "stay away from tsunami". I am particularly interested in how societies memorialize events like this it and if any of the methods become institutionalized. Stamping "tsunami" on cloth goods is one of the first of the memorial signs. Samoans print T-shirts for many events such as track meets, youth groups, and so forth, so it's not surprising to see the tsunami goods showing up. Although the tsunami products were selling briskly in the flea market, only one person in our group has seen anyone wearing them and it is not clear if the intended market are tourists or residents.

Today our driver-guide is off with the two engineers in our group so we asked his sister, the owner of the place we are staying, to accompany us. She is a former Pan Am and United flight attended who grew up speaking both Samoan and English. Turns out she is a terrific translator. Her brother would often tend to give a one sentence translation after the interviewee had spoken for a number of minutes. Frustrating not being able to speak the language – so much is lost in translation. We also have the same meteorology trainee accompanying us today.

We drive along the north coast and around the east side of the island. First stop is the village of Amaile. It wasn't affected by the tsunami but is a very important village in Samoan history and a very powerful family still lives there. It was interesting to me because it was intact and gave us a picture of what the coastal villages may have looked like before the tsunami. We began seeing damage just south of Amalie. First village we stopped at was Sale'a'unaunua. We were fortunate in having a woman translator with us because we were an all female group and were able to talk to a group of young women that I don't think would have been as willing to talk to us if we had been a mixed group. One of the women had gotten caught in the tsunami and her leg was stuck by debris. She was barely able to escape when the second wave came. They were aware that tsunamis could follow earthquakes but admitted that evacuating on feeling the earthquake would

have been embarrassing and they didn't want to appear foolish. Of course now they have no such reticence – any felt earthquake sends everyone inland.

These two young women in Sale'a'unaunua were embarrassed to evacuate after feeling the earthquake because a group of young men were nearby and would think them foolish. They were caught in the tsunami and barely survived.

The next village was Lalomanu at the SE tip of the island. This was one of the hardest hit villages – the lower parts of the town were completely erased and many people died. Almost everyone has moved away from the coastal area so at first we thought it would be hard to find someone to talk to. One part of the town is high and the houses survived. Our translator hailed a woman in front of one house in Samoan – she replied in English that she didn't understand Samoan. She was the daughter of the people who lived in the house – a Samoan father and a Maori mother and lived in New Zealand. She arranged for her father to talk to us. He probably had the best view of the tsunami as anyone in his village. The earthquake was strong enough to cause some damage to his house. He was watching the ocean when he saw the water recede and thought that maybe the same thing was about to happen here as in Indonesia. But he was rooted to the spot and not able to move. He could hear a roar and see water piling up. His son finally grabbed him and pulled him to the front of his house. The tsunami surged through the house, reaching the roof line and stopped a few hundred yards in front of it. He lost all of his appliances and the house was filled with a foot of muck afterwards. His house was built only three years ago and had no serious structural damage but he doesn't like living here any more. It takes him two beers to fall asleep. Several people have mentioned that drinking has increased since the tsunami. His wife is having a very hard time and will go back to New Zealand when his daughter leaves. He was very frustrated by the lack of information about what happened in the tsunami and the initial media reports that suggested the entire south coast had been destroyed.

The physical toll of the tsunami is striking. Even a month afterwards and the removal of much debris, the losses are startling. But the mental toll is also evident. We've met a number of people with close relatives that have left the country. While the Samoan village culture is very supportive

of people who lost homes, a few people have told us they are concerned about those who are mentally struggling. There is a fear of being identified as crazy and the villages have few resources to help people with long lasting trauma. In most natural disasters, mental trauma expresses itself in a number of ways including an increase in child and spousal abuse, divorces, alcohol abuse, and crime. The areas hardest hit by the tsunami were also some of the poorest in the country and were under stress before the event. The biggest industry was tourism and all of the beach hotels and fales were destroyed.

The last village we visited was Tafatafa and a small resort with beach fales. At first glance we thought the tsunami had somehow missed this spot. Not a piece of debris remained on the beach or the wide lawns. A row of beach fales stood along the coast and the house back a few hundred yards from the coast looked ok. On closer inspection all the fales were brand new and the house foundations were seriously undermined. The owner turned out to be a relative of our interpreter and he explained that his two boats and all the fales had been destroyed in the tsunami and water had swept through his house. He recognized the ground shaking as a sign of a tsunami and got everyone in his family into a car and picked up some elderly neighbors and got them to safety. All of the cleanup and rebuilding had been done by the family – they had gotten no government assistance. They were ready to reopen for business. It was an uplifting way to end what had been a very hard day.

Day 11: Sunday November 1

Our field team became smaller today. Two team members (Heather and Jen) head to American Samoa and then back to the mainland. It's been seven days of working from before 7 AM to past 10 PM and we've become strongly bonded. It's sort of a breaking of the "fellowship". I'm also tired - the field days are so full that there is little time to transcribe notes, download and sort photos and, if the internet is working, try to keep on top of my day job. Right now I'm about 3 days behind.

Sundays in Samoa are for church, family and reflexion. I spend the day at the Hidden Gardens condensing what we've done into the outline of a report. Since our assignment in Samoa was to focus on community vulnerability and resilience, we've developed a framework that defines resilience and vulnerability as a process rather than a product. It covers both pre- and post-event components and short and long term perspectives. Perhaps the most important issue that has jumped out of our visits both here and in American Samoa is that most people tried to do the right thing. Some were spectacularly successful like the Sinalei Resort manager who had a siren, practiced evacuation drills, and sounded his siren on feeling the earthquake. He could not have performed any better and his prompt action likely saved hundreds of lives both at Sinalei and at nearby resorts where people could hear the siren. Most people, however, needed more than the single trigger of the earthquake shaking to get them to take action. Studies of human behavior have shown that many people need a second or third signal before they will respond. At Coconut Beach next to Sinalei, people didn't respond to the shaking, but did to the combination of shaking and the neighboring siren. The most common second signal was seeing the water recede. The tide gauge recordings at both Apia and Pago Pago show that the first wave arrival was actually a small positive wave – the water rose initially. But the amplitude was very small and we haven't talked to anyone who noticed it. This was followed by a substantial drawdown the sea floor exposed in many areas. Unlike many stories from Indian Ocean countries where people were drawn to the ocean by the receding water, everyone in both Samoa and American Samoa recognized this as a danger signal. But there was still a lot of confusion – confusion on how far inland or up to go, confusion about multiple waves. A number of people headed back into the inundation area after

the first wave retreated – usually to look for relatives – and were surprised by a larger second or third wave.

I've been mulling over a number of themes that my teammates and I have noted over the past 5 days we've been in Samoa, and how the situation here differs from American Samoa. One topic I'm interested in looking into further is altruism. In every disaster there are stories of people taking action that puts themselves at risk for people who may be total strangers. While these stories sometimes are noted in the newspaper, I'm need to see if much work has been done on this topic from the natural disaster perspective. I'm only aware of altruism as an academic topic because of the work of the Oliners at HSU who have made a career of examining altruism in the context of the holocaust. I never thought of it before as having a relationship to natural disaster response – but now the connection seems obicous.

I'm not making much progress pulling together the report. It's hard for me to work without internet access. I'm so accustomed to pulling up various web sites to fill in holes and answer questions. A diversion mid afternoon when a young woman shows up at the Hidden Garden to claim her luggage before flying back to New Zealand. In the course of our conversation about who we were, what we were doing and how long we were staying she tells me the Wednesday flight I've got from Pago Pag back to Honolulu has been cancelled. I'm hoping this is only a rumor – I'll deal with it tomorrow when I'm back in American Samoa.

Day 12: Monday November 2

Switching island day. We have an exit meeting with Ausetalia, the Government Official from the Ministry of Natural Resources, Environment and Meteorology who has been coordinating the overseas group. One of the stressful aspects of post-event reconnaissance is the need to synthesize our field observations to brief officials. We emphasize the preliminary nature of our remarks and the likelihood that some of our ideas may change and others added once we've had the chance to examine and thoroughly discuss our field data. Our conversation starts with the need for tsunami hazard maps that consider not only the September 29 event but other possible Pacific sources. Everything else builds upon a credible estimate of hazard – signing evacuation zones and routes, placement of evacuation/assembly sites, zoning and engineering design discussions, and educational messages. We also suggested some ideas for mapping the vulnerability of villages to tsunamis. A simple first step could be to time how long it takes to walk to a safe area and consider all areas that take ten minutes or longer problem zones that need to improve access to high ground or consider changes in land use. Our discussion touched on a number of other areas – education and outreach, building on the village structure to promote tsunami safety, design of coastal structures, formal and informal notification systems, and the need for better planning to coordinate warning response for far field events.

The skies are clear for our flight back to American Samoa and I get a good view of Amenave and Leone before we land. I check with Hawaiian on the status of my outbound flight and confirm the rumor is true. The Wednesday flight has been cancelled so I can't leave until late Thursday which means changing the rest of my itinerary and missing another day of class. I've got a tight connection in Honolulu which makes me a little nervous. Get a good view of the scrap metal yard as we leave the airport. Tomorrow is a "debris day" and we hope to learn more about how the debris removal process is going.

Day 13: Tuesday November 3

The California State Lands Commission is one of the agencies that is helping to sponsoring our trip. The Commission's interest in tsunamis is from its responsibilities for the safety of tankers off- and on-loading crude oil and processed petroleum products in the state and establishing safety regulations for marine oil terminals. They funded a project I worked on a few years ago looking at the tsunami hazard associated with marine oil terminal sites within San Francisco Bay. So today we visit the tank farm and fuel dock in Pago Pago harbor. The dock and tank farm are on government land and operated by BP. Tankers typically arrive twice a month to supply American Samoa with gasoline, diesel, fuel oil. Fortunately no tanker was in the area on September 29. The tank farm and fuel dock are located on the western side of the bay. Pago Pago harbor was one of the most heavily hit areas in American Samoa. Most of the water heights on the southern side of the island were in the 6 to 12 foot range. The harbor is shaped like a twisted triangle with a one mile wide mouth narrowing to less than a quarter mile at its head. This shape concentrated the flow and the International Survey Teams measured water heights of over 20 feet at the head of the bay. The Pago Pago tide gauge is located about 400 m west of the fuel dock and recorded peak water heights of about 7.2 feet above the mean tide level, with a maximum peak to trough oscillation of 12 feet. Observers at the fuel dock noted that the water came nearly to the dock platform but saw no water on the platform. The tank farm, on higher ground inland of the highway, also remained dry. We spoke with the safety officer and the managing engineer of the site who were concerned about what might have happened had a tanker been at the site. Their main worries were the currents, estimated between 12 and 16 knots, that might have been strong enough to pull the tanker away from the moorings if it had been at the dock. Two tuna boats double docked on the opposite side of the bay at the Startkist tuna cannery were reportedly broken loose of their moorings (we're still following up on this story to get more details). The BP staff were concerned that the mooring bollards, the metal posts for connecting the mooring lines from the ships to the dock, would not have been strong enough to resist the flow. They thought that the mooring lines would have held but the two 50 ton and six 25 ton bollards might not have been sufficient to restrain the tanker. They are proposing replacing two of the smaller bollards with 50 tons. There were no problems at the tank farm. The facility is new – the oldest tank in the tank farm was built in 1989 and the newest in 2002 and all are built to resist seismic zone 4 shaking.

Next on the agenda was debris disposal. The first day we were in American Samoa, we heard an estimate of about 65,000 cubic yards of tsunami-generated debris. The debris is hand sorted on site into scrap metal and non-scrap, potentially hazardous materials like batteries and fuel drums removed, and the remainder sent to the Futiga landfill. Landfills are particularly problematic in tropical islands with limited space and high rainfall. The Futiga landfill is already nearing capacity – before the tsunami it was estimated to be filled in two years. It's rather startling to see this large landfill tucked in the verdant valley adjacent to farms and homes. At the moment the tsunami debris are being piled on the edge of the landfill while the normal refuse is being incorporated into the main fill. There is a currently a debate going on as to how to process it – whether to do some compacting processing such as incineration before putting it into the landfill.

Day 14: Wednesday November 4

Last field day. We wanted to hike down to Massacre Bay but Don Vargo said it wasn't a good idea. There is no good trail and it would be too easy to get disoriented. Instead he offered to go with us to the north side of the island. Afono was another community success story. The village suffered significant damage but no one died. The school was another example of how pre-planning and drills led to success. They had been practicing drills for over 10 years. On September 29, most of the children had just arrived when the earthquake occurred and everyone knew exactly what to do. The school cafeteria was badly damaged. We talked to two cousins – one a teacher at the

school who helped lead the evacuation and the other who rescued his aunt. This was another example of how important long interviews are. Early on in our discussion we asked if anyone had been injured and he said no. About 15 minutes later we asked why he had bruises and bandages on his legs. Turned out he had to dive under the water and banged his legs on the side of the house in order to rescue his aunt.

Highlight of the day was umu at Tisa's. Umu is the Samoan version of a luau. Instead of digging a pit, wet banana leaves are laid out on the sand and layers of meats, sea food, breadfruit, squash are stacked in between more banana leaves and coals heaped over the entire pile. Delicious. And afterwards, the coals and leaves are picked up and the sand looks untouched.

Day 15: Thursday November 5

We spent the morning working on our powerpoint for a presentation at American Samoa Community College. Exit briefings and presentations serve several purposes. It's important to pull notes together into a framework of preliminary lessons learned before you leave and get caught up in everyday activities and it is equally important to share your findings with the host country. On our way to the College, we had a look at the power plant in Pago Pago. The tsunami had reached up to the second floor of the plant taking out all of the generators and leaving car carcasses in the back. The island is still operating on portable generators. Not good to have your critical facilities in a tsunami inundation zone. The presentation at the College was sparsely attended – they may have been getting tired of tsunami presentations – but the group in attendance were a good audience.

The departure scene at the airport was unforgettable and has firmly fixed Samoa as a very special place in my memory. There are only two flights from Honolulu in and out of American Samoa every week. Smaller planes fly to Samoa or to the other islands in American Samoa, but that is the full extent of the airline traffic. The arrival/departure of the Hawaiian jet is a country-wide event. Everyone who leaves or arrives is attended or met by many of their friends and relatives and some Samoans have a ritual of just going to the airport even if they don't know anyone flying, because it's the thing to do and they will probably run into many acquaintances. I was surprised by how many people we knew who hugged us and gave us going away presents. I've never felt so welcomed before. This is a wonderful place and I look forward to returning under more pleasant circumstances.