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Dear Harry:

In your e-mail to me of 1 September 2006, you said you would like to distribute my letter to you of 25 August 2006 to the participants. I am sending the letter herewith in electronic form, for distribution. The original letter follows, with a few corrections.

I have just read again the e-mail you sent on 11 July 2006 in regard to the NSF tsunami workshop, scheduled for Hilo, Hawaii, 26-28 December 2006. You say:

"...it is time to go back to fundamentals, reviewing and re-evaluating basic theories and analyses associated with critical topics of tsunamis.... The critical topics may be: 1) fluid and debris-impact forces on man-made and natural objects, 2) mechanism of and mathematical analysis for tsunami scour, sediment transport, and deposit, 3) mathematical modeling for human behaviour and casualties."

This is a mixed bag. Topic 3 is very different from either Topic 1 or Topic 2. Another approach would be to consider Topics 1 and 2, and take advantage of the location of the workshop to lead into these topics - Hilo, Hawaii, with its history of tsunamis, the Pacific Tsunami Museum which is in Hilo, and the following reports:

Designing for Tsunamis: Seven Principles for Planning and Designing for Tsunami Hazards, National Tsunami Hazard Mitigation Program (NOAA, USGS, FEMA, NSF, Alaska, California, Hawaii, Oregon, and Washington), March 2001, 60 pp.

Designing for Tsunamis: Background Papers, National Tsunami Hazard Mitigation Program (NOAA, USGS, FEMA, NSF, Alaska, California, Hawaii, Oregon, and Washington), seven background papers developed for Seven Principles for Planning and Designing for Tsunami

Hazards, March 2001, various pagination. Available online at http://www.prh.noaa.gov/itic/library/pubs/online_docs/Designing_for_Tsunamis.pdf

Development of Design Guidelines for Structures that Serve as Tsunami Vertical Evacuation Sites, by Harry Yeh, Ian Robertson, and Jane Preuss, Washington State Department of Natural Resources, Washington Division of Geology and Earth Resources, Open File Report 2005-4, November 2005, 34 pp.

Analysis of Structural Damage from the 1960 Tsunami at Hilo, Hawaii, by Hudson Matlock, Lymon D. Reese, and Robert B. Matlock, University of Texas, Structural Mechanics Research Laboratory, Austin, Texas, prepared for the U.S. Defense Atomic Support Agency, Washington, D.C., Rept. DASA 1268, March 1962, 95 pp (incl. 50 photos of damage, and two large mosaics of vertical aerial photos, prior to and after the tsunami).

The tsunami evacuation map from the civil defense section of the Hilo, Hawaii, telephone book is reproduced on page 50 of *Designing for Tsunamis*. The workshop is being held within the evacuation zone. A copy of this map should be given to each participant, and the **Plan for Evacuation** described by a member of the County of Hawaii civil defense staff.

Remind the participants of a statement by K. Horikawa and N. Shuto:

"It is quite dangerous to believe that the violent attack of tsunami can be completely prevented by man-made structures. Based on past experience evacuation to a safe area and before tsunami attack is the best recourse for the inhabitants. It is incorrect to depend too much on the functioning of coastal defense structures."

("Tsunami Disasters and Protection Measures in Japan," *Tsunamis - Their Science and Engineering*, eds. K. Iida and T. Iwaki, Terra Scientific Pub. Co., Tokyo, 1983, pp 9-22.)

The **Pacific Tsunami Warning System (PTWS)**, with 26 international members, should be described, and how it operates. The regional tsunami warning center for Hawaii, and which serves a broader Pacific-wide function, is the **Pacific Tsunami Warning Center (PTWC)** at Ewa Beach, Oahu, Hawaii. It is operated by U.S. NOAA's National Weather Service. This should be described by the Director, or one of the staff.

The photo on page 10 and another photo on page 41 of *Designing for Tsunamis* shows a bore advancing inland at Hilo; the 1 April 1946 tsunami. [One of the tsunami waves running up Waianuenue Street in Hilo is in my chapter "Tsunamis" (page 283), in *Earthquake Engineering* (1970).] Damage in Hilo from the 1946

tsunami is shown on page 42, and from the 1960 tsunami is shown on pages 13, 29, 32, and 47 of *Designing for Tsunamis*.

The photographs illustrate what has occurred in Hilo. Follow this by describing and showing at the site what has been done in Hilo as part of their tsunami mitigation strategy. Refer to the Hilo Downtown Development Plan, page 27 of *Designing for Tsunamis*. The original plan was adopted in 1974, and superseded in 1985 by the Downtown Hilo Redevelopment Plan under authority of Chapter 27, Flood Control, of the Hawaii County Code. Two examples are shown in photos; open space at the bay front (page 18) and an elevated restaurant (page 25).

After setting the scene, refer to Principle 3 in *Designing for Tsunamis: Locate and Configure New Development that Occurs in Tsunami Run-up Areas to Minimize Future Tsunami Losses*. A case study is given; it is the Hilo Downtown Development Plan (page 27).

One mitigation strategy by type of development is (page 25):

"3) High-Rise Hotels. New hotels in coastal areas are typically multi-level concrete frame structures. The lower levels of these buildings can be designed for public areas such as lobbies and support uses (such as parking) for upper level rooms. In Hawaii, for example, lower levels of hotels have been designed to allow waves to pass through the ground floor parking, lobby, and service spaces, leaving upper level rooms and meeting spaces undamaged. These buildings must be designed to withstand both tsunami and earthquake forces."

The several hotels on Banyan Drive along the bay front in Hilo are of this type, I believe; including the Hilo Hawaiian Hotel, which is the workshop site. [This should be checked; were they designed and constructed in accordance with the above?] Someone from Hawaii could speak on this.

This can be expanded. Principle 7 in *Designing for Tsunamis* is **Plan for Evacuation**. This principle includes a section on the **Role of Vertical Evacuation in Reducing Tsunami Losses**. It is stated on page 48:

"New buildings to be designed as vertical evacuation shelters must have sufficient structural integrity to resist expected tsunami forces and earthquake groundshaking for tsunamis originating locally. Building codes and other applicable standards should ensure the tsunami and earthquake resistance of new buildings. These standards should go beyond the minimum life safety requirements of most locally-adapted codes."

This leads to the Yeh, Robertson, and Preuss (2005) report cited

above, *Development Design Guidelines*. This, in turn, can be expanded by including a case study, such as a hotel that was planned for the north shore of Oahu, Hawaii, just west of Kahuku Point. [Was this hotel built? If so, was it designed and built in accordance with the report cited below? This should be checked.]

Structural Design Criteria for Tsunami Loads on the Kuilima Hotel: Final Report, prepared by R.E. Lowe, of Richard R. Bradshaw, Inc., Structural Engineers, May 1971, 78 pp.

This can be expanded by presentation of papers with specific details, such as the recent paper "Inundation Velocities in Banda Aceh Estimated from Video Recordings of the 2004 Sumatra Tsunami," by Tsutomu Sakakiyama, Hideo Matsutomi, Sindhu Nugroho, Yoshinobu Tsuji, and Yoshikane Murakami (2006, 8 pp; this was sent to me by Dr. Sakakiyama a few weeks ago, without a publication citation). Or, an old paper on forces exerted on a vertical circular pile by a broken wave (similar to a bore) in the surf zone: "Forces Induced by Breakers on Piles," by Robert L. Wiegel, *Proceedings of the Eighteenth Coastal Engineering Conference, Nov. 14-19, 1982, Cape Town, Republic of South Africa*, ed. Billy L. Edge, ASCE, 1983, Vol. II, pp 1699-1713)

Why have I made this suggestion? First, the workshop is being held in Hilo. Second, I have already thought much about the subject. Some of my ideas are in the Introduction of: *Tsunami Information Sources. Part 2*, by Robert L. Wiegel, Univ. California, Berkeley, CA, Hydraulic Engineering Laboratory Report UCB/HEL 2006-1, 18 April 2006, 36 pp.

It is evident from a review of many of the sources in the report that much is known about what to do (or not to do), and how to assess tsunami hazard and risk. But, decisions must be made, and implemented, and this is often difficult. Mitigation works may affect the quality of daily life, inconvenience/convenience, and efficiency of use of the waterfront. They involve choices, tradeoffs and risk; they also involve adjustment. The meaning of the terms adjustment and risk will be given subsequently.

An example of a tradeoff is the use of seawalls. In Hawaii, it is difficult (perhaps nearly impossible) to get a permit to build a new seawall. Experience in the Sumatra tsunami of 26 December 2004 has shown the value of seawalls in protection from the tsunami (*Sumatra - Andaman Islands Earthquakes and Tsunami of December 26, 2004 Lifeline Performance: Preliminary*, eds. Carl Strand and John Masek, ASCE Technical Council on Lifeline Earthquake Engineering, TCLEE Monograph No. 29, Oct. 2005, 270 pp).

Much is known about damage to structures and infrastructure by tsunamis, or destruction, and to injury and loss of life

(public safety), on land and in harbors. This includes secondary damage such as oil spill, spread and fire. How does one plan, engineer, construct new, retrofit old, and manage for protection/mitigation in regard to tsunami hazards, and how does one adjust to the hazards? What is the relative importance of zoning/land-management, open-space, elevation, tsunami-resistant structures, defense structures (breakwaters, seawalls, dikes, gates, forests/groves, drainage canals), aesthetics, convenience/inconvenience to people, public education? Details of specific components are important. Flow characteristics of the water, and the resulting scouring and sediment movement, transport and impact of wreckage, other debris, boats, automobiles, and floating objects which may include buildings not adequately attached to the foundation. Data are available on hydrodynamic forces, hydrostatic and buoyancy forces, impact forces, scour. [These are your Topics 1 and 2.]

Let us look at Principle 4 in *Designing for Tsunamis: Design and Construct New Buildings to Minimize Tsunami Damage*. This is in chart form on page 35, and is attached hereto. First, does this cover it all? If not, what should be added. Should anything be deleted? Then, add details. For example, much information on loads and design are in the report:

Tsunami Subcommittee Report: Draft, Structural Engineers Association of Hawaii, October 1972, 38 pp

I believe that Charles L. Bretschneider did much of the work on the section **Tsunami Wave Forces** in this report; it is thorough.

One statement in Principle 4 (on page 32) is:

"Substantially constructed buildings of concrete, masonry, and heavy steel frames are likely to perform fairly well in a tsunami unless compromised by earthquake shaking. Wood-frame buildings, manufactured housing, and light steel-frame structures at lower elevations close to the shoreline are likely to fare poorly in a tsunami."

This seems to be in agreement with the experience in the Sumatra (Indian Ocean) tsunami of 26 December 2004 (see the TCLEE Monograph No. 29, Oct. 2005). It is also in agreement with the data in the paper:

"Tsunami Inundation Depth, Current Velocity and Degree of Damage to Houses," by Hideo Matsutomi and Nobuo Shuto, in *International Workshop on Wind and Earthquake Engineering for Offshore and Coastal Facilities: Proceedings, Univ. California, Berkeley, CA, Jan. 17-19, 1995*, compiled by Charles E. Smith, Robert G. Bea and Tatsuo Uwabe, 1995, pp 195-199

Details and references should be given.

I believe the following is as valid today as it was thirty years ago. Ayre (with Mileti and Trainer), in *Earthquake and Tsunami Hazards in the United States: A Research Assessment*, 1975, say:

"The word "adjustment," as used here is not meant to imply complete avoidance of risk. Some degree of risk must be acceptable, for economic reasons. Furthermore, because of the infrequent occurrence of tsunamis, information regarding their possible impact locations and runup heights is very scanty, and it must be assumed that no reasonable action can take into account all possible risk..."

I would modify this, by adding after the words economic reasons the term and convenience of daily life. [e.g., "Characteristics of Tsunami Disaster and Countermeasures Against Tsunamis in Japan," by Tomotsuka Takayama, *Proceedings of the Fourth Japan-Chinese (Taipei) Joint Seminar On Natural Hazards Mitigation, Kyoto, Japan, Nov. 25-28, 1997*, pp 183-190.]

Risk can be defined as (from *Tsunami Risk Reduction for the United States: A Framework for Action*, National Science and Technology Council, Executive Office of the President of the United States; A Joint Report of the Subcommittee on Disaster Reduction and the United States Group on Earth Observation, December 2005:

"Risk - the probability of harmful consequences or expected losses (death and injury), losses of property and livelihood, economic disruption, or environmental damage: resulting from interactions between natural or human-induced hazards and vulnerable conditions"

Much is known about what to do for tsunami mitigation. This includes both adjustment and risk. However, too often little or nothing is done. Use Hilo, Hawaii as an example of tsunami protection and mitigation being planned and implemented, including utilizing the tsunami warning system and being prepared for evacuation and emergency response.

You did not include tsunami runup as one of your topics. I know you have had workshops on this subject, and perhaps this is the reason. However, many of the hydraulic laboratory studies have been made using solitary waves, for well known reasons. However, tsunamis are not solitary waves. Two papers about the effect of an initial drawdown followed by a rise which indicates the importance of the subject are:

"The Run-up of N-waves on Sloping Beaches," by S. Tadepalli and C.E. Synolakis, *Proc. Roy. Soc. (London)*, Vol. A445, No. 9123, 8 April 1994, pp 99-112

"On the Influence of the Sign of the Leading Wave on the Height of Runup on the Coast," by S.L. Soloviev and R. Kh. Mazova, *Science of Tsunami Hazards*, Vol. 12, No. 1, 1994, pp 25-31

Later, I am going to give some thought to tsunamis in ports. It is generally recognized that the best procedure if adequate warning time is available, is to move the ships and boats out of a port, to sea. In regard to facilities, it is important to keep them well maintained. William Herron comments (p. 6-60) on the difference in the Long Beach - Los Angeles Ports, between the 1960 and 1964 tsunamis. The characteristics of the tsunamis were important, but he also gives credit to the rehabilitation of facilities after the 1960 tsunami made them better prepared to withstand the 1964 tsunami. This is on page 6-60 of:

Oral History of Coastal Engineering Activities in Southern California, 1930-1981, U.S. Army Corps of Engineers, Los Angeles District, January 1986, 254 pp.

One of the most important things that should be decided in regard to tsunami mitigation at a specific site is the type of runup that is likely to occur. Runup/inundation maps are being developed; but what type of runup? Will the tsunami move onto shore like a fast rising tide, a bore, or a surge? Are there enough data available at a particular site to judge this? Or, if the local authorities must make a decision in regard to a building code, or the issuance of a building permit, do they have to assume the "worst case"? If so, which is the worst case? Perhaps there is not a single type "worse case." Are there quantitative information on this?

Sincerely yours

Robert L. Wiegel