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Tsunami Information Sources

by Robert L. Wiegel, Professor Emeritus

A great amount of technical information on tsunamis is available in journals, books, reports, newspapers, and websites. After the Sumatra–Andaman Islands Earthquake and the accompanying Indian Ocean Tsunami of December 26, 2004, I updated my ongoing list of tsunami information sources, increasing it substantially to about 3,500 entries. I continued to update the list for several months, and to modify its presentation in two subsequent reports. These three reports are available in both print and electronic format at the Water Resources Center Archives (WRCA), and I am currently in the process of preparing a fourth report (see details at the end of this article). Many of the printed references mentioned herein are available at WRCA or in other branches of the University of California library system.

In searching the technical literature for information on tsunamis, it is helpful to keep in mind that the water waves now generally known as tsunamis were commonly called “tidal waves” or “seismic sea waves” in the past.

Much is known about tsunamis—about their generation, transmission, runup, and effects, and about the damage they cause. That damage includes harm to structures and infrastructure, and injury and loss of life (public safety), on land and in harbors, and also secondary damage such as oil spill, spread, and fire.

How does one plan, engineer, construct new, retrofit old, and manage for protection from and mitigation for tsunami hazards, and how does one adjust to the hazards? What is the relative importance of zoning/land management,

Continued on page 9

The California Shore & Beach Preservation Association (CSBPA) held a short conference in April 2007 on “Technical Information Resources for Coastal Studies,” at which Professor Wiegel gave a talk on tsunami information sources. This article is based on the handout that accompanied that talk.



California Colloquium on Water

Fall 2007 Schedule

Lectures are held from 5:30 to 7:00 p.m. in Wurster Hall, Room 112. *Please note the room change from last semester.*

November 13

Climate Change Implications of Waste Treatment

Perry L. McCarty

Silas H. Palmer Professor Emeritus, Environmental Engineering and Science, Stanford University

December 4

A Camera Aloft: California's Wetlands and Streams from a Bird's Perspective

Charles Benton*

Professor of Architecture, UC Berkeley

Visit the Colloquium Web site for more information, including lecture abstracts:

<http://www.lib.berkeley.edu/WRCA/ccow.html>.

You can view the flyer for each lecture and the brochure for the fall semester as PDF files. Streaming videos of the lectures will be posted there as they become available. The lectures will also become available in DVD format for loan or in-house viewing at WRCA. You can also sign up online for the Colloquium & Events Listserv list.

This fall's Colloquium opened September 11 with "Confluence, Confusion, or Catastrophe: Prospects for Ending the Delta Stalemate," by John Cain, director of restoration programs at the Natural Heritage Institute, and continued on October 9 with "Tracking the Nation's Ground Water Reserves," by Dr. William M. Alley, chief of the Office of Groundwater at U.S. Geological Survey.

If you missed these lectures, you can watch them on the Colloquium Web site as streaming video (October lecture video will be available soon).

The Colloquium is sponsored by the Water Resources Center Archives of the University of California. It is financially supported by the Deans of the UC Berkeley Colleges of Engineering, Environmental Design, Letters

& Science, Natural Resources, and the Boalt Hall School of Law; the Beatrix Farrand Fund of the Department of Landscape Architecture & Environmental Planning; the UC Berkeley Executive Vice Chancellor & Provost; the Earth Sciences Division of the Ernest Orlando Lawrence Berkeley National Laboratory; the Groundwater Resources Association of California; and the Metropolitan Water District of Southern California.

* See some of Charles "Cris" Benton's aerial kite photographs on pages 15 and 16.

Water Resources Center Archives

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Mission *To maintain and continue to develop a collection of current and historical water-related materials to meet the needs of the University of California and the people of the state.*

Newsletter edited & designed by Nancy Novitski. Photos: pages 1 (details), 5, 6 & 17 © Sally Mack; pages 15 & 16 © Charles Benton; page 18 (detail) © Brendan DeTemple; page 4 as noted.

Announcements

Hello Blog, Farewell Newsletter!

Find out what's up with water in the West at WRCA's blog, *On Water*. Launched in October 2006, the blog features posts on the following topics:

- Daily news updates
- Calls for proposals
- UC research
- New publications issued by the UC Department of Agriculture & Natural Resources
- Events
- WRCA collections & services

Check it out at [http://blogs.lib.berkeley.edu/wrca.php!](http://blogs.lib.berkeley.edu/wrca.php)

You can read the blog online or sign up to receive the latest content via RSS (Really Simple Syndication). This new forum of ours promises to grow with time.



With the advent of the blog, WRCA has decided to cease production of the newsletter after this issue. *WRCA News* has been published since February 1994. It was launched to inform patrons about our collections and services, and later evolved to include a lead article written by a scholar on some aspect of water resources.

Please visit the blog—and “subscribe” via RSS—to receive ongoing information about new WRCA collections, services, grant projects, and events!

Welcome, Briant!

Briant Carcamo joined the ranks of WRCA student assistants in January 2007. Briant is in his third year at UC Berkeley, majoring in International Political Economy and minoring in Public Policy. He hopes to change water law some day, and it was his desire to become environmentally knowledgeable that brought him to WRCA. From shelving books to going on extended errands across campus, Briant diligently performs all the tasks that the WRCA staff assigns to him.

Welcome back, Grayson!

The WRCA staff is excited to welcome back Grayson Vincent, student assistant and interlibrary loan coordinator. Grayson studied abroad during the spring semester and interned at ESRI in Washington, D.C., in the summer. She participated in the Semester at Sea study abroad program, traveling around the world to 12 different countries, including Brazil, South Africa, India, several

Southeast Asian countries, China, and Japan. Grayson will be back at WRCA for the fall semester only, because she plans to graduate early. After graduation she plans to work in Washington, D.C., and apply to graduate school.

David Todd Memorial

As mentioned in the last issue of *WRCA News*, groundwater expert and longtime WRCA supporter David K. Todd died of leukemia on April 23, 2006. The UC Academic Senate has published a memorial about David Todd, coauthored by WRCA Director Linda Vida, Professor Emeritus Robert L. Wiegel, and Iris Priestaf, president of Todd Engineers. You can read the essay on the Academic Senate web site:

<http://www.universityofcalifornia.edu/senate/inmemoriam/davidkeithtodd.htm>.

Archival News

KRIS Documents Come to WRCA

This summer, WRCA obtained an assortment of materials originally collected for the Klamath Resource Information System (KRIS). The collection includes mostly unpublished documentation and data about certain designated watersheds in northern California. WRCA accepted three cartons of unique mixed-media materials on local rivers and creeks, primarily in Sonoma, Napa, and Humboldt Counties.

The KRIS materials are being incorporated into WRCA's extensive collection on local watersheds. They are already searchable in Melvyl, the online library catalog for the UC system: <http://melvyl.cdlib.org>. For further information on the KRIS project, see <http://www.krisweb.com>.

Tulare Litigation Exhibits

In spring 2007, WRCA received nine boxes of trial exhibits from the 2001 case *Tulare Lake Basin Water Storage District v. United States*. These materials constitute the new Tulare Litigation Exhibits Collection.

had significant consequences for subsequent related cases: "The federal government is certainly free to preserve the fish; it must simply pay for the water it takes to do so."

In that case, the irrigators in the Tulare Lake basin, in Southern California, sued the U.S. government after the Bureau of Reclamation had shut down water deliveries. To keep its obligations under the Endangered Species Act, the Bureau had determined that water needed to be left instream for the benefit of endangered fish. Irrigators in the basin alleged that the shut-down of water had been unconstitutional because the government had taken the irrigators' water without paying for it.



Wetland habitat in the Tulare Basin. Photo (detail): Scott Frazer, U.S. Fish & Wildlife Service. From *Tulare Basin: Land Protection Planning Study (Planning Update 3, March 2003)*, available online at <http://www.fws.gov/pacific/planning/draft/docs/CA/Tulare/tulare3.pdf>.

The Federal Court of Claims agreed. The court held that the irrigators had rights to a quantity of permitted water through their irrigation contracts. The contractual right to water equated to "property" that the government must pay for if it took the water. The opinion's oft-cited conclusion is unambiguous and has

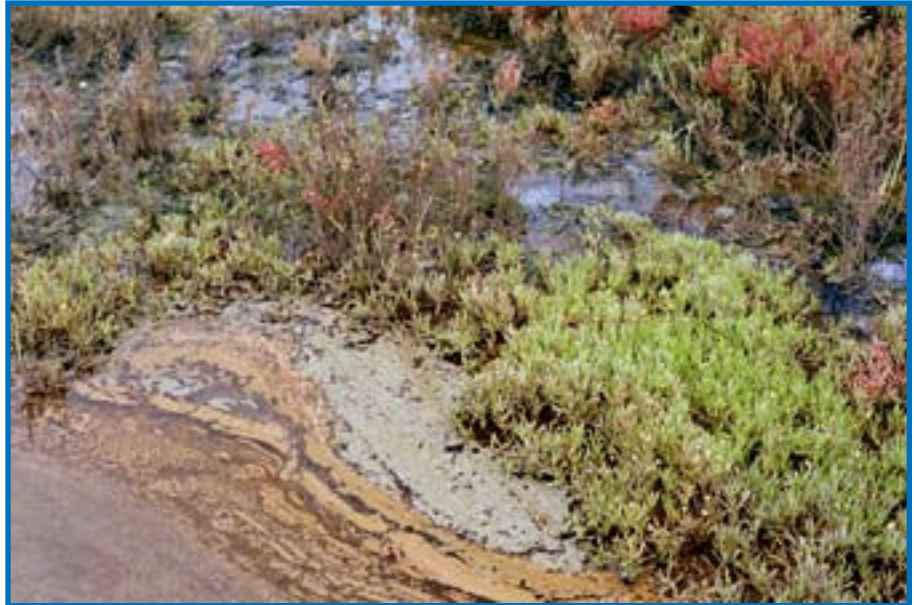
Alf. W. Brandt, who served as defense co-counsel, coordinated with the U.S. Department of Justice to donate the trial exhibits to WRCA. The collection comprises 14 volumes, including as follows: plaintiffs' exhibits, defendants' exhibits, and joint exhibits. The Tulare Litigation Exhibits Collection is currently being processed and will be made publicly available in the near future.

Guadacanal Village Wetlands: Take Two

by Joe Eaton and Ron Sullivan with photos by Sally Mack

Editor's note: Guadacanal Village Wetlands was last featured in WRCA News in March 2006, with photos and insights from Sally Mack. This time, two bird enthusiasts share their perspective on the wetlands.

Over decades of birding, we've learned to see and imagine the possibility of wonders in the most unpromising-looking places: mudflats, overgrazed pastures, dumps, sewage treatment plants. People don't believe us when we tell them where we're excited to be spending a free day. Except every now and then. Every now and then we meet someone else who Gets It.



What's really unusual: sometimes that person's not a fellow birder, at least not as self-described.

When Sally Mack showed us some photographs she'd taken at a place oddly named Guadacanal Village, we knew we'd chanced upon something extraordinary. When she offered to let us in on her trips there, of course we jumped at the opportunity. We found a place of mingled alchemies, a world apart from the abandoned buildings and paving and busy highways bordering it, a site of surprises and transformations.

It's an odd mix of refuge and dump, the sort of dump that had been graced with a patina of opportunistic



plants mingling with the abandoned markers of human dwelling, like eucalypts and mirrorbush. Common California weeds filtered in—fennel, pepperweed, annual grasses—but there are big enough areas of native plants to support native birds and other animals. This is an oddly balanced, tilting bit of place and time and chemistry.

Formerly a Navy housing site (and at a later point a paintball arena), Guadacanal Village Wetlands is now a tidal marsh in the making. The 53-acre parcel was chosen as a Caltrans mitigation project to compensate for habitat lost when State Route 37 was widened in Vallejo, damaging White Slough. Mitigation is a tricky business; you can build the habitat, but there's no guarantee that endangered species like the California clapper rail, California black rail, and salt marsh harvest mouse will move in. But there have already been encouraging developments at Guadacanal Village since the levee that held back the Napa River was breached in October 2001.

Virginia rails seem to have taken up residence. We've heard their piglike vocalizations from channelside vegetation on several visits, in winter and late spring. Virginia rails have a broader habitat tolerance than their more specialized relatives, the clapper and black rails,

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Guadacanal Village Wetlands

Continued from previous page

which are more salt-marsh specialists. Their presence is a hopeful sign, though. Maybe the rarer birds will follow.

The marsh birds that get your attention at Guadacanal Village are a trio of songbirds: marsh wren, salt marsh common yellowthroat, and San Pablo song sparrow. The last two are California species of special concern. The song sparrow, a subspecies found only in San Pablo Bay, is a nondescript dusky brown bird with short wings and a sedentary lifestyle. Much of its original tidal-marsh habitat has been destroyed. San Pablo song sparrows are more salt-tolerant than their upland relatives, although the insects they eat provide most of their water needs. Yellowthroats, especially the black-masked males, are showier, although they often sing their “wichety-wichety-wichety” song from points of concealment. The pugnacious marsh wrens are known for their impressive repertoire of over 200 songs. Listen closely and you’ll hear dueling males matching each other’s song types.

As for harvest mice, who knows? We’ve seen California voles, though, one of which was being handed off by a male white-tailed kite to his mate in an aerial *pas de deux*. The abundance of birds of prey at Guadacanal Village suggests a healthy rodent population. The kite, an ethereal-looking raptor once known as the “angel hawk,” is hard to miss. California almost lost this species, but it’s staged an impressive comeback. Northern harriers, or marsh hawks—gray males, brown females, and juveniles—also patrol here. They hunt rodents by ear; a harrier’s sense of hearing isn’t owl-acute, but it comes close. We were once fortunate enough to be in the wetlands at change of shift, when a short-eared owl emerged from its dayroost while the harriers were still flying. Bird-hunting raptors are here too, like the bullet-fast merlin, and whatever it was—a peregrine falcon?—that left behind the neatly detached wings of a female gadwall.

Back from the water’s edge, Guadacanal Village’s vegetation is ruderal—hardscrabble scrubby stuff—and mostly exotic. A baseline survey in 2000 logged 25 plant species, only three of them natives. (We’ve found a few that were either missed or arrived later, like the white-flowered hayfield tarweed.) And the animals

are a mixed bag of natives, like the noisy killdeer and the ubiquitous black-tailed jackrabbit, and exotics, like the ring-necked pheasants that rocket out of the shrubbery in their unsettling way. It’s in this part of the restoration site that Sally Mack has found—and revealed to us—a hidden world.

There’s a Russian science fiction novel called *Roadside Picnic* by Arkady and Boris Strugatsky (filmed by Andrei Tarkovsky as *Stalker*). Its premise: aliens visited an ordinary spot on our planet—no one knows why—and left it irrevocably different. In the Zone, different natural laws apply. Those who venture in for booty or scientific treasure, the Stalkers, come out changed themselves. In her own way, Sally is a kind of friendly Stalker, and Guadacanal Village Wetlands is her Zone.

We were able to tell Sally what birds she was seeing, the few she didn’t already recognize. What Sally gave us was more than telling: it was new eyes to see, new senses to capture the extraordinary facets of this place. A mere fringe on mental and drawn maps, not even wallpaper for most of the traffic on Route 37 or on the nearby water of Dutchman Slough, Guadacanal Village Wetlands is beautiful in its rebirth—if you know how to see.



Joe Eaton and Ron Sullivan are natural history and garden writers whose work appears in the San Francisco Chronicle and the Berkeley Daily Planet.

Sally Mack is a contract and grant administrator for UC Berkeley. She has been a photographer for over 30 years. You can see more of her photos on pages 1 and 17, in an exhibit on display at WRCA, or online at <http://www.sallymack.us>.

California Colloquium on Water

Summary: Fall 2006 & Spring 2007

The Sacramento–San Joaquin Delta was the hot topic of the 2006-2007 California Colloquium on Water seasons, both fall and spring. Nearly all the lectures touched on at least some aspect of the Delta and its accompanying controversy. Other lectures addressed issues of climate, water supply, and restoration in the West.

UC Berkeley Professor Ray Seed kicked off the fall semester with “New Orleans and Hurricane Katrina: Lessons for California’s Levees.” Seed spoke of his study on the New Orleans levees after Hurricane Katrina, and what California should do to avoid a catastrophe on the same level. Among the lessons he outlined for California’s levees were: defend what we can, but concede some ground to nature (avoid hubris); “engineer it well, build it right”; and always put community safety above special interests.

In October, Justice Greg Hobbs of the Colorado Supreme Court spoke about “The Role of Climate on Water Institutions in the Western Americas.” Hobbs discussed the need of government and other institutions in the western United States to adapt to climatic changes. He provided examples of how the Incas and other indigenous South Americans were able to overcome climate setbacks, such as extensive drought seasons, by perfecting dry-land farming and establishing reservoirs.

The focus returned to the Delta in November, with “Tales of the New Fish Patrol: Saving California’s Largest River—The Mighty Sacramento,” from Diana Jacobs, retired Department of Fish and Game deputy director and science advisor. The Sacramento River empties into the Delta, and the flow of water and fish from the river impact life in the Delta. Jacobs spoke about her career devoted to juggling competing interests, including those of farmers and fish. She felt the conflict had been reconciled when state and local governments came together for a solution.

In contrast, Mike Taugher, an environmental reporter for the Contra Costa Times, discussed hard-fought battles in his December lecture, “When the Environment and Politics Collide: Recent Developments in the Sacramento–San Joaquin Delta.” Taugher gave an overview

of the Delta and shared his perspective that politics has stood in the way of any real improvements in the region thus far.

The spring semester opened with Steve Ritchie, executive project manager of the South Bay Salt Pond Restoration Project. In his talk, “The South Bay Salt Pond Restoration Project: The Wild Heart of Silicon Valley,” Ritchie spoke of working for change outside any government framework. Private companies provided \$20 million to fund

Missed the Lecture? Watch the Video!

Streaming videos of these lectures will be posted at WRCA’s Colloquium Web site as they become available (<http://www.lib.berkeley.edu/WRCA/ccow.html>). The lectures will also be available in DVD format for loan or in-house viewing at WRCA.

the Salt Pond project, the largest tidal wetland restoration project on the West Coast, according to the Project. One of the goals of the project is to improve flood management; Ritchie pointed out

that the levees in the South Bay are just as much in need of repair as the levees in the Delta. He acknowledged that restoration is often more of a buzzword than an attainable goal, but still held that restoration attempts could serve only to improve existing conditions.

In March, UC Berkeley Professor B. Lynn Ingram talked about “Late Pleistocene to Holocene Evolution of the San Francisco Bay.” Ingram outlined the development of the Bay and the Delta as an estuary, and the climatic cycles that the system has gone through over time. She described her methods for gathering the supporting data, and showed that those data predict that a cooling trend should now be in effect—but isn’t. Ingram attributed that discrepancy to human effects on the system.

Ellen Hanak, a research fellow at the Public Policy Institute of California, spoke in April about “Envisioning

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Colloquium Video Digitization Project Now Complete

The California Colloquium on Water just got even easier to enjoy. WRCA is pleased to announce that all remaining videos of past California Colloquium on Water lectures have been digitized. Previously only available in VHS format from WRCA, these 26 videos from 2001 to 2004 have now been converted to RealMedia format, thanks to a grant from the Metropolitan Water District of Southern California through its Community Partnering Program. To view these videos and the latest Colloquium lectures online, visit <http://www.lib.berkeley.edu/WRCA/ccow.html>.

The California Colloquium on Water covers wide-ranging, interdisciplinary topics that share water as the common thread, from groundwater resources and fisheries to water rights, the Colorado River, and beyond. Since 2000, WRCA has worked with a faculty committee to invite speakers from a variety of disciplines to speak on the most pressing water issues of the day. The lectures have been videotaped since spring 2001, the Colloquium's second semester. Filming has been in digital format since the 2004-2005 Colloquium season.

Making these lectures available online fulfills the goal of the Colloquium to increase the understanding and appreciation of water resources and to contribute to informed decisions about water in California. Digitally archiving these taped lectures means that people all over the world—students, faculty, and the general public—will be able to learn from them for years to come.

Sylvia McLaughlin Lecture Now in Digital Video Format

Now it's even easier to watch the memorable September 2003 lecture given by Sylvia McLaughlin, cofounder of Save the Bay. In her talk, entitled "Four Decades of Saving the Bay," she reflected on her work establishing the well-known nonprofit and on her life in conservation in the San Francisco Bay Area. View her lecture at <http://www.lib.berkeley.edu/WRCA/ccow.html>.

Colloquium Summary

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Futures for the Sacramento–San Joaquin Delta.” Whereas Seed’s and Taugher’s lectures focused on the problems facing the Delta, Hanak presented several possible solutions from the then-unpublished report that she had been working on with several UC Davis professors. Among the report’s recommendations was a call for allowing part of the Delta to return to fluctuating salinity levels. This reflects a change in thinking about the Delta, since the focus used to be on keeping the water as salt-free and stagnant as possible.

Closing out a dynamite season of Colloquium lectures was a dynamite speaker: Pat Mulroy, general manager

of the Southern Nevada Water Authority. In her talk, “Overcoming the Traditions that Divide Us: Tomorrow’s Reliable Water Supply Dependent Upon Partnerships,” Mulroy outlined the history of Nevada’s water supply, from the strict groundwater-use policies of the early 20th century to the “water bank” arrangement with Arizona today, which ensures that the burden of shortages along the Colorado River will be shared. Her ultimate message was that all state agencies along the Colorado need to work together to secure future water supplies for everyone.

Tsunami Information Sources

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open space, elevation, tsunami-resistant structures, defense structures (breakwaters, seawalls, dikes, gates, forests/groves, drainage canals); aesthetics, convenience to people, public education?

A great deal is known about what to do (or not to do), and how to assess tsunami hazard and risk. But there has often been insufficient implementation of coastal policy, procedures, and works, and insufficient maintenance and upgrading. Mitigation works and procedures may affect the quality of daily life and the efficiency of use of the waterfront. They involve choices, tradeoffs, risk, and adjustment, either explicitly or implicitly. They may be costly. Although we would always like to know more, decisions must be made and implemented with existing knowledge. This can be done, and must be done, although it may be difficult. Often little or nothing is done; but it has been done in some places.

The knowledge of these subjects is widely scattered. From the several thousand tsunami information sources listed in the first report and listed in the first portion of the subsequent reports (Parts 2 and 3), I have extracted the sources about these subjects; there are several hundred. These are listed in the second portions of both Parts 2 and 3, as Section C: Planning and engineering design for tsunami mitigation/protection; adjustments to the hazards; damage to structure and infrastructure.

Closely associated with the above subjects are tsunami propagation nearshore, such as edge waves, Mach-reflection/Mach-stem, wave trapping, refraction/diffraction, wave focusing, wave scattering, shelf and basin response, bay and harbor oscillations, and the runup of tsunamis onto shore (and drawdown/receding floodwater). Runup may occur as a fast rising tide, or a surge, or a bore. In addition to information on inundation/flooding, the subject runup and drawdown includes flow characteristics of the water; and the resulting scouring and sediment movement. It includes transport of wreckage, boats, automobiles, and other floating objects and debris, including buildings which are not adequately attached to their foundations and have floated away. Several hundred sources on these subjects are listed separately in the second portion reports, Part 2

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Risk, Adjustment & Mitigation

The words risk, adjustment, and mitigation are used in many references. As used herein, they are defined as follows:

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.”

—National Science and Technology Council, Dec. 2005, p. 23

Adjustment

“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. For some locations the decision might be to make no adjustment whatever.”

—Ayre, Robert S., with Dennis S. Mileti and Patricia B. Trainer, 1975, p. 104

* I recommend that this definition be modified by adding “and convenience in daily life” after the words “economic reasons” in the second sentence.

Mitigation

“Mitigation involves sustained actions taken to reduce or eliminate the long-term risk to human life and property based on tsunami risk assessments. This includes planning and zoning to manage development in areas particularly at risk for tsunami, embracing tsunami resistant construction, and protecting critical facilities and infrastructure.”

—National Science and Technology Council, Dec. 2005, p. 1

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and Part 3 as Section D: Tsunami propagation nearshore; induced oscillations, runoff/inundation (flooding) and drawdown.

Designing for Tsunamis: Seven Principles

Distributed throughout reports, monographs, papers, newspaper articles, etc., are comments, data, and recommendations for designing for tsunami hazards. Building codes have been developed for some areas; they vary in detail of what they recommend. What can be done by local planners, policy makers, and coastal engineers and geologists? Where can they start? I recommend the following publication. This monograph is concise. It is illustrated with sketches and photos. It is written to be easily understood. Reading it is the first step in learning what to “mine” from the technical information sources.

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

(For more details, see the companion report: Designing for Tsunamis: Background Papers, March 2001.)

The seven principles are:

1. Know your community's tsunami risk: hazard, vulnerability, and exposure
2. Avoid new development in tsunami run-up areas to minimize future tsunami losses
3. Locate and configure new development that occurs in tsunami run-up areas to minimize future tsunami losses
4. Design and construct new buildings to minimize tsunami damage
5. Protect existing development from tsunami losses through redevelopment, retrofit, and land reuse plans and projects
6. Take special precautions in locating and designing

infrastructure and critical facilities to minimize tsunami damage

7. Plan for evacuation

As an example of what is recommended, refer to Principle 4. Details about this principle are in a chart on page 35 of the monograph. Some of the effects or design solutions listed are: evaluate bearing capacity of soil in a saturated condition, hydrostatic forces, and buoyancy (flotation or uplift forces caused by buoyancy); design for dynamic water forces on walls and building elements; design for breaking wave forces; design for debris impact; design for scour and erosion of the soil around foundations and piles; design waterfront walls and bulkheads to resist saturated soils without water in front; and provide adequate drainage. Valuable technical information resources on loads and design are in reports by Dames and Moore (1980), FEMA (2000), Matlock, Reese, and Matlock (1962), Matsutomi and Shuto (1995), Structural Engineers Association of Hawaii (1972), Wilson and Torum (1968), Yeh, Robertson and Preuss (2005).

Tsunami Hazards in California

Information on tsunami hazards in California is in a number of papers and reports. Four are: *Evaluating Tsunami Potential*, by McCulloch (1985); *Tsunami Inundation Model Study of Eureka and Crescent City, California*, by Bernard, Mader, Curtis, and Satake (1994); *Evaluating the Tsunami Risk in California*, by Synolakis, McCarthy, Titov, and Borrero (1997); and *Inundation Maps for the State of California*, by Eisner, Borrero, and Synolakis (2001). Lists of tsunamis in California are in: *Tsunamis Affecting the West Coast of the United States, 1806-1992*, by Lander, Lockridge, and Kozuch (1993); *Evaluating Tsunami Potential*, by McCulloch (1985); *Tsunamis and Their Occurrence Along the San Diego County Coast*, by Joy (1968; for years 1769-1968); *Tsunamis*, by Wiegel (1970).

Probability predictions of tsunamis from far-field sources (teletsunamis) are in three reports prepared for the Federal Insurance Administration (FIA) by the U.S. Army Corps of Engineers, Waterways Experiment Station: two by Houston and Garcia (1974; 1978), and one by Houston (1980). Predicted 100-year and 500-year elevations (“runups”) are shown on a series of plates. The authors say (1978, p. 7):

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A 100-year runup is one that is equaled or exceeded with an average frequency of once every 100 years; a 500-year runup has a corresponding definition. Runup values in this report are referenced to mean sea level (msl) datum.

(Note: As commented by Synolakis, et al. (1997, p. 1,229): “The computational boundary was a vertical wall at the shoreline, i.e., there were no inundation computations. Houston (1980) noted that the runup elevations, i.e., the elevation of the maximum inland penetration of the tsunami, may not equal shoreline elevations at locations where dunes prevent flooding, or if the land is flat, where inland flooding maybe extensive.” Please refer to this source for additional pertinent comments on the above-mentioned reports.)

During the past decade or so, studies have been made of a major co-seismic tsunami that was generated along the Cascadia Subduction Zone in the year 1700 (e.g., Atwater, 1987; Atwater, Musumi-Rokkaku, Satake, et al., 2005; Satake, Shimazaki, et al., 1996). This paleotsunami, and the occurrence of a small tsunami generated by the Cape Mendocino earthquake on April 25, 1992, triggered the development and use of scenarios for California of possible future tsunamis hypothesized to be generated at the southern Cascadia Subduction Zone, a “near-field event” (e.g., *Tsunami Inundation Model study of Eureka and Crescent City, California*, by Bernard, Mader, Curtis, Satake 1994). Eisner, Borrero, and Synolakis (2001, p. 76) wrote that the Cape Mendocino tsunami “was a wake up call that led to the immediate development of inundation maps for Humboldt Bay.” An inundation map of Crescent City was also prepared.

(Note: Recently, a study of sedimentation rates was made in Bolinas Lagoon, Marin County, California by Byrnes, Reidy, and others (2006), of the UC Berkeley Department of Geography. Cores were taken and analyzed, including studies of pollen and dating. A layer of sand was found at all of the “short core sites,” above the peaty clay (2006, p. 29). The date was not inconsistent with that of the Cascadia Subduction Zone earthquake and tsunami in the year 1700, but they state that “more radiocarbon dates are needed to resolve the

issue.” Perhaps it is similar to the findings from sediment cores in Tillamook Bay, Oregon, by Komar and Styllas (2006, p. 15), in which the sand layer was probably from overwash from the beach by the Cascadia Subduction Zone earthquake and tsunami of the year 1700, and other overwash and breaching events made possible by subsidence of the spit.)

In regard to the preparation of tsunami inundation maps for emergency preparedness and evacuation planning, Eisner, Borrero, and Synolakis (2001) made the following comments. (Richard K. Eisner was Regional Administrator of the California Governor’s Office of Emergency Services (OES), Coastal Region.)

As early as 1997, California’s Coastal Regional Administrator of the Governor’s Office of Emergency Services (OES), through a series of workshops and publications, informed local governments and emergency agencies of the plans to address tsunami hazards and presented the NTHMP [National Tsunami Hazard Mitigation Program]. OES solicited input as to the levels of hazards to be represented on the maps, as the short length of the historic record did not permit a comprehensive probabilistic hazard assessment. As early as 1997, it was decided that the maps would include worst case scenarios to be identified further in the mapping process...

They caution (p. 67), “These maps are only to be used for emergency preparedness and evacuation planning.” Several examples of inundation maps are in the paper: Santa Barbara, Marina del Rey, San Francisco (Golden Gate south to Lake Merced).

Palos Verdes Peninsula and Vicinity, California; Ports of Long Beach and Los Angeles

There have been discussions recently (mid-2005) in *Civil Engineering* about the possibility (what probability?) of damage to the Ports of Long Beach and Los Angeles, California, by a hypothesized nearby underwater-landslide-generated tsunami, with substantial disagreement, as well as some agreement (Borrero, Cho, Moore II, Richardson, and Synolakis, 2005; Thiessen and Gioiello, 2005; Sterling, Edge, Calhoun, et al., 2005; Synolakis, Moore II, Borrero, et al., 2005).

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One area of agreement of the writers was the need to estimate the hazard risk in probabilistic terms. This is difficult for several reasons. One reason is that although present underwater mapping of previous slides has improved, little is known about underwater slide speeds, and hence, the size of the resulting tsunami. (Details of estimating quantitatively for the Palos Verdes debris avalanche is in a paper by Locat, Lee, Locat, Imran (2004).) Another problem is the timing; when did an event occur? The date for the Palos Verdes debris avalanche has been estimated from carbon dating of samples from cores to be about 7,500 years ago (Normark, McGann, and Sliter, 2004). As already mentioned, earlier studies of tsunami risk were for tsunamis generated in the far-field by co-seismic underwater tectonic displacements (e.g. Houston and Garcia, 1974, 1978; Houston, 1980). These are two different tsunami “populations.” How should the probability distributions of two different populations be treated?

In the report of the California Seismic Safety Commission, *The Tsunami Threat to California: Findings and Recommendations on Tsunami Hazards and Risks*, one of the findings is (2005, p. 1, with details on p. 6):

Tsunamis present a substantial risk to the economy of the State and Nation, primarily through the impact on our ports.

This report is based on the work of the Commission's Tsunami Safety Ad Hoc Committee, which held 6 meetings and took testimony from representatives of local governments and the scientific community in California during 2005.

Borrero, Cho, Moore II, Richardson and Synolakis (2005), and Synolakis, Moore II, Borrero and Richardson (2005) write about several locally generated offshore tsunamis in southern California. They write about tsunamis generated by submarine landslides, and the importance of this mechanism to southern California. (Submarine landslides may be triggered by earthquakes or by other mechanisms.) The authors discuss how a locally generated tsunami might adversely affect the ports of Long Beach and Los Angeles. Owing in part to this, I have prepared a list of about

350 references for tsunamis generated by rapid mass movements, either submerged or from land into the ocean or into a bay, lake, or reservoir. This includes papers and reports on fluid mechanics, theory, numerical modeling, physical modeling, characteristics of mass movements, paleo-events, and the little information I have found on speeds of such movements in nature. This list is available in print and electronic format at WRCA.

In a few of the technical sources it has been mentioned that underwater slides of accumulations of sediment at submarine canyons may be triggered by earthquakes. One case in which this might have been expected is at Newport Submarine Canyon from the March 10, 1933, Long Beach earthquake. The earthquake epicenter was on the Newport–Englewood fault zone, near Newport Submarine Canyon. But no tsunami was recorded (Barrows, 1974; Hauksson and Gross, 1991). (Note: The generally accepted location of the foreshock–main shock–aftershock sequence was relocated by Hauksson and Gross as onshore rather than offshore.)

I have not had time to write as much as I want to about the Southern California Bight region. Some information on undersea slope instability and the potential for submarine landslide-generated tsunamis in this area are in the paper by Clarke, Greene and Kennedy (1985) and in the abstract of a paper by Greene, Maher, and Paull (2000). Responses of bays and harbors (oscillations) to tsunamis are important, as are tsunami spectral characteristics, and spectral characteristics of the California Borderland basins and bays. Refraction is important. Several papers on these subjects are listed in the References of this article: Houston (1977), Jen (1969), Miller, Munk and Snodgrass (1962), Raichlen (1972; 1979), Snodgrass, Munk and Miller (1962) Wilson (1971).

There has been substantial subsidence of the Long Beach Port area and contiguous land owing to oil and gas withdrawal; what might the long term effects of this be (e.g., U.S. Army Corps of Engineers, Los Angeles District, 2002)? What about the long term effects of sea level rise? The ocean floor-landslide-generated tsunami that is discussed in the papers by Locat, Lee, Locat and Imran (2004) and by Normark, McGann, and Sliter (2004) was 7,500 years ago. The sea level was many tens of feet lower then, and the shore a considerable distance seaward of where it is now. Terrestrial deposits from a

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tsunami that occurred 7,500 years ago would be under water now.

In regard to port and harbor facilities, it is important to keep them maintained properly. William Herron comments on the performance difference in the Long Beach/Los Angeles ports between the 1960 Chile and the 1964 Alaskan tsunamis (USACE, Los Angeles District, 1986, p. 6-60). Herron said that the characteristics of the tsunamis were important; but he also said that the rehabilitation of facilities after the 1960 tsunami made them better prepared to withstand the 1964 tsunami.

Just after I completed my handout for the CSBPA Conference, I received a copy of the following report: *Tsunami Hazard Assessment for the Ports of Long Beach and Los Angeles. Final Report*, which had been prepared for the Port of Long Beach and the Port of Los Angeles by Moffatt & Nichol, Long Beach, CA, M&N File: 4839-169, April 2007, 91 pp. I have added this short note about it to my handout. The report has a review of historical tsunamis that impacted the two ports; these have been from distant sources (Chile, Alaska). The report identifies and evaluates the likelihood of potential local tsunami sources. Scenarios were developed, and numerical (hydrodynamic) models used to generate and propagate hypothesized tsunamis from these sources to, and into the ports. Seven potential tsunami sources were modeled: four local tectonic scenarios, two local submarine-landslide scenarios, and one distant-source scenario (Cascadia Subduction Zone). Potential impacts to the ports from the scenario tsunamis were described. They say (pp 1-2):

The study expands on the previous work in that it includes more details regarding local maximum water levels, current speeds, arrival times, and overtopping rates at selected locations.... The likelihood of the occurrence of these potential sources is also discussed to place the results in the proper perspective for the design of coastal structures.

One of their conclusions (p. 84) is, "Based on the seismicity, geodetics and geology, a large locally generated tsunami from either local seismic activity or a local submarine landslide would likely not occur more than once every 10,000 years."

Tradeoff Example: Seawalls

I concluded my presentation with a suggestion for the participants—something for them to consider. It was in regard to one type of tradeoff: the use of seawalls. What can they find in the technical information resources about the effectiveness and design of seawalls to protect against a tsunami? What has been the experience with seawalls during tsunamis? What is the present opinion about the value of seawalls for protection from tsunamis? Have the risks and the mitigation/adjustment values been quantified numerically?

In Hawaii, in California, and perhaps elsewhere, it is difficult or nearly impossible to obtain a permit to build a new seawall (e.g., Eversole and Norcross-Nu'u, 2006). Experience in the Indian Ocean (Sumatra) tsunami of December 26, 2004, has demonstrated the usefulness of seawalls for protection from the tsunami, even where they were overtopped (e.g., BBC News, 2005; Strand and Masek, 2005). Shepard, Macdonald and Cox (1950, pp 443, 458, 466, photos in plates 12a and 30a) comment on the value of the strongly built concrete seawall at the Puu Maile Hospital in Hilo, Hawaii, during the April 1, 1946, tsunami, where the wave rose about 20 feet, flooding over the wall. They say: "The wall itself was undamaged, and buildings sheltered by it were undisturbed except for minor damage by flooding." Seawalls have been used in Japan for many decades (e.g. Horikawa, 1960; Togashi, 1981; Miyoshi, 1983; Kawaguchi, Itoh, and Takeuchi, 1995). There are probably other places that they should be used. They must be well designed, constructed, and maintained; they should be long; the elevation at the crest should be adequate; and they are usually expensive.

A word of caution: Horikawa and Shuto (1983) say the following about the need for a tsunami warning system, and the preparation and education for emergency response. This is important to a community with regard to both risk and accommodation.

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.

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However, in some regions, the tsunami generating source is so close that almost no time is available for evacuation. In some areas, both tsunami and direct earthquake effects (shaking, subsidence/uplift, ground-breaking [fissures], liquefaction, landslides) occur nearly simultaneously.

Tsunami Information Sources Reports

The three reports I prepared on tsunami information sources are available in print and in electronic format at WRCA:

Tsunami Information Sources (Robert L. Wiegel, University of California, Berkeley, CA, UCB/HEL 2005-1, 14 December 2005, 115 pages). Available in printed format and on a diskette. Also available in electronic format at <http://www.lib.berkeley.edu/WRCA/tsunamis.html> and in *Science of Tsunami Hazards* (the International Journal of The Tsunami Society), Vol. 24, No. 2, 2006, pp 58-171 at <http://www.sthjournal.org/stb6.htm>

Following publication of the above report, additional sources were listed in two subsequent reports, Part 2 and Part 3:

Tsunami Information Sources: Part 2 (Robert L. Wiegel, University of California, Berkeley, CA, UCB/HEL 2006-1, 18 April 2006, 36 pp). Available in printed format and on a diskette. Also available in electronic format at <http://www.lib.berkeley.edu/WRCA/tsunamis.html> and in *Science of Tsunami Hazards* (the International Journal of The Tsunami Society), Vol. 25, No. 2, 2006, pp 67-125

Tsunami Information Sources: Part 3 (Robert L. Wiegel, University of California, Berkeley, CA, UCB/HEL 2006-3, 18 December 2006, 23 pp). Available in printed format and on a diskette. Also available in electronic format at <http://www.lib.berkeley.edu/WRCA/tsunamis.html>

Also, sources given in all three reports on the following subjects were listed separately as well, in Sections C and D, to help investigators.

Section C: Planning and engineering design for tsunami mitigation/protection; adjustment to the hazards; damage to structures and infrastructure.

Section D: Tsunami propagation nearshore; induced oscillations; runup/inundation (flooding) and drawdown.

Recently, I have been developing a list of technical sources about water waves generated by a rapid mass movement, either submerged or from land into the ocean or into a bay, lake, or reservoir. The mass movement may be a landslide, rockfall, debris avalanche, slump, or rigid body. This is work in progress. A list of about 350 sources was appended to the handout for the conference. An expanded version of this list is available at WRCA in electronic format.

Acknowledgements

I wish to acknowledge my appreciation of the great help of the WRCA staff in finding some difficult-to-obtain publications.

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