Usability and Visual Communication for Southern California Tsunami Evacuation Information

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Abstract. Evacuation behavior, including participation and response, is rarely an individual and isolated process and the outcomes are usually systemic. Ineffective evacuation information can easily attribute to delayed evacuation response. Delays increase demands on already extended emergency personal, increase the likelihood of traffic congestion, and can cause harm to self and property. From an information design perspective, addressing issues in cognitive recall and emergency psychology, this case study examines evacuation messaging including written, audio, and visual presentation of information, and describes the application of design principles and role of visual communication for Southern California tsunami evacuation outreach. The niche of this project is the inclusion of cognitive processing as the driving influence when making formal design decisions and measurable data from a 4-year cognitive recall study to support the solution.

1 Introduction and background

Emergency management departments in the United States distribute informational and instructional messaging to its residents and communities before an evacuation is required in hopes to make the population "information aware" and therefore more prepared (FEMA 2014). Emergency management is a public authoritative agency interconnected with agencies responsible for the safety, response, recovery, and preparedness of "any unplanned event that can cause deaths or significant injuries to students, employees, customers or the public; or that can disrupt operations, cause physical or environmental damage, or threaten the facility's financial standing or public image" (Oregon State Office of Emergency Management). Local departments are funded and regulated at the county, state and federal level.

Beginning in 2005, I interfaced with design and its role in emergency procedures with first-hand as a certified emergency medical technician and member of Santa Barbara Sherriff Search and Rescue. The specific focus of evacuation information

centers in its systemic and capacious variables. Evacuations require different cognitive processing of information due to the unpredictable onset of stress and sudden sense for protection of self, family and property. In a national collection of over 20 official outreach material on evacuation preparedness used for hurricane, flood, and tsunami, the implementation of a map as the main visual infrastructure to communicate messaging was used. The majority of the maps were repurposed roadmaps or inundation maps originally intended for internal emergency planning. The maps were inconsistent in the use of visual variables, amount of graphic density, symbology, semiotics, and severe qualities in legibility and usability.

There are currently no guidelines, regulations, or methodology that include stakeholders in the process of developing and evaluating these maps and their messages. Nor is there data to support that materials are being understood, are memorable, or useful. A problem in conveying evacuation information using a "map" as the main visual infrastructure is assuming the skill set necessary in map reading. An individual will need the following skillset in basic map reading and comprehension; 1) how to use a legend or key; 2) how to determine orientation of the map to physical space; 3) understand meanings of color, texture, and symbols; and 4) how to determine self location to destination in order to create a route. Maps can be confusing to read and dense with information. They can also be authoritative and can imply that the user must understand the map instead of the map being developed to understand the user's needs.

Ineffective evacuation information can easily attribute to delayed evacuation response and communities not evacuating at all. Evacuation behavior and decision-making is rarely an individual and isolated process and responses become systemic. Ineffectual behaviors increase demands on an already extended emergency personal, increase the likelihood of traffic congestion, and harm to self and property. Evacuation materials need to be developed with the inclusion of emergency cognition and disaster psychology. The ability to problem-solve, make rational decisions and recall information becomes vulnerable when confronted by urgent situations. Processing information during high levels of stress contribute to information overload, tunnel vision, temporary cognitive paralysis, and forms of denial. Tunnel vision is associated with extreme stress and exhaustion in which primitive tasks become central to cognitive processing and problem-solving capabilities are limited. Temporary cognitive paralysis, such as when people "freeze", is also associated with people experiencing dramatic shifts in cognitive demands as a result of an abrupt change in the environment. Even though panic is not a likely response in evacuation behavior these cognitive phenomena effects how a person receive and retains information. Variables that contribute to cognitive paralysis include limitation of reaction time, perception of danger to self, and previous training or experience. This is especially true if people do not receive instructions and evacuation information until the time of evacuation is required. Findings from the 2012 FEMA National Survey found that 92% of respondents received their information from the media with the top three sources from local television, national television, and radio. Emergency management departments in Southern California are consistent in relying on these sources, including the web, for evacuation information. Media sources are problematic for two main reasons; 1) they

are audio reliant, which data from our study demonstrated was the lowest performing outcome in information recall; and 2) information is usually distributed or accessed at the time of impact providing new information on a population already in distress.

In other related work, airline safety cards share the same objective of informing emergency procedure using visual communication to air passengers. I collected international safety cards to assess them in the same way I did evacuation maps. I found more unity and cohesion in messaging and use of visual variables across all local and international airlines. A major contributor is having a governing body that dictates and regulates how emergency and safety information is presented. The Federal Aviation Administration's Office of Airport Safety and Standards and National Transportation Safety Board require that all airlines flying into the United States comply with their regulations. Airline safety cards demonstrated more consistency in their use of symbology, iconography, and text in a cross-cultural environment. Success can also be attributed to repetition when passengers fly regularly. Repetition allows for people to develop and improve a cognitive framework for emergency procedure helping to memorize a cadence and rhythm of information. Relating this work to evacuation material I developed syntax for visual communication that could be universally applied to tsunami evacuation preparedness outreach.

2 Methodology

2.1 Context

The U.S. Geological Survey (USGS) and the California Geological Survey (CGS) provide geologic and seismic expertise to local and government offices that include inundation maps for the purpose of emergency planning. These maps are for "local governmental agencies [to] use these new maximum tsunami inundation lines to assist in the development of their evacuation routes and emergency response plans". Yet, I found a number of these maps were used in its original format, or slightly altered, for public outreach. The presentation of these maps have serious issues in readability, scale, labeling, and graphic density for a person who does not have, or should have, experience in topology or geographical map reading. When we tested one of these maps provided on a public outreach brochure in Santa Barbara, comprehension and cognitive recall failed by 100% early in the study and was excluded from further testing.

2.2 Cognitive Recall Study

To map or not to map—this was the first question to ask before a redesign would be explored. In 2011, I approached Dr. Steve Schandler, director of Chapman University's Cognitive Psychophysiology Laboratories, to systematically evaluate evacuation material and improve the quality of content and recall of information by going into the community and testing materials. To date, we have data from over 300 participants in the control group at Chapman University and 100 participants recruited from

the communities of coastal cities including Santa Barbara and San Clemente (the evacuation information was directly relevant to participants in these cities, resulting in a study group that was highly motivated to learn the information). We tested 3 different presentations of information; written, audio, and visual (e.g. map). All participants were evaluated for corrected vision and hearing, educational level, literacy level, and general health status.

Participants served individually in one study session, followed 24-hours later with a phone call interview. One third of the subjects were given the visual redesign evacuation map; one third received a written description of the same movement routes; and one third was presented with a digital audio recording describing the same movement routes. They either had 4 or 2 minutes to review or listen to the material. Immediately following the presentation of the information, the subject completed a 15-question multiple-choice test regarding the information that was presented. Twenty-four hours later the subject was contacted via telephone and completed another test regarding the information presented in the first session. The review period was determined by the average time people spent looking at direct mail marketing because the scenario and distribution of the proposed campaign will mimic how people retain information without cognitive impairments.

Across all groups and both review periods, the visual (map) presentation of information produced better retention (less forgetting) of information from Day One to Day Two.

2-minute review period: For all information types, Day One and Day Two recall were greater for the community sample suggesting higher motivation for persons most affected by the evacuation information. Compared to the other information forms, the greatest recall scores were associated with the written presentation of information. However, compared to the visual (map) presentation, proportionally less written information was recalled during Day Two. Auditory information presentation was associated with the greatest reduction in information retention from Day One to Day Two.

4-minute review period: Increased information review time increased recall for each information type. This was exactly what was predicted. The recall superiority of the visual (map) presentation of information remained, indicating that its effectiveness is due more to the information type than due to the time allowed to evaluate the information. The increased processing produced more permanent storage of the information. Compared to written information, the auditory information presentation also benefitted more from the increase in review time.

In summary, the written presentation of evacuation information resulted in the greatest immediate recall for both groups. However, visual presentation produced the most stable recall across the 24-hour retention period. This is particularly significant in trying to initiate a preparedness campaign prior to a disaster event so at the time an event occurs, experience with the information would have already made a cognitive imprint reducing the amount of learning new information under stress.

2.3   Design Principles and Wayshowing

During an evacuation, learning is already compromised by anxiety. Because evacua-

tion information is given under levels of stress, recalling information reduces the ability to process and learn new information. We revised the map by simplifying it down to only relevant layers of information. We formulated length and levels of components (e.g. compositional space and hierarchy) and use of visual variables. This approach was particularly critical for the continuity and application of other tsunami evacuation campaigns to be used in other coastal cities. The redesign prioritized a distinct clarification between foreground and background information driven by "wayshowing" principles. This approach changed the main visual infrastructure from a geological, topology, or road map to assimilating the more commonly recognized diagrammatic public transportation map.

In 2005, Per Mollerup coined the term "wayshowing", derivative of the term "wayfinding" originated by Kevin Lynch from The Image of a City in 1960. Mollerup suggested that in order to assist in wayfinding, principles of wayshowing is needed. Maps are static forms of communication relying on the reader to decode the information, finding out where they are on the map, navigating the space, and determining which routes are relevant. By approaching the map from the perspective of the user, information takes an active role indicating directions for movement and instructions. Formal decisions of visual variables included conventions already used by public transportation in southern California, including what Jacques Bertin defined as *visual verbs*—presentation of arrows—which made the maps less static and effectively communicated directions and instructions for movement.

Texture.

Texture creates visual noise, a vibration or disruption, of the composition causing the eye to move towards that noise. When used sparingly, texture can help with calling attention to significant areas on the page. Texture was used to create noise indicating possible road closure due to inundation. The use of high-contrast "checker" texture was used to cause disruption in order to make potential closures on major routes and highways a priority top-level read (see figure 1). The Orange County Transportation Authority currently uses this texture for possible route closures on bus maps syncing the conventional meaning of this pattern to the tsunami maps. Another texture used in cities with military restricted areas was a crosshatched pattern. Crosshatches, made from patterns of "x", represent the idea of "fencing-off" or "do not enter.

Fig. 1. The first map uses texture intentionally to bring attention to areas of importance. The second map shows when too much texture is used, there is no place for the eye to settle.

Color.

When developing a color palette, we acknowledged that using blue for the tsunami evacuation routes could be confused with flood direction or movement of water rather than safety routes because the symbolic meaning between signified, water, and signifier, blue, is iconic. Exploring this issue further, we felt confident that the California Department of Transportation had already officially branded the color blue by implementing tsunami evacuation route and evacuation site identification signage throughout coastal cities (see fig. 1). The convention had already been established with the community and it would be more effective to keep that color value consistent. All evacuation routes are indicated as blue.

Fig. 2. State Of California - Department Of Transportation (2007)

We relied on the conventional meaning of red for the inundation area—associated with meanings such as emergency exit signs, fire (fire trucks, extinguishers, etc.), emergency room signage, emergency call and stop buttons, and the American Red Cross. A third color, gold, was used for landmarks (useful for spatial orientation) and hospital locations. The remaining neutral color palette was used to support the use of color. We ensured that the color palette had clearly defined hierarchy, in-

tension, and priority of information. We had to make sure color called attention where necessary and not compete with another. Headers and mastheads that framed the map were coded gold and black, sharing the conventional meaning "caution".

Typography.

One of the most important revisions we negotiated was with content. Major cuts were made in the amount of information in existing evacuation material. We identified relevant streets, landmarks, and routes, removing any other "visual noise" that was too specific for the public's use. A great deal clutter was removed as seen in figure 2.
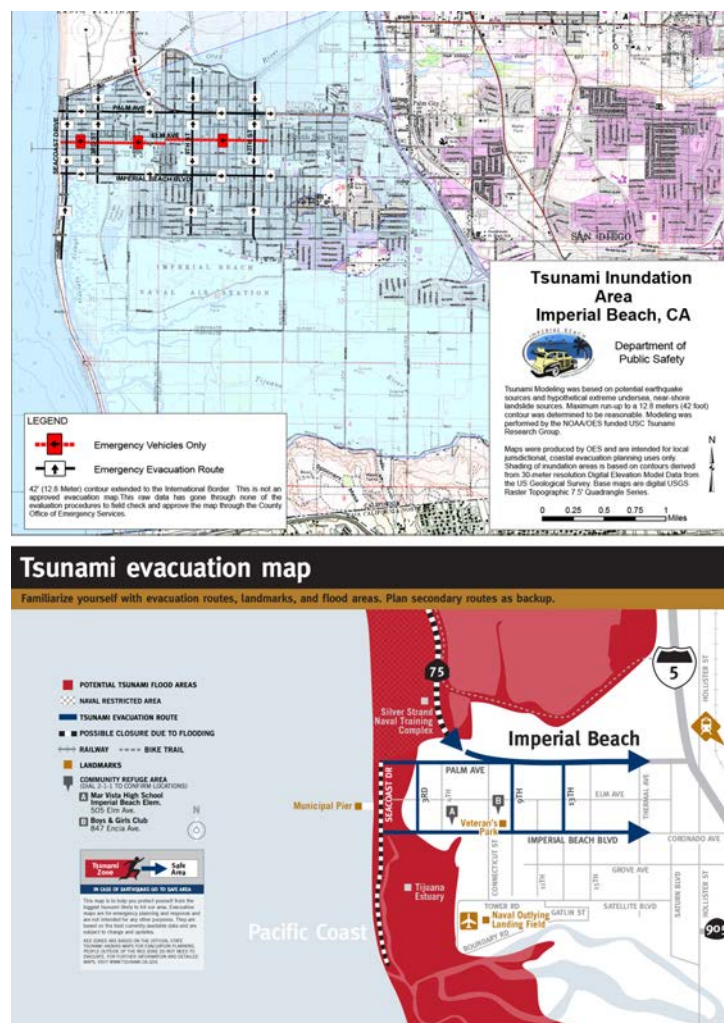

Fig. 3. The first map used by Imperial Beach was dense and full of competing visual noise. The second map demonstrates how our revisions improved legibility revealing and usable and relevant information intended for the public to use.

A disciplined typographic approach was established into 5 levels of hierarchy. The following list of information was given a consistent type size, use of caps, and color in every map we have produced. The order is from the most prominent, foreground information, to lower level, background information:

1) Identification of the city represented.
2) Identification of neighboring cities and major highways for spatial orientation.
3) Names of landmarks, including train stations, hospitals, parks, tourist sites, and in some cases, well known residential areas known to the people who live in the city.
4) Street names and highways of evacuation routes
5) Other smaller, but relevant, street names needed in order to connect to the major evacuation routes

We used Meta, a humanist sans serif designed by Erik Spiekermann and released in 1991, because of its cleanliness and legibility. In some cases, the typeface had to be legible at 7 points and Meta's subtle inclusion of serifs helped shape words the same way serif typefaces do.

Editing the amount of information was also a significant and successful negotiation in reducing text when applied to the content of brochures mailed out to residents and businesses in the inundation areas. We re-stylized the writing using direct conversational (e.g. using "you", "your", etc.) throughout the material to be more specific and direct in instruction and what was being asked of the reader (see fig. 3).
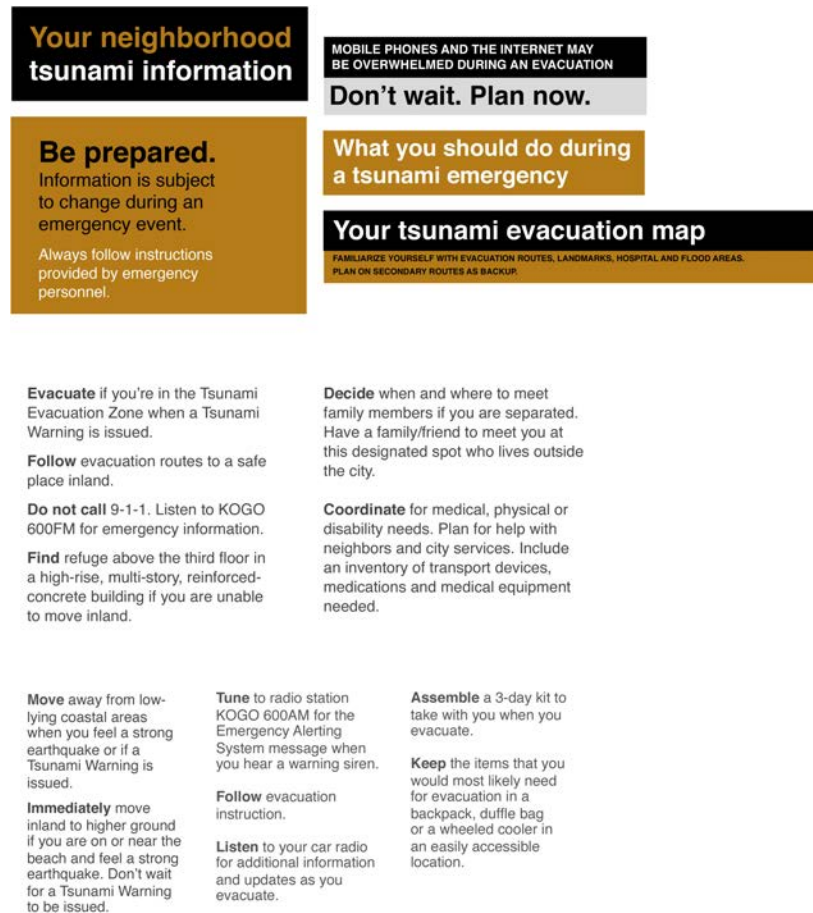
Your neighborhood tsunami information

MOBILE PHONES AND THE INTERNET MAY BE OVERWHELMED DURING AN EVACUATION

Don't wait. Plan now.

Be prepared.
Information is subject to change during an emergency event.

Always follow instructions provided by emergency personnel.

What you should do during a tsunami emergency

Your tsunami evacuation map
FAMILIARIZE YOURSELF WITH EVACUATION ROUTES, LANDMARKS, HOSPITAL AND FLOOD AREAS. PLAN ON SECONDARY ROUTES AS BACKUP.

Evacuate if you're in the Tsunami Evacuation Zone when a Tsunami Warning is issued.

Follow evacuation routes to a safe place inland.

Do not call 9-1-1. Listen to KOGO 600FM for emergency information.

Find refuge above the third floor in a high-rise, multi-story, reinforced-concrete building if you are unable to move inland.

Decide when and where to meet family members if you are separated. Have a family/friend to meet you at this designated spot who lives outside the city.

Coordinate for medical, physical or disability needs. Plan for help with neighbors and city services. Include an inventory of transport devices, medications and medical equipment needed.

Move away from low-lying coastal areas when you feel a strong earthquake or if a Tsunami Warning is issued.

Immediately move inland to higher ground if you are on or near the beach and feel a strong earthquake. Don't wait for a Tsunami Warning to be issued.

Tune to radio station KOGO 600AM for the Emergency Alerting System message when you hear a warning siren.

Follow evacuation instruction.

Listen to your car radio for additional information and updates as you evacuate.

Assemble a 3-day kit to take with you when you evacuate.

Keep the items that you would most likely need for evacuation in a backpack, duffle bag or a wheeled cooler in an easily accessible location.

Fig. 4. Example of mastheads and copywriting using direct conversational style in brochure that was mailed to residents

Other information, such as the legend and safety message required by California Geological Survey, was included and we were given flexibility to revise the language and design to match the visual guidelines that fit our approach.

Walking sign systems.
Santa Barbara, Coronado, and Marina del Rey have major foot and bike traffic and are especially populated with tourists and people who do not know the city well. We explored a walking sign system that would address the populated tourist areas and help this demographic make decisions in an area that may be unfamiliar to them. For example, if someone was on the pier in Santa Barbara and an evacuation order was given, signage would indicate that walking 5 minutes to safety would be better than

retrieving a car in a parking lot that is further away and in the direction of the potential inundation area.

We require that maps included in the walking sign system be aligned in a heads-up position and that the placement and unique orientation will correspond to the direction the user is facing (see fig. 4). We conducted walk-throughs of pedestrian traffic areas and identified areas where signage would benefit decision-making in the event of an evacuation. Due to limited budgets, we were required to use kiosks or sign posts that were already in place.

Fig. 5. Example of heads-up positioning for a walking sign system in Santa Barbara and Huntington Beach

Print vs. Web

Web is the most cost effective and efficient mode of information from the perspective of emergency management. Changes can be uploaded instantly with no limitations in the amount of content. There are major problems relying on virtual information whether distributed before a tsunami event or during. Research continues to support that sudden influx placed on telecommunications will most likely overwhelm infrastructure. Technology is an invaluable resource, but limitations must also be

acknowledged. A report written by Anthony Townsend and Mitchell Moss, Telecommunications Infrastructure in Disasters: Preparing Cities for Crisis Communication (2005), sheds light on the increasing concern of relying on technology for communication distribution:

The breakdown of essential communications is one of the most widely shared characteristics of all disasters. Whether partial or complete, the failure of telecommunications infrastructure leads to preventable loss of life and damage to property, by causing delays and errors in emergency response and disaster relief efforts. Yet despite the increasing reliability and resiliency of modern telecommunications networks to physical damage, the risk associated with communications failures remains serious because of growing dependence upon these tools in emergency operations.

Their investigation revealed 3 causes of failure that is still relevant today; 1) physical destruction of network components; 2) disruption in supporting network infrastructure; and 3) network congestion. FEMA's tips for communicating during an emergency (2014) emphasizes the need to have charged devices if you know an event is coming, but this excludes disasters that are unpredictable and devices need infrastructure to function.

Even though people are encouraged to learn about evacuation preparedness, they do not volunteer to do so prior to evacuation. A person must volunteer to access virtual community outreach. We surveyed L.A. and Orange County residents in 2009 and 86% of those surveyed did not know what to do in case of an evacuation and 80% would not how they would be notified. Emergency management spends a lot of energy on community outreach, including online and social media presence. Websites such as Ready.gov and TsunamiZone.org are valuable resources of information and I would be interested to measure how many people from the public visit these sites and how they use the information. Until then, I have advocated for an "information confrontation" approach to distributing information, similar to direct-mail marketing campaigns. Aside from consumer-targeted marketing, these direct-mail pieces also come from city utility agencies. People spend an average of 2-minutes reviewing the relevance of direct-mail information before making the decision to either save or discard the material. This interaction places evacuation information in front of people so they take responsibility to confront the material. Reoccurring and repetitive cadence of mailings (at least annually) is also critical so information begins to build a cognitive framework. Fire drills and airline safety demonstrations are good examples of successful repetitive exercises. Below are images of the 33k brochures printed and mailed to all residents living in the inundation area in San Diego County.

3   Future work

Since 2011, this project has generated interest from the Emergency Management community, California Geological Survey, and invitations to present at the National Evacuation Conference, the California State Emergency Management Conference, and California State Tsunami Steering Committee meetings. I have also been invited to me a permanent member of the CA Tsunami Steering Committee, not only demonstrating the relevance of our work, but also the role of design in civic service and the

significance of design principles in safety and health risk communication. Below are examples of completed redesigns for tsunami evacuation instructions.
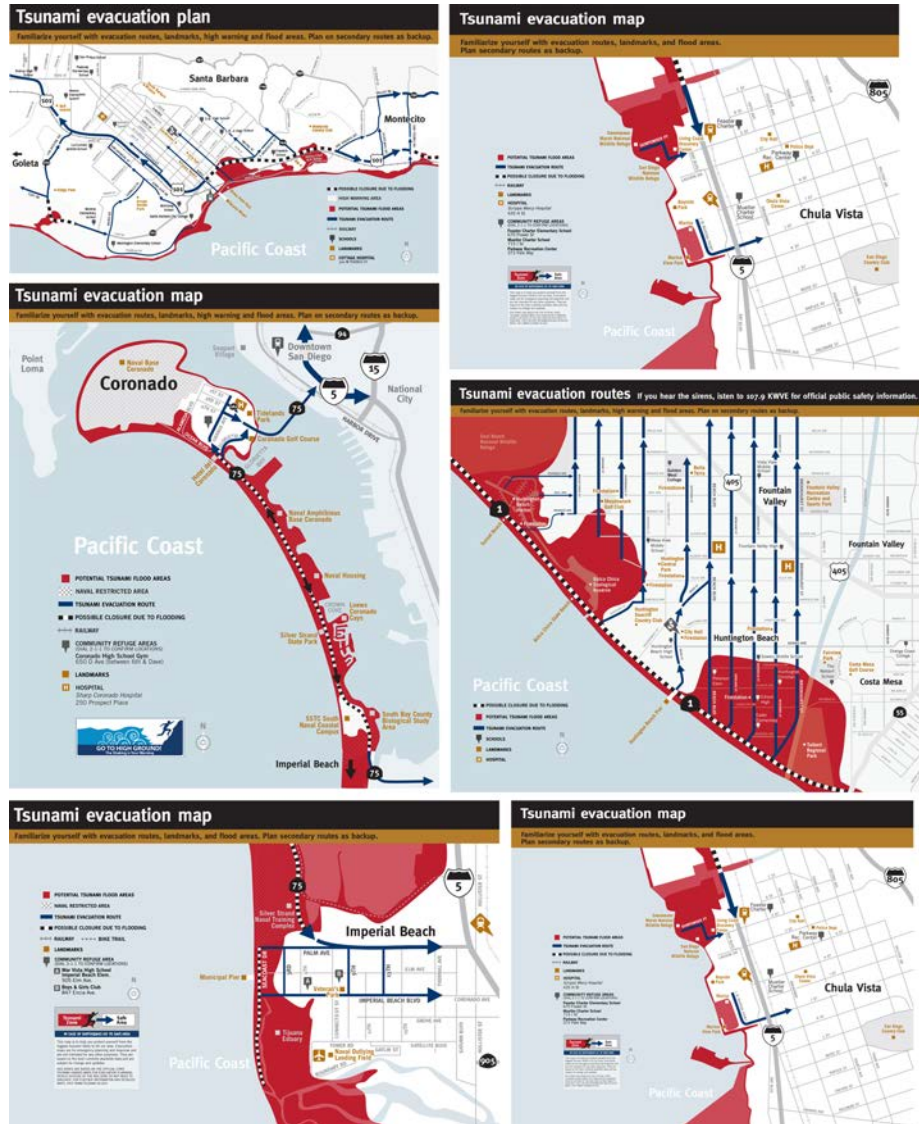
To date, we have completed work for 12 coastal cities in California including Santa Barbara, Huntington Beach, Carlsbad, City of San Diego, Coronado, Chula Vista, Del Mar, Encinitas, Imperial Beach, National City, Oceanside, and Solana Beach. We are under production with the County of Los Angeles and have first drafts with 8 coastal cities including Venice, Marina del Rey, Harbor City, Long Beach, Santa Monica, Malibu, El Segundo, and Manhattan Beach. Within the established design standards, flexibility is necessary to meet the individual needs and politics of

counties and cities. Budget constraints and limited resources for information distribution also challenge us to think about future work and the continuing cognitive recall study. For example, Los Angeles County will host an electronic version of the map and brochure on their city website instead of a mass mailing completed for San Diego County. We plan to monitor the number of visits and download of the map/brochure in order to establish a benchmark in how effective using web for information distribution really is. We are also preparing for a follow-up study with the cities we have worked with post-tsunami evacuation to determine the performance of the campaign and the role of cognitive recall in participation and preparedness.