Updating the City of Los Angeles' Tsunami Preparedness Plan, from Venice Beach to the Port of Los Angeles

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Abstract. In 2010, the City of Los Angeles Emergency Management Department (EMD) awarded a grant-funded design-build project to Willdan Engineers and Constructors (Willdan) to update its Tsunami Preparedness Plan. The need for the project was driven by the recently updated tsunami inundation zone maps and the new required format of the tsunami annex. The update consisted of three main elements: the update and revision of the City's Tsunami Response Plan Annex; an engineering study and the installation of tsunami signs; and the update, printing and distribution of the City's tsunami brochures. Each of the project elements presented challenges to the team. Some of the challenges were due to tasks that had little or no precedence to draw from. Other challenges involved the coordination with and cooperation of several departments within the City and agencies outside of the City. One of the greatest challenges was the sheer size of the project and the diverse areas it covered. At the conclusion of the project in 2011, the Tsunami Annex had been updated and re-written; the tsunami inundation maps and evacuation routes had been updated for the City's three inundation zones; 550 signs had been removed, relocated or installed at 350 locations on City streets, on the beaches and in the harbor; and the brochure for each inundation zone had been updated, translated into four foreign languages, then converted to large print, and transcribed into Braille, and 45,000 copies had been printed and distributed. The project was initiated in June 2010 and completed in March 2011. When the Japan earthquake struck in March 2011, generating a series of tsunamis that reached the California coast, the Tsunami Annex and tsunami brochures had been updated and were available for use, and installation of the tsunami signs had been partially completed.

Introduction

The City of Los Angeles, California, is situated in earthquake country and located on the Pacific Rim, also known as the Ring of Fire. Its coastal areas are, consequently, at risk of being inundated by tsunamis. In recent years, the City had updated their Tsunami Annex, prepared tsunami information brochures for residents in/near the inundation zones, and installed a limited number of tsunami signs. In 2009, however, new California Tsunami Inundation maps, based on updated tsunami computer simulation models, were released by the National Oceanic and Atmospheric Administration (NOAA). The models reflected new knowledge gained from the Indian Ocean tsunami that hit Indonesia and Thailand in 2004 and other recent tsunamis. The City's Emergency Management Department (EMD) applied for and received an Urban Area Security Initiative Grant to update the Tsunami Annex, the tsunami brochures and the tsunami signs based on the revised inundation zone boundaries. Subsequently, the City of Los Angeles awarded a design/build contract to Willdan Engineers and Constructors (Willdan) to update the City's Tsunami Preparedness Plan. The project consisted of three basic elements: Tsunami Response Plan Annex Revision, Engineering Study and Sign Installation, and Brochure Printing and Distribution.

A tsunami is one or more intense ocean waves, usually caused by an earthquake. There are two types of tsunamis that could strike California: local and Pacific-wide. Local tsunamis are caused by earthquakes near the local coast and could arrive within 10 minutes of a local earthquake. Pacific-wide tsunamis are caused by earthquakes far away from the local coast and could arrive within an hour. Each type of earthquake was considered for the project.

The City of Los Angeles, California has about 10 miles of coastline that include Will Rogers State Beach, Venice Beach, Dockweiler State Beach and Cabrillo Beach, as well as the Port of Los Angeles, all of which are at risk of being inundated by a tsunami. The City of Los Angeles' coastline is divided into three inundation zones, referred to as the West Los Angeles Area, the Venice Area and the Harbor Area (see Figure 1). Each of the inundation zones was addressed separately in each project phase.

Figure 1. City of Los Angeles' Tsunami Inundation Areas

The Tsunami Preparedness Plan project presented many challenges, primarily due to there being relatively few examples to draw on for guidance and the project covering such a large and diverse area. This paper discusses the challenges we encountered in updating the Tsunami Preparedness Plan, how they were resolved, and recommendations for others.

Tsunami Response Plan Annex Revision

The Tsunami Response Plan Annex (Tsunami Annex) is one of the hazard-specific annexes the City maintains as a supplement to its overall Emergency Operations Plan (EOP). The Tsunami Annex provides specific information regarding the roles, actions and responsibilities of each City department as they pertain to responding to tsunamis. Willdan was tasked with updating the Annex in accordance with the new requirements contained in the *Comprehensive Preparedness Guide (CPG) 101*, Version 2, released in November 2010 by the Federal Emergency Management Agency (FEMA). *CPG 101* is a fundamental guide to planning and developing emergency operations plans and their annexes with respect to prevention, protection, response, recovery, and mitigation. Version 2 expands on these basics and encourages emergency managers to involve the entire community in addressing all of the risks that might impact their jurisdictions. In addition to updating inundation maps, evacuation routes and contact information, *CPG 101* required a complete reorganization of the City's Tsunami Annex and the collection of additional information.

Since *CPG 101* was released shortly before Willdan began work on the Tsunami Annex, there were no other references to use as examples and the new format resulted in a number of revisions before Willdan was satisfied with it. The new guidelines also required additional information to be collected and provided in the updated Tsunami Annex. Toward that end, Willdan contacted 17 departments and divisions within the City. Willdan also contacted approximately 40 related agencies outside of the City, including neighboring cities and law enforcement agencies; county, state and federal agencies, including a federal prison and the US Coast Guard; as well as the City's school district and the Red Cross. As a result of the project, the City has a reference document and the current list of contacts to use in updating their other annexes. Responses also needed to be noted for the two different kinds of tsunamis: those caused by far away earthquakes that would not arrive for at least an hour, or those caused by local earthquakes or underwater landslides, providing mere minutes to prepare for a tsunami.

The City's Tsunami Annex was one of the first emergency operations documents to be prepared under the new FEMA guidelines and serves as an example for other agencies to follow in updating EODs and Annexes to meet the new guidelines.

Engineering Study and Sign Installation

The second main element of the project involved updating the tsunami signs. First, an engineering study was performed, which included researching other agency's practices, updating the evacuation routes, developing tsunami sign installation guidelines, identifying where the various types of tsunami signs should be located, making recommendations regarding the addition or removal of signs, and preparing a GIS inventory of the existing and proposed signs. The study was followed by the preparation of a plan to install the signs, the purchase and installation of the signs and the creation of a GIS-based inventory of the existing and installed signs. In addition to the ocean beaches within the City, the project included the Port of Los Angeles and was later expanded to include Marina Del Rey (Los Angeles County). There were existing tsunami signs at approximately 150 locations with signs to be removed from 50 of those locations. Willdan estimated that tsunami signs would need to be installed in approximately 300 additional locations.

Tsunami Sign Research

The initial task of the engineering study involved researching what had been done by other agencies regarding tsunami signs. Using the Internet, information from a number of websites was reviewed regarding the signs and installation of tsunami signs. Staff at local cities in Orange County that had installed tsunami signs were also consulted regarding how they had decided where to locate tsunami signs and what they recommended, based on their experiences. A list of the agencies whose material was reviewed is included in the References section. Information from these same sources was reviewed regarding evacuation routes and tsunami brochures.

Tsunami Evacuation Routes Update

The second primary task was to update the City's existing tsunami evacuation routes, which were then used to determine the location of the Tsunami Evacuation Route signs. The tsunami evacuation routes were also included in the Tsunami Annex.

In the City of Los Angeles, the Police Department (LAPD) is in charge of establishing the evacuation routes and has internal procedures for doing so. In the Port of Los Angeles, the Port Police (LAPP) has jurisdiction. Since the City's evacuation routes are used for various types of emergency conditions, LAPD/LAPP wanted to maintain the current routes and only extend/add routes in the new inundation areas. The inundation zones in the West Los Angeles and Venice areas had decreased, whereas the inundation zone in the Harbor area had increased. In accordance with the LAPD/LAPP's policy, the evacuation routes were only modified to reflect expansions in the inundation zones. The proposed new and modified evacuation routes were presented to the LAPD and LAPP in a joint meeting. The proposed evacuation routes were then finalized based on feedback from the LAPD and LAPP.

Tsunami Sign Installation Guidelines

Tsunami signage is relatively new and the signs that were installed were based on the guidelines available at the time. All signs that are approved for use in the state of California are contained in the *California Manual on Uniform Traffic Control Devices* (CA MUTCD), which is a modification of the Federal Highway Administration's (FHWA) *Manual on Uniform Traffic Control Devices* (MUTCD). The MUTCD provides the federal sign standards by which all states must abide. Neither the MUTCD nor the CA MUTCD currently includes tsunami signs. California has, however, identified five tsunami signs on its Department of Transportation (Caltrans) website that have been approved by the FHWA for use as experimental signs. The website includes brief requirements for each sign's usage.

Since the Caltrans requirements are not detailed, the installation of tsunami signs has been inconsistent both within the City of Los Angeles and within the state. To provide more comprehensive direction and detailed standards for the installation of tsunami signs in Los Angeles, Willdan developed the *Tsunami Sign Installation Guidelines*. The guidelines were based on the research of guidelines and standards used in other southern California cities, other states, the country of Japan, federal and international tsunami warning centers, and emergency management agencies. They were also based on input from the City of Los Angeles Department of Transportation (LADOT) and Port of Los Angeles, and the County of Los Angeles Fire Department, Department of Beaches and Harbors, and Department of Public Works.

The *Tsunami Sign Installation Guidelines* include general guidelines that apply to the installation of all of the tsunami signs, specific guidelines for each type of tsunami sign, Caltrans' tsunami sign specifications, and special provisions. The tsunami signs shown in the CA MUTCD and used in the project are illustrated below.

EM-1A (CA)
TSUNAMI EVACUATION ROUTE Sign

EM-1B (CA)
TSUNAMI HAZARD ZONE / IN CASE OF EARTHQUAKE GO TO HIGH GROUND OR INLAND Sign

EM-1C (CA)
ENTERING / LEAVING TSUNAMI HAZARD ZONE Sign

EM-1E (CA)
*TSUNAMI HAZARD ZON*E Sign

Tsunami Sign Design

Four types of tsunami signs were installed as part of the project: the Tsunami Evacuation Route sign with directional arrow signs, the Tsunami Hazard Zone/In Case of Earthquake Go To High Ground or Inland sign, the Entering/Leaving Tsunami Hazard Zone signs, and the Tsunami Hazard Zone sign. As previously noted, tsunami signs were not included in FHWA's MUTCD or the CA MUTCD at the time of the project, but were included on Caltrans' website, as experimental. The website also included a brief description of the intended use of each type of tsunami sign. The Caltrans experimental tsunami sign designs and sizes were utilized in the project as the only available standards. The available sign sizes, however, created unresolved problems during installation. The existing tsunami signs in the Harbor area were the smallest available size (12" x 12" or 12" x 15"). On the other hand, the signs recommended to the City, for visibility purposes, were the largest available size (24" x 24" or 24" x 30"). Due to budget constraints, none of the existing signs were replaced. This resulted in the tsunami sign sizes being inconsistent in the field. For the existing evacuation route signs that did not have directional arrows, the standard MUTCD arrow signs that were added to them, were actually wider than the evacuation route signs (21" vs. 15"). It is recommended that when new tsunami signs are installed, any existing signs be upgraded, as necessary, to be consistent in size with the proposed signs.

Updated Tsunami Sign Locations

The updated tsunami signs and their locations were based on the updated inundation zone maps, the updated evacuation routes, the project's *Tsunami Sign Installation Guidelines,* and input from the City of Los Angeles, Port of Los Angeles and County of Los Angeles.

The first step was to conduct a field inventory of the City and Port's estimated 120 existing tsunami signs, based on the agencies' records. The inventory also noted the condition of the existing signs, allowing some of the signs that were being removed to be re-used at new locations. Had the budget allowed, the inventory would also have been used to swap out signs in poor condition. Willdan then identified appropriate locations for the different types of tsunami signs, using the *Tsunami Sign Installation Guidelines*, the updated evacuation route maps and the updated inundation zone maps. The proposed signs/locations were compared to the existing signs/locations and the overlaps noted. Because the inundation zone boundaries had moved, most of the Entering/Leaving Tsunami Hazard Zone signs had to be removed or relocated, whereas there was no need to adjust most of the existing Tsunami Evacuation Route signs. New Tsunami Hazard Zone/In Case of Earthquake Go To High Ground or Inland signs were recommended for installation on the beaches and in the beach parking lots. New Tsunami Hazard Zone signs were recommended for certain evacuation routes in the Harbor area for traffic traveling in the direction opposite to the evacuation route, to remind motorists that they are in a tsunami hazard zone. The proposed removal or relocation of existing signs and the proposed locations of the new signs were presented to the City and Port for review and approval.

Several questions came up during the project regarding installing tsunami signs in an urban area. These issues should be discussed and resolved before including tsunami signs in the MUTCD. In an urban area, it is impractical to install tsunami signs on every street. Naturally, the evacuation route and "entering/leaving" signs were only installed on evacuation routes, which were typically major arterial streets. It is recommended that consideration and direction be given as to whether certain collector streets should also be made evacuation routes. This discussion should involve others, such as police officers, who typically determine the evacuation routes.

Since signs are being installed on major arterials, it is also recommended that consideration be given to increasing the available sign sizes to be consistent with standard signs on urban highways. This brings up another issue to be resolved: How noticeable should the tsunami signs be? Should they be as obvious as other signs or somewhat less obvious? Our experience in locating existing signs made it clear that the smallest signs were so small that the average motorist did not see them at all. It appears, however, that Caltrans is moving in the direction of making the signs larger: the draft 2011 CA MUTCD proposes to include the Tsunami Evacuation Route sign, with the only sign size being the largest shown on the Caltrans website and the one used for this project. It is still smaller, however, than signs typically installed on urban arterial streets.

Tsunami Sign Inventory and Preparation of Plans

A particular challenge of the project was how to develop plans for installing the wide variety and great number of signs to be removed/relocated/installed, in widely scattered locations. Typical street projects involve a limited number of signs that are spaced 100 to 200 feet apart on a single roadway and designated on signing and striping plans. This project involved over 400 signs that

were typically installed at least one-half mile apart, in a 21 square mile area that included 10 miles of beaches. We had initially planned to send staff out to do the usual field measurements with measuring wheels and to record data by hand. Small sketches of each existing and proposed location would be prepared, with several sketches on a plan sheet. Even using a standard format for the sketches, this was a rather daunting task. Since the project required that the sign data be provided to the City in GIS form, we began to consider using GPS units to collect the data. Willdan was already using GPS tablets to collect field data for other types of projects, so we knew that we could collect GPS data points that could converted by the GIS software to the distances needed to locate the signs for installation and for City records.

Willdan purchased two hand-held GPS units that we custom-programmed using GIS software, to collect the other specific data that we needed for the project and that the City needed for its records. The required data included the date, type/size of sign, condition of sign, type of pole/post, other signs on the same post, primary street, cross street, end of block street, side of street, direction of travel and survey area. Comments could also be entered by hand. GPS readings were taken at three locations for each sign: at the sign location, at the beginning of the block and at the end of the block. The hand-held unit had a built-in camera and photos were taken of each sign/location. All of the data was downloaded into a computer using GIS software, where it could be viewed on a map that had been created for the project. The map was based on street centerline data and aerial maps provided by the City. Each sign location was indicated by an icon and number on the map. Clicking on an icon opened a menu showing all of the data that had been collected for that sign, as well as the photo that had been taken. Using the GIS software, customized data could be extracted and provided on an Excel spreadsheet.

The GIS software and GPS units were used in the opposite sequence for the proposed sign locations. The proposed locations were first hand-plotted on a print-out of the map, and then the locations were entered by hand on the map in the GIS software. Specific data about each sign, such as type of sign, were entered into an Excel spreadsheet and the data loaded into the GIS software and paired with the points that had been previously entered. All of the data was then loaded into a hand-held GPS unit, which was taken into the field, with a copy of the map. In the field, specific sign locations were identified based on the general location provided, and the GPS information and other data was collected. As before, the collected data was downloaded into the GIS program, where it could be viewed or extracted into an Excel spreadsheet.

To finalize the action for each sign location, the existing and proposed sign locations were combined into one spreadsheet. Using the information in the spreadsheet, it was easy to tell where a sign post should be removed along with the sign and what existing signs being removed could be reused and posted at a new location. New columns were added to the spreadsheet for “sign action” and “post action”.

The spreadsheet also solved the problem of how to show the locations of the beach signs, which had no standard reference points, on a set of plans. The other main advantage of using the spreadsheets and maps instead of signing and striping plans is that the sign data is presented in a format that can be entered directly into the City’s sign database, with no need for a separate work order.

The installation of tsunami signs on the beaches presented several unusual challenges. The first challenge was determining who had jurisdiction over installing signs on the beaches. Another challenge was determining where to install the signs so as to capture the attention of most beach-goers. Although parking lots are provided for the beaches, many beach-goers park on adjacent streets and walk directly onto the beaches. The final challenge was figuring out how to install signs in the sand. Regarding the jurisdiction, we found that City has a contract with the County of Los Angeles (County) to administer and operate four of the five City beaches. The fifth beach is in the Port of Los Angeles and managed by City lifeguards. We also found that two County departments have jurisdiction regarding the placement and installation of signs on the beach. The Department of Beaches and Harbors controls access to and activities on the beaches, whereas the Fire Department's Chief Lifeguard controls the lifeguard towers and related equipment. In meetings with the two departments, it was agreed that a tsunami warning sign would be installed at the entrance to each parking lot, but that signs would also need to be installed on the beaches to capture the beach-goers that parked on the adjacent streets. It was determined that it was not feasible to install the signs on the lifeguard towers, but that we could install the signs on the existing telephone pole adjacent to each lifeguard tower, instead. Since the tsunami project team would not be allowed to drive their vehicles on the beaches, the County agreed to transport the data collector and the sign crew to each proposed beach sign location to conduct the sign survey and to install the signs, respectively.

County staff further informed us that all of the beaches fall under the jurisdiction of the California Coastal Commission, which ultimately has a say in all activities on the beaches. It was eventually determined, however, that by only installing signs on existing poles and posts in the beaches, we could install the signs under the County's current agreement with the California Coastal Commission without any additional approval.

Tsunami Sign Installation

New tsunami signs, including arrow signs, were purchased, based on the proposed sign actions. Instead of a set of full-sized signing and striping plans, the GIS-based spreadsheet and maps, noting the action to be taken and the location of each existing and proposed sign, were provided to the sign crew. The use of the six-page 11" x 17" spreadsheet and the maps worked well as a substitute for plans and reduced the paperwork the sign crew had to carry around. The sign crew noted the date each sign was installed and any necessary adjustments, and this information was input into the master sign spreadsheet.

Wherever possible, new/relocated signs were installed on existing street light poles or existing sign posts. The installation of signs on existing posts helped minimize sign pollution, but it frequently turned out to be more expensive than merely installing a sign on a new post. Existing posts were often not tall enough to accommodate the additional sign(s), requiring removal of the existing post and installation of a new post. The existing signs on the post also had to be moved from the old post to the new post. The reduction of sign pollution should be carefully weighed against the cost of installing signs on existing posts, particularly if done by a contractor instead of by City forces.

The subcontractor removed approximately 20 signs, relocated 30 signs, and installed 450 new signs in various locations, including 100 new signs on the beaches. Once the signs were installed, a Willdan inspector reviewed each installation, noted any discrepancies, and took a

GPS reading and photograph of each of the locations. The inspector's data was also input into the master spreadsheet. The proposed actions were compared to the sign crew's actions and to the inspector's records. Discrepancies were noted, a punch list was developed, and necessary modifications to the installed signs were made by the sign crew. The master sign spreadsheet was finalized and provided in electronic form, along with the matching digital maps, to the City for their records.

Brochure Printing and Distribution

The original task for this phase was to update the brochure for each of the three inundation areas by showing the new inundation zones and any new evacuation routes, revising any out-dated instructions and making them easier to read/follow. We were to also print the brochures and mail them to City-provided addresses within or near the inundation zones. The City later expanded the task to include translating and providing the brochures in Spanish, Chinese, Korean and Armenian. The primary challenge for this phase was meeting Americans With Disabilities Act (ADA) requirements. As we were finalizing the brochures, we were informed that in order to meet ADA requirements, we also needed to provide the three brochures in both large print and Braille formats, for all five languages. To accommodate the larger font, the large print versions were resized for printing on 11" x 17" paper instead of the 8½" x 14" paper used for the regular-size brochures. By the end of the project, Willdan had printed and distributed 45,000 brochures.

The Braille versions required additional research. It was found that each organization that transcribes documents into Braille has their own special format. In this case, the Los Angeles Braille Institute prepared the transcriptions and anyone wanting a Braille version of any of the City's tsunami brochures will need to go to them for copies. The Braille versions presented another challenge. In lieu of the maps in the other brochures, we provided descriptions of the inundation zones' boundaries and the evacuation routes. Since the inundation zones' boundaries are frequently circuitous, particularly in the Harbor area, we selected streets just outside of the inundation zones to use as general boundaries of an "evacuation" zone. This idea came from the City of Huntington Beach, California, which has a separate evacuation zone map whose boundaries are more general than those on the City's inundation zone map.

Conclusion

This was a unique project that presented interesting challenges. Many of the tasks had not been done before, or not to the extent/scale required by the project. Despite the challenges, the project was a success:

- The City's updated Tsunami Annex was one of the first emergency operations documents to be prepared under the new FEMA guidelines and serves as an example for the City to use in updating their other Annexes and for other agencies to follow in updating EODs and Annexes to meet the new guidelines.
- The City has the *Tsunami Sign Installation Guidelines* to follow for future tsunami sign updates. The current tsunami signs are consistent with the new inundation zones and evacuation routes and include signs on the beaches. The sign installation data was presented to the City and the Port of Los Angeles and the County of Los Angeles, and

provided in a format that is consistent with their sign databases. The data was also provided in GIS format to update the City's NavigateLA on-line GIS database.

- The City has new tsunami brochures for each inundation zone that have the latest inundation zones and evacuation routes, with English, Spanish, Chinese, Korean and Armenian versions, all available in large print and Braille.
- The project was initiated in June 2010 and completed in March 2011. When the Japan earthquake struck in March 2011, generating a series of tsunamis that reached the California coast, the Tsunami Annex and tsunami brochures had been updated and were available for use, and installation of the tsunami signs had been partially completed.

References

1. In particular, Willdan's research included information from the California cities of Huntington Beach, Newport Beach, Seal Beach, San Clemente, Dana Point, Long Beach and Imperial Beach; the State of Oregon Department of Geology and Mineral Industries, Bellingham, Washington, Hawaii County Civil Defense, the states of California, Hawaii, Alaska, Oregon and Washington, the country of Japan, the National Oceanic and Atmospheric Agency's (NOAA) Pacific Tsunami Warning Center, NOAA's West Coast and Alaska Tsunami Warning Center, the International Tsunami Information Center (ITIC), and the Federal Emergency Management Agency (FEMA). The cities of Huntington Beach, Newport Beach and Seal Beach, Hawaii County Civil Defense, and NOAA's Pacific Tsunami Warning Center were contacted directly. Information from the other locations was accessed via their websites.
2. The State of California Department of Transportation (Caltrans) websites for tsunami signs (http://www.dot.ca.gov/hq/traffops/signtech/signdel/tsunami.htm) and for the California 2009 and draft 2011 versions of the *Manual of Uniform Traffic Control Devices* (http://www.dot.ca.gov/hq/traffops/signtech/mutcdsupp/).
3. Willdan Homeland Solutions, *City of Los Angeles, Emergency Operations Plans, Tsunami Response Annex*, December 2010.
4. Willdan Engineering, *Tsunami Preparedness Project Engineering Study*, prepared for the City of Los Angeles, California, December 2010.

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