



## Address-Level Effects in Aguadilla, Puerto Rico, from the 1918 $M_w$ 7.3 Earthquake and Tsunami

by Roland LaForge and William R. McCann

### ABSTRACT

The 11 October 1918  $M_w$  7.3 earthquake and tsunami that occurred about 20 km northwest of Puerto Rico is the most recent damaging seismic event to affect the island. As part of the relief effort, residents whose homes were damaged or destroyed filled out petitions that described the damage, and they were granted funds to repair or rebuild their residences based on these petitions. The records from this program were recently discovered in the General Archive in San Juan, Puerto Rico. After having apparently lain untouched for almost 100 years, they were scanned and preserved in digital format. Petitions from the town of Aguadilla, which was closest to the epicenter, were analyzed to show a detailed address-level picture of which sections of the town were affected by ground shaking and tsunami damage, and to what extent.

### INTRODUCTION

On 11 October 1918, almost 100 years ago, an  $M_w$  7.3 earthquake occurred beneath Mona Canyon, about 20 km off the northwest coast of Puerto Rico. This event caused 116 deaths and \$4 million (in 1918 dollars) in damage (Reid and Taber, 1919). The towns of Mayagüez, Aguadilla, Aguada, and Añasco suffered the most damage from the resulting ground shaking and tsunami, although additional minor damage occurred throughout the island. A reference map of these towns and an approximate location of the origin of the tsunami from Hornbach *et al.* (2008) are shown in Figure 1.

At the time, Puerto Rico was governed by a United States military administration, following the Spanish–American war of 1898. In response to the earthquake damage, a Special Earthquake Commission was formed during an emergency session of the Puerto Rico legislature in December 1918. The Commission was established, among other purposes, to collect information about damage to civilian infrastructure caused by the earthquake and to supervise the allocation of funds for repairs or replacement of resident-owned housing. The petitions for aid, Commission correspondence, and other related documents

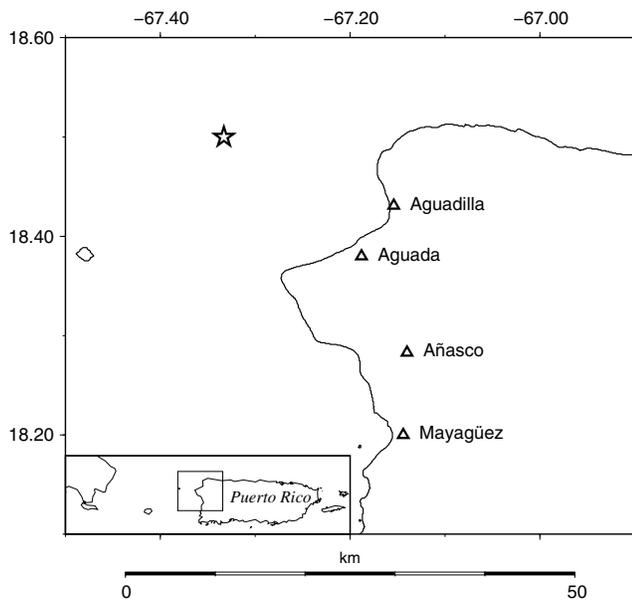
are archived in the General Archive in San Juan, Inventory of Public Works, Misc. Matters, Boxes 160–165. To our knowledge, until now this information had not yet been examined for historical earthquake research because of the volume and fragile nature of the documents, as well as probable ignorance of its existence.

The research presented here had two main goals: (1) to categorize, document, and scan the documents contained in the San Juan Archive to make them more readily available to the scientific community as well as to the general public and (2) perform preliminary analyses on the petitions for aid, from the town of Aguadilla. This second task consisted of detailed documentation, examination, and analysis of the petitions for aid from Aguadilla. The petitions contained descriptions of damage to houses in specific neighborhoods, on streets, and sometimes addresses, and thus they provide a unique ground truth dataset that paints a more detailed, location-specific picture of ground shaking and tsunami damage than more general accounts have done. The analysis provides important information to help construct fine-scale hazard maps and to corroborate models of tsunami runup and ground shaking from this earthquake.

### THE PETITIONS

The relief effort provided funding for the repair or replacement of individual owner-occupied residences. To obtain funding, homeowners were required to fill out a four-page form. Most were filled out by hand, making transcription of the information in some instances difficult, although some forms were typewritten. An architect was sent to inspect and verify the claim of the petitioner, determine the nature of the repairs, and estimate cost. Each form was signed by the inspector and the mayor of the municipality in which the damage occurred. In general, inspector reports, correspondence associated with the petition, and the petition itself were found together, facilitating examination of each petition on a case-by-case basis.

Information on the forms included the owner's name, age, civil status, occupation, and neighborhood (*barrio*), along with information about the house including its dimensions, type of construction, bordered on front by what street, names of neighbors to left, right, and back of property, address number



▲ **Figure 1.** Map of northwest Puerto Rico with towns most impacted by the earthquake and tsunami. The star shows the approximate origin of the tsunami from [Hornbach et al. \(2008\)](#).

of house, and plot size. All petitions, the forms as well as the responses, were in Spanish.

The petitions were processed, and funds disbursed, by February 1921, two and a half years after the event. Table 1 shows the final disposition for the towns where major damage occurred. A new house meant that \$250 was provided if the house was destroyed. In addition, materials for 50 houses were shipped in from the United States, and a new neighborhood (Barrio Obrero) was constructed at the south end of Aguadilla. It is presumed that owners who lost their houses were given the option of taking a house in the new neighborhood or rebuilding on their existing property. Table 1 shows the disposition and cost estimates resulting from the petition-based relief program from the final report of the Special Earthquake Commission. The total cost of home repair or replacement, including the 50 new houses for Aguadilla (not included in Table 1), is listed at \$103,660 in 1921 dollars. According to the U.S. Department of Labor (see [Data and Resources](#)), this equates to about \$1,250,000 in 2016 dollars. Petitions from Aguada were not found in the archives and are presumed stored elsewhere or lost. Reasons for denial of a petition included falsification of the damage report, the petitioner did not own the house, or the owner possessed adequate funds to make the necessary repairs.

## PETITIONS FOR AGUADILLA

From the archived records, at the time Aguadilla had a population of 6135. Of these, 42–46 (depending on the source) lost their lives, 300 were seriously injured, and 1500 were rendered homeless. Total property loss was estimated at \$300,000 in 1918 dollars.

The petitions for Aguadilla were examined in detail in an attempt to locate and assess tsunami and ground-shaking damage with street-address resolution. Of the 275 received petitions, however, only 88, or 32%, were found in the San Juan Archives. Thus, 187 were stored elsewhere, discarded, or lost. A total of 118 or 80% of the new house petitions were not found, whereas only 12 or 33% of the repaired houses were not found in the archive. This suggests that petitions involving repairs were preferentially saved. From summary statements, 37 petitions are known to have come from areas outside the town limits of Aguadilla, mostly along the east–west-trending coastline to the north.

Of the 88 petitions, only 29 contained street numbers. All others were identified by street and barrio. Although these barrios exist today, their 1918 boundaries are not well known, and it is also not known if their present-day boundaries are the same today as they were in 1918. From a town map found in the archives made sometime prior to 1918, street locations for the most part have not changed, but some had different names. Modern addresses, in sequence and direction, appear to be roughly consistent with those in the petitions.

To give a rough quantification to damage at specific petition sites, the damage scale shown in Table 2 was created. The damage for each petition was assigned a number, and its location was plotted specifically if an address was given or assigned to a more general area if only the street or barrio was entered on the form.

## DAMAGE IN AGUADILLA

The results are presented on the map shown in Figure 2, along with the locations discussed below and in Table 3. Elevations based on light detection and ranging (lidar) data are also plotted. Figure 3 shows street names referred to.

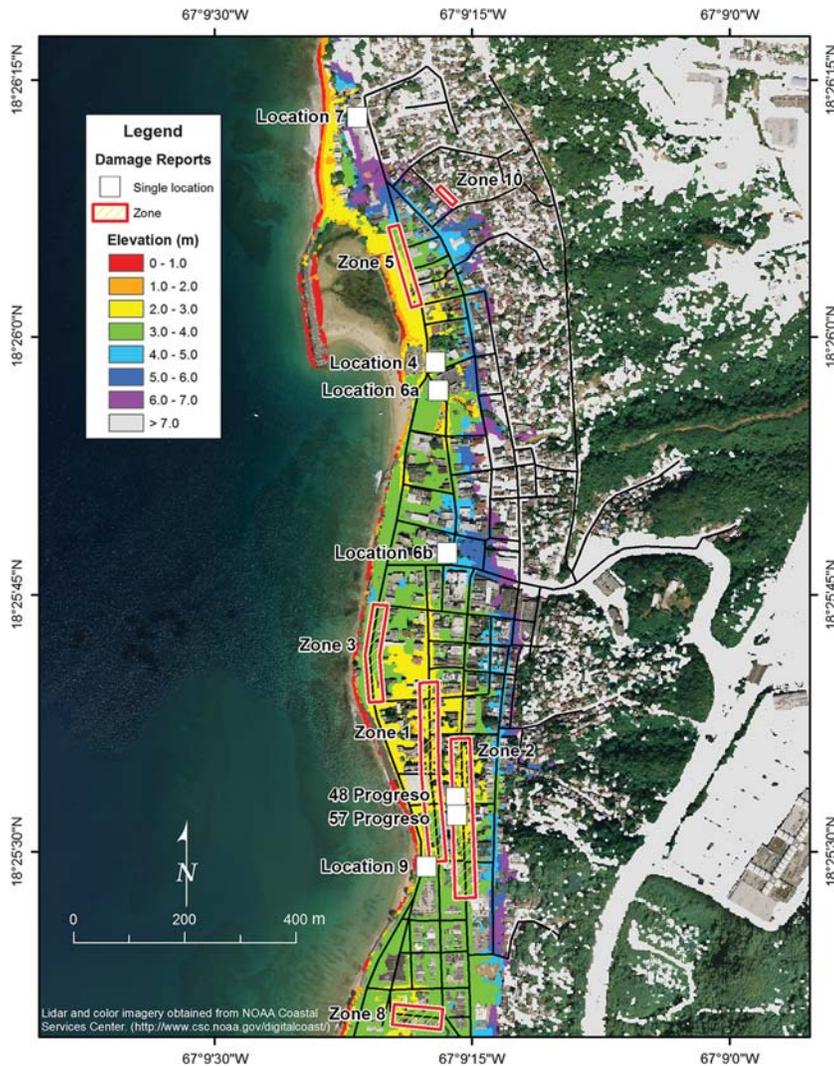
The damage summary is shown in Table 3. The reports were grouped by either a zone, where one or more reports can be located with some degree of confidence, or specific locations where one or more reports can be precisely located.

The damage reports come from two main areas.

The first is the neighborhood to the south between Calle Concepción and Calle Sol (north to south), and the shoreline

**Table 1**  
**Summary of Disposition of Petitions**

Town	Petitions Received	Denied	Granted	Houses Repaired	New Houses	Cost
Mayagüez	326	101	225	167	58	\$21,860
Aguadilla	275	92	183	36	147	\$41,621
Añasco	171	28	143	137	26	\$13,673
Aguada	86	23	86	37	26	\$8,806



▲ **Figure 2.** Damage summary and elevations for Aguadilla.

<b>Number</b>	<b>Damage</b>
1	House carried away by tsunami
2	House moved by tsunami, not repairable
3	House destroyed by tsunami, not repairable
4	House moved by tsunami, repairable
5	House not moved by tsunami, repairable
6	House destroyed by ground shaking
7	House severely damaged by ground shaking, repairable
8	House moderately damaged by ground shaking, repairable
9	House lightly damaged by ground shaking, repairable
10	Tsunami and ground shaking damage
11	No damage

and Calle Progreso (west to east). Along Calle Comercio, which runs along the shoreline, all petitions report complete destruction, often with the house completely carried away by the tsunami. This includes the Calle Sol reports (location 9) which are on the beach.

The Calle Betances addresses, where two can be located by virtue of a cross street and railroad crossing (which are visible on pre-1918 maps) being named in the petition, with one exception, lie along a roughly 200 m line between Calle Mercedes (now Rogelio Castro) and Calle Sol. This zone (zone 1) lies between a few and 70 m of the shoreline (on pre-1918 maps the south termination of the street ends at the beach). Damage to these houses ranged from complete disappearance to being pushed off their foundations as much as 50 m, but in some cases, retrievable and repairable. Address 42 suffered no tsunami damage. If addressing was consistent at the time, this location would be directly west and a short distance north of 48 Calle Progreso.

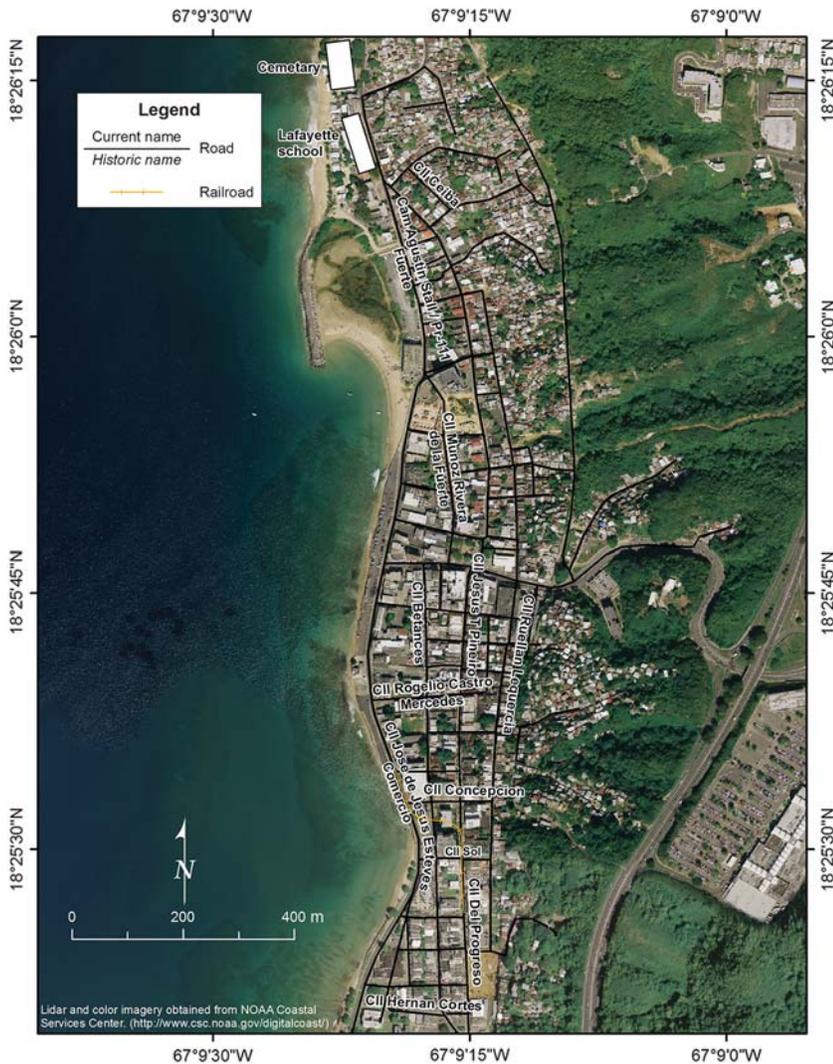
Figure 5 is an 1899 photo looking south from the southern end of Calle Betances, probably from near Calle Concepción. It gives an idea of architectural styles and building practices of this neighborhood, albeit 20 years before the earthquake. The photo was probably taken to show roof damage due to a severe hurricane of that year.

Calle Progreso (zone 2) lies about 50 m east of Calle Betances. Reports tied to street corners and the railroad imply that the addresses increase from north to south and fall within a roughly 200 m line between Calle Concepción and Calle Central (Calle Central is about half-

way between Calle Concepción and Calle Hernán Cortés). Addresses 48 and 57 report some water damage but not enough to cause major damage. These are precisely located and are consistent with present-day address locations. At address 61, currently just south of the Calle Concepción intersection, the inspector reported no damage. Address 134, presumably some distance to the south, suffered repairable structural damage but no tsunami damage. Most of the houses on this street were larger, relatively older houses.

The Calle Comercio reports comprise zone 3. Although 9 addresses were gleaned from 17 damage reports, the locations of these addresses remain unknown. Damage reports, as described above and in Table 3, vary widely. Knowledge of these address locations would be valuable.

About 200 m north of this area, at 10 Calle las Mercedes (now Calle Rogelio Castro, shown in Fig. 3), a false report was filed for a small wood house; the inspector found no damage. From the old map, that street ran from the shoreline 250 m to the east, ending at present-day Calle Ruella Lequerica. The low address number implies that this location was at either the east



▲ **Figure 3.** Streets referred to in damage discussion. Note that Calle Mercedes in 1918 is now Calle Rogelio Castro, Calle Comercio is now Calle Jose de Jesus Esteves, and Calle de la Fuente is now Calle Muñoz Rivera.

**Table 3**  
**Aguadilla Damage Location Summary**

Zone	Location	Area	Damage
1		Calle Betances	1, 3, 4
2		Calle Progreso	9, 10, 11
3		Calle Comercio	3, 4, 5, 8, 10
	4	Stahl and Fósforo	6
5		Calle Stahl	10
	6	Calle de la Fuente	7
	7	Playa, Escuela Lafayette	1
8		Calle Hernán Cortés	8
	9	Calle del Sol, Playa	1
10		Calle de Ceiba	6

or west end of the street. The east location is more likely, for if at the west end the house would have been impacted by the tsunami. However, modern addresses on this street appear to increase from west to east. The fact that this house suffered no damage is noteworthy.

The second main area is to the north, between the old Lafayette School (now Escuela Carmen Gomez Tejera) on the north, and the intersection of Calle Stahl and Calle Fósforo to the south, a length of about 200 m.

Location 4 is explicitly at the corner of Stahl and Fósforo. The two-story mamposteria (unreinforced masonry) structure was rendered uninhabitable by ground shaking, but there is no mention of tsunami inundation. At location 6a or 6b, another large mamposteria structure was damaged, but judged repairable. Again, no tsunami damage was noted. If street numbers on Calle de la Fuente increased to the south, this implies a location very close to location 4. Alternatively, this location could be at the south end of Calle de la Fuente. This is possible, because location 4 is in Barrio Tamarindo whereas location 6 is in Barrio Iglesia, which is to the south of Barrio Tamarindo. Therefore, the 6b location in Figure 2 is considered more likely.

Zone 5 attempts to encompass the address 58 Calle Stahl. This older larger house was severely damaged, but deemed repairable for \$248. The kitchen and dining room at the rear (beach side) of the house disappeared, but apparently enough of the house was left to reconstruct it.

Location 7 is the beach area between the Lafayette School and the Cemetery. Houses here were completely destroyed and carried away by the tsunami.

Zone 10 attempts to encompass a report from Calle Ceiba, where a wood house was destroyed by ground shaking. The zone conforms to the hill to the rear of the house in the damage petition, as observed in present-day topography.

Zone 8 lies about 100 m south of Calle Sol, on Calle Hernán Cortés. Today, this street is 50 m long and in the same location as in 1918. A report for a larger wooden house with kitchen on the back indicates it was severely damaged, but repairable. There is no mention of tsunami damage.

## IMPLICATIONS FOR TSUNAMI INUNDATION

Although the damage reports for Agudilla are far from complete (the archive contained only 32% of the total), there are enough reports indicating the extent of tsunami damage that some conclusions can be drawn.

The first, and most obvious, is that all houses along the beach were severely impacted, in many cases with no trace of



▲ **Figure 4.** Photo from Puerto Rico Ilustrado number 452, showing shoreline damage near zone 3 in Figure 2.



▲ **Figure 5.** Photo from San Juan archives looking south from the south end of Calle Betances (near location 9 in Fig. 2) in 1899.

the structure remaining. Figure 4, from Puerto Rico Ilustrado issue number 452, shows shoreline damage in the La Ñamera district, whose exact location is unknown, but from the shoreline in the background is probably near where modern Calle Rogelio Castro (Fig. 3) meets the sea. Evident from this photo is that some houses were knocked of their stilt foundations, but they remained more or less intact and could be moved back to their original locations, as confirmed in some of the damage reports. Another observation is that palm groves and other vegetation

along the shoreline appears to be dense and may have impeded the tsunami movement inland. Figure 5, looking south from the south end of Calle Betances, also shows dense tree and vegetation growth along the shoreline.

The second major observation is that, although limited in completeness, the reports of tsunami damage inland come from two zones: the area between Calle Stahl to the south and the Lafayette School, El Fuerte (the old Spanish fort), to the north, and the area along Calles Betances and Progreso to the south. The lidar map (Fig. 2) shows that these areas have elevations of less than 3 m. There are no reports of tsunami damage inland between these two areas, which is of higher (3–4 m) elevation, though such reports may have existed. However, a report from Calle Hernán Cortés (zone 8 in Fig. 2), in the 3–4 m elevation range, clearly indicates no tsunami effects.

Location 6 in Figure 2 apparently sustained no tsunami damage. This location corresponds to a specific address, 3 Calle de la Fuente. If this location is on the north end of Calle de la Fuente its elevation is 2–3 m; if on the south end it would be 4–5 m. As discussed above, location 6b is considered more likely. Location 4, precisely located at the intersection of Calles Stahl and Fósforo, is in the 3–4 m range and did not mention tsunami damage. The house at address 58 Calle Stahl, represented by zone 5 (exact location unknown, but north of Calle Fósforo), faced east and had its back to the shoreline. The report states that the kitchen and dining room at the back of the house were destroyed by the tsunami, with much structural damage to the rest of the house although the house was repairable. Because the precise dimensions and construction of this house were documented, it may prove valuable in estimating the physical characteristics of the tsunami as it hit this location, which is at an elevation of 3–4 m.

To the south, zones 1 and 2 show progressive tsunami effects from west to east. Along Calle Betances (zone 1), which lies 30–70 m from the shoreline, houses closest to the beach were totally destroyed, while those to the north were knocked off their foundations and pushed inland. The house with the lowest address number, probably in the northern part of zone 1, though severely damaged, did not mention tsunami effects. Figure 5, a photo taken looking south from the south end of Calle Betances, shows what houses along the street looked like, albeit 20 years before the earthquake. Some of the Betances damage reports may be for houses shown in this photo.

Along Calle Progreso about 50 m to the east (zone 2), and about 70 m from the shoreline, the tsunami reached its maximum inland extent. At 48 Progreso (Fig. 3), water damage was claimed, but because the inspector could not detect it after the owner repaired the damage, it must have been minimal. At 56 Progreso, the inspector claimed the water came up to within 6 ft of the house, and denied a claim for water damage. At 57 Progreso (Fig. 3), water carried away clothing and furniture. At 61 Progreso, no damage was detected, and the claim was denied. These reports clearly identify this localized area as where the extent of inundation was reached, in this part of town. The area lies 70–80 m from the shoreline, and at an elevation of no more than 4 m.

## CONCLUSIONS

The digital restoration, archiving, and analysis of these documents provide valuable insights into the location and extent of damage from the 1918  $M_w$  7.3 earthquake and tsunami. Tsunami damage from these reports is placed exclusively in areas of less than 4 m elevation, and in most cases, less than 3 m. At two locations in the 3–4 m elevation range, no water damage was noted. Fortunately, on Calle Progreso, two addresses correlated with a cross street and railroad track provide precise locations, and they revealed the maximum extent of inland inundation. These addresses appear to be consistent with modern-day ones.

The general conclusions for Aguadilla are consistent with the original Reid and Taber (1919) report and those of Hornbach *et al.* (2008), who computed wave heights of 2.4–3.4 m for the Aguadilla coastline. They are also consistent with wave heights computed by López-Venegas *et al.* (2015). The analysis presented here provides more detail into which parts of the town were most impacted by the tsunami, and therefore most likely to suffer damage in a similar event.

Further work on this dataset could be performed for Mayagüez and Añasco as well. An additional research topic could be estimation of ground motions that caused damage or destruction of structures, given construction techniques of the time.

## DATA AND RESOURCES

Source data were scanned from the General Archive in San Juan, Inventory of Public Works, Misc. Matters, Boxes 160–165. In addition, documents and photographs relevant to the 1918 earthquake were scanned from the Puerto Rico National Library and Photographic archive. These digitized documents are available in DVD format by e-mail request from

the first author. Generic Mapping Tool (GMT; Wessel and Smith, 1998) was used to generate Figure 1. The final National Earthquake Hazards Reduction Program (NEHRP) report for this research can be obtained from <http://www.nehrp.gov> (last accessed May 2017). The U.S. Department of Labor is available at <http://www.bls.gov/data/> (last accessed May 2017). ☒

## ACKNOWLEDGMENTS

Mark Zellman produced Figures 3 and 4. Ramon Calero of Aguadilla aided in investigating past and present postal addressing protocols for that town. Seth Dee transcribed petitions for Añasco. The task of scanning the several thousand archive documents was performed by Paola Schiappacasse and Beatriz Cueto of Guaynabo, Puerto Rico. The article was improved by a careful review by John Ebel. This research was supported by National Earthquake Hazards Reduction Program (NEHRP) Grant Number G10AP00083.

## REFERENCES

- Hornbach, M., S. Mondziel, N. Grindlay, C. Frohlich, and P. Mann (2008). Did a submarine landslide trigger the 1918 Puerto Rico tsunami? *Sci. Tsunami Hazards* 27, 22–31.
- López-Venegas, A., J. Horrillo, A. Pampell-Manis, V. Huérfano, and A. Mercado (2015). Advanced tsunami numerical simulations and energy considerations by use of 3D–2D coupled models: The October 11, 1918, Mona passage tsunami, *Pure Appl. Geophys.* 172, no. 6, 1679–1698, doi: [10.1007/s00024-014-0988-3](https://doi.org/10.1007/s00024-014-0988-3).
- Reid, H., and S. Taber (1919). *The Porto Rico Earthquake of 1918, with Descriptions of Earlier Earthquakes (Report of the Earthquake Investigation Commission)*, House of Representatives Document 269, Washington D.C., 74 pp.
- Wessel, P., and W. H. F. Smith (1998). New, improved version of Generic Mapping Tools released, *Eos Trans. AGU* 79, 559.

*Roland LaForge*  
*LaForge GeoConsulting*  
*16682 W 56th Drive*  
*Golden, Colorado 80403 U.S.A.*  
*LaForgeGeoconsulting@gmail.com*

*William R. McCann*  
*Earth Sciences Associates*  
*10210 West 102nd Avenue*  
*Westminster, Colorado 80021 U.S.A.*  
*wrmccann@comcast.net*

Published Online 5 July 2017