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Using Historical Information to Inform Planning for Floods after Fires

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Abstract

Historical information about floods is not commonly used in the US to inform land use planning decisions. Our current approach to manage floods is based on static maps that do not reflect the processes involved in creating a flood disaster. We developed a method to analyze how the exposure has evolved in flood hazard zones in Montecito, California, an area devastated by debris flows on January 9, 2018. Results show that despite policies discouraging developments in hazard areas, developments have increased substantially since Montecito joined the National Flood Insurance Program in 1979. The knowledge produced in this project can help the Montecito community better understand how they came to be vulnerable to floods and inform what actions might increase or reduce their vulnerability to the next big flood.

Key words: Floods after fires, debris flow, Montecito, Sanborn insurance maps, Flood Insurance Rate Maps.

1. Introduction

On January 9, 2018, intense rains over the burnt catchments of Santa Ynez Mountains in Montecito, California, released a deadly debris flow, leading to 23 fatalities, 167 injuries (Diskin, 2020), and 558 buildings damaged (CAL FIRE, 2018). The debris flow followed the Thomas Fire which burned 440 square miles in Santa Barbara and Ventura Counties over the prior month (Diskin, 2020). The denuded slopes and impermeable soil from the fire, together with a sudden heavy storm produced the debris flow (Keller et al., 2019).

Debris flows after fires are common in Montecito (Keller, 2020; Gurrola and Rogers, 2020). The problem is that exposure in hazard zones has increased substantially in the last decades. Since 1900 there have been six debris flows and debris-laden floods after fires in Montecito (1914, 1926, 1964, 1969, 1971 and 2018, 2019) (Gurrola and Rogers, 2020), which have caused significant property damages, and on some occasions, loss of lives.

In this paper we develop a method to (1) analyze how the information depicted in FEMA flood hazard maps has evolved over time in Montecito, and (2) quantify the increase of exposure in flood hazard areas over the last 100 years. This paper also investigates major challenges of using Flood Insurance Rate Maps (FIRMs) to manage land use in alluvial fan areas such as Montecito.

In the spirit of Gilbert White's (1994) Boulder Creek Flood Notebook, this study provides insights into how the community of Montecito came to be vulnerable to floods through steadily increasing exposure in high hazard zones. Our hope is that this paper can promote the understanding of how future land-use decisions may either reduce or increase the human consequences of the next large flood.

1.1. Study area

Montecito, an unincorporated community east of Santa Barbara, has alluvial-fan landforms sloping north-south from the Santa Ynez Mountains' front down to the gentle-sloping coast of the Pacific Ocean. Between the Santa Ynez Mountains and the coast sits a wide swath of urbanized areas, traversed by valley creeks and Highways 101 and 192. Debris flows after wildfires are common in Southern California, they reoccur on time scales of 30-65 years (Keller et al., 2019).

2. Hypothesis and Methods

Our hypothesis is that despite policies discouraging developments in flood hazard areas, exposure has increased significantly not only outside, but also inside the current regulatory flood hazard area (called the Special Flood Hazard Area or SFHA), even after Montecito joined the National Flood Insurance Program (NFIP) in 1979. To test this hypothesis, we have:

(1) Analyzed how official FEMA flood hazard maps have evolved over time in Montecito. To do so we have compiled, georectified and digitized historical documents, the Flood Hazard Boundary Map (FHBM) from 1977 and the FIRM from 1996, overlain with digital maps from 2012 and 2018 (the "effective FIRM"), as well as the FEMA recovery map created for the reconstruction process after the January 9, 2018 debris flow.

(2) Delineated an extended flood hazard area for Montecito beyond the current Special Flood Hazard Area by overlaying all the FEMA maps mentioned above with the map of the 2018 debris flow footprint created by the California Geological Survey (figure 1).

(3) Quantified the exposure evolution in this extended flood hazard area using Sanborn (Fire) Insurance Maps from 1918, 1942, aerial imagery from 1970-1971, NAIP Imagery from 2016, and a GIS data layer with the structures from 2016 provided by Santa Barbara County (figure 2).

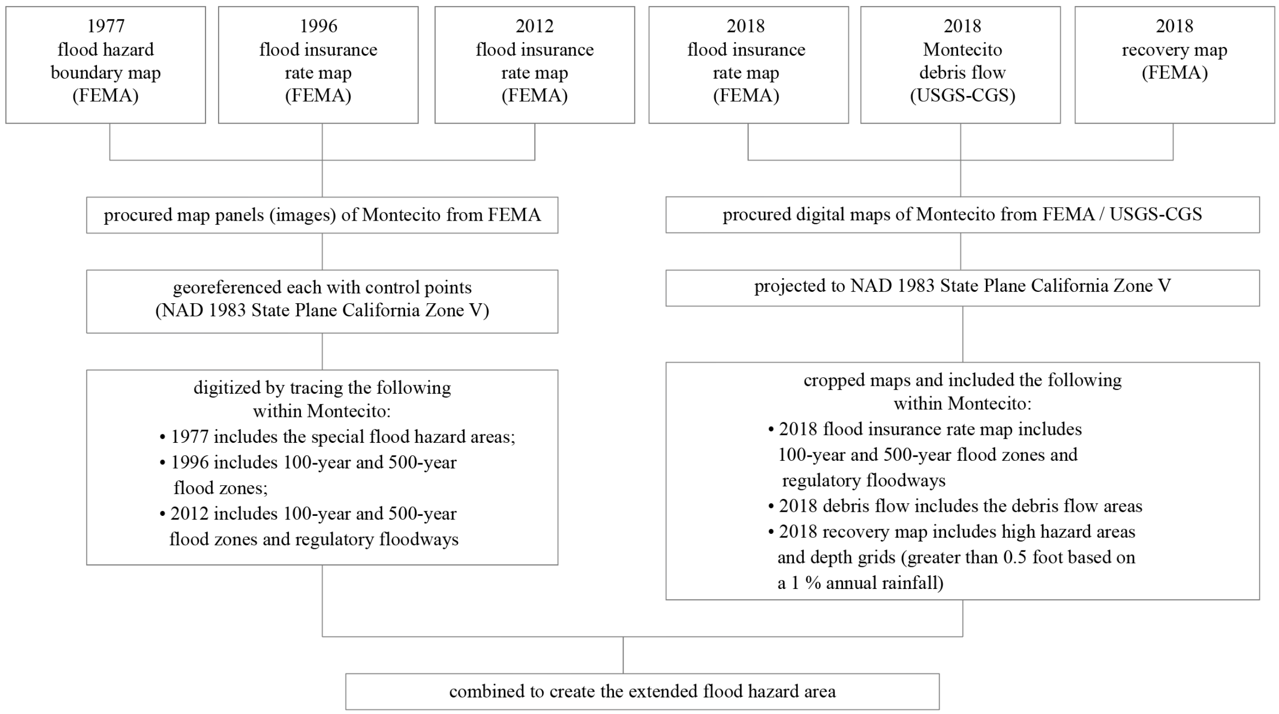

Figure 1. Diagram showing the steps to create the extended flood hazard area (overlay of FEMA maps produced over the last 50 years and the 2018 debris flow footprint).

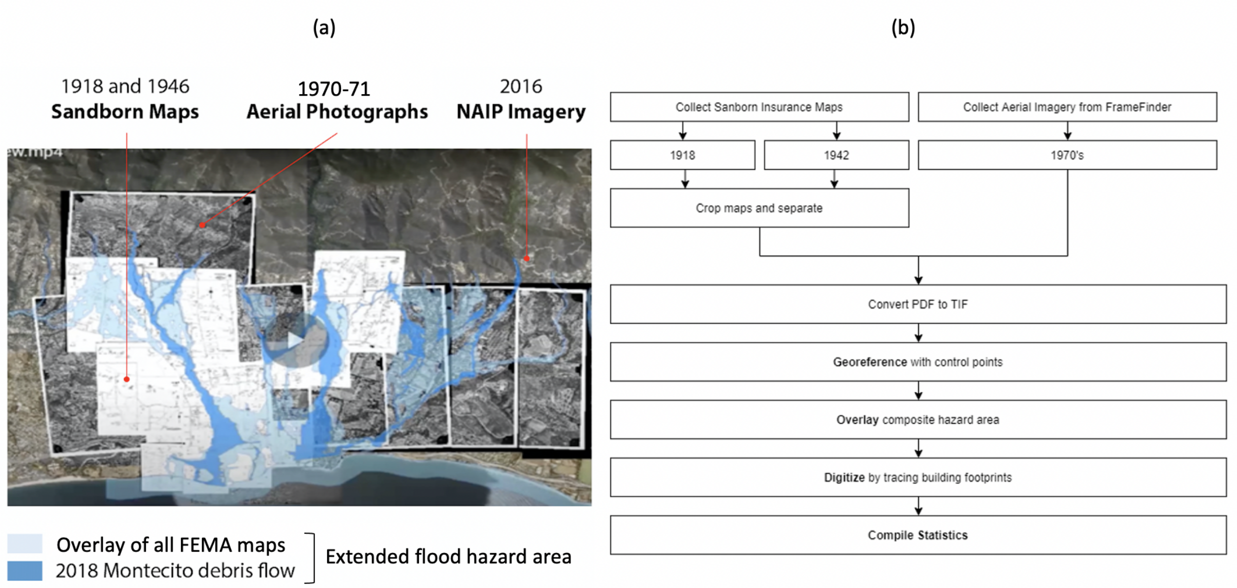

Figure 2. Image showing: (a) the extended flood hazard area (overlay of FEMA maps produced over the last 50 years and the 2018 Montecito debris flow footprint), and the material used to analyze the evolution

of the exposure over time, and (b) the steps followed to georectify and digitize historic documents and quantify the evolution of structures in hazard areas of Montecito.

3. Results and Discussion

3.1. Evolution of flood hazard maps in Montecito

The area mapped as being in the flood hazard footprint in the FIRMs has decreased considerably in the last 50 years. However, the reduced area of the SFHA does not necessarily imply that the risk has reduced.

One important limitation of using FIRMs to manage land use in Montecito is that these maps are made using a riverine flooding approach. However, Montecito is built on alluvial fans. FIRMs are made using clear water models and assumptions that don't encapsulate the complexity of alluvial fan behavior, such as frequent switching of channels (avulsion) and debris flows.

During the 2018 Montecito debris flow, 558 structures were damaged, 162 of which were considered destroyed (CAL FIRE, 2018). After this event, Santa Barbara County decided to facilitate the reconstruction of all the structures impacted by the 2018 event, even if they were located inside the SFHA.

Aware of the limitations of using the new FIRM created in 2018 for the reconstruction process, the same year FEMA created another map showing flood water depth (100y) and using assumptions that try to reproduce the behavior of debris flows (e.g. assuming that culverts and bridges will be clogged with debris and water will overtop these structures), although it is still based on clear water models. This map is known as the "FEMA recovery map". This map does not replace the effective FIRM but is intended to inform the recovery process (e.g. requiring building codes for the reconstruction beyond the FIRM boundaries), since most of the houses destroyed, not surprisingly, were located outside of the Special Flood Hazard Area.

3.2. Evolution of exposure in hazard areas of Montecito

Figure 3 shows the evolution of the structures in the extended flood hazard area of Montecito during the 20th century and beginning of the 21st century. Figures 3 (a) and (b) show how the number of structures in the part of the hazard area covered by the Sanborn maps increased from 624 in 1918 to 886 in 1942. Over the last 50 years, the number of structures in the overall flood hazard area has almost doubled, increasing from 1,164 in 1970 to 1,976 in 2016 (figures 3 c-d). Although the different periods are not comparable quantitatively, this image gives us an idea that Montecito was much less dense 100 years ago and the more intense development happened during the second half of the 20th century. However, the structures in the community on Montecito as a whole are less dens compared to similar areas in southern coastal California. The extended flood hazard area also has to be used cautiously - beyond this boundary, there is still an area of uncertainty where floods may occur.

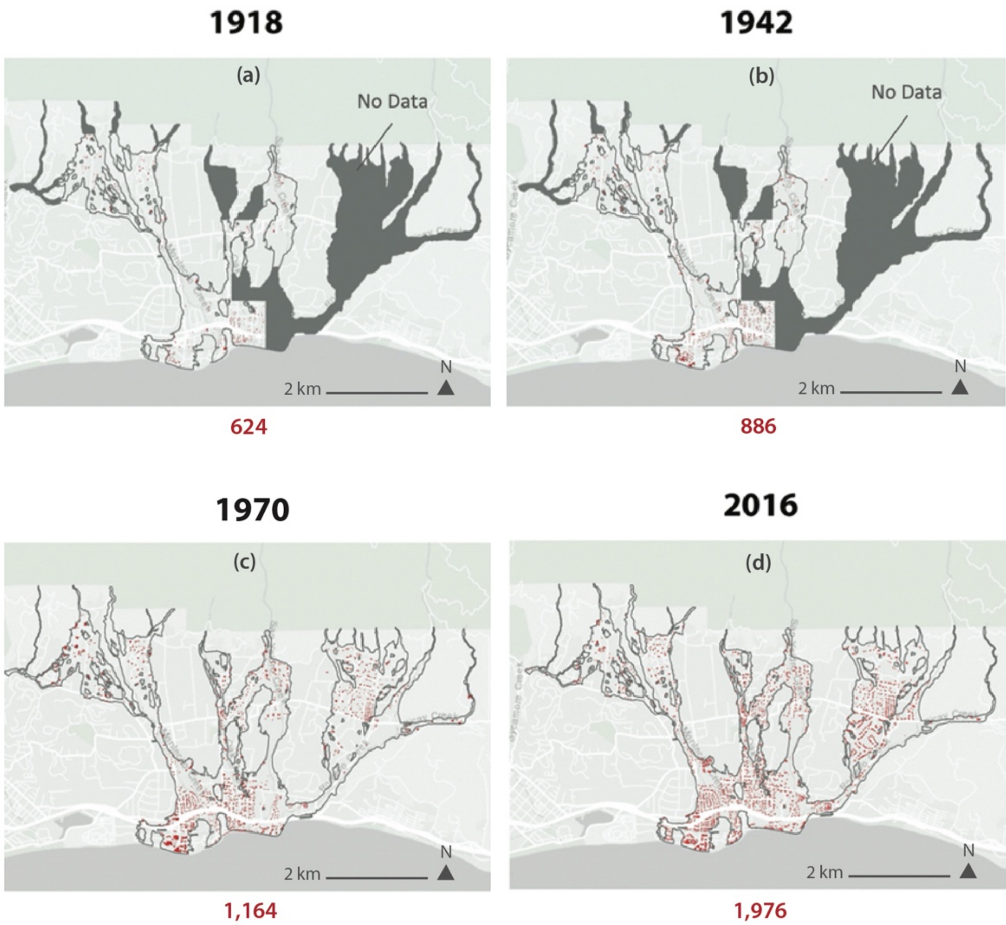

Figure 3. Evolution of exposure (structures) in the extended flood hazard areas of Montecito during the last 100 years.

While the magnitude of the 2018 event was unusually large (Keller, 2020), some of the areas affected had experienced repeated damage from floods and debris flows over the past century (Gurrola and Rogers, 2020). However, damaged houses had been rebuilt and new houses constructed within the hazard zone. In 1979 Santa Barbara County joined the NFIP. Although this program is intended to reduce exposure in hazard areas the number of houses in flood hazard areas of Montecito has increased substantially in the SFHA. Currently, more than 90% of land use in flood hazard areas is zoned as residential, the most incompatible land use in hazard zones. Montecito is not a unique case; this is a very common pattern across the US. This is in part due to the fact that under the NFIP, developments in high hazard zones are highly discouraged but not forbidden, as they are in other countries such as Spain, France or Austria.

4. Conclusions

This study shows that despite policies discouraging developments in hazard zones, exposure has increased significantly since Montecito, even after joining the NFIP in 1979, what reflects a common trend in the US. Furthermore, the analysis of the evolution of the FIRMs in Montecito shows the limitations of using clear water maps to describe much more complex processes involved in the dynamics of debris flows. In light of this results our main recommendations for the community of Montecito are: (1) to replace the effective FIRM based on clear water (riverine flooding model) with the California Geological Survey post-fire debris flow hazard map (an alluvial fan flooding approach) created in 2018 using sediment transport models, historical and geomorphological information, and (2) to reclassify land use in high hazard zones to stop the trend of rebuilding in zones that have been repeatedly impacted by destructive flash floods and debris flows.

Finally, this study emphasizes the importance of contextualizing risk as a process and not as a phenomenon isolated in time and space (Hewitt, 1997). The method developed to analyze how exposure and the information about flood hazard has evolved over time can be applied elsewhere in the US to help other communities in flood hazard zones to better understand, in words of Gilbert White, “the key decisions that resulted in public exposure to flood loss” and “what kinds of decisions may either reduce or enlarge the human consequences of the next large flood” (White 1994).

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