Sacramento: Vulnerable Capital in a Flood-prone State

Author: JieQi Yan

Abstract

Sacramento has had a number of large and, at times, disastrous floods in the past decades. As the state capital and a city with a population density of around 5,500 people per square mile, flooding directly affects human life. It causes property damage, agricultural devastation, and livestock loss. This term paper is intended to provide an overview of floods in Sacramento. To better understand flood's impact in the capital, I reviewed public hearings and reports produced by the City of Sacramento, the Federal Emergency Management Agency, the U.S. Army Corps of Engineers, and the State of California Natural Resources Agency Depart of Water Resources. In this paper, I lay the groundwork for the demographic and geographic understanding of floods. With this context, I focused on flood history and the corresponding flood control. In addition, I provided a list of structural and non-structural mitigation methods currently in place in Sacramento. For future discussion, this paper attempts to produce a policy brief regarding the National Flood Insurance Program and other policy recommendations that can be implemented on a local level.

Introduction

Flooding is simply an excess of water that submerges dry terrain. It is a hydrological problem that greatly impacts agriculture, the economy, and public health. According to the Department of Homeland Security, flooding involves 90% of natural catastrophes in the United States. One in every five Californians and more than $580 billion in assets are at risk in a flood-prone state like California (Mount 2017). California's capitol is located at the confluence of the Sacramento and American rivers. Solving the problem requires work from many fields, including civil engineering, data interpretation, reducing risks, and educating the public. Floods will be examined through the lenses of geology and geophysics in this article. It will also look at the consequences of urban growth on floods, the history of floods in Sacramento, and the policies put in place to avoid, protect, and mitigate floods.

Flood

When a river or stream overflows into the surrounding region due to continuous rain over many days, heavy rainfall over a short period, or an ice or debris jam, flooding occurs. A flood can also happen if a structure that regulates water, such as a levee or dam, fails. The most common source of flooding is precipitation and/or snowmelt that accumulates faster than soils can absorb it, or rivers can take it away.

Flooding is most likely to occur in river floodplains and along the coast. Still, it can also occur in areas where continuous periods of heavy rain raise the water level in an existing waterway, such as a river, stream, or drainage ditch, or cause water to pool at or near where the precipitation fell. The most prone to floods are river floodplains and coastal locations. There is, however, no particular period of the year when flooding cannot occur. Many occur yearly once the snow melts in the winter or after heavy spring rains.

Demography and Geography

Demography

According to the United States Census Bureau, the city has a total area of 257.0 km^2 (99.2 mi^2). It covers 251.6 km^2 (97.2 mi^2) of land and 5.4 km^2 (2.1 mi$^{2)}$ of water, accounting for 2.1% of the total area. In 1990, the population was 395,100. Sacramento's current metro area population in 2022 is 2,186,000, a 1.44% increase from 2021. Among California's major cities, Sacramento is the fastest-growing population. With the increase in population, the city is also expanding in urban areas. For example, the Greenbriar Project (P11-093) requests to process approximately 577 acres of land at the southwest corner of Elkhorn Boulevard and Highway 99.

The Greenbriar Project

The project applicant is requesting entitlements for approximately 577 acres to be developed into 2,956 residential units (2,428 single-unit dwellings and 528 multi-unit dwellings), three commercial sites, open space/habitat buffers, open space/freeway buffers, six park sites, a community center, a lake/detention basin, a light rail station and park-and-ride facility, a school site, and various landscape corridors and related facilities (figure 1).

Fig.1 : An aerial of the Greenbriar Project site (City of Sacramento, 2017)

Geography

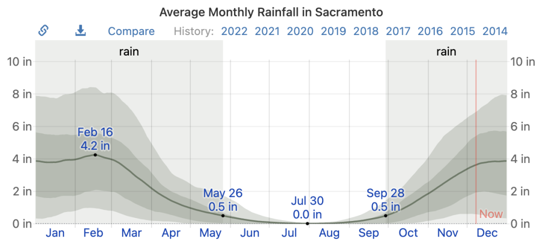
Sacramento is known as the “River City.” The city is located at the junction of the Sacramento and American rivers (Figure 2). It has a deepwater port connected to San Francisco Bay by a canal that runs via Suisun Bay and the Sacramento River Delta. It serves as a shipping and rail hub for the Sacramento Valley for fruits and vegetables, rice, wheat, dairy products, and beef. Food processing is one of the area's primary industries.

The average depth to groundwater is roughly 30 feet. A large portion of the land west of the city (in Yolo County) is a flood control basin. As a result, the broader metropolitan area extends just four miles (six kilometers) west of downtown (as West Sacramento, California) but 30 miles (50 kilometers) northeast and east into the Sierra Nevada foothills and 10 miles (16 kilometers) south into valley farming.

Fig.2: A mao outlining Sacramento city, the Sacramento River, and American River (ArcGIS).

Climate

Sacramento has a Mediterranean climate, which includes moderate winters and dry summers. The humidity in the region is typically low. The city, however, experiences extreme seasonal variation in monthly rainfall. From September 28 to May 26, there are 7.9 months of rain, with a typical 31-day rainfall of at least 0.5 inches. February has an average rainfall of 4.2 inches, making it the wettest month in Sacramento. Between May 26 and September 28, there were 4.1 months without rain. August has an average rainfall of 0.0 inches, making it the driest month in Sacramento. On average, it rains 58 days per year (Figure 3).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	3.8″	4.2″	3.2″	1.5″	0.7″	0.2″	0.0″	0.0″	0.3″	1.1″	2.6″	3.8″

Fig.3: The average precipitation (solid line) gathered during a 31-day precipitated on the given day, with 25th to 75th and 10th to 90th percentile bands (Weatherspark, 2016).

Most flood-related precipitations are caused by atmospheric rivers from the Pacific Ocean. An atmospheric river is a warm, intense stream of tropical moisture that produces days-long precipitation in the Central Valley (Nguyen, 2017). One noticeable flood that was caused by an atmospheric river is the 1986 flood that had a 10 in. of rainfall in 11 days. The massive floodwaters ripped bridges from their foundations and breached levees. The Northern California flood resulted in thirteen fatalities, the evacuation of fifty thousand people, and over $400 million in property damage.

Atmospheric River

Atmospheric rivers are the world's largest "rivers" of fresh water. An atmospheric river begins to emerge near the equator. The sun heats the globe directly at the equator, causing water to evaporate and rise into the sky.

The water vapor is then drawn away from the equator by air circulation, generating a narrow band that acts like a conveyer belt, transporting the water vapor to U.S. West Coast. Atmospheric rivers run at the lowest level of the atmosphere, only a half mile to a mile above the land. When atmospheric rivers reach the coasts and flow inland across mountains, they are pushed higher, forcing much of the water vapor to condense and fall to the ground as rain or snow, resulting in an atmospheric river-driven storm (Figure 4).

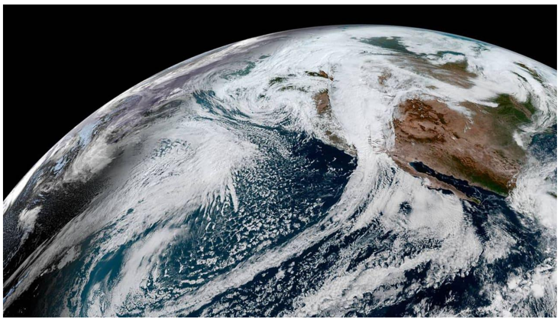


Fig.4: A satellite image of the 2019 atmospheric river. (NOAA)

Flood History

Since the 1840s, the settlement of John Sutter In Sacramento. It marks the beginning of a never-ending game of Tome and Jerry; water and man. Sacramento has been identified as the nation's greatest metropolitan flood risk. During the early day of flood control, the responsibility lay on the shoulder of the landowner. Due to the lack of firm city regulation, property owners compete to build a "slightly higher" levee than their neighboring owner on the opposite side of the river (SAFCA, Robert Lloyd Kelley, 1998).

History of Flood Control

1861-1872: The period marks one of the first primary flood control through road elevation. The American River Levee failed east of 30th Street on December 9, 1861, flooding what is today known as River Park. The flood subsequently overran the City's levee. The streets west of the Sacramento River to 12th Street were raised to 14 feet.

1864-1868: Sacramento engineers straightened the remaining two miles of the American River in an effort to produce quicker flows that may scour off mining detritus. When the project was finalized in 1868, the American River was nearly a mile upstream of its previous site.

1878-1880: State Engineer William Hammond Hall designed an integrated, comprehensive flood management strategy for the Sacramento Valley in response to the 1878 flood. To safeguard existing population centers, the concept was later expanded to incorporate a system of levees, weirs, and bypass routes. This was the first comprehensive flood control plan.

1911: The Yolo Bypass was built when the state approved the Flood Control Act. The two most significant construction of the Yolo Bypass, the

Sacramento Weir, constructed in 1916, and the Fremont Weir, completed in 1929.

1944: The Flood Control Act of 1944 granted the United States Army Corps of Engineers (Corps) permission to construct a dam on the lower American River known as the Folsom Dam. The dam was completed in 1996. It is a concrete dam flanked by earth wing dams and dikes with a total length of about 9 miles

1986: Sacramento received 10 inches of rain in 11 days during the February 1986 storm. The American River flows into Folsom at a rate that exceeds its capacity. After two days of design-level releases of 115,000 cubic feet per second (cfs), authorities increase discharges to 134,000 cfs.

1989: Sacramento Area Flood Control Agency was formed in October.

1997-1999: Watersheds buried in snow and already saturated from one of the wettest Decembers received 30 inches of rain over three days. High water caused significant damage to levees along the Sacramento and Yolo Bypasses, as well as inside RD 900 along the Sacramento River. Congress approved a significant Sacramento Flood Control Project that included increasing Folsom Dam release capacity and rise levees along the American River and Morriason creek in 1999.

2000-2007: Congress, the city, and Sacramento property owners support improving flood control. Improvement construction continues over the next decade. The new legislation mandates metropolitan areas in California's central valley to have a system that can safely pass a 200-year flood by 2025.

2008: Another Pacific storm flood occurred. Construction on the Folsom Dam Joint Federal Project begins, allowing the dam to safely pass a 200-year flood with a peak flow of no more than 160,000 cfs.

2012-2014: Reconstructing more than 42 miles of levees through SAFCA Natomas Levee Improvement Project.

2018: The Bipartisan Budget Act of 2018 is passed by Congress, and $1.8 billion is allocated for the construction of levees and erosion control projects authorized by Congress in 2016, as well as the widening of the Sacramento Weir and Bypass and the raising of Folsom Dam by 3.5 feet for additional flood protection.

Flood Relation to Urbanization

In the central valley, an estimated four million acres of wetlands have been lost since the mid-1800s. The changes in land use associated with urban development affect flooding in many ways. Removing vegetation and soil, grading the land surface, and constructing drainage networks increase runoff to streams from rainfall and snowmelt. As a result, the peak discharge, volume, and frequency of floods increase in nearby streams. Changes to stream channels during urban development can limit their capacity to convey floodwaters.

Overall, urbanization causes a decrease in evaporation and infiltration and significantly increases runoff (Figure 5). Today, Sacramento has one of the most extensive street systems in California, with over 3,000 lane-miles of streets ([City of Sacramento, 2020]()). From 2001 to 2021, Sacramento lost 869ha of tree cover, equivalent to an 8.6% decrease in tree cover ([Global Forest Watch]()). Currently, 25% of the city is within the Special Flood Hazard Area, at risk of facing a 1-percent (100-year flood) and 0.5 percent (500-year flood) chance of flooding each year.

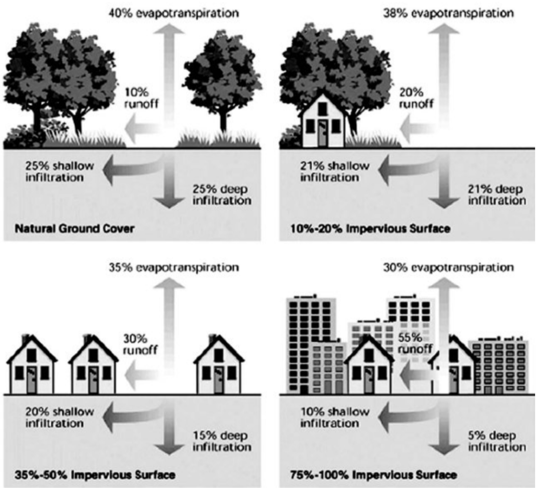


Fig.5: the influence of urbanization on a different component of the water (Gupta & Chakrabarti, 2009).

Mitigation Methods

Flood mitigation strategies are classified into two types: structural and nonstructural. Structured approaches of mitigation reduce harm by rebuilding landscapes. Nonstructural methods mitigate damage by relocating people and goods from dangerous regions.

Flood Management Options

Structural Mitigation	**Non-Structural Mitigation**
Levees	Evacuation
Dams	Relocation
Floodwalls	Land use regulation
Retention ponds	Insurance
Local detention basins, drainage, and pump	Risk disclosure
Reservoirs	Public snd Policymaker education
Bypasses	
Integrated urban water management	

Levees

The Lower Sacramento River East Levee System spans roughly 12 miles from downtown Sacramento to the community of Freeport. This levee protects almost all of Sacramento south of the American River and west of Highway 99. On the other hand, The Lower American River Levee System comprises 26 miles of levees between Folsom Dam and downtown Sacramento (Figure 6).

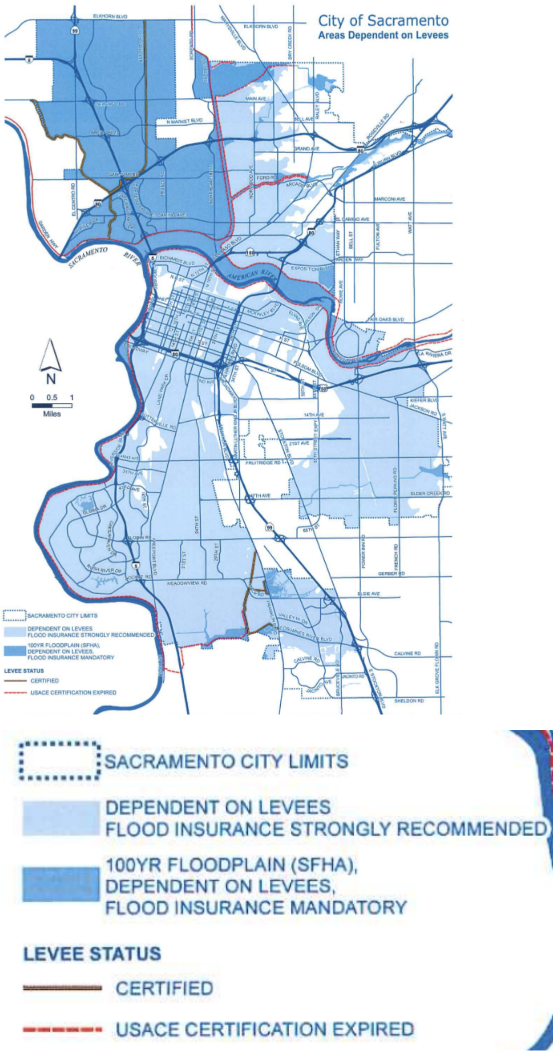


Fig.6: Areas in Sacramento dependent on levees ([City of Sacramento](#)).

Yolo Bypass

When the Sacramento River's flow reaches roughly 55,000 cubic feet per second (93,000 m3/min), the surplus water is discharged into the Yolo Bypass at the passive Fremont Weir, near the junction of the Sacramento and Feather rivers. The Fremont Weir, located on the south side of the Sacramento River, is approximately 32 feet (9.8 meters) in height, roughly 12 feet (3.7 meters) shorter than the levee on the north bank. When the water level hits 32 feet (9.8 meters), it begins to flow into Yolo Basin.

Evacuation

The City of Sacramento has created comprehensive maps depicting possible levee breaches for a 200-year flood event. These maps predict the flood levels, the time it would take for the waters to rise in impacted communities, and rescue and evacuation zones if no mitigating measures were taken for seven days.

Due to the city's reliance on levees, it is necessary to be aware of your potential evacuation routes, which may vary based on the location of a levee breach. Follow the evacuation directions offered by emergency officials during a flood warning. Sacramento's emergency radio station is KFBK Radio 1530 AM.

Future Prediction

Occurding to the [2022 Central Valley Flood Protection Plan](#) update, Over a 50-year period (2022 through 2072), the annual economic damages estimate almost doubles in the Sacramento River Basin and more than quadruples in the San Joaquin River Basin. Runoff from the Sacramento river basin, based on previous experience predicted 56% increase.

Current SAFCA Project

America River Levees

Beginning as early as 2021, the U.S. Army Corps of Engineers (USACE) intends to construct 11 miles of erosion protection along sections of the north and south banks of the American River. Once finished, the cumulative flood control upgrades will enable the levee system to safely manage sustained flows of up to 160,000 cubic feet per second in the event of a catastrophic flood in the American River watershed.

Natomas Basin

Due to the risk of seepage from deep underneath, the USACE found in 2006 that the Natomas Basin had less than 100-year flood protection. The Natomas Basin has to have at least 200 years of flood protection. Thus, USACE started building the additional 24 miles of necessary levee enhancements.

Folsom Dam and Reservoir

To further increase flood control space in the reservoir, the USACE is raising the existing main dam and reservoir's surrounding dikes by 3.5 feet, which began in 2019.

Sacramento Weir and Bypass

To allow more water to enter the Bypass system during flood events and lower the water surface level in the Sacramento River, USACE and the State want to expand the Sacramento Weir and Bypass. This project includes building a new 2-mile-long setback levee along the Sacramento Bypass and enlarging the current weir by 1,500 feet. Construction's initial phases started in 2020.

Discussion

Here, I attempt to produce a policy brief regarding the National Flood Insurance Program and other policy recommendations. The Policy Brief is intended to call for reform on a national level. Policy recommendations, however, can be implemented locally to aid Sacramento with non-structural flood mitigation.

UCDAVIS
Graduate Program of
Environmental Policy and Management

Policy Brief: National Flood Insurance Program Reform

Executive Summary

90% of natural disasters within the U.S. involve flooding. The cost of flood damage will increase by an average of 26% and $40.6 billion within the next 30 years (Figure 1). To combat this and to reduce the socioeconomic impact. The Federal Emergency Management Agency (FEMA) maps and mandates national flood insurance for communities within a 100-year flood zone. A 100-year flood zone is an area with a 1% chance of water inundation in one year. These communities are known as the Special Flood Hazard Area (SFHA). However, the National Flood Insurance Program (NFIP) is not serving its purpose and is currently burdened by debt and a low participation rate. Compared to private flood insurance coverage, the national insurance rebuilt limit is half of the private sector. The waiting period is twice as long for insurance to activate. National insurance does not cover replacement cost contents, loss of use, and loss avoidance coverage. Consequently, 100-year flood zone communities mandated to purchase from the government are disadvantaged, and other vulnerable communities would choose private over national insurance. The National Flood Insurance Program must reform to be compatible with the private counterpart to encourage engagement and to recover from debt with a higher participation rate.

Background

The Federal Emergency Management Agency (SFHA) identifies Special Flood Hazard Areas with frequent 100-year floods, mudflow, and other flood-related erosion hazards throughout the nation. The Flood Disaster Protection Act of 1973 and the National Flood Insurance Reform Act of 1994 mandate the SFHA communities to participate in the NFIP, where the program's floodplain management regulation must be enforced. The program was first introduced to share the risk of flood losses through affordable flood insurance, reduce flood damage by restricting floodplain development, and enforce floodplain management regulations. Communities outside SFHA also have the option of purchasing NFIP to help reduce the socioeconomic impact of floods. Today, the Federal Emergency Management Agency has registered more than 20,000 communities in the U.S. as flood zones.

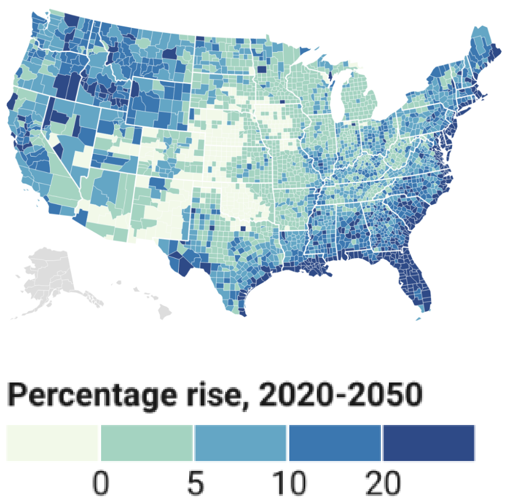


Fig.1: An analysis of projected changes in flood risk between 2020 and 2050 by zooming in on every neighborhood across the U.S. The map shows county-level data on the average annual loss due to flood damage (Wing et al., 2022).

Issue Analysis

The National Flood Insurance Program (NFIP) fails to address floods' socioeconomic impact and prevent flood damage. Communities mandated to participate in NFIP only have half of the maximum home rebuild limit, where NFIP offers up to $250,000 for a single-family home, while private insurance can increase the limit to $500,000. The NFIP's 30-day waiting period is significantly longer than the standard 15-day. This left the house owner vulnerable to a sudden rainfall or hurricane that could cause a flash flood. Furthermore, the NFIP has no room for customization where it does not offer replacement cost contents coverage, loss of use coverage, and loss avoidance coverage (Figure 2). With the lack of customization, the NFIP can sometimes be more expansive than private flood insurance. Some of the private companies' average annual cost that is less than NFIP includes Wright Flood with a 36% cost difference, Bankers Insurance with a 71% cost difference, Centauri Insurance with an 11% cost difference, and Steadfast Insurance with a 30% cost difference (Howard & Bloom, 2022).

Additionally, NFIP has been struggling to pay off its debt in recent years. Major coastal flooding from Hurricanes Harvey, Maria, and Irma in 2017 caused $11.1 billion in damage. While inland flooding can also cause major damage. Such as the Louisianan flood in 2016 caused another $3 billion in damage. A Low participation rate over the last decades and increased precipitation and sea level rise leads to more frequent rain and seawater inundation. With high-cost flooding and a low participation rate, the program is currently in a $20.5 billion debt (FEMA.org, 2022).

The latest significant update to the NFIP was over eight years ago through the Homeowner Flood Insurance Affordability Act of 2014 (HFIAA). The Congress bill delayed the increase of flood national insurance premiums and allowed homeowners to pass the original insurance premiums to the next owner when selling their properties (113th Congress, 2014). The NFIP's authorization ends on December 16th, 2022, and Congress must reauthorize NFIP's statutory authority to operate. The reauthorization is an opportunity for Congress to reform and improve the program's financial framework (FEMA.org, 2022).

NFIP vs. Private Flood Insurance Policy		
	NFIP	**Private flood insurance**
Maximum home rebuild limit	$250,000	Typically up to $500,000 or higher
Availability	Participating communities in all 50 states	May be limited in higher-risk areas
Waiting period	30 days	Two weeks
Accepted by mortgage lenders	Yes	Yes
Replacement cost building coverage	Yes	Yes
Replacement cost contents coverage	No	Yes
Loss of use coverage	No	Yes
Loss avoidance coverage (sandbags, etc.)	No	Yes
Debris removal coverage	Yes	Yes

Fig.2: Side-by-side comparison of national and private flood insurance policies (Howard & Bloom, 2022).

Policy Recommendations

A low participation rate results in debt when the program lacks sufficient funds to cover claims. The NFIP must be compatible with the private counterparts to encourage engagement. Below is a list of potential reforms recommendations to the NFIP:

- Reevaluate the Design Flood Elevation within the Special Flood Hazard Area.
    - The Design Flood Elevation is the highest elevation standard for new construction.
- Shorten the reevaluation period of flood zone mapping and zoning code.
- Strengthen building codes for critical infrastructures such as hospitals, fire and police departments, schools, and electric and water plants.
- Reconsider the 100-year benchmark as the Special Flood Hazard Area.
- Develop a national program that mandates the local government to support the relocation of repeatedly-flooded families.
- Require sellers to disclose all past flood damages to prospective buyers.
- Shorten the waiting period from 30 days to 20 days.
- Add a minimum replacement loss content, loss of use, and loss of avoidance coverage.
- Increase the maximum rebuilt limit from $250,000 to $350,000.

The Federal Emergency Management Agency is currently open to receiving any comments and concerns regarding the NFIP through Federal eRulemaking Portal. Submissions are due December 13th, 2022.

Further reading (linked)

- New Flood Maps Show Stark Inequity in Damages, Which Are Expected to Rise Over Next 30 Years
- An Overview of the National Flood Insurance Program in Washington, DC
- Request for Information on the National Flood Insurance Program's Floodplain Management Standards for Land Management and Use, and an Assessment of the Program's Impact on Threatened and Endangered Species and Their Habitats

References

113th Congress. (2014). *H.R.3370 - Homeowner Flood Insurance Affordability Act of 2014*. https://www.congress.gov/bill/113th-congress/house-bill/3370

Carey, W. C. (1969). Formation of Flood Plain Lands. *Journal of the Hydraulics Division*, *95*(3), 981–994. https://doi.org/10.1061/jyceaj.0002112

City of Sacramento Department of Utilities. (2016). *Comprehensive Flood Management Plan*.

FEMA.gov. (2020, July 28). *Laws and Regulations*. Www.fema.gov. https://www.fema.gov/flood-insurance/rules-legislation/laws

Kelman, I., & Spence, R. (2004). An overview of flood actions on buildings. *Engineering Geology*, *73*(3-4), 297–309. https://doi.org/10.1016/j.enggeo.2004.01.010

Laws and Regulations | FEMA.gov. (n.d.). Www.fema.gov. https://www.fema.gov/flood-insurance/rules-legislation/laws

Lund, J. R. (2012). Flood Management in California. *Water*, *4*(1), 157–169. https://doi.org/10.3390/w4010157

Nguyen, M. (2017). *Yolo Bypass: the inland sea of Sacramento*. California WaterBlog. https://californiawaterblog.com/2017/02/20/yolo-bypass-the-inland-sea-of-sacramento

O'Connor, J. E., Grant, G. E., & Costa, J. E. (2002). The Geology and Geography of Floods. *American Geophysical Union*, *5*.

Robert Lloyd Kelley. (1998). *Battling the inland sea : floods, public policy, and the Sacramento Valley*. University Of California Press.

Rozalis, S., Morin, E., Yair, Y., & Price, C. (2010). Flash flood prediction using an uncalibrated hydrological model and radar rainfall data in a Mediterranean watershed under changing hydrological conditions. *Journal of Hydrology*, *394*(1-2), 245–255. https://doi.org/10.1016/j.jhydrol.2010.03.021

State of California Natural Resources Agency Department of Water Resources. (2022). *Central Valley Flood Protection Plan Update 2022 Public Draft*.

Thompson, K. (1960). Historic Flooding in the Sacramento Valley. *Pacific Historical Review*, *29*(4), 349–360. https://doi.org/10.2307/3636308

Tingsanchali, T. (2012). Urban flood disaster management. *Procedia Engineering*, *32*, 25–37. https://doi.org/10.1016/j.proeng.2012.01.1233

US Department of Commerce, N. (n.d.). *Burn Scar Flash Flood & Debris Flow Risks*. Www.weather.gov. Retrieved November 17, 2022, from https://www.weather.gov/cys/burnscarflashflood

Wing, O. E. J., Lehman, W., Bates, P. D., Sampson, C. C., Quinn, N., Smith, A. M., Neal, J. C., Porter, J. R., & Kousky, C. (2022). Inequitable patterns of US flood risk in the Anthropocene. *Nature Climate Change*, *12*(2), 156–162.

Wohl, E. (2021). An Integrative Conceptualization of Floodplain Storage. *Reviews of Geophysics*. https://doi.org/10.1029/2020rg000724

Yang, Z., Wang, T., Leung, R., Hibbard, K., Janetos, T., Kraucunas, I., Rice, J., Preston, B., & Wilbanks, T. (2013). A modeling study of coastal inundation induced by storm surge, sea-level rise, and subsidence in the Gulf of Mexico. *Natural Hazards*, *71*(3), 1771–1794. https://doi.org/10.1007/s11069-013-0974-6