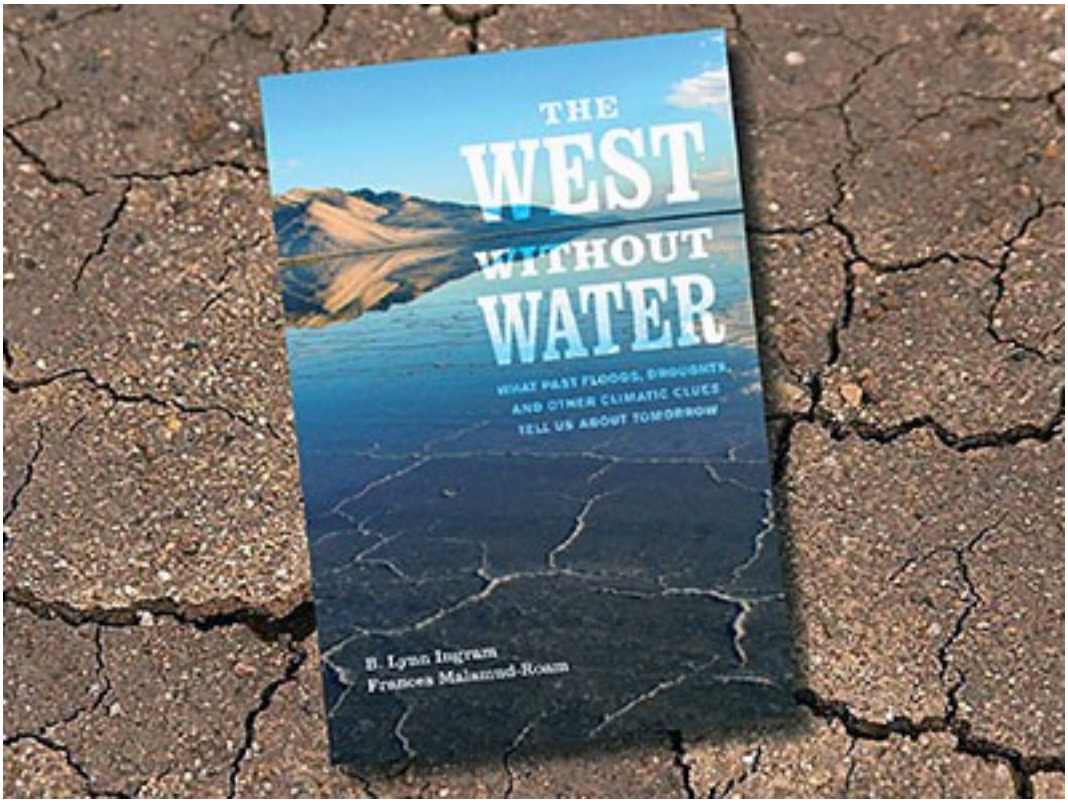
A Must Read: "The West Without Water"

By Sharon Rushton (June 15, 2016)



Given the American West's recent drought, a highly relevant book to read is "The West Without Water: What Past Floods, Droughts, and Other Climate Clues Tell Us About Tomorrow" by Dr. Lynn Ingram and Dr. Frances Malamud-Roam.

Ingram's and Malamud-Roam's research assesses how climates and environments have changed over the past several thousand years based on the geochemical and sedimentologic analysis of aquatic sediments, archeological deposits, and tree-ring records. The authors bring together many lines of evidence by paleoclimatologists (those that study past climate change using geologic evidence), including various aspects in sediment cores and the fossils in them, the chemistry of the fossils and the sediments, pollen remnants, and charcoal remains (which indicate past wildfires). The archeological record contains clues on how past climate and environments impacted human populations.

The book imparts information that is essential for making sound decisions and preparations for future climate change. As such, I wish to share some of Ingram's and Malamud-Roam's key findings.

The following information was taken from the book entitled; “The West Without Water: What Past Floods, Droughts and Other Climate Clues Tell Us About Tomorrow” and related articles.

At 4,841 years old, the ancient Bristlecone Pine named Methuselah, located in the White Mountains of California, is the oldest known non-clonal organism on Earth. Tree ring records of Bristlecone Pine reveal climate history. Courtesy of Rick Goldwasser, Flickr

Figure 1

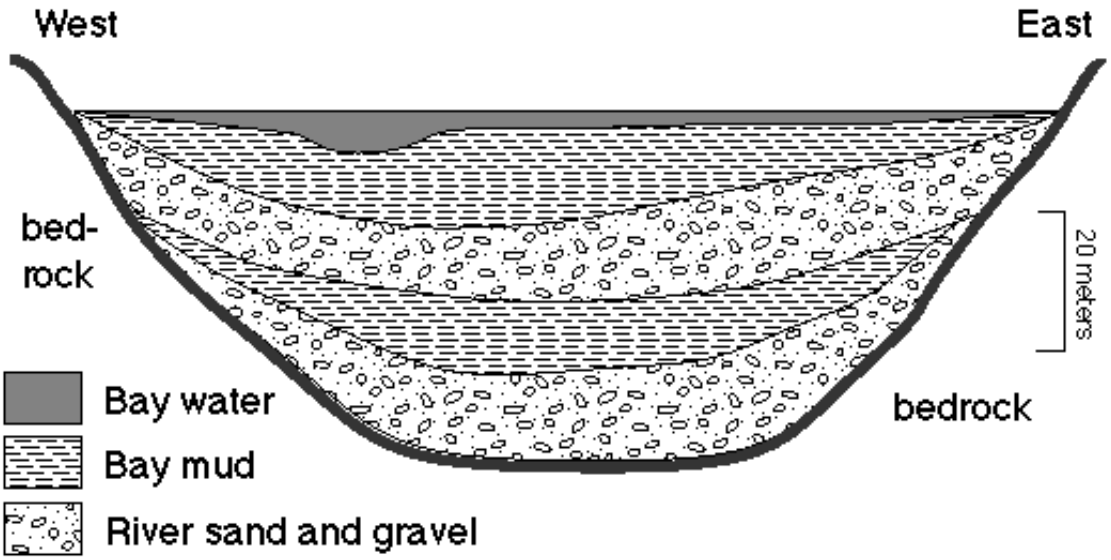


Figure 1: This figure is a profile of sediments beneath San Francisco Bay that is based on sediment cores collected from the Bay bottom for engineering purposes when the San Mateo Bridge was built. The upper layer of mud is sediment deposited as sea level rose in the Bay during the past 10,000 years. The mud, sand and gravel layers beneath were deposited during previous cycles of sea-level change. B. Atwater et al, USGS

Causes of the Long-Term Climate in the Western US

"Over the long-term, natural climate variations are driven by a number of factors, including the ocean temperatures in the north Pacific (Pacific Decadal Oscillation), the El Nino Southern Oscillation, sunspots, slight changes in the earth's orbit over thousands of years, and volcanic eruptions. On top of these natural causes, the human-caused increase in greenhouse gases also impacts our climate."[1]

Major Climatic Events of the Past Thousand Years in the Western US

Climate in the last 150 years (post 1850) has been relatively benign, with an ample water supply, compared to what it was like over the last 10,000 years.

During the past several thousand years, California and the West have experienced extremes in climate that we have not seen in modern history. Evidence shows that mega-floods and multidecadal droughts, which were more

[1] Tavares, E. "The West Without Water: An Interview with Dr. B. Lynn Ingram." Sept. 2014. Web. 27 April 2016. < https://www.linkedin.com/pulse/20140905215458-1088431-the-west-without-water-an-interview-with-dr-b-lynn-ingram >

catastrophic than we can imagine, have been a regular feature of the climate and are likely to repeat themselves.[2]

Throughout the "Medieval Warm Period", 900 to 1400 AD, the western United States had a relatively dry period. There were several prolonged periods of drought that lasted decades to over a century! This was followed by the "Little Ice Age", a cooler, wetter period that continued until the 19th century. The 20th century was unusually wet, with fewer droughts on average than the previous 1000 years.[3]

The recent dry decade and drought in California may be telling us that we could be seeing the start of a reversion to much drier conditions going forward.[4]

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[2] Tavares, E. "The West Without Water: An Interview with Dr. B. Lynn Ingram." Sept. 2014. Web. 27 April 2016. <https://www.linkedin.com/pulse/20140905215458-1088431-the-west-without-water-an-interview-with-dr-b-lynn-ingram>

[3] Tavares, E. "The West Without Water: An Interview with Dr. B. Lynn Ingram." Sept. 2014. Web. 27 April 2016. <https://www.linkedin.com/pulse/20140905215458-1088431-the-west-without-water-an-interview-with-dr-b-lynn-ingram>

[4] Tavares, E. "The West Without Water: An Interview with Dr. B. Lynn Ingram." Sept. 2014. Web. 27 April 2016. <https://www.linkedin.com/pulse/20140905215458-1088431-the-west-without-water-an-interview-with-dr-b-lynn-ingram>

Megafloods

California's megaflood of 1861-62 left Sacramento, California under ten feet of water. This photo from January 10, 1962, shows K Street in Sacramento, looking east from 4th Street. Credit: Sacramento History Archives

Megafloods have hit California every one to two centuries. The last one was in 1861-1862 and was caused by 43 days of rain from atmospheric river storms. "Atmospheric rivers" carry vast amounts of water vapor for thousands of miles and may contain as much water as ten to fifteen Mississippi Rivers. When conditions are right, these conveyor belts of moisture travel eastward until they hit the Sierras and drop their moisture as rainfall or snow.[5]

The 1861-1862 megaflood filled the entire Central Valley (350 miles long and 20 miles wide) with water 20 feet deep. The City of Sacramento was ten feet under water, forcing the state legislature to move to San Francisco for six months.

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[5] Wilson, A. December 2012. "It's Raining in California." Resilient Design Institute. Web. 27 April 2016. <http://www.resilientdesign.org/its-raining-in-california/>

Thousands of people are believed to have perished and the state was bankrupted. Compared to today, these areas were sparsely populated in the 1860's. When the 1861-62 mega-storm hit California, the state population was only a half million. Today, there are 6 million residents just in the Central Valley. A storm of the magnitude of 150 years ago, would do vastly more damage.

"To get a sense of the extent of damage, the U.S. Geological Survey (USGS) recently used a storm damage simulation program to predict damage from a storm like the one in 1861-62—only they modeled a storm lasting 23 days instead of 43 days. The results showed that 1.4 million residents would have to be evacuated and $400 billion in property damage and agricultural loses would result, with long-term business and employment interruptions eventually reaching $700 billion. These losses are roughly three times as high as would result, according to USGS simulations, from a magnitude 7.8 earthquake striking Southern California (the "Big One" that everyone has been talking about)."[6]

Multidecadal Droughts

Dust storm approaching a Midwestern town during the Dust Bowl in 1932. Natural Resources Conservation Service, U.S. Department of Agriculture.

[6] Wilson, A. December 2012. "It's Raining in California." Resilient Design Institute. Web. 27 April 2016. <http://www.resilientdesign.org/its-raining-in-california/>

The Long Drought of the Mid-Holocene

The "Holocene" is the name given to the last 11,700 years of the Earth's history, the time since the end of the last major glacial epoch or "Ice Age". During the Mid-Holocene Period, roughly from 7000 to 5000 years ago, climate in the West shifted toward warmer, drier conditions, and prolonged drought.

The inland areas, such as the Great Basin, what is known as southeastern California, were the hardest hit. In response, the archaeological evidence suggests that populations migrated to the coast, which offered cooler climate, more moisture, and plentiful food, particularly from marine sources such as shellfish and salmon. Settlements were established along the Pacific Northwest coast, around present-day San Francisco Bay, and as far south as California's Santa Barbara Basin and Channel Islands.[7]

Medieval Warm Period (900 to 1400 AD)

A more recent protracted period of dryness occurred during the Medieval Ages between 900 AD and 1400 AD. Droughts lasted decades to over a century during that time.

Life in the interior of California was particularly difficult. Native Americans, whose populations had grown during the wetter periods leading up to the droughts, suffered greatly. There is evidence of conflict (Warfare between groups arose over territory and resource), disease (E.g. malnutrition), and finally mass migration in search of water, food and other resources.

Coastal groups appear to have fared better than inland groups because most of their food came from the ocean. Eventually freshwater was scarce, however, and all along California's coast, including San Francisco Bay, sites were abandoned in search of new water sources. Experts speculate that the population moved over large territories as resources became scarcer, alternating between inland and coastal sites on a seasonal basis. Such mobility allowed the coastal groups to survive.[8]

Prediction of Future Droughts

In a 2015 study, researchers from NASA, Columbia University, and Cornell University reported that there is above 80 percent chance of a 35-year or longer

[7] Ingram, B.L. Malamud-Roam, F. "The West Without Water: What Past Floods, Droughts, and Other Climatic Clues Tell Us About Tomorrow." Berkeley: The Regents of the University of California, 2013.

[8] Ingram, B.L. Malamud-Roam, F. "The West Without Water: What Past Floods, Droughts, and Other Climatic Clues Tell Us About Tomorrow." Berkeley: The Regents of the University of California, 2013.

drought occurring in the Southwest and Central Great Plains by 2100, if the world stays on its current trajectory of greenhouse gas emissions.

If countries reduce their emissions to "middle of the road" targets, the chances of a megadrought striking the Great Plains in this century drop to between 60 and 70 percent but remain nearly 80 percent for the Southwest.[9]

The Hydraulic Era & Deterioration of Aquatic Ecosystems

The twentieth century has been called the "hydraulic era" in the American West. The natural hydrology was re-engineered through massive public works, such as dams and aqueducts. In less than a century, water engineers harnessed almost all of the naturally flowing water throughout the American West to provide enough water for the ever-growing population and expanding agriculture. The water works also provide hydroelectric power and flood protection. Water engineering allowed the population to grow to a size far larger than the region could support naturally.

"The monumental changes to the region's natural rivers, lakes, and wetlands have wreaked havoc on the natural aquatic ecosystems that these waters harbored. The plants and animals that depend on streams, lakes, and wetlands declined rapidly over the twentieth century due to large-scale land and water development in the West. Hundreds of species that are federally listed as threatened or endangered depend on rivers and streams. Over three quarters of the native freshwater fish in the West are either extinct already or listed as endangered."[10]

Water development has come at a steep price to the environment, particularly to aquatic ecosystems. Policymakers have begun to restore water resources and aquatic habitats. More effort in this direction is needed. Water conservation should be given a higher priority in order to share this life-giving resource with the natural world.

California's Groundwater Depletion

Groundwater comes from aquifers, sponge-like gravel and sand-filled underground reservoirs, and we see this water only when it flows from springs and wells.

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[9] Howard, B.C. "Worst Drought in 1000 Years Predicted for American West." National Geographic February 2015. Web. May 16, 2016. <http://news.nationalgeographic.com/news/2015/02/150212-megadrought-southwest-water-climate-environment/>

[10] Ingram, B.L. Malamud-Roam, F. "The West Without Water: What Past Floods, Droughts, and Other Climatic Clues Tell Us About Tomorrow." Berkeley: The Regents of the University of California, 2013.

California does not regulate groundwater like it does surface water. Landowners have pumped as much water as they want, drawing down the water table. "California's new Sustainable Groundwater Management Act, which went into effect in 2014, eventually will require farmers to report their groundwater use, but not until around the year 2022 or later. And even then, the new law requires water officials to keep farmers' groundwater use secret, shielding gluttonous users from public scrutiny."[11]

"Californians drained about 125 million acre-feet of groundwater (about 41 trillion gallons) from the Central Valley between 1920 and 2013, according to U.S. Geological Survey. That's equivalent to enough water to provide every person on Earth with a 30-year supply of drinking water."[12]

A report from Stanford University says that 40% of California's water needs are met by groundwater when normal amounts of rain and snow fall and 60% in years of drought.[13] Such usage is not sustainable. The groundwater has not been able to replenish and instead continues to decline in quantity each year.

"Some shallow aquifers recharge from surface water, but deeper aquifers contain ancient water locked in the earth by changes in geology thousands or millions of years ago. These aquifers typically cannot recharge, and once this "fossil" water is gone, it is gone forever, potentially changing how and where we can live and grow food, among other things."[14]

A Sinking State

Many of our state's groundwater basins are so heavily pumped out that the land is sinking – in some places by 1" each month. "As the below-ground aquifers are drained, the land sinks to partially fill the space left by the removed water. Scientists call this subsidence. Subsidence was first documented in California in the 1930's. It primarily affects farmland since farmers use about 80% of the state's water. Although cities, such as San Jose and San Luis Obispo, have experienced costly subsidence too. Back in the 1960's, California farmland in the

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[11] Haverson, N. June 2015. "Sobering Facts About California's Groundwater Problem." Reveal News. Web. 27 April 2016. < https://www.revealnews.org/article/9-sobering-facts-about-californias-groundwater-problem/ >

[12] Haverson, N. June 2015. "Sobering Facts About California's Groundwater Problem." Reveal News. Web. 27 April 2016 < https://www.revealnews.org/article/9-sobering-facts-about-californias-groundwater-problem/ >

[13] Nagel, T. "*Stanford's Water in the West program offers new way to view groundwater resources.*" Stanford Report July 31, 2014. Web. 27 April 2016. < http://news.stanford.edu/news/2014/july/groundwater-lane-woods-073114.html >

[14] Dimick, D. August 2014. "If You Think The Water Crisis Can't Get Worse, Wait Until The Aquifers Are Drained." National Geographic. Web. 27 April 2016. < http://news.nationalgeographic.com/news/2014/08/140819-groundwater-california-drought-aquifers-hidden-crisis/ >

Central Valley was sinking at a record pace. By the late 1970's, some areas had sunk about 30 feet. The sinking took off again in 2008."[15]

Joseph Poland of the U.S. Geological Survey used a utility pole to document where a farmer would have been standing in 1925, 1955 and where Poland was standing in 1977 after land in the San Juaquin Valley had sunk nearly 30 feet. Credit: U.S. Geological Survey

The Need to Prepare for Our Variable Climate

Ingram's and Malamud-Roam's tales of California's variable climate history teach us that even during wetter times, we need to prepare for the eventual dry climate that always follows and during dry times we need to prepare for the eventual megafloods. Extreme variability is the nature of our climate.

**Please note that the following ways to potentially prepare for multidecadal droughts and megafloods are not taken from the book; "The West Without Water".

[15] Haverson, N. June 2015. "Sobering Facts About California's Groundwater Problem." Reveal News. Web. 27 April 2016. < https://www.revealnews.org/article/9-sobering-facts-about-californias-groundwater-problem/ >

Preparing for Multidecadal Droughts
A report by the Public Policy Institute of California (an independent, objective, and nonpartisan research organization) entitled "Policy Priorities for Managing Drought" reviews lessons learned from California's recent drought and Australia's response to its decade-long "Millennium Drought" and provides policy recommendations for strengthening drought management. In summary, the report recommends that State leaders address weaknesses in four areas of drought preparation and response by:

1. Improving water use tracking and information;
2. Setting clear goals and priorities for public health and the environment;
3. Promoting water conservation and more resilient water supplies; and
4. Strengthening environmental management.

Here is a link to the Public Policy Institute of California's report entitled; "Policy Priorities for Managing Drought":
http://www.ppic.org/main/publication_quick.asp?i=1141

In order to address severe droughts, additional questions, besides those answered by the Public Policy Institute of California, come to mind:

- Should urban growth be linked to water supply and availability? Should land use regulations, allowable build-out, and projected water demand reflect our projected water supply? Should we limit water demand by limiting development, farmland and population in California and more specifically in Marin?

- Besides the Sustainable Groundwater Management Act (2014), what additional legislation should be adopted to protect and prevent over-use of our groundwater? (The timeline of the new groundwater law is long, over 25 years to attain sustainability. Additional legislation could expedite this process.)

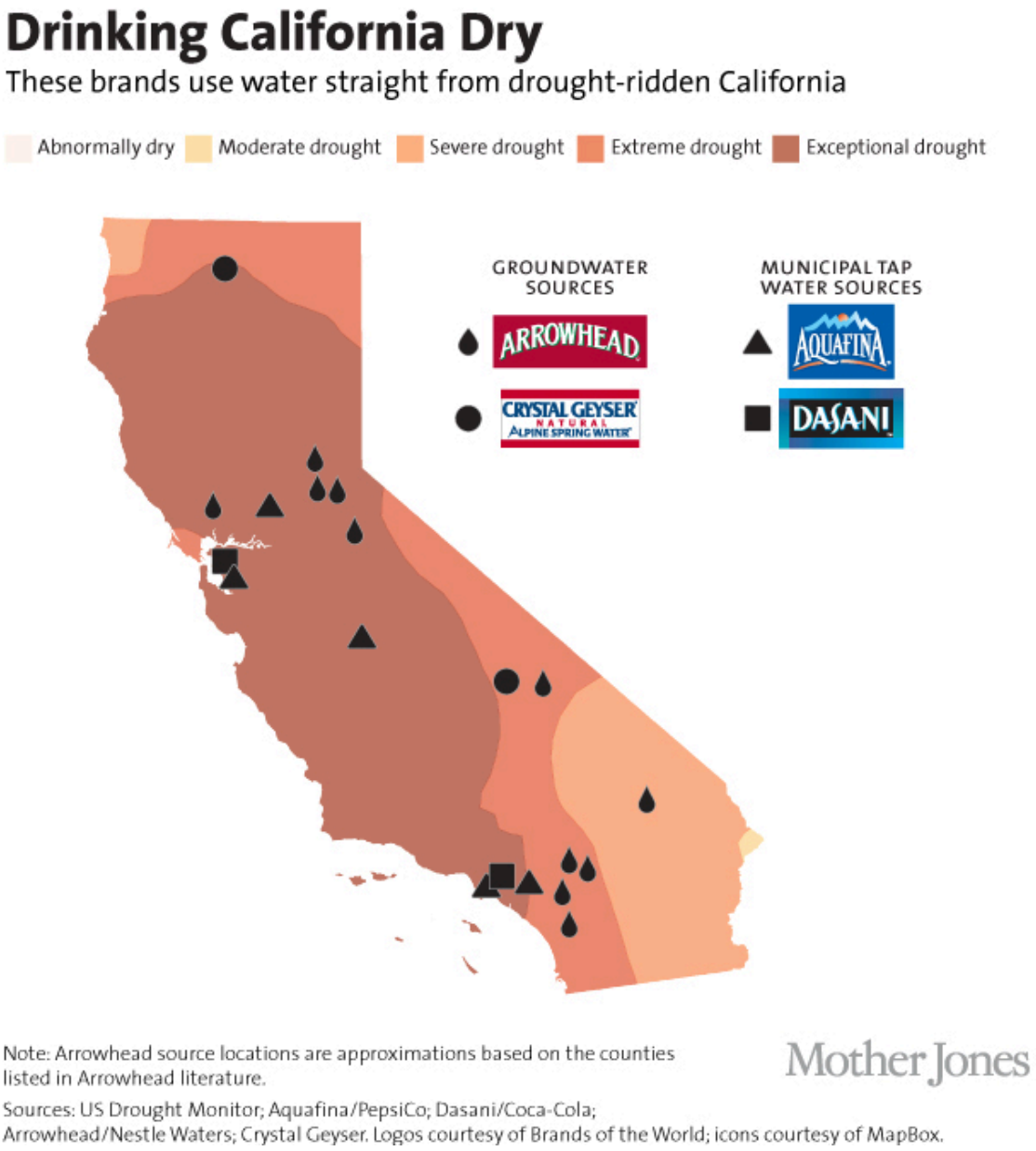
- Since farms account for about 80% of the state's water usage, should new water policies be pursued to reduce water use by farms?

    - Should we start the transition of moving some farming (crops that can be grown elsewhere) away from California's dry areas to wet areas, where water is reliable and bountiful?
    - Should Californian farms be prohibited from growing water-intensive crops, which are incapable of being fallowed during drought years (E.g. grapevines, almond trees, pistachio trees)?
    - Should farmers be required to incorporate new, more effective irrigation methods, such as adjusting the timing and amount of irrigation to maintain specific soil moisture requirements of crops,

replacing irrigation systems with closed-conduit systems (E.g. drip or trickle systems), recycling excess irrigation water, and the technique of dry-farming (carefully cultivating soil so it can sustain plant growth with little or no irrigation)?

- Should new water regulations be pursued regarding water-intensive industries, such as the oil industry?

- Who should own our water resources? Should water rights be revisited? Should for-profit corporations be allowed to bottle water in areas with a history of drought, like California, and sell it nationally and internationally? (E.g. Pepsi-Cola's "Aquafina" bottled water and Coca-Cola's "Dasani" bottled water come from California municipal water suppliers (treated tap water); The water source for Nestle's Arrowhead and Crystal Geyser is spring water derived from California's groundwater.)



Preparing For Megafloods

The Bay Area Council Economic Institute's 2015 report entitled; "Surviving The Storm" gives recommendations on how to prepare for extreme storm events, including megafloods, delta flooding, sea-level rise, and the impact of earthquakes on flood protection structures.

Here is the link to the Bay Area Council Institute's report:
http://documents.bayareacouncil.org/survivingthestorm.pdf

In general, the report recommends the following:

- **Infrastructure**: Support the development of cost-effective structural and non-structural strategies, tailored to the region's variety of local environments, to reduce flood risk.

- **Funding**: Identify new and expand existing local, regional, state and federal funding for flood infrastructure investment. (**Please see comment below under "Flaws".)

- **Prioritization**: Identify and prioritize projects necessary to protect key economic assets such as transport, power, water, wastewater, employment centers, and communications infrastructure. (**Please see comment below under "Flaws".)

- **Planning**: Incorporate community resilience to extreme storms into Hazard Mitigation and General Plans.

- **Early Warnings**: Support development of accurate weather and flood forecasting, particularly for lead-time on atmospheric rivers.

- **Emergency Response**: Support the development of Flood Emergency Management Plans and increase coordination and communication among disaster responders, facility managers, and flood management planners to improve readiness for flood disasters.

- **Coordination**: Promote coordination among flood protection agencies and other regional agencies, businesses, and cities, in developing shared strategies, methods, policies and funding mechanisms.

Flaws in the Bay Area Council Economic Institute's findings
Much of what the Bay Area Council Economic Institute's 2015 report seems valid. However, there are a couple of areas that are lacking:

- **Under "**Prioritization**", there should also be a recommendation to identify floodplains where new development should be limited (E.g. limited to structures on stilts) or prohibited and existing development should be moved to higher ground. Restoration of floodplains, marshes and deltas would allow them to resume their natural function of holding floodwater. Scientists suggest that tidal wetlands are the best protection from the dangerous combination of rising sea levels and extreme storms. In addition, recommendations should include identification and prioritization of projects necessary to protect the environment (habitat and wildlife).

- **Under "**Funding**", there should be a discussion on what types of funding organizations are preferred. It would be important to recommend that all decisions about funding should be decided by elected representatives, rather than unelected appointed directors and/or executives. For instance, Joint Powers Authorities (JPAs) have been referred to as "hidden governments" and are known to lack disclosure and transparency of their organization and financial information to taxpayers. The governance of a JPA is usually conducted through a structure consisting of a board of directors, an executive committee, and advisory committees, with members that are typically appointed rather than elected by citizens.

Conclusion

As shown throughout the book, "The West Without Water", the American West faces a climatic future that is predicted to repeat the past and become generally warmer and drier, with longer droughts interspersed with larger and more frequent floods. Society needs to be educated about the West's extremely variable climate, water's vital importance and scarcity, the delicate balance between consumption and conservation, and what individuals can do to help. Policymakers need to begin taking action to prepare for both the dry and wet ends of the climate spectrum facing the region, in a way that meets the needs of society and the needs of a healthy environment.