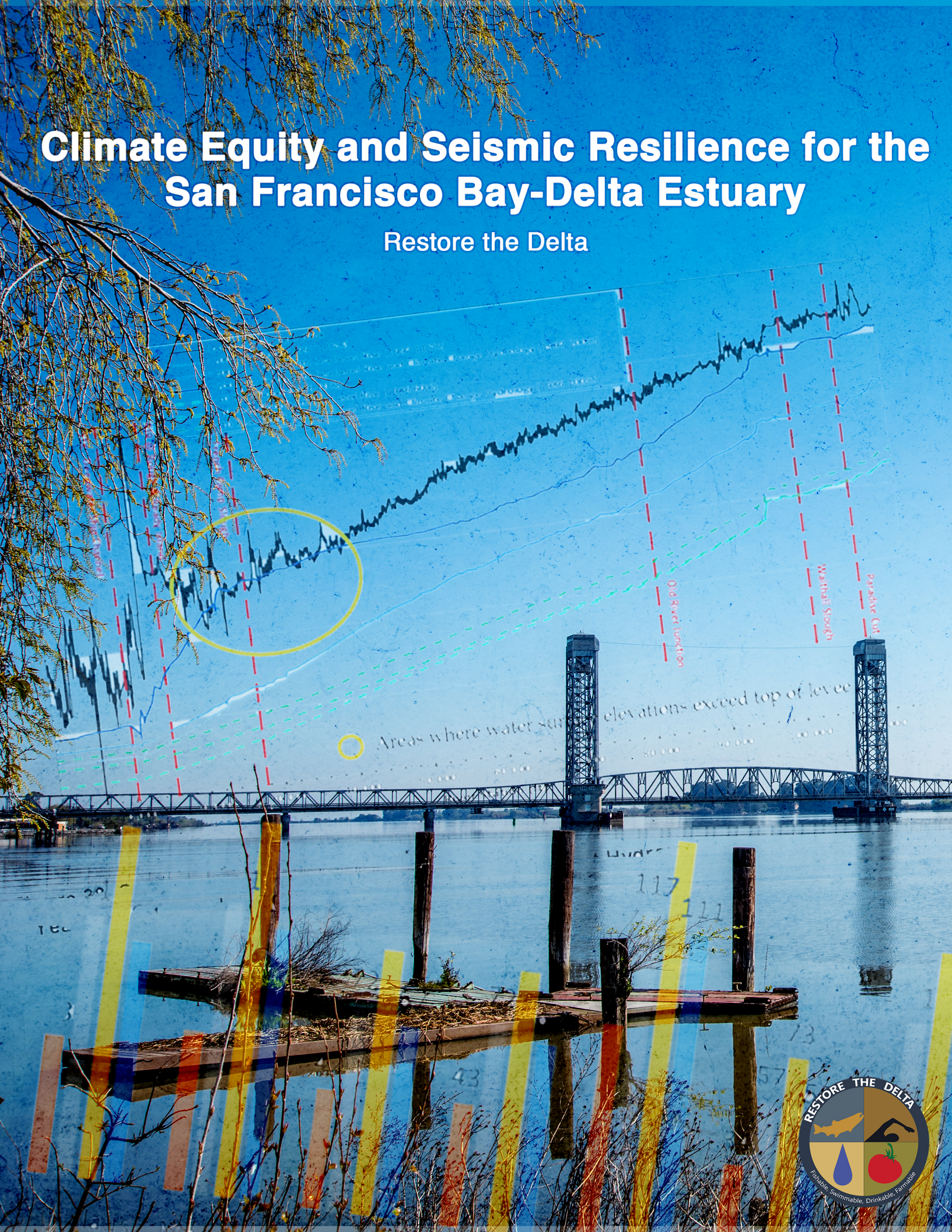
Climate Equity and Seismic Resilience for the San Francisco Bay-Delta Estuary

Restore the Delta



Climate Equity and Seismic Resilience for the San Francisco Bay-Delta Estuary

Barbara Barrigan-Parrilla
Tim Stroshane

For the children of the Delta:
There is no better antidote for anxiety than action.

Table of Contents

This page is left blank intentionally.

EXECUTIVE SUMMARY:

Climate Equity and Seismic Resilience for the San Francisco Bay-Delta Estuary

After Governor Gavin Newsom announced the end of California WaterFix—also known as the Twin Tunnels—Restore the Delta decided that we needed a period of reflection.

Serving for such an extended period as the voice of the Delta, we needed time to re-think and re-vision what we wanted to see for the future of the San Francisco Bay-Delta Estuary.

We also needed to understand the Newsom Administration's water priorities for California. We agree with the administration's overall concern regarding climate change impacts on state water management planning, meeting the goals of the Human Right to Water legislation passed several years ago, and pulling together all Californians to solve our water challenges.

We dove into the state's Fourth Climate Change Assessment and its supporting research regarding California's future water supply, Delta management, and sea level rise. We also examined the most recent science regarding seismic risk to the Delta.

The result of our research and reflection is this report.

This report shows how Restore the Delta will evaluate the Water Resilience Portfolio and single tunnel conveyance proposal going forward. We don't have time to waste on expensive projects and planning that will not address the climate crisis facing California's future water needs, the Bay-Delta Estuary, our lands, and our people.

This report finds:

While Delta levees in their present condition may be vulnerable to failure from ground shaking during large earthquakes, recent studies of seismic shaking indicate that Delta regional geology diminishes or attenuates shaking effects. Delta seismic risk as the reason for new conveyance should not be a primary narrative used by the state to justify a single tunnel.

However, the probability of large earthquakes in both northern and southern California should refocus attention on upgrading all California State Water Project facilities near the state's major earthquake faults, not just the Delta.

Delta levees are needed, whether there is to be a single tunnel or not. This is because Delta levees are necessary protection against increased flood risks resulting from climate change impacts for the Delta's four million residents, including environmental justice communities, which seldom recover fully from floods. Additionally, other operating conditions dictate that the south Delta pumping plants of the state and federal water projects must receive water through existing Delta channels at times when the tunnel intakes in the north cannot operate.

Very recent climate science studies indicate that permafrost thawing, peat soil fires, and faster-than-expected loss of Antarctic and Greenland ice sheets all are contributing to the increased likelihood of abrupt climate change effects, including sea-level rise. Climate change impacts within the Delta include more extreme flood events, reduced runoff into the Delta watershed, warmer water temperatures, and reduced freshwater flows that will alter environmental conditions in the Delta, and the amount of water available for export during droughts.

The Governor's executive order announcing the Water Resilience Portfolio process also calls for solutions that create multiple benefits. We provide several examples of multi-benefit proposals in our Recommendations chapter for consideration in the process.

This report recommends:

Understanding that the San Francisco Bay-Delta Estuary is one place, connected by water, ecology, wildlife, transportation, commerce. The state's Water Resilience Portfolio must integrate water policy for the entire Estuary.

Portfolio projects should be "no regrets" actions and investments that foster regional water self-sufficiency while also protecting lives and property.

Regional projects should be determined BEFORE a decision is made to construct a single tunnel conveyance option through the Delta. Any modeling for a tunnel must also account for sea level rise, storm surge, and flood flows with respect to both new north Delta intakes and at existing south Delta pumps.

Modeling must address directly when diminished amounts of Delta river inflow and tunnel operations under depleting conditions would lead to harmful algal blooms, and degraded Delta water quality. That is, modeling must show true water quality conditions under various tunnel operational scenarios.

Delta levees should be upgraded to meet seismic, flood and sea level stressors regardless of whether a single tunnel is built or not.

State environmental justice policy must be integrated with the state's current flood protection planning using as many creative and cost-effective means and designs to embody this principle.

We also recommend using flood flows captured by natural and/or artificial recharge methods to increase groundwater supplies.

Chapter 1 INTRODUCTION

To Restore the Delta's relief (and relief of many Delta region residents), the California WaterFix project was ended by new California Governor Gavin Newsom early in 2019. The water rights petition was withdrawn from the State Water Board[1], its bond financing validation suit was dismissed, and the California WaterFix web site is now archived. The idea of boring two tunnels under the Delta, from Courtland to Clifton Court, is now history.[2]

Newsom's new Secretary of Natural Resources, Wade Crowfoot, said of the state's landmark water policy shift, "A smaller project, coordinated with a wide variety of actions to strengthen existing levee protections, protect Delta water quality, recharge depleted groundwater reserves, and strengthen local water supplies across the state, will build California's water supply resilience."[3]

Of course, Delta water politics is never over. What comes next? A new process, naturally.

Governor Newsom issued an executive order (Appendix A, this report) on May 2, 2019, to lay out his proposal for a "Water Resilience Portfolio that meets the needs of California's communities, economy, and environment through the 21st century."[4] The proposal is to be formulated jointly by the Natural Resources Agency, the California Environmental Protection Agency, and the California Department of Food and Agriculture "in consultation with the Department of Finance." These agencies are to "first inventory and assess":

- Water demand and supply;
- Water quality conditions of our major water bodies, including groundwater;
- Project water needs throughout the state "in the coming decades for communities, economy and environment";
- Climate change impacts to the state's water systems from both flood and drought events "and other challenges to water supply reliability";
- "[V]oluntary settlement agreements" for the Sacramento and San Joaquin river basins for flow and habitat in relation to Delta water quality control planning;
- "[C]urrent planning to modernize conveyance through the Bay Delta with a new single tunnel project";
- Expansion of the state's drinking water program to make certain all communities have access to "clean, safe and affordable drinking water"; and
- Existing water policies, programs and investments of the state.[5]

Then the agencies are to apply seven principles in order to establish the Water Resilience Portfolio. They include: 1) prioritization of "multi-benefit approaches that meet multiple needs at once"; 2) use of "natural infrastructure" such as forests and floodplains; 3) application of new technologies to solve water problems; 4) encouragement of regional approaches among water users sharing watersheds; 5) incorporation of "successful approaches from other parts of the world"; 6)

integration of “investments, policies and programs across state government”; and 7) strengthening of partnerships with existing water agencies and tribal governments and other stakeholders.[6]

Finally, the governor’s order requires these agencies to “conduct extensive outreach to inform this process” including the usual water agencies at all levels, and sovereign tribes, and environmental justice and environmental conservation organizations, as well as business leaders, academic experts, and other stakeholders.[7]

Governor Newsom has recognized that there are no easy answers to California’s water puzzle. “But,” he remarked in February to the state legislature, “the only way to find them is to face these issues honestly,” adding “we can build on the important work that’s already done. That’s why I do support a single tunnel. The status quo is not an option.”

He then expressed an old wish raised by past governors, judges, academics, and newspaper editors since California’s beginning—to build trust among contending water interests: “We have to get past the old binaries, like farmers versus environmentalists, or North versus South. Our approach can’t be ‘either/or.’ It must be ‘yes/and’….We must get this done—for the resilience of our mighty rivers, the stability of our agriculture sector, and the millions who depend on this water every day.”[8]

At Restore the Delta, we hear a governor seeking to recast the terms of water conflicts in California in January 2019, particularly after a dozen extremely contentious years, and this governor has taken meaningful steps in that direction—first and foremost the many steps that have ended the twin tunnels.

The bravery of Newsom’s action should not be underestimated: with all the momentum that former governor Jerry Brown marshaled within the state water contractors and the California Department of Water Resources (DWR) to break ground on WaterFix before leaving office in January, Newsom could have let these political forces have their way so that he could focus on other pressing problems facing California.

But he did not. Governor Newsom instead ordered DWR to end California WaterFix and undertake a different approach to California water policy. He held over features from the previous administration—for example, the commitment to Sacramento and San Joaquin River basin Voluntary Settlement Agreements—while placing greater emphasis on water conservation, efficiency, recycling —and potentially a single tunnel.

More subtly, his christening this new policy process with the term “resilience” is a quiet recognition of the imperative that California water policy must be synced up with the state’s other initiatives addressing climate change. Water has for too long been isolated from California’s more innovative approaches to greenhouse gas emission reduction, wildfire strategy, and the state Coastal Commission’s efforts to adapt to sea level rise in our coastal zone. How will California provide for its future water needs (as called for in the Delta Reform Act of 2009) in an era of increased climate and earthquake risk?

At the outset of the Newsom Administration, Delta groups and elected officials met with Secretary Crowfoot. He has told us that the risks to the state’s water systems posed by earthquake

events and climate change are uppermost in their minds—and for these reasons they (Crowfoot and DWR) maintain they are serious about a single tunnel.

Our position is that the state assessment of Water Resilience Portfolio projects must include a no-tunnel alternative. In other words, portfolio projects of this alternative should be identified that could meet California's future water needs without a single tunnel conveyance project in the Delta. Secretary Crowfoot informed us that new alternatives would be part of the upcoming planning and environmental impact report processes.

During Governor Brown's advancement of the twin tunnels project, alternative plans were rigged by state agencies to fail narrow water policy objectives and to appease the desires of the State Water Contractors to build the tunnels project. In order to meet Governor Newsom's goal of eliminating the old "binaries," we at RTD maintain that it will not be acceptable to simply repurpose the California Water Plan or reheat California WaterFix analyses. State follow-through to fully and accurately vet, and to compare and contrast alternative Delta conveyance plans including a no-tunnel option, must proceed if Governor Newsom and Secretary Crowfoot are serious about assembling their Water Resilience Portfolio for genuine and comprehensive resilience and climate adaptation.

The report before you assumes that this governor sincerely wants to do things differently, unlike our previous two governors. We believe he wants his administration to conduct a public search for water policies, programs, and projects that congeal into a 21st century "Water Resilience Portfolio" for California, and to do so, we hope, in good faith with as many supportive and diverse stakeholders as he can muster.

In that spirit, this report offers our perspectives on a number of long-standing myths, straw men, and errant justifications for California WaterFix that will need to be faced by the state, but which have yet to occur.

Trust between stakeholders and government officials rests on their ability to agree on the facts of a situation. We have commented on the previous administration's aspirational claims about the California WaterFix, and we have experience with placing actual facts into the record.

There remains no shortage of bad legacies in California water policy to this point. Delta watershed rivers and streams have failing, depleted ecosystems providing dismal habitat for fish generally, and specifically for several listed fish species including various runs of Chinook salmon, steelhead, sturgeon, and formerly abundant schooling prey fish like longfin smelt and Delta smelt.

State and federal agencies routinely cherry-picked water policies—like the "co-equal goals" of improved water supply reliability with improved ecosystem performance—at the expense of the Delta Reform Act's statewide policy mandating reduced Delta reliance for California's future water needs.[9]

Water industry lobbyists, along with Metropolitan Water District member agencies, recently sought congressional approvals to bar any litigation (normally every citizen's right) against the California WaterFix project or the future operations of the State Water Project (SWP) and the federal Central Valley Project (CVP), which was fortunately defeated during the federal government shutdown last winter. But this effort was a particularly egregious affront to citizens' rights we will not

soon forget, as it was the apogee of water industry hubris and opportunism to seek such approval in the first place.[10]

DWR's recent web page "Why Delta Conveyance" attempts to repackage a number of California WaterFix myths in support of the single tunnel concept, suggesting strongly that at least some officials at DWR prefer to leave little to chance about how a single tunnel project is seen by the public.[11]

While the Newsom Administration established some new leadership in the state bureaucracy, there is considerable momentum left over from the only recently concluded WaterFix era.

For this moment, we hope the Newsom Administration will re-channel the momentum from the WaterFix era into real solutions that will restore the Delta and that will protect water supplies for Californians in an uncertain, even dangerous climate future.

This report details for the Newsom Administration the criteria by which Restore the Delta will evaluate the upcoming Water Resilience Portfolio product and any proposed new Delta conveyance. We have stated these criteria elsewhere, but here we restate them for the Newsom Administration to consider.

This report is submitted in good faith to the Newsom Administration. It suggests a rubric through which the state can complete a thorough and accurate analysis of portfolio options and the no-tunnel alternative that will be logical, reasonable, and even scientifically defensible.

Among the issues at stake in the Water Resilience Portfolio process are:

- A more balanced and open discussion of seismic risks faced by the Delta as well as for other key state reservoirs and aqueducts (Chapter 2, this report).

- How best to manage the Delta for in-Delta communities, fish and wildlife, and drinking water supplies during periods of flood and extreme drought resulting from climate change impacts (Chapter 3, this report).

- A plan for safe, clean, and affordable drinking water for environmental justice communities everywhere in California, including the Delta and the San Joaquin Valley.[12] Population projections of California's future water needs must be tempered by realistic and detailed incorporation of recent water conservation and efficiency experience and their future potential (Appendix B, this report).

Residents of the San Francisco Bay-Delta (there are more than 4 million of us) will evaluate proposals by the Newsom administration with clear eyes and in a spirit of collaboration. Here are some questions Delta people plan to ask as we engage with this new process.

DOES THE PLAN REDUCE WATER EXPORTS?

The primary purpose of a single Delta tunnel is likely no different than the purpose of the old twin tunnels, California WaterFix: to facilitate water transfers from Northern to Southern California. A

large single tunnel can do as much or more damage than two tunnels, depending on where it is located, and how and when it is built and operated.

While we well understand the need to share fresh water with the southern half of the state, it must be at sustainable levels that also protect Delta communities and ecosystems. For ten years, we and our coalition partners have been asking for a water availability analysis. How can the people of California possibly know how much water to transfer safely from a collapsing estuary and its upstream water sources if we don't know how much water is really available, and as compared with over-promised water right claims? No accurate analysis was completed by the Brown Administration on how a Delta tunnel would divert flows from Trinity, Feather, and McCloud River basins, in addition to the Sacramento River basin, among others. It is also important to ask what will be the impacts on wild and scenic protection of these rivers and to Sacramento Valley groundwater basins? The Newsom Administration has promised a water availability analysis. This is an area where Delta advocates need to, in the words of President Ronald Reagan, "trust, but verify" to ensure the analysis is completed thoroughly.

DOES THE PLAN PROTECT NORTHERN CALIFORNIA INDIAN TRIBES?

Continued overdraft of Northern California water sources will further impact salmon restoration. Salmon are essential to the cultural and economic well-being of Northern California indigenous communities. These communities are part of California's water environmental justice community.[13] The state's water rights system was erected on their removal from many watersheds throughout California. Yet, zero to little acknowledgement of this water environmental justice (EJ) community ever shows up in the state's water needs analysis. More recently, the state has made overtures on water issues to California indigenous peoples to acknowledge water rights and resource needs of indigenous communities, including land stewardship and fire management.

Recently, Governor Newsom issued a formal apology on behalf of the state of California to California's Indigenous Peoples (Appendix C, this report). His action initiates a new official relationship between the state of California and the Indigenous Peoples of the state. In his executive order, Newsom commended and honored "California Native Americans for persisting, carrying on cultural and linguistic traditions, and stewarding and protecting this land that we now share" and apologized "on behalf of the citizens of the State of California to all California Native Americans for the many instances of violence, maltreatment and neglect California inflicted on tribes." His order goes on to assign his Tribal Advisor to establish a Truth and Healing Council "to bear witness to, record, and 0examine existing documentation of, and receive California Native American narratives regarding the historical relationship between" the state and the tribes "in order to clarify the historical record of this relationship in the spirit of truth and healing." The new council will report annually to the governor and issue a full report on or before January 1, 2025.[14]

We at Restore the Delta incorporated testimony from Gary Mulcahy, government liaison with the Winnemem Wintu Tribe of Northern California, in our case to the State Water Resources Control Board opposing the water rights petition of California WaterFix. We will be watching to see that the Water Resilience Portfolio needs analysis accounts for the water and fishery needs of the Winnemem

Wintu and other northern California tribes reliant upon salmon culture and nutrition. This is a matter of both climate and environmental justice (Appendix B, this report).

DOES THE PLAN PROTECT BAY-DELTA ENVIRONMENTAL JUSTICE COMMUNITIES?

As with Northern California's Indigenous Peoples, DWR has only grudgingly acknowledged that other Delta environmental justice communities exist (and conducted a poorly constructed opinion survey in 2010 with faux-environmental justice community representatives), let alone what the impacts will be from greater water transfers on all the Delta watershed's most vulnerable residents.[15]

The Public Policy Institute of California held a conference in February this year to champion solutions for some water environmental justice communities in CA, but not all. At that conference, the message became clear that increased Delta water exports were the solution for San Joaquin Valley water needs. It is disheartening that California's vaunted public policy think-tank continues to divide California's water EJ Community, ignoring Delta environmental justice communities in the process.

Percentage-wise, the Delta region has the largest environmental justice community in California, with parts of Stockton hitting the 95th percentile for economic distress, and small Delta towns comprised of 52 percent of residents for whom English is not their first language. The economic distress of many Stockton environmental justice communities exceeds that of all other environmental justice communities of California.[16]

In small north Delta farm communities, farmworker families will lose their homes, jobs, and groundwater supplies with Delta tunnel construction. Stockton's large environmental justice population will see significantly increased pollution and salinity in its Delta and groundwater supplies resulting from tunnel construction and operations, and the proliferation of toxic algal blooms throughout its waterways. The Water Resilience Portfolio process and future conveyance analyses must address these concerns fully and forthrightly with response, prevention, mitigation, and adaptation strategies.

WILL THE PLAN SERIOUSLY CONSIDER CLIMATE CHANGE?

The water industry, including DWR and state and federal water contractors, continues to focus on the need to divert water during wet periods from the Delta for southern California and the San Joaquin Valley as part of climate change planning. We agree. Opportunities will continue to exist to share water during wet periods, so long as we all ensure that enough freshwater flows from the Delta to San Francisco Bay to sustain the economies and communities along its path. There are also opportunities to capture more rainwater in each region of California from more frequent extreme storms that are also expected in the future.

However, the primary contractor-proponent of the Delta tunnel, the Metropolitan Water District of Southern California, continues to model water exports in board meeting presentations as increasing during dry periods, exactly when the Delta needs freshwater flows to prevent toxic algal

blooms, and to keep salinity out of the freshwater areas of the estuary. And in dry periods, a single tunnel is likely to be of less use than MWD implies (Chapter 3, this report).

What does climate change science and current modeling tell us about water availability for exports during extended periods of drought? Even though reduced Delta water yields will result in smaller exports to Southern California, tunnel bond repayments would continue, even in lean water years. Why would California commit to projects that could lead to potentially severe, onerous financial obligations for a climate-dependent project, when California could first benefit from greater reliance on more flexible, "no regrets" solutions like recycling, conservation, and water use efficiency measures for the state's future water needs?

WILL OUR LEVEES BE FIXED?

Whether a tunnel for new conveyance is built, or the existing pumps are re-engineered instead, Delta levees will still need to be strengthened to protect human life, and the billions of dollars of public utility infrastructure within the Delta (Chapter 2, this report). If an earthquake event were to occur here, the Delta would experience 100% of the loss of human life — and 80 percent of the state's economic loss. In addition, engineering reports completed on the twin tunnels by WaterFix engineers under the Brown Administration were woefully incomplete. The tunnels were not, and to date, have yet to be designed for seismic safety. After an earthquake it would be much harder to fix an underground tunnel, than repairing levees for through-Delta flows to the pumps. These factors are largely ignored by water industry analysts.

With regard to sea level rise, mitigation will likely be needed, using such strategies as wetlands restoration and seawalls along San Francisco Bay and Suisun Marsh, even extending into the Delta. The existing Delta export pumps are inland, off-river, and protected by levees which could be raised, renovated, and strengthened for both habitat expansion and public safety. Proposed intakes for any tunnel would be placed in the north Delta, potentially unprotected from sea level rise and storm surge, and could be inundated.[17] To date, the state has yet to complete and reveal an analysis that looks at conveyance intake locations, mitigation of rising water levels, and the fine details around tidal influences, and downstream floods from increased runoff.

LOOKING AHEAD

We "Delta interests" look forward to participating in the new governor's process with open yet questioning minds. In considering the challenges imposed on us all by climate change, is a single Delta tunnel, remodeled on previous WaterFix assumptions, engineering, and modeling, the silver bullet for restoring the Delta and ensuring water supply reliability for our friends and neighbors to the south? While we agree that the single tunnel option is worthy of study, we have strong doubts.

We offer our critique and criteria here in the hope that other water stakeholders and those Californians interested in state water issues will consider our views as they formulate and convey their own about Governor Newsom's upcoming Water Resilience Portfolio and new Delta conveyance.

[1] Joint letter from James Mizell, assistant chief counsel, California Department of Water Resources, and Amy L. Aufdemberge, assistant regional solicitor, U.S. Department of the Interior, to Hearing Officer Tam Doduc, State Water Resources Control Board, May 2, 2019. Accessible at https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Delta-Conveyance/Letter-from-DWR-Reclamation-to-SWRCB---Withdrawal-of-Petition_a.pdf?la=en&hash=23D367D6950B37174273F538CD041E4F2885FCF8.

[2] Official DWR and US Bureau of Reclamation withdrawal and rescission documents are available at https://water.ca.gov/Programs/State-Water-Project/Delta-Conveyance in the right margin at this time. We appreciate DWR making these documents available to the public all in one place and easily obtained.

[3] Crowfoot quoted at https://water.ca.gov/News/News-Releases/2019/May/State-Withdraws-WaterFix-Approvals.

[4] Executive Order N-10-19, paragraph 1. See Appendix A to this report.

[5] *Ibid.*, section 2.

[6] *Ibid.*, section 3.

[7] *Ibid.*, section 4.

[8] "Governor Gavin Newsom Delivers State of the State Address," text as prepared for delivery at https://www.gov.ca.gov/2019/02/12/state-of-the-state-address/. In this same address, Newsom also decried the "moral disgrace and medical emergency" of poor Stanislaus County communities paying more for bad water than do Beverly Hills for "its pristine water."

[9] California Water Code Section 85021.

[10] We recall and appreciated learning that then-Secretary of Natural Resources John Laird authored a brief yet timely letter expressing the Natural Resources Agency's opposition to this legislation to congressional representatives.

[11] DWR. 2019. *Why Delta Conveyance.* Accessible at https://water.ca.gov/News/Blog/2019/June-2019/why-delta-conveyance. See also Chris Shutes. 2019. "Oops, DWR Did It Again." Accessible at http://calsport.org/news/oops-dwr-did-it-again/.

[12] Currently, the California Environmental Justice Alliance has the Department of Water Resources on its state agency evaluation "watch" list. Accessible at https://caleja.org/wp-content/uploads/2019/06/CEJA-Agency-Assessment-FULL-FINAL-Web.pdf.

[13] Restore the Delta. 2018. *The Fate of the Delta: The Impacts of Proposed Water Projects and Plans on Delta Environmental Justice Communities,* pp. 52-54, concerning the Winnemem Wintu Tribe. Accessible at https://www.restorethedelta.org/thefateofthedelta/.

[14] Executive Department, State of California. 2019. *Executive Order N-15-19.* Accessible at https://www.gov.ca.gov/2019/06/18/governor-newsom-issues-apology-to-native-americans-for-states-historical-wrongdoings-establishes-truth-and-healing-council/.

[15] *The Fate of the Delta, op. cit.*, "Environmental Justice Outreach Efforts by Petitioners," pp. 47-51.

[16] *Ibid.*, pp. 23-27, p. 89 (see table).

[17] Barbara Barrigan-Parrilla. 2019. Delta Residents and the Single Tunnel Plan. February 28. Accessible at https://www.restorethedelta.org/2019/02/28/delta-flows-delta-residents-and-the-single-tunnel-plan%ef%bb%bf/.

Chapter 2 SEISMIC ISSUES

PAST STATE HANDLING OF DELTA SEISMIC RISK

This chapter explains first our skepticism of earlier DWR treatment of seismic risk to Delta levees and infrastructure, and goes on to describe recent science that bears on assessment of that risk.

In our view, there is prediction of and preparation for earthquakes based on realistic evaluation of the best available science, and then there is propagation of fear of earthquakes.

The California Department of Water Resources (DWR) and its allies have since the CalFED process in the 1990s propagated fear of earthquakes causing multiple levee failures, leading to disruption of Delta exports to the San Joaquin Valley agriculture and southern California cities. DWR's use of earthquake fear as a preferred message to the public is an important source of bad faith that we at Restore the Delta want the state to rectify during the Water Resilience Portfolio process now unfolding.

With the onset of the Bay Delta Conservation Plan and California WaterFix planning processes from 2006 through 2018, DWR ratcheted up its use of earthquake fear to support new Delta conveyance as a hedge against levee failures and Delta export disruption. While its message of fear for Delta levee stability did not convince the public to support California WaterFix, the state's reliance on this strategy unfortunately has muddied Delta earthquake and flooding issues. In this section we wish to bring out key scientific and policy issues involved in hopes that the state will seriously consider investment in Delta levees—to reduce seismic risk and protect all water supplies, both locally and for export, with or without a single-tunnel conveyance scheme.

THE DELTA'S LOCAL FAULTS

In 1997, the United States Geological Survey (USGS) summarized the structural geology and fault zones of the Delta and the eastern Coast Range mountains nearby.[1] Of course, the Bay Area's two major fault zones, the San Andreas to the west and the Hayward in the East Bay hills, form the tectonic boundary between the Pacific and North American plates—the two plates slide and scrape past each other in a "transform" or horizontal motion (as distinct from more of an up-down or vertical motion). The eastern Coast Range mountains (such as those in the interior East Bay of Contra Costa and Solano counties) are believed to have formed from the scraping of Pacific Ocean sea floor crust and sediments onto the North American Plate at a time when the Pacific Plate was "subducting" or diving beneath the North American Plate. Various shear zones in these older rocks east of the Hayward Fault help fashion the hills and mountains just west of the Delta. Using well drilling geologic data for the Delta region, geologists and seismologists identified the Pittsburg/Kirby Hills fault slicing south through the city of Pittsburg in the western Delta area, and the Midland fault further east just beyond the Montezuma Hills of southern Solano County.

The USGS identified historical earthquakes of note near to those faults, whose magnitudes were estimated after the fact: a magnitude 6.0 quake near Antioch in May 1889, and two large quakes in 1892 near Vacaville and Winters with magnitudes 7.0 and an aftershock of 6.75. A magnitude 6 quake was felt in May 1902, but the 1997 study stated, "Since modern seismic recorders have been installed, no earthquakes larger than about Magnitude (M) 4.5 have occurred in the area," adding,

"but clearly the potential exists for events with magnitudes greater than 6.0 in the study area."[2] From all these events just one death and some property damage was reported, but nothing specific to Delta levees, which were not yet all in place in the late nineteenth century. Nor were there surface ruptures found, suggesting the fault ruptures were "deep or blind." The death toll and property loss was small due to much lower population than exists today.

The USGS report stated that the Midland fault separates "Great Valley" sediments from "younger strata" to the west. Both sit atop underlying basement (bottom floor) rocks that make up the Sierra Nevada and Coast Range under the Central Valley. The geologists were uncertain that the Midland fault's plane continued through these bottom rocks, but by explaining that a "decollement" may be present, the structural blocks of these faults may slide separately from the basement, bottom rocks.[3]

(To envision "decollement" structure, imagine a block of cheese sitting atop a wooden cutting board: a knife cutting the cheese creates a "fault" between two cheese slices, but does not slice through the cutting board wood. The surface between the cheese and the board represents the "decollement" plane. "Cheese faults" above the cutting board could move independently relative to each other and to the cutting board beneath. Quakes could be generated via movement on any of these planes.)

MOUNTING EARTHQUAKE FEAR

DWR geologist Michael Finch authored a brief 1985 article in *California Geology* about earthquake damage in the Delta. His research presented photographs of a few lengthy cracks in Delta levees or islands in the wake of recent quakes. His article described fifteen instances of earthquake damage on six different islands—Mandeville, Bacon, Empire, Webb, Venice, and King—correlated to five different quakes: Coyote Lake (M. 5.9, 1978), Livermore (M. 5.9, 1980), Coalinga (M. 6.7, 1983), Pittsburg (M. 3.6, 1983), and Morgan Hill (M. 6.2, 1984). Only one quake, the Pittsburg, occurred in close proximity to the Delta, and was the smallest of the five. Finch identified cracks ranging in length from "minor cracks" to several hundreds of feet long and one that was about 1,000 feet long. None of the damage Finch described represented levee failure with subsequent flooding.[4] There is no mention in the article whether Finch's field and archival research was peer-reviewed or field checked by other geologists prior to publication.

The CalFED Bay-Delta Program stated mildly in a 1999 study of seismicity and Delta levee stability, "The vulnerability of the Delta levee system to failure during earthquakes is a concern. Although levee failure from a seismic event has never been documented, the Delta has not experienced a significant seismic event since the levees reached their current size. However, levee failures from a seismic event may result in multiple levee failures on more than one island."[5] Because there had been no seismic impact experience in the Delta levee system, the CalFED analysis relied on a probabilistic (statistical) evaluation of levee failures based on expected regional and local faulting ground motions. The study noted:

> Since the overall seismic hazard is dominated by moderate local events, *it is unlikely that the entire Delta region will be subject to large motions in any single earthquake. For example, a magnitude 6 event near the northern Delta may cause significant ground motions in the*

> *northern Delta, but not in the southern Delta, as peak accelerations produced by events of only moderate magnitude attenuate [slack off] fairly rapidly with distance from the source (fault rupture).*[6]

Where the CalFED Delta levee seismic study was low-key about Delta levee seismic risk, DWR began to stoke fears by 2008. "A moderate to large earthquake in the San Francisco Bay region could cause major damage to Delta and Suisun Marsh levees, and could cause many of them to fail," DWR stated in its 2008 Risks and Options study, adding, "Levee foundations could fail due to liquefaction or the levees themselves could deform and fail. Seismically induced levee failures would be expected to extend for thousands of feet if not miles and impact many locations simultaneously."[7] While acknowledging that "No Delta levee is known to have failed from an earthquake" DWR pointed out that "the last 100 years of land subsidence [due to oxidation of peat soils in many Delta islands] has made the Delta islands deeper and resulted in building levees higher. These levees," claimed DWR, "are more susceptible now to failure during an earthquake than they were in 1906." Moreover, says the study, the hiatus of large earthquakes along Bay Area earthquake fault zones means that "stress is building, increasing the chance of a large earthquake." (See our discussion below of this hiatus.) The USGS, said DWR, concluded in that decade that there is a "62 percent probability of at least one magnitude 6.7 or greater quake, capable of causing widespread damage, striking the San Francisco Bay region by 2032."[8]

In 2017, Kern County Water Agency (KCWA) informed its board (using materials from the Metropolitan Water District of Southern California [MWD] and the State Water Contractors [SWC]) that the state of California concluded that "a seismic event is the single greatest risk to [Delta] levee integrity" and repeated the USGS forecast of "a 62 percent probability of a magnitude 6.7 or greater earthquake occurring in the Bay Area between 2003 and 2032." Such a quake, said KCWA, could result "in multiple levee failures that would simultaneously flood 20 or more Delta islands" interrupting state and federal Delta exports for up to eighteen months. KCWA further stated at the time:

> Implementing California WaterFix would help reduce the risks from a catastrophic seismic event in the Delta. With the uncertainty of where a seismic event might occur, the addition of the new north Delta diversion and conveyance facilities provides redundancy in critical water supply infrastructure. Additionally, all California WaterFix infrastructure would be built to meet current seismic standards, as applicable.[9]

Note that KCWA did not simultaneously call for retrofit or renovation of Delta levees to further engineer redundancy of Delta conveyance. That same year, MWD repeated the same information in a report to its board, also with no expressed support for improving Delta levees.[10]

The USGS actually updated its Bay Area earthquake probabilities in 2016, prior to the prediction quoted by KCWA and MWD: that there is a 72 percent likelihood that a quake of M 6.7 or greater will occur on some Bay Area fault between 2014 and 2043. (The more active faults in a region, the greater the likelihood.) The Hayward Fault some 50 miles west of the Delta, said the USGS, has its specific probability of 33 percent for such a quake, a one-in-three chance. The smallest faults, including those near the Delta, have a total probability for such a quake of just 13 percent for the same period.[11]

Chapter 2 SEISMIC ISSUES

USGS seismologists in 2015 updated their modeling for earthquake probabilities statewide, stating:

> One particularly ready fault is the Southern San Andreas, which contributes to its continued status of being the most likely to host a large earthquake. Specifically, it has a 19 percent chance of having one or more events larger than magnitude 6.7 in the next 30 years near Mojave, Calif. The comparably low values for the Northern San Andreas, such as 6.4 percent near San Francisco, are partly because of the relatively recent 1906 earthquake on that fault.[12]

While the risk of moderate to large earthquakes in the Bay Area has risen with advances in seismological research, it is not clear that additional quake risk translates into worse shaking and seismic outcomes specifically in the Delta.

Scientists often say that it is best to get empirical (observed) data in order to validate and confirm models about how a physical process works. With enough data, they hope their models can mirror the behavior they see in nature, and then use these models to predict future behavior.

An opportunity arrived with the 2014 Napa earthquake (M. 6.0). This quake caused no damage to Delta levees despite its epicenter being less than 40 miles west. Yet MWD stated in a California WaterFix "Q&A" document for the public that "although observed ground motions in the Delta were less than model predictions, the difference between predicted and observed ground motions would not significantly change calculated deformation to Delta levees."[13] MWD's statement ignores the fact that, while Delta levees may be constructed of materials vulnerable to seismic shaking, they were just plain unaffected by the nearby Napa quake. The question is less about whether Delta levees "deform" or can be shown mathematically to be unstable during seismic ground shaking; we acknowledge that they can. ***But why didn't Delta levees liquefy and fail during the 2014 Napa quake?***

SEISMIC GROUND MOTION REDUCTION (ATTENUATION)

We at Restore the Delta are not stating there is no reason to fear major earthquakes damaging Delta levees. Instead, a balanced portrayal of seismic risk to Delta levees is essential to the Delta's future—including its water export capability, the protection of life and property, and the economy of the Delta region. Everyone in the Delta and beyond is concerned about seismic stability of Delta levees, and flooding and water quality impacts that can result from their failure. The focus of this issue is about whether the interests involved in the Delta are properly framing the relationship of the current state of scientific understanding to its application to Delta levees' seismic stability. Confusion on this point has been rife in the media and abetted by misleading treatment of seismic stability issues by the state and its Delta tunnels conveyance allies. The State of California has an opportunity now to carefully apply the best available science to its Delta levee protection, flood prevention and mitigation priorities, and its Delta conveyance decision-making during the Water Resilience Portfolio process.

A study published online (July 29, 2014) less than a month before the Napa quake found that the Delta's underlying geology reduces or attenuates ground shaking from earthquakes compared with either the Sacramento or San Joaquin Valleys. The Delta itself, its authors found, has beneath it

"a broad zone of…thick alluvium and permeable high porosity sedimentary rock" whose properties contribute to reducing ground shaking from earthquakes.[14]

Ground shaking from the Napa quake on August 24, 2014 (M 6.0) was recorded by nineteen stations within 20 km (about 12.4 miles) and 292 stations within 100 km (about 62.1 miles) of the quake's surface rupture. Seismologists studying the recordings found that the seismic waves generated at Napa "at all frequencies" attenuated (reduced, diminished) at rates for the Napa and San Francisco Bay Delta region that were "stronger than the average attenuation in California."[15] Observed quake motions were all less than what would have been predicted for the Delta by five sets of models called "ground motion prediction equations (GMPEs)." A Delta Independent Science Board workshop poster by USGS seismologists from 2016 found agreement specifically in the Delta region with these 2015 findings, stating that,

> If the attenuation in the northern Bay Area is significantly stronger than the average attenuation for California, then using a path-specific or regional attenuation to predict ground shaking in the Delta from large earthquakes on a range of nearby and distant faults will significantly reduce the hazard to the Delta levees.[16]

In 2016, the Delta Independent Science Board (DISB) held a workshop and produced a report addressing earthquakes and high water as Delta levee hazards. Quake hazards to Delta levees, the DISB found, depends on the source of the earthquake with respect to the levees affected. Bay Area earthquakes are considered the main source of strong ground motions since "Bay Area faults produce earthquake shaking in the Delta more often than faults beneath the Delta itself," wrote the DISB, adding:

> How strongly a Bay Area earthquake affects the Delta, however, depends on attenuation—on how abruptly the ground motions diminish as the seismic waves advance eastward from the Bay Area into the Delta. A DRMS study [the Delta Risk Management Study from 2008] used attenuation equations that were considered state of the art at the time. *These equations have now been found to overestimate Bay Area transmission of ground motions by factors of two to four in the case of the 2014 South Napa earthquake of magnitude 6.0, and also for smaller Bay Area earthquakes.*
>
> …
>
> Whatever the earthquake source, the seismic response of Delta levee[s] was shown to depend on materials through which the seismic waves travel. These materials include rocks between the fault and the Delta, rocks beneath the Delta, and unconsolidated materials in the Delta that amplify ground motions by slowing seismic waves as they approach the ground surface.[17]

In lay terms, large Bay Area earthquakes may generate strong ground shaking, but that shaking attenuates (diminishes) as it reaches the Delta, depending on where the quake originates.

A newer study confirms this view of the seismic hazard to Delta levees, but with refinement: using large and medium-size earthquake shaking data, seismologists found that the relative "differential attenuation does not appear to depend on azimuth [that is the direction from which the

shaking originates] or magnitude of the earthquake; however, earthquake depth may have an effect….In turn, the risk of levee failure from shaking produced by Bay area earthquakes would be substantially reduced," these seismologists concluded.[18]

The California Aqueduct, the primary water conveyance facility of the State Water Project, crosses the southern San Andreas Fault in the mountains north of Los Angeles. Castaic, Perris, and Pyramid reservoirs of the State Water Project are also located in the fault-riven mountains of southern California. We find it ironic that southern California water agencies like KCWA and MWD worry more about Delta seismicity than about their immediate facilities' seismic resilience. While total earthquake probability increased in the Bay Area, recent seismic attenuation studies reveal that, at least in recent seismic activity, shaking attenuates significantly as it reaches the Delta.

We are unaware that these water industry leaders trumpet USGS seismic concerns in their home regions to raise awareness and evaluate community water supply readiness concerning the aqueduct and its terminal reservoirs mentioned above. Acknowledging the seismic threats nearer to home probably interferes with their preferred tale that alleged Delta levee failure is the biggest seismic threat, at the expense of significant threats nearer to their service areas.

DELTA LEVEES ARE STILL NEEDED

Though seismic risk to Delta levees may be conceptually reduced relative to what was thought a decade ago when California WaterFix and the Bay Delta Conservation Plan were in early planning stages, this does not mean there is no risk. The reduction in risk, however, merits "attenuation" in the state's rhetoric about seismic risk to Delta levees, and in the rhetoric of the state's allies concerning some new type of Delta conveyance.

Delta levees are still needed. Each iteration of California WaterFix's operations since 2012 relied for some portion of the year on conveyance of state and federal stored water in and through Delta channels to reach the state's Banks Pumping Plant near Byron and the federal Jones Pumping Plant near Tracy. Through-Delta conveyance means passage of water intended for export between Delta levees for the entire distance. Environmental reviews of the tunnels project revealed that about half the time (48 percent) on average the south Delta pumps would continue to be the point from which state and federal exports would originate. DWR and the Bureau sought to modify their water rights permits from the State Water Resources Control Board between 2015 and 2019 to ***add*** points of diversion in the north to augment their south Delta pumping plants—***not to replace*** the south Delta diversions with the north. There would be times when listed fish species would be present or fresh water flows entering the north Delta would be too low (seasonally or from drought) to permit such diversions through the tunnels. ***Sending water through leveed Delta channels is still vital to the State Water Project and the Central Valley Project in addition to the health of the Delta itself.***

Over the last decade of water debates we at Restore the Delta have continually found it irresponsible of tunnels advocates to push for tunnels as some sort of seismic insurance policy while excluding Delta levees from that same treatment. ***We have no reason to believe at this time that a "single tunnel" conveyance concept for the Delta would have less need for Delta levee stability in the face of any level of seismic risk than did California WaterFix.*** Delta levee stability investment is an essential component of any investment in long-term conveyance for the Delta—with

or without a single-tunnel concept—whether the levee failure hazard results from earthquakes or sea level rise due to climate change. If DWR and the Bureau, and their urban and agricultural customers, are to continue to export water from the Delta for the long haul, they must come to grips with the fact that Delta levees are essential to their future as well as to the Delta's—and help persuade the public to support Delta levee investments, and soon.

THE SEISMIC HIATUS

Sometimes scientific research raises rather than answers questions in an effort to push the scientific community forward. Such questions help to outline agendas for new and continuing research. Using historical earthquake records, seismologists Glenn Biasi and Katherine Scharer studied the likelihood of seismically quiet or quiescent periods. Looking at four major California faults (including San Andreas, Hayward, and San Jacinto faults) revealed to these seismologists that six large ground-rupturing quakes occurred on these faults during the nineteenth century and two more in the first two decades of the twentieth century, "yet there have been no occurrences in the last 100" years. The most recent such ground-rupturing quake occurred in 1918 on the San Jacinto fault in southern California, so it has already been one hundred years since such a major earthquake ("the big one") has occurred. Biasi and Scharer also considered whether the last 1000 years of earthquake activity from geologic ("paleoseismic") records showed any significant hiatuses in their probability. They found that such hiatuses are quite rare, on the order of three-tenths of a percent (0.3%) for any particular 100-year period in their data.

"Whether due to statistical anomaly, some long-term modulation of earthquake occurrence, or another cause," they conclude, "our results emphasize that the hiatus of the last century has been exceptional."[19]

"There have been other big earthquakes in California in the past 100 years, but they haven't happened in the places that we would have expected them, the really fast moving faults," said another seismologist with the USGS.[20]

The hiatus raises the issue for seismologists of whether their models include enough empirical data, or enough robust concepts about the underlying geologic structure to facilitate research and improve explanation of the hiatus. A news release on Biasi and Scharer's research indicates the range of issues the hiatus raises for scientists:

> "Our paper confirms that this hiatus is very improbable and it's our view that our efforts will be better spent considering explanations for this, rather than trying to bend the data to make the hiatus a 'statistically improbable but could happen' kind of thing," said Biasi.
>
> "We're saying, no, it's not a data problem, it's not a data choice problem, it doesn't matter how you slice this," he added. "We just have not had earthquakes that past records predict that we should have had."
>
> He likened the hiatus to what a person might see if they pulled up a chair alongside a freeway to count passing cars. "You might say that a certain number of cars per hour is kind of

representative, and then something happens and you go ten minutes of seeing no cars. If it's just ten minutes, you could say it was a statistical fluke."

But if the freeway stays clear of traffic for a long time, "the other reason there might be no cars is that up around the bend, there's a wreck," said Biasi.

The researchers would like more seismologists to focus on the reasons—"the wreck around the bend"—behind the current hiatus.

"We had the flurry of very large earthquakes from 1800 to 1918," Biasi said. "It's possible that among them they just wrung out—in the sense of wringing out a dishrag—a tremendous amount of energy out [of] the system."

There may be stronger long-range interactions between the faults than suspected, or there may be unknown features of the mantle and lower crust below the faults that affect the probability of ground-rupturing earthquakes, he noted.[21]

The hiatus problem bears on the likelihood of when major Bay Area earthquakes will occur, not just whether their seismic waves will be attenuated in the Delta, and the potential for catastrophic Delta levee failure from quake shaking. The problem is, how much time do we Californians have to improve the seismic and flood stability of Delta levees? "If our work is correct," say the seismologists, "the next century isn't going to be like the last one, but could [be] more like the century that ended in 1918."[22]

In conclusion, while attenuation and its potential for lessening the impacts of seismic activity within the Delta have been understated, the true frequency of seismic events may be more frequent than recent geological studies have documented.

The lesson of the state of seismic science is that for California's long-term water resilience (whether recovering from earthquake damage or effects of sea level rise or flooding) it is no longer enough just to claim that Delta levees are vulnerable to failure and therefore new Delta conveyance is the solution. It is clear that with or without tunnel conveyance, Delta levees are needed. The new Water Resilience Portfolio must invest in levee improvements that mitigate seismic risk, improve Delta public safety, and increase the resilience of Delta conveyance (again, with or without tunnel) in response to actual seismic events. And, of course, any tunnel design should meet seismic requirements that are state of the art. We haven't the time to wait for seismological science to be certain of its ability to predict quake events to invest in protecting such critical infrastructure from disruptions—either from quakes or flooding. Yet the potential for seismic catastrophe should not continue to be overstated to create buy-in for a single tunnel project that may or may not deliver enough water to satisfy water contractor expectations due to drought impacts resulting from climate change.

---

[1] Weber-Band, J., et al. 1997. *Active Tectonic Deformation at the Eastern Margin of the California Coast Ranges: Results of the BASIX and CalCRUST Programs.* USGS Open-File Report 97-691. Accessible at https://pubs.usgs.gov/of/1997/0691/report.pdf.

[2] *Ibid.*, pp. 10-11.

[3] *Ibid.,* pp. 13-14. "Geophysical data suggest a continuous basement extends westward from beneath the Central Valley to beyond the Hayward fault. Above this basement occurs a major strike-slip fault (Concord/Green Valley) and active compression-related structures (Los Medanos thrust, Pittsburg/Kirby Hills fault, Midland fault). In the study area, contemporary seismogenic [that is, earthquake-causing] deformation appears concentrated in the basement where fault mechanisms are primarily strike-slip while upper crustal structures are clearly compressional. We interpret faults at the surface to be independent, separated from basement deformation by tectonic wedges and decollement structures." p. 14. "Decollement" (from French *décoller*, meaning 'to detach from') is a gliding plane between two rock masses, also known as a basal detachment fault. Décollements are a deformational structure, resulting in independent styles of deformation in the rocks above and below the fault. They are associated with both compressional settings (involving folding and overthrusting) and extensional settings." See https://en.wikipedia.org/wiki/D%C3%A9collement.

[4] Finch, M. 1985. Earthquake Damage in the Sacramento-San Joaquin Delta. *California Geology*. February, Table 1, p. 41. Accessible at ftp://ftp.consrv.ca.gov/pub/dmg/pubs/cg/1950/03_12.pdf.

[5] CalFED Bay-Delta Program. 1999. *Revised Draft Long-Term Levee Protection Plan*. January, p. 2-17. See also the plan's Appendix G, CalFED Bay-Delta Program, Levees and Channels Technical Team, Seismic Vulnerability Sub-Team. 1998. *Seismic Vulnerability of theSacramento-San Joaquin Delta Levees.* December. Final Draft.

[6] CalFED Bay Delta Program. 1998*. ibid.*, Section 3.3, Hazard Results, p. 9. Emphasis added.

[7] Department of Water Resources and Department of Fish and Game. 2008. *Risks and Options to Reduce Risks to Fishery and Water Supply Uses of the of the Sacramento/San Joaquin Delta.* January. A Report Pursuant to Requirements of Assembly Bill 1200, Laird, p. 14. AB 1200, authored by John Laird (who would eventually become Secretary of Natural Resources under Governor Jerry Brown), required DWR to evaluate potential impacts of 50-, 100-, and 200-year projections on the Delta of the following risks: subsidence, earthquakes, floods, changes in precipitation, temperature, and ocean levels, and inclusive combinations of these risks. The act also required DWR to evaluate a variety of options for addressing these impacts to water supply disruptions, drinking water quality, salinity, infrastructure (including Delta levees), and areas of origins water rights and ecosystems of the Delta. Accessible at https://cawaterlibrary.net/wp-content/uploads/2017/05/AB1200_Report_to_Legislature.pdf.

[8] *Ibid.*, p. 12. See also Mount, J. and R. Twiss. 2005. Subsidence, Sea Level Rise, and Seismicity in the Sacramento-San Joaquin Delta. *San Francisco Estuary and Watershed Science.* 3(1). Accessible at https://escholarship.org/content/qt4k44725p/qt4k44725p.pdf?t=plq2mv. Neither Mount nor Twiss are seismologists, and their study did not account for seismic mechanisms or detailed regional geology in assessing likelihood of levee catastrophic events in the Delta, though this article generated much debate at the time of its publication.

[9] Kern County Water Agency. 2017. *Draft California WaterFix Overview: Materials for Discussion and Decision,* p. 46*.* Author's collection.

[10] Metropolitan Water District of Southern California. 2017. *Modernizing the System: California WaterFix Operations.* July, p. 18. Accessible at https://cawaterlibrary.net/wp-content/uploads/2017/09/CWF-WP2.pdf.

[11] Aagaard, B.T., et al. 2016. *Earthquake outlook for the San Francisco Bay region 2014–2043* (ver. 1.1, August 2016): U.S. Geological Survey Fact Sheet 2016–3020, 6 pages. Accessible at http://dx.doi.org/10.3133/fs20163020.

[12] Field, E.H., and 2014 Working Group on California Earthquake Probabilities, 2015, *UCERF3: A new earthquake forecast for California's complex fault system*: U.S. Geological Survey 2015–3009, p. 4. Accessible at https://dx.doi.org/10.3133/fs20153009.

[13] Metropolitan Water District of Southern California. 2017. A California WaterFix Dialogue: Questions and Answers. September, p. 22. Accessible at http://www.mwdh2o.com/2018%20Background%20Materials/CA%20WaterFix%20Dialogue%20Questions%20and%20Answers.pdf#search=california%20waterfix%20dialogue.

[14] Eberhart-Phillips, D. et al. 2014. Imaging P and S Attenuation in the Sacramento-San Joaquin Delta Region, Northern California. *Bulletin of the Seismological Society of America.* 104(5): 2322. Accessible at http://dx.doi.org/10.1785/0120130336.

[15] Baltay, A.S. and J. Boatwright. 2015. Ground-Motion Observations of the 2014 South Napa Earthquake. *Seismological Research Letters*. 86(2A): 355.

[16] Erdem, J.E. et al. 2016. *Ground-Motion Attenuation for the South Napa Earthquake in the Sacramento-San Joaquin Delta, California*. Conference poster. Author's collection, originally obtained from the Delta Stewardship Council.

[17] Delta Independent Science Board. 2016. Workshop report—Earthquakes and High Water as Levee Hazards in the Sacramento-San Joaquin Delta. September, p. 3. Emphasis added. Accessible at https://cawaterlibrary.net/wp-content/uploads/2017/04/DISB-2016-09-30-final-levee-workshop-report.pdf.

[18] Erdem, J.E. et al. 2019. Ground-Motion Attenuation in the Sacramento-San Joaquin Delta, California, from 14 Bay Area Earthquakes, including the 2014 M 6.0 South Napa Earthquake. *Bulletin of the Seismological Society of America*. 109(3): 1025, 1031-1032. Accessible at https://doi.org/10.1785/0120180182.

[19] Biasi, G. and K.M. Scharer. 2019. The Current Unlikely Earthquake Hiatus at California's Transform Boundary Paleoseismic Sites. *Seismological Research Letters*. 90(3): 1168. Accessible at https://doi.org/10.1785/0220180244.

[20] USGS seismologist Morgan Page quoted in Seismological Society of America. 2019. "How to Explain California's Recent Earthquake Hiatus?" published April 25. Accessible at https://www.seismosoc.org/news/how-to-explain-californias-recent-earthquake-hiatus/.

[21] Seismological Society of America. 2019. "California's Current Earthquake Hiatus is an Unlikely Pause." April 3. Accessible at https://www.seismosoc.org/news/californias-current-earthquake-hiatus-is-an-unlikely-pause/.

[22] Scharer and Biasi quoted in Seismological Society of America. 2019. "How to Explain California's Recent Earthquake Hiatus?" published April 25. Accessible at https://www.seismosoc.org/news/how-to-explain-californias-recent-earthquake-hiatus/.

Chapter 3 CLIMATE CHANGE ISSUES

CLIMATE CHANGE AND CALIFORNIA'S FUTURE WATER NEEDS

In crafting the Water Resilience Portfolio, climate change presents an extremely difficult task in planning for the state's future water needs. Our climate appears to be changing faster than climate scientists have anticipated, and with a greater likelihood that acceleration will appear as abrupt changes.

There is immense pressure to act quickly here in California, since:

- Present key national decision-makers prefer to deny climate change reality and impacts, and obstruct actions badly needed to protect infrastructure, homes, cities, and businesses, and to prepare Americans to adapt; and

- Mitigating and adapting to climate changes that loom over life and property throughout our state.

The Delta as a region is susceptible to the effects of climate change from downstream and upstream forces. Sea level rise and storm surges will push in from San Francisco Bay, while droughts and floods will shift widely how the Delta experiences fresh water flows in its channels.

This chapter addresses recent weather and environmental events to which scientists have already attributed greater likelihood from climate change. These anticipated climate events can be described in "Rumsfeldian" fashion as: 1) the "known knowns" of climate change and what they pose for California's water supply and the fate of the San Francisco Bay-Delta estuary; 2) and some important "known unknowns" or uncertainties about the pace and character of climate change this century and what these uncertainties portend for California's water supply and the Delta estuary.

In the same spirit that we described recent seismological science relevant to Bay Area and Delta earthquake risk, we here (and in Appendix E, this report) summarize recent science concerning abrupt release of greenhouse gas (GHG) emissions from ocean sediments and permafrost thawing, projections of increased extreme heat days in the Central Valley and their relevance to the future of California agriculture, and their importance to what is already known about California's future water condition. We also examine analyses completed by the state to date on climate change impacts to the Delta, including storm surge, sea level rise, and reductions in Delta outflow and exports.

We offer this information to help ensure that the state's upcoming Water Resilience Portfolio process takes the measure of new uncertainties about looming abrupt planetary changes, and plans carefully with them in mind.

We also offer this information to Delta counties, flood agencies, reclamation districts and cities so that they can serve as fully active partners with the state in planning for the impacts of climate change within the Delta. Their local knowledge and authorities will be indispensable in crafting measures that respond, prevent, mitigate, and adapt to the effects of climate change in the Delta.

Chapter 3 CLIMATE CHANGE ISSUES

RECENT WEATHER AND ENVIRONMENTAL EVENTS

Evidence of changing global and regional climate plays out about us. Hardly a week passes this year without anomalous weather or environmental events—whose probabilities are greater now than in the past—crowding media headlines and other news coverage. From April through the end of July 2019, consider these breaking news reports this spring and summer:

• Extensive tornadoes lashed southern states (killing eight people) in April 2019, and again in parts of the industrial and agricultural heartland of the United States in May.[1]

Vox reported:

> Tornadoes have been tearing up huge swaths of the United States this week, leaving death and devastation in their wake. On Monday alone, about 55 tornadoes touched down, and at least 27 tornadoes were reported Tuesday. That made Tuesday the 12th consecutive day with at least eight reported tornadoes, beating the record set in 1980. The Washington Post reported Wednesday that 225 tornadoes have been confirmed since May 17.
>
> Idaho, Colorado, Texas, Oklahoma, Kansas, Missouri, Ohio, Indiana, Pennsylvania, and other states all saw massive twisters touch down over the past several days. Several people were killed, dozens injured, and hundreds of homes were destroyed. Walls of some buildings were ripped off, making them look like dollhouses.[2]

• Western states saw record high heat during early June: Las Vegas (100 °F), Sacramento (103 °F), Phoenix (109 °F), Modesto (106 °F), and Portland, OR (97 °F).[3]

• In the last week of June, Europe sweltered under record heat, with the French town of Gallargues-le-Montueux experiencing 45.9 °C (about 114.6 °F) on June 28. Climate scientists attending a conference in Toulouse, France, calculated in real-time the probability that the heat wave during which they labored was five times more likely because of climate change.[4] The late June heat "helped raise average global temperatures to a record for the month," breaking the previous record set in June 2016, according to the European Center for Medium-Range Weather Forecasts.[5]

• Southern Alaska, including the city of Anchorage, Alaska, endured an eleven-day heat wave between June 27 and July 7 that broke all previous temperature records for equivalent periods—80.8 degrees Fahrenheit (°F)—by 5.5 °F over the next-closest period fifty-six years earlier (1953).[6]

• Briefly a hurricane before coming ashore near New Orleans on July 13, tropical depression Barry threatened to overtop the city's flood control levees by combining Barry's potential storm surge with the still-swollen Mississippi River, before the threat subsided. Flooding in the Mississippi basin had already devastated several Midwestern states, including Nebraska and Iowa, earlier in the year.[7]

• In addition to Alaska's heat wave, the Arctic Circle "is in the midst of an 'unprecedented' wildfire season on record, with more than 100 blazes raging across the region since the start of

June," according to Smithsonian.com. The World Meteorological Organization (WMO) reported that June 2019 was Earth's warmest June on record, and due in large part "to this heat surge, wildfires are now running rampant in Siberia, Greenland, Alaska and Canada, producing plumes of smoke visible from space. The fires occur mainly in peat, which is made up of decomposing organic matter that has hardened into a coal. When peat dries out, as it is in the warming Arctic, it is highly flammable. The burning releases carbon dioxide, the most common greenhouse gas."[8] The Arctic peat fires are said by scientists to have released more carbon in June alone than Sweden does in an entire year, about 50 megatons of carbon dioxide.[9] Environmental geographer Thomas Smith of the London School of Economics added, "The amount of [carbon dioxide] emitted from Arctic circle fires in June 2019 is larger than all of the CO2 released from Arctic circle fires in the same month from 2010 through to 2018 put together."[10]

CLIMATE CHANGE IMPACTS IN CALIFORNIA

California's Fourth Climate Change Assessment found the following:

• "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia."[11]

• "In California's highly variable climate setting, with models projecting less frequent but more extreme daily precipitation, year-to-year precipitation becomes more volatile and the number of dry years increases. As the climate continues to warm, atmospheric rivers, responsible for many of the heaviest extremes, will carry more moisture, and extreme precipitation may increase."[12]

• "Warming air temperatures throughout the 21st century will increase moisture loss from soils, which will lead to drier seasonal conditions even if precipitation increases. Warming air temperatures also amplify dryness caused by decreases in precipitation. These changes affect both seasonal dryness and drought events….[S]easonal summer dryness in California may become prolonged due to earlier spring soil drying that lasts longer into the fall and winter rainy season. The extreme warmth during the drought years of 2014 and 2015 intensified some aspects of the 2012-2016 drought…and may be analogous for future drought events."[13]

• "Much of California's water conveyance infrastructure was developed with a heavy reliance on snowpack for seasonal water storage….Climate projections suggest snowpack will decrease with air temperature warming, regardless of whether precipitation increases or decreases."[14]

• "A census of western snow courses (area where snowpack is measured) reveals that since the 1950s, April 1 snow water storage, averaged across western U.S., has declined by about 10 percent….Spring snowpack…declines substantially under modeled climate changes. The mean snow water equivalent (SWE) declines to less than two-thirds of its historical average by 2050, average over several model projections under both RCP 4.5 and 8.5 scenarios.[15] By 2100, SWE declines to less than half the historical median under RCP 4.5, and less than one-third under RCP 8.5. Importantly, the decline in spring snowpack occurs even if the amount of precipitation remains relatively stable over the central and northern California region; the snow loss is the result of a progressively warmer climate….[T]he likelihood of attaining spring snowpack that reaches or exceeds historical average is project to diminish markedly."[16]

• "By end century, when elevation-dependent warming is most pronounced, snowpack accumulation rates diminish by 77.1% to 80.3% between 0- and 2,000-m [meters] elevations [about 6,600 feet]. Therefore, snowpack accumulation rates at 1,500-2,000 m by midcentury and 2,000-2,500 m [about 6,600-8,200 feet] by end century resemble those at 0-500 m [up to about 1,600 feet] historically. Similarly, by end century, snowpack melt rates reduce to 67-73% of historical rates across all elevations….Without changes to current water management practice based on the assumption of an abundance of mountain snowpack deleterious impacts on water resources could affect the prosperity of California's future."[17]

• "California's varying and changing climate is impacted by regional processes within the state as well as by changes around the globe. Notably, over the past several decades, the Arctic has been warming at rates higher than any other area in the world, resulting in immense loss of sea ice cover….[Recent simulations estimate] that Arctic sea-ice loss at the magnitude expected in the next few decades could, on average, decrease the amount of winter precipitation in California by up to 15 percent; however, they also found in their simulations that some years became wetter. However, more studies are needed to confirm the link between reduced sea ice in the Arctic and dry conditions in California."[18]

• "Sea-level along the central and southern California coast has risen more than 15 cm (5.9 inches) over the 20th century." California's Fourth Climate Change Assessment "uses new modeling results that quantify the potential rapid demise of the Antarctic land-based ice mass," and under the BAU scenario (RCP 8.5) there is "a slim possibility that sea-level rise will exceed 9 feet by 2100."[19]

• "From San Diego to Humboldt counties," wrote journalist Rosanna Xia in a recent feature story in the *Los Angeles Times*, "homeowners scramble to fend off increasing erosion and storm surges, pleading with officials for bigger seawalls that can hold back the even bigger ocean." Seawalls come with a hidden cost, however, wrote Xia: "For every new seawall protecting a home or a road, a beach for the people is sacrificed." She adds:

> Then there's what scientists and economists and number-crunching consultants call "managed retreat": Move back, relocate, essentially cede the land to nature. These words alone have roiled the few cities bold enough to utter them. Mayors have been ousted, planning documents rewritten, campaigns waged over the very thought of turning prime real estate back into dunes and beaches.
>
> Retreat is as un-American as it gets, neighborhood groups declared. To win, California must defend.
>
> But at what cost? Should California become one long wall of concrete against the ocean?… More than $150 billion in property could be at risk of flooding by 2100—the economic damage would be far more devastating than the state's worst earthquakes and wildfires. Salt marshes, home to shorebirds and endangered species, face extinction. In Southern California alone, two-thirds of beaches could vanish.
>
> The state has both no time and too much time to act, spiraling into paralyzing battles over the why, who, when, and how. It's not too late for Californians to lead the way and plan ahead for sea level rise, experts say, if only there is the will to accept the bigger picture.

…

We've all played by the shore and built castles in the sand, but seem to forget what happens next: The ocean always wins.[20]

• "In the Delta, over 1,000 miles of levees are vulnerable to collapse from earthquakes, rising sea-levels, and potentially increasingly severe storms….[A]cross the state, a decline in performance of storage and conveyance systems is expected, including a decline in reservoir carryover storage (amount of water available in the reservoirs before start of the wet season in October), reduced Delta water exports, and diminished drought resilience and operational control to meet future downstream river flow temperature requirements."[21]

• There will be "challenges within the regulatory and administrative system in the state, especially in terms of its flexibility and response time in addressing drought-stressors within the water conveyance system. Because future California droughts are likely to be more frequent, longer, and more intense, they will pose increasing challenges for water management, raising the stakes for effective drought response….[C]urrent water management practices will need to continue to improve to be resident to what is expected from a changing climate."[22]

From one study supporting the state's Fourth Climate Change Assessment these probabilities are estimated for the California State Water Project (SWP) and the federal Central Valley Project:

• There is a probability of 59 to 65 percent that north-of-Delta (NOD) April storage—at the start of the traditional irrigation season—"will be inferior to current performance." There is a 95 percent probability—a virtual certainty—that NOD carryover storage (on September 30) will be worse than current performance, which was also found for Shasta, Oroville, Folsom, and Trinity lakes' carryover storage. The probability that Net Delta Outflow will fall below historic levels is between 58 and 63 percent in the Winter; 59 and 63 percent in the spring; 21 percent in the summer, and 40 to 42 percent in the fall. There is between an 89 and 93 percent probability that annual Delta exports will be reduced.[23]

• By visually interpreting probability distribution surfaces produced to support the fourth California climate assessment, we estimate that if temperatures rise 2 °C by 2050 and precipitation falls about 10 percent, NOD April storage would likely decrease about 10 to 15 percent. But if precipitation decreases 20 percent at that level of warming, NOD end of April storage will decrease 25 to 30 percent.[24]

• The same study estimates, using probability distribution surfaces that with 2 °C warming by 2050 and precipitation falling about 10 percent, NOD carryover storage (on September 30) would decrease 30 to 35 percent. But if precipitation decreased by 20 percent at this level of warming, NOD carryover storage would decrease by 40 to 50 percent.[25]

• Similarly, at 2 °C degrees of warming by 2050 and precipitation decreasing about 10 percent, wintertime Net Delta Outflow would decrease on the order of 30 percent. In the spring, this scenario would result in between 40 and 60 percent decrease in Net Delta Outflow. A decrease of 20 percent in precipitation at this warming appears to result between about 75 to 85 percent decrease in Net Delta Outflow. In summer, this warming and precipitation scenario results in a 10 percent decrease

in Net Delta Outflow, and in the fall the decrease in Net Delta Outflow is about 35 to 55 percent by visual inspection.[26]

• At 2 °C warming by 2050 and a 10 percent decrease in precipitation, average annual Delta exports are estimated to decrease by about 30 percent; at a 20 percent decrease in precipitation, Delta exports may decrease between 40 and 50 percent from historic levels.[27]

• A climate assessment supporting study of average and extreme climate effects on the State Water Project found that "the flow seasonal pattern shift in rim [that is upstream reservoir] inflows from the Sierra Nevada and sea level rise in the San Francisco bay together would…[lead] to a half million-acre feet export reduction in the middle of this century [2050]."[28]

• "Exported water and environmental water quality in the Delta would also worsen throughout the year in terms of X2[29] extending eastward as much as 4.5 kilometers [about 2.8 miles], a result caused not only by sea level rise but also by the flow seasonal pattern shift [by 2050]."[30]

• With more progress on GHG reduction, Delta export reductions could be cut in half and lessen carryover storage reductions.[31]

• "During drought episodes in the middle of this century, climate change impacts on the SWP and CVP operations are much worse in the driest climate model projection scenario. Delta exports would reduce to half of that in historical droughts. Carryover storage would decrease to one-fifth of that in historical droughts."[32]

• Another study supporting analysis of water impacts for California's Fourth Climate Change Assessment states: "Mean annual precipitation is projected to increase modestly in the northern part of the state, but year-to-year variability is also projected to increase, leading to a greater incidence of dry years in future decades, which may affect hydropower generation."[33]

• "By the end of the century under the RCP 8.5 [business-as-usual] scenario, winter precipitation is projected to increase by up to 20%, but decrease in spring and autumn by up to 20%. These changes will present a challenge to the operation of existing water storage infrastructure including reservoirs and associated hydroelectric plants, which are an important source of California's electricity."[34]

• "Daily extreme precipitation values are projected to increase 5-15% (RCP 4.5 [moderate GHG reduction scenario]) to 15-20% (RCP 8.5), presenting challenges for storm drainage and flood control."[35]

• "Basins that are currently snow dominated show a shift to earlier flow as more winter precipitation falls as rain instead of snow and what snow there is melts earlier. These shifts will have further implications for the operation of reservoirs and hydroelectric energy generation in addition to those effects noted above."[36]

• "Moisture deficit is projected to increase over much of the state, but with only small changes in the Central Valley. Top level soil moisture is projected to decrease, especially in the southern half of the state."[37]

Chapter 3 CLIMATE CHANGE ISSUES

California's Fourth Climate Change Assessment helps prepare all informed Californians of the dramatic conditions that await us: sea level rise, extreme heat, drought, flooding, and water quality degradation—with or without a tunnel—in the Delta and elsewhere.

However, the effects of sea level rise in the Delta and its watershed continue to be poorly studied, though it appears to us that California has made modest progress in recent years. In 2017, the state's Ocean Protection Council projected sea level rise for three representative coastal locations —La Jolla, San Francisco, and Crescent City.[38] Despite the fact that the Delta is tidally-affected (and it is well known too that several of its islands have elevations below sea level), it is not considered part of California's coast.

In addition, water quality effects in Delta channels [whether from tunnel diversions upstream of Stockton and/or sea level rise] would affect groundwater in San Joaquin County, since surface and groundwater supplies in the Delta are connected. Restore the Delta's case against California WaterFix included testimony on this point (Appendix D, this report). The Delta area has a large "cone of depression" that causes an influx of water from the Delta to percolate to underground water supplies. The saline front of groundwater intrusion beneath south and downtown Stockton is projected to move another 1.5 miles east by 2030, just as future urban water demand was expected to see a net increase among the cities of San Joaquin County of 146,600 acre-feet per year.

At San Francisco's Golden Gate, the Ocean Protection Council report projects a two-in-three chance by 2030 (just eleven years away) of sea level rising 3.8 to 5.7 millimeters (mm), with a 1-in-20 chance of it rising 6.5 mm and a 1-in-200 chance of 8.4 mm (about a third of an inch).[39] The same study projects by 2040 a 3.3 percent chance of sea level rising by a foot. By 2050, however, that likelihood accelerates tenfold to 31 percent (three-in-ten chances) that sea level at the Golden Gate will rise at least one foot (about 305 mm). By 2100, that likelihood of a one-foot rise in Golden Gate sea level increases to near certainty (96 percent).[40]

The 2017 Ocean Protection Council study incorporates what was at that time the latest science on the impact of sea level rise from Earth's ice sheets in West Antarctica and Greenland calving, melting, and sliding into oceans. At that time, the scientists authoring the study stated:

> In summary, the current pace of global sea-level rise (1.2 inches per decade) is already impacting California's coastline. New ice-sheet projections suggest the rate of rise could accelerate sharply later in this century, with the potential for two meters (6.5 feet) or more of total sea-level rise by 2100. While the uncertainty in these projections remains high, the risk is not negligible given the stakes to future society, development, and infrastructure. Given the level of uncertainty but also the potential impacts, significant investment in any major new coastal development with long lifespans needs to be carefully assessed. Similarly, responses to both long-term sea-level rise and short-term elevated sea levels for existing infrastructure and development also need to consider economic, social, and environmental impacts and costs as well as the lifespan of any approach.[41]

Two other studies supporting California's Fourth Climate Change Assessment address sea level rise. One led by Scripps Institute's David W. Pierce incorporates the same science on ice-sheet melting[42] as that of the Ocean Protection Council; the other does not, a point to which we return below and in Appendix E.[43] The challenge of the ice-sheets lies in both the large impact on sea level

rise they will likely cause, but scientists also have high uncertainty as to when they will occur.[44] For the business-as-usual GHG emissions scenario (RCP 8.5), the first study projects a median of 8 centimeters (80 mm, just over three inches) of sea level rise at Golden Gate by 2030, 23 cm (nearly 10 inches) by 2050, and 137 cm (about 54 inches) by the end of this century (2100). The low probability, high level projections were for 38 cm (about 1.25 feet) by 2050 and 240 cm (about 7.8 feet) by 2100.[45] Again, this study shows that while sea level rise appears to be rising only slowly for the moment, its rate of change will accelerate as the 21st century proceeds.

The second study by DWR analyst Romain Maendly addresses sea level rise amid the dynamic natural processes that normally operate in the Delta: the freshwater rivers that flow into it from upstream, storm surge, and the tides that wash into it from downstream (beginning at the Golden Gate).[46] Maendly projects Delta water levels (called "stage") when its levee systems would be most stressed—during extreme storms—by modeling both storm surge (the effect of Pacific storms pushing tidal flows higher into the Delta as the storm arrives) and the amount of runoff to Delta in-flow that is generated by precipitation falling on Delta watersheds during the storm. In all, Maendly's modeling effort seems to frame the Delta problem well: Given what is known about existing Delta tidal and freshwater hydrology, and the known effects of climate change, how may Delta levees perform during extreme events?[47] Maendly concludes:

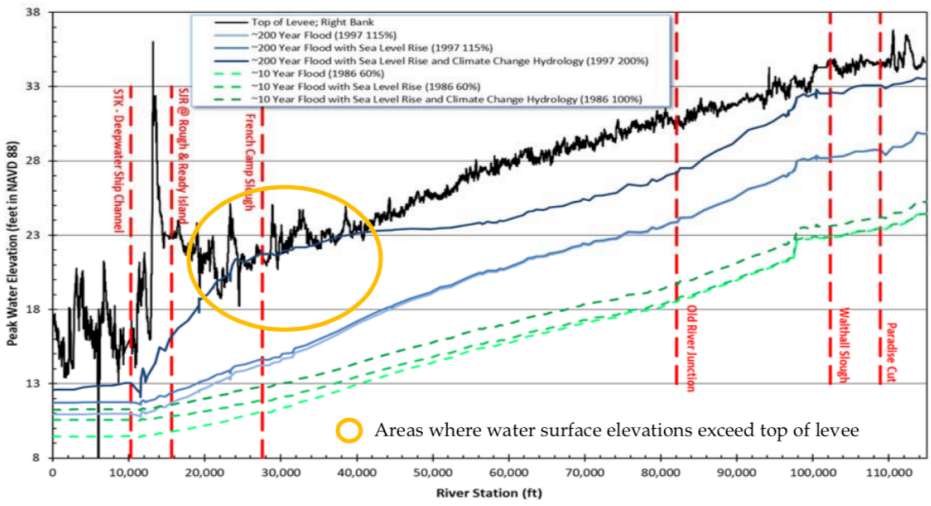


Figure 38: San Joaquin River Profiles of Scaled Events Meant to Represent the 10-Year and 200-Year Return Period Flood for Current Hydrology, Current Hydrology with Sea Level Rise and Climate Change Hydrology with Sea Level Rise

Source: Maendly 2018.

> The outcome of the study shows a significant rise of water surface elevations from sea level rise and climate change hydrology. For smaller flood events, sea level rise has a large effect on water surface elevation in locations further downstream in the Delta. For larger flood events, the effect of sea level rise diminishes because flood-flows drive the water surface elevations. Climate change hydrology shifts the stage-frequency curve to more frequent large flood events. Climate change hydrology has a greater consequence on water surface elevation than sea level rise in the San Joaquin River with stage increase up to 7 feet for the 200-year return period flood event, which overtops the levee near the city of Stockton.[48]

The Delta and the City of Stockton are at the crossroads of climate change effects—increased and combined extreme flooding risk, storm surge, and sea level rise. Deeper in the report, Maendly states:

> On the San Joaquin River, under the 200-year return period flood, sea level rise is projected to increase the water surface elevation by 0.8 foot at Burns Cut Off. The impact of sea level rise dissipates to zero by 8.5 miles upstream of Burns Cut Off (near River Station 45,000 feet on Figure 38). Climate change hydrology plus sea level rise causes more than a 7-foot increase in water surface elevation above existing conditions upstream of the confluence with French Camp Slough. This is because of significantly more flow in the system under climate change hydrology in the San Joaquin River system, which is exacerbated by a change in flood-flow routing with the higher flows.[49]

Maendly's study, unfortunately, does not disclose more detailed Delta impacts than its rather dire implications for the City of Stockton. What steps should be taken to protect Stockton and other communities in the Delta? Such questioning extends to other infrastructure at low elevations in the Delta: What are the sea-level rise effects of this modeling effort on locations such as Courtland and Clarksburg, which are Delta legacy communities that are still in the vicinity of even a single-tunnel option's intake structures? On locations like the tidal gate at Clifton Court Forebay and the Jones pumping plant? How will travel be affected to and through the Delta on the many county roads and state highways that crisscross the region? What will become of power transmission lines and natural gas fields? What will become of Delta residents' domestic wells and homes? Do new open intakes for a single tunnel facility on a tidal river system, the Sacramento River, provide protection to the state water system from sea level rise, storm, and flooding impacts? Will the state produce modeling that examines how the full range of climate change impacts could impact these new intakes? Last, but not least, when will the state produce its own projections of climate change and sea level rise impacts on Delta exports and reservoir operations that water contractors and the public can reliably plan from?

ICE-SHEET LOSS, ARCTIC ICE LOSS, PERMAFROST THAWING, AND HEAT

Breaking science news indicates that California's Fourth Climate Change Assessment, as path breaking as it was just a year ago, is behind the curve when it comes to abrupt changes that could have large effects on global temperature increases, loss of ice sheets, and loss of arctic ice. Playing an emerging and likely key role in future climate assessments is permafrost thawing. The details of this are summarized in Appendix E, this report. The main points here are:

- That DWR's sea level rise assessment of the Delta for California's Fourth Climate Change Assessment did not include new reasons to believe that sea level rise would accelerate, given the calving of major ice sheets in Greenland and Antarctica, the melting of Arctic ice, and the collapse of permafrost regions (and the burning of peat soils mentioned above). Thus, the Assessment's expectations concerning temperature increases, drought, floods, and sea level rise, may already be out of date.

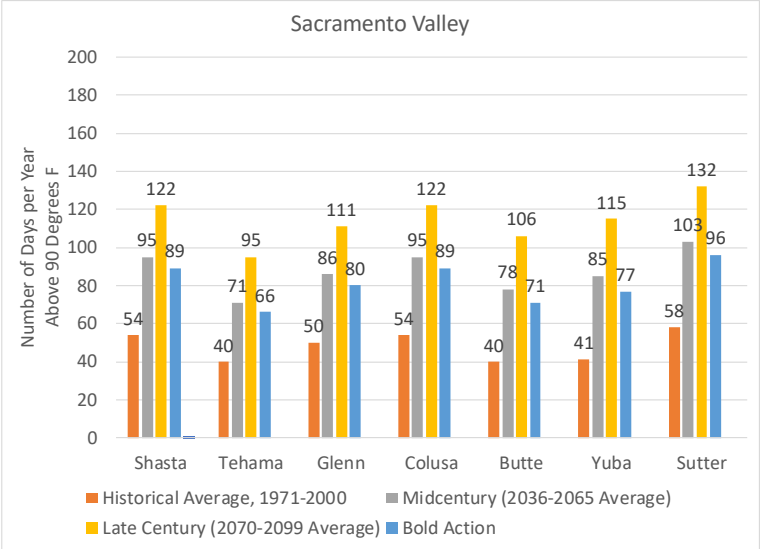
- The carbon in permafrost regions of the Arctic—in Alaska, Canada, Scandinavia, and Russia—greatly exceeds the amount of all existing living forms of carbon now on earth. Whether these carbon deposits burn or ferment, release of these deposits to the atmosphere will have grave implications for "baking in" global temperature increases and the cascading effects greater heat will have on climate world-wide, including California and the Delta.

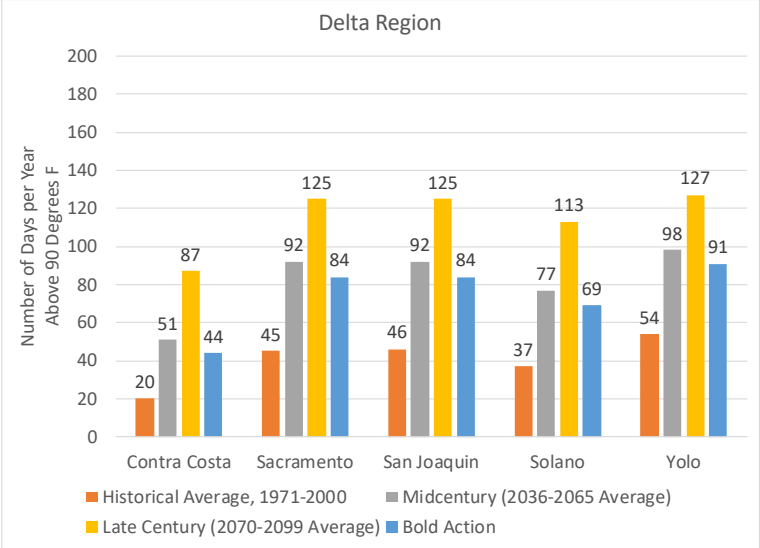
Union of Concerned Scientists' heat index projections are dramatic for Central Valley counties during the rest of this century. (See charts next page.) For Sacramento Valley counties, the historical (1971-2000) average number of days with the heat index (defined as including temperature plus humidity factored in) exceeding 90 degrees F will increase on average at mid-century by 82 percent (from about 58 to 103 days per year) and by the end of the century, about 138 percent (from about 58 to 132 days per year). In other words, the hot season in the Sacramento Valley is projected to nearly double by mid-century and could triple by the end of the century.

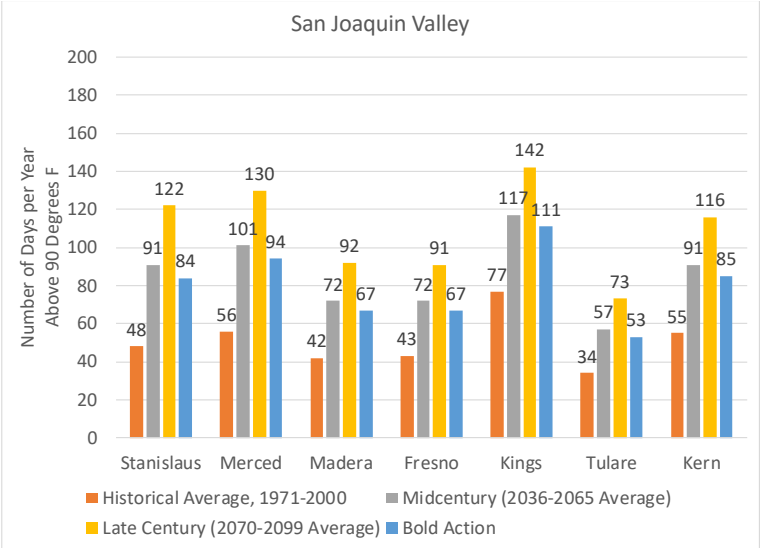
In the Delta region, the same measures for the 90 degree F heat index are 103 percent (from about 40.4 days historically to 82 days at mid-century, more than doubling) and 186 percent (from 40.4 days to 115.4 days, nearly tripling by 2100).

In the San Joaquin Valley counties, the 1971-2000 period saw about 51 days on average with the heat index at or above 90 degrees F—less than two months typically in the summer. By mid-century, the UCS report indicates that these counties will see about 86 such days per year on average by mid-century and about 109 by the end of the century where the heat index exceeds 90 degrees F. The experiential change would be from just shy of two months to about three months by mid-century, to over three and a half months by 2100.

Projected temperatures will place millions of people at greater risk of illness and death from heat levels exceeding their abilities to sweat and naturally cool themselves.[50] As important will be impacts on California agriculture. The persistence of heat in the Central Valley is likely a significant threat to agriculture and water supply, and to our knowledge none of the analyses available from







Source: Dahl, K., et al. 2019. *Killer Heat in the United States.*

the Union of Concerned Scientists' heat index projections have been applied to models used to project climate change impacts to the state's water supply and agriculture. It appears to us there is a gap in the state's climate analysis and the Water Resilience Portfolio assessment should fill it.

CALIFORNIA AGRICULTURE AND CLIMATE CHANGE

Agriculture is California's single largest user of developed water supplies. This sector produces about 4 percent of the state's gross domestic product. Agriculture is deeply climate dependent. Its products depend on all manner of natural conditions to be successful: maximum and minimum temperatures; the length of the growing season; the presence or absence of overnight and seasonal chill; the presence or absence of a variety of fungal, insect, wildlife, and other pest species; availability of prime farmland and soil resources; and of course availability of water supplies for and methods of irrigation.

"Increasing global food demand, low grain reserves and climate change threaten the stability of food systems on national to global scales," write two University of California at Santa Barbara agricultural researchers. Along with policies to increase yields, irrigation, and tolerance of crops to drought, they find that increased crop diversity

> at the national level is associated with increased temporal stability of total national harvest. Crop diversity has stabilizing effects that are similar in magnitude to the observed destabilizing effects of variability in precipitation. This greater stability reflects markedly lower frequencies of years with sharp harvest losses…. Ensuring stable food supplies is a challenge that will probably require multiple solutions. Our results suggest that increasing national effective crop diversity may be an additional way to address this challenge.[51]

The United States Department of Agriculture (USDA) oversaw research and development of responses to climate change for the nation's agricultural sector until recently. A sweeping climate change response plan had been in the works at USDA when new leadership under President Trump's agriculture secretary Sonny Perdue took charge and "quashed" its release. The plan was intended to outline "how the department should help agriculture understand, adapt to and minimize the effects of climate change."[52] The uncovered document acknowledges that climate change already affects farmers, ranchers, and forests, all with which USDA is engaged in daily life. The plan described the effects of climate change on agriculture, and recommended broad adaptation and mitigation responses, and outlines research, development, and monitoring tasks to be undertaken to address climate change effects to agriculture in the United States. The plan states the need for research into effects and their importance for adaptation and mitigation:

> The effects of climate change may be amplified by feedbacks to the climate system. Fire and accelerated decomposition from disturbance can increase the release of GHGs to the atmosphere; conversion of natural or managed lands to developed uses can also increase the release of GHGs. Changes in cloud, land, snow, and sea ice cover can also alter the amount of solar radiation absorbed and reflected by the earth's surface.
>
> An understanding of current and predicted future effects allows USDA to target policy and management activities to expand economic opportunity, promote agricultural sustainability, and preserve and conserve natural resources in a changing climate. This effort is particularly

> important as current and future climate change may differ from the past in both the rate and intensity of change. As regional ecological, agricultural, and socioeconomic systems become exposed to a range of changing climate and non-climate stressors, public and private decision makers need context-specific information on both climate effects over time and the basic processes driving these effects to be able to plan for desired outcomes.[53]

In California, a team of researchers published a review of climate change effects on the state's agriculture. Its farmers, they state, have long adapted to the state's diverse microclimates and soil conditions to become one of America's important farm states. But they summarize their vulnerability to climate change:

> Agricultural production in California is highly sensitive to climate change. Changes in temperatures and in the amounts, forms, and distribution of precipitation, increased frequency and intensity of climate extremes, and water availability are a few examples….Irrigated agriculture produces nearly 90% of the harvested crops in California and a decrease in water availability could potentially reduce crop areas and yields. Permanent crops are among the most profitable commodities in California. They are most commonly grown for more than 25 years, which makes them more vulnerable to impacts of climate change…. [I]mpacts on agricultural production due to climate change would not only translate into national food security issues but also economic impacts that could disrupt state and national commodity systems. While California farmers and ranchers have always been affected by the natural variability of weather from year to year, the increased rate and scale of climate change is beyond the realm of experience for the agricultural community.[54]

These researchers found further that:

- "Individual crops have specific optimum temperature ranges (temperature thresholds) at which vegetative and reproductive growth thrive and exposure to extremely high temperatures during these growth stages can affect growth and yield. Acute exposure to extreme temperature may be most detrimental during the crop reproductive stages."[55]

- Chilling requirements for many crops needing 500 hours or more of chill will be undermined by climate change, including chestnut, pecan, quince, apricot, kiwifruit, peach, nectarine, plum, walnut, apples, cherries and pears (the latter three of which have chilling hour requirements of more than 1000 hours per year. "Among the most climate-sensitive trees and vines, walnuts require the highest number of chill hours, implying a future decline in walnut acreage within the valley."[56]

- "Climate change may have impact on the incidence and severity of plant disease and influence the further co-evolution of plants and their pathogens….Plant diseases, insects, and invasive weeds are mostly caused by temperature-related climate factors, with the invasion of previously uninhabitable areas….For instance, [ ] milder winters help many frost-sensitive insects to survive, and increased temperature may help promote more rapid reproduction in other insects….Statewide integrated pest management (IPM) involves listing common diseases and insects, and allows us to elucidate potential plant disease and manage all kinds of pests elsewhere within the state."[57]

• An "Agricultural Vulnerability Index," which integrates indices for climate, crop, land use, and socioeconomic vulnerability, shows that much of the San Joaquin Valley is among the most vulnerable of California's farming regions to effects of climate change, while "northern regions of the state may provide hospitable environments for fruits (wine grapes) and vegetables….Grassland habitat in the Sacramento Valley may decline by 1-20% by 2070 due to warmer winter temperatures and variable precipitation. The eastern edge of the Central Valley might become climatically unsuitable for grassland habitats including valley oak under drier conditions and the northern Central Valley to a large degree may become unsuitable for such habitats under wetter conditions."[58] These are areas where today cattle grazing supports the state's beef and dairy industries.

• "Temperature increases and extreme heat waves have direct impacts on agricultural production….Several California fruit and nut crops are losing yield and decreasing in acreage due to reduced chill hour accumulations as a direct consequence of increased winter and nighttime temperatures….Since different crops react to temperature changes differently, research efforts on climate adaptation should be crop-specific and related to local environmental conditions for successful adoption."[59]

• "Due to increased temperatures, the impact of pests, diseases, and weeds is increasing substantially, with their altered growth cycles possibly becoming concentrated and impacting crop harvests….[R]esearch efforts should focus on documenting crop-specific potential threats due to existing and new pests and diseases."[60]

• "[I]ncreased variability in precipitation patterns, reduced snowpack, and groundwater depletion due to recurring and prolonged droughts have added further pressure to the existing strain of the state's agricultural water supply."[61]

During historically normal to wet years, California relies on groundwater for 30 to 40 percent of its water supplies. That figure can rise as high as 65 percent of water supplies during droughts. As is well known, groundwater has been overdrafted severely in San Joaquin Valley and other state groundwater basins for many years. Said one group of researchers of the San Joaquin Valley recently:

> Sustaining the remarkable scale of agriculture in the San Joaquin Valley has required large imports of surface water and an average annual groundwater overdraft of 2 million acre-feet. This level of water demand is unsustainable and is now forcing changes that will have profound social and economic consequences for San Joaquin Valley farmers and communities. Land will have to come out of agriculture production in some areas. Yet, the emerging changes also provide an important opportunity to strike a new balance between a vibrant agricultural economy and maintenance of natural ecosystems that provide a host of public benefits—if the land is retired and restored strategically.[62]

Implementation of the Sustainable Groundwater Management Act (SGMA) requires agricultural communities with groundwater basins to bring their basins into balance by 2040 through use of groundwater sustainability plans. These plans are meant to stabilize groundwater elevations, decrease underground water quality problems, and halt land subsidence caused by overpumping.

Coming at a time when surface water supplies are expected by state climate change modeling (see above) to decline this century, irrigated cropping will likely decrease.[63]

WATER RIGHTS, WATER PROJECTS, AND CLIMATE ADAPTATION IN CALIFORNIA

Response to immense pressure from climate change must be balanced with careful forethought.[64] Doubts are cast by some experts on the viability and feasibility of new water storage and conveyance as meaningful responses to climate change and adaptation. Two recent peer-reviewed articles pose significant challenges from climate change to water rights and to the question of whether the state should construct more reservoir storage. Water rights are the legal property regime through which water is incorporated into our economic system and allocated (especially during droughts). Water rights mobilize water as property for a select few who own and control them in California, and they will mediate how Californians who rely on water (of course, all of us at some level) will experience climate change impacts on water distribution and allocation. While there have been calls for reform of California's water rights regime[65], the state's hybrid system of riparian and appropriative water rights will prevail for the foreseeable future.

In a 2015 study of water rights and climate change in the Sacramento, Feather, and American river watersheds, Andrew Schwarz (then with DWR, now with the Delta Stewardship Council) found it likely that the State Water Resources Control Board (which is empowered to administer and adjudicate water rights in California) will enforce longer periods of drought-related water diversion curtailments (stoppages) than at present, by both the middle of the twenty-first century and the end. At present, he found that there are about 80 percent of years when curtailments occur, with an average curtailment of 80 days. The mid-century (between 2030 and 2059) curtailments would occur in about 90 percent of years and last for about 95 days (about three months) on average, he projected. This represents a nearly 20 percent increase over present curtailment days. By 2100 curtailments would increase to 92 percent of years and last an average of 107 days (about three and a half months), a 26 percent increase in curtailment days over present levels.[66] Water right holders diverting during winter "are likely to see the reliability of their water rights increase," wrote Schwarz. But as curtailment periods—most of which are during summer at present—lengthen and occur more frequently, "more water users will be turning to groundwater, fallowing land, or looking for water transfers from others to meet their demands—ratcheting up water scarcity in the Delta watershed and potentially leading to additional conflicts over water."[67] He concludes:

> Put another way, the shift in average curtailment duration…represent[s] an additional 2 weeks by mid-century and nearly 4 weeks by end-of-century each year during which water is being released from storage [to meet Delta water quality standards and senior water rights in the Sacramento valley basin] instead of being stored. This effect will undoubtedly result in lower storage levels in CVP and SWP reservoirs….Increases in the number of days during which storage releases occur highlight a growing challenge—storage reserves may not be able to meet all uses in the future and still provide the level of drought protection we desire. Additional curtailments would likely need to be contemplated to preserve stored water for critical periods.[68]

Despite the likelihood that the reliability of most junior water rights in the Delta watershed will decrease, there are still calls to build new storage reservoirs such as those at Sites and Temperance

Flat, as well as raise dam crests and enlarge existing reservoirs at Shasta and San Luis (near Los Banos). But the scenario Schwarz outlines implies strongly that building costly reservoirs may not increase storage. In separate research, engineers with the Merced and Davis campuses of the University of California analyzed this very problem. Earlier this year they wrote, "additional storage capacity rarely has high economic value, and its economic benefit changes significantly with location, climatic conditions, and ability to overdraft groundwater," given the degree to which California has already developed its state and federal water systems. They concluded:

> On average, expanding facilities north of California's Delta provides some benefit in 92% of 82 years modeled under historical conditions and in 61% of years modeled in a warm-dry climate. South of California's Delta, expanding storage capacity provides no benefits in 14% of years modeled under historical conditions and 99% of years modeled with a warm-dry climate. Results vary across facilities between and within regions. The limited benefit of surface storage capacity expansion to statewide water supply should be considered in planning California's water infrastructure.[69]

The engineers' modeling was based on a model developed in 2010 and does not appear to incorporate any of the more recent science of permafrost thawing risk, heat impacts, or even the representative concentration scenarios used in California's Fourth Climate Change Assessment. But while their model inputs may not be state-of-the-art in the fast-changing world of climate change science, and of state and national climate change assessments, updating their models with projections of even greater warming in the not-too-distant future is unlikely to change either their results or conclusions.

In conclusion, arguments put forth to the public by the Department of Water Resources and state and federal water contractors for new surface storage and Delta conveyance do not acknowledge and account for the full range of anticipated impacts on the Delta, California's watersheds, and California's reservoir systems resulting from climate change. The scenarios documented in this chapter reveal a broad range of climate change projections by a wide variety of scientists that must be examined thoroughly and truthfully by the state in its development of the Water Resilience Portfolio and plan for a single Delta tunnel. We are concerned that the state is susceptible to overestimating its ability to capture water during wet periods when dams will have to be operated for flood protection, and to underestimating duration and intensity of droughts resulting in reduced water supplies for export from the Delta.

To continue down this path would result in a dangerous missed opportunity to create a new and resilient water system that could protect California's water supplies, the Delta, and the Delta's 4 million residents and environmental justice communities throughout the state. California does not have time to waste, and cannot afford to get water resources and flood control planning wrong.

---

[1] John Bacon, "Death toll rises to 8 as tornadoes cut swath of destruction through South," *USA Today* April 14, 2019; and Umair Irfan, "More than 200 tornadoes devastated the Midwest over 13 days. Why?" *Vox*, May 30, 2019.

[2] Irfan, *ibid.*

[3] Nicholas Bogel-Burroughs, "California Heat Wave: Why It's 100 Degrees in San Francisco in June," *New York Times*, June 12, 2019.

[4] Quirin Schiermeier, "Europe's mega-heatwave boosted by climate change: Global warming made record-breaking June temperatures in France five times more likely," *Nature* 571: 155, 11 July 2019.

[5] Henry Fountain, "Heat Wave Nudged the Planet to Its Hottest June, European Forecasters Say," *New York Times*, July 3, 2019.

[6] Ian Livingston, "Alaska's exceptional heat wave delivers state's hottest days on record," *Washington Post*, July 9, 2019.

[7] Jenny Jarvie, "Barry, now a tropical depression, soaks much of Louisiana while sparing New Orleans," *Los Angeles Times*, July 14, 2019.

[8] Meilan Solly, "The Arctic is Experiencing Its Worst Wildfire Season on Record," smithsonian.com July 29, 2019. Accessible at https://www.smithsonianmag.com/smart-news/arctic-experiencing-its-worst-wildfire-season-record-180972749/; Brian Kahn, "Are We Watching the Arctic Pass a Tipping Point This Summer?" *Gizmodo* July 30, 2019. Accessible at https://earther.gizmodo.com/are-we-watching-the-arctic-pass-a-tipping-point-this-su-1836824810; Jessica Corbett, "Satellite Images Ignite Alarm Over 'Unprecedented' Scale and Planet-Heating Emissions of Raging Arctic Wildfires," *Common Dreams*, July 23, 2019. Accessible at https://www.commondreams.org/news/2019/07/23/satellite-images-ignite-alarm-over-unprecedented-scale-and-planet-heating-emissions?cd-origin=rss.

[9] Solly, *ibid*; Corbett, *ibid.*

[10] Quoted in Edward Helmore, "'Unprecedented': more than 100 Arctic wildfires burn in worst ever season," *The Guardian* July 26, 2019. Accessible at https://www.theguardian.com/world/2019/jul/26/unprecedented-more-than-100-wildfires-burning-in-the-arctic-in-worst-ever-season.

[11] State of California. 2018. *California's Fourth Climate Change Assessment: Statewide Summary Report*. Coordinated by Governor's Office of Planning and Research, p. 22. Accessible at http://climateassessment.ca.gov/.

[12] *Ibid.*, p. 25.

[13] *Ibid.*, p. 26.

[14] State of California. 2018. *California's Fourth Climate Change Assessment: Statewide Summary Report*. Coordinated by Governor's Office of Planning and Research, pp. 56-57.

[15] "RCP" is the acronym for "representative climate concentration pathways." "RCPs do not represent a specific policy, demographic, or economic future but are defined in terms of their total radiative forcing (Watts per square meter by 2100 (i.e., the net balance of radiation into and out of Earth's surface due to human emissions of GHGs [greenhouse gases] from all sources.)." RCP 4.5 refers to a more "moderate" carbon dioxide [CO_2] concentration by 2100 of about 550 parts per million (ppm). RCP 8.5 refers to what is "commonly understood as a business-as-usual (BAU) scenario that would result in atmospheric CO_2 concentration exceeding 900 parts per million…by 2100, more than triple the level present in the atmosphere before human emissions began to accumulate." *Ibid.*, p. 20.

[16] *Ibid.*, pp. 26-27. See also: Reich, KD. et al. 2018. *Climate Change in the Sierra Nevada: California's Water Future.* UCLA Center for Climate Science. Accessible at https://www.ioes.ucla.edu/wp-content/uploads/UCLA-CCS-Climate-Change-Sierra-Nevada.pdf; Basagic, H.J. and A.G. Fountain. 2011. Quantifying 20th Century Glacier Change in the Sierra Nevada, California. *Arctic, Antarctic, and Alpine Research.* Accessible at https://www.tandfonline.com/doi/full/10.1657/1938-4246-43.3.317.

[17] Rhoades, A.M. et al. 2018. The Changing Character of the California Sierra Nevada as a Natural Reservoir. *Geophysical Research Letters.* 45, p. 10. Accessible at https://cloudfront.escholarship.org/dist/prd/content/qt6hw5v41q/qt6hw5v41q.pdf.

[18] *Ibid.*, p. 27. See also Cvijanovic, I., et al. 2017. Future loss of Arctic sea-ice cover could drive a substantial decrease in California's rainfall. *Nature Communications*. 8:1947. Accessible at https://www.nature.com/articles/s41467-017-01907-4.pdf; and Teng, H. and G. Branstator. 2017. Causes of Extreme Ridges that Induce California Droughts. *Journal of Climate*. 30(1477-1492). Accessible at https://doi.org/10.1175/JCLI-D-16-0524.1.

[19] *Ibid.*, p. 31, including sidebar on "Sea-Level Rise Projections: Fourth Assessment and SLR Guidance.".

[20] Rosanna Xia, "The California coast is disappearing under the rising sea. Our choices are grim." *Los Angeles Times* July 7, 2019. Accessible at https://www.latimes.com/projects/la-me-sea-level-rise-california-coast/.

[21] State of California. 2018. *Fourth Climate Change Assessment State Summary*, p. 57.

[22] *Ibid.*

[23] Schwarz, A., et al. 2018. *Climate Change Risk Faced by the California Central Valley Water Resource System*. California's Fourth Climate Change Assessment, Table 4, pp. 17-18. Accessible at http://climateassessment.ca.gov/techreports/docs/20180827-Water_CCCA4-EXT-2018-001.pdf.

[24] *Ibid.*, Figure 6, p. 19. Schwarz et al note that "End of April storage is less sensitive to temperature increases than carryover storage because end of April storage measures accumulated runoff into NOD reservoirs during the winter rainy season. Higher temperatures are likely to generate less snow and accelerated melting rates, with the result that a higher proportion of the winter precipitation would flow immediately to the reservoirs, and less would remain high in the watershed as snow storage."

[25] *Ibid.* Schwarz et al note "Carryover storage, on the other hand, is affected by the diminished snow reserves associated with higher temperatures, with smaller late-spring/early-summer snow-fed flows culminating in much lower storage levels at the end of the summer. Carryover storage response is also related to the higher sea levels assumed at higher temperature values…requiring more water to be released from storage (especially during the summer months) to repel sea water intrusion, and meet Delta outflow and salinity requirements."

[26] *Ibid.*, Figure 10, p. 24.

[27] *Ibid.*, Figure 11, p. 25.

[28] Wang, J., et al. 2018. Mean and Extreme Climate Change Impacts on the State Water Project. California's Fourth Climate Change Assessment, p. 41. Accessible at http://climateassessment.ca.gov/techreports/docs/20180827-Water_CCCA4-EXT-2018-004.pdf.

[29] X2 is the state's estuarine water quality standard, administered by the State Water Resources Control Board through its Bay-Delta Water Quality Control Plan and Water Rights Decision 1641 (2000). It provides flows via releases from reservoir storage through the Delta sufficient to maintain a seasonally appropriate location of the estuary's low salinity zone where estuarine beneficial uses can be protected. This passage from Wang, *ibid.*, implies that less water will be available in the future to maintain present levels of estuarine-protective flows.

[30] *Ibid.*

[31] *Ibid.*

[32] *Ibid.*

[33] Pierce, D.W., et al. 2018. Climate, Drought, and Sea Level Rise Scenarios for California's Fourth Climate Change Assessment. California's Fourth Climate Change Assessment, p. iv. Accessible at http://climateassessment.ca.gov/techreports/docs/20180827-Projections_CCCA4-CEC-2018-006.pdf.

[34] *Ibid.*

[35] *Ibid.*

[36] *Ibid.*

[37] *Ibid.*

[38] Griggs, G., et al. 2017. Rising Seas in California: An Update on Sea-Level Rise Science. Prepared for California Ocean Protection Council and California Ocean Science Trust. Accessible at http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf.

[39] One inch equals 25.4 millimeters.

[40] Griggs, G., et al, *op. cit.*, Table 4a, p. 31.

[41] *Ibid.*, Appendix 2, p. 67.

[42] Pierce, D.W., et al, *op. cit.*, p. 57-58.

[43] Maendly, R. 2018. Development of Stage-Frequency Curves in the Sacramento-San Joaquin Delta for Climate Change and Sea Level Rise. California's Fourth Climate Change Assessment. Accessible at http://climateassessment.ca.gov/techreports/docs/20180827-Water_CCCA4-EXT-2018-011.pdf.

[44] Pierce, et al, convened an expert panel to help them assess the ice-sheet science that had come out in 2016. That science was showing that fracturing within the ice-sheet and the collapse of adjacent ice shelves, combined with increased warming, would accelerate ice loss and global sea level rise, especially under higher global warming scenarios (like the RCP 8.5, business as usual scenario). Pierce, et al, wrote: "The median result…is approximately 70 cm [centimeter] greater contribution to SLR from Antarctica at the end of century under RCP 8.5…" than was found in a study from two years earlier. They did not report what the extremes were in these results. Pierce, D.W., et al. 2018. Climate, Drought, and Sea Level Rise Scenarios, p. 58.

[45] Pierce, D.W., et al, *op. cit.*, Table 5, p. 61.

[46] Maendly, *op. cit.*

[47] Maendly frames the research this way: "The Delta poses inherent complexity in the determination of stage-frequency and requires a number of considerations. One needs to account for river flows coming into the Delta, as well as the effect of tides from the Delta's connection to the ocean through San Francisco Bay. During storms, Delta water levels are also affected by storm surge from the advancing storm fronts coming from the Pacific Ocean. Under climate change, Delta water levels will also be affected by rising sea levels and expected changes in hydrology, such as shifts in timing and amount of precipitation and runoff and changes in how much of our precipitation falls as rain or snow (referred to as climate change hydrology in this paper)."

[48] *Ibid.*, p. iv.

[49] *Ibid.*, p. 43.

[50] Dahl, K., et al. 2019. Increased frequency of and population exposure to extreme heat index days in the United States during the 21st century. *Environmental Research Communications.* 1: 075002. Accessible at https://iopscience.iop.org/article/10.1088/2515-7620/ab27cf; and Dahl, K., et al. 2019. *Killer Heat in the United States: Climate Choices and the Future of Dangerously Hot Days*. Prepared for Union of Concerned Scientists, July. Accessible at https://www.ucsusa.org/sites/default/files/attach/2019/07/killer-heat-analysis-full-report.pdf.

[51] Renard, D. & D. Tilman. 2019. National food production stabilized by crop diversity. Letter. *Nature* 571, 257-260, plus supplemental methods information. 11 July 2019. Accessible at https://www.nature.com/articles/s41586-019-1316-y.

[52] Helena Bottemiller Evich, "Trump's USDA buried sweeping climate change response plan," *Politico*. July 18, 2019. Accessible at https://www.politico.com/story/2019/07/18/usda-suppresses-climate-change-plan-1598987."The revelation comes after a recent POLITICO investigation found that the department had largely stopped promoting its own scientific findings about the consequences of climate change. The USDA had also moved away from using phrases like climate change, climate, and greenhouse gas emissions in press releases and social media posts." This link contains a link to the previously unreleased report.

[53] *Ibid*., USDA plan, pp. 6-7.

[54] Pathak, T.B., et al. 2018. Climate Change Trends and Impacts on California Agriculture: A Detailed Review. *Agronomy* 8, 25. Accessible at https://doi.org/10.3390/agronomy8030025.

[55] *Ibid*., p. 10 of 27.

[56] *Ibid*., pp. 13-14 of 27.

[57] *Ibid*., p. 15 of 27.

[58] *Ibid*., pp. 15-16 of 27.

[59] *Ibid*., pp. 21 of 27.

[60] *Ibid.*

[61] *Ibid*., pp. 21-22 of 27.

[62] Kelsey, R. et al. 2018. Groundwater sustainability in the San Joaquin Valley: Multiple benefits if agricultural lands are retired and restored strategically. *California Agriculture* 72(3): 151. Accessible at http://calag.ucanr.edu/archive/?type=pdf&article=ca.2018a0029.

[63] *Ibid.*

[64] We freely acknowledge this is not easy.

[65] Sugg, Z. 2018. An Equity Autopsy: Exploring the Role of Water Rights in Water Allocations and Impacts for the Central Valley Project during the 2012-2016 California Drought. *Resources.* 7. Accessible at https://doi.org/10.3390/resources7010012.

[66] Schwarz, A. 2015. California Central Valley Water Rights in a Changing Climate. *San Francisco Estuary & Watershed Science.*13(2): Figure 3, p. 7 and Table 2, p. 8. Accessible at http://escholarship.org/uc/item/25c7w914 or http://dx.doi.org/10.15447/sfews.2015v13iss2art1.

[67] *Ibid*., p. 9.

[68] *Ibid*., p. 10.

[69] Nover, D.M. et al. 2019. Does More Storage Give California More Water? *Journal of the American Water Resources Association*, p. 1. Accessible at https://onlinelibrary.wiley.com/doi/abs/10.1111/1752-1688.12745.

Chapter 4 RECOMMENDATIONS

With apparent climate thresholds looming—foretold by immolation of Arctic peat soils, the rapid collapse of thawing carbon-rich permafrost soils where peat is not yet burning, and the accelerated melting of the Greenland and Antarctic ice sheets this summer—California and American society have likely reached a stage of ***climate emergency.*** Whether or not the emergency is acted upon, "change" is fast becoming too gradual a word to convey the likelihood that abrupt heating and drying will increase faster than it does at present. In California, at least, the matter requires all hands on deck and paying attention—even if our national administration resolutely and foolishly denies this reality.

The implications of what we argue in this report snowball (to use an endangered metaphor). The Water Resilience Portfolio's needs analysis must provide an accurate and realistic assessment of:

- California's future water needs;
- The state's claim of fearing for seismic risks in the Delta;
- The need to include stabilization of Delta levees among California's future water needs; and
- Accelerating heat, rising sea levels and storm surges, more frequent droughts, and more intense storms.

San Francisco Bay and the Sacramento-San Joaquin Delta are connected by many types of flows.

Foremost, they are connected by the flow of water. Both water bodies are dominated by tides as in the summer and fall; and by freshwater flow, as can occur in the winter and spring when California does not labor under a drought. They are connected by flows of people driving vehicles on the regions' freeways and commute-sheds, and people residing in and moving among its housing markets while working in the regions' job markets. They are connected by flows of animals (over land and through air) via wildlife corridors connecting uniquely productive ecosystem boundaries—like the low salinity estuarine zone in the water where salt water meets fresh; adjacent wetlands and marshes where water meets land; and where forests meet grass and brush lands. Birds make direct connections between the Bay and Delta by fishing the waters, hunting the landscapes, and traversing the two interlocked regions carrying to and fro the seeds of plants; and the bodies of their prey. Many scientists conducting research in these regions refer to this place as the "San Francisco Bay-Delta Estuary," a name describing their proximity to each other, their connections, and their ecological functions. Even our coastal clean-up days recognize the fundamental fact that our Delta is itself part of California's coast.

Many scientists conducting research in these regions refer to this place as the "San Francisco Bay-Delta Estuary," a name describing their proximity to each other, their connections, and their ecological functions.

Despite these connecting flows, our climate change response and water awareness artificially divide these regions in two. On one hand, climate conscious watershed activists in the Bay Area commendably mobilize to preserve vulnerable habitats, particularly wetlands, marshes, and riparian

corridors of tributary creeks and rivers in that region. Still others work to protect economically and publicly vital lands on which lie productive industries and businesses, where neighborhoods reside, and through which vital infrastructure like freeways, power lines, and public spaces pass.[1]

A recent report published in *Nature* of a dynamic flooding model for the California coast's flooding potential earlier this year did not include the Delta, though much of the Delta sits at or below sea level, and from a topographic standpoint at least should reasonably be included in the model. Asked about this omission, one of the study's eleven authors commented to us that there were four factors: first, *complexity* of including the Delta would "take a massive effort to develop an accurate vulnerability assessment"; second, *funding* priorities centered on the Bay and outer coast; third, *lack of available scientific experts*; and finally, "*politics.*" Even though the Delta is considered widely to be an estuary and the team studies beaches and estuaries, the scientific team did not wish to risk "stepping on the toes of our Water Resources Division (based in Sacramento) and/or state entities like DWR."[2] This scientist also felt these seeming obstacles could be overcome, but that it appears to be a question of political will and having enough scientific labor and expertise to address the problems of how the Delta adapts to flooding, sea level rise, climate change generally, and how that adaptation interacts with the Bay Area as a region.

DWR's 2018 California Water Plan report on Sustainability Indicators also contains a map of coastal areas' risk of sea level rise that fails to apply the social vulnerability index to three of the five Delta region counties—Yolo, Sacramento, and San Joaquin, which together comprise a clear majority of Delta population.[3] Yet Clarksburg lies at elevation 14 feet in Yolo County; Courtland lies at 10 feet and Ryde at 1 foot in Sacramento County; Stockton's port just west of Interstate 5 is tidally influenced, while the city is at just 15 feet of elevation on average. Clifton Court Forebay is at just 3 feet of elevation.[4] Are these communities and infrastructure exempt from studying climate change effects of sea level rise, storm surge, and flood runoff just because they're a source area for state and federal water project imports? If cities lining San Francisco Bay build levees to fight sea level rise, tidal flood risk upstream in the Delta will worsen. The arbitrary distinction between the fates of the Bay and the Delta contributes to a lack of critical knowledge about the flood risk to be faced in the Delta.

We at Restore the Delta think such disconnection risks a societal mistake, one that originates with the two areas' position in the drama known as "California water": ***The Delta is a source of fresh water***, unlike the seaward Bay, and has a special status in state politics and economics as a consequence. ***The Bay region's cities are largely importers of water from elsewhere***—the Tuolumne River, the Mokelumne River, and the Delta itself are the principal source regions for the Bay Area's high quality water supplies. Without the Delta and its upstream source waters that would ultimately flow through it, the Bay Area would not have grown and prospered as it has.

We recommend that the state's Water Resilience Portfolio take conceptual and practical steps to integrate water policy for the Estuary.

Failure to act on these myriad connections between the Bay and the Delta to enforce the Estuary's water quality standards would be a political decision by the state. This means taking to heart the Delta Reform Act's mandate to reduce reliance on the Delta for California's future water needs, and using the portfolio to boost the local and regional water self-sufficiency of current Delta-

importing areas, including Bay Area, San Joaquin Valley, and Southern California communities. The Delta Reform Act also points the way ahead from here when it states:

> The policy of the State of California is to reduce reliance on the Delta in meeting California's future water supply needs through a statewide strategy of investing in improved regional supplies, conservation, and water use efficiency. Each region that depends on water from the Delta watershed shall improve its regional self-reliance for water through investment in water use efficiency, water recycling, advanced water technologies, local and regional water supply projects, and improved regional coordination of local and regional water supply efforts.[5]

Implementing the Delta Reform Act will foster water and climate equity in California because all regions will be responsible for balancing their future needs with future supplies. At the same time that justice would be served, climate adaptation and mitigation needs for water supply through the state would also be addressed. This would represent a substantial multi-benefit outcome.

We recommend that portfolio projects be determined as "no regrets" actions and investments first and foremost. Such investments will include water recycling, water use efficiency measures, and conservation techniques as called for by the Delta Reform Act because they foster local and regional self-sufficiency in water supply. In addition to reliance on the portfolio's needs assessment, ***these projects should be determined for all regions of the state before a decision is made to construct and operate a single tunnel conveyance option through the Delta***.

While Governor Newsom supports a single tunnel option, the single tunnel idea is a very climate-dependent, high risk, and expensive project. The single tunnel's costs and risks must be carefully evaluated with respect to climate risk and societal support at this juncture. Studying the value of the single-tunnel option (including these climate-related criteria) would represent a rational and fiscally responsible approach to planning California's response to our climate emergency. Yet it should be remembered that Santa Clara Valley Water District staff found that California WaterFix (consisting then of two Delta conveyance tunnels) was the riskiest project in the District's 2017 water supply master plan portfolio—in terms of cost, operations, implementation, and stakeholder risks. Their analysis did not take climate change impacts into account.[6] It noted, on the other hand, that "the lowest risk projects are those that are locally controlled or similar to already completed projects….Projects that require substantial construction and cost-sharing are higher risk…."[7]

We further recommend that DWR and the Delta Conveyance Design and Construction Authority do more than just model Delta flows and potential exports to south-of-Delta water contractors with and without a tunnels project.

Modeling needs to place its operations—and the absence of operations—in the context of key elevations throughout the Delta: Courtland, Clarksburg, the location of any intermediate forebay, connectors to Contra Costa Water District facilities, (which had negotiated a California WaterFix settlement with DWR that provides north Delta imports to its service area), Stockton's Empire Tract water diversion, CCWD diversions at Mallard Slough, Rock Slough, and Victoria Island, and other sensitive diversion points in and around the Delta.

The modeling must also account for permutations of sea level rise, storm surge, and flood flows with respect to both new north Delta intakes and at existing south Delta pumps. Such a scope

to tunnel conveyance modeling for the portfolio planning process would answer the key questions of whether there is a best location for tunnel intakes and where that location might be. However, non-conveyance projects of the portfolio must be planned, funded, and implemented first as "no regrets" actions and investments to determine whether single-tunnel Delta conveyance is even needed to address California's unfolding climate emergency and its future water needs.

We recommend that Water Resilience Portfolio modeling identify for each alternative the times when water conditions in the Delta will be ripe for harmful algal blooms, and for selenium partitioning in the water column as prelude to bioaccumulation by sturgeon and other animal species that feed at the bottom of Delta and stream channels.

As part of Restore the Delta's case opposing California WaterFix before the State Water Resources Control Board, we presented testimony describing aquatic and temperature conditions that contribute to harmful algal blooms, selenium contamination, and further spread of invasive clam and other species.[8] Single-tunnel advocates must show that there will be no harm from a tunnel project to delta water quality and to the Estuary's beneficial users.

Just as critical, we recommend that the Water Resilience Portfolio address directly what amount and frequency of Delta river inflow and tunnel operations become subject to regulatory curtailments, modeled on the methodology of Schwarz (2015).[9]

We recommend, further, that Delta levees should be upgraded to meet seismic, flood and sea level stressors regardless of whether a tunnel is built or not.

The question then becomes whether a single tunnel provides any significant benefits in terms of water supply reliability for the cost, especially when considering that the legitimate needs of other Delta beneficial users could be further diminished by tunnel operations?

Recent seismic studies (described in Chapter 2) suggest that potential seismic damage to Delta levees has been overestimated because rock and soil formations adjacent to the Delta function to reduce ground shaking. Despite these findings, we must expect in our plans that Bay Area earthquakes will likely return at a rate more frequent than occurred in the last one hundred years. Upgrading levees to meet seismic standards aligns closely with levee upgrades for flood threat protection; the two justifications provide that Delta levee upgrades are a "no regrets" investment of the highest order—for Delta communities as well as for communities importing water from the Delta. Protecting both communities makes good sense looking ahead.

The earthquake threat to Delta levees could happen at any time, resulting in "sunny day flooding."[10] However, we acknowledge that the Delta is also at increasing risk from the effects of climate change: rising sea level, greater ocean surge from storms, and increasingly extreme storms, expected by climatologists to result more frequently from atmospheric rivers. As we noted in this report, a DWR engineer performed an initial modeling study (applying earlier, less dangerous assumptions about climate change than may now be warranted) that examined the "perfect storm" combination of factors to Delta water levels and levee heights. Abrupt and continuing release of intensive greenhouse gases to Earth's atmosphere (via permafrost thawing and smoldering peat fires) with record volumes of ice-sheets melting in both Greenland and Antarctica will necessitate that the state's Water Resilience Portfolio (as well as the state's next climate change assessment) revisit impacts to California's coasts—including the Delta. Are two-hundred-year levee protections enough

when the potential for levee overtopping and failure, and seven foot storm surge could happen in vulnerable populated Stockton environmental justice communities?

We recommend that state environmental justice policy be integrated practically and conceptually with the state's current flood protection planning.

No community in the Bay-Delta Watershed and Estuary should be left without adequate flood protection as climate change unfolds this century.[11] This comprehensive principle aims to ensure that flood resilience in the Water Resilience Portfolio does not become an instrument to create more flood-disadvantaged communities. Instead, it should eliminate climate inequities that could result from careless, hands-off flood adaptation to climate change.

We also recommend that the state employ as many creative and cost-effective means to embody this principle as it can.

To us, this means that some reaches of Bay-Delta Watershed rivers and streams may be suitably flood-protected by simply upgrading levees. The closer our Watershed's rivers and streams get to the Delta, the more runoff they collect from other parts of the Watershed and the more water they deliver to and through the Delta on their way to the Golden Gate and Pacific Ocean. Communities all along the way should not be left without flood protection simply because they lack the wealth of others. We must also remember that when it comes to flood control as well, Governor Newsom's executive order seeks "multi-benefit" solutions to problems of water and climate resilience.

So simple levee upgrades and raising will be insufficient to respond to flood risk. In the absence of a broader view of the watershed, levees push flooding problems upstream and downstream. Levees limit the flow that can be carried and increase the speed at which water travels between them. Lower elevation gaps in a stream's levee system become opportunities for water to spread out and slow down, potentially resulting in flooding, property damage, and loss of life.

The January 1997 flooding in the San Joaquin River basin revealed the extent to which flood infrastructure solutions are needed. In addition to significant levee upgrades, flood plain restoration upstream along the San Joaquin River and its tributaries could help relieve flood pressure on the Delta by slowing the rate at which high flows from snowmelt (either from more warm winter and spring Sierra days or increasing rain-on-snow storms that are expected) will provide important protections in these watersheds as well as downstream in the Delta, where Delta and importing communities depend on strong Delta levees and local water supplies. In addition, restoring local floodplains upstream in the San Joaquin basin can, by slowing and spreading out the flow of water, help recharge groundwater basins for water supplies needed during inevitably recurring droughts. Still others may be more effectively protected from flooding by construction of setback levees, where some land in other uses is returned to floodplain and habitat use much if not all year long, and a levee is constructed so as to give the river more "room" to spread out and avoid local flooding. Perhaps there are new opportunities for flood bypass channels as well. Similar opportunities must be sought in the Sacramento River Basin as well.

These flood-related recommendations embody just the sort of actions that underlie our suggestions for "no regrets" actions and investments as well as the Governor's executive order principle stating his clear preference for "multi-benefit" projects that create and sustain climate and water resilience.

We recommend using these flood flows captured by natural and/or artificial recharge methods to increase groundwater supplies and to help mitigate San Joaquin Valley farmers' and communities' fears of the implementation of California's Sustainable Groundwater Management Act.

We further recommend more climate change modeling to guide Delta levee investments that incorporate storm surge and river flows for all portions of the Delta. This is needed to gain greater understanding of safety and health impacts for local Delta communities and infrastructure. The modeling should also strive to answer how various flooding scenarios under new climate conditions would impact operation of the new proposed single tunnel Delta intakes. How would they operate? Would the new intakes and fish screens be operable during extreme flood conditions? The public deserves to see how such decisions will be made, rather than relying on "truthy" and simplistic arguments that sea level rise in the Delta merely requires new intakes on the Sacramento River. If Bay Area levees force more tidal flows upstream into the Delta, water levels will rise, including in the Sacramento River where tunnel intakes would be located.

California heat index (temperature plus humidity) projections by the Union of Concerned Scientists beg the question: Will it be hot too to grow some if not a lot of crops in the San Joaquin Valley? How quickly will farmers need to adapt in order to survive economically? To what degree will agricultural land retirement be driven by heat and resulting pest and water supply problems (as distinct from and in addition to growing soil salinity and toxic contaminant concentrations on the west side)? If agriculture in the San Joaquin Valley becomes less viable because its prodigious land base is too water short and too hot, would protecting Delta agriculture, with its advantages of being near a fresh water supply and possibly shorter heat season make more sense for crop production from heat and energy consumption standpoints?

Plans exist through the Delta Conservancy to increase carbon sequestration and raise Delta island elevations. These actions could help mitigate sea level rise when combined with raised and strengthened levees. Setback levees can also provide greater channel space through which future flood flows could pass more safely than at present. Other opportunities exist to reverse subsidence through rice production on Delta islands. Rice projects could accrete sediment and raise landmass for protection against flood faster than tule planting, and provides seasonal habitat for migrating and other waterfowl. A best case scenario would be promotion of farming practices that combine both types of plantings with incentives and rebates for farmers to convert their fields, along with consistent and adequate budgeting to maintain new flood and wildlife mitigation habitats. These working landscapes could provide multiple benefits to California and the Delta, including food production, carbon sequestration, jobs, and flood protection. Prompt arrival of a new California State University at the eastern edge of the Delta in Stockton can provide the scientific, technical, and professional expertise by which these multiple benefits can spread into Stockton's economy and environmental justice communities.

Delta outflow is likely to decrease from snowpack reductions and shifting of precipitation from snow to rain, which in turn will decrease average river inflows to the Delta from north, east, and south. The quality of Delta outflow will be increasingly important for fish and wildlife, to reduce and stop development of toxic algal blooms, and to protect water quality from saltwater intrusion into all beneficial uses in the Delta. Reduced reliance on the Delta will not only be a legal mandate, but a likely physical reality for water exporters, as the state's own climate modeling indicates. Analysis within the Water Resilience Portfolio assessment should look at reductions in water supply through

2100 to ascertain how much water will be available for export, and compare those numbers to projected demand. From there, the Portfolio process should complete a cost-benefit analysis for public review to see if the project is financially viable, if water will be affordable for consumers, especially those in Southern California environmental justice communities.

Local Delta government agencies—from counties to flood control boards, cities to reclamation districts—all must keep up-to-date on the latest climate change science and build the latest forecasting and projection studies into local emergency preparedness planning, water supply planning (including groundwater sustainability plans), and flood management plans. In addition, they must stay on top of the state's analysis of climate change science—making sure that it is not being used to justify Delta management practices that fail to protect Delta communities, fisheries, and the overall Estuary. Time and time again we find that best management practices of Delta water management are what will create a reliable water supply for south of Delta water users. Delta government agencies additionally should be critiquing state water management planning through an understanding of climate change science—not ignoring it or cherrypicking arguments to deny the full range of potential impacts, which fails to serve the public interest.

We recommend that to maintain the sensible and multi-benefit connections that existing between the Bay region and the Delta region, the state of California needs to commence a process that plans for what happens to Bay/coastal and Delta communities as sea level rises and coincides with storm surge and heavy upstream runoff from the Central Valley watershed.

At present climate change planning—for response, mitigation, adaptation, and protection of the state's communities and environments—is piecemeal, and separates the Bay from the Delta. Yet communities close in to the Delta, such as Pittsburg, Antioch, Tracy, and Suisun City are at very low elevations and are adjacent to more inland coastal designations the DWR has already made.[12] Communities upstream of, yet near to the Delta are also at very low elevations (under 50 feet above sea level), including Manteca, Brentwood, Woodbridge, Davis, Verona, Knights Landing, Grimes, Sacramento, West Sacramento, and Oakley. Protecting the Delta from sea level rise and storm surge will only grow in importance. What must California do to adapt to Central Valley inundation, and by when?

A single Delta conveyance tunnel concept may not save California's water supply infrastructure and the south-of-Delta import-dependent communities. This gets at the importance of "no regrets" actions and investments—through them, we focus our early dollars on local self-reliance for water supplies and adapt to that reality. We haven't time to waste on expensive projects and planning that will not benefit our response to the long emergency facing California's future water needs, the Bay-Delta Estuary, our lands, and our people. The state will need to address whether a single tunnel makes economic and even topographic sense.

---

[1] An exemplar of this level of climate forethought in the Bay Area includes San Francisco Estuary Institute and San Francisco Planning and Urban Research. 2019. *San Francisco Bay Shoreline Adaptation Atlas: Working with Nature to Plan for Sea Level Rise Using Operational Landscape Units*. Accessible online at https://www.sfei.org/adaptationatlas.

[2] Anonymous personal communication (email) with Tim Stroshane, March 15, 2019.

[3] Stantec. 2019. *Sustainability Outlook Indicator Descriptions and Methodology*. May. Prepared for California Department of Water Resources, Figure 4-26, p. 4-108. Accessible at https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/California-Water-Plan/Docs/Update2018/Final/SupportingDocs/Sustainability-Outlook-Indicator-Descriptions-and-Methodology.pdf. Within the legal Delta, these three counties have about 62 percent of the population.

[4] Elevations gleaned from Benchmark Maps, *California Road & Recreation Atlas*, 2017.

[5] California Water Code section 85021.

[6] Santa Clara Valley Water District. 2017. *Water Supply Master Plan 2017—Project Risks: Results of Pairwise and Traditional Risk Analyses*. September 8, pp. 7-19. Accessible at https://www.valleywater.org/sites/default/files/Risk%20Ranking%20Report.pdf.

[7] *Ibid.*, p. 19.

[8] See Testimony of Barbara Barrigan-Parrilla (RTD-20) and of Tim Stroshane (RTD-11), accessible at https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/restore_the_delta.html.

[9] Schwarz, A.M. 2015. California Central Valley Water Rights in a Changing Climate. *San Francisco Estuary and Watershed Science* 13(2). Accessible at http://escholarship.org/uc/item/25c7w914.

[10] The classic example of sunny day flooding is the June 2004 flooding of Upper Jones Tract, attributed, however, to a burrowing animal, not an earthquake.

[11] We remind our readers that the Bay-Delta Watershed includes all rivers from north to south that drain to San Francisco Bay and through the Bay-Delta Estuary.

[12] Stantec. 2019. *Sustainability Outlook Indicator Descriptions and Methodology, op. cit*.

EXECUTIVE DEPARTMENT
STATE OF CALIFORNIA

Appendix A

Executive Order N-10-19

WHEREAS, water is a human right, and is central to California's strength and vitality; and

WHEREAS, we face a range of existing water challenges, including unsafe drinking water across the state, major flood risks that threaten public safety, severely depleted groundwater aquifers, agricultural communities coping with uncertain water supplies, and native fish populations threatened with extinction; and

WHEREAS, climate change is having a profound impact on water and other resources, making the climate warmer and more variable, which reduces mountain snowpack, intensifies drought and wildfires, and drives shorter, more intense wet seasons that worsen flooding; and

WHEREAS, California continues to grow, with our population projected to grow to 50 million over the next several decades and our economic activities expanding as the world's fifth largest economy; and

WHEREAS, the future prosperity of our communities and the health of our environment depend on tackling pressing current water challenges while positioning California to meet broad water needs through the 21st century; and

WHEREAS, many state programs, policies and investments are being implemented, such as the Sustainable Groundwater Management Act and new urban water efficiency standards, that can be built upon to meet these evolving challenges; and

WHEREAS, providing clean, dependable water supplies to communities, agriculture, and industry while restoring and maintaining the health of our watersheds is both necessary and possible; and

WHEREAS, achieving this goal requires a broad portfolio of collaborative strategies between government, sovereign tribes, local communities, water agencies, irrigation districts, environmental conservationists, academia, business and labor leaders, and other stakeholders.

NOW, THEREFORE, I, GAVIN NEWSOM, Governor of the State of California, by virtue of the power and authority vested in me by the Constitution and the statutes of the State of California, do hereby issue this Order to become effectively immediately.

IT IS HEREBY ORDERED THAT:

1. The California Natural Resources Agency, the California Environmental Protection Agency, the California Department of Food and Agriculture, in consultation with the Department of Finance, shall together prepare a water resilience portfolio that meets the needs of California's communities, economy, and environment through the 21st century.

These agencies will reassess priorities contained within the 2016 California Water Action Plan, update projected climate change impacts to our water systems, identify key priorities for the administration's water portfolio moving forward, and identify how to improve integration across state agencies to implement these priorities.

2. These agencies shall first inventory and assess:
    a. Existing demand for water on a statewide and regional basis and available water supply to address this demand.
    b. Existing water quality of our aquifers, rivers, lakes and beaches.
    c. Projected water needs in coming decades for communities, economy and environment.
    d. Anticipated impacts of climate change to our water systems, including growing drought and flood risks, and other challenges to water supply reliability.
    e. Work underway to complete voluntary agreements for the Sacramento and San Joaquin river systems regarding flows and habitat.
    f. Current planning to modernize conveyance through the Bay Delta with a new single tunnel project.
    g. Expansion of the state's drinking water program to ensure all communities have access to clean, safe and affordable drinking water.
    h. Existing water policies, programs, and investments within state government.

3. This water resilience portfolio established by these agencies shall embody the following principles:
    a. Prioritize multi-benefit approaches that meet multiple needs at once.
    b. Utilize natural infrastructure such as forests and floodplains.
    c. Embrace innovation and new technologies.
    d. Encourage regional approaches among water users sharing watersheds.
    e. Incorporate successful approaches from other parts of the world.
    f. Integrate investments, policies and programs across state government.
    g. Strengthen partnerships with local, federal and tribal governments, water agencies and irrigation districts, and other stakeholders.

4. These agencies shall conduct extensive outreach to inform this process, including to other state agencies, sovereign tribes, federal and local government, local water agencies, agricultural groups, environmental justice and environmental conservation organizations, local and statewide business leaders, academic experts and other stakeholders.

IT IS FURTHER ORDERED that as soon as hereafter possible, this Order shall be filed with the Office of the Secretary of State and that widespread publicity and notice shall be given to this Order.

This Order is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its departments, agencies, or other entities, its officers or employees, or any other person.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 29th day of April 2019.

GAVIN NEWSOM

Governor of California

ATTEST:

ALEX PADILLA

Secretary of State

Appendix B PORTFOLIO NEEDS ASSESSMENT

THE FAILURE TO JUSTIFY CALIFORNIA WATERFIX

Since Restore the Delta's founding, we have experienced a long history of skepticism toward state water needs analyses. This skepticism predates California WaterFix, but we knew in our bones that the project that would emerge from the Bay-Delta Conservation Plan process between 2006 and 2012 would need thorough scrutiny.

The state of California (led by the California Department of Water Resources [DWR]) and the United States Bureau of Reclamation (the Bureau) never successfully or persuasively demonstrated actual need for their two-tunnel California WaterFix project. To be sure, they have asserted they need and want the project, but they have never shown compelling reasons—backed by solid evidence—as to why such a Delta conveyance project is needed. In short, they failed to conduct a reasoned needs assessment for the project.

Compelling reasons grounded in robust evidence are what DWR and the Delta Conveyance Design and Construction Authority need to prepare and document on behalf of the new Water Resilience Portfolio, especially when it comes to a single tunnel concept and design. Lazy reasoning from the last ten years will not do for the next ten or twenty.

For instance, California has a water policy framework that provides long-legislated public criteria against which project design, performance, and control of a single tunnel option should be evaluated. This framework includes:

- Reduced Delta reliance for meeting California's future water needs[1];
- The constitutional prohibition against waste and unreasonable use of water[2];
- The constitutional requirement that all uses, methods of use, and methods of diversion of water must be reasonable and beneficial[3];
- That all appropriations of water must comply with the state's public trust doctrine that protects ecosystems, water quality, and other common environmental and economic resources for the benefit of all Californians[4]; and
- The Human Right to Water and other federal and state requirements for environmental justice analysis.[5]

There are other public principles applicable to water projects that make up this framework, including some that are specific to the Delta and its resources. They also include DWR's own rules and regulations, such as the need for a cost-benefit analysis.

For California WaterFix, DWR and the Bureau ignored and avoided these long-established policies as inconvenient or contrary to their planning. Instead, they justified the project as necessary to fulfill long-standing state and federal water service contracts "to the maximum extent feasible" and to provide alleged ecological benefits to listed fish species whose abundance and life histories were already disrupted by existing CVP and SWP operations. The 2015 Conceptual Engineering Report

stated: “The purpose of the overall system is to gain a sustainable and reliable water supply capable of withstanding earthquake and climate.”[6] Moreover, WaterFix justifications seemed predicated on long-term abandonment of the Delta, its ecosystems, and levee systems (since building the tunnels implied DWR would not need existing levees protecting Delta channels to operate tunnels).[7]

It seemed to us at the time that instead of fomenting fear of Delta levee collapses, a more accurate state proposal would include investments not only in the tunnels but in the levees lining channels through which water would still have to flow to reach the CVP and SWP pumping plants in the south Delta. But DWR and the Bureau did not frame Delta levee sustainability this way for California WaterFix. This left many of us with the distinct impression that DWR and the Bureau intended WaterFix to make Delta levees obsolete.

Things were so bad, DWR and the Bureau claimed, that:

> The ecological health of the Delta continues to be at risk, the conflicts between species protection and Delta water exports have become more pronounced, as amply evidenced by the continuing court decisions regarding the intersection of the ESA, CESA, and the operations criteria of the SWP and the CVP. Other factors, such as the continuing subsidence of lands within the Delta, increasing seismic risks and levee failures, and sea level rise associated with climate change, serve to further exacerbate these conflicts. Simply put, the overall system as it is currently designed and operated does not appear to be sustainable from an environmental perspective, and so a proposal to implement a fundamental systemic change to the current system is necessary. This change is necessary if California is to ‘achieve the two coequal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem.’ (California Public Resources Code Section 29702 subd. a.)[8]

Passionate as this summary justification for California WaterFix reads, it did not demonstrate the water supply need from the project. It merely expressed frustration with ongoing endangered species litigation and alleged that earthquake risk to Delta levees was beyond debate. This approach to needs analysis fails utterly to apply reason and promote trust among and between stakeholders.

DWR and the Bureau failed completely in the California WaterFix process and in its water rights proceeding to demonstrate how they would comply with reducing Delta reliance of water importers when addressing California’s future water needs, as called for by the Delta Reform Act of 2009. Not only that, DWR and the Bureau soft-pedaled probably the most compelling reason that they and their customers wanted California WaterFix—it would fulfill their aspirations to enlarge the volumes of water that northern water sellers could transfer to south-of-Delta buyers during droughts in California’s water transfer market, while remaining unaccountable to the public.[9]

None of these justifications will do for assessing California’s future water needs in the upcoming Water Resilience Portfolio process. The Newsom Administration must use this opportunity to better justify new Delta conveyance, if that is at all possible. We hope Governor Newsom is open to the possibility that a well-run, comprehensive process might reveal that, while the status quo is not an option, neither may be the single tunnel concept.

Appendix B PORTFOLIO NEEDS ASSESSMENT

In this appendix, we identify criteria of analysis that the Water Resilience Portfolio approach should employ when evaluating population change, income distribution, water use behavior, affordability of water rates, and project performance—whether of a single-tunnel project concept, a water recycling plant, or water conservation and efficiency measures.

TOWARD BETTER STATE WATER NEED ASSESSMENTS

Governor Newsom's Water Resilience Portfolio appears to us to be a timely next step planning process for further statewide adaptations to climate change, known earthquake risk, and California's changing demographics and economics—to apply the implications of climate change to the water arena in California, and place it in the broad "future water needs" context that is so necessary at this moment.

Given our skepticism toward state assessments of water need, we look upon Governor Newsom's Water Resilience Portfolio executive order with some concern about the Administration's intent to rely on already existing information about California WaterFix.[10] "These agencies shall first inventory and assess[…][c]urrent planning to modernize conveyance through the Bay-Delta with a new single tunnel project," states the order. To us, "inventorying and assessing current planning" refers to existing information available from California WaterFix documentation, among other potential sources.

All well and good, except that this overestimates the quality of WaterFix's base of information—its conceptual engineering report, its environmental documentation, its economic studies, and more. These documents (voluminous as they are) proved insufficient for a full and comprehensive grasp of the problems of tunnel-type Delta conveyance before the State Water Resources Control Board's water rights hearing. Other potential information sources should include the transcripts, exhibits, and testimony (including rebuttal testimony) that the Board amassed. All of these data sources remain available online, even though DWR and the Bureau withdrew the California WaterFix petition.

OVERESTIMATING WATER NEED

The matter of overestimation is critical here. Many water suppliers overestimate actual water demand when they fail to take account of myriad factors that affect demand for and use of fresh water, including the price of water and its effect on demand, recent drought use reductions, local and regional economic changes, and the future availability of water as our climate changes—the latter a problem that is not amenable to simple linear growth projection into the future.[11]

DWR and the Bureau framed adaptation to reduced south-of-Delta water supplies in only the most general, qualitative manner for California WaterFix and the Bay Delta Conservation Plan process. They did not conduct detailed, quantified studies of various responses to such reductions: water conservation, reservoir storage (such as regional or local storage opportunities), groundwater storage, water transfers, recycled water, desalination, and "contingency plans" to address critical water shortages during droughts.[12] There was no attempt at that time (2013) to quantify potential changes in these parameters, what effects they could have for meeting California's future water

needs, and whether other methods of water production and use could be marshaled to reduce or eliminate the need for new Delta water conveyance like WaterFix.

We agree with the public-spirited nature of Governor Newsom's contention that existing state and federal Delta water export systems need to be protected in the long-run. Frustrated as we have been with how the state and its major customers operate the State Water Project, it remains a public infrastructure investment that must be preserved and used efficiently. This position is consistent with the 1959 Delta Protection Act.[13] We seek from DWR an accurate, quantified, well-reasoned, and transparent water needs assessment for the Water Resilience Portfolio and single-tunnel project (including plain language explanations and translations for publics who do not speak English as their first language). That is also consistent with the state's overarching water policy framework.

The Water Resilience Portfolio needs assessment must identify what the state's future water needs will be—by sector and by region—and do so in a manner that reflects not simply population or housing growth (which is typically what many water agencies rely on). California's future water needs must also entail a forecast of how California's economy could change (which we recognize is no easy task given climate change, alterations to trade policy, and immigration challenges). Moreover, behavioral factors must be incorporated into the state's needs assessment, since water demand is very much a social and economic phenomenon (not just a biological one) and subject to climate adaptation.

If the assessment assumes business as usual concerning climate change and export levels, without other more adaptive alternatives, the Water Resilience Portfolio would likely be a non-starter for Restore the Delta and many other water interests.[14]

CONSERVATION AS A CALIFORNIA WAY OF LIFE

Near the end of the 2012-2016 California drought, the state of California released an interdepartmental report entitled, *Making Water Conservation a California Way of Life.*[15] By this time, California had achieved potable water savings of 25.1 percent in February 2017 over February 2013—which the State Water Resources Control Board said was savings enough to supply 13 million residents with water for a year.[16] And Governor Jerry Brown signed legislation in his final year of office to improve water conservation and drought planning efforts statewide through implementation of four goals: use water more wisely, eliminate water waste, strengthen local drought resilience, and improve agricultural water use efficiency and drought planning.[17] These measures will clearly help Californians—including agricultural water users who consume most of the state's developed water supply—cope with the water austerity that climate change will force upon us, making the state as a whole more water resilient.

At the height of our most recent drought, Delta farmers volunteered to reduce their irrigation diversions by 25 percent to help provide some additional water for export by the SWP and CVP (whose water rights are junior to those of Delta farmers and others). The Delta Watermaster, Michael Patrick George, provided a retrospective study of their efforts the following spring. He found that 217 separate diversion reduction plans were submitted covering roughly two-thirds of farmable land in the central and southern Delta. They proposed a number of methods for reducing surface water diversions by 25 percent, including land fallowing, moving to less water-intensive crops, reducing

irrigation frequency, and greater use of efficient irrigation equipment and techniques. Delta Watermaster George found that the Delta irrigators reduced their diversions 32 percent compared with 2013 usage, and that average irrigation decreased from 2.70 acre-feet per acre to 1.91 on central and southern Delta farmlands.[18]

The Water Resilience Portfolio needs assessment must take account of Californians' demonstrated willingness to change their behavior to: stretch drinking and other water supplies (including how much of their conserving behavior continues post-drought, and for how long[19]); increase adoption of new water technologies; and alter their landscape and outdoor water use patterns.[20] It should also incorporate as well the ability and willingness of farmers and growers to undertake measures that will increase water efficiency of crop production and reduce crop water use, while still minimizing or optimizing plant metabolic stress and supplying American markets with healthy and affordable food.[21]

Water demand is also a function of its cost and the energy needed to lift it against gravity. Most people—except perhaps the wealthiest among us—typically use less water when they must pay more for it. Water rates have risen for many years throughout California, but especially south of the Tehachapi Mountains over which the State Water Project must pump to deliver water to the Metropolitan Water District and its member agencies and customers. Confronted with higher water rates, people find ways to reduce water use to control their household costs. The Water Resilience Portfolio needs assessment must take account of changes in the cost of water already under way throughout California and the effect such changes will have on consumer and business owner behavior, as well as the behavior of water districts reliant on pumped water supplies. Their behavior will reflect their ability to afford the cost of water, and there are innovative methods for identifying the affordability of water that measure household and personal ability to afford an water rate increases which the Water Resilience Portfolio needs assessment should take account of.[22]

---

[1] Water Code section 85021.

[2] California Constitution, Article X, Section 2; Water Code section 100.

[3] *Ibid.*

[4] Water Code section 85023.

[5] See "California Anti-Discrimination and Environmental Justice Policy," in Restore the Delta. 2018. *The Fate of the Delta,* pp. 19-20. Accessible online at https://www.restorethedelta.org/wp-content/uploads/The-Fate-of-the-Delta-final.pdf.

[6] California Department of Water Resources, Division of Engineering. 2015. *Conceptual Engineering Report: Dual Conveyance Facility Modified Pipeline/Tunnel Option—Clifton Court Forebay Pumping Plant (MPTO/CCO).* July 1, p. 1-1. Accessible at https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/petitioners_exhibit/dwr/dwr_212.pdf.

[7] See Chapter 3 of this report.

[8] Bay Delta Conservation Plan and California WaterFix. 2016. *Recirculated Draft Environmental Impact Report/ Supplemental Environmental Impact Statement.* Section 1.1.4, "Project Objectives and Purpose and Need," p. 1-7, lines 31-35, and p. 1-8, lines 1-6. Accessible at https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/exhibit3/index.shtml.

[9] Stroshane, T. 2018. Testimony of Tim Stroshane. Part 2 of California WaterFix Water Rights Change Petition Proceeding. RTD Case in Chief. Accessible at https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/RestoretheDelta/part2/RTD_12.pdf;and Stroshane, T. 2018. Rebuttal Testimony of Tim Stroshane—Revised. Part 2 Rebuttal Phase for San Joaquin County Protestants. Accessible at https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/COSJ%20et%20al/part2rebuttal/sjc_337_revised.pdf.

[10] Executive Order N-10-19, paragraph 2.f.

[11] Heberger, M. et al. 2016. *A Community Guide for Evaluating Future Urban Water Demand.* August. Pacific Institute. Accessible at https://pacinst.org/wp-content/uploads/2016/08/A-Community-Guide-for-Evaluating-Future-Urban-Water-Demand-1-1.pdf.

[12] Bay Delta Conservation Plan. 2013. *Draft Environmental Impact Report/Environmental Impact Statement*. November. Appendix 5B. *Responses to Reduced South of Delta Water Supplies.* Section 5B, pp. 5B-7—5B-39. See Table 5B-2, p. 5B-31 for vague summaries of each type of response in both the short and long terms (which are also undefined). Accessible at https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/exhibit4/index.shtml.

[13] California Water Code sections 12201, 12202 and 12203.

[14] See Heberger, et al, note 10, pp. 24-31, where accounting for climate change, drought, and uncertainty are discussed in the formulation of water demand forecasts. These authors also suggest a useful checklist for reviewing water demand forecasts at pages 3-5.

[15] Accessible at http://cert1.mail-west.com/anmc7rmpGycT/pGgtmyuzj/fof51/ionnh5d4s/4/2pGqfm.

[16] This was “approximately the combined population of Los Angeles, Contra Costa, Fresno, and San Joaquin counties, or one-third of the state’s population.” State Water Resources Control Board. 2017. *Fact Sheet: February 2017 Statewide Conservation Data.* Last updated April 4, 2017. Accessible at *ibid.*

[17] California Department of Water Resources and State Water Resources Control Board. 2018. *Making Water Conservation a California Way of Life: Primer of 2018 Legislation on Water Conservation and Drought Planning, Senate Bill 606 (Hertzberg) and Assembly Bill 1668 (Friedman).* November. Accessible at https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Water-Use-And-Efficiency/Make-Water-Conservation-A-California-Way-of-Life/Files/Publications/Final-Primer-2018-Water-Conservation-Drought-Planning-Legislation-1152018.pdf?la=en&hash=81BD043882DE503E937E2FFC49D6272A5DC22528.

[18] George also disclaimed that his reporting is based on reports prepared by program participants and their advisors, and that the “vast majority of diversions in the Delta are estimated, not measured… [and that] the underlying diversion data should be viewed as approximations.” George, M.P. 2016. *Report on Voluntary Diversion Reduction Program among in-Delta Riparian Water Right Claimants.* March 11. Accessible at https://www.waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/diversion_reduction15.pdf.

[19] Gonzales, P. and N. Ajami. 2017. Social and Structural Patterns of Drought-Related Water Conservation and Rebound. *Water Resources Research.* 53: 10,619-10,634. Accessible at https://doi.org/10.1002/2017WR021852.

[20] Turf replacement programs run by various large urban water districts should be inventoried to ascertain their impact on (even "hardening of") urban water demand (e.g., Metropolitan Water District of Southern California, East Bay Municipal Utilities District, and others). The State Water Resources Control Board's data on residential per capita per day consumption during the recent drought should be considered, as well as the continuing presence of lawns and the potential for further reduction in turf landscaping. See Hanak, E. and M. Davis. 2006. Lawns and Water Demand. *California Economic Policy.* 2(2): July. Accessible at https://www.ppic.org/publication/lawns-and-water-demand-in-california/. Useful web sites include State Water Board's water conservation portal: https://www.waterboards.ca.gov/water_issues/programs/conservation_portal/resources.html; and DWR's water use and efficiency page: https://water.ca.gov/Programs/Water-Use-And-Efficiency.

[21] Numerous reports on agricultural and urban water use efficiency have been produced in recent years. Some include: California Department of Water Resources. 2009. Agricultural Water Use Efficiency. Volume 2—Resource Management Strategies, Chapter 2 of California Water Plan. 33 pages; California Department of Water Resources. 2009. Urban Water Use Efficiency. Volume 2—Resource Management Strategies, Chapter 3 of California Water Plan; Natural Resources Defense Council, et al. 2014. *Wetter or Not: Actions to Ease the Current Drought and Prepare for the Next.* November 17. Accessible at https://www.nrdc.org/resources/wetter-or-not-actions-ease-current-drought-and-prepare-next; Cooley, H., Christian-Smith, J., and P. Gleick. 2009. *Sustaining California Agriculture in an Uncertain Future.* Pacific Institute. July. Accessible at https://pacinst.org/publication/sustaining-california-agriculture-in-an-uncertain-future/; Cooley, H. et al. 2008. *More With Less: Agricultural Water Conservation and Efficiency in California: A Special Focus on the Delta.* Pacific Institute. September. Accessible at https://pacinst.org/publication/more-with-less-agricultural-water-conservation-and-efficiency-in-californiaa-special-focus-on-the-delta/; Cooley,H. and R. Phurisamban. 2016. *The Cost of Alternative Water Supply and Efficiency Options in California.* Pacific Institute. October. Accessible at https://pacinst.org/publication/the-cost-of-alternative-water-supply-and-efficiency-options-in-california/; and Mark Schapiro. 2019. A Time of Reckoning in the Central Valley: Climate change is upending agriculture and land use in California's Central Valley. *Bay Nature.* Posted 23 June at https://baynature.org/article/a-time-of-reckoning-in-the-central-valley/.

[22] Teodoro, M.P. 2018. Measuring Household Affordability for Water and Sewer Utilities. *Journal of the American Water Works Association*. 110(1): 13-24. Accessible at https://doi.org/10.5942/jawwa.2018.110.0002. See also Feinstein, L. 2018. *Measuring Progress Toward Universal Access to Water and Sanitation in California: Defining Goals, Indicators, and Performance Measures.* Pacific Institute. September. Accessible at https://pacinst.org/publication/measuring-progress/.

Appendix C

EXECUTIVE DEPARTMENT
STATE OF CALIFORNIA

EXECUTIVE ORDER N-15-19

WHEREAS, in the early decades of California's statehood, the relationship between the State of California and California Native Americans was fraught with violence, exploitation, dispossession and the attempted destruction of tribal communities, as summed up by California's first Governor, Peter Burnett, in his 1851 address to the Legislature: "[t]hat a war of extermination will continue to be waged between the two races until the Indian race becomes extinct must be expected"; and

WHEREAS, the State of California's laws and policies discriminating against Native Americans and denying the existence of tribal government powers persisted well into the twentieth century; and

WHEREAS, despite these wrongs, California Native Americans resisted, survived and carried on cultural and linguistic traditions defying all odds; and

WHEREAS, the State of California and California Native Americans have never jointly formally examined or documented their relationship for the express purpose of acknowledging and accounting for historical wrongs committed by the State of California toward California Native Americans; and

WHEREAS, the State of California has never formally apologized for historical wrongs tolerated, encouraged, subsidized and committed by State actors against California Native Americans; and

WHEREAS, the State of California seeks to more closely explore the historical relationship between the State of California and California Native Americans in the spirit of truth and healing through the establishment of a Truth and Healing Council; and

WHEREAS, the State of California intends that the work of the Truth and Healing Council be done respectfully and in collaboration and consultation with California Native American tribes pursuant to this Executive Order and Executive Order B-10-11.

NOW, THEREFORE, I, GAVIN NEWSOM, Governor of the State of California, in accordance with the authority vested in me by the Constitution and statutes of the State of California, do hereby issue the following order to become effective immediately.

IT IS HEREBY ORDERED THAT:

1. The State of California hereby:

    a. recognizes that the State historically sanctioned over a century of depredations and prejudicial policies against California Native Americans;

    b. commends and honors California Native Americans for persisting, carrying on cultural and linguistic traditions, and stewarding and protecting this land that we now share;

    c. apologizes on behalf of the citizens of the State of California to all California Native Americans for the many instances of violence, maltreatment and neglect California inflicted on tribes; and

d. reaffirms and incorporates by reference the principles outlined in Executive Order B-10-11, which requires the Governor's Tribal Advisor and the Administration to engage in government-to-government consultation with California Native American tribes regarding policies that may affect tribal communities.

2. The Governor's Tribal Advisor shall establish the Truth and Healing Council to bear witness to, record, examine existing documentation of, and receive California Native American narratives regarding the historical relationship between the State of California and California Native Americans in order to clarify the historical record of this relationship in the spirit of truth and healing. The Truth and Healing Council shall be led and convened by the Governor's Tribal Advisor and shall include representatives or delegates from California Native American tribes, and may include relevant state and local agencies, as well other relevant non-governmental stakeholders.

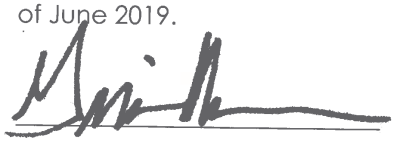
3. The Truth and Healing Council shall consult with California Native American tribes to shape the overarching focus and develop the work of the Council and shall endeavor to accurately represent the diversity of experience of California Native Americans within the State of California.

4. The Truth and Healing Council shall: (i) report draft findings to the Governor's Tribal Advisor on an annual basis beginning January 1, 2020 and (ii) produce a final written report of findings regarding the historical relationship between the State of California and California Native Americans on or before January 1, 2025.

IT IS FURTHER ORDERED that as soon as hereafter possible, this Order shall be filed with the Office of the Secretary of State and that widespread publicity and notice shall be given to this Order.

This Order is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its agencies, departments, entities, officers, employees, or any other person.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 18th day of June 2019.



GAVIN NEWSOM

Governor of California

ATTEST:

ALEX PADILLA

Secretary of State

Appendix D GROUNDWATER SALINITY

This appendix excerpts testimony presented to the State Water Resources Control Board by RTD policy analyst Tim Stroshane (RTD-20) concerning the relationship of Delta water channel infiltration to groundwater in San Joaquin County. Exhibits referred to in this excerpt are accessible at https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/restore_the_delta.html.

Water quality effects on groundwater supplies for municipal beneficial uses.

[W]ater quality effects in Delta channels [from the proposed California WaterFix intakes operations] would affect groundwater, since surface and groundwater supplies in the Delta are connected. The Delta area has a large pumpage depression or “cone of depression” that causes an influx of water from the Delta to percolate to underground water supplies. (RTD-145, p. 167, column 2.) United States Geological Survey groundwater modeling estimates that Delta surface channels lose between 100 to over 500 acre-feet per year to groundwater percolation. (RTD-145., pp. 171-172, Figure C19.) Surface water was also found to recharge groundwater from Calaveras and Stanislaus rivers and Dry Creek. On average there was a net lateral inflow to the groundwater system of 120,000 acre-feet between 1970 and 1993 (an estimated annual average of about 5,000 acre-feet per year). (RTD-146, p. 69, Section 2.3.4.4.) Generally, groundwater pumping rates in San Joaquin County in 2004 were found to exceed the sustainable yield of the groundwater basin, estimated to be approximately 150,000 to 160,000 acre-feet. (RTD-146, p. 69, Section 2.3.6.) The eastern San Joaquin groundwater basin management plan assumed that "all basin inflow in west Stockton is saline" because "accretions in the western fringes of the Basin and the Lower San Joaquin River are undesirable due to elevated salinity levels. Saline groundwater intrusion has forced the closure of several wells in the Calwater service area." (RTD-146, pp.69, Section 2.3.6.) The City of Stockton’s domestic water supply permit from the State Water Resources Control Board shows that Stockton has nine inactive wells and has destroyed another 17 wells. (RTD-220, pp. 13-14.) Increased west-to-east flow is considered by San Joaquin County’s groundwater basin management plan is "undesirable," as this water is typically higher in TDS and chloride levels and causes degradation of water quality in the Basin. (RTD-146, p. 71, Section 2.3.7.) The plan further states:

> Degradation of water quality due to TDS or chloride contamination threatens the long-term sustainability of a very important water resource for San Joaquin County, since water high in TDS and/or chloride is unusable or either urban drinking water needs or for irrigating crops. Damage to the aquifer system could for all practical purposes be irreversible due to saline water intrusion, withdrawal of groundwater from storage, and potential subsidence and aquifer consolidation.
>
> (RTD-146, p. 71, Section 2.3.7.)

The saline front of groundwater intrusion beneath south and downtown Stockton is projected to move another 1.5 miles east by 2030, just as future urban water demand was expected to see a net increase among the cities of San Joaquin County of 146,600 acre-feet per year. (RTD-146. p. 74, Figure 2-27, p. 75, Table 2-4; RTD-147, pp. 2-15 to 2-16, Figures 2-8 and 2-9, and p. 2-18, Table 2-3.)

Appendix E ICE SHEET LOSS, ARCTIC ICE LOSS, PERMAFROST THAWING, AND EXTREME HEAT THREAT

This appendix details points made in Chapter 3, Climate Change Issues. They concern the "breaking science news" surrounding ice sheet loss, arctic ice loss, permafrost thawing, and the significant potential for abrupt changes in global atmospheric heating. While these geophysical events occur far from California, they are expected by climate scientists to have global repercussions—which extend to California and the Delta.

Romain Maendly's study (described in Chapter 3, this report) of Delta sea-level rise uses only the NRC 2012 sea-level rise projections for the Golden Gate. The NRC projections were recognized but superseded by both the Ocean Protection Council and Pierce studies as out of date and lacking insight into the impact of accelerated ice-sheet melting on global and regional sea levels. On the other hand, the NRC's 2050 projections for Golden Gate/San Francisco sea level rise, were slightly higher than those of the more recent studies through 2050; but they are just over half the median projections for 2100 compared with the business-as-usual scenario of California's Fourth Climate Change Assessment (82 cm in 2100 versus 137 cm), meaning that the newer scientific findings indicate more rapid acceleration of sea level rise than the NRC 2012 study.[1] Maendly does not explain why these more recent approaches to sea-level rise were neither recognized nor included.

On top of excluding ice sheet research used by some and not others, new ice-sheet research needs to be factored into the climate change analysis produced for the Newsom Administration's Water Resilience Portfolio. Loss of south pole ice shelves from warming Southern Ocean waters cause some of Antarctica's glaciers to accelerate calving into the sea, according to studies publicized in May 2019. "The biggest uncertainty in near-future sea level rise…comes from the Antarctic Ice Sheet," said one team of scientists. "Between 1992 and 2017, ice thinning has grown in extent to include 24% of West Antarctica, and reaches 122 metres [about 400 feet] in places," said a separate team of scientists, adding that, "Ice losses from Pine Island and Thwaites Glaciers [West Antarctica's largest glaciers] have risen fivefold."[2] The East Antarctic ice sheet contains enough ice to raise sea levels by about 60 meters (or nearly 200 feet).[3]

Sea-level rise, drought, and extreme storms are all driven (scientists call it "forced") by mounting concentrations of greenhouse gases (GHGs) in Earth's atmosphere. These gases include carbon dioxide, methane, nitrous oxide and fluorinated gases. Carbon dioxide is mainly emitted from burning fossil fuels (coal, natural gas, and oil) for energy and transportation. Methane is emitted mainly from leaks in natural gas systems, raising of livestock, and natural wetlands. Methane's lifetime in the atmosphere is much shorter than that of carbon dioxide, but it is about twenty-five times more efficient at trapping atmospheric radiation (heat) while it is present. In other words, one pound of methane will absorb the same amount of heat as about 25 pounds of carbon dioxide.[4]

In 2013, the National Research Council (NRC) estimated that permafrost soils (which are located in the lands of northern latitudes of North America [Alaska and Canada] and Asia [Scandinavia and Russia]) have between 1700 and 1850 gigaton of carbon (Gt C; see figure below). In addition, there are stores of "ocean methane hydrates" buried in ocean sediments that range between 1000 to 10,000 Gt C. Finally, there are still fossil fuels not yet extracted, refined, and then burned. The NRC reported that modeling of ocean hydrates to climate change "is in its infancy" with many uncertainties about their concentration in ocean sediments and the rate at and mechanisms by which they could be could be released to the atmosphere. Because of the many uncertainties and lack of research we could find in time for this report, we do not cover the potential for oceanic

methane release here; it is generally considered to be a slow process, though it could be triggered and accelerated by undersea landslide failures.[5] The societal—even global—controversy about keeping fossil fuels in the ground has yet to be resolved. (Fortunately, keeping them in the ground is a choice humans and their institutions could make.)

Courtesy of National Snow and Ice Data Center.

The NRC said that permafrost carbon "contain[s] enough carbon to drive a powerful carbon cycle feedback to a warming climate," adding for context:

> *To put the Arctic soil carbon reservoir into perspective, the carbon it contains exceeds current estimates of the total carbon content of all living vegetation on Earth (approximately 650 Gt C), the atmosphere (730 Gt C, up from ~360 Gt C during the last ice age and 560 Gt C prior to industrialization…), proved reserves of recoverable conventional oil and coal (about 145 Gt C and 632 Gt C, respectively), and even approaches geological estimates of all fossil fuels contained within the Earth (~1,500 – 5,000 Gt C). It represents [the equivalent of] more than two and a half centuries of our current rate of carbon release through fossil fuel burning and the production of cement.*

These vast deposits exist largely because microbial breakdown of organic soil carbon is generally low in cold climates, and virtually halted when frozen in permafrost. Despite slow rates of plant growth in the Arctic and sub-Arctic latitudes, massive deposits of peat have accumulated there since the last glacial maximum.[6]

Permafrost soils are extensive in the high latitudes, essentially ringing the Arctic Ocean on all adjacent continents, and with the most continuous permafrost extending northward from about 65 degrees north latitude in both Asia and North America. (See Arctic region map.)

Carbon stocks in permafrost are comprised of dead plants and animals that have not fully decayed because the microbes that break down plant and animal biomass have been frozen, at least until recently. Permafrost thawing now activates bacterial decay of these carbon-rich materials. In the presence of water, carbon emissions come in the form mostly of methane. Drier conditions result in more carbon dioxide than methane being released by bacteria. Consequently, the relative proportions of methane versus carbon dioxide emissions from permafrost thawing will depend on the degree to which water from its once-buried ice remains present as lake water, which in turn determines whether the carbon decay process oxidizes or ferments.[7]

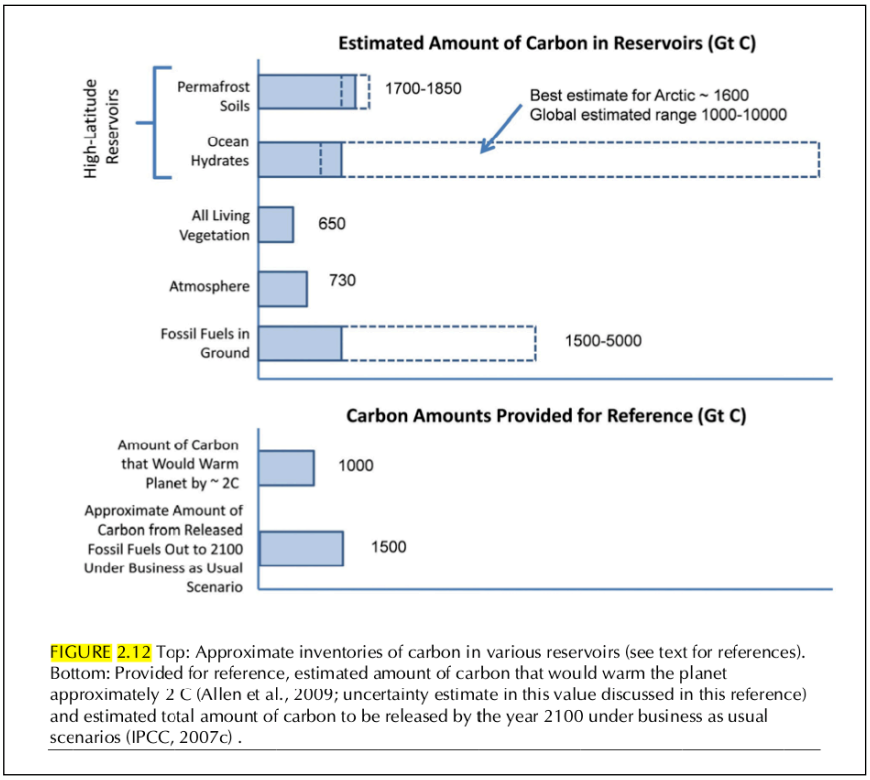


FIGURE 2.12 Top: Approximate inventories of carbon in various reservoirs (see text for references). Bottom: Provided for reference, estimated amount of carbon that would warm the planet approximately 2 C (Allen et al., 2009; uncertainty estimate in this value discussed in this reference) and estimated total amount of carbon to be released by the year 2100 under business as usual scenarios (IPCC, 2007c) .

Source: National Research Council, 2013.

Uncertainties associated with permafrost carbon thawing are high. "Under business as usual climate forcing scenarios," wrote NRC in 2013, "much of the upper permafrost is projected to thaw within a time scale of about a century. Exactly how this will proceed is uncertain. The rate of carbon degradation increases nonlinearly with temperatures above the freezing point of water." The NRC added, in 2013:

> [I]t is clear that the time scale for deep permafrost thaw is measured in centuries, not years….There are no currently proposed mechanisms that could liberate a climatically significant amount of methane or CO_2 from frozen permafrost soils within an abrupt time scale of a few years, and it appears gradual increases in carbon release from warming soils can be at least partially offset, owing to rising vegetation net primary productivity. Over a time scale of decades, however, a possible self-sustaining decomposition…could occur before the end of this century. A related idea is the possibility of rising soil temperatures triggering a "compost bomb instability"—possibly including combustion—and a prime example of a rate-dependent tipping point. Such possibilities would represent a rapid breakdown of the Arctic's very large soil carbon stocks and warrant further research. Even absent an abrupt or catastrophic mobilization of CO_2 or methane from permafrost carbon stocks, it is important to recognize that Arctic emissions of these critical greenhouse gases are projected to increase gradually for many decades to centuries, thus helping to drive the global climate system more quickly towards other abrupt thresholds examined in this report.

Appendix E ICE SHEET LOSS, ARCTIC ICE LOSS, PERMAFROST THAWING, AND EXTREME HEAT THREAT

A demoralizing aspect of climate change science and research can come when something scientists thought changed only gradually may instead change abruptly. One 2016 expert assessment[8] of permafrost thawing stated:

> Assessments indicate that end-of-the-century organic carbon release from Arctic rivers and collapsing coastlines could increase by 75% while carbon loss via burning could increase four-fold. Experts identified water balance, shifts in vegetation community, and permafrost degradation as the key sources of uncertainty in predicting future system response. *In combination with previous findings, results suggest the permafrost region will become a carbon source to the atmosphere by 2100 regardless of warming scenario but that 65%–85% of permafrost carbon release can still be avoided if human emissions are actively reduced*.[9]

In the main it appears that the nations of the world continue at a largely "business-as-usual" clip with regard to GHG emissions. The above phrase "will become a carbon source to the atmosphere" means that the balance of methane and carbon dioxide from permafrost thawing will be a "source" releasing more carbon to the atmosphere, rather than becoming a "sink" (the more desirable situation in which carbon is chemically and physically prevented from interacting with heat in Earth's atmosphere).[10] The 2016 expert assessment sought to evaluate whether forest or other biomass growth on the continents could counteract methane and carbon dioxide release, but they concluded that "Combining our estimates of biomass uptake with a recent projection of permafrost soil carbon release suggests that the permafrost region will become a carbon source to the atmosphere by 2100 for all warming scenarios."[11] They further concluded that

> [O]ur results indicate a 5-fold difference in emissions between the business as usual scenario (RCP 8.5) and active reduction of human emissions (RCP 2.6), suggesting that up to 85% of carbon release from the permafrost region can still be avoided, though the window of opportunity for keeping that carbon in the ground is rapidly closing. Models projecting a strong boreal carbon sink and models that do not consider hydrologic and fire emissions may substantially underestimate net carbon release from the permafrost region. If such projections are used as the basis for emissions negotiations, climate targets are likely to be overshot.[12]

But permafrost is now thought to be thawing faster. An international team of field researchers studying permafrost carbon feedback (the process that includes its thawing) published research in August 2018—the same month that California's Fourth Climate Change Assessment and its supporting reports appeared—showing that "methane and carbon dioxide emissions from abrupt thaw beneath thermokarst lakes [which form where ice in soil melts and causes the structure of land to fail] will more than double radiative forcing [meaning increased atmospheric heat] from circumpolar permafrost-soil carbon fluxes this century." They added, "These findings demonstrate the need to incorporate abrupt thaw process in earth system models for more comprehensive projection of" permafrost carbon feedback the rest of this century.[13] "The release of this carbon as [methane] and [carbon dioxide] is irreversible in the 21st century," they conclude, adding, "This irreversible, abrupt thaw climate feedback is large enough to warrant…[speeding] up deep permafrost-carbon thaw and placed into large-scale models used to predict the rate of Earth's climate change."[14]

In a comment submitted to the British science magazine, *Nature*, another team—only one member of which authored the 2018 paper to *Nature* about the acceleration of permafrost thawing—

raised urgent questions about the uncertainties and potential dangers of rapid release of methane and carbon dioxide from melting permafrost. In a particularly vivid and dramatic passage —for erstwhile dispassionate scientists, especially—this team told their *Nature* readers:

Thermokarst lakes along the Arctic coast in Alaska, which form when ice and permafrost thaws. Source: Turetsky et al 2019.

> Current models of greenhouse-gas release and climate assume that permafrost thaws gradually from the surface downwards. Deeper layers of organic matter are exposed over decades or even centuries, and some models are beginning to track these slow changes.
>
> But models are ignoring an even more troubling problem. Frozen soil doesn't just lock up carbon —it physically holds the landscape together. Across the Arctic and Boreal regions, permafrost is collapsing suddenly as pockets of ice within it melt. Instead of a few centimetres of soil thawing each year, several metres of soil can become destabilized within days or weeks. The land can sink and be inundated by swelling lakes and wetlands.

Crater in eastern Russia formed when land began to sink in the 1960s owing to permafrost thawing. Source: Turetsky et al 2019.

> Abrupt thawing of permafrost is dramatic to watch. Returning to field sites in Alaska, for example, we often find that lands that were forested a year ago are now covered with lakes. Rivers that once ran clear are thick with sediment. Hillsides can liquefy, sometimes taking sensitive scientific equipment with them.
>
> This type of thawing is a serious problem for communities living around the Arctic.…Roads buckle, houses become unstable. Access to traditional foods is changing, because it is

becoming dangerous to travel across the land to hunt. Families cannot reach lines of game traps that have supported them for generations.

In short, permafrost is thawing much more quickly than models have predicted, with unknown consequences for greenhouse-gas release. Researchers urgently need to learn more about it.[15]

We relate this profound concern of scientists who study melting permafrost because methane is the dominant form of carbon released from these lakes while there is still water in them. Methane's rate of heat absorption in the atmosphere is at least 25 times that of carbon dioxide. Permafrost thaw may "source" carbon to the atmosphere, accelerating the climate warming projected for the end of this century closer to our present—but we don't know yet how close or how hot, because keepers of global climate models have not yet built into them abrupt permafrost thaw.

We relate this profound concern of scientists about permafrost thaw too because in a July 2019 Union of Concerned Scientists study the heat anticipated to increase the number of days that American cities will experience by mid-century does not factor in the acceleration of carbon release from permafrost thawing. They relied on the same climate scenarios as did California's Fourth Climate Change Assessment (RCPs 4.5 and 8.5; Chapter 3, this report).

Two decades ago, several studies found that Arctic sea ice had thinned and decreased in extent over the twentieth century, and that future GHG emissions and warming were likely to further reduce Arctic ice cover. Some climatologists study how heat energy circulates through complex mechanisms in Earth's atmosphere, redistributing colder and warmer air and colder and warmer ocean waters between the tropics and the poles.[16]

Early this century, some modeling studies indicated "the surprising result that decreased Arctic sea ice causes drying of western North America," which of course includes California.[17] Many of us are less surprised now. More recently, several other California-based scientists concluded that "sea-ice loss of the magnitude expected in the next decades could substantially impact California's precipitation, thus highlighting another mechanism by which human-caused climate change could exacerbate future California droughts…. Our results implicate both Arctic and Antarctic sea-ice loss as potential drivers of future precipitation changes over the American southwest. We show that substantial loss of high-latitude sea-ice cover [in both northern and southern hemispheres] is likely to have significant far-field effects, and can impact California's precipitation through atmospheric teleconnections involving tropical convection changes." What happens in the polar latitudes, these and other scientists find, does not stay in the polar latitudes.[18]

---

[1] NRC sea level rise projections reproduced in Pierce, et al, *op. cit.*, Table 5, p. 61.

[2] Damian Carrington, "'Extraordinary thinning' of ice sheets revealed deep inside Antarctica: New research shows affected areas are losing ice five times faster than in the 1990s, with more than 100 m thickness gone in some places," *The Guardian.* 16 May 2019. Accessible at https://www.theguardian.com/environment/2019/may/16/thinning-of-antarctic-ice-sheets-spreading-inland-rapidly-study; Studies referred to in this article are: Martin, D.F., et al. 2019. Millennial-Scale Vulnerability of the Antarctic Ice Sheet to Regional Ice Shelf Collapse. *Geophysical Research Letters.* 46: 1467-1475. Accessible at http://dx.doi.org/10.1029/2018GL081229; and Shepherd, A., et al. 2019. Trends in Antarctic Ice Sheet Elevation and Mass. *Geophyusical Research Letters*. Accessible at https://doi.org/10.1029/2019GL082182.

[3] Some research points to a countervailing process that may slow ice-sheet loss in the Antarctic. See Larour, E., et al. 2019. Slowdown in Antarctic mass loss from solid Earth and sea-level feedbacks. *Science.* 364: 969. Accessible at https://science.sciencemag.org/content/364/6444/eaav7908/tab-pdf; and Steig, E.J. 2019. How fast will the Antarctic ice sheet retreat? Feedbacks between glacier retreat and the solid Earth may slow ice loss from Antarctica. *Science.* 364: 7 June. Accessible at https://science.sciencemag.org/content/364/6444/936/tab-pdf. Steig notes, however: "For those concerned about potentially catastrophic sea level rise, the results of Larour et al may be taken as welcome news. But it is important to recognize that [they] do not make a specific prediction. There are too many unknowns about the topography of the glacier bed at the finest spatial scales, the process of glacier calving, and how winds and ocean currents will change. Rather, the results should serve as a guide to the magnitude and sign of uncertainty in existing predictions, and as a road map for future research. Accounting for solid-earth feedbacks suggests that although the greatest effects may be delayed by a few decades, Antarctic ice sheet retreat remains virtually certain."

[4] According to the United States Environmental Protection Agency (USEPA), each gas's effect on greenhouse warming and climate change depends on three main factors: How much of each gas is in the atmosphere? How long do they stay in the atmosphere? and How strongly do they impact and interact with the atmosphere? https://www.epa.gov/ghgemissions/overview-greenhouse-gases.

Nitrous oxide is emitted from agriculture, fuel burning, industry, and wastewater treatment, as well as naturally by bacteria in soils breaking down nitrogen and in oceans. Fluorinated gases have no natural sources, therefore they are primarily emitted by industry (where many are used to substitute for ozone-depleting compounds that were phased out to protect Earth's ozone layer) and energy facilities.

[5] National Research Council. 2013. *Abrupt Impacts of Climate Change: Anticipating Surprises.* Washington, DC: National Academies Press, pp. 85-88; and Archer, D., et al. 2009. Ocean methane hydrates as a slow tipping point in the global carbon cycle. *Proceedings of the National Academy of Sciences.* December 8. Accessible at https://www.pnas.org/content/106/49/20596.short.

[6] *Ibid.*, p. 82. Emphasis added.

[7] *Ibid.*, p.84. NRC writes: "The chemical fate of the decomposing carbon (i.e., methane versus CO_2 emission) depends primarily on the availability of oxygen, which is controlled in these settings by how wet the soil is. Dry, well-aerated soils oxidize the carbon to produce CO_2. Wet soils tend to be anoxic [without oxygen], leaving anaerobic fermentation as the degradation pathway. The maximum methane yield fraction is about 50 percent. However, methane can be oxidized to CO_2 in the soil column, so the methane fraction of the net carbon emissions to the atmosphere can be, and usually is, much lower than this."

[8] Abbott, B.W., et al. 2016. Biomass offsets little or none of permafrost carbon release from soils streams, and wildfire: an expert assessment. *Environmental Research Letters.* 11(034014). Accessible at https://iopscience.iop.org/article/10.1088/1748-9326/11/3/034014/pdf. Of expert assessments, the nearly 100 authors of this paper concurred that, "When data are sparse but management decisions are pressing, expert judgments have long been used to constrain possible system response and risk of dangerous or undesired outcomes." This resort to expert assessment here indicates the urgency and seriousness with which these authors regard an abruptly warming permafrost region.

[9] *Ibid.*, p. 3. Emphasis added.

[10] We ask our readers to bear in mind that the ratio of methane to carbon dioxide is almost irrelevant to the hope for comfort from favoring one compound over the other. Release of methane in dominant concentrations will hasten atmospheric warming, in turn accelerating evaporation of water from thermokarst lakes. As those lakes shrink, GHG emissions from decomposition would switch more to carbon dioxide and less methane. Carbon dioxide is the longer-lived GHG of the two.

[11] *Ibid.*, p. 9.

[12] *Ibid.*, p. 11.

[13] Anthony, K.W., et al. 2018. 21st-century modeled permafrost carbon emissions accelerated by abrupt thaw beneath lakes. *Nature Communications.* 9: 3262, p. 1. Accessible at https://www.nature.com/articles/s41467-018-05738-9.

[14] *Ibid*., p. 7.

[15] Turetsky, M.R., et al. 2019. Permafrost collapse is accelerating carbon release. *Nature.* April 30. Accessible at https://www.nature.com/articles/d41586-019-01313-4. Emphasis added.

[16] There are many accounts of ocean circulation, atmospheric circulation, and ocean-atmosphere interactions. Two of note are: Vettoretti, G., et al. 2009. Polar Climate Instability and Climate Teleconnections from the Arctic to the Midlatitudes and Tropics. *Journal of Climate.* 22: 1 July. Accessible at https://doi.org/10.1175/2009JCLI2481.1; and Tomas, R.A., et al. 2016. The Role of Ocean Heat Transport in the Global Climate Response to Projected Arctic Sea Ice Loss. *Journal of Climate.* 29: 1 October. Accessible at https://doi.org/10.1175/JCLI-D-15-0651.1.

[17] Sewall, J.O. and L.C. Sloan. 2004. Disappearing Arctic sea ice reduces available water in the American west. *Geophysical Research Letters.* 31(L06209). Accessible at https://doi.org/10.1029/2003GL019133; and Sewall, J.O. 2005. Precipitation Shifts over Western North America as a Result of Declining Arctic Sea Ice Cover: The Coupled System Response. *Earth Interactions.* Paper 9-026. Accessible at https://doi.org/10.1175/EI171.1.

[18] Cvijanovic, I., et al. 2017. Future loss of Arctic sea-ice cover could drive a substantial decrease in California's rainfall. *Nature Communications*. 8:1947, p. 1, 8. Accessible at https://www.nature.com/articles/s41467-017-01907-4.pdf.