THE YEAR IN WATER 2018 2019

The Bay Institute | bayecotarium

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Gary Bobker
Program Director

Peter Vorster
Hydro-geographer

Greg Reis
Hydrologist

THE BAY INSTITUTE

On the cusp of its 40th year, The Bay Institute (TBI) is the research, policy and advocacy arm of BayEcotarium (501c3) that includes five additional branches- the Aquarium of the Bay, the Sea Lion Center, the Bay Model (established by the US Army Corps of Engineers in 1957), Studio Aqua and the Bay Academy, with a unified mission to protect, conserve and preserve the San Francisco Bay and its watershed from Sierra to the Sea™.

Environment, Equity, Education and Engagement are at the heart of our mandate. While in recent times, reactive measures have dominated most discourses around pandemic shutdowns, it is time to re-think pro-active containment and intelligent design to address the ecosystem of interconnected congruence, as opposed to fractal short-term solutions. Seeking out the common denominator of mindful mobility that reduces carbon footprints, policy planners and thinkers must focus on the next five decades of environmental justice, driven by the core principles that sustain vibrant civil societies. Nature holds the key to its design dynamics. Symbiotic adjacency, organic growth, sustainable rejuvenation, cyclical resilience and biomimetics offer insights into how we envision communities, resources and equitable access as we work towards UN Sustainable Development Goals (SDG).

Since 1981, The Bay Institute's scientists and policy experts have worked to secure stronger protections for endangered species, water quality, and estuarine habitats; reform how California manages its water resources; and design and promote comprehensive ecological restoration projects and programs in San Francisco Bay, the Sacramento-San Joaquin Delta, the Central Valley watershed, and the Gulf of the Farallones.

Much of The Bay Institute's four decades of publications, reports and studies have now been digitally archived and uploaded onto our website. The 20th Anniversary Hard-Cover Edition of the Ecological History of the San Francisco Bay- Delta Watershed is also available on our website.

George Jacob
President and CEO, BayEcotarium

Chief Advisor to UN Environment on Climate Museums (Caribbean)
Board of Directors, ICOM USA
Board of Directors, California Travel Association
Board of Directors, Bay Area Council

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From *San Francisco Bay, Portrait of an Estuary*; Text by John Hart, Photographs by David Sanger (UC Press, ©2003).

INTRODUCTION

In order to understand both the health of the great San Francisco Bay estuary and the sustainability of California's water supplies it is essential to know a few key facts:

- How much water falls each year in the form of rain and snow throughout the Central Valley, and when;
- How much is captured by the state's massive water supply infrastructure system, and when; and,
- How much actually makes it all the way down the rivers and streams of the Sacramento and San Joaquin River basins to the Delta, and ultimately to San Francisco Bay, and when.

Knowing how much water actually flowed down rivers and through the estuary – as opposed to total precipitation – is especially important, because the viability of fish and wildlife populations is closely related to the amount of actual water movement that they experience. The large-scale storage, diversion, and transfer of water throughout the Bay's watershed (and to areas outside of it) radically alters the amount and timing of natural runoff, with devastating results to fish, wildlife, and their habitats throughout the Bay estuary and the river systems that feed it. (More information about how flow alteration affects the Bay ecosystem can be found at https://bayecotarium.org/wp-content/uploads/freshwater_report.pdf).

It's easy to find out how much total precipitation there was – whether it's a wet or dry year. But information regarding how total precipitation was shaped into the actual hydrograph – the magnitude and spatial-temporal extent of how freshwater runoff was altered – is harder to come by.

The Year in Water describes how water management affected the flow of fresh water in each major part of the system. Starting downstream, this report details how the amount and timing of flow into San Francisco Bay from its Delta and Central Valley watershed was modified. Next, we look at modification of flow from the Sacramento and San Joaquin River basins into the Delta, the upper portion of the Bay estuary. Finally, we highlight natural and modified flow patterns in the Tuolumne River, a representative river in the Bay's watershed. These analyses span Water Years (WYs) 2018 and 2019. WY 2018 began in October 2017 and ended in September 2018, and WY 2019 began in October 2018 and ended in September 2019. For each region analyzed, the Year in Water 2018 & 2019 provides the following information:

- **Unimpaired vs. actual flow:** the amount of water that would have flowed if there were no dams or diversions or imports into the Central Valley watershed from the Trinity River, compared to the flow that actually occurred, after accounting for water storage and diversion activities. Unimpaired flow is an important measure to use because it reflects the natural variability of precipitation, a critical factor for both ecosystem health and sustainable water use. Because of watershed modifications that have altered natural runoff patterns, unimpaired flow is not the same as natural flow.
- **Actual vs. minimum required flow:** the amount of water that actually flowed, compared to the minimum amount required by various regulations.
- **Actual flow vs. diversions:** the amount of water that actually flowed, compared to the amount of water diverted for offstream uses such as irrigation and municipal and industrial supply.
- **A comparison of 2018-2019 inflows with the historical record:** the water year type and volume of water in 2018 & 2019, compared to the 1975-2019 record.

Throughout this document, water year types refer to quintiles based on unimpaired flow exceedances. The five categories (and their exceedances) are Wettest (0-20%), Above Average (20-40%), Average (40-60%), Below Average (60-80%), and Dry (80-100%). Each of these categories represent one-fifth of the years as measured by unimpaired runoff. The Super Critical category, which is a subcategory of Dry, represents the driest 2 years in the record.

The bottom line for YW 2018 & 2019? Due to high reservoir storage at the end of 2017--the second wettest year on record--actual inflows in 2018 were often higher than the current minimum required flows. Yet 2018 was Below Average, and these flows were still dramatically reduced from unimpaired flows or even from the minimum amounts that the scientific record indicates is needed to protect and restore viable fish and wildlife populations. In contrast, 2019 was in the Wettest quintile of unimpaired flow, and actual inflows were much higher than the current minimum required flows (although still much less than unimpaired flows). As a result, unlike 2018 and most other years, 2019 flows often achieved the minimum thresholds that the scientific record indicates is needed to protect and restore viable fish and wildlife populations—a condition now usually only met in the Wettest years in our highly altered system.

WATER YEAR 2018

	Actual % of Unimpaired	Minimum Required Flow	Net Diversions	Public Trust Criteria
San Francisco Bay (Jan-Jun)	42% (7.1 MAF)	24% (4.0 MAF)	58% (9.7 MAF)	75% (12.6 MAF)
Sacramento Basin (Nov-Jun)	65% (8.8 MAF)	4% (0.5 MAF)	35% (4.8 MAF)	75% (10.2 MAF)
San Joaquin Basin (Feb-Jun)	26% (1.0 MAF)	18% (0.7 MAF)	74% (2.8 MAF)	60% (2.3 MAF)
Tuolumne River (Feb-Jun)	28% (0.4 MAF)	7% (0.1 MAF)	71% (1.0 MAF)	60% (0.8 MAF)

WATER YEAR 2019

	Actual % of Unimpaired	Minimum Required Flow	Net Diversions	Public Trust Criteria
San Francisco Bay (Jan-Jun)	62% (24.1 MAF)	20% (7.7 MAF)	38% (14.7 MAF)	75% (29.1 MAF)
Sacramento Basin (Nov-Jun)	80% (22.4 MAF)	2% (0.5 MAF)	20% (5.6 MAF)	75% (21.0 MAF)
San Joaquin Basin (Feb-Jun)	46% (3.6 MAF)	15% (1.2 MAF)*	54% (4.3 MAF)	60% (4.7 MAF)
Tuolumne River (Feb-Jun)	57% (1.4 MAF)	8% (0.2 MAF)*	42% (1.0 MAF)	60% (1.4 MAF)

*Under existing water rights permits. In 2019, the state adopted (but not has not yet implemented) a new requirement that 40% of unimpaired flow remain undiverted on three San Joaquin River tributaries: Stanislaus River, Tuolumne River, Merced River.

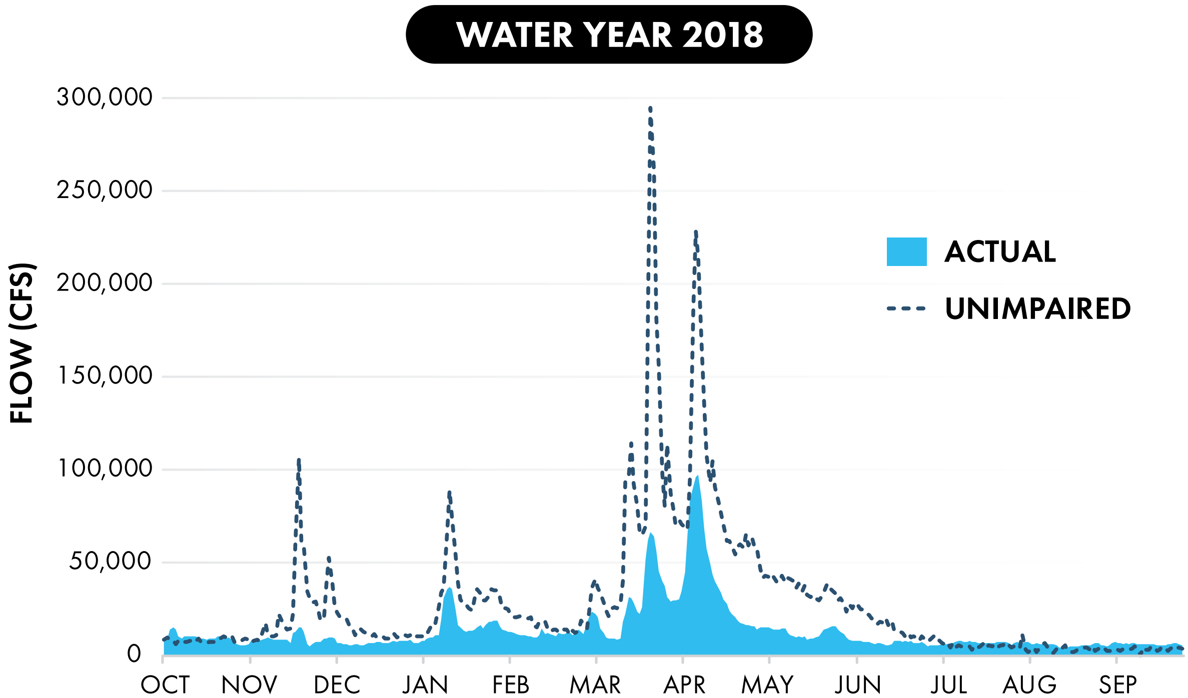
THE YEAR IN WATER: 2018 & 2019

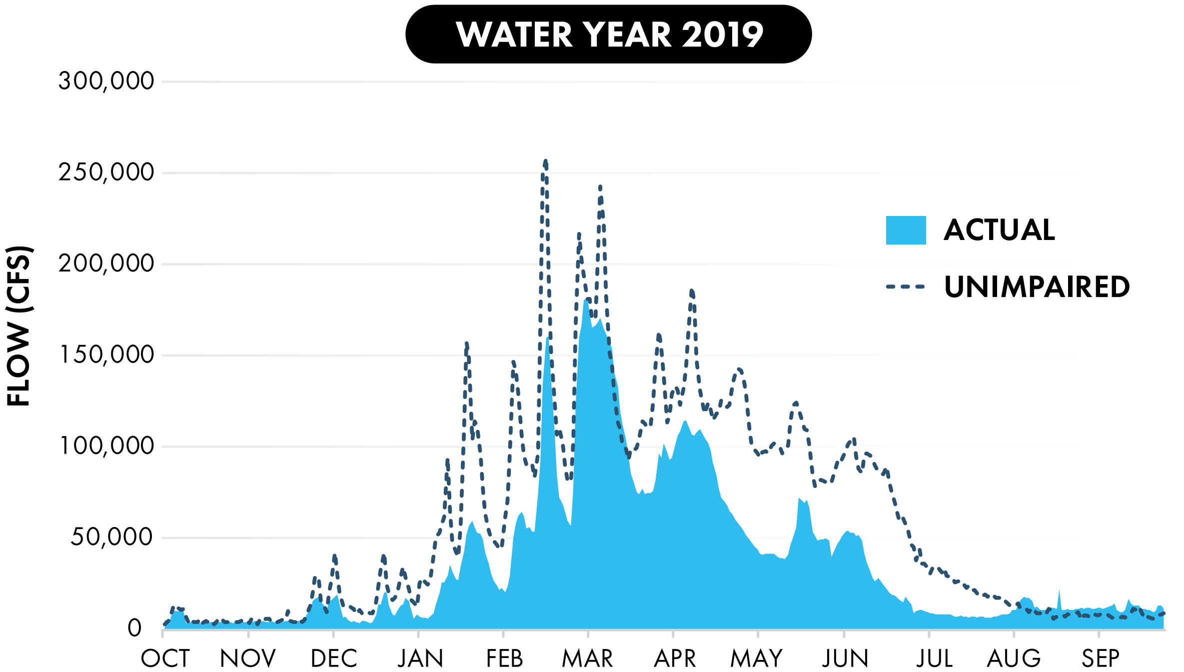
SAN FRANCISCO BAY

FIGURE 1

SAN FRANISCO BAY INFLOW FROM THE CENTRAL VALLEY WATERSHED

Actual vs. Unimpaired





Actual vs. Unimpaired

Figure 1 compares actual inflow to San Francisco Bay (solid blue) in WY 2018 & 2019 with the unimpaired runoff (dashed blue line)--water that would have made it to the Bay if there were no dams or diversions upstream.

In WY 2018, actual Bay inflow was 9.8 million acre-feet (MAF), or only 49% of the 20.2 MAF of unimpaired runoff from rainfall and snowmelt in the Bay's Central Valley watershed. As a result, whereas 2018 water year was a Below Average year in terms of what nature provided as runoff, in terms of the actual volume of water experienced by the fish and wildlife of San Francisco Bay, WY 2018 was transformed into a Dry year.

Because of high storage levels in Central Valley reservoirs as a result of high runoff in WY 2017, which resulted in higher reservoir releases because of flood control criteria, the level of flow impairment in WY 2018 was slightly less than in many previous years (see Fig. 6). Nonetheless, many of the large peaks in runoff during fall, winter and spring were captured by these upstream reservoirs, leaving a small proportion of unimpaired runoff flowing to the estuary. Bay inflow was augmented by releases from reservoir storage, mostly to maintain water quality (salinity) in the western Delta, first to implement Delta smelt protections in October and then to protect municipal, industrial, and agricultural uses the following summer.

During the ecologically critical January - June period, when many fish spawn, rear and/or migrate through the Bay on their way to or from spawning grounds, the percent of actual inflow was even less than the annual value – only 42% of unimpaired runoff. Storage and diversion of peak flows in March and April reduced the volume of water flowing into the Bay during these months by an average of 53,000 cfs.

In WY 2019, actual Bay inflow was 27.5 MAF, just 63% of the 43.8 MAF of unimpaired runoff. During the ecologically-critical January through June period, 62% of the unimpaired runoff reached the Bay. As a result, whereas 2019 was a Wettest quintile year-type in terms of what nature provided as runoff, in terms of the actual volume of water experienced by the fish and wildlife of San Francisco Bay, 2019 was transformed into an Above Average year.

San Francisco Bay is the centerpiece of a vast estuary and watershed that is home to hundreds of plant and animal species, many found nowhere else on earth, and this ecosystem is highly dependent on the amount of water flowing into it and the timing of those flows. Separate analyses by the Bay Institute and the State Water Resources Control Board have found that approximately 65 – 75% of unimpaired winter-spring runoff is needed to protect and restore viability of the estuary's fish and wildlife populations. Reducing runoff in other times of the year can also be damaging, eliminating usable habitat and lessening food web productivity.

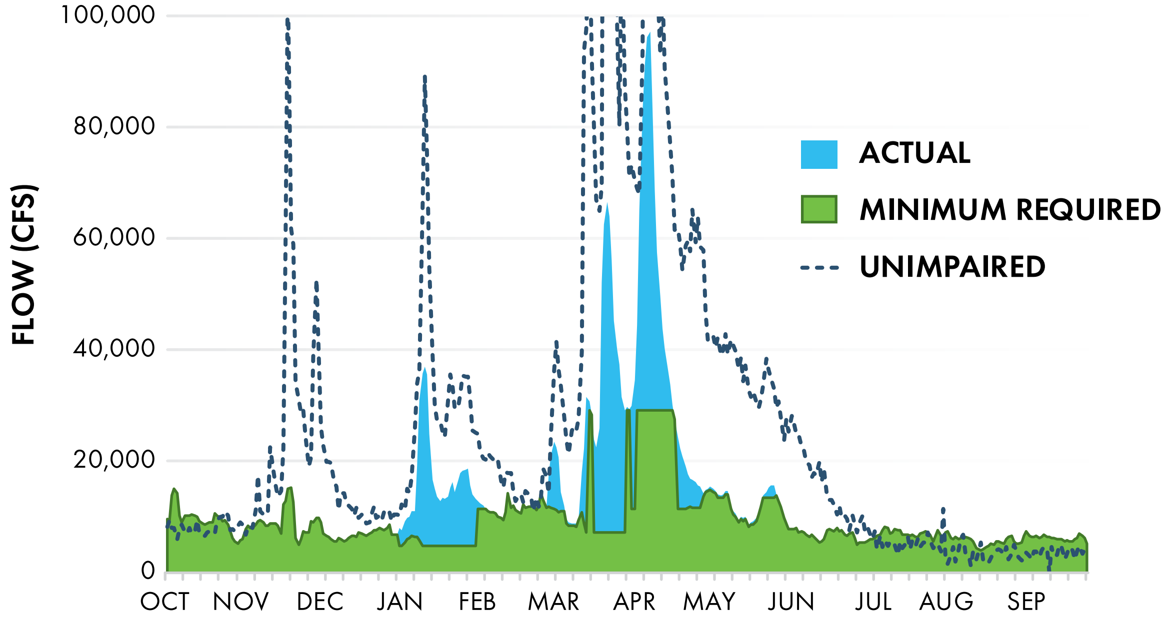
By this measure, the volume of the Wettest year-type flows of January-June 2019 was very close to what the estuary needs, providing a rare respite from chronic human-caused drought conditions. Unfortunately, it will take a lot more than one good year to help fish populations at or near record lows to rebound to sustainable levels.

FIGURE 2

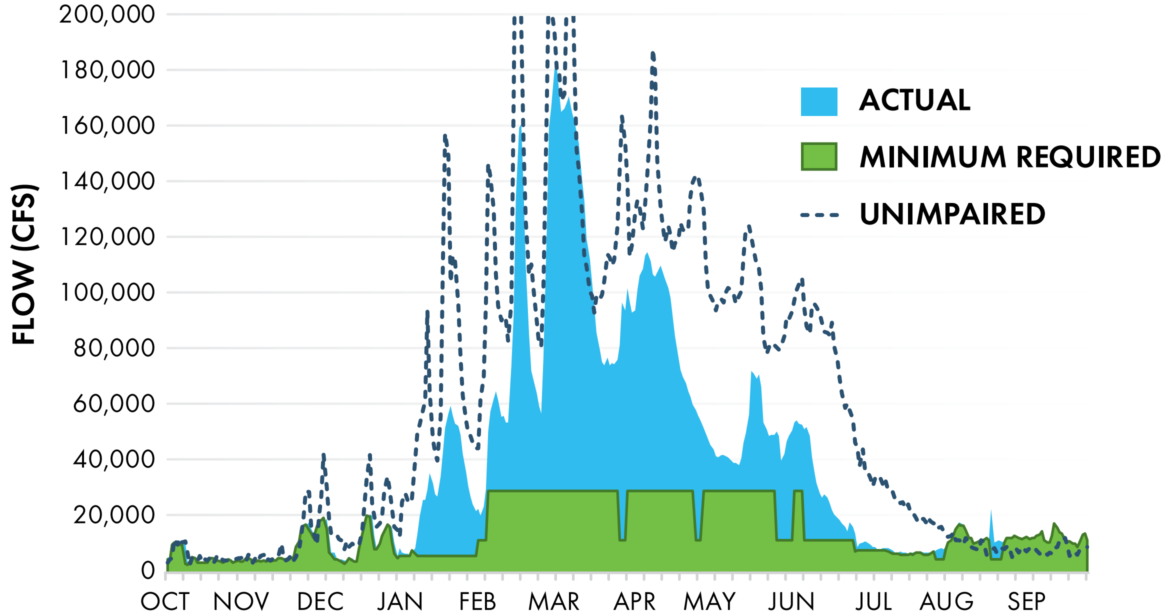
SAN FRANISCO BAY INFLOW FROM THE CENTRAL VALLEY WATERSHED

Actual vs. Minimum Required

WATER YEAR 2018



WATER YEAR 2019



Actual vs. Minimum Required

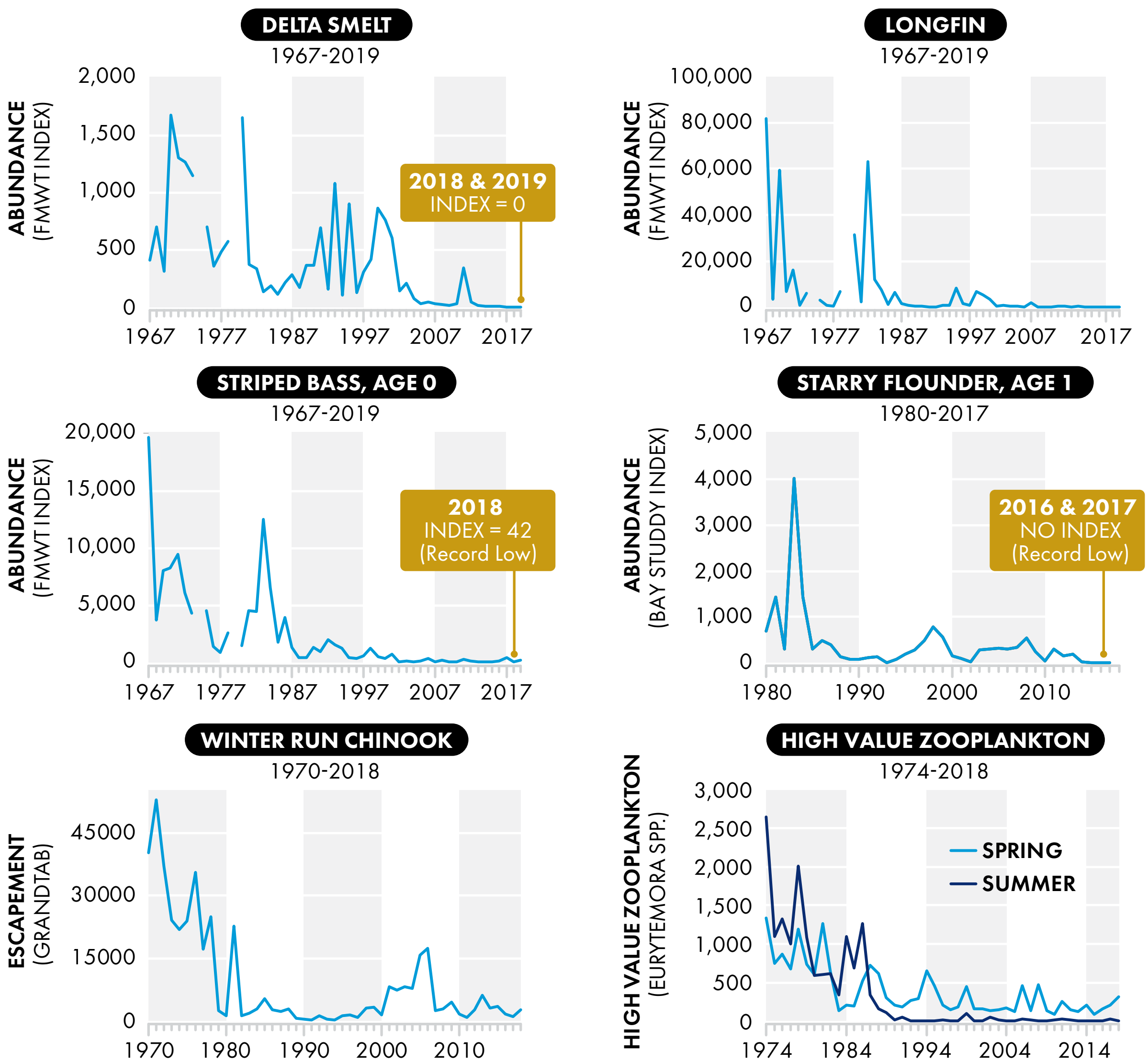
Figure 2 compares actual Bay inflow (solid blue) and unimpaired runoff (dashed blue line) with the flows (solid green) required to meet state water quality standards for the Bay and Delta, as well as federal Endangered Species Act protections for Delta smelt that applied in the fall of wet years like 2017 and 2019. (This analysis reflects the federal requirements, adopted in 2008-9, that were in place during 2018 and 2019, not the much weaker ones adopted in 2020 by the Trump Administration. The analysis also does not include the 2008-9 ESA restrictions on Delta exports, since those restrictions did not specifically require additional Bay inflow but only restrict export pumping of upstream releases that reach the Delta). Termed "Fall X2", this flow is often reduced for the purposes of "adaptive management." The Trump Administration's newly adopted biological opinions for smelt, salmon and steelhead reduce or eliminate Fall X2 and restrictions on exports that are intended to protect salmon and steelhead. Lower carryover storage proposed for the State Water Project and federal Central Valley Project in future years could also eliminate a portion of the January-March high flows, especially in years like 2018 and 2019 when flood control releases occurred.

Even though only 49% of total runoff actually made it to the Bay, WY 2018 was still one of those years in which inflow exceeded minimum requirements for much of the peak runoff season, largely because of high existing storage levels as a result of the extremely wet WY 2017 conditions. During the January through June period, uncaptured runoff from rainfall in lower elevations, flow from the watershed's few remaining uncontrolled streams, and flood control releases from large reservoirs combined to provide 3.1 MAF of Bay inflow in excess of the minimum required for fish and wildlife, or a startling 44% of the total January – June actual inflow to the Bay. The Wettest year-type flows of 2019 exceeded minimum flows to an even greater degree.

In most years, the amount of water that actually makes it to the Bay exceeds the minimum required under federal and state laws, which is far less than the minimum needed to protect fish, wildlife, and their habitat according to the best available science. (The Bay Institute's analyses indicate that 65 -75% of runoff should reach the Bay; Figure 3 shows how the populations of many flow-dependent species have collapsed after decades of inadequate flow conditions and other problems). These relatively brief periods during winter and spring can provide an important measure of relief from otherwise generally bleak conditions for the Bay estuary's imperiled native species, especially in the Wettest year-types when very high flood peak flows exceed the capacity to store and divert them. Numerous efforts underway to expand or construct reservoirs, recharge groundwater with flood flows, and modify real-time reservoir operations using better forecasting tools could reduce or eliminate these "surplus" flows in the future, unless minimum required flows are increased based on the strong evidence that significantly higher flows are needed to protect the Bay ecosystem.

FIGURE 3

COLLAPSE OF SPECIES ACROSS MULTIPLE TROPHIC LEVELS



Data provided by: California Department of Fish and Wildlife's Bay Study, Fall Midwater Trawl, Zooplankton Study, Anadromous Resources Assessment and the Interagency Ecological Program for the San Francisco Estuary.

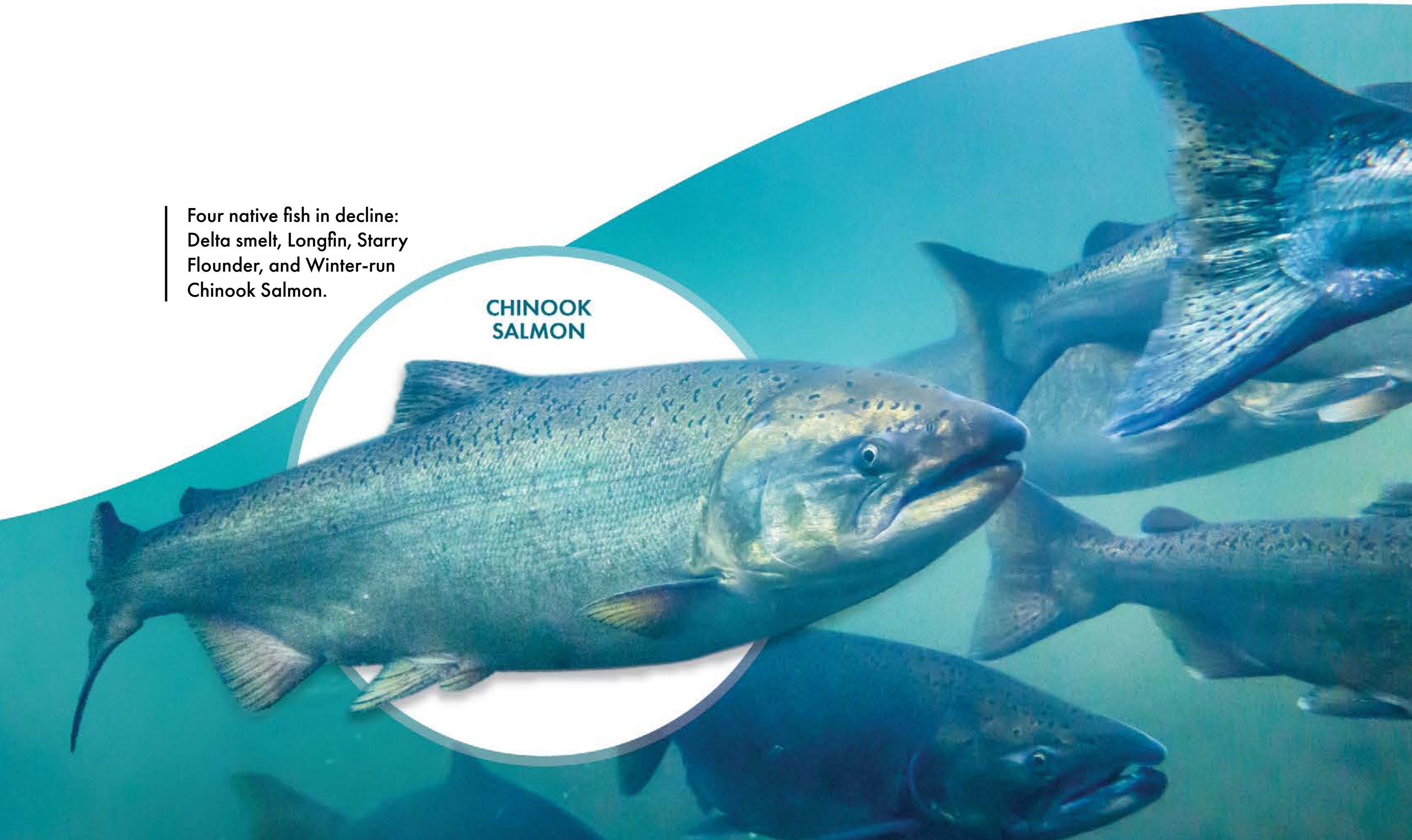
Photo by Rene Reyes, USBR

Photo by Peter Johnsen, USFWS

Collapse of Species Across Multiple Trophic Levels

Figure 3 shows the collapse of populations of native and desirable aquatic organisms across multiple trophic levels. Many species have been declining since the 1970s. 2019 surveys found record or near record low abundances of Delta smelt and longfin, once the estuary's most common fish species, and 2018 was a record low for striped bass (a popular game fish introduced in 1879). Since 2015, starry flounder have not been abundant enough to produce an index. Almost all the emerging year classes of winter-run Chinook salmon were lost in 2014 and 2015.

The bump in populations that would normally be expected following the wet years of 2017 and 2019 did not materialize, except for striped bass. The likely reason is that population levels have gotten so low that the observation error is now larger than the index, making fluctuations hard to detect. This underlies the need to restore adequate conditions for positive population growth in a greater percentage of years, allowing depressed populations to rebuild over time to sustainable levels and making it easier to maintain them once sustainable levels are achieved. Failure to do so will doom many species to extinction.

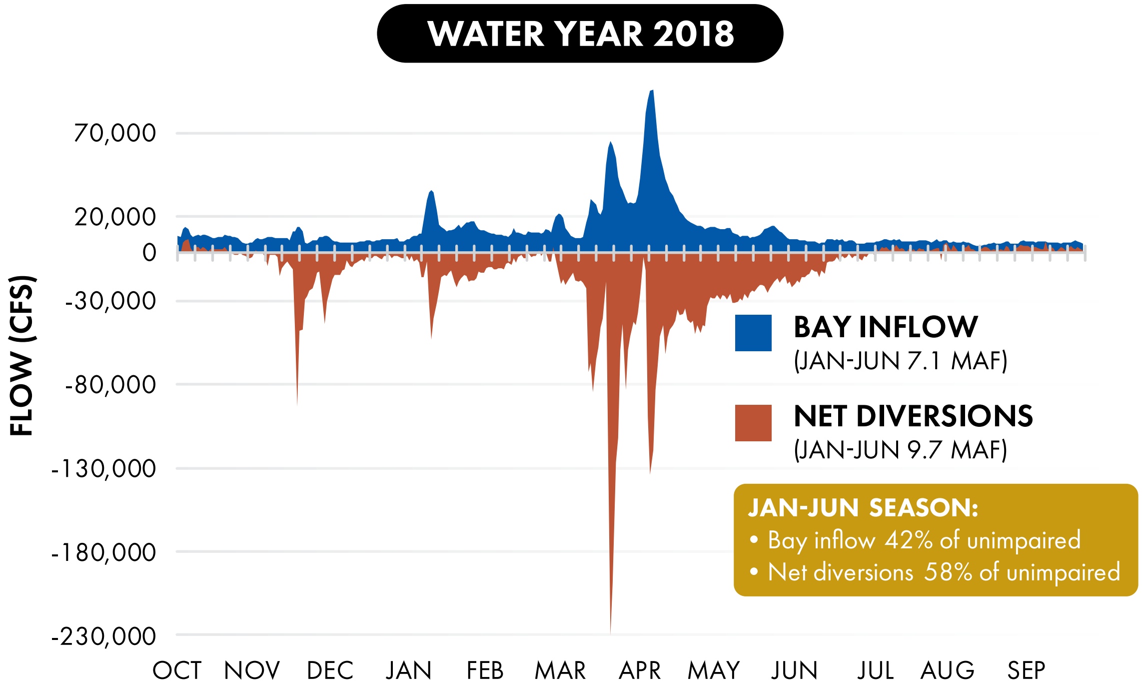


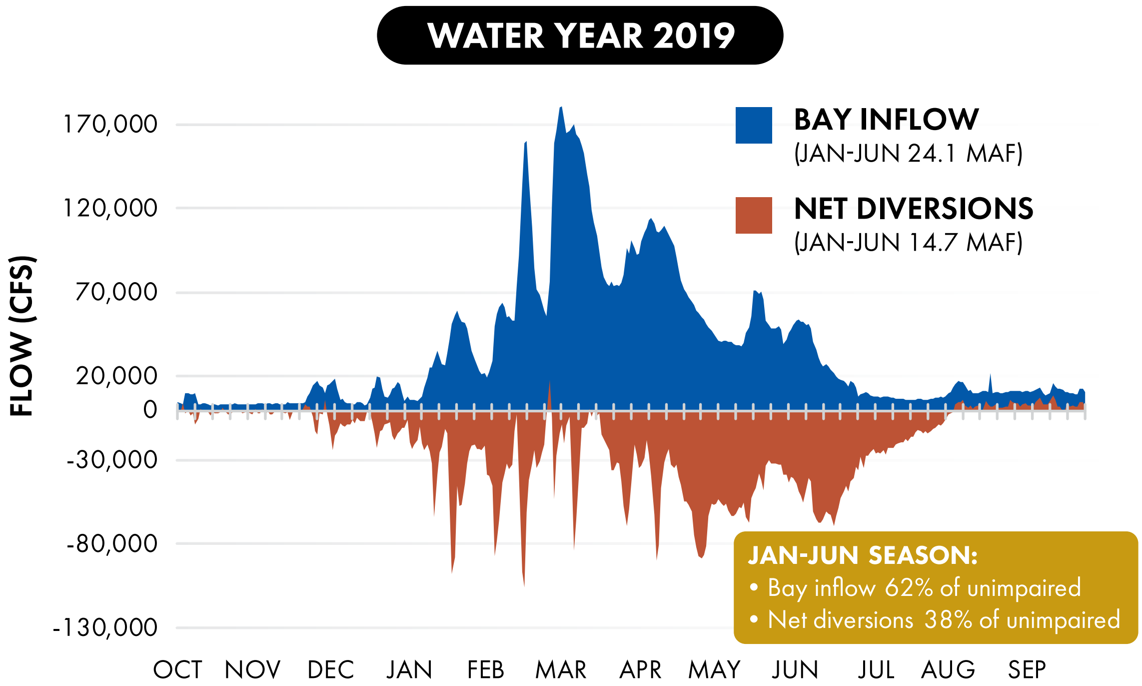
Four native fish in decline: Delta smelt, Longfin, Starry Flounder, and Winter-run Chinook Salmon.

FIGURE 4

SAN FRANISCO BAY INFLOW FROM THE CENTRAL VALLEY WATERSHED

Bay Inflow vs. Net Diversions





Bay Inflow vs. Net Diversions

Figure 4 directly contrasts and compares the amount of water that occurred as actual Bay inflow (solid blue) versus the amount of net diversions from the Bay's watershed (solid brown). The solid brown shows the amount of net runoff that did not make it all the way to the Bay due to dams and diversions. This is actually less than the total amount of water used in the Bay's watershed and areas outside the watershed that import water from it, because total water use includes withdrawals from water previously stored in reservoirs and aquifers and water imported from other watersheds, such as the Trinity River.

There are periods when actual flows can exceed unimpaired runoff during the summer and fall, when water is released from storage to protect drinking and irrigation water quality from salinity incursions. These augmentations are shown as net diversions (brown) occurring above the horizontal axis at the base of the blue area.

The 2018 portion of Figure 4 demonstrates the inaccuracy of the assertion – frequently made by water districts, politicians and even the media – that the majority of the state's water is "wasting to the sea". Ignoring the fact that freshwater inflow reaching estuaries and coastal waters is ecologically vital to their health, the reality is that in WY 2018 the net diversion of 9.7 MAF, or 58% of the January through June high flow season runoff, when uncontrolled "surplus" flow reaches the estuary, was far greater than the 7.1 MAF that actually reached the Bay. Even the Wettest year of 2019 fell just below the "healthy estuary" threshold of 65-75% when diversions are factored in.

3 TYPES OF DIVERSIONS

Upstream Dams

Friant Dam

Photo by Greg Reis

Large Pumps

CVP pumps in the Delta

Direct Diversions

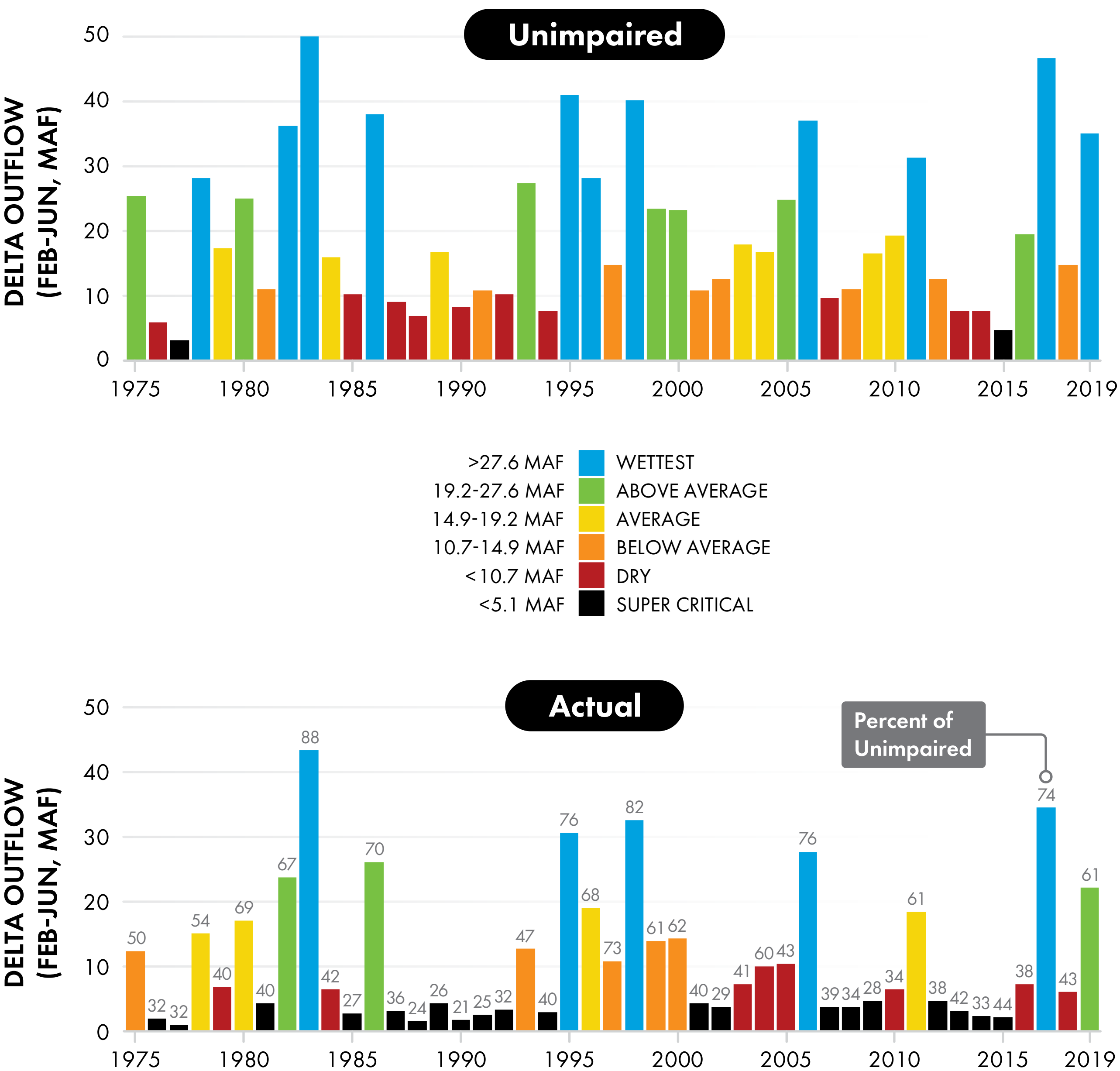
Sack Diversion Dam

Photo by Greg Reis

FIGURE 5

SAN FRANCISCO BAY INFLOW FROM THE CENTRAL VALLEY WATERSHED

Water Years 2018 & 2019 Compared to the Historical Record



Water Years 2018 & 2019 Compared to the Historical Record

Dividing winter-spring runoff conditions into categories, the bar charts in Figure 5 show when Wettest (blue), Above Average (green), Average (yellow), Below Average (orange), Dry (red), and Super Critical (black) years occurred in the Bay's watershed (upper bar graph; "unimpaired") and the corresponding conditions that actually occurred in the Bay (lower bar graph, "actual"). Each of these categories represent one-fifth of the years as measured by their unimpaired runoff, except for the Super Critical category, which represents the driest two years in the 95-year record.

Figure 5 shows how radically disconnected from its watershed San Francisco Bay has been rendered by extremely high levels of storage and diversion upstream. Although Super Critical conditions occurred naturally in the watershed only twice from 1975 through 2019, the Bay experienced these extremely dry conditions in twenty years, or a stunning 44% of the time. Record or near-record low fish population levels and other evidence of ecosystem collapse demonstrate clearly that current water management and minimum required flows are not working.

Category	Unimpaired (years)	Actual (years)
Wettest	11 (24%)	5 (11%)
Above Average	7 (16%)	3 (7%)
Average	7 (16%)	4 (9%)
Below Average	8 (18%)	5 (11%)
Dry (including Super Critical)	12 (27%)	28 (62%)
Super Critical	2 (4%)	20 (44%)

Without dams or diversions, wet 2019 would have had the Bay inflow we actually saw in extremely wet 2017. But due to dams and diversions, "Wettest" 2019 became a rare "Above Average" year.

The upper-middle year-types of "Average" and "Above Average" have become quite rare. The estuary hasn't experienced an Above Average year-type since 1986, and only two Average years since then.

The inadequate minimum flows are doing what they are designed to do—protect the lowest flows, while encouraging the storage and diversion of all the "surplus". Under this type of management, the Bay-Delta gets the extremes: chronic low flows, and the occasional wet year sneaks through. But the critical fact to remember is that positive population growth occurs in the middle and wetter years, when habitat conditions are better--not in drier ones. So it's no surprise that the vast majority of estuarine species that thrive in the middle and wetter years are imperiled by these decisions.

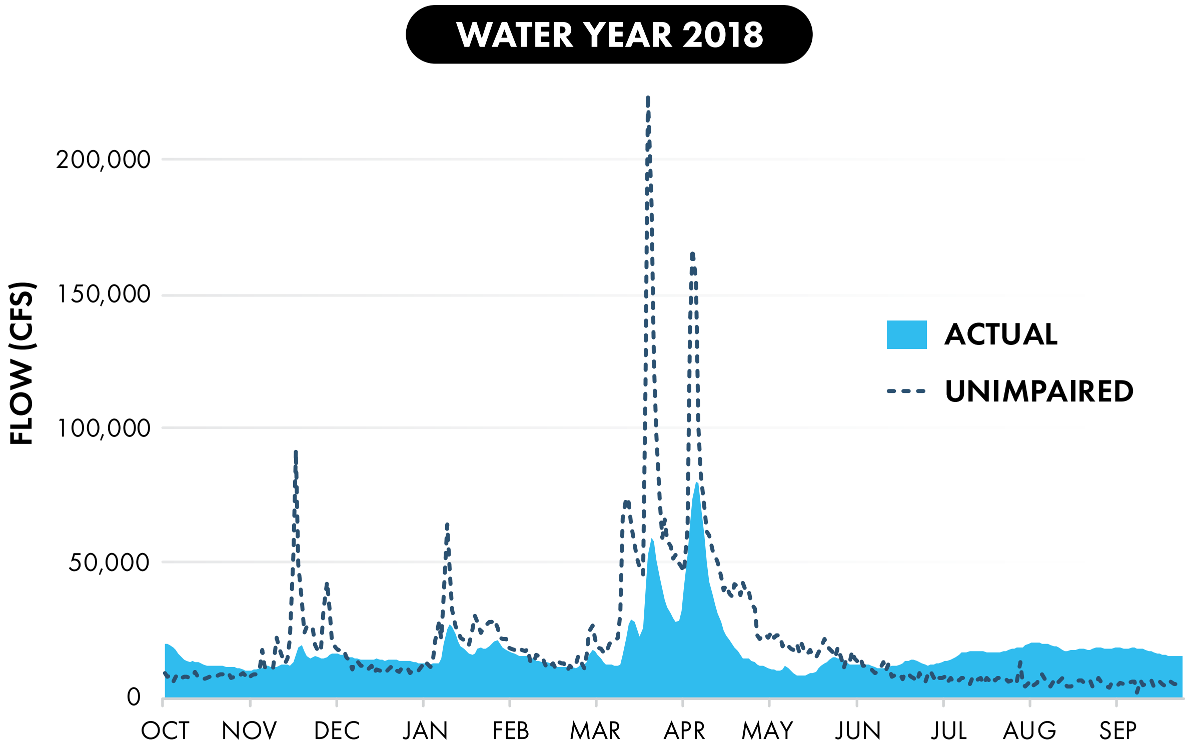
THE YEAR IN WATER: 2018 & 2019

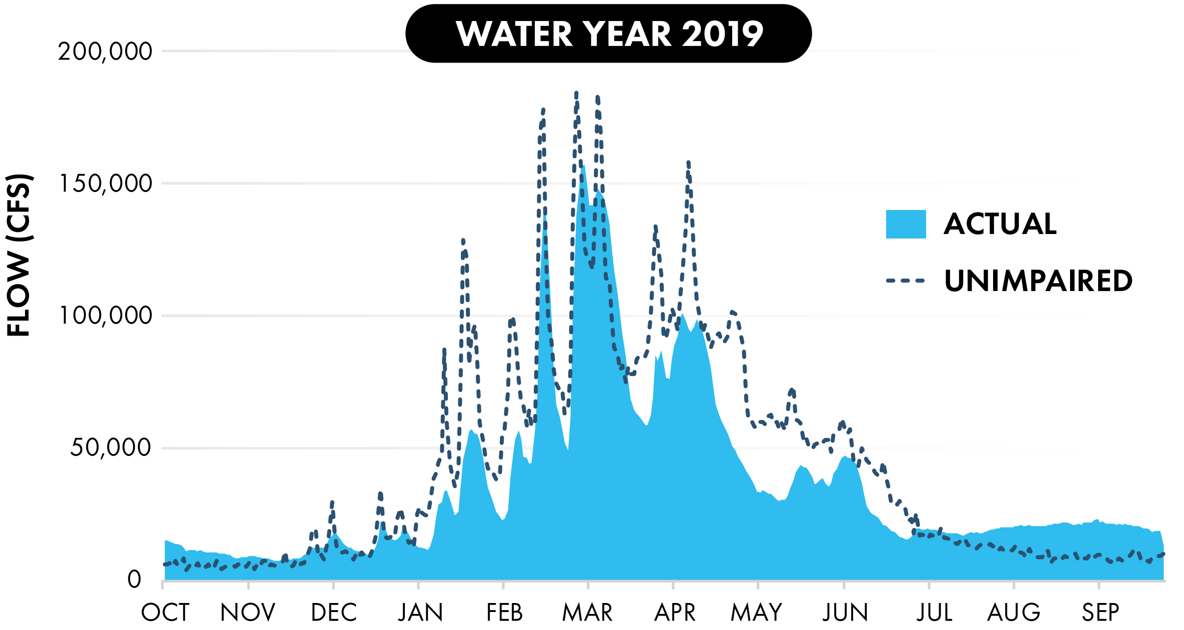
SACRAMENTO BASIN

FIGURE 6

SACRAMENTO RIVER INFLOW TO THE DELTA

Actual vs. Unimpaired

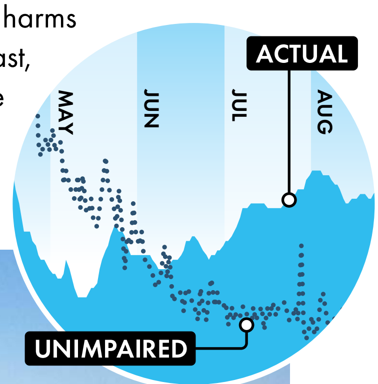




Actual vs. Unimpaired

Figure 6 compares flow from the Sacramento River basin that actually reached the Delta, the upper part of the Bay estuary (solid blue) with unimpaired runoff (dashed blue line). In WY 2018, the 12.9 MAF of actual flow to the Delta represented 86% of 14.9 MAF total annual runoff. However, during the January-June period, only 7.1 MAF reached the Delta – just 63% of the 11.3 MAF of runoff in those months. This is because runoff was stored in large reservoirs like Shasta and Oroville and released in the summer, when much of the Sacramento basin inflow to the Delta is directly exported by the Central Valley Project and State Water Project pumping facilities; some is also used to repel salinity in order to maintain water quality in the Delta. (There are also large inter-basin transfers from the Trinity River for export from the Delta via the Sacramento River in the summer and fall). Starting WY 2018 with relatively full reservoirs following the extremely wet WY 2017 explains both why actual winter – spring flows were relatively high and why there was such a large amount of stored Sacramento basin water conveyed to the Delta in the summer.

The Sacramento River and its tributaries are the source of most of the water that reaches San Francisco Bay and the only river in the world with four runs of Chinook salmon (fall, late-fall, winter, and spring). Due to the flattening of the hydrograph—lowering wintertime peaks and raising summertime low flows—the Sacramento now functions more like a water conveyance than a river, affecting native species and habitats from the uplands to the estuary. The loss of peak winter – spring flows harms salmon migration and degrades downstream habitat and water quality. In contrast, riparian plants are adapted to the unimpaired pattern of receding flows in late spring and early summer, but the altered hydrograph often results in rising flows in excess of unimpaired runoff during this time, as occurred in WY 2018:



This unnatural pattern of flows rising during summer is also evident in 2019. Summertime flows were similar in 2018 (Below Average) and 2019 (Wettest), since at this time of year the Sacramento River is managed as a conveyance for salinity control and exports in the Delta. Summer flows tend to be inflated in excess of unimpaired runoff, and have little variability between years compared to natural variability.

The 2019 WY actual flow of 26.8 MAF was 88% of 30.3 MAF of unimpaired Sacramento Valley runoff. January through June, 20.9 MAF out of 26.6 MAF reached the Delta, or 79% of unimpaired runoff. 2019 was a rare year when the lower Sacramento River experienced Above Average conditions during winter and spring.

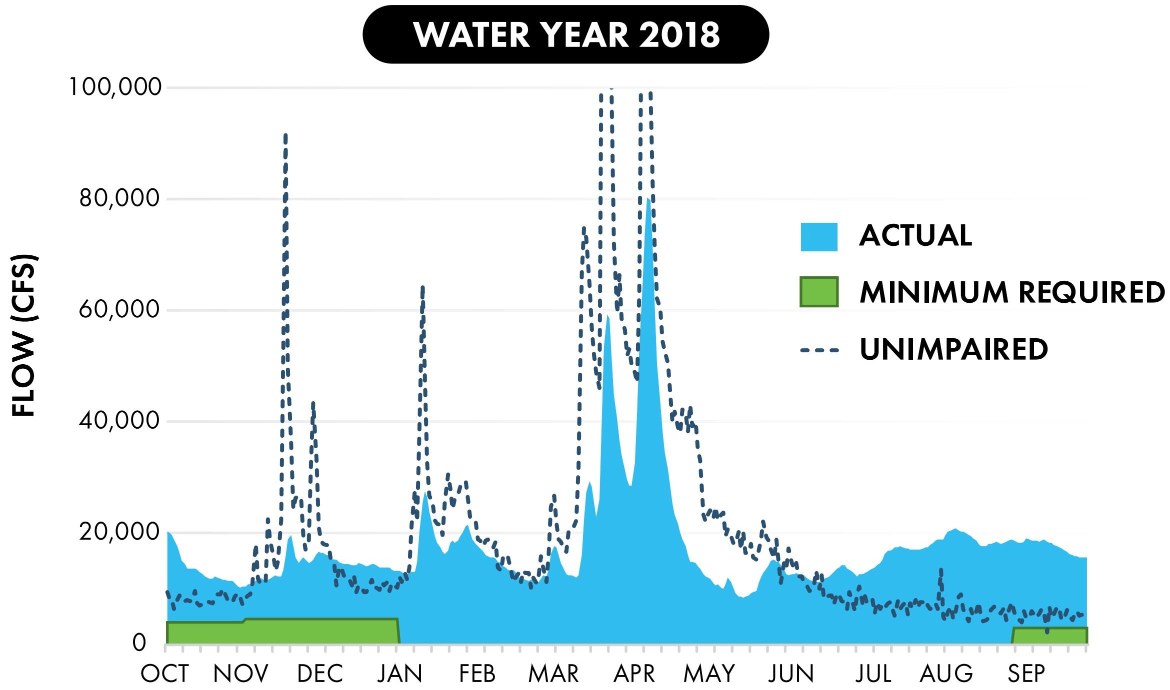
Photo by Greg Reis

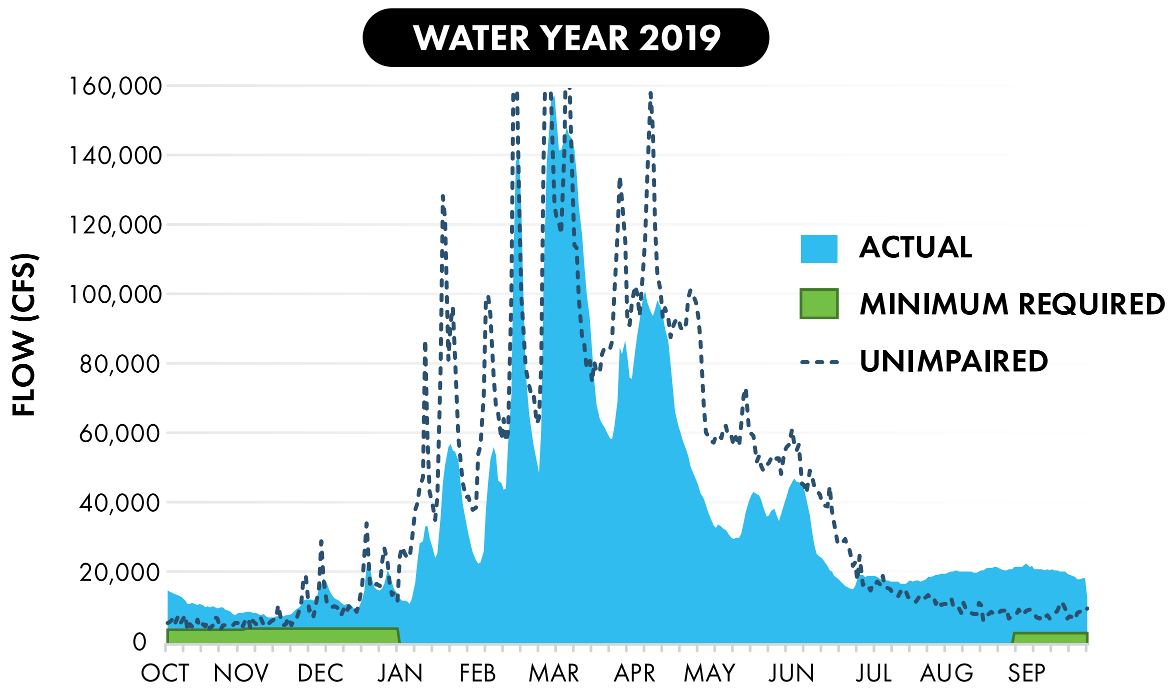
Augmented summer flows and a change in the timing and pattern of spring flows impact riparian vegetation along the Sacramento River.

FIGURE 7

SACRAMENTO RIVER INFLOW TO THE DELTA

Actual vs. Minimum Required





Actual vs. Minimum Required

Figure 7 shows the minimum required flow (solid green) at Rio Vista, intended to keep enough water flowing past the Delta Cross Channel for fish and wildlife protection, compared to both actual (solid blue) and unimpaired (dashed blue line) Sacramento basin inflows. Because the Sacramento River functions as a water conveyance system, the disconnect between unimpaired and actual flows in the winter – spring period, while ecologically significant, was less dramatic in WYs 2018 and 2019 than in the San Joaquin River basin, where storage and diversion for local use is extremely high, or San Francisco Bay, where inflow is reduced upstream by both low San Joaquin inflow and diversion of both Sacramento and San Joaquin inflow at the Delta export pumps.

As noted earlier, the loss of peak flood flows affects river and estuary habitat and the migration of salmonids. Most attention in improving minimum regulatory requirements has focused on these winter – spring impacts. However, summer flows that are higher than unimpaired can limit the extent and abundance of riparian vegetation; the export in the Delta of high summer inflows from the Sacramento River may also be damaging food web productivity by removing large amounts of organic material from the system.

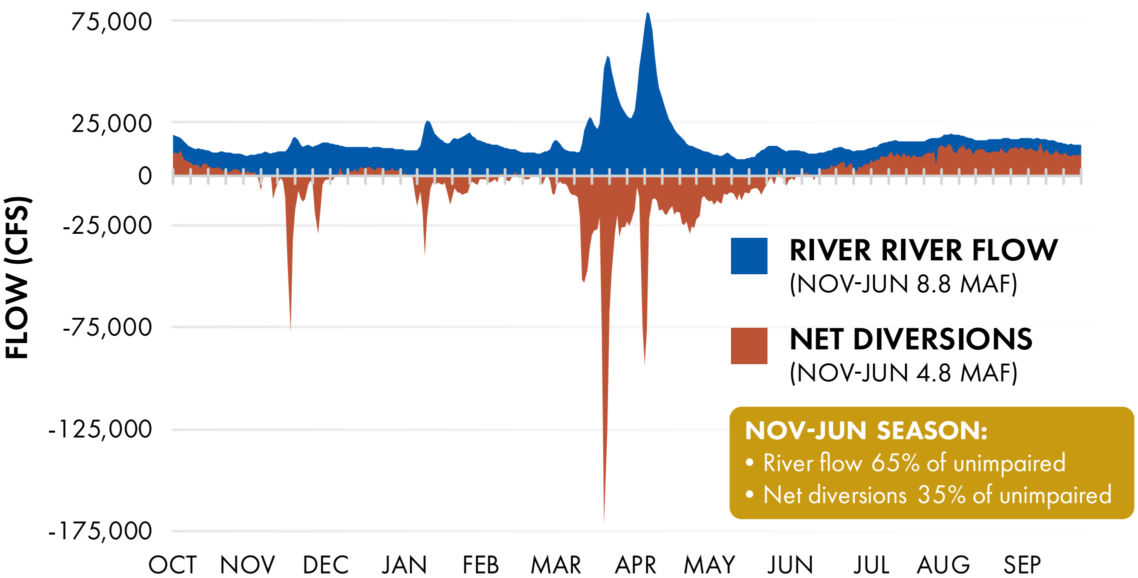
The large degree to which actual flows exceeded minimum required flows in both years is an indication of both the inadequacy of the requirements and the priority given to management of the Sacramento River system as a conveyance for transporting water to the Delta. The larger difference in 2019 is due to wetter conditions. The State Water Board was making progress toward updating the Bay-Delta water quality requirements to ensure that up to 65% of Sacramento basin inflow reaches the Delta, but the so far unsuccessful process to develop voluntary agreements between the Newsom Administration and water districts that would require far less water has been holding up the Board decision.

FIGURE 8

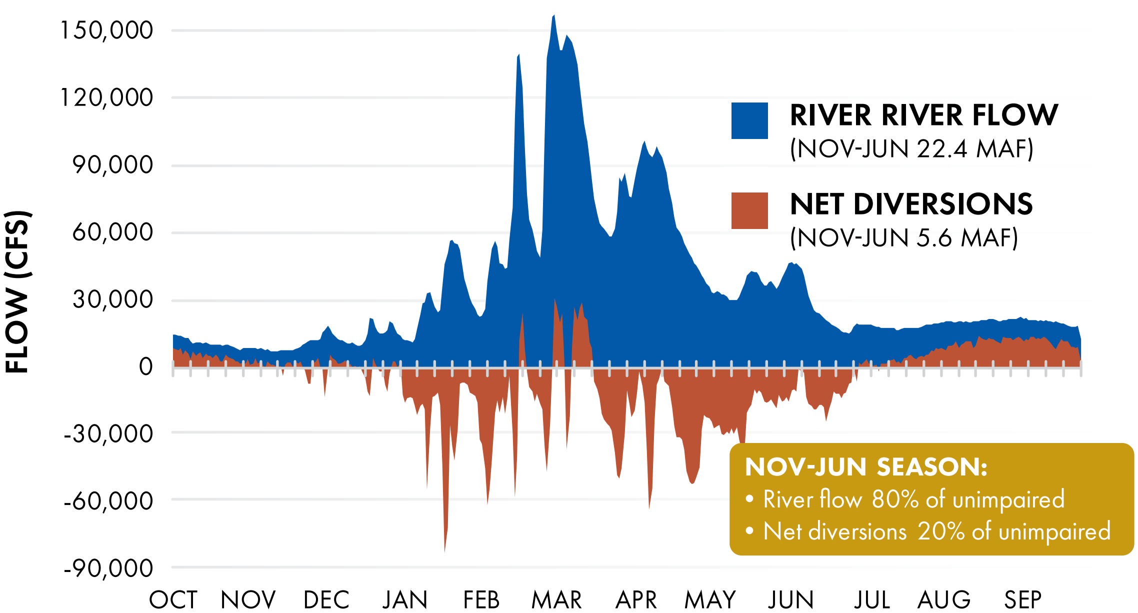
SACRAMENTO RIVER INFLOW TO THE DELTA

River Flow vs. Net Diversions

WATER YEAR 2018



WATER YEAR 2019



River Flow vs. Net Diversions

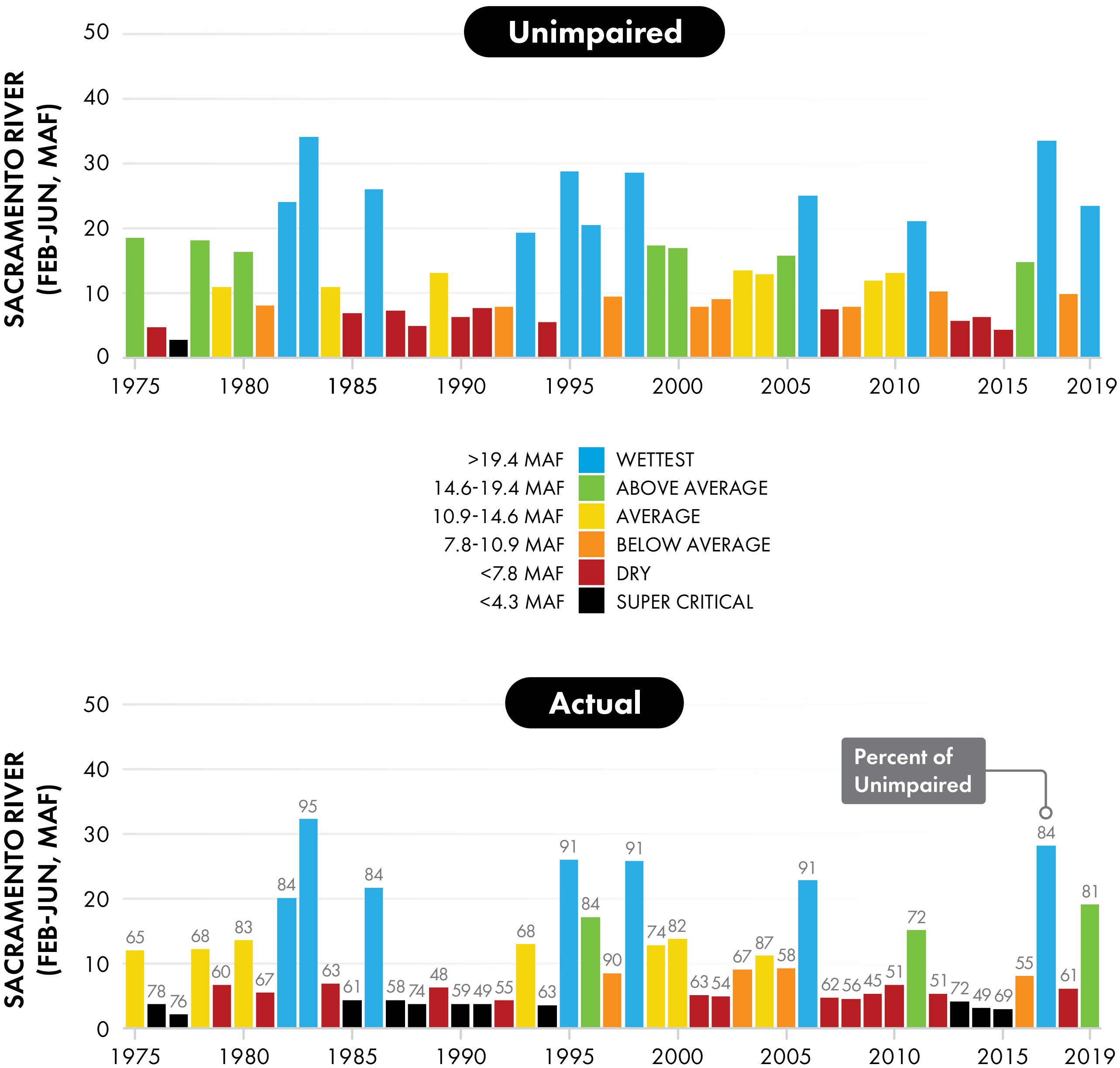
Figure 8 contrasts and compares the amount of water that occurred as actual Sacramento basin inflow to the Delta (solid blue) versus the amount of net diversions within the basin (solid brown). Imported water from the Trinity River and releases from storage during summer and fall for export from the Delta or to repel salinity resulted in actual inflows significantly exceeding unimpaired inflows during those periods; these actions also significantly contribute to net diversions downstream.

Unlike the inflow vs diversion figures for San Francisco Bay, the San Joaquin basin, and the Tuolumne River, Figure 8 represents the one part of the watershed where 2018 diversions for in-basin use are not larger than actual flows left instream. Indeed, in 2018 and 2019 flows were in or near the 65-75% range for the share of November-June unimpaired flow from the Sacramento Valley that TBI, the State Water Board and others have found should reach the Delta in order to support a healthy ecosystem. The in-basin environmental impact is mostly caused by reshaping the hydrograph – in other words, changing the timing of runoff – to eliminate flood peaks and augment flows in naturally drier periods. But the picture of the Sacramento basin is not complete without understanding that in most years much of the flow that leaves the region is diverted at the export pumps of the state and federal water projects in the Delta for delivery to San Joaquin Valley irrigators and Central and Southern California. Some of the in-basin environmental impact, like the water, is in effect being shifted to fish, wildlife and habitat downstream in the estuary.

FIGURE 9

SACRAMENTO RIVER INFLOW TO THE DELTA

Water Years 2018 & 2019 Compared to the Historical Record



Water Years 2018 & 2019 Compared to the Historical Record

The bar charts in Figure 9 show the frequency of Wettest (blue), Above Average (green), Average (yellow), Below Average (orange), Dry (red), and Super Critical (black) years under unimpaired conditions in the Sacramento River basin (upper bar graph; "unimpaired") and under actual conditions (lower bar graph, "actual"). Each of these categories represent one-fifth of the years as measured by their unimpaired runoff, except for the Super Critical category, which represents the driest single year in the 45-year sequence shown here and the driest two years in the 95-year record. While less dramatic than in the San Joaquin basin or San Francisco Bay, Figure 10 shows how, as a result of massive storage capacity in the Sacramento basin that allows for water capture and transfer on an unprecedented scale, the driest years now dominate the record, with actual Dry and Super Critical years occurring over half of the time, as opposed to less than a third of the time under unimpaired conditions.

Category	Unimpaired (years)	Actual (years)
Wettest	11 (24%)	7 (16%)
Above Average	7 (16%)	3 (7%)
Average	7 (16%)	7 (16%)
Below Average	8 (18%)	4 (9%)
Dry (including Super Critical)	12 (27%)	24 (53%)
Super Critical	1 (2%)	11 (24%)

Even with the alterations we have discussed, the Sacramento basin remains the least hydrologically impaired of all the areas in the Bay estuary and its watershed. However, looking at each decade beginning in the 1970s, it is clear that even here the total amount of actual flow – both the average and the maximum values – has consistently declined each decade. It is therefore important to act now to preserve the relatively healthy flow conditions that exist in the Sacramento basin before they too dip permanently below the thresholds necessary to support fish and wildlife.

Decade Beginning	Decadal Average % UIF	Decadal Maximum % UIF
1970	73%	99%
1980	72%	95%
1990	72%	91%
2000	67%	91%
2010	65%	84%

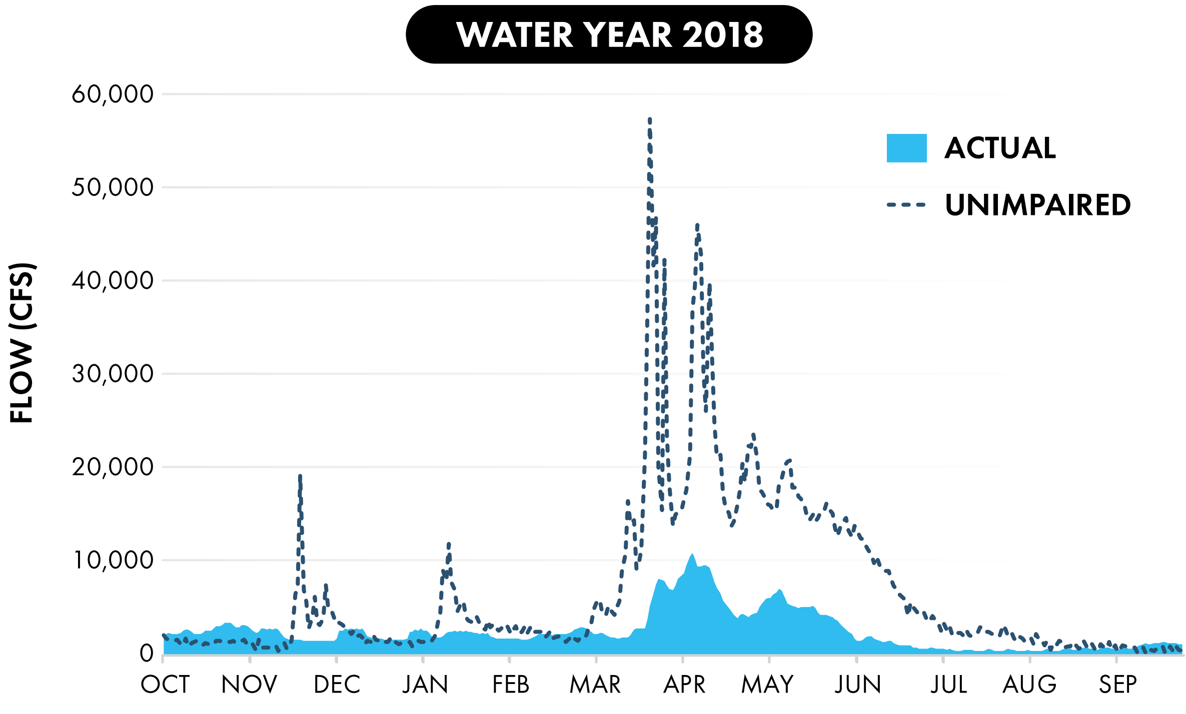
THE YEAR IN WATER: 2018 & 2019

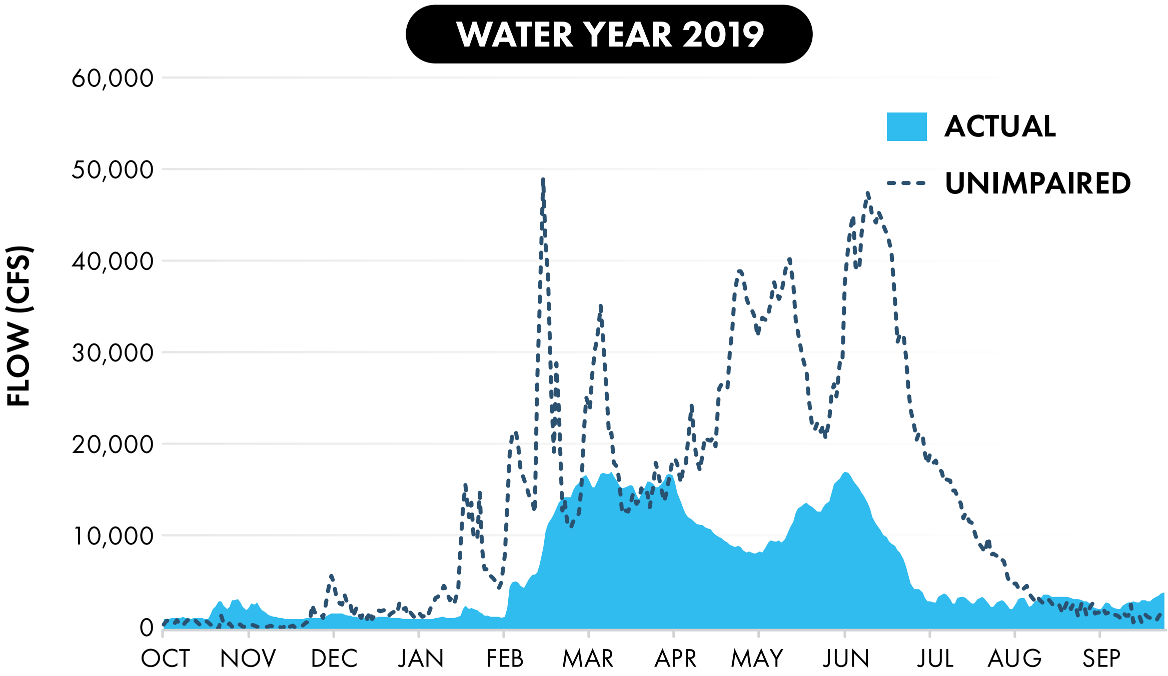
SAN JOAQUIN BASIN

FIGURE 10

SAN JOAQUIN RIVER INFLOW TO THE DELTA

Actual vs. Unimpaired





Actual vs. Unimpaired

Figure 10 compares freshwater flow from the San Joaquin River basin that actually reached the Delta (solid blue) with unimpaired runoff (dashed blue line). In WY 2018, only 38% of the San Joaquin basin's unimpaired flow, or 1.9 MAF out of an annual total of 4.9 MAF, actually reached the Delta. There was a complete loss of high fall and winter pulse flows, which were entirely stored in reservoirs. In WY 2019, 4.6 MAF out of 9.7 MAF, or 47% of the unimpaired San Joaquin Valley runoff reached the Delta. Most of the spring snowmelt pulse in both years was diverted.

The San Joaquin River basin is one of the most heavily used – and abused – watersheds in the United States. Storage and diversions have essentially flatlined the hydrograph in all but the wettest years. Flows on the mainstem San Joaquin itself were largely eliminated by construction of Friant Dam in the 1940s, and with it one of the state's largest spring salmon runs. Other salmon runs are struggling given low flows on all of the tributaries (Figure 11). Flows and salmon are now being reintroduced on the mainstem San Joaquin to implement a settlement agreement between TBI and its partners, Friant Dam water users, and the Bureau of Reclamation; however, the settlement does not attempt to address the needs of fish and wildlife downstream of the confluence of the Merced River.

FIGURE 11

AVERAGE ANNUAL SALMON ESCAPEMENT IN THE SAN JOAQUIN BASIN BY DECADE

1940's to 1990's (REDRAWN FROM CAIN ET AL 2003)

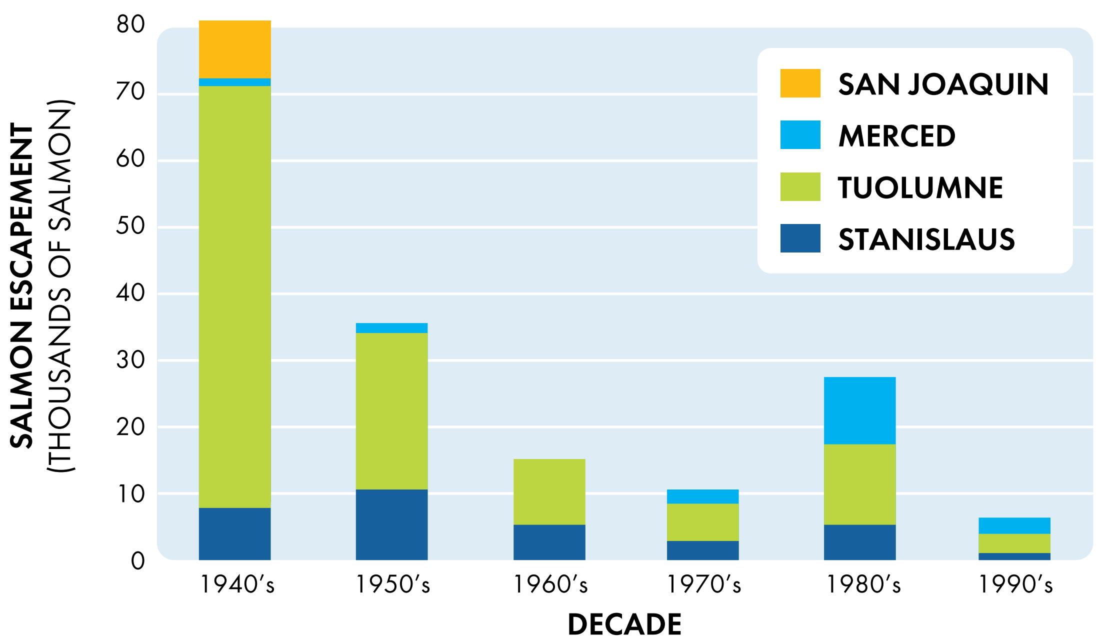
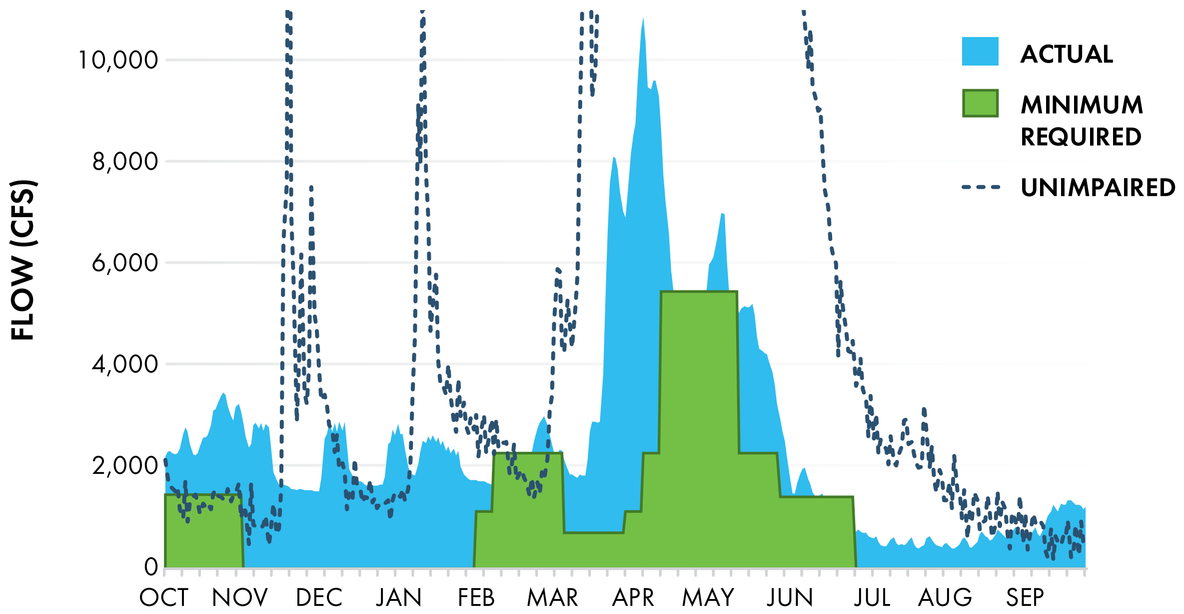


FIGURE 12

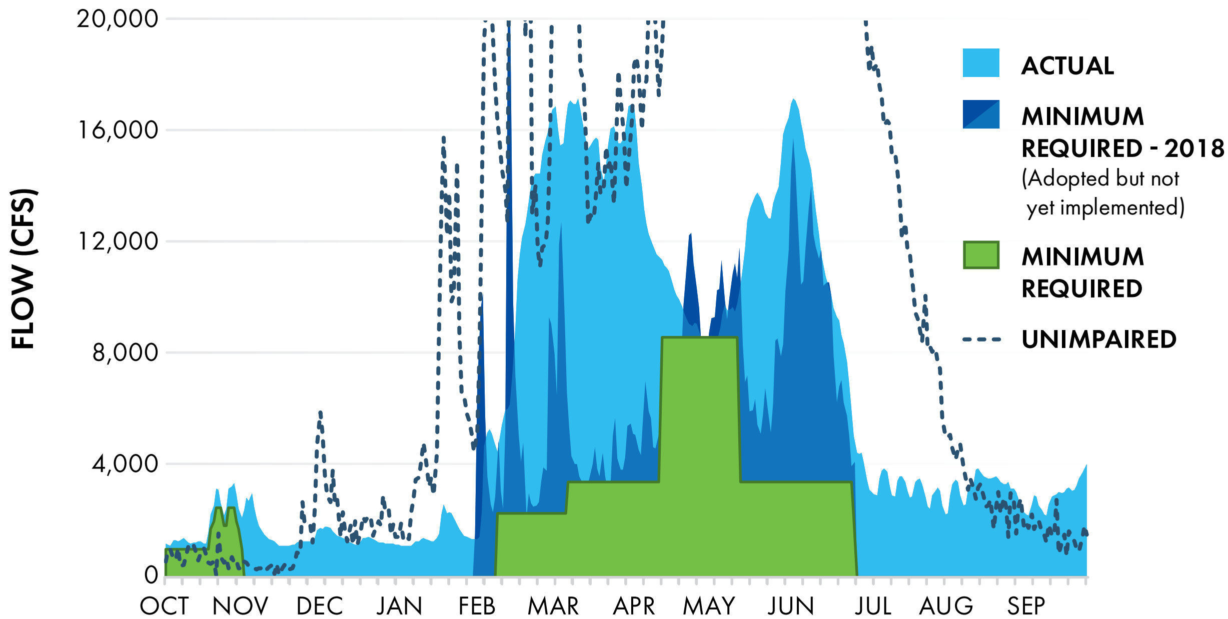
SAN JOAQUIN RIVER INFLOW TO THE DELTA

Actual vs. Minimum Required

WATER YEAR 2018



WATER YEAR 2019



Actual vs. Minimum Required

Figure 12 shows the minimum required flow (solid green) at Vernalis, a measuring station where the lower San Joaquin River enters the Delta, primarily intended to protect fall-run Chinook salmon migration, compared to both actual (solid blue) and unimpaired (dashed blue line) San Joaquin basin inflows. Relatively small, short pulse flows are required in October for adult salmon migrating upstream to spawn, and in the February – June period for juvenile salmon migrating downstream to the ocean. Figure 12 shows that actual flows in 2018 exceeded these minimums slightly, as a result of reservoir releases due to high storage levels following the extremely wet WY 2017. In contrast, only meeting minimum requirements would have resulted in even less runoff than the 26% that actually occurred in February – June 2018 – a condition that will only become more frequent if new storage capacity is added in the watershed.

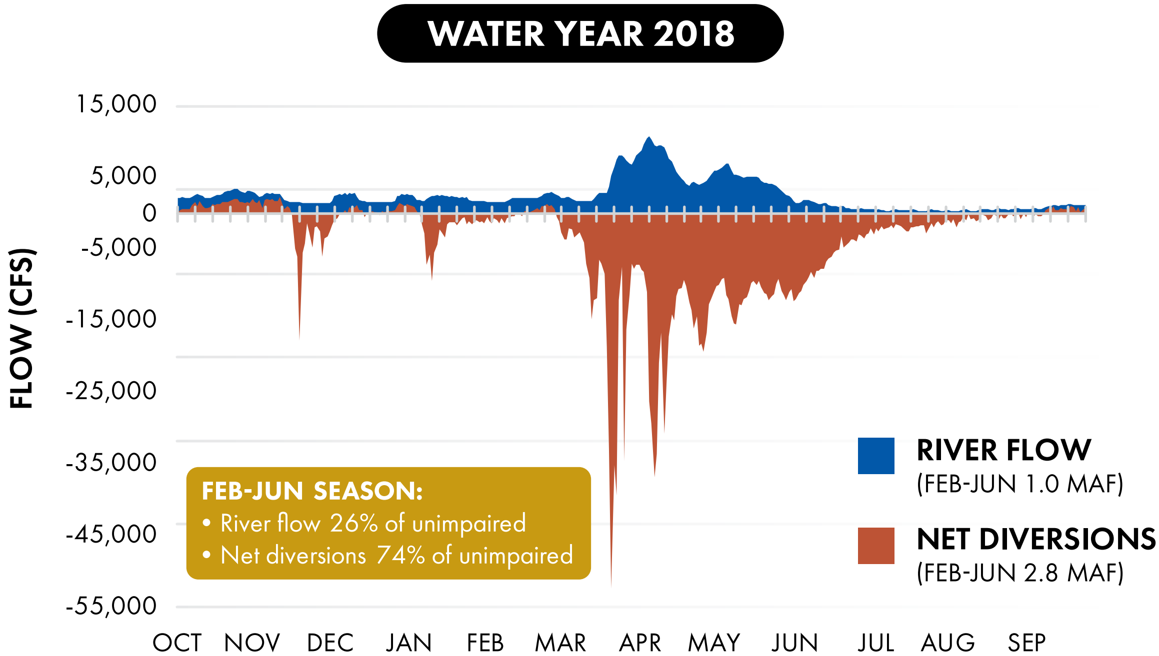
These minimum requirements represent a fraction of the amount needed to reverse the decline of San Joaquin basin salmon runs and other fisheries. Studies by the Bay Institute and fish and wildlife agencies identified 50 – 60% of winter – spring runoff as the amount needed to restore salmon populations. New state water quality regulations adopted in 2018 will require future releases from three of the San Joaquin's tributaries (the Stanislaus, Tuolumne, and Merced Rivers) to be 30-50% with a starting point at 40%. In addition to providing a critically needed boost in the amount of flow, the natural pattern and timing achieved by the percent of unimpaired approach is superior to the current blocky minimum flow requirements.

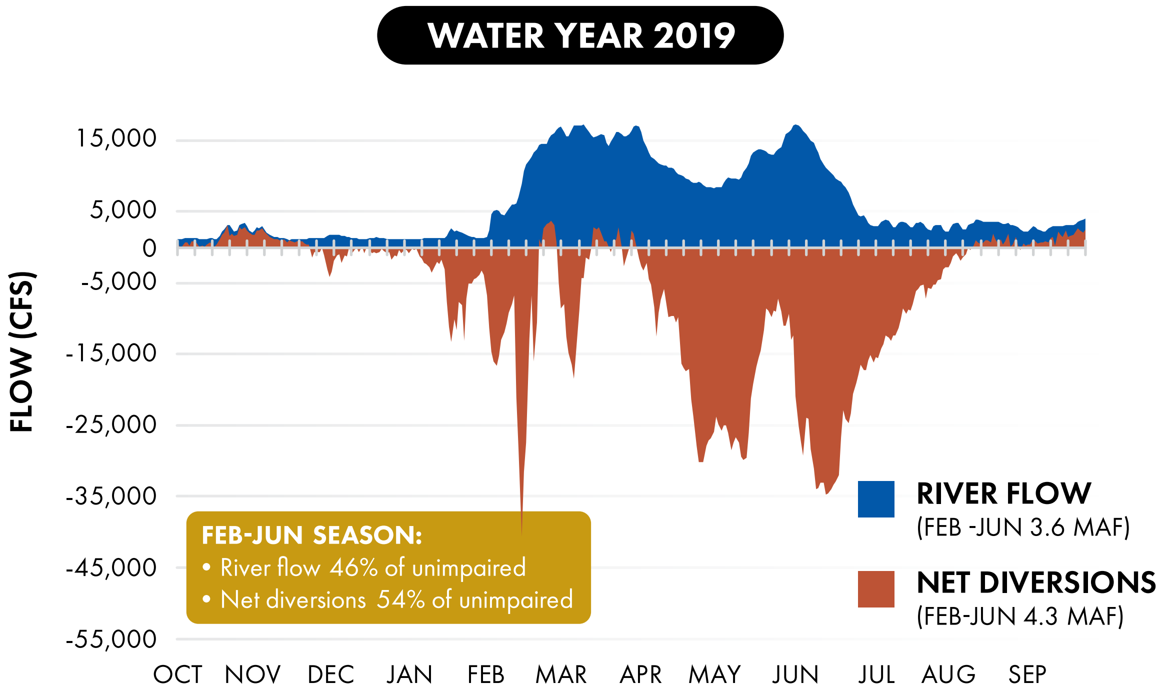
The 2019 graph shows both the minimum required under the pre-2018 water quality regulations; and also an approximation of the 40% required (but not yet implemented) by the State Water Board in 2018. In a wet year like 2019, due to flood control releases, the winter-spring flows for the most part met the current and future minimum flows (which amounted to 15% and 28% of unimpaired flow, respectively). The April-July snowmelt hydrograph, however, is heavily diverted on the mainstem San Joaquin, where 40% of unimpaired flow February-June is not required (at least not until the initial phase of the restoration project is complete, the long unused river channel rehabilitated, and spring-run Chinook successfully re-established). Minimum flows to support San Joaquin restoration are not shown, since they are intended to restore conditions on the mainstem above the confluence with the Merced and may be diverted downstream under certain conditions.

FIGURE 13

SAN JOAQUIN RIVER INFLOW TO THE DELTA

River Flow vs. Net Diversions





River Flow vs. Net Diversions

Figure 13 contrasts and compares the amount of water that occurred as actual San Joaquin basin inflow to the Delta (solid blue) versus the amount of net diversions within the basin (solid brown). This figure clearly shows how large reservoirs and canal diversions throughout the San Joaquin basin captured almost three-quarters of the entire basin's runoff in WY 2018 – and yet this is nowhere near the highest level of net diversion (solid brown) experienced in the basin! (See Figure 14 to view the historical record). A variety of water management measures, from improvements in the accuracy of snowmelt forecasting to the proposed addition of additional storage capacity, will contribute to water managers' ability to divert even more water and minimize actual river inflow (solid blue), to the detriment of the ecosystem.

In 2019, 46% of February-June unimpaired flow reached the Delta—a volume more in line with new water quality requirements adopted in 2018 (but not yet Implemented). These wet years with flows that meet fish needs are rare, however, as the next figure (Figure 14) shows.

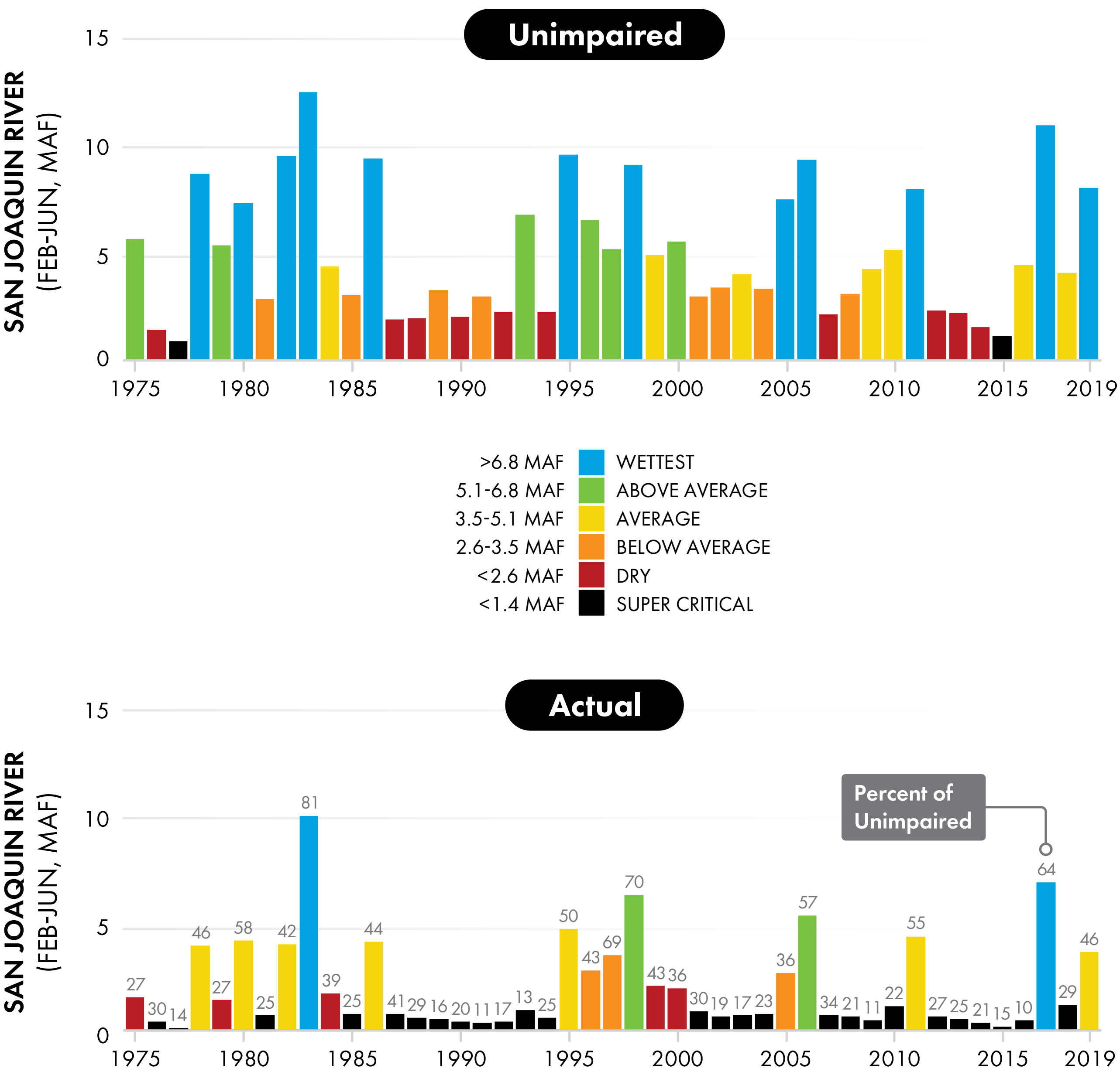
Photo by San Joaquin River Restoration Program

Thanks to wet year flows exceeding minimum restoration flows and improving fish passage conditions at obstacles on the San Joaquin River, over 300 Spring-run Chinook Salmon that hatched and reared in the river returned in 2019 to spawn below Friant Dam.

FIGURE 14

SAN JOAQUIN RIVER INFLOW TO THE DELTA

Water Years 2018 & 2019 Compared to the Historical Record



Water Years 2018 & 2019 Compared to the Historical Record

The bar charts in Figure 14 show the frequency of Wettest (blue), Above Average (green), Average (yellow), Below Average (orange), Dry (red), and Super Critical (black) years under unimpaired conditions in the San Joaquin River basin (upper bar graph; "unimpaired") and under actual conditions (lower bar graph, "actual"). Each of these categories represent one-fifth of the years as measured by their unimpaired runoff, except for the Super Critical category, which represents the driest two years in the 95-year record and in the 45-year sequence shown here.

Figure 14 offers chilling evidence of the destruction of a river basin. The driest runoff years (Dry and Super Critical) naturally occurred in the San Joaquin basin only about a quarter of the time during the 1975 – 2019 period, but storage and diversion turned runoff conditions into Dry and Super Critical 69% of the time. There were only 2 Super Critical years in this watershed during that period, but the basin experienced human-caused Super Critical flows in 26 years – a thirteenfold increase in extreme drought.

Category	Unimpaired (years)	Actual (years)
Wettest	12 (27%)	2 (4%)
Above Average	6 (13%)	2 (4%)
Average	7 (16%)	7 (16%)
Below Average	8 (18%)	3 (7%)
Dry (including Super Critical)	12 (27%)	31 (69%)
Super Critical	2 (4%)	26 (58%)

THE YEAR IN WATER: 2018 & 2019

TUOLUMNE RIVER

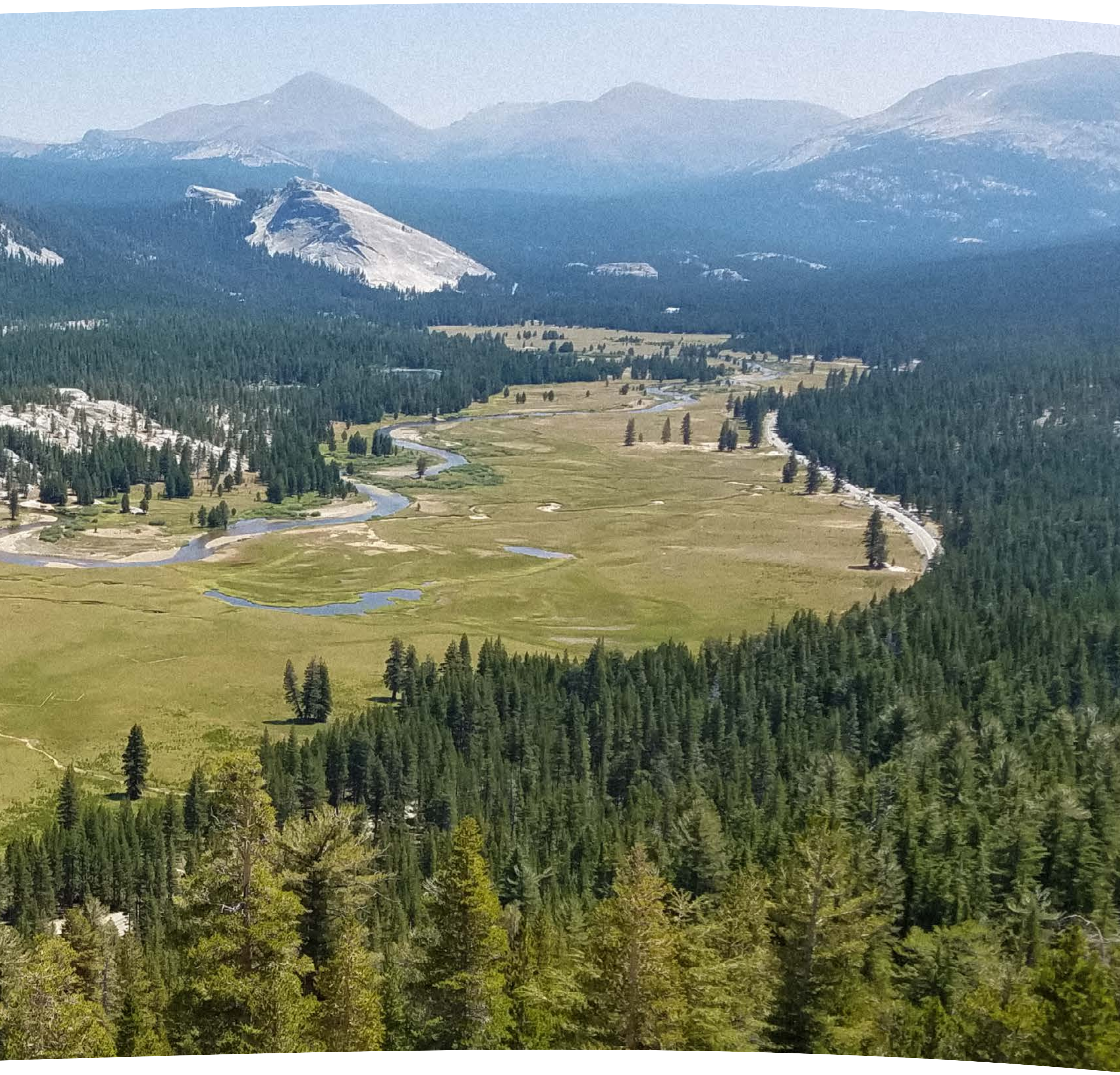
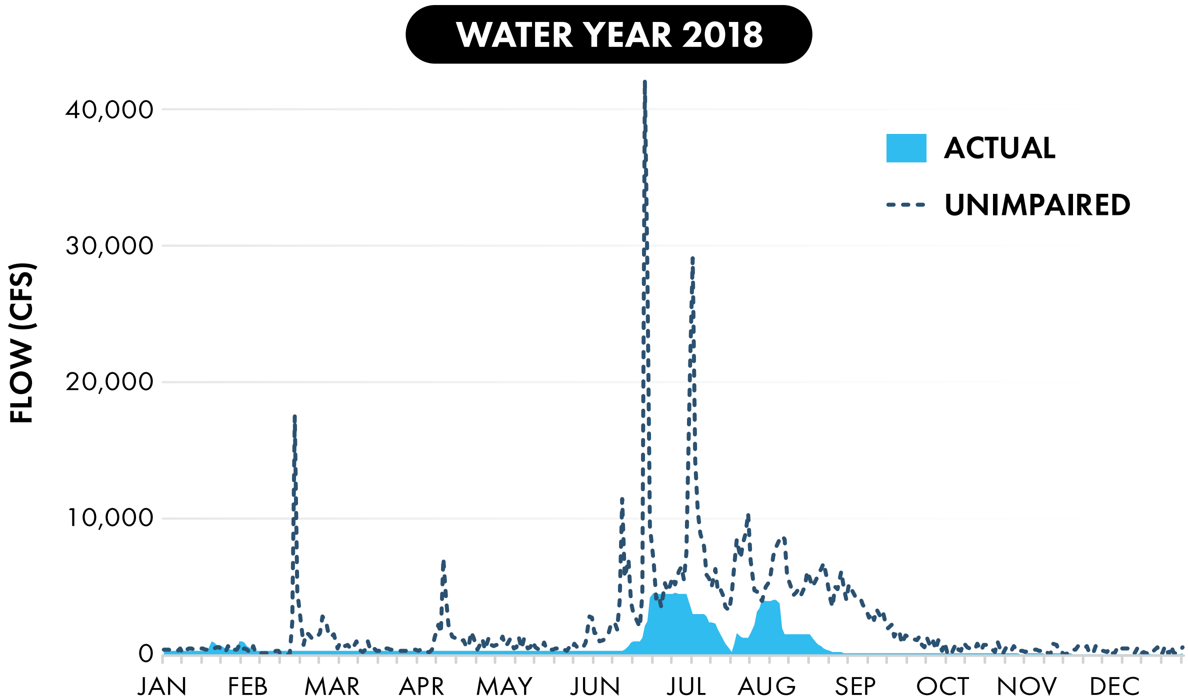
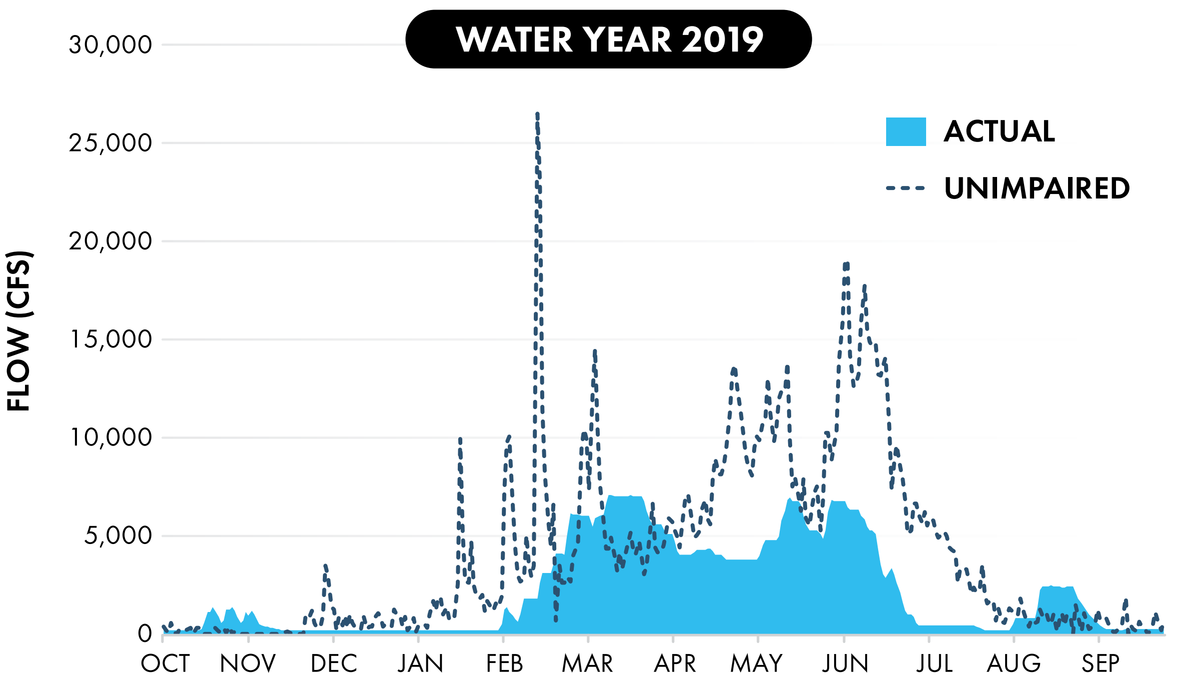


FIGURE 15

TUOLUMNE RIVER CONTRIBUTION TO DELTA INFLOW

Actual vs. Unimpaired





Actual vs. Unimpaired

Figure 15 compares freshwater flow from the Tuolumne River watershed that actually made it all the way to the Delta (solid blue), measured as releases from La Grange Dam, the lowest elevation dam on the river, with unimpaired runoff (dashed blue line). In WY 2018 only 600,000 acre-feet of actual flow, or 33% of the year's 1.7 MAF of unimpaired runoff, made it all the way down the Tuolumne River to the Delta. Ironically, this was one of the higher actual runoff figures from the Tuolumne watershed in the past dozen years (see Fig. 19 for Feb-Jun runoff).

The Tuolumne River, with its headwaters in the Yosemite high country, is the largest river running off the Sierra Nevada to the San Joaquin Valley. Multiple large reservoirs and high levels of diversions between the uplands and Valley floor siphon off most of the river's flow for either local irrigation or for export to Bay Area urban water users. The river's fall-run Chinook salmon population has been declining in most years as a result (Figure 16).

2019 "Wettest" year-type flows resulted in 1.6 MAF, or 55% of the year's 3 MAF of runoff, making it to the Delta.

FIGURE 16

ANNUAL SALMON ESCAPEMENT

TUOLUMNE RIVER 1952-2018

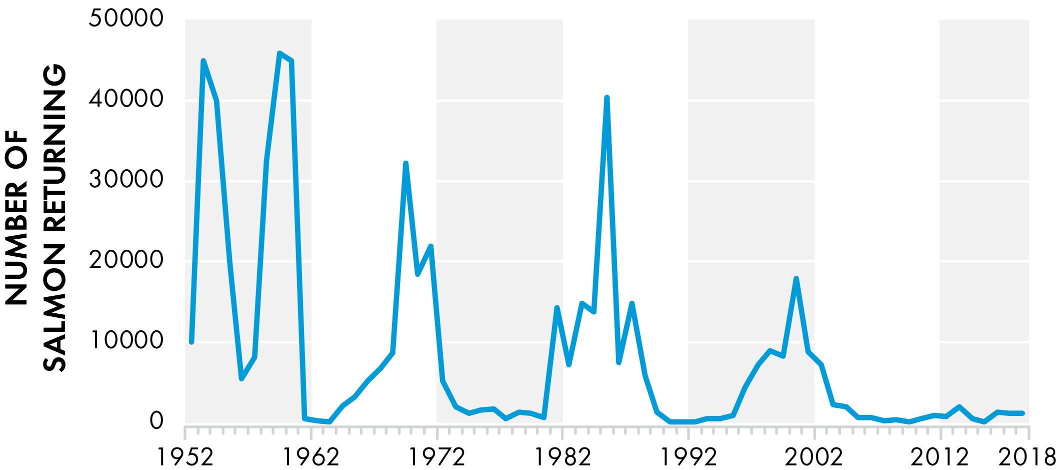
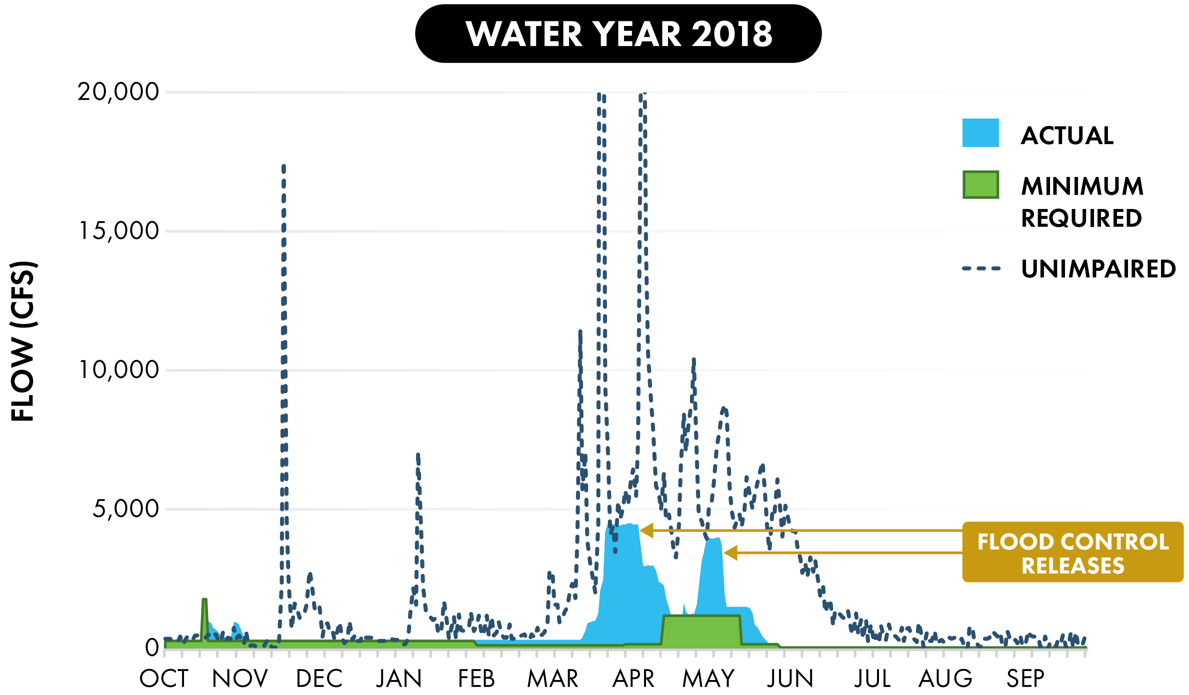
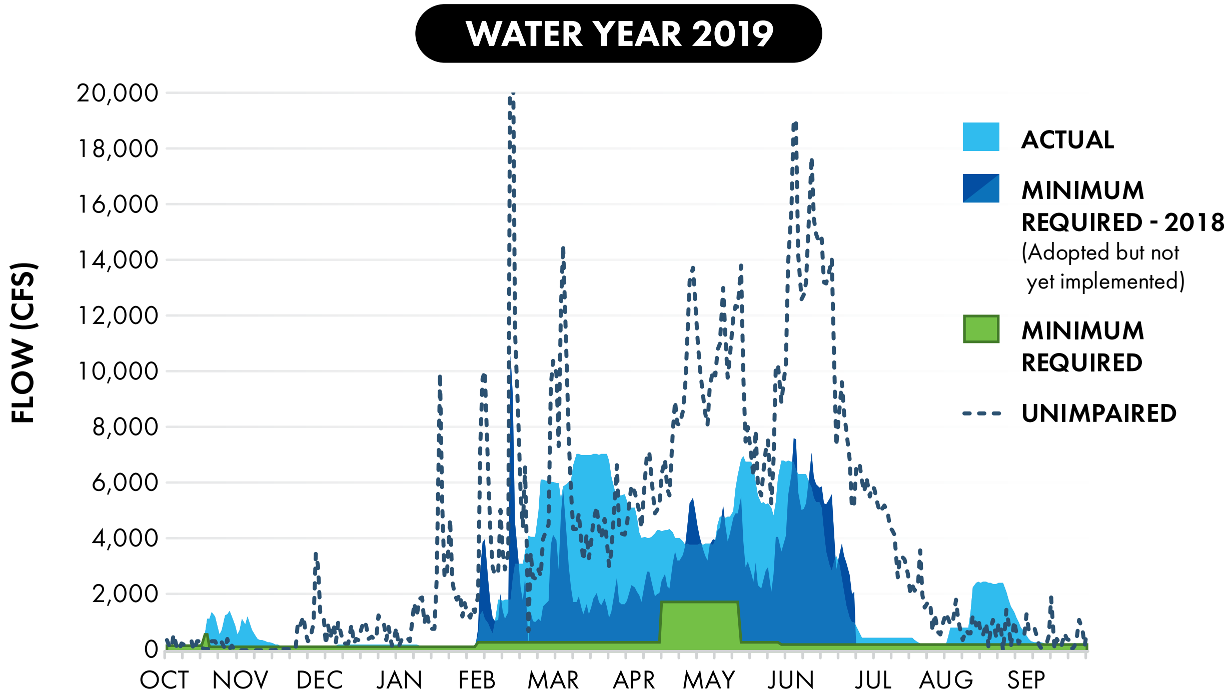


FIGURE 17

TUOLUMNE RIVER CONTRIBUTION TO DELTA INFLOW

Actual vs. Minimum Required





Actual vs. Minimum Required

Figure 17 compares approximate minimum required instream flow (solid green) below La Grange Dam—the lowest dam in the system—to actual Tuolumne River inflows (solid blue) to the San Joaquin River. Meeting only the current minimum required February-June flow in 2018 would have left only 8% of the unimpaired flow in the river. Actual flows were higher due to flood control releases following wet WY 2017, resulting in actual runoff of 28% of unimpaired flow.

Studies by the Bay Institute and fish and wildlife agencies indicate that 50% to 60% of runoff in San Joaquin basin rivers is needed to restore salmon populations. State regulators adopted new rules in 2018 to require 40% (with a range of 30-50%) in the future.

In 2019, meeting only the current minimum required February-June flow would have left only 7% of the unimpaired flow in the river (this would almost double to 13% under the water-agency-proposed Voluntary Agreements). Actual flows were higher due to flood control releases, resulting in actual runoff of 57% of unimpaired flow, volumetrically close to the 60% identified as the target for doubling salmon populations, and significantly higher than the 40% minimum requirement adopted (but not implemented yet) in 2018.

Note: pulse flow volumes are adaptively managed and will not necessarily match the required flows shown.

Photo by Patrick Koepele, Tuolumne River Trust

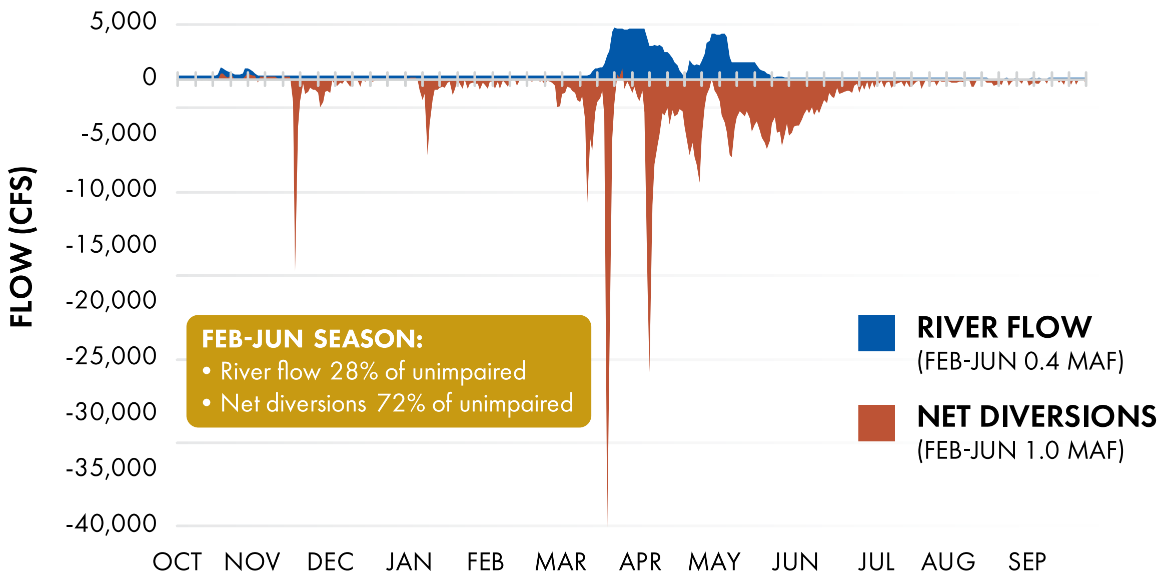
Tuolumne River floodplain, when inundated by high flows, provides important rearing habitat for juvenile Chinook salmon.

FIGURE 18

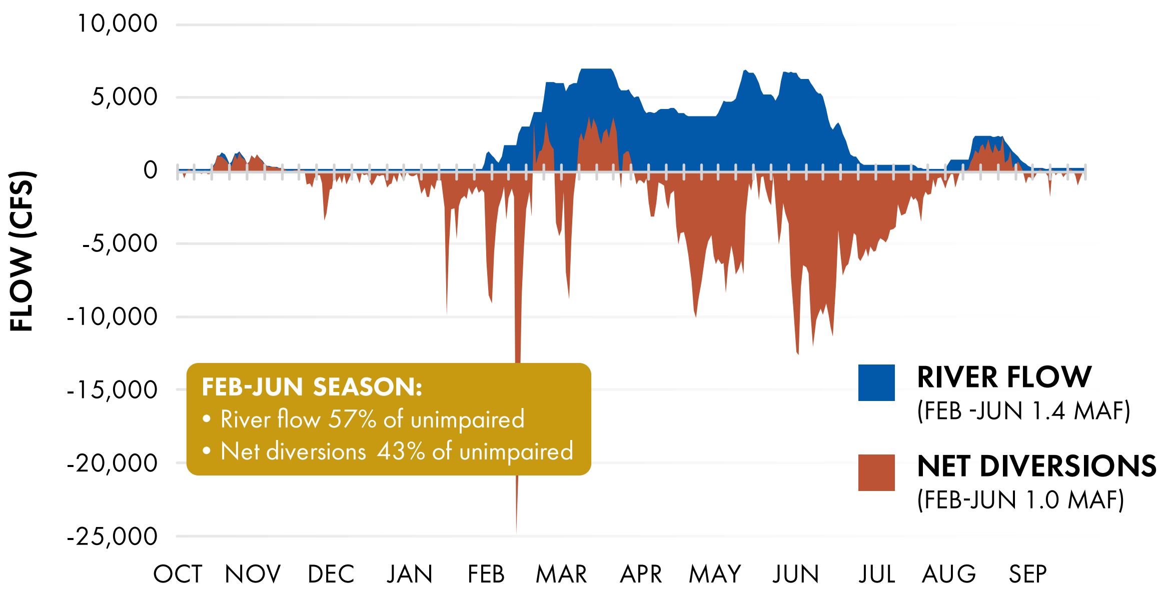
TUOLUMNE RIVER CONTRIBUTION TO DELTA INFLOW

River Flow vs. Net Diversions

WATER YEAR 2018



WATER YEAR 2019



River Flow vs. Net Diversions

Figure 18 contrasts and compares the amount of water that occurred as actual Tuolumne River inflow to the Delta, measured at La Grange Dam (solid blue), versus the amount of net diversions within the watershed (solid brown). The huge gap in 2018 between actual runoff (solid blue) and net diversions (solid brown) in the Tuolumne River, reflects intensive human uses that represent about two and a half times the amount devoted to river protection. These diversions are for both local irrigators and for urban water users in San Francisco, who received exported water from Hetch Hetchy Reservoir.

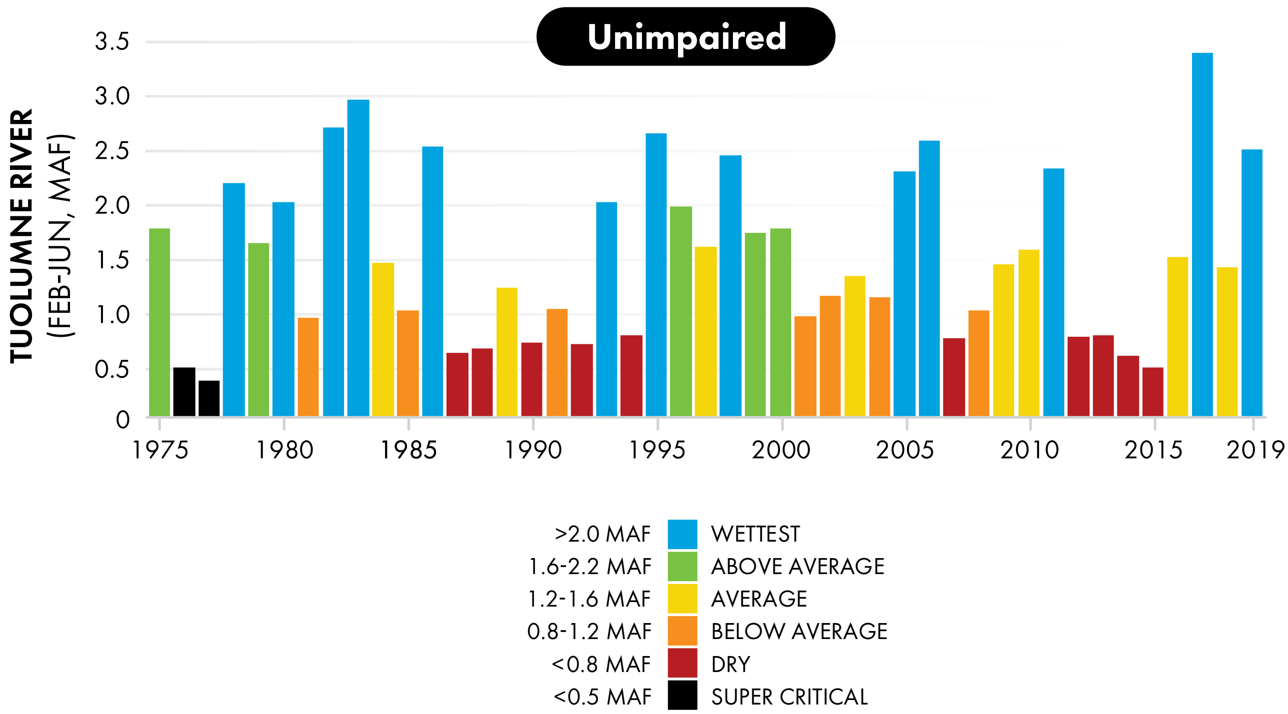
2019 Wettest year-type flood control releases resulted in the river getting more than half its flow during the February-June season. As water agencies work to improve their ability to capture more flow, however, this kind of surplus flow condition will be experienced less frequently in the future.

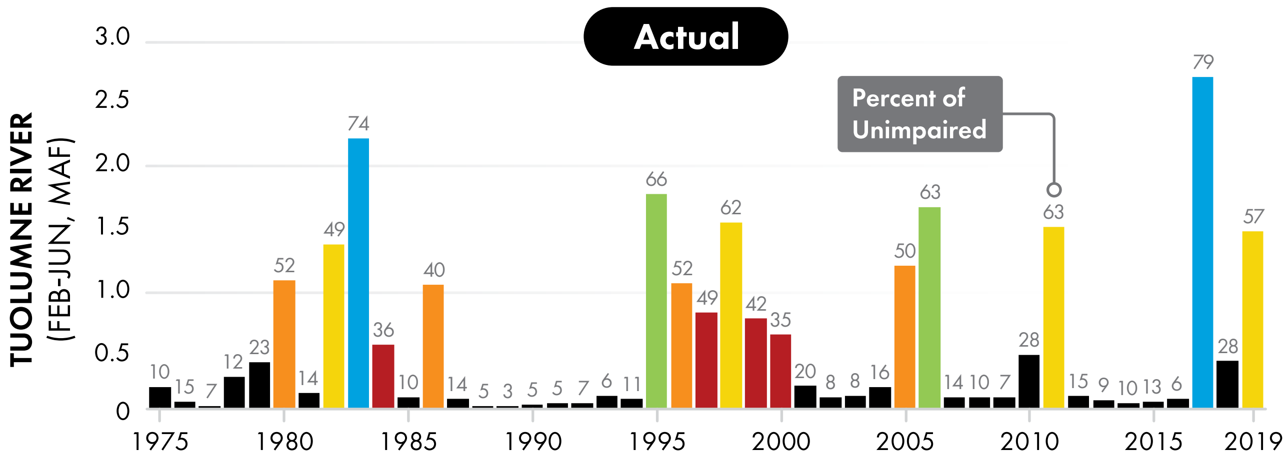
Photo: Adobe Stock
O'Shaughnessy Dam

FIGURE 19

TUOLUMNE RIVER INFLOW TO THE DELTA

Water Years 2018 & 2019 Compared to the Historical Record





Water Years 2018 & 2019 Compared to the Historical Record

The bar charts in Figure 19 show the frequency of Wettest (blue), Above Average (green), Average (yellow), Below Average (orange), Dry (red), and Super Critical (black) years under unimpaired conditions in the Tuolumne River watershed (upper bar graph; "unimpaired") and under actual conditions (lower bar graph, "actual"). Each of these categories represent one-fifth of the years as measured by their unimpaired runoff, except for the Super Critical category, which represents the driest two years in the 95-year record and in the 45-year sequence shown. Like other rivers in the San Joaquin basin, water development along the Tuolumne River has created what is essentially a permanent drought. Figure 19 shows how Super Critical runoff, the driest 2 percent, which occurred naturally in only two years during the 1975 – 2019 period, was experienced as actual flow in the river 29 times during the same period, or two-thirds of the time.

Category	Unimpaired (years)	Actual (years)
Wettest	13 (29%)	2 (4%)
Above Average	5 (11%)	2 (4%)
Average	8 (18%)	4 (9%)
Below Average	7 (16%)	4 (9%)
Dry (including Super Critical)	12 (27%)	33 (73%)
Super Critical	2 (4%)	29 (64%)

IMPROVING THE OUTLOOK FOR FUTURE WATER YEARS

What can be done to ease the permanent, human-induced drought in the Bay estuary and its watershed, and make more years look like WY 2019, a rare year when actual flows were much more closely synced up with unimpaired runoff?

1 Secure water to meet unmet environmental flow needs.

Current minimum required flows represent a small fraction of both the actual, unprotected "surplus" flows that occur in some years (providing major boosts to ecosystem conditions above the minima in those years) and the flow thresholds that the best available science indicates are necessary for restoring and maintaining a healthy aquatic ecosystem. The main vehicle to secure these flows is the long overdue adoption and implementation of new water quality standards for the entire Bay estuary and its watershed by the State Water Resources Control Board (which completed only the first of three phases in 2018, a decade after it began). California should also commit to acquiring instream water rights and long term environmental water transfers in order to provide supplemental flows in addition to meeting new, more protective standards.

2 Ensure adequate flows to protect habitat investments.

Restoration of flows and of physical habitat like stream channels or wetlands go hand-in-hand, but often habitat is viewed as a substitute for flows. This can have disastrous results when flows are inadequate to maintain functional habitat or support organisms that spawn, rear or otherwise use these habitats. Habitat restoration projects should include assured, adequate flows in order to receive funding and permits.

3 Expand the pool of responsible parties.

Only a subset of California water users is currently required to release flows to protect the Bay estuary. In 2018 the State Water Board adopted new San Joaquin requirements that for the first time included upstream water users and senior water rights holders, and is proposing to do the same for the rest of the Bay's watershed. The Newsom Administration is currently pursuing Voluntary Agreements with many of these same parties. Neither approach has been implemented. It is long past due for all water users in the Bay's watershed to contribute water to ending the estuary's permanent drought.

4 Integrate environmental, flood, and water supply management decisions.

Better coordination and integration of water management actions within and among rivers and basins offers opportunities to improve flows and ecological conditions in coordination with water management for other purposes. For example, flood control releases can be shaped to provide environmentally beneficial flows and to avoid abrupt changes in flow that can strand fish.

5 Conserve water more aggressively on farms and in cities.

California has made significant progress in more efficiently using its water resources, but much more can be done to reduce the need to divert water from rivers and the estuary. Next steps include adopting strong and enforceable targets for improving efficiency in all sectors and reducing reliance on imported water supplies; constructing systems to reclaim and recycle urban and on-farm water supplies; no longer irrigating drainage-impaired and other marginal lands; and reforming the pricing and measurement of water use in all sectors.

Red and White ferry in the
San Francisco Bay.

EXPLORE
ENGAGE
EXPERIENCE

Aquarium of the Bay

Bay Model Alliance

Studio Aqua

Sea Lion Center

The Bay Institute

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