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Introduction

Today's event is not for modelers, even though we at RTD consume and evaluate models all the time. For example, an environmental impact report can and should be thought of as a type of model. But this event is not about computer-based modeling and statistical analysis.

We decided to put on this webinar topic because RTD is interested in whether models about the Delta and its watershed usefully approximate our experience with reality. We get a new document from a water agency or regulator, so we turn the key, kick the tires, and open and shut its doors to see how useful the model is. We do this because our advocacy has to be as reality- and fact-based as possible.

We do this also because while some things are measured in the Delta watershed, other measurable things are not. The relevance of facts can open a door in public debate, revealing both the power of reality and the reality of power as they confront each other. To us, that is where the Delta's water struggles get interesting.

This webinar is about the measurement of water, and of chemicals and creatures that live in Delta waters. It deals with the adage, "You cannot manage what you haven't measured." Unless you have key facts about resources you hope to use, exploit, harvest—you know, *manage*—you will not have a prayer of being a good steward for the resource. You need access to and interest in analyzing data to answer questions like:

- How much is enough?
- Who gets how much of the resource and when?
- What is the most efficient way to allocate this resource to those who want it?
- How do we know we're doing the right thing at the right time?
- If we know stuff, are we willing to take action based on that knowledge? and
- If we don't know stuff, are we willing to invest in data collection and scientific analysis of it to learn more?

These types of questions need data and analysis to answer them, and answer them holds implications for more than just water: also fish, almonds, nonnative invasive clams, harmful algal blooms, and the Bay Delta Estuary and its watershed.

Back on April 8, when Restore the Delta hosted a webinar on "Voluntary Agreements." In the "Notes" to that webinar, I introduced the audience to the basic geography of California's rivers and streams, the California State Water Project (SWP), the federal Central Valley Project (CVP), and the agency responsible for regulating Delta water quality and public trust values, the State Water Resources Control Board (SWRCB)and its Bay-Delta Water Quality Control Plan. If any of these topics are new to you, please visit **those notes** and then come back to these.[1]

The data source links in these notes are for standard data uses by journalists, scientists, regulators, activists, and any else who is just curious to seek facts about California and Delta watershed conditions. Some links provide for interactive chart-making based on query parameters you select. I certainly encourage you to explore these as you wish—you really can do as much or more than you might imagine with these data sources. Look up your favorite river's runoff, the storage levels or release rate at your favorite reservoir, or check on how much pumping occurs at the south Delta pumps. When this webinar is over, I hope you still enjoy asking questions of these data —and getting answers that may lead you to other questions. That is the very stuff of science right there!

These notes are not exhaustive. I made choices of what to include based on interactivity and accessibility of the data to someone new to Delta watershed data. I also chose some data sources that are relevant to the case studies I present later in these notes.

Why Take the Delta Watershed's Pulse? And Who Does?

There are at least four main reasons for taking the water pulse of the Delta's extensive watershed. First is **water project operations and allocations**. Second is the **regulation by various agencies** of water project operations, to make sure they are complying with their water rights permits and licenses (in the case of older water

[1] You can find the April 8 webinar notes and presentation at https://www.restorethedelta.org/webinar-archive/.

systems). Third, to **monitor whether flood warnings** may be needed, in connection with weather forecasts. Fourth, to **monitor whether drought conditions** are setting in, in connection with other measures of drought. This is not an exhaustive list.

- ***Operations and Allocations***

Operations refers to how the dams and reservoirs, pipelines, aqueducts, canals, hydropower generating plants, pumping plants, and treatment plants—function individually and together to store, convey, and deliver safe, reliable, and healthful supplies of fresh water for human use.

Measurement for water project operation begins in California with **snowpack**. By looking at the snow-water content of samples of snow, water managers can make projections of how much surface water will eventually run off to the rivers and streams below. There is an extensive snowpack monitoring network system in the Sierra Nevada that the state relies on to estimate how much water is actually stored as snow. You can think of the water that is measured in snowpack as "frozen runoff."

Once the snow actually melts, it runs off to adjacent rivers and streams. There it is measured as "runoff" using flow gauges at specific locations. **Flow gauges** for liquid water are essential at the back ends of reservoirs, at the pipes that pass through dams to release water from storage, and at key diversion points at pumping plants, and along canals or pipelines where water gets delivered to a customer.

Finding Monitoring Stations for Data Queries:
CDEC Station Search: http://cdec.water.ca.gov/dynamicapp/staSearch

(Try selecting "Station ID/Name" and "Delta" river basin, and then click "Search for CDEC stations." You should turn up 87 stations, listed alphabetically for the Delta region.)

CDEC Station Locator Map: http://cdec.water.ca.gov/cdecstation2/

Historical Data Selector: http://cdec.water.ca.gov/dynamicapp/selectQuery

Precipitiation and Runoff Sources:
Daily Statewide Hydrologic Update: http://cdec.water.ca.gov/floodER/hydro/

California Data Exchange Center—Precipitation: http://cdec.water.ca.gov/snow_rain.html

California Data Exchange Center—Snow: http://cdec.water.ca.gov/snow/current/snow/

California Data Exchange Center—Water Supply Projections: http://cdec.water.ca.gov/water_supply.html

California Data Exchange Center—River Stages/Flows: http://cdec.water.ca.gov/riv_flows.html

California Data Exchange Center—Report Products Summary: http://cdec.water.ca.gov/reportapp/

You can find some useful search tools for data to begin your searches at the California Data Exchange Center's drop-down menu ("Query Tools"), or some preselected reports brought together at CDEC here: http://cdec.water.ca.gov/reportapp/.

A great deal of effort goes into forecasting water supplies from snowpack and runoff data during the early months of each calendar year (which coincide with the end of winter and the beginning of spring when snowmelt occurs). This is because these forecasts are crucial for how water projects will actually allocate water to their customers.

Customers have historically executed contracts with the big water projects. The SWP has 29 direct customers called "State Water Contractors" (www.swc.org) and their contracts have provisions in them called "Table A amounts" that specify the maximum amount of water supply they can expect to receive annually while the contract is in effect. Total Table A amounts for state water contractors is about 4.17 million acre-feet claimed.[2] Most of SWP demand lies south of the Delta in the San Joaquin Valley, the Silicon Valley, San Luis Obispo and Santa Barbara counties, and Southern California. The ratepayers of SWP contractors also pay property taxes to support the financing of the State Water Project. There are no direct US taxpayer subsidies for most SWP operations. Subsidies internal to the SWP come in years when surplus water is available.

Federal Central Valley Project customers are referred to as "CVP contractors." The CVP has 300 contractors whose total contract quantities (analogous to the SWP "Table A amounts") claim 9.5 million acre-feet. About 57 percent of these contracted claims occur south of the Delta. About 57 percent of these contracted claims occur south of the Delta, including Westlands Water District with a contract for up to 1.15 million acre-feet annually. There are only a handful of small towns who are CVP contractors. Most are agricultural water districts and most of their direct customers are farmers. Their tax bases are fairly small because they're rural. US taxpayers subsidize all CVP operations to a significant degree, as do CVP electric power customers.

[2] An acre-foot is approximately 326,000 gallons or about 43,560 cubic feet—approximately the area of a football field flooded with water to a depth of one foot.

Allocations are made by the California Department of Water Resources (DWR) for the SWP and the US Bureau of Reclamation (the Bureau) for the CVP. They are expressed as a percentage of their contractors' contract amounts. A year in which DWR or the Bureau determine allocations of, say, 100 percent, means that the state and federal water projects expect to deliver to each contractor the full contract amount. This year, however, DWR contractors and the Bureau south-of-Delta agricultural contractors were each allocated 15 percent of their contract amounts. The hydrological basis for these allocations had much to do with snowpack surveys and runoff projections that were based on measurements of snow water content and river flow.

- ***Regulation—Compliance Thresholds Against Which to Measure and Compare***

The California Constitution and the state Water Code require that all uses of water, and all methods of use and of diversion, be reasonable. What's reasonable is a matter of the specific facts in a case. Most conflicts over whether a water use or method of diversion is reasonable do not become "court cases"—it is very expensive to litigate over water. But the SWRCB (and its earlier incarnations dating back to 1914) is supposed to enforce state water law and was intended in part to bring an independent authority to enforce reasonable water use—and offer an alternative to court litigation, a water court system, in a way.

Within water rights law, it is illegal to injure or harm another's right to use water either by taking too much water or by degrading the quality of water to the point that its beneficial use is impaired.

In each of these situations—using or diverting water unreasonably, stealing someone else's lawful access to and use of water, and impairing or polluting the beneficial use of water by another water right holder—the **measurement of water diversions, flows, and water quality** is critical to ascertaining the facts of a case and arriving at a fair decision in the matter, whether rendered by a judge or the SWRCB.

The state's water regulating apparatus includes the central SWRCB (SWRCB), which supervises the activities and policies of its nine **Regional Water Quality Control Boards**. These boards monitor and regulate water quality in their regions' water bodies, from the North Coast to California's border with Mexico. They have no water rights permitting or enforcement authority.

The water boards explicitly recognize and seek to apply the "human right to water," which became state law in 2012.

Regulation and Operation Data Sources:
Central Valley Operations Office: https://www.usbr.gov/mp/cvo/

SWP Operations and Delta Status: https://water.ca.gov/Programs/State-Water-Project/Operations-and-Maintenance/Operations-and-Delta-Status

Daily Reservoir Storage Summary: http://cdec.water.ca.gov/reportapp/javareports?name=RES

Current Conditions for Selected Reservoirs: http://cdec.water.ca.gov/reservoir_map.html

SWRCB eWRIMS Water Rights Database: https://ciwqs.waterboards.ca.gov/ciwqs/ewrims/EWMenuPublic.jsp

SWRCB Mapping Tool for Fully-Appropriated Streams: https://www.waterboards.ca.gov/waterrights/water_issues/programs/fully_appropriated_streams/

SWRCB Water Rights Decisions, Orders, and Judgments: https://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/

- ***Floods***

Obviously, it is important to measure snowpack to gauge runoff potential because if there is a lot of snow-water content, its melting will generate a lot of runoff. And the more snow there is, the more runoff you could have—especially if a warm rainstorm arrives that causes snow to melt rapidly. It is vitally important for public safety during flood seasons to know whether and when to sound the alarm for evacuation and other kinds of flood-related emergency responses (like opening shelters on high ground, providing meals, etc.).

This was very much in play during the series of atmospheric rivers that hit the Feather River portion of the Delta watershed in February 2017. During that period, weather forecasts revealed that the storm system would be wet and likely warm. Such a storm falling on a large snowpack signaled to DWR officials that Lake Oroville and Oroville Dam would see heavy flows, and they would have to release more water from the Dam to accommodate expected flood flows.[3] DWR officials used weather data, snow-water content data, and temperature data to forecast about how much flow would come, by when, and for how long.

Flood Control:
US Army Corps of Engineers—Water Control Data System: https://www.spk-wc.usace.army.mil/

[3] Of course, they did not anticipate that the main spillway west of the Dam would break up and fail completely, but that is another story.

US Army Corps of Engineers—California: https://www.spk-wc.usace.army.mil/plots/california.html

US Army Corps of Engineers—California (new plot format): https://www.spk-wc.usace.army.mil/plots/california_new.html

Daily Hydrologic Summary for Central Valley Rivers: http://cdec.water.ca.gov/reportapp/javareports?name=PAGE1

USBR CVP Reservoirs: https://www.usbr.gov/mp/cvo/vungvari/wtr_rpt.pdf

DWR SWP Reservoirs—Dispatcher's Daily Water Reports and Weekly Reservoir Storage Reports at: https://water.ca.gov/Programs/State-Water-Project/Operations-and-Maintenance/Operations-and-Delta-Status

- ***Droughts***

Drought is simply the build-up of rainless day after rainless day—in data terms, it is a long streak of zeros, or near-zeros, for both rain and snow. Droughts are important because, from a data and measurement standpoint, zeros are data too—they add up, literally to zero or near-zero, which is what drought is.

On the other hand, there are actually many ways that scientists define drought. For most of us, it is the absence of rain, the need to conserve water at home and in our communities, and perhaps the rationing of water. It may also mean increased water rates, because your water purveyor still has fixed costs to bring us all safe and clean drinking water, even if we're using less of it during a drought.

Drought can also be measured as reduced soil moisture. Plants begin to die without sufficient water to bring up from the soil bearing nutrients and regulating their internal temperature. When soils dry out, plants die. Fire danger rises.

Measurement remains important for water managers and regulators because they must be mindful of weather factors like temperature and season, runoff, storage, and their customers' water consumption patterns.

Monitoring runoff data is crucial for regulating and enforcing water rights. It has been said that "water rights are social policy in times of drought." The SWRCB has that authority to enforce water rights as "social policy" during droughts. Their role is especially critical in the Central Valley where every major tributary of the Delta watershed is developed with dams, reservoirs, and diversion canals to customers' water service areas. Water right holders with more recent permits to divert and store water have in their permits something called "Term 91," putting them on notice that if their permit was issued during or after 1965, their water right would be "curtailed" when runoff is low until such time as there is sufficient runoff to allow their use of water. Others, whose rights are older than 1965 would still be able to divert in that situation. When runoff is particularly low, the SWRCB has authority to move that priority date for curtailment earlier (that is, for example, to 1938 or 1927, say).

Drought Monitoring:

United States Drought Monitor: https://droughtmonitor.unl.edu/

U.S. West Drought Monitor: https://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?West

California Drought Monitor: https://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?CA

Drought Monitor Tutorials: https://drought.unl.edu/Education/Tutorials.aspx

SWRCB—Term 91 Curtailment Information: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/term_91/

• ***Endangered Fish***

State and federal laws exist to protect species from going extinct—the federal Endangered Species Act and the California Endangered Species Act are most central for the protective status provided to listing species that are at risk of going extinct. There are other related laws as well.

There have been a few times where fish species in the Delta have experienced population crashes. In the late 1980s, several years of intensive water project operations, and a drought emerging in 1987, led to listing of two Chinook salmon runs and Central Valley Steelhead trout, both of which migrate through the Delta and whose spawning grounds were severely reduced (by over 90 percent) from upstream dam construction and reservoir operation. These listings occurred in the early to middle 1990s. Delta smelt, a small schooling fish native to the Delta, and that numbered in hundreds of thousands just 25 years earlier, suffered dramatic population declines and also became ESA-listed in the early 1990s.

As Delta exports and upstream reservoir operations continued to increase in the early 2000s, scientists observed that by 2005 these same fish species and other species as well were experiencing dramatic declines, including of fish and other species that reside year-round in the San Francisco Bay-Delta Estuary. They called this ecosystem collapse the "pelagic organism decline"—"pelagic" simply means "open water" and the "decline" refers to the fact that so many species residing in Delta open waters were dying off.

Under these laws, continued operations of the state and federal water projects have been somewhat curtailed relative to earlier decades due to their contribution to destruction of the now-listed fish species.

- ***Biological opinions (BiOps):***
  Biological Opinions page with US Bureau of Reclamation: https://www.usbr.gov/mp/bdo/lto/biop.html

  Salmon from National Marine Fisheries Service: https://repository.library.noaa.gov/view/noaa/22046

  Delta smelt from US Fish and Wildlife Service: https://www.fws.gov/sfbaydelta/cvp-swp/index.htm

  California Department of Fish and Wildlife Incidental Take Permit for the State Water Project (2020): https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/State-Water-Project/Files/ITP-for-Long-Term-SWP-Operations.pdf?la=en&hash=AE5FF28E0CB9FA5DC67EF1D6367C66C5FF1B8B55

- ***Fish "Salvage" Monitoring at Pumping Plants:***
  Chinook Salmon Losses: https://www.usbr.gov/mp/cvo/vungvari/salmondly.pdf

  Steelhead Trout Losses: https://www.usbr.gov/mp/cvo/vungvari/steelheaddly.pdf

  Delta Smelt and Splittail Loses: https://www.usbr.gov/mp/cvo/vungvari/dsmeltsplitdly.pdf

  Interagency Ecological Program: https://water.ca.gov/Programs/Environmental-Services/Interagency-Ecological-Program

  Interagency Ecological Program Data and Metadata: https://water.ca.gov/Programs/Environmental-Services/Interagency-Ecological-Program/Data-Portal (Click on links within tables to get to California Department of Fish & Wildlife and other data sources.)

  California Department of Fish & Wildlife Studies and Surveys: https://wildlife.ca.gov/Conservation/Delta

- ***Estuary Beneficial Uses***

There are many many sources of data and scientific analysis of Bay-Delta Estuary ecological, hydrological, and biological issues, as well as social, cultural, and economic topics. Many of these sources are funded (and often undertaken) by DWR and the Bureau, but also by US Fish and Wildlife Service, National Marine Fisheries Service, California Department of Fish and Wildlife, United States Geological Survey, and the Delta Science Program of the Delta Stewardship Council. Researchers come from government agencies as well as universities and colleges, and non-governmental research organizations.

Ecologists, hydrologists, and biologists figured out about thirty years ago that the bigger the low salinity zone (LSZ) in the western Delta is, the better for the estuary's food webs, many species, and especially its food supplies (like plankton and small invertebrate species that float in open water). The size of the estuary—in both its depth and its breadth—is measured by something called "X2" which measures where the salinity "sweet spot" of the LSZ is found as a distance from the Golden Gate downstream. The estuary is at its largest between about 60 to 74 kilometers (about 37 to 46 miles) from the Golden Gate. When it goes above 74 kilometers, it means that the LSZ gets more and more confined to the channels of the Sacramento and San Joaquin Rivers upstream of their confluence by the city of Pittsburg, instead of the wide-open spaces of Suisun Bay.

The SWRCB regulates the position of X2 between the months of February and June most years; "regulates" means that as part of the water rights permits by which the SWP and CVP are allowed to operate, the Board requires DWR and the Bureau to provide sufficient flows into and through the Delta so that X2 is positioned properly where it can still benefit actively reproducing estuary species and food webs. Put too little fresh water into an estuary, and the salt will push the fresh water upstream more and shrink the habitat for species that depend on the low-salinity sweet spot.

In 2009, the California Legislature passed the Delta Reform Act in a special session that November. The new law called for the SWRCB to convene an "informational proceeding" about "what flows fish need to recover their populations in the Delta and its larger watershed." That proceeding turned out numerous scientists to provide their best available research to help the Water Board address that charge from the Legislature. Hearings were held in March 2010 and testimony was taken from scientists and lay people alike. The SWRCB adopted findings in August 2010 that recovery of fish populations to historic population abundances would take significantly more flow than was allowed fish at present. The reason was that more flows overall would generally improve the ecological conditions of the estuary—not just for fish but for many other components of its various food webs. In the course of holding the proceeding, a large archive of scientific studies was amassed on which testimony and ultimately some of the Board's findings were based.

Estuary Beneficial Uses:

San Francisco Estuary Project's original scientific report on a water quality objective to protect Bay-Delta Estuary beneficial uses: https://19january2017snapshot.epa.gov/sfbay-delta/sfep-managing-freshwater-discharge-san-francisco-baysacramento-san-joaquin-delta-estuary_.html Report link: https://19january2017snapshot.epa.gov/sites/production/files/documents/sfep_1993_managing_fw_discharge_sf_bay_delta_estuary_0.pdf

San Francisco Estuary and Watershed Science (scientific journal dedicated to Bay Delta science topics—open access, searchable, no paywall): https://escholarship.org/uc/jmie_sfews

Delta Science Program of the Delta Stewardship Council: https://deltacouncil.ca.gov/delta-science-program/

Delta Regional Ecosystem Restoration Implementation Plan (and link to list of conceptual models): https://www.dfg.ca.gov/ERP/conceptual_models.asp (Click on list link at upper right for access to specific conceptual model reports and topics.)

2010 SWRCB Delta Flow Criteria Informational Proceeding
Testimony and Exhibits: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/entity_index.shtml

Final 2010 SWRCB Delta Flow Criteria Report: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/final_rpt.shtml

Case Studies

The following case studies describe several ways in which the adage "you can't manage what you haven't measured" plays out in reality. These examples illustrate that there are corollary adages at work as well. In the case of Coordinated Operations Agreements between the CVP and SWP, a corollary lesson would also be, "if you don't like how the system is managed, change the parameters for which you measure."

- ***Case Study 1: Coordinated Operations Agreement (COA) of CVP and SWP and the 2018 COA Addendum***

Planning and construction of both the CVP and SWP had very long lead times. For example, while the CVP was originally federally funded as early as 1937. Its major operational divisions were completed about 1979. Similarly, the State Water Project was originally conceived in the late 1940s and authorized in 1951, received voter-approved bond support in 1960, but was not completed in its initial phases until 1973. Throughout the 1950s, state and federal engineers worked on "operations studies" (which we today call "modeling") to figure out just how their two huge coordinated water systems could operate in the midst of hundreds of pre-existing senior water right holders—few of whom were sympathetic to having these two large projects on their river systems—without causing litigation. More details on the history of efforts to coordinate CVP and SWP operations is found in **Appendix 1** to these notes.

In 1971, a document probably intended for journalists and the public described the "need for coordination" between the CVP and SWP this way:

> ***Each agency*** [that owns water projects in the basin] ***regards its water as valuable property to be retained and controlled, but the water at one project is physically indistinguishable from that of another when they are mingled.*** Since many projects, the CVP and SWP in particular, use the same stream channels simultaneously to carry water, a coordination agreement is needed to assure that each project obtains its equitable share of available water and bears its share of obligations to protect the water-related environment and support other forms of benefit.[4]

At its essence, Coordinated Operations Agreements (COA) provide CVP and SWP operators with a conflict prevention and resolution process by which they "trust, but verify" each other's water diversions, storage, and releases benefiting their customers. It sets out accounting concepts and procedures for this ongoing, continuous process of measurement and manipulation of water.

The COA embodies a belief among state and federal operators that the two projects dominate, if not outright control, Central Valley rivers and streams of the Delta watershed. This belief is reflected in the essential equations that govern how they behave and what they measure to police each other under the COA. These equations describe on one hand, "excess" conditions in the Delta Watershed and on the other, "balanced" conditions.

Excess conditions are described as "periods when it is agreed that releases from upstream reservoirs [UR] plus unregulated flow [UF] exceed Sacramento Valley inbasin uses [SV], plus exports [EX]," or:

1) UR + UF > SV+ EX.

[4] United States Bureau of Reclamation and California Department of Water Resources 1971. *Descriptive Summary of the Supplemental Agreement for Coordinated Operation of the Central Valley Project and State Water Project*, USBR/DWR Draft, June 2, pp. 1-2. Hereafter *Descriptive Summary.* Author's collection, originally obtained from the Central Valley Flood Control Association collection at the California State Archive in Sacramento.

Balanced conditions are described as "periods when it is agreed that releases from upstream reservoirs plus unregulated flow equal the water supply need to meet Sacramento Valley inbasin uses, plus exports."

2) UR + UF = SV +EX.

The left side variables **(UR + UF) describe water supply conditions**—how much water is available from developed rivers and streams for capture and delivery to customers?

The right side of the equation **(SV + EX) describe water demand conditions**—how much water do project customers hope or can expect to receive?[5]

Of course, **the situation of supplies being less than demand suggests a drought.** Accordingly, water demand (SV + EX) must adjust downward until it matches water supply measures until "balanced" conditions are achieved in the COA equation.

The COAs (1971 and 1986) both state that during "excess" conditions, the projects will use their facilities to divert, store, and deliver as much water as their facilities' capacity will allow:

> During periods of excess water conditions there is more than enough water to meet Sacramento Valley and export demands for CVP and SWP. Under these conditions it is not necessary to determine a division of water between CVP and SWP. However it is necessary to consider operations during periods of excess water conditions because it is important that each project divert as much water as possible for export during these periods in order to assure obtaining its exports….Except to the extent it may be diverting storage withdrawals, each agency must divert unstored flows up to its potential export capability, or risk not having sufficient water to meet its exports.[6]

The COAs since 1971 have always committed the projects to operating "in conformity" with Delta water quality objectives and standards adopted by the SWRCB in that board's water quality control plans. Because of its access to the legal protection of "sovereign immunity," the federal government reserves the right to object to the standards the state adopts, even though Congress has also required the Bureau of

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[5] United States Bureau of Reclamation and California Department of Water Resources. 1986. *Agreement Between the United States of America and the State of California for Coordinated Operation of the Central Valley Project and the State Water Project.* November 24. Article 3(a) and (b), p. 4. Accessible at https://cawaterlibrary.net/document/coordinated-operating-agreement-for-the-central-valley-project-and-the-state-water-project/. Hereafter "*1986 COA*."

[6] *Ibid.*, pp. 13-14.

Reclamation comply with state water law and regulation under the 1902 National Reclamation Act.[7]

The equations for excess and balanced conditions set up a rigid water budget by which both the CVP and SWP aggressively exercise their property rights on behalf of their customers while providing just enough flows from upstream reservoir releases to protect Delta water quality—and typically no more. Excess conditions provide them an opportunity to take what has been called "the big gulp" of surplus (also known as unstored) flows up to the limitations of their engineered pumping and storage capacity (at Banks and Jones pumping plants and at San Luis Reservoir and the other southern California SWP reservoirs).

"Unstored flows" (UFs) are the wild card here in both equations. UFs include but are not limited to waters nature provides that have not otherwise been accounted for by water right holders' claims to divert or store. Some UFs are picked up by CVP and SWP pumping plants, while some of them are left to nature.[8] These are referred to as "uncaptured flows", flows that make it to and through the Delta as outflow to San Francisco Bay and the Pacific Ocean because they were beyond reach of CVP and SWP facilities.[9]

"In the future," the authors of the 1971 COA's descriptive summary wrote, "with increased local requirements, additional water storage facilities and additional exports, the length of the periods of balanced water conditions will increase." Water occurring as "unstored flow," will decrease over time the more that developed water facilities and water right claims associated with these facilities and new water-consuming development in the Sacramento Valley encroach on and reduce unstored flow. In short, the COA anticipates an inevitable takeover of natural flow by the CVP and SWP—commodified for incorporation into our economy at the expense of nature, and limited only by engineered capacity of the facilities involved.

This COA language also signals that water for all uses—domestic, municipal, agricultural, industrial, and environmental uses—will get scarcer and political conflict over the allocation of water will become more intense.

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[7] *Ibid.*, Article 11(b) and (c). These provisions of the 1986 COA reserve the Bureau's rights to sue the state of California if it thinks the state's Delta standards are inconsistent with Congressional directives, and to seek new legislation to avoid complying with Delta standards.

[8] Some people consider this "water wasting to the sea," a statement that ignores the importance of water to natural aquatic and shoreline ecosystem functions for public well-being, a healthy and balanced human diet, and environmental health overall.

[9] Gregory Reis, Jeannette Howard, and Jonathan Rosenfield. 2019. "Clarifying Effects of Environmental Protections on Freshwater Flows to—and Water Exports from—the San Francisco Bay Estuary." *San Francisco Estuary and Watershed Science* 17(1). Accessible at https://escholarship.org/uc/item/8mh3r97j.

> …The Coordination Agreement is intended to provide an operational procedure for sharing the available water supply between the two projects in order to produce the project annual supplies [that is, water supply goals included in an appendix to the agreement].[10]

And we haven't yet factored in the effects of climate change.

By single-mindedly pursuing the property-protecting logic of their water rights and the COA, DWR and the Bureau reveal that their prime objectives are to maximize their storage for and exports to customers above all else, even as they strive to balance this objective with meeting Delta water quality criteria. In the COA they agree to collaborate because they can each achieve their prime objectives better by working together than they can pursuing them separately.

This drive to maximize their water exports to customers took a turn for the worse in December 2018—at the same time that the SWRCB approved its San Joaquin River flows water quality plan for the Bay-Delta estuary.

A "**COA Addendum**" was negotiated in the fall of 2018 between the Bureau and DWR. The Bureau took a hard line, having been authorized by then Interior Secretary Ryan Hinke to "maximize water supplies" to the Central Valley Project. Revisiting the 1986 Coordinated Operations Agreement was a natural place to begin fulfilling that directive. The COA Addendum adjusts the shared responsibility between the projects for meeting Sacramento Valley in-basin uses and storage withdrawals by water year type (wet, above and below normal, dry, and critical years) so that the Bureau will have *less responsibility* in dry and critical years than it used to. That way, more of its supplies can go to its south-of-Delta customers during droughts. This also means that in dry years, there will be much less water available to State Water Project contractors. More water will go to agricultural water contractors of the Central Valley Project, including the largest, Westlands Water District.

The COA Addendum also reveals that CVP reservoir storage will gain average storage levels year-round, while the State Water Project's Lake Oroville will shoulder much greater responsibility for meeting flow obligations under D-1641 and the 2006 Bay-Delta Water Quality Control Plan. The Central Valley Project reservoirs serve primarily agricultural water contractors, while the State Water Project serves primarily urban water contractors, most of whose customers are residential water users.

The COA Addendum will likely reduce State Water Project's capacity to adapt to climate change because of its increased responsibilities under the COA Addendum. Lake Oroville will be called upon much more to "backstop" water quality objectives in dry years while the Central Valley Project continues to export water from the Delta.

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[10] *Descriptive Summary*, *op. cit.*, p. 8.

- ***Case Study 2: Subsistence Fishing in the Delta***[11]

Finally, the matter of protecting subsistence fishing as a beneficial use of water yields a further corollary to the "management/measurement" adage: "If you don't want to manage something that would be fair and just to manage to benefit all members of our community, don't measure it."

At least subsistence fishing is now recognized by the SWRCB as a beneficial use of water, one deserving of water quality regulatory protection. But this beneficial use has not yet been placed into the Bay-Delta Water Quality Control Plan. Its importance lies in providing a diverse and affordable and healthy protein source for low-income households and communities of color for whom fishing is a traditional practice—and subsistence fishing is vital to the cultural survival of many Northern California Indian tribes who struggle to protect salmon as full partners with the state's commercial fishing industry and environmental water activists. And the SWRCB actually recognized a separate beneficial use for tribal subsistence fishing.

This non-market, non-commodified access to fish as food unmediated by a money exchange gives the lie to media tropes that water battles in California are about "fish versus food"—as if agriculture was the only source of food for human beings. It is not. The trope is not intended by its users to reflect reality, but to distort reality, and in doing so, render invisible the reliance of environmental justice communities on subsistence fishing.

If only we devoted as much funding, expertise, and legal priority to subsistence fishing as our society does for drinking water quality and supply—we would likely have an excellent bunch of fisheries in the beloved Delta! But there has never been a census of Delta subsistence anglers, let alone ongoing or continuous monitoring by state agencies, despite potential health risks of catching and consuming fish routinely from Delta channels.

Because of this huge gap in knowledge about this particularly important beneficial use in the Delta, Restore the Delta undertook, with a favorable procedural assist from the SWRCB, to make subsistence fishing visible for our case in the water rights proceeding for the California WaterFix project. Using publicly available fishing license data from the California Department of Fish and Wildlife (DFW), we estimated through two distinct methodologies that there are, on any given day, between 66 and 110 licensed subsistence anglers from distressed communities fishing Delta waterways. Our methodologies rely on both an angling hours survey and county-level fishing license data from DFW. Our methods conservatively assume that each angler fishes just once a

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[11] This case study draws from Restore the Delta's 2018 report, *The Fate of the Delta*, pp. 54-55. Accessible at https://www.restorethedelta.org/thefateofthedelta/.

year which probably underestimates total subsistence fishing activity in the Delta. Despite this limitation of our methods, we estimate between 24,000 to 40,000 subsistence fishing visits annually in the Delta from local residents of distressed communities. We offer no estimate of the biomass of fish nor the number of persons actually consuming those fish.[12]

Restore the Delta's witnesses Barbara Barrigan-Parrilla and myself were never cross-examined about this estimate of subsistence fishing potential nor our assumptions used to assemble it. We succeeded in making subsistence fishing visible to the Board through creative use of data and analysis, and we wrote about it in our report, The Fate of the Delta two years ago.

We researched Delta subsistence fishing to see what had been done by others. Delta region subsistence anglers have been found to fish along both the Sacramento and San Joaquin Rivers, despite the latter being an impaired water body due to a number of contaminants. Delta region subsistence anglers are known to catch and consume a variety of native and introduced fish species, including American shad, bluegill, carp, catfish, crappie, Chinook salmon, largemouth bass, pike minnow, Sacramento split tail, Sacramento sucker, steelhead/rainbow trout, striped bass, sturgeon, and sunfish.[13]

Many fish caught and consumed by subsistence anglers consume prey from the bottom of river channels where contaminants can accumulate.[14] Other fish consumed by subsistence anglers feed on prey consumed in open water or other parts of river channels.[15] In the course of consuming prey, these species may also consume contaminants such as mercury, pesticides, selenium, and other chemicals that accumulate in prey tissues and that are regulated via Total Maximum Daily Loads adopted by the SWRCB and Central Valley Regional Water Quality Control Board. Consequently, environmental justice communities are at risk of heightened exposure to health risks associated with consuming fish caught through subsistence angling in the Delta.[16]

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[12] Restore the Delta, "Methodology for Estimating Population of Delta Region Subsistence Anglers from Fishing License Data" and "Methodology for Estimating Delta Counties Subsistence Anglers from Angling Intensity (Hours) Data," both accessible from RTD on request.

[13] F. Shilling, A.White, L. Lippert, and M. Lubell, 2010. Contaminated fish consumption in California's Central Valley Delta. Environmental Research 110(2010): 334-344, p. 335, Figure 1 and p. 336, Table 1.

[14] May include green sturgeon and white sturgeon.

[15] May include largemouth bass, black bass, striped bass and other fish.

[16] Shilling et al 2010; Davis et al 2008; Silver, E., J. Kaslow, D. Lee, S. Lee, M.L. Tan, E. Weis, and A. Ujihara, 2007. Fish consumption and advisory awareness among low-income women in California's Sacramento-San Joaquin Delta. Accessible at http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/RestoretheDelta/RTD_235.pdf. Hereafter Silver et al 2007.

In addition, such fish may be vulnerable to disease and death from exposure to toxins released by harmful algal blooms, such as microcystin, a hepatotoxin (toxic to liver tissue and skin) produced by *Microcystis*, a common cyanobacterium found in the Delta since 1999. Key factors believed by scientists to drive algal blooms that cause harm in open water ways include water temperature, sunlight irradiating water, water clarity, a stratified water column coupled with long residence times of water; availability of nitrogen and phosphorus; and salinity.[17]

Two of these factors would be directly affected by operation of a tunnel project: residence time of water and salinity. Increased residence time of water decreases the loss rate of cyanobacteria from a water body. Inversely, increased residence time of water also influences the stratification of the water column; the slower the flow of water the more the upper levels of a water column can warm to an optimal growth temperature range for *Microcystis*, between 25 and 35 degrees Centigrade (77 to 95 degrees Fahrenheit). Such conditions may occur mainly in late summer months, but climate change effects may shorten California's winter wet season and contribute to extending the season during which harmful algal blooms may occur.[18]

Operation of the tunnels project would also increase residence time of water in the Delta. When such increased residence time is combined with reduced flows and increased salinity from tunnels' operations, the period of time could increase during which environmental conditions favor algal blooms.

The Delta environmental justice effects of increased harmful algal blooms would include increased contamination of fish populations locally from microcystin uptake and accumulation and increased risk of illness and death for environmental justice community members and pet dogs they may take with them fishing, due to contact with water while engaged in subsistence fishing. These dangerous effects would be borne disproportionately by racial and ethnic minorities, people in poverty, and people challenged by language barriers. These disproportionate effects would accumulate with the economic distress already prevalent in their communities and would undermine long-term growth in jobs, economic output, and sustainable economic development in the Stockton region.

The good news here is that there are state regulatory agencies monitoring and working to prevent fish and other forms of aquatic contamination in the Delta watershed. The California Office of Environmental Health Hazard Assessment does its best to monitor

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[17] Berg, M. and M. Sutula, 2015. *Factors affecting the growth of cyanobacteria with special emphasis on the Sacramento-San Joaquin Delta*, Southern California Coastal Water Research Project Technical Report 869, August 2015, p. ii, p. 4, pp. 21-33. Hereafter Berg and Sutula 2015; and P.W. Lehman, K. Marr, G.L. Boyer, S. Acuna, and S.J. 2013. Long-term trends and causal factors associated with *Microcystis* abundance and toxicity in San Francisco Estuary and implications for climate change impacts. *Hydrobiologia* 718: 142. Hereafter Lehman et al 2013.

[18] Berg and Sutula 2015, p. iii, 31-33, 48, 51; Lehman et al 2013.

toxins of various kinds in clams and fish consumed by people. The Central Valley Regional Water Quality Control Board (Region 5) has initiated programs that address mercury in sediments (including in the Delta) and harmful algal blooms. The Department of Pesticide Regulation, as the name implies, seeks to protect the public from unreasonable health and ecological effects of agricultural and other pesticide use in California.

OEHHA Activities:

Developing fish advisories for mercury and other contaminants in sport fish from water bodies throughout the state, and making recommendations regarding fishing safety and closures after marine oil spills.

Collaborating with the California Department of Public Health and Department of Toxic Substances Control on the Biomonitoring California program, which measures levels of chemicals found in Californians' bodies.

Developing a pioneering environmental health screening tool that can be used to put together a more comprehensive picture of the burdens California communities face from environmental pollutants and their vulnerability to health and economic impacts.

Identifying and analyzing Indicators of Climate Change in California.

CalEnviroScreen 3.0[19]: https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30 (Linked from the California Department of Pesticide Regulation's Environmental Justice web site as well.)

Region 5 Projects:

Sacramento-San Joaquin Methylmercury TMDL Project: https://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/

Cyanobacteria and Harmful Algal Blooms (HABs) in the Central Valley: https://www.waterboards.ca.gov/centralvalley/water_issues/nonpoint_source/harmful_algal_blooms/

19 A screening tool used to help identify communities disproportionately burdened by multiple sources of pollution and with population characteristics that make them more sensitive to pollution.

• ***Case Study 3: Nonnative Invasive Clams***[20]

Data collection and study can be important with nonnative invasive species. What are their life histories and habitat tolerances? Do they have predators in their new environs? If not, what advantages do they have over native species or other introduced species that fit better with local ecological conditions? Are their actions informed by data, monitoring, and scientific analysis that can alter the prospects for controlling spread of such an invasive species? If there are options, are they feasible, and if not, why not? All of these questions are germane to the situation of a new clam discovered in Suisun Bay in summer 1986.

Once it was understood by scientists that the new clam posed a threat to the Bay-Delta Estuary's ecology, the matter of "How do you measure what you need to manage?" came to the fore. In the case of nonnative invasive clams that wreak ecological havoc in the Delta estuary, another corollary would be: "If you don't like the implications of what you've learned to fix the ecosystem, ignore the problem and hope it goes away."

The 1986 arrival of *Potamocorbula amurensis* (hereafter *P. amurensis*, with the common name "overbite clam") has had a remarkable impact on the food webs and ecology of the San Francisco Bay and Delta. *P. amurensis* is a formidable clam. In Asian coastal Pacific waters, its range extends from cold temperate waters off Korea, Russia, and Japan to tropical waters off southern China.[21] *P. amurensis* adults tolerate salinity ranges of 2 to 30 parts per thousand.[22] It issues fertilized gametes in the early fall that are planktonic in open waters for up to three weeks.[23]

Immediately prior to *P. amurensis*'s discovery in Suisun Bay in October 1986, a dry period benthic clam community led by *Macoma balthica* and *Mya arenaria* dominated in Suisun Bay by the end of the 1976-1977 drought with other species, some of which were themselves introduced to the estuary as early as the 1870s.[24] But an extreme flood in February 1986 likely eliminated this community from high suspended sediment

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[20] This case study is based on my testimony representing Restore the Delta to the California WaterFix water rights change petition proceeding before the SWRCB in 2018.

[21] J. Carlton, Thompson, Schemel, and Nichols, 1990. Remarkable Invasion of San Francisco Bay by Potamocorbula amurensis: I: Introduction and Dispersal. *Marine Ecology Progress Series* 66: 88.

[22] Bay Delta Conservation Plan. 2013. Appendix 5.F, pp. 5.F-112 to 5.F-114. Hereafter cited as a *BDCP 2013.*

[23] *The Exotics Guide: Corbula amurensis*, accessible 18 October 2017 at http://www.exoticsguide.org/corbula_amurensis; *Ibid.*

[24] Nichols & Permatmat, 1988. *The Ecology of the Soft-Bottom Benthos of San Francisco Bay: A Community Profile*, pp. 13-14; Nichols, Thompson & Schemel, 1990. Remarkable invasion of San Francisco Bay by the Asian clam, Potamocorbula amurensis: of a former community. *Marine Ecology Progress Series* 66: 98-99.

loads, bottom scouring, and transport of bottom sediments. This clam community was apparently, literally, carried out to sea and has not returned.

Ranging in size up to about 25 mm (about 1 inch) in length, a new clam, *P. amurensis*, almost completely and suddenly replaced the established clam community in the Bay and Delta, including *Macoma balthica* and *Mya arenaria.* Wrote one team of scientists of this event:

> Thus, in mid-1986 when [*P. amurensis*] was introduced, presumably via ship ballast water, the Suisun Bay region was inhabited by a depauperate benthic community. It is possible, therefore, that this species was initially successful because it exploited a naturally disturbed, sparsely occupied habitat rather than interjecting itself among and displacing existing species. If this is true. *P. amurensis* was acting, at least initially, as a colonizer rather than an invader.[25]

Ecologists studying San Francisco Bay and Delta ecosystems may refer to invasive species like *P. amurensis* as "stressors"; that is, such species "stress" native or long-established Bay and Delta species by creating stiff competition for niches, consumption of food resources, and energy—the bases for reproductive advantage in ecology.[26] *P. amurensis* has had two important "stressor" roles:

- First, its voracious consumption of plankton outcompetes native open water larval fish like Delta smelt.
- Second, its physiology takes up bioavailable selenium and eliminates it only very slowly. The clam's shallow burial in sediments makes it easy prey, and its predators bioaccumulate the selenium it contains into their tissues. Both of these stressor impacts are directly related to flow and water quality changes that result from CVP and SWP operations. Selenium toxicity and the overbite clam's propensity to bioaccumulate it, is described in **Appendix 2** to these notes.

***P. amurensis* grazing activity and its significance**

P. amurensis's voracious feeding habits in shallow subtidal to open water have reduced planktonic food resources in the vicinity of the Bay-Delta's low salinity zone (LSZ), making it a suspect responsible for declines in planktonic food availability for listed

[25] Nichols, Thompson & Schemel, 1990, *Ibid.*, p. 100; SWRCB-5, Appendix 5.F, p. 5.F-109.

[26] For example, the *BDCP 2013*, Appendix 5.F, included among biotic stressors on covered fish invasive vegetation, invasive mollusks (*P. amurensis* and *C. fluminea*), and *Microcystis*, a key cyanobacterium causing harmful algal blooms.

native fish like larval stage delta smelt and longfin smelt.[27] Its voraciousness and great fecundity generate highly dense colonies in much of Suisun Bay near the LSZ.[28] This compounds the fact that considerable amounts of the open water plankton in the western Delta near Suisun Bay get exported by Banks and Jones pumping plants in the south Delta.[29]

The Bay Delta Conservation Plan (BDCP) described physiological tolerances for *P. amurensis*, including a side-by-side comparison with *Corbicula fluminea* (*C. fluminea*), a fresher-water invasive clam that also resides upstream in the Delta. *P. amurensis* tolerates saltier waters than *C. fluminea*, a similar range of temperatures, and hypoxic (i.e., low oxygen) conditions.[30] Salinities fluctuate in the Bay Delta Estuary, and *P. amurensis*'s larvae tolerate a wide salinity range.[31] One study found that 2-hour-old embryos can tolerate salinities from 10 to 30 practical salinity units (psu) and by 24 hours they can tolerate the same salinities as can adult *P. amurensis*.[32]

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[27] J. York, et al, 2014. Trophic Links in the Plankton in the Low Salinity Zone of a Large, Temperate Estuary: Top-down Effects of Introduced Copepods. *Estuaries and Coasts* 37: 576-588; W. Kimmerer & J. Thompson, 2014. Phytoplankton Growth Balanced by Clam and Zooplankton Grazing and Net Transport into the Low Salinity Zone of the San Francisco Estuary. *Estuaries and Coasts*, January 7; A. Jassby, 2008. Phytoplankton in the Upper San Francisco Estuary: Recent Biomass Trends, Their Causes, and the Trophic Significance, *San Francisco Estuary & Watershed Science* 6(1): February 29; A. Alpine & J. Cloern, 1992. Trophic Interactions and Direct Physical Effects Control Biomass and Production in an Estuary, *Limnology & Oceanography* 37(5): 946-955; L. Brown et al, 2016. Food Webs of the Delta, Suisun Bay, and Suisun Marsh. *San Francisco Estuary & Watershed Science* 14(1), p. 4.

[28] *The Exotics Guide*, *op. cit.*, p. 1.

[29] 2008 Delta Smelt Biological Opinion by the US. Fish and Wildlife Service, pp. 184-185. "Water diversions represent one of the major factors controlling lower trophic level production int he Delta. Water diversions directly entrain zooplankton and phytoplankton biomass which might impact food availability to delta smelt. Entrainment impacts to lower trophic level production are of concern during the spring and summer when newly hatched delta smelt larvae and juveniles are vulnerable to starvation and thermal stress; food limitation may lead to disease, poor growth, or death….[D]uring high periods of high exports, such as the summer, much of the lower trophic level production is entrained rather than dispersed downstream to Suisun Bay. Summer entrainment [at the export pumps] of phytoplankton and zooplankton could therefore adversely affect delta smelt if food supplies are not transported to the [low salinity zone]."

[30] *BDCP 2013*. Appendix 5.F, p. 5.F-113, Table 5.F.7-1.

[31] *Ibid.*, p. 5.F-112:36-38.

[32] M.H. Nicolini & D.L. Penry, 2000. Spawning, Fertilization, and Larval Development of *Potamocorbula amurensis* from San Francisco Bay, California. *Pacific Science* 54(4): 377, 385.

Analysis of DWR (DWR) benthic monitoring data from the Bay-Delta Estuary showed that benthic assemblage composition varied with salinity and hydrology (but was not associated with different substrate types).[33]

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) conceptual model for Delta aquatic food webs indicates that salinity's importance to such clams is high, its predictability as an abiotic factor in their abundance and life history is moderately high, and scientists' understanding of these relationships is also moderately high. It further notes that "[b]road shifts in salinity effectively determine the complementary ranges of these two bivalves, with [*P. amurensis*] residing primarily in marine to brackish water and [*C. fluminea*] in fresh water."[34]

An ecological problem posed by these two nonnative clam species is that they graze the same relatively shallow open water column as larval Delta smelt and longfin smelt.[35] At typical densities, *P. amurensis* tends to occupy channel bottom sediments in Delta and Suisun Bay waters downstream of X2's position in fresher water areas where it can filter phytoplankton from the entire water column more than once per day in open water Delta channels and almost "13 times per day over shallow areas." *P. amurensis*'s filtration rate enables its consumption to exceed the phytoplankton growth rate in the Delta.[36] *C. fluminea,* which tends to occupy benthic sediments in Delta and Suisun Bay waters upstream of X2's position[37], is considered less efficient than *P. amurensis* at filtering out shallow water bodies like Franks Tract. But *C. fluminea* can still "filter out the entire water column in less than a day."[38]

BDCP sums up interrelationships of the *P. amurensis* and *C. fluminea* and their physical habitat tolerances this way:

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[33] H.A. Peterson & M. Veyssierres, 2010. Benthic Assemblage Variability in the Upper San Francisco Estuary. *San Francisco Estuary & Watershed Science* 8(1): 13 [Figure 8], p. 17 [Figure 9, showing lower benthic abundance after 1986], and 19; Bay Delta Conservation Plan. 2013. Appendix 5.F, p. 5.F-112.

[34] J. Durand, 2008. *DRERIP Delta Conceptual Model: Delta Aquatic Food Web*. See link to DRERIP conceptual models above in these notes.

[35] *Ibid.*; Peters & Veyssierres, 2010, *op. cit.*, comparing Figures 8 and 9 for comparative bivalve abundance for these two species in Grizzly Bay and Lower Sacramento River assemblages.

[36] *BDCP 2013*. Appendix 5.F, p. 5.F-110:7-13; see also I. Werner & J.T. Hollibaugh, 1993. P. amurensis: Comparison of Clearance Rates and Assimilation Efficiencies for Phytoplankton and Bacterioplankton. *Limnology & Oceanography* 38(5): 949-964.

[37] "X2 is defined as the horizontal distance in kilometers up the axis of the estuary from the Golden Gate Bridge to where the tidally averaged near-bottom salinity is 2 practical salinity units (psu). [citation] The position of X2 roughly equates to the center of the low salinity zone...." (SWRCB-25, p. 29.)

[38] *BDCP 2013*. Appendix 5.F, p. 5.F-111:18-25.

> Thus, a long period of high flows may lead to increases in [*C. fluminea*] but limit [*P. amurensis*] juvenile success and increase adult mortality because of prolonged exposure to low salinities. However, if an extended period of high flows is followed by a dry year, higher than normal numbers of juvenile [*P. amurensis*] may be seen the following year as X2 moves upstream [citation].[39]

As X2 moves east with lower Delta outflow, planktonic food production in the LSZ would be fully consumed by *P. amurensis* (which would also spread eastward into the Delta, particularly in drier, lower-flow years), turning the western Delta and Suisun into a zone of high nonnative invasive clam production at the cost of reduced plankton abundance.[40]

P. amurensis is a formidable clam. A conceptual model for *P. amurensis* states that prolonged high outflow events (floods!) are required to reduce *P. amurensis*'s estuary-wide population over an extended period of time or even to shift the east edge of its range westward.[41] It regularly produces larval, open water offspring twice a year, which can float upstream with tidal incursions and survive where their salinity ranges permit.[42] The DRERIP Model states:

> Increased outflow periods would need to be maintained for this to be a long term solution, as depauperate periods such as was seen in 2006 can be followed by an increase in the population size of [*P. amurensis*] during subsequent years with normal salinity distributions. ***Therefore, sustained reduction in grazing would require the water for controlled floods most if not all years.***[43]

There is little to no will in the taut water budget of the COA and its 2018 Addendum to spend so much water for so long on a clam that contributes to food shortages for fish species like Delta smelt, which are at risk of imminent extinction; the same is true for trying to eliminate *P. amurensis* as an ecologically toxic species here in the Delta watershed (**see Appendix 2** to these notes). It is also true that neither the flood nor the arrival of *P. amurensis* were the fault of the CVP and SWP. On one hand, why should

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[39] *Ibid.*, Appendix 5.F, p. 5.F-114:38-42; RTD-189, Section 2.11.

[40] L. Lucas & J. Thompson, 2012. Changing Restoration Rules: Exotic bivalves interact with residence time and depth to control phytoplankton productivity. *Ecosphere* 3(12): Article 117 p. 19; see also American Rivers and the Nature Conservancy, 2013. *Independent Panel Review of the Bay Delta Conservation Plan*. September 19, pp. 78-79, 82.

[41] J. Thompson & F. Parchaso, 2012. Delta Regional Ecosystem Restoration Implementation Plan Conceptual Model for *Potamocorbula amurensis*, peer reviewed and approved by editor, August 2012, p. 21, p. 39, Figure 4.

[42] *Ibid.*, p. 40, Figure 5.

[43] *Ibid.*, p. 21. Emphasis added.

they be expected to fix something—with sustained high releases from their reservoirs—they did not cause?

On the other hand, the overbite clam poses a sustained threat to the food web of the Delta estuary, contributes to the risk of extinction of Delta smelt, and its further spread—made potentially easier by removing fresh Sacramento River flows from the estuary by north Delta diversions to a tunnel project—could pose a public health threat because of its affinity for bioaccumulating selenium (again **see Appendix 2**). A reasonable policy toward *P. amurensis* should be to contain it, keep its range as narrow as possible by applying fresh water to its range from the east and north. ***First do no more harm to the Delta Estuary***, should be the underlying premise of such a policy. That means keeping the Sacramento River flowing through its mainstem from I Street in Sacramento through to Chipps Island the way we now do. And mimicking the patterns (though not the historical volumes) of inflow from both the Sacramento and San Joaquin should also help contain spread of the overbite clam.

It has been proposed that humans prey directly on *P. amurensis*. Yet its selenium tissue concentrations are likely too high for safe human consumption—unless a way can be found to somehow induce the clams to eliminate their selenium loads. A silent stalemate persists about how to deal with *P. amurensis*, one that benefits the water industry.

Mostly, the water industry prefers to think about how it maximizes exports and development of more stored water in reservoirs (think of the proposed Sites Reservoir and Temperance Flat Dam, near Fresno) from the Delta given the other constraints that are laid out in the Coordinated Operations Agreement (see previous case study). Voluntary agreements are not known to have been invoked to solve the knotty problems posed by *P. amurensis*, the overbite clam.

Appendix 1
Chronology of Coordinated Operating Agreements

Year	Event Description
1850-1914	Persons seeking water rights are able to acquire and defend rights simply by posting a notice and recording a notice with the County Recorder.
1914	California voters approve a referendum to establish a California Water Commission that requires people to apply for a water rights permit. The new commission grandfathers in all water rights previous to 1914 as senior (that is, having a higher priority) to all new applicants' water rights.
1920	Worst drought in California history provokes the Town of Antioch to sue upstream rice growers whose crop expansion increased irrigation needs depleted fresh water flows to the Delta, injuring the water rights of downstream Antioch and associated Delta farmers because of encroaching tidal salts.
1922	California Supreme Court decides that it would be unreasonable to require upstream irrigators to release sufficient water supplies to the Delta flowing past Antioch in *Antioch v. Williams*.
1923	**Fall:** State water officials recognize a water shortage unfolding in the Valley threatened to revive the issues involved in *Antioch* over reduced flows to the Delta and encroaching tidal salts that harmed Delta irrigators.
1924	**January:** First Sacramento-San Joaquin River Problems Conference convened in Sacramento. An Office of Water Supervisor was created within the California Department of Public Works to "bring about the greatest possible conservation of water and to commence the collection of records of the use of water, stream flow, and other engineering data necessary in the ultimate attainment of a solution of the water problems…"
1927	**July:** California Department of Finance files for water rights on behalf of the state in many river basins throughout California, including the Sacramento River and the Delta. Many of those rights that would underpin the Central Valley Project were later assigned to the US Bureau of Reclamation, when it took over the project in 1935.
1938	**December:** State water officials consider a proposal for "Adjudication Under Statutory Procedure" for the Sacramento-San Joaquin Valley. At that time, adjudication in court was estimated to cost about $475,000 to cover determining water water rights from the upper Sacramento River (at the eventual site of Shasta Dam) to the Kings River (which occasionally drains to the San Joaquin River and the Delta). Such legal action, said the proposal, "is desirable if the difficulty of Federal rights can be ironed out."
1942	**December:** State water rights attorney Henry Holsinger authors a memorandum calling for study by the US Bureau of Reclamation (Bureau) of adjudication of the Sacramento and San Joaquin River basins to be adjudicated between the Bureau and all senior water rights holders. The Bureau rejects the suggestion.
1951	The Bureau initiates the proceeding before the State Water Rights Board to determine its Central Valley Project water rights. The Bureau's water rights applications are protested en masse by Sacramento River Basin senior water rights holders.

Appendix 1
Chronology of Coordinated Operating Agreements

Year	Event Description
1952-1956	California Department of Public Works and the Bureau work on "operations studies" to try to figure out how their two large water projects—with junior water rights in the Sacramento River Basin—could be feasibly operated amid hundreds of diverters whose rights were senior and took priority.
1957-1958	The Bureau and DWR consider a proposed "agreement" by which CVP operations could help satisfy senior water rights holders according to flow and diversions schedules while still allowing their CVP and Feather River projects (later State Water Project) to move forward.
1960	**May 16:** The Bureau and DWR conclude their first Coordinated Operations Agreement. Its key provisions called for: 1) accommodating water shortages by proportional reductions in DWR and Bureau diversions (the Bureau 61 percent, DWR 39 percent); 2) neither entity protesting the other's water rights applications for new facilities; 3) "respecting each other's project service areas" as defined by their respective long-term water contracts with customers; 4) establishing mutually acceptable "operating criteria" "that will produce the maximum accomplishment" of both projects' goals; and 5) not affecting the rights of others ("third parties"). **November 8:** California voters narrowly pass general obligation bonds to fund construction of the State Water Project.
1961	**December 30:** The Bureau and DWR executive a coordinated operating agreement for San Luis Reservoir, which will be jointly financed and operated.
1964	The Bureau completes negotiation and execution of settlement contracts with hundreds of Sacramento Valley senior water rights holders.
196?	DWR completes negotiation of settlement agreement with Feather River Settlement Contractors.
1965	November 19: The Bureau, DWR and several other parties execute an agreement for operating and water quality criteria for the Delta, concerning salinity and total dissolved solids.
1967	SWRCB formed by merging the state's previous water rights and water quality agencies into one board. The reorganization enables California to use water rights regulation and enforcement to protect water quality from degradation.
1971	Coordinated Operations Agreement supplemental to the May 16, 1960 COA is executed by the Bureau and DWR. With most SWP facilities in place, and several Water Board decisions setting Delta water quality objectives, the Bureau and DWR agreed to allocations by each to Sacramento in-basin uses and storage withdrawals (75% to Bureau, DWR 25%), as well as for how unstored flows (later unstored water for export, also sometimes referred to as "surplus water") would be split between the two projects (60% to Bureau, DWR 40%).
1975-1977	Worst drought in modern modern California history (since both SWP and CVP were operating together) tests the 1971 COA, and the Bureau breaks rank by not contributing flows to protect in-Delta water quality as called for by the COA and SWRCB water quality objectives (based on the 1965 objectives).

Appendix 1
Chronology of Coordinated Operating Agreements

Year	Event Description
1981	SWRCB issues Water Rights Order 81-15 adopting a "Term 91 Method" for determining water availability in the Delta watershed during water shortage periods. The method's equation defines available water (AW) as equal to exports plus carriage water, less stored releases from Shasta, Oroville, Folsom and Trinity reservoirs (SOFT). When AW is greater than zero, water is considered by the Board to be available for diversion by junior right holders in the Sacramento River Basin. If AW equals zero, stored releases must be greater than exports plus carriage water.
1983	**November:** SWRCB adopts D-1594, which approves the Term 91 Method for changing the season of diversion during dry periods, and applies the method to over 500 junior water right holders in the Delta watershed. It becomes the legal basis for curtailing junior water right diversions during droughts.
1986	**October 27:** Congress approves Public Law 99-546 to authorize and direct the Interior Secretary to operate the CVP "in conformity" with state water quality standards for the San Francisco Bay-Delta Estuary, and directs the Secretary to sign a new COA with DWR. The law also requires the Interior Secretary to make findings in a report before terminating the COA with 60 days' notice. **November 24:** The Bureau and DWR sign the new COA that suspends the May 16, 1960, COA and the 1971 supplemental COA. The new COA benefits the SWP by allowing it a higher share of unstored water for export (45% raised from 40% in 1971) compared with the Bureau (55%, down from 60% in the 1971 COA).
2018	**August 17:** The-Interior Secretary Ryan Hinke issues a memorandum calling for "maximizing water supply deliveries," "reassessing legal interpretations" predating "the existence of the significant constraints" on CVP operations, and "resolving issues…regarding the Coordinated Operations Agreement, the California WaterFix, the potential enhancement of Shasta Dam," and "preparing legislative and legal measures to maximize water supply deliveries to people…" **December 12:** The Bureau and DWR announce an Addendum to the 1986 COA, whose changes increase CVP deliveries in dry and critical (drought) years, at the expense of SWP deliveries. The Addendum introduces new and extended requirements for export pumping that benefits CVP, including reallocating shared Sacramento in-basin and storage withdrawal responsibilities according to water year types, such that the Bureau (with its larger storage capacity) has lower in-base and storage withdrawal obligations during dry years, and DWR is required to wheel Bureau water for a longer period of the year in any type of year.

Appendix 2
Toxicity and Bioavailability of Selenium

Selenium is necessary to the health of most vertebrate species, including humans, in small doses. For example, adequate amounts of selenium are found in a well-balanced human diet. But at just slightly elevated levels, selenium becomes poisonous. As ingested concentrations rise, selenium can cause embryonic defects, reproductive problems, and death in vertebrate animals.[44]

Selenium can readily substitute for sulfur in salts (such as selenates for sulfates) in certain amino acids, the building blocks of proteins.[45] Selenium's ability to substitute chemically for sulfur clears pathways to toxicity, increased gene mutation, and ecological damage.[46]

At higher tissue concentrations, proteins in predator species may be altered by excessive exposure to selenium, leading to sterility and suppression of the immune system "at critical development stages when rapid cell reproduction and morphogenic movement are occurring." Changes in the structure of many antibodies (such as from substitution of selenium for sulfur atoms) can compromise the organism's immune defenses, making it more susceptible to disease.[47]

The western San Joaquin Valley and its Coast Range foothills have naturally high levels of selenium in the rocks and soils.[48] Three areas of the western San Joaquin Valley have the highest soil selenium concentrations:

- The alluvial fans near Panoche and Cantua creeks in the central western valley (near Gustine and Firebaugh);
- An area west of the town of Lost Hills; and

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[44] T. Presser, 1999. Selenium Pollution. Encyclopedia of Environmental Science ed. D.E. Alexander & R.W. Fairbridge, pp. 554-556.

[45] E.g., seleno-cysteine and seleno-methionine; *ibid.*, p. 554-555; T. Presser & S. Luoma, 2006. *Forecasting Selenium Discharges to the San Francisco Bay-Delta Estuary: Ecological Effects of a Proposed San Luis Drain Extension*, USGS Professional Paper 1646, p. 40.

[46] Presser 1999, *op. cit.*

[47] *Ibid.*, p. 555.

[48] R.R. Tidball, et al, 1986. Distribution of Selenium, Mercury and Other Elements in Soils of the San Joaquin Valley and Parts of the San Luis Drain Service Area. *Symposium III: Selenium and Agricultural Drainage*; R.J. Gilliom, 1989. *Geologic Source of Selenium and Its Distribution in Soil, in Preliminary of Sources, Distribution, and Mobility of Selenium in the San Joaquin Valley, California*, USGS Water Resources Investigation Report 88-4186.

- The Buena Vista Lake Bed Area, west of Bakersfield.[49]

Irrigation has played a key role in physical processes mobilizing selenium to the San Joaquin River, and from there to the Delta:

> Prior to about 1940, groundwater moved toward valley stream channels, and much of the valley was a discharge area. By 1970, pumping for agriculture and other uses had drawn groundwater reservoirs down hundreds of feet. Importation of irrigation water (from rivers or from the [CVP]) together with continued overuse of groundwater means the Central Valley is now primarily a groundwater recharge area, and most groundwater discharge is a result of pumping rather than natural seepage. As a result, salts and selenium accrete in Central Valley soils, poisoning agricultural runoff water.[50]

Because of the extent of the geologic formations and rocks containing selenium in the western San Joaquin Valley, it is important to recognize that at time scales relevant to society, "there are, for all practical purposes, unlimited reservoirs of selenium and salt stored within the aquifers and soils of the valley and upslope in the Coast Ranges."[51] The selenium reservoir will be with Californians for a very long time to come—by one estimate, 304 to 2,828 years.[52]

The National Research Council's 2012 report on Bay-Delta sustainable water management recognized this selenium reservoir as well, stating:

> A very large reservoir of selenium exists in the soils of the western San Joaquin Valley associated with the salts that accumulated there during decades of irrigation [citation]. Irrigation drainage, contaminated by selenium from those soils, is also accumulating in western San Joaquin Valley groundwaters. The problem is exacerbated by the recycling of the San Joaquin River when water is exported from the delta. While control of selenium releases has improved, how long those controls will be effective is not clear because of the selenium reservoir in groundwater.
>
> ...Other aspects of water management also could affect selenium contamination. For example, infrastructure changes in the delta such as construction of an isolated facility could result in the export of more Sacramento River water to the south, which would allow more selenium-rich San Joaquin River water to enter

[49] Gilliom, *ibid.*, p. 8, Figure 2.

[50] CalFED Science Program, 2008. *The State of Bay-Delta Science*, p. 43.

[51] T. Presser & S. Schwarzbach, 2008. *Technical Analysis of In-Valley Drainage Management Strategies for the Western San Joaquin Valley*, USGS Open File Report 2008-1210, p. 2

[52] Presser & Luoma, 2006, *op. cit.*, Appendix A, p. 111, Table 5.

> the bay. ***The solutions to selenium contamination must be found within the Central Valley and the risks from selenium to the bay are an important consideration in any infrastructure changes that affect how San Joaquin River water gets to the bay.***[53]

P. amurensis selenium bioaccumulation

P. amurensis's other "stressor" impact is to take bioavailable selenium[54] into its tissues with high efficiency, and its metabolic elimination of selenium is slow. Consequently, *P. amurensis* specimens subject to high exposures of particulate selenium in their planktonic diet (such as through phytoplankton) will bioaccumulate large concentrations of selenium in their biomass. Seasonal variability in selenium contamination is important since measured selenium tissue concentrations were found to be highest in the fall.[55]

Selenium dissolved in water is the predominant form (ranging from 80 to 93 percent) of total selenium loading in the Bay Delta, but it represents only a small proportion of organismic exposures.[56] Selenium can undergo "partitioning" reactions in a slowing water column through many types of interaction with phytoplankton, algae, and organic particles in suspension.[57] The rate and degree of partitioning determine whether and how much selenium remains dissolved or enters what chemists refer to as its "particulate phase."[58] This is the phase wherein selenium becomes bioavailable and may be taken up by aquatic organisms.

Currently, San Joaquin River flows to the Delta are mostly diverted at Banks and Jones pumping plants and circulated back to irrigated lands of the western San Joaquin Valley, along with salts.[59] This helps limit selenium exposures in the Delta and Bay sourced

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[53] National Research Council, 2012. *Sustainable Water and Environmental Management in the California Bay-Delta*, p. 94. Emphasis added.

[54] That is, selenium appearing in a chemical form that can be biologically consumed and metabolized.

[55] R.G. Linville et al, 2002. Increased selenium threat as a result of invasion of the exotic bivalve, P. amurensis. *Aquatic Toxicology* 57: 62; A.R. Stewart, et al, 2004. Food Web Pathway Determines How Selenium Affects Aquatic Ecosystems. *Environmental Science & Technology* 38(17): 4525.

[56] *Total Maximum Daily Load for Selenium in North San Francisco Bay, Draft Staff Report for Proposed Basin Plan Amendment*. San Francisco Bay Regional Water Quality Control Board, July 2015., p. 81. Hereafter citied as *Region 2 Selenium TMDL*; T. Presser & S. Luoma, 2006. *Forecasting Selenium Discharges to the San Francisco Bay-Delta Estuary: Ecological Effects of a Proposed San Luis Drain Extension*, USGS Professional Paper 1646, p. 38.

[57] *Region 2 Selenium TMDL*, p. 81-83.

[58] Presser & Luoma, 2006, *op. cit.*, p. 41; S. Luoma & T. Presser, 2009. Emerging Opportunities in Management of Selenium Contamination. *Environmental Science & Technology* 43(22): 8483-8487, November 15.

[59] *Region 2 Selenium TMDL*, p. 94, 116; *Ibid.*, p. 53.

from San Joaquin flows. But construction and operation of north Delta diversions for a tunnel would decrease Sacramento River flows into the Delta and increase both the proportion of Delta flows contributed by the San Joaquin (with less of its flows diverted at the existing pumps) and by increased residence time of inflows slowed by countervailing tidal action from the Bay.

Calm waters of marshes, wetlands, and estuaries facilitate selenium partitioning. Presser and Luoma catalog a range of hydrologic environments and how they influence selenium's partitioning behavior.[60] This partitioning is expressed in modeling efforts as a "selenium partitioning factor," which varies with different aquatic environments and hydrologic conditions.[61] Once selenium is consumed by prey organisms, predators can then bioaccumulate selenium depending on how much these prey are part of predator diets in higher trophic levels of Bay-Delta Estuary food webs.[62]

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[60] T. Presser & S. Luoma, 2010. A Methodology for Ecosystem-Scale Modeling of Selenium. *Integrated Environmental Assessment and Management* 6(4): 692, Table 2, and 703, Figure 6**;** summarized in California Water Impact Network, 2012. *Testimony on Recent Salinity and Selenium Science and Modeling for the Bay-Delta Estuary*, submitted by Tim Stroshane, August 17, 2012 for Workshop #1, Ecosystem Changes and the Low Salinity Zone, p. 26, Table 7.

[61] T. Presser & S. Luoma, 2010. *Ecosystem-Scale Modeling in Support of a Fish & Wildlife Criteria Development for the San Francisco Bay-Delta Estuary*, Administrative Report for USEPA by the U.S. Geological Survey, showing a variety of Bay-Delta Estuary K_d values in Supplemental Tables 8 through 10, 14 through 19.

[62] Presser & Luoma 2006, *op. cit.*, pp. 41-94; Presser & Luoma 2010,*Ibid.*, pp. 689-705.