980 NINTH STREET, SUITE 1500
SACRAMENTO, CALIFORNIA 95814
HTTP://DELTACOUNCIL.CA.GOV
(916) 445-5511

Delta Independent Science Board

To: Mr. Les Grober, Deputy Director, Division of Water Rights
State Water Resources Control Board

From: Delta Independent Science Board

Re: Review of SWRCB's "Working Draft Scientific Basis Report for New and Revised Flow Requirements on the Sacramento River and Tributaries, Eastside Tributaries to the Delta, Delta Outflow, and Interior Delta Operations"

Summary

Insightful, informative, well-illustrated, clearly written—these are among our overall impressions of "Working Draft Scientific Basis Report for New and Revised Flow Requirements on the Sacramento River and Tributaries, Eastside Tributaries to the Delta, Delta Outflow, and Interior Delta Operations". The comments below focus on recommended improvements.

In particular, we recommend clarifying, and further justifying scientifically, the proposed use of percent of "unimpaired flow" as the main basis for establishing an annual environmental water budget. We also suggest presenting a further review of cold-water management, a deeper analysis of non-flow stressors, additional consideration of near-term responses to climate change, and elaboration of how regulations managed adaptively may improve scientific understanding of environmental flows.

Introduction

Staff of the State Water Resources Control Board asked us on October 13, 2016, to review the SWRCB's "Working Draft Scientific Basis Report for New and Revised Flow Requirements on the Sacramento River and Tributaries, Eastside Tributaries to the Delta, Delta Outflow, and Interior Delta Operations" (draft of October 16, 2016). The staff described this draft report as proposing a science basis for eventual policy decisions that would balance water management policies across management objectives. The staff provided questions that guided our review, and also provided paper copies of the report.

The draft report begins by describing its purpose and structure, and by summarizing much of its content (Chapter 1). Next it presents, stream by stream, differences between present-day flows and unimpaired flows, chiefly in the Sacramento Valley (Chapter 2). The draft report then quantifies relationships between freshwater flows and the abundance and distribution of selected species of fish and invertebrates in the Delta and in other parts of the San Francisco Bay estuary (Chapter 3). In a mainly qualitative way, the report also considers stressors other than reduced freshwater flows (Chapter 4). Finally, these various findings are brought together to support recommendations on environmental flows (Chapter 5). Comprehensive reference lists follow (as Chapter 6).

The SWRCB is commended for developing the in-house expertise that this draft report reflects. The draft provides an insightful, informative, highly readable compendium and analysis of existing scientific understanding of how the populations of certain native species, chiefly fish, are likely related to freshwater flows. It also acknowledges stressors other than low freshwater flows and considers in a brief but appropriate fashion how these stressors can interact with flows.

We recommend strengthening the draft's treatment of unimpaired flow, cold-water management, non-flow stressors, climate change, and adaptive management. We also offer additional suggestions on content and presentation.

Recommendations

1. Clarify the use of annual volumes in the "unimpaired flows" approach

The report could build on the explanations in sections 5.1 and 5.2 to describe more clearly the "unimpaired flow" approach and to explain how this approach would be implemented.

In our understanding, the proposed approach would establish a fixed annual volume of water to be used for environmental purposes, while also yielding flows that resemble natural flows in "frequency, timing, magnitude, and duration" (p. 5-3). The fixed annual volume of water would ideally provide environmental managers with a tool to operate in cooperation with other basin interests for more effective, flexible, and adaptable ecosystem management. The quantity of this environmental water budget would be based on a fixed annual percentage of unimpaired flow on each tributary or for the basin to operation for environmental purposes. If cooperative basin operations are not negotiated successfully, then the annual unimpaired flow volume would be operated under state authority.

It would be useful for the report to separately clarify a) how the fixed annual quantity of water would be used, with and without successful agreements among basin water managers and b) how the annual water volumes would be calculated (by basin and/or by tributary). The "unimpaired flows" label seems to better describe the basis for annual volume calculation, rather than the perhaps more ecologically important issue of how the volume would be managed.

2. Compare the SWRCB approach with alternatives

The report could be improved by adding a comparison of the "unimpaired flows" approach with other science-based approaches to establishing flow requirements for fish and aquatic ecosystems. Examples of other approaches can be found in reports by Adams, Arthington, Bunn, Linnansaari, Poff, Richter, Tharme, and Yarnell (full citations are provided in our reference list). Three alternative approaches are briefly reviewed below, after comments on the "unimpaired flows" strategy.

The recommended comparisons could evaluate approaches in terms of scientific merit, ability to respond to extreme events and climate change, ability to accommodate other water management objectives (water supply, flood management, etc.), and alignment with regulatory objectives.

The comparisons may show how the proposed environmental water-budget approach can combine the best aspects of other scientific approaches for establishing environmental flows. A hybrid approach, which often has value (Kiernan et al. 2012), could allow for more effective and adaptable environmental flows, and these could have less impact on other water users than would a single, less flexible approach.

Unimpaired flows. The proposed unimpaired flow basis for environmental flows is relatively easy to administer and should support flexibility in working with regional interests and different regulatory needs, water projects, and water users to implement diverse operational and management activities to benefit native species and human water users. Establishing the size of an annual environmental water budget as a fraction of unimpaired flows would result in flows that largely depend on each year's precipitation. A consistent technical method for quantifying the unimpaired flow for different years will be needed, such as the proposed Sacramento Valley Unimpaired Flow Model (SVUFM). This unimpaired approach roughly approximates natural annual flow variability. Quantifying the environmental water budget this way has relatively few complications and is relatively fast to implement. Moreover, it seems to allow considerable flexibility in working with regional interests for the benefit of both native species and human water users. Flexibility in its implementation might be its greatest advantage.

An unimpaired flow approach for quantifying annual environmental flow assets could still be controversial, but it would add quantification to decision making and discussions about its appropriate use. Field data from river mouths and tributaries are often limited, and this limitation can lead to heavy reliance on modeling. A program of monitoring and modeling, in which models are frequently tested and updated, will be needed to support quantification of unimpaired flows. Because each year's operations will need a forecast estimate of unimpaired flow, some basis for correction of carryover of unused environmental water should be considered. Any modeling and monitoring framework used as a regulatory assessment tool for reckoning flow in junctions, river mouths and smaller tributaries should be tested thoroughly with field data and modified as needed to improve efficacy and reliability. Like many other entities, the SWRCB will need additional monitoring to support adaptive-management activities in the Delta.

Natural flows. The draft report recognizes that native biota and ecosystems evolved with natural flows over millennia (the "natural flow doctrine"); flows more nearly natural than those of recent decades should be favorable for restoring native species and ecosystems. Section 3.2.1 notes, for instance, that emulation of natural flows helped native fish regain dominance along lower Putah Creek (Kiernan et al. 2012). The report further recognizes that natural flows are difficult to produce in today's altered Delta, with its diminished and disrupted habitats (especially lost floodplains), non-native species, and pollutants. The report also briefly identifies climate change as likely to lead to further departures from the natural conditions that prevailed in the centuries before the mid-19th century Gold Rush (sec. 4.6).

The report could elaborate on how and why unimpaired flows differ substantially from natural flows in parts of the Central Valley where loss of floodplains and wetlands has been extensive (DWR 2016; Fox et al. 2015). These differences could be considered where the SWRCB or others are recommending habitat expansion or improvement, invasive species management, and/or contaminant management to enhance the native food web. Of course we do not recommend attempts to precisely re-create natural flows for the Delta, but modeling natural flows may be informative, even though pre-development conditions and natural flows are difficult to simulate accurately.

Statistical correlations. Regression and other statistical analyses can be insightful where data on flows and fish can be correlated (Linnansaari, et al. 2012). Examples in the SWRCB report show that populations of many native and non-native species are correlated with streamflows in, around, and out of the Delta. Indeed, many native species appear to benefit from additional streamflows at some times and locations, either directly or from additional habitat that comes from greater inundations. Correlations do not always indicate clear causation. The SWRCB report nicely explains many of the broad statistical relationships.

Nevertheless, regressions from past data may not be predictive into the uncertain future, especially in the face of ‘regime’ changes like the pelagic organism decline and the consequences of climate change. Fundamental ecological relationships between newer fish assemblages and changes in chemical discharges and runoff will affect future statistical relationships, as will changes in water temperature. Also, some correlations are spurious, and some statistical analyses have led policies astray.

The draft report could briefly discuss the relative value of statistical approaches and how to address their weaknesses over the long term, particularly in the implementation of the proposed SWRCB approach.

Functional flows. Functional flows are a mechanistic approach for estimating flow needs and trade-offs (Yarnell et al. 2015; DISB 2015). Flows needed are based on field observations of life stages and computer and conceptual models of hydrodynamics, habitat, and ecological conditions for different flows. Environmental flows are then chosen to support different ecological functions and life stages of selected species. The report acknowledges this approach in many aspects of its discussions and organization (such as in section 3.3 and 3.4.1).

The advantage of a mechanistic approach is its greater ability to explain cause-effect and to lead to new knowledge (via adaptive management). The disadvantage of this approach is the requirement for long-term organization, funding, modeling, and research. In this sense, it would not be possible in the near term to base effective environmental flows exclusively on functional flows. Mechanistic modeling has been developed for other major aquatic systems (DISB 2015), but not for California's inland fishes. Over time it is desirable for ecosystem management to increasingly employ more of a functional flows approach, which can better adapt to changes in conditions and scientific understanding and better integrate management of flow and non-flow stressors, as has been seen for floodplain restoration (Sommer et al. 2001; Ahearn et al. 2006).

In comparing scientific bases for establishing environmental flows, the report could discuss how this approach might fit in implementation of the SWRCB approach in the near term and in the long run, as well as the scientific advances that would be needed to apply a functional flows approach in individual river basins or system-wide. This should include some discussion of the experimental aspects of environmental flow operations in an adaptive management context.

3. Include more emphasis on managing water temperature

The draft report briefly introduces the importance of water temperature for aquatic organisms (sec. 4.3.4) and contains a major section on management of cold-water pools downstream from reservoirs (sec. 5.4). We agree that water temperature strongly controls fish physiology and survival and that temperature cues are important for specific life history phases and migrations. Temperatures also affect a range of chemical and other biological processes that affect aquatic ecosystems in many ways.

The report could expand on this important stressor. Potential amendments include:

- Further efforts to assimilate and synthesize available data on flow-temperature-fish relationships, and on how such information should be considered in management.
- Further evaluation of temperatures expected from a warming climate (beyond those cited in sec. 5.4.1).
- References to each agency's ongoing temperature data collection, modeling, and monitoring efforts for major rivers tributary to the Delta. These could be useful and informative for basin discussions and overall regional and state coordination.
- Recommendations for research in support of managing temperature in real time and seasonally.

4. Include more examination of non-flow stressors

Chapter 4 of the draft report acknowledges many non-flow stressors and identifies them as having contributed to species declines. It considers interactions that enable the effects of non-flow stressors to exacerbate the effects of low flows, and vice versa. These interactions show that greater scientific understanding of non-flow stressors could provide a better basis for negotiated agreements among responsible agencies, as sought by SWRCB.

The report could do more in assessing the contributions of non-flow stressors to declines in native fish and wildlife in the Delta and estuary. For example, quantitative assessments have been made for effects of pesticides on salmonids (Baldwin et al. 2009), and fish abundances could be graphed against non-flow stressors (with suitable caveats about the pitfalls of statistical correlations).

The report could also provide more information about direct and indirect stress from non-native aquatic plants. Their effects include increasing water clarity (to the likely detriment of Delta smelt) and reducing sunlight penetration and flows in some areas (as shown by recent studies of Boyer et al.). Conversely, flows have direct and indirect effects on the extent and timing of alien-plant invasions and residence times of contaminants and nutrients. Section 4.4.3 describes control efforts for non-native vegetation, but it would be helpful to indicate efforts to reduce the impacts of non-flow stressors and interactions with flows and climate change.

5. Pay additional attention to climate change

Climate change is identified as a stressor that affects fish and wildlife via water supply reliability, flooding, salinity intrusions and temperature (p. 4-16). Hydrologic conditions, particularly unimpaired flow and stream temperatures, are also expected to respond to climate change. Despite uncertainties in the quantitative effects of climate change, we suggest adding literature on the effects of climate change on hydrologic conditions in the Delta, (e.g., Cayan et al. 2010; Cloern et al. 2011; Stern et al. 2016). Even if changes in climate are modest in the near future, the report should consider longer-term changes because: (1) Substantial responses needed to sustain native ecosystems with climate change are likely to require near-term actions, such as land acquisition to prepare tidal marshes and habitats for higher sea levels. (2) To manage for maintaining coldwater conditions, planning to change water-temperature controls from dams and other infrastructure changes to manage rising temperatures might require consideration decades in advance. (3) Data collection in the near term could better prepare ecosystem managers for changes in climate mixed with the other expected changes. (4) Longer-term adaptability, particularly in implementing regulations, will require strategic changes in regulatory philosophy and methods. At this stage, regulatory responses would be anticipatory, but could still be substantial. (5) The flow plan under development suggests maintaining 'current' flows within 35% - 75% of the unimpaired flows, and it acknowledges the long-term variability of unimpaired flow (Gleick and Chalecki 1999). Discussion in this report could extend beyond the current focus on year-to-year variability and include multi-year variability and climate cycles.

6. More on Adaptive Management

Both management and regulations will benefit from adaptive, science-based approaches. Flow regulations will continue to evolve as the Sacramento-San Joaquin Delta changes and new scientific understanding emerges.

The revised report could examine how adaptive management could dovetail with the new flow regulations and approach proposed (DISB 2016). This discussion could include speculations on a long-term science and technical program (including modeling and experimental approaches to setting flows) to support the SWRCB's long-term interests in the effectiveness of environmental flow regulations, which should be done in conjunction with other agencies having related interests. A common scientific and technical program would have obvious benefits for supporting traditional regulations, and even more benefits for the SWRCB proposals to implement regulations through broad basin agreements involving many parties, likely including various state agencies. Agreements become more difficult to negotiate, implement, enforce, and improve without a common scientific and technical basis. The same holds true for adaptive management; we recommend a sustained scientific and technical program for adaptive management, in concert with other agencies.

We thus suggest that SWRCB should consider developing a scientific program to address scientific and technical issues that are likely to arise while implementing this round of regulatory changes and the development of more flexible operating standards, in concert with stakeholders and other agencies. The report would also benefit from a discussion of how the organization of monitoring and research might improve regulatory decisions into the future.

Other suggestions

Content:

Add new science on vegetation. Because vascular plant growth and distributions are related to hydroperiod and salinity (Boyer and Sutula 2015), the Delta's existing wetlands will respond to increased environmental flows. The habitats include shallow waters dominated by submersed aquatic plants (Boyer et al. 2012, 2015) and habitats dominated by emergent plants. Increased flows could result in greater plant growth, which might be considered positive for the regional ecosystem, because vascular plants contribute to the base of the food web and structure habitats for aquatic invertebrates (Boyer et al.

2013, 2016). On the other hand, potential negative effects of increased flows could include increased growth of existing and future invasive plants (Boyer and Sutula 2015).

Consider setting inundation-duration periods in standards for floodplains. This approach may be useful in Yolo Bypass or the northeastern Delta. Different parts of streams might need different flow characteristics. Floodplains seem to have a disproportionate role in sustaining native fish species. Rip-rapped edges might need different flow velocities than vegetated streams or streams with overabundant floating or submerged vegetation. (Sommer et al. 2001, 2004; Ahern et al. 2006)

Address sediment flows. Water flows, especially floods, have a major role in mobilizing and transporting sediment and associated materials (e.g., particulate organic carbon).

Consider suppressing undesirable species by managing flows. Native species might benefit from this approach.

Balance species and economics. While most native species tend to cluster in areas with the more natural flows, the most popular non-native recreational fish (striped bass, *Morone saxatilis*) has somewhat different flow preferences. Could the SWRCB report present science-based trade-offs? Similarly, are there trade-offs between environmental benefits and economic benefits of water uses (for cities, agriculture, and recreation) that might have a science base? Or will economic and other socially-desired flows be addressed in other reports or impact statements?

Elaborate on coordination with other entities. Many state, local, and federal agencies share concerns expressed in this report and have substantial scientific expertise and policy responsibilities for the maintenance and management of ecosystems in the Delta estuary and upstream. Effective coordination among SWRCB and other agencies is warranted for compiling and synthesizing the science that informs flow regulating in the Delta for the common purposes of state, local, and federal agencies.

Presentation:

Add or improve graphics and tables. Add a diagram early to show how this Scientific Basis report fits into the larger scheme of SWRCB reports and regulations. Readers would benefit from seeing coverage and issues in this broader context. The diagram could show how each report is intended to support the process of establishing environmental flows and their implementation and updating.

Add a summary table. Add a summary table identifying and summarizing Delta flow and export limits as they exist today and as they might change with the proposed approach; this would be useful in the last chapter.

Add selected graphics. Amend Fig. 3.13-1 to explore potential cause and effect. Declines could be compared by stacking each species graph above a time series of flow parameters. On each flow graph, the “protective” ranges in Table 3.13-2 could be highlighted to support how “many of the native fish and wildlife species maintained healthy populations until the past several decades when water development intensified” (p. 1-3, and p. 5-2). Graph the contrast on page 1-13 between a wet 2011 and a dry 2012–2015 as “a dramatic example of the importance of flow for native fish species.” Add graphs on the effects of the invasive clam *Corbula* on pages 3-7, 3-11, and 4-13. Show stressors and outcomes against time, for referencing dates of key efforts to improve outcomes, such as “implementation of D-1641” (p. 1-13).

Add a small table covering each stream. Comparable summary statistics for each stream, and information such as mean annual flow, lowest flow, major hydrograph components, species composition, major reservoirs or blockages, diversions, and existing flow requirements would be a welcome addition. Some better location and descriptive maps would also help.

Forewarn that different geographic ranges will be used. Chapter 1 begins with “Sacramento River watershed and related areas” (p. 1-1) which could be clarified in a map that plots the geographic ranges considered in Chapters 2 and 3. The hydrology in Chapter 2 covers the watershed north and east of the Delta, and also considers the Delta itself and the Suisun “region.” The “related areas” include migratory ranges that extend into the Pacific Ocean (salmon, p. 3-3) and San Pablo Bay (Longfin Smelt, p. 3-8). Species considered in detail (section 3.3) include many that depend on the estuary (p. 3-10). The “related areas” in the context of loss of tidal wetland, as a stressor, appears to exclude estuarine areas seaward of Suisun Bay (p. 4-2).

Consolidate references. Users of paper copies will struggle to find references cited among the lists that are specific to chapter or section.

Add a record of track changes. If this is a living document, include a tabular summary of changes to flow requirements and their scientific basis.

References cited

Adams, J.B. 2014. A review of methods and frameworks used to determine the environmental water requirements of estuaries. Hydrological Sciences Journal, 59 (3–4), 451–465.

Ahearn, D.S., J.H. Viers, J.F. Mount, and R.A. Dahlgren. 2006. Priming the productivity pump: flood pulse driven trends in suspended algal biomass distribution across a restored floodplain. Freshwater Biology 51(8):1417-1433.

Arthington, A. 2012. Environmental Flows: Saving Rivers in the Third Millennium.

Baldwin, D.H., J.A. Spromberg, T.K. Collier and N.L. Scholz. 2009. A fish of many scales: extrapolating sublethal pesticide exposures to the productivity of wild salmon populations. Ecological Applications 19:2004-2015.

Borgnis, E. and K. Boyer. 2016. Salinity tolerance and competition drive distributions of native and invasive submerged aquatic vegetation in the Upper San Francisco Estuary. Estuaries and Coasts 39:707–717 doi:10.1007/s12237-015-0033-5.

Boyer, K.E., J. Lewis, W. Thornton and R. Schneider. 2012. San Francisco Bay Expanded Inventory of Submerged Aquatic Vegetation (Part 1). Final report for NOAA/National Marine Fisheries Service, Southwest Region, Habitat Conservation Division.

Boyer, K.E., E. Borgnis, J. Miller, J. Moderan, and M. Patten. 2013. Habitat values of native SAV (*Stuckenia* spp.) in the low salinity zone of San Francisco Estuary. Final report prepared for the Delta Science Program.

Boyer, K.E., J. Miller, M. Patten, J. Craft, J. Lewis and W. Thornton. 2015. San Francisco Bay expanded inventory of submerged aquatic vegetation (Part 2): Trends in distribution and phenotypic plasticity: Final report for NOAA/National Marine Fisheries Service, Southwest Region, Habitat Conservation Division.

Boyer, K. and M. Sutula. 2015. Factors controlling submersed and floating macrophytes in the Sacramento-San Joaquin Delta. Technical Report 870. Southern California Coastal Water Research Project Authority.

Boyer, K., J. Miller, E. Borgnis, M. Patten and J. Moderan. 2016. Salinity effects on native and introduced submerged aquatic vegetation of Suisun Bay and the Delta: Final Report to the CALFED Ecosystem Restoration Program and California Department of Fish and Wildlife.

Cayan, D. R., T. Das, D.W. Pierce, T.P. Barnett, M. Tyree, and A. Gershunov. 2010. Future dryness in the southwest US and the hydrology of the early 21st century drought. Proceedings of the National Academy of Sciences, 107(50):21271-21276.

Cloern, J.E., N. Knowles, L.R. Brown, D. Cayan, M.D. Dettinger et al. 2011. Projected Evolution of California's San Francisco Bay-Delta-River System in a Century of Climate Change. PLoS ONE 6(9): e24465. doi:10.1371/journal.pone.0024465

Delta Independent Science Board. 2015. Flows and Fishes in the Sacramento-San Joaquin Delta: Research Needs in Support of Adaptive Management. Delta Stewardship Council.

Delta Independent Science Board. 2016. Improving Adaptive Management in the Sacramento-San Joaquin Delta. Delta Stewardship Council.

DWR. 2016. Estimates of Natural and Unimpaired Flows for the Central Valley of California: WY 1922-2014.

Fox, P., P.H. Hutton, D.J. Howes, A.J. Draper and L. Sears. 2015. Reconstructing the natural hydrology of the San Francisco Bay–Delta watershed. Hydrology and Earth System Sciences 19:4257–4274. doi:10.5194/hess-19-4257-2015.

Gleick, P.H., and E.L. Chalecki. 1999. The impacts of climatic changes for water resources of the Colorado and Sacramento-San Joaquin river Basins. Journal of the American Water Resources Association 35(6):1429-1441.

Kiernan, J., P. Moyle, P.K. Crain. 2012. Restoring native fish assemblages to a regulated California stream using the natural flow regime concept. Ecological Applications: 22(5):10.

Linnansaari, T., W.A. Monk, D.J. Baird, D.J. and R.A. Curry. 2013. Review of approaches and methods to assess Environmental Flows across Canada and internationally. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/039.

Poff, N.L., et al. 2009. The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards. Freshwater Biology, Vol. 55, No. 1, pp. 147 – 170.

Sommer, T., et al. 2001. California's Yolo Bypass: Evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. Fisheries 26(8):6-16.

Sommer, T., W.C. Harrell, A.M. Solger, B. Tom, W. Kimmerer. 2004. Effects of flow variation on channel and floodplain biota and habitats of the Sacramento River, California, USA. Aquatic Conservation: Marine and Freshwater Ecosystems 14(3):247-261.

Stern, M.A., L.E. Flint, J.T. Minear, A.L. Flint and S.A. Wright. 2016. Characterizing changes in streamflow and sediment supply in the Sacramento River Basin, California, using hydrological simulation program—FORTRAN (HSPF). Water 8(10):432.

Tharme, R.E. 2003. A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. River Research and Applications 19:397-441.

Yarnell, S.M., G. Petts, J. Schmidt, A. Whipple, E. Beller, C. Dahm, P. Goodwin, J.H. Viers. 2015. Functional flows in modified riverscapes: hydrographs, habitats and opportunities. BioScience. 65(10):963-972.