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Discussions

Interactive comment on "Reconstructing the natural hydrology of the San Francisco Bay-Delta watershed" *by* P. Fox et al.

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1. This reviewer has investigated natural and unimpaired flows in the Bay-Delta-River system over the last two decades. I was a primary author of the 1998 publication, From the Sierra to the Sea, The Ecological History of the San Francisco Bay-Delta Watershed (TBI 1998), which was partially funded by water users and agencies who provided exhaustive technical review including Dr. Phyllis Fox, the paper's lead author, particularly on Delta outflow and salinity.

2. The findings from that work and subsequent analysis concurs with the observation that the unimpaired Delta outflow is not the same as the natural Delta outflow because vegetation conversion, levee building and elimination of flood basin storage altered the

flow pattern. Despite the assertion that "this is the first estimate of natural Delta outflow into the San Francisco Bay-Delta estuary" I reviewed other estimates of natural or pre-development outflow using similar simple average annual water budgets (e.g. Fox 1987, Dawdy 1987 and Williamson et al. 1989) and computed one myself based upon mapping of the natural vegetation distribution. I noted a wide variation in the computed outflow estimates (from 15 billionm3yr-1 to 31 billionm3yr-1) attributable primarily to the values assigned to the areal extent of different vegetation types and their ET rates as well as assumptions about the source of water supplying the natural vegetation. Using a different approach Ingram et al. 1996 converted paleosalinity estimates into a paleo-discharge value for Delta outflow that are much higher than the water budget estimates (an average of about 39.5 billionm3yr-1 for the past 700 years). This paper should note the previous water budget estimates and other methods used to estimate natural Delta outflow.

3. This paper and the paper by Howes et al. in press 2015 attempt to refine the estimates of the natural vegetation assemblages and ET rates but does not fully analyze one of the fundamental simplifying assumptions of their water budget approach: all of the rim station runoff and precipitation is a potential supply source for vegetative demand. Their attempt to address this issue with the different "cases" of vegetation demand is an incremental but incomplete step in what needs to be a more refined attempt to determine where the natural vegetation assemblages were in relation to the sources of their supply and how they responded to the seasonal and yearly variation in supply. Nearly half of the total area of water demanding vegetation is grasslands and vernal pools, and another 27% are seasonal wetlands and oak woodlands and savanna for a total of 75% of the total area that was either not in the floodplain of the primary surface drainages or were far enough away from the perennial water courses to be seasonally water limited. The pre-development groundwater budget by Williamson et al. 1989 calculates that only about 9.2 billionm3yr-1 of the low-lying central part of the Valley where groundwater levels are less than 3 meters are derived from stream channels while this study calculates more than twice that amount (20.8 billionm3yr-1).

4. The study does not include the Tulare Basin in its water balance; rather, it assumes the DWR calculated unimpaired inflow from the Tulare Basin would be the natural inflow into the study area. The unimpaired inflow from the Tulare Basin calculated by DWR is not a natural inflow. It is quantified as the modern day flow in James Bypass (CDWR 2007), which are derived from the flood control release into the Kings River. Historic evidence suggest that the natural inflow from the Tulare Basin would have included semi-regular seasonal flows from the Kings River north and occasional overflow from Tulare Lake. In a report on the Tulare Lake Basin Hydrology and Hydrography for the Environmental Protection Agency (available at http://www.epa.gov/region9/water/wetlands/local-wetlands.html), the authors estimated, based upon historical reconstructions, that Tulare Lake would have overflowed into the San Joaquin River Basin in nearly 40% of the years in the 20th century. The DWR calculated average annual unimpaired inflow from the Tulare Basin is about 0.09 billionm3yr-1 while the above evidence suggests it would be significantly higher. Quantification of the natural inflow from the Tulare Basin should be part of future research.

5. The average inflow and outflow should be compared to the measurements and estimates of Sacramento River at Freeport and Collinsville as well as other upstream locations by state engineer William Hammond Hall in the 1879-85 period (Hall 1986). The annual flow estimates for the Collinsville location at the downstream end of the Delta (i.e., the location of Delta outflow) ranged from 22 to 40 billionm3yr-1 , averaging 32 billionm3yr-1 for the 1879-1885 period, which encompassed both above and below average precipitation years in the watershed (see for example the annual Nevada City precipitation in the California Water Atlas, p. 7 (Kahrl 1979)). Although localized alterations of natural landscape by hydraulic mining and land reclamation had already occurred by 1879, particularly along the lower portions of the Sacramento and Feather Rivers, the Valley-wide hydroscape was still largely representative of natural conditions making Hall's observations an important point of reference for natural flow estimates.

6. The natural/unimpaired issue obfuscates the Delta outflow issue since the species

declines and the X2 relationships were developed in the altered 20th century estuarine system. More relevant is the change in actual Delta outflow in the 20th century as large dams and water transfer projects significantly altered the timing and magnitude of Delta outflows. The effects of these alterations can be discerned by comparing the computed actual Delta outflow (Dayflow) in the 1922-43 (pre-project) period (prior to the construction of Shasta and Friant Dams and Federal Delta export facilities) with that of the 1968-94 (post-project) period (after the State Water Project dams and export facilities were completed). When all but the "wet" year types are examined, annual Delta outflow is 30% to 60% less than comparable years of the pre-project period, with even greater percentage reductions in spring outflows in drier year types. The average annual Delta outflow during the pre-project period was about 15% more than the post-project period, but the average rim station inflow was 17% less in the pre-project period than in the post-project period (i.e., the pre-project period had less rim inflow but more Delta outflow). Noteworthy is that the driest 11-year period in the 20th century – the 1924-34 pre-project period- had about half the runoff of the wettest post-project 11-year period (1995-2005).

7. Unimpaired runoff can be used along with actual runoff as one of the metrics of hydrological alterations in the system since 1922, particularly on an annual and seasonal basis for Delta outflow and on a monthly time step for the rivers just below the dams. Neither DWR or others who use it purport it to represent natural Delta outflow, although there is consensus that it is an adequate representation of the magnitude and timing of natural flow peaks of the runoff into the Central Valley, with recognition that the hydrograph peaks would be reduced and the falling hydrograph limbs would be extended as flows moved down-Valley towards the Delta due to engagement of the floodplains and attenuation by the flood basins as well as groundwater contribution to the summer baseflow.

8. This paper does not prove provide a coherent ecological explanation for how the rough equivalency of the average annual simple "natural" water balance for the 1922-

2009 hydro-climate with the current (2011 level of development) average modeled outflow for the 1922-2003 period provides insight on “understanding of the biological functions provided under natural conditions” or support a conclusion that “ it is unlikely that reductions in annual average Delta outflow have caused the decline in native freshwater aquatic species”.

9. I agree with recommendations for additional research particularly more detailed landscape reconstructions and an assessment of the flows on a monthly time-step. In addition I also recommend assessing the impact of forest practices and land use on the quantity and seasonality of rim station inflow. Although the conclusions of the study to this point have limited relevance to the efforts by regulators to establish flow standards to protect beneficial uses of the Bay-Delta Estuary and its tributaries, I encourage continued collaborative work to gain a better understanding of the watershed's historic landscape ecology. Unfortunately the State Water Contractors and SLDMWA have politicized these efforts. Early in this study I offered to provide all of the data and information from the TBI 1998 study and to provide input and review. The funders turned down my offers despite some of the authors encouraging that input.

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