Appendix E

Analysis of UPP

Using Perry Survival Model

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
650 Capitol Mall, Suite 5-100
Sacramento, California 95814-4700

June 16, 2017

MEMORANDUM FOR: ARN: 151422-WCR2016-SA00204

FROM: Cathy Marcinkevage, California WaterFix Branch,
Erin Strange, San Joaquin River Basin Branch, California Central Valley Office, West Coast Region

REVIEWED BY: Maria Rea, Assistant Regional Administrator, California Central Valley Office, West Coast Region

SUBJECT: Technical memorandum regarding analysis of revised NDD real-time operations of the California WaterFix

Purpose of Analysis:

The purpose of this analysis is to identify change in annual mean through-Delta survival rates for migrating winter-run and spring-run Chinook salmon affected by the California WaterFix (CWF) proposed action (PA) based on analysis of the June 2, 2017, initial approach to the real-time operations of the north Delta diversions (NDD) using river flow data and Knights Landing catch index data from 2003-2012 and 2014 water years.

Background:

RTO for the NDD proposed in the August 2, 2016, BA submission were partially determined by the Knights Landing catch index (X_p), whereby the capture five or more winter-run-sized and spring-run-sized fish would trigger fish pulse protection operations downriver at the NDD (i.e., reduced water diversion flows). The operations included the implementation of pulse protection for a maximum of two pulses.

On June 2, 2017, Reclamation submitted a Revised PA that included revisions to the NDD RTO. The objective of these revisions are to lessen the adverse impacts of both PA and Level 1 Only (L1) operational scenarios identified in the January 21, 2017, Initial Draft Biological Opinion effects analysis.

The Revised PA Unlimited Pulse Protection scenario (UPP or Revised) includes revisions such

that the real-time operations of the north Delta diversions are as described in BA Section 3.3.3.1 North Delta Diversion. Specifically,

> *"…Under RTOs, the NDD would be operated within the range of pulse protection, and Levels 1, 2, and 3, depending on risk to fish and with consideration for other factors such as water supply and other Delta conditions, and by implementing pulse protection periods when primary juvenile winter-run and spring-run Chinook salmon migration is occurring. Post-pulse bypass flow operations may remain at Level 1 pumping depending on fish presence, abundance, and movement in the north Delta; however, the exact levels will be determined through initial operating studies evaluating the level of protection provided at various levels of pumping. The specific criteria for transitioning between and among pulse protection and post-pulse bypass flow operations will be based on real-time fish monitoring and hydrologic/ behavioral cues upstream of and in the Delta that will be studied as part of the PA's Collaborative Science and Adaptive Management Plan (Section 3.4.6)…."*
>
> *"The following operational framework serves as an example that is based on the recommended NDD RTO process (Marcinkevage and Kundargi 2016)…."*
>
> - *A fish pulse is defined as combined catch of X_p winter-run and spring-run sized Chinook salmon in a single day at specified locations.*
> - *Upon initiation of fish pulse, operations must reduce to low-level pumping.*
> - *Pumping may not exceed low-level pumping for the duration of fish pulse. However, additional pumping above low-level may be allowed as long as a minimum of 35,000 cfs bypass flow is maintained during the period of pulse protection. A fish pulse is considered over after X consecutive days with daily combined catch of winter- and spring run-sized Chinook salmon less than X_p at or just downstream of the new intakes.*
> - *Post-pulse bypass flow operations will be determined through initial operating studies evaluating the level of protection provided at various levels of pumping.*
> - *All subsequent pulses of winter- and spring-run Chinook salmon will be afforded the same level of protection as the first pulse.*
> - *Unlimited fish pulses are protected in any given year.*

Under the UPP scenario, flow operations are adjusted based on capture of winter-run and spring-run Chinook salmon in the Delta. Due to the high likelihood of non-discretionary conditions the pending CDFW California Fish and Game Code section 2081 permit, NMFS has used the permit conditions as initial catch and index values that would trigger operational adjustments for purposes of the analysis in this Opinion.

Catch or index values that would trigger the operational adjustments are not specifically defined in the revised PA; however, CDFW's draft permit for the PA under California Fish and Game Code Section 2081 includes a condition that triggers pulse protection based on a Knights Landing catch index (X_p) greater than or equal to 5 winter-run-sized and spring-run-sized fish.

The number of days pulse protection would be implemented once triggered are to be based on empirical Chinook smolt migration rates and are not specifically defined under the revised PA; however, CDFW's draft permit for the PA under California Fish and Game Code Section 2081 includes a condition related to pulse protection that considers a pulse to be over when Knights Landing catch index (X_p) is less than 5 for a duration (X) of 5 days. The effectiveness of this operation relies on a robust monitoring program coupled with efficient and expedient real-time operations adjustments.

Description of Analysis:

The following analysis was conducted by evaluating through-Delta survival for previously determined RTO (L1) and revised real time operations (UPP or Revised) based on observed Knights Landing Catch Index for the 2003-2012 and 2014 water years using the Perry Survival Model (Perry 2017). Through-Delta survival for each day of WY 2003-2013 and 2014 was calculated for: 1) No diversion (i.e., bypass discharge = Freeport discharge); 2) L1 real time operations; and 3) Revised real time operations. Daily through-Delta survival was calculated for each draw of the joint-posterior distribution to represent uncertainty in survivability. In addition to daily survival, posterior distributions were calculated for the difference in daily survival of each scenario relative to no diversion. Posterior distributions of annual survival was calculated by weighting each daily survival by the fraction of the total Knights Landing Catch Index for each day. In addition, posterior distributions were calculated for the difference in annual survival of each scenario relative to no diversion.

Assumption #1: Annual survivals were calculated by weighting each daily survival by the fraction of the total Knights Landing Catch Index for each day. In addition, the difference in annual survival of each scenario relative to NAA (i.e., no diversion from the new NDD facility) were calculated. Because this analytical method is bound by the frequency of monitoring and capture efficiency at Knights Landing, the reliance on the existing Knights Landing monitoring data could underestimate both the abundance and the temporal extent of winter-run and spring-run Chinook salmon presence during the migration season. As described in PA, the final development of the trigger values and monitoring location would depend on: 1) operation of a new or additional monitoring station(s) closer to the NDD, 2) the method used to identify winter-run and spring-run Chinook salmon, and 3) the collection of sufficient fish monitoring data collected during the appropriate time of year with a large enough sample size with appropriate sampling gear to estimate fish abundance not just presence.

Assumption #2: The violin plots used to describe mean annual survival are not inclusive of all daily survival probabilities that could occur during the winter-run and spring-run Chinook salmon migration window for any given year. These only include survival probabilities for those days when winter-run and spring-run Chinook salmon were captured at Knights Landing. If no catch occurred, the daily survival rates were not included in the estimate of mean annual survival because the proportion of total annual catch for those days was zero. Therefore, the results may underestimate the survival reductions experienced in any given year since fish presence is solely dependent on fish catch at Knights Landing. In other words, this modeling exercise assumes any fish present would be captured with 100 percent accuracy, which is an overestimate given that 100 percent catch is extremely unlikely. Furthermore, UPP would cease when capture of fish is fewer than 5 winter-run or spring-run Chinook sized fish for five consecutive days, thereby

exposing any fish still present near or downstream of the intakes to the more adverse L1, L2, or L3 operating scenarios

Assumption #3: Fish passing Knights Landing on a given day experience the calculated bypass flows on that day. This means that for the purposes of this analysis: 1) no lag time was applied to the weighted survival values to account for fish travel time from Knights Landing to the north Delta diversion, and 2) no travel times were applied to different reaches within the Delta to account for flow variation over a given cohort of fish. When real-time operations are implemented, new/additional monitoring locations and information from baseline studies are expected to allow a better characterization of the typical travel time, and therefore lag time, from monitoring stations to the diversion locations. This would allow better resolution of fish presence and abundance to coordinate operations.

Results:

Compared to the previously-proposed operations, the survival analysis of the application of the revised initial approach to NDD real-time operations to river flow and Knights Landing catch index data from 2003-2012 and 2014 shows either a general improvement or no difference in annual mean survival. As seen in the panel plots below (all odd-numbered figures; see in particular, the third panel of each plot), survival increases during the migration pulses (as characterized by the catch index data) in the UPP scenario compared to the L1 scenario due to the general increase in bypass flow during those pulses. When viewing results, the time series of daily trends in survival (summarized in the panel plots), are more informative than the seasonal average (summarized in the violin plots; all even-numbered figures). For example, even when there was little difference in mean annual survival between scenarios, the daily trends often revealed that survival was more frequently higher under revised operations compared to the L1 scenario. Last, we caution that the mean annual survivals are generated using catch at the Knights Landing rotary screw traps as an index of abundance and run timing, but given very low capture probabilities (likely 1% or less), the annual mean survival likely under-represents survival on days when catch was zero during times where true abundance is expected to be greater than zero.

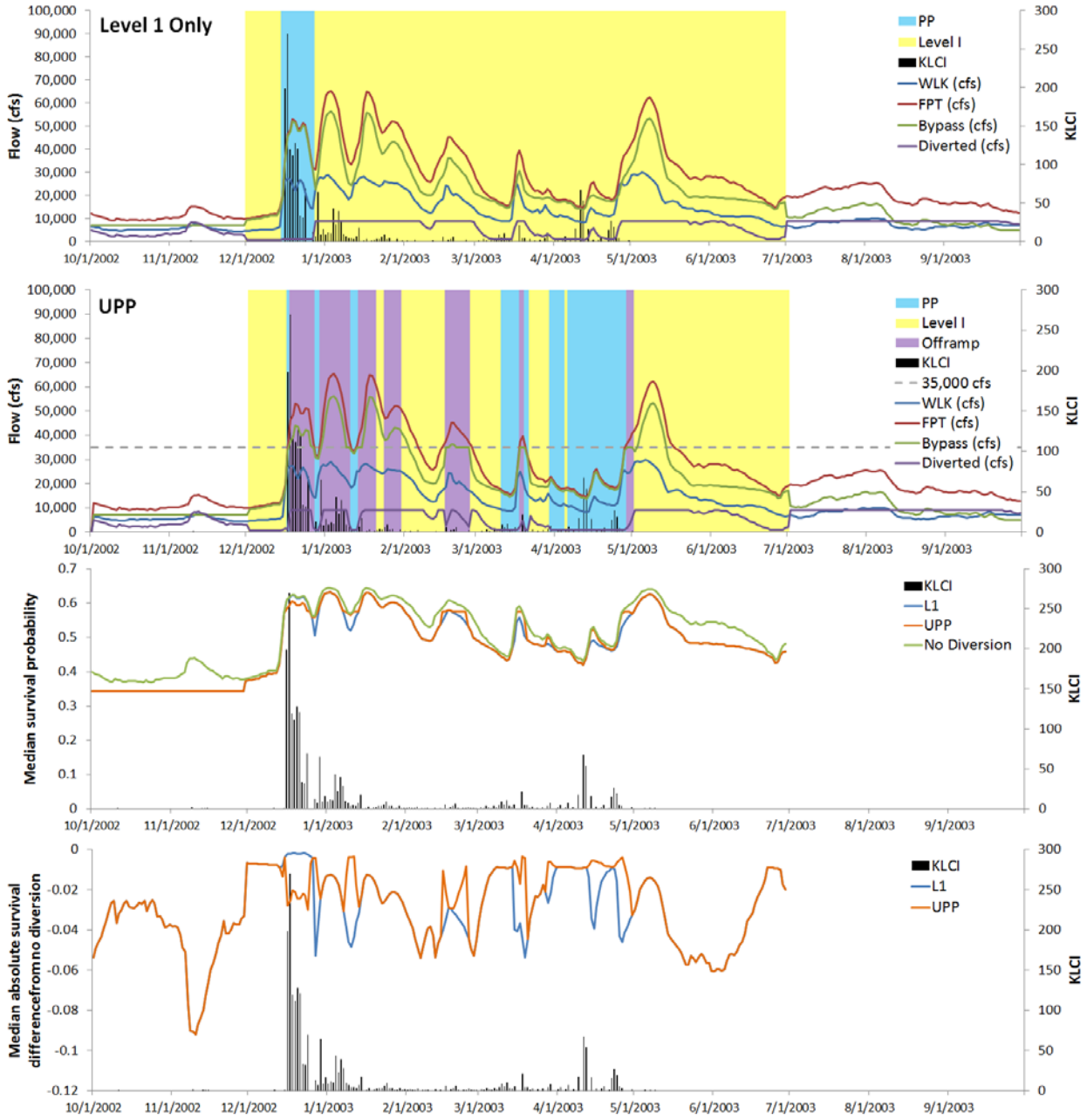

Figure 1. Summary for Water Year 2003 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

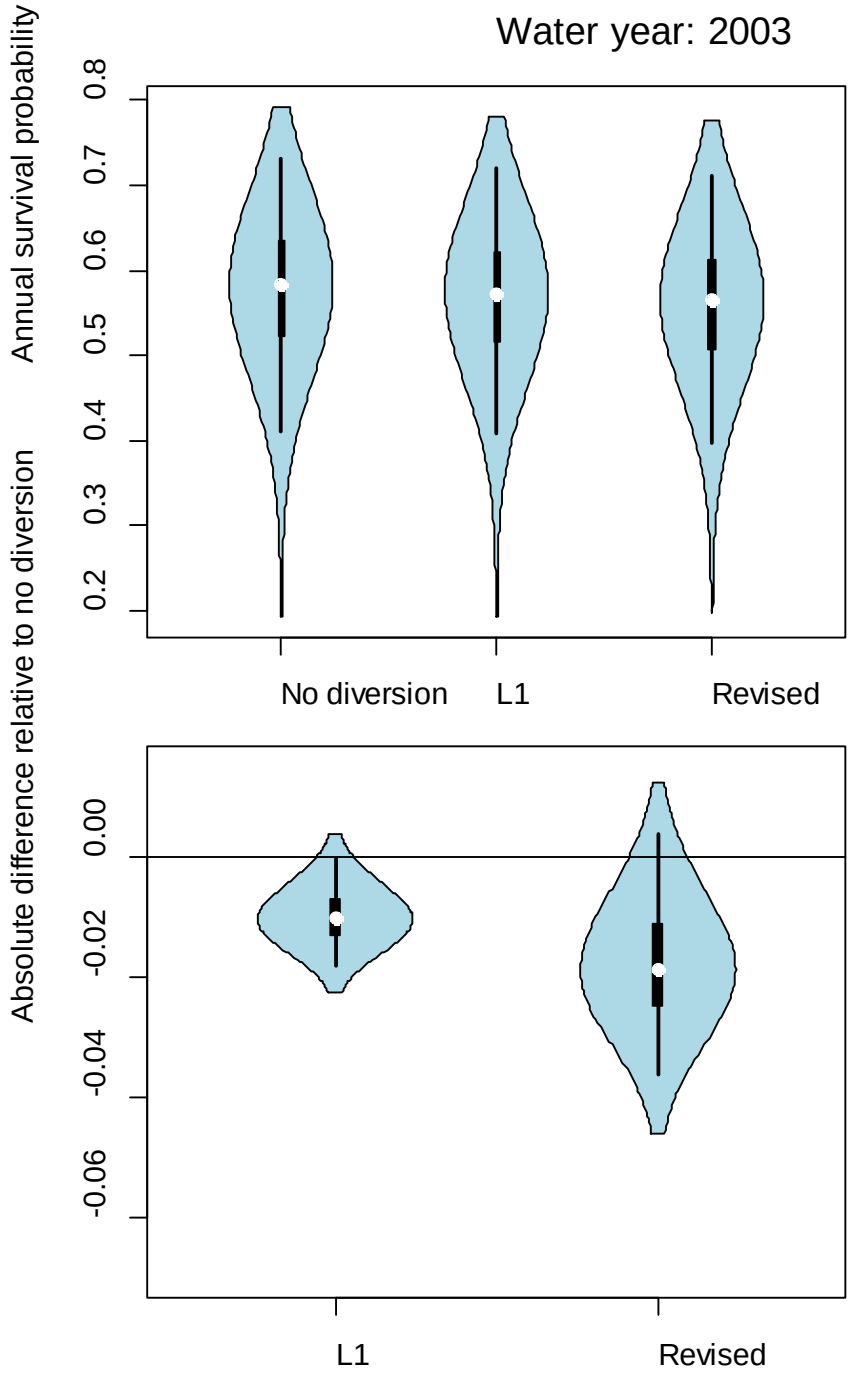

Figure 2. Violin plots for Water Year 2003 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25^{th}-75^{th} percentile, and the white dot shows the median.

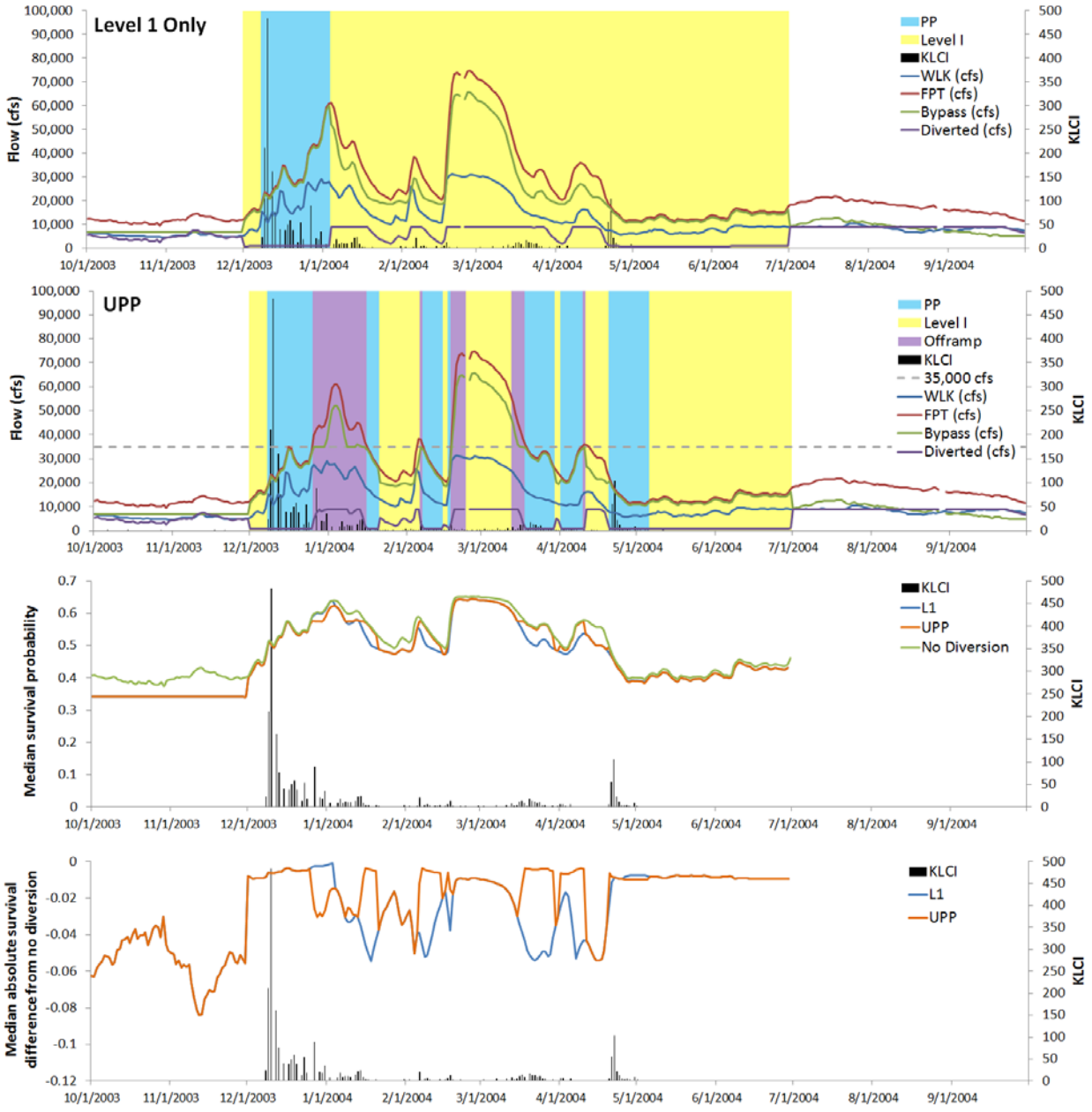

Figure 3. Summary for Water Year 2004 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

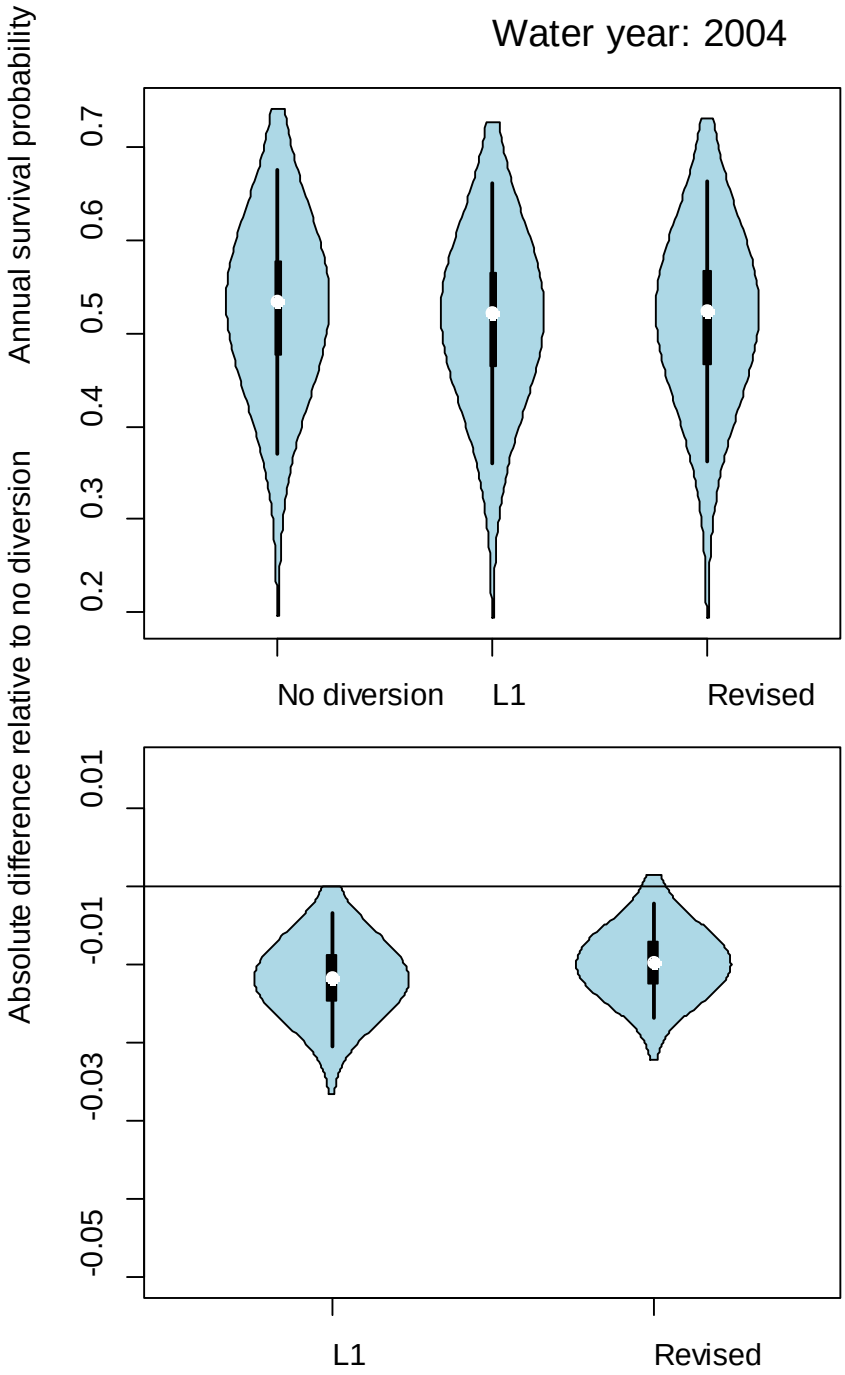

Figure 4. Violin plots for Water Year 2004 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25^{th}-75^{th} percentile, and the white dot shows the median.

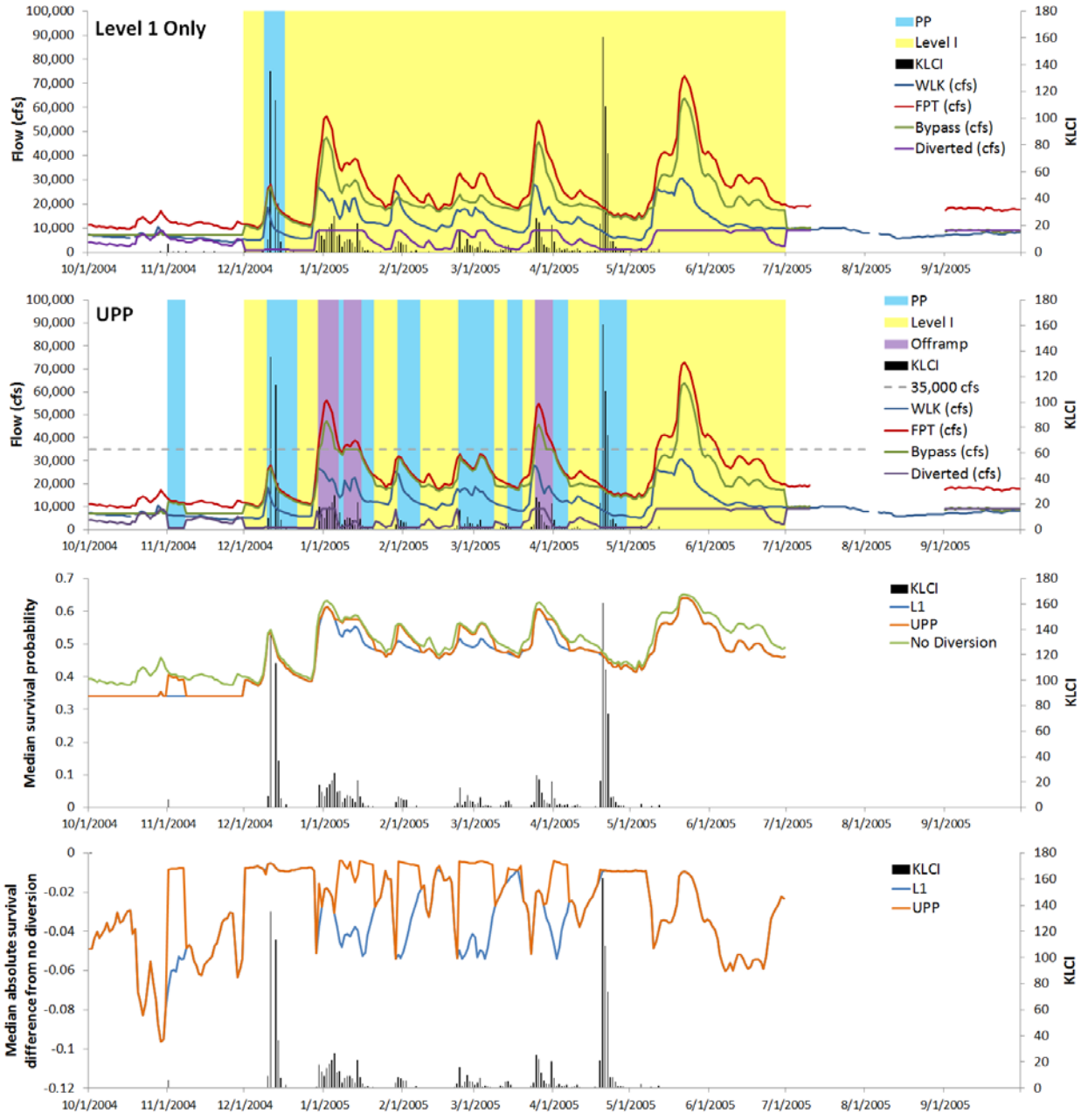

Figure 5. Summary for Water Year 2005 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

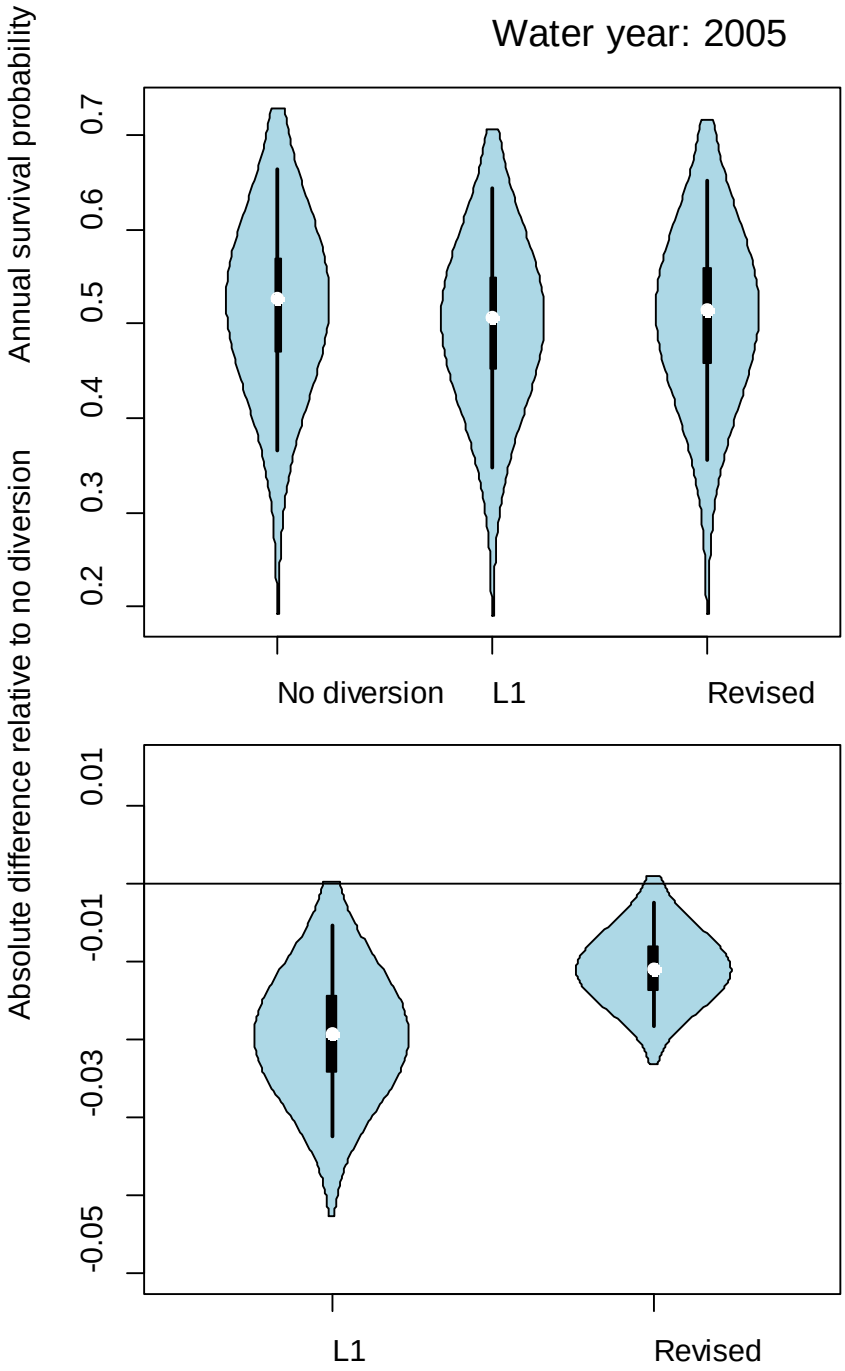

Figure 6. Violin plots for Water Year 2005 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25th-75th percentile, and the white dot shows the median.

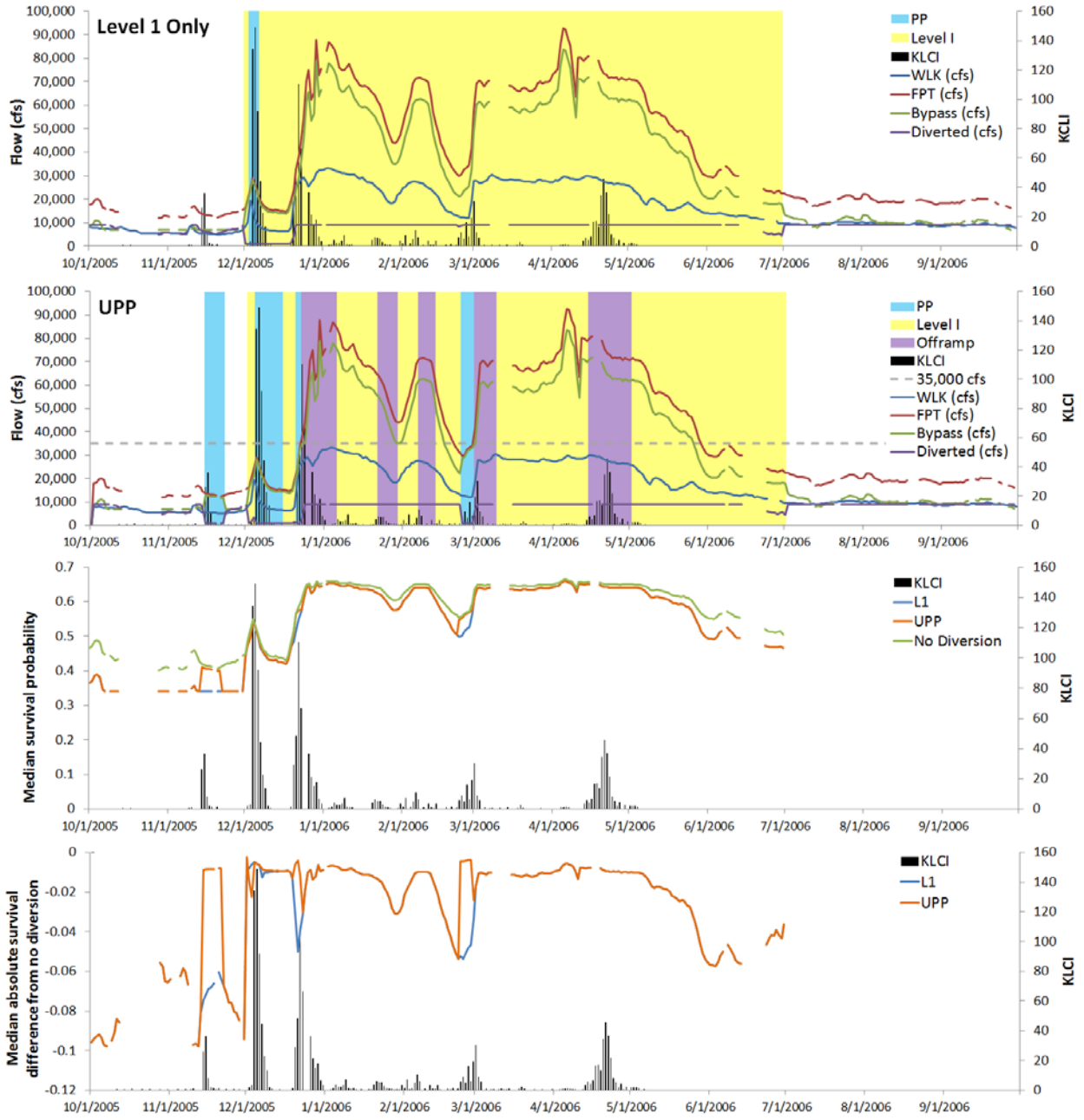

Figure 7. Summary for Water Year 2006 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

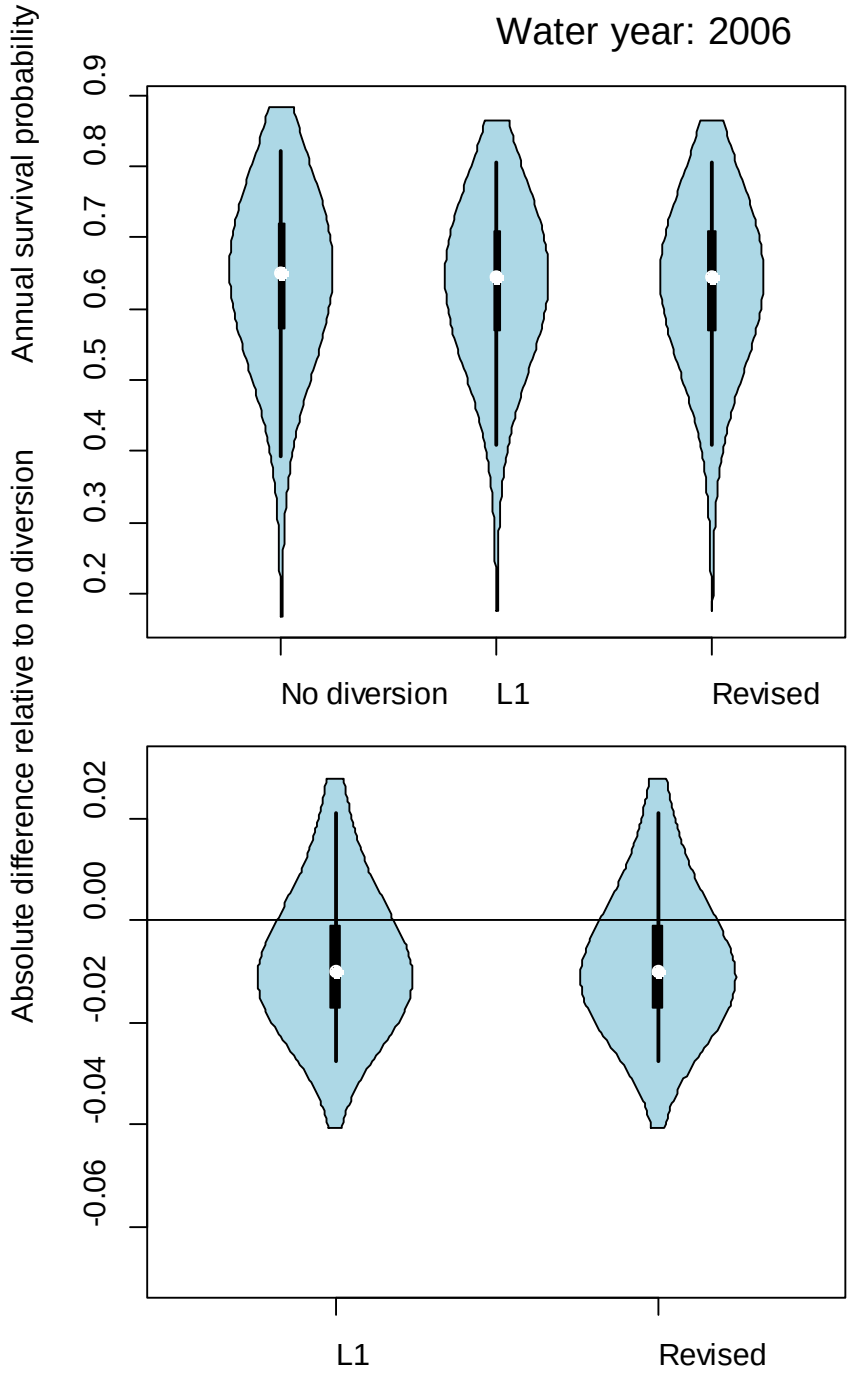

Figure 8. Violin plots for Water Year 2006 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25^{th}-75^{th} percentile, and the white dot shows the median.

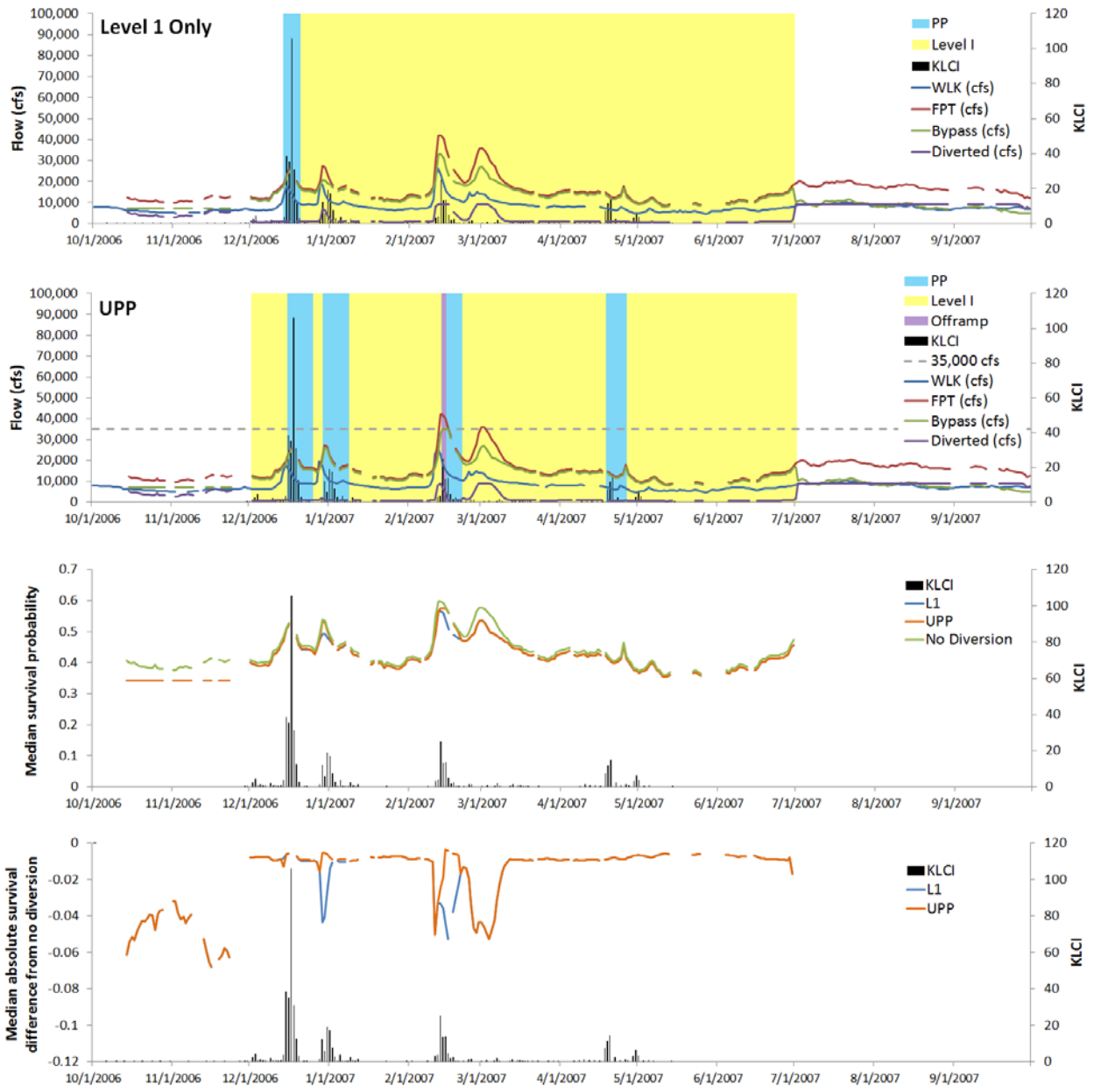

Figure 9. Summary for Water Year 2007 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

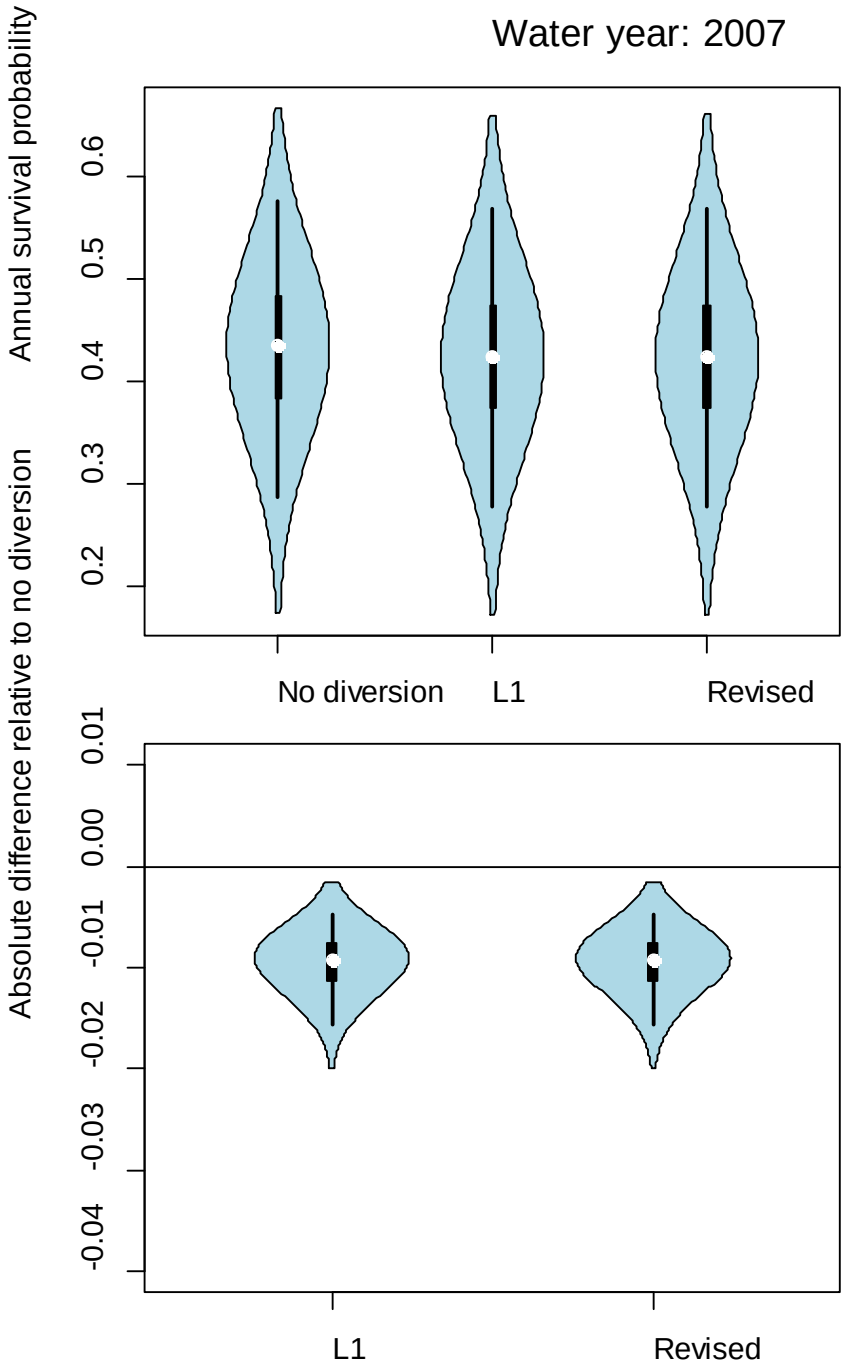

Figure 10. Violin plots for Water Year 2007 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25^{th}-75^{th} percentile, and the white dot shows the median.

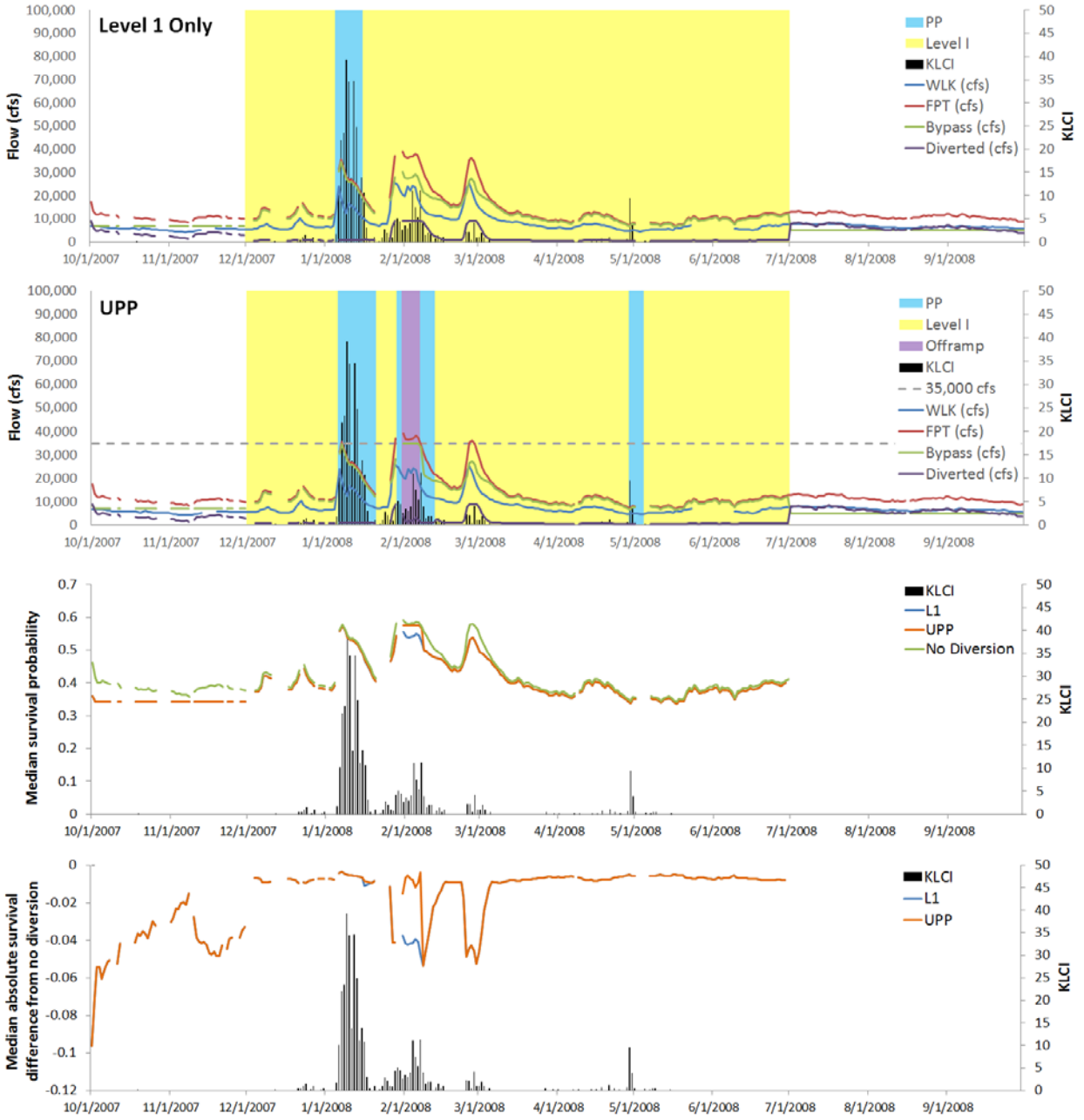

Figure 11. Summary for Water Year 2008 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

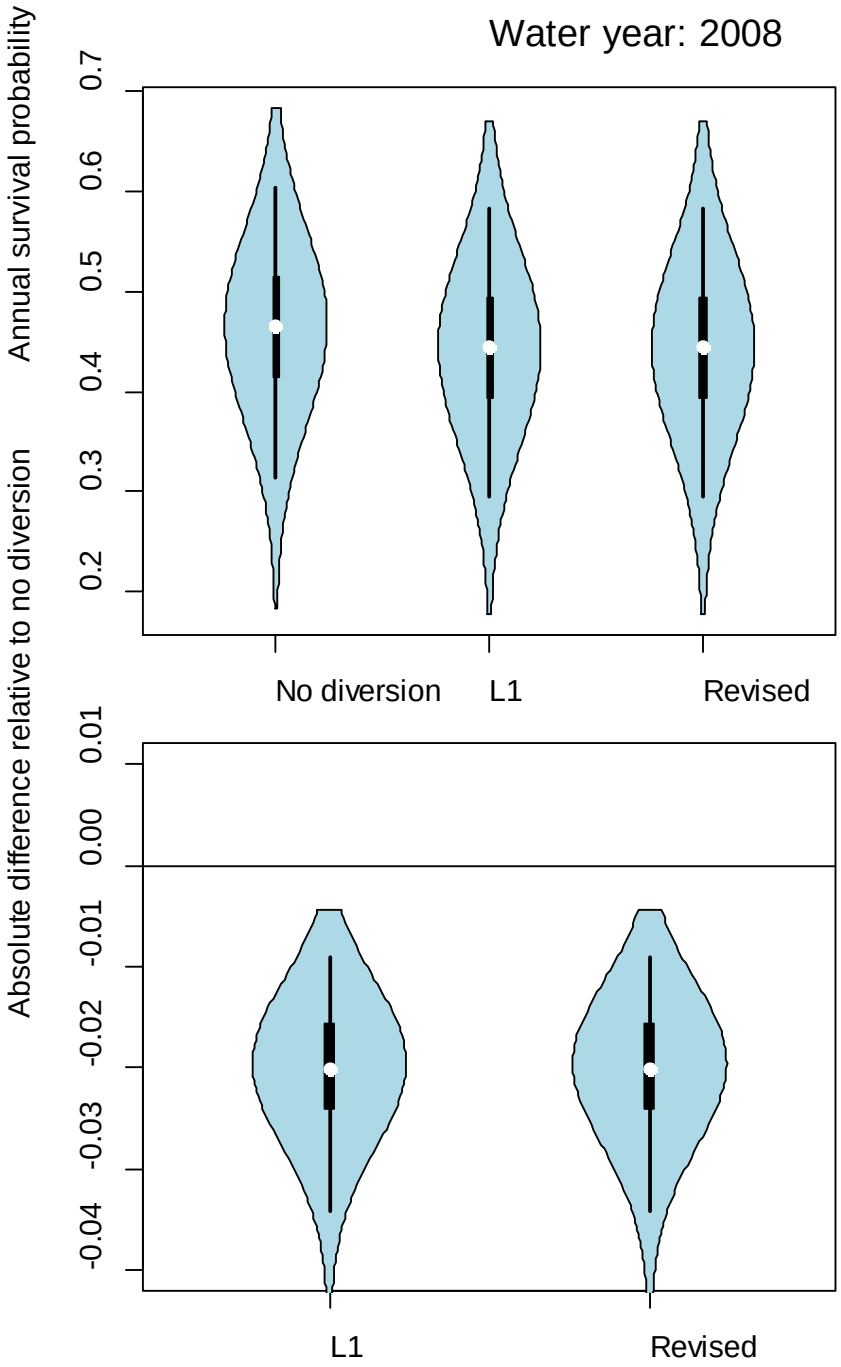

Figure 12. Violin plots for Water Year 2008 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25th-75th percentile, and the white dot shows the median.

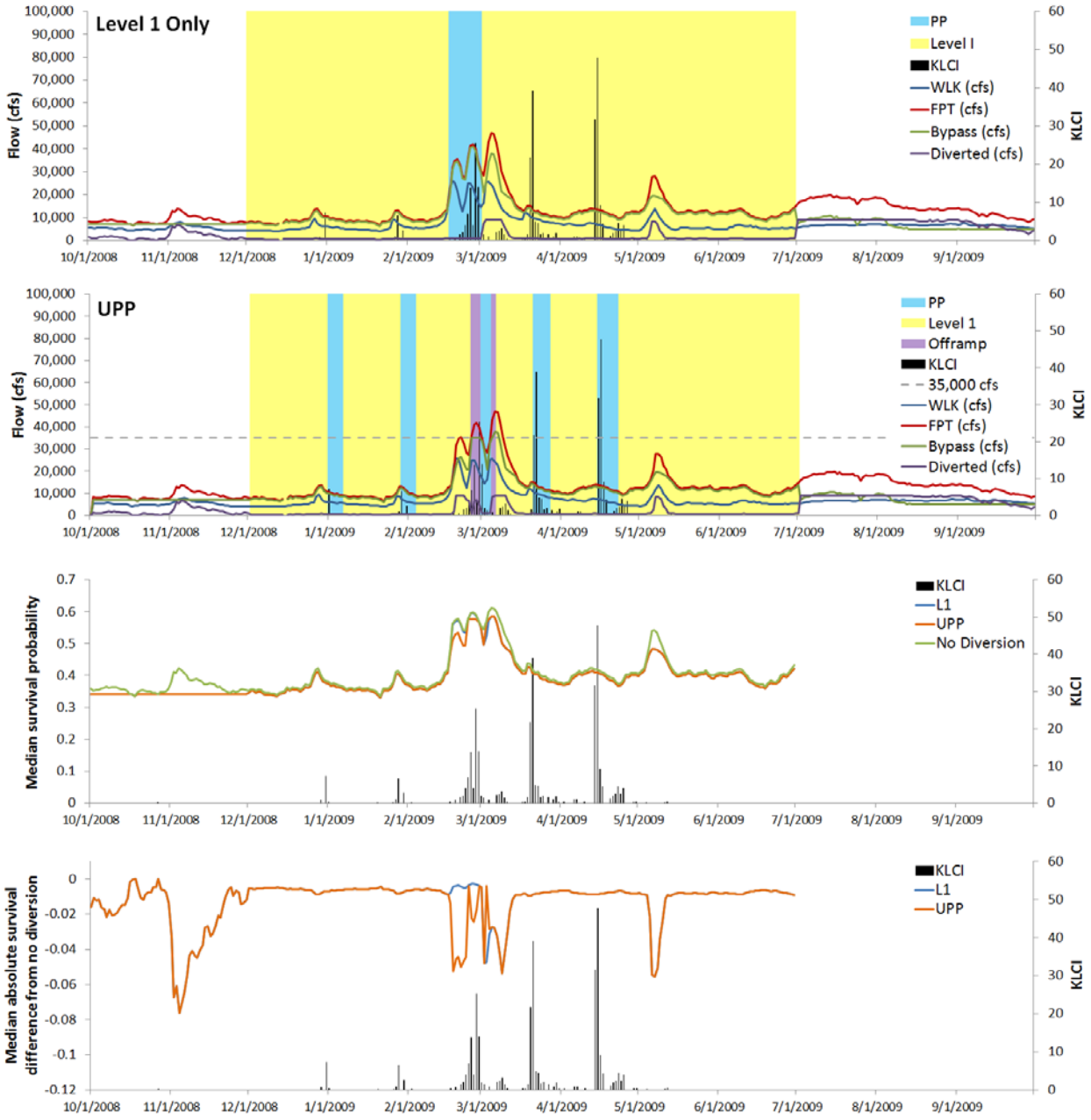

Figure 13. Summary for Water Year 2009 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

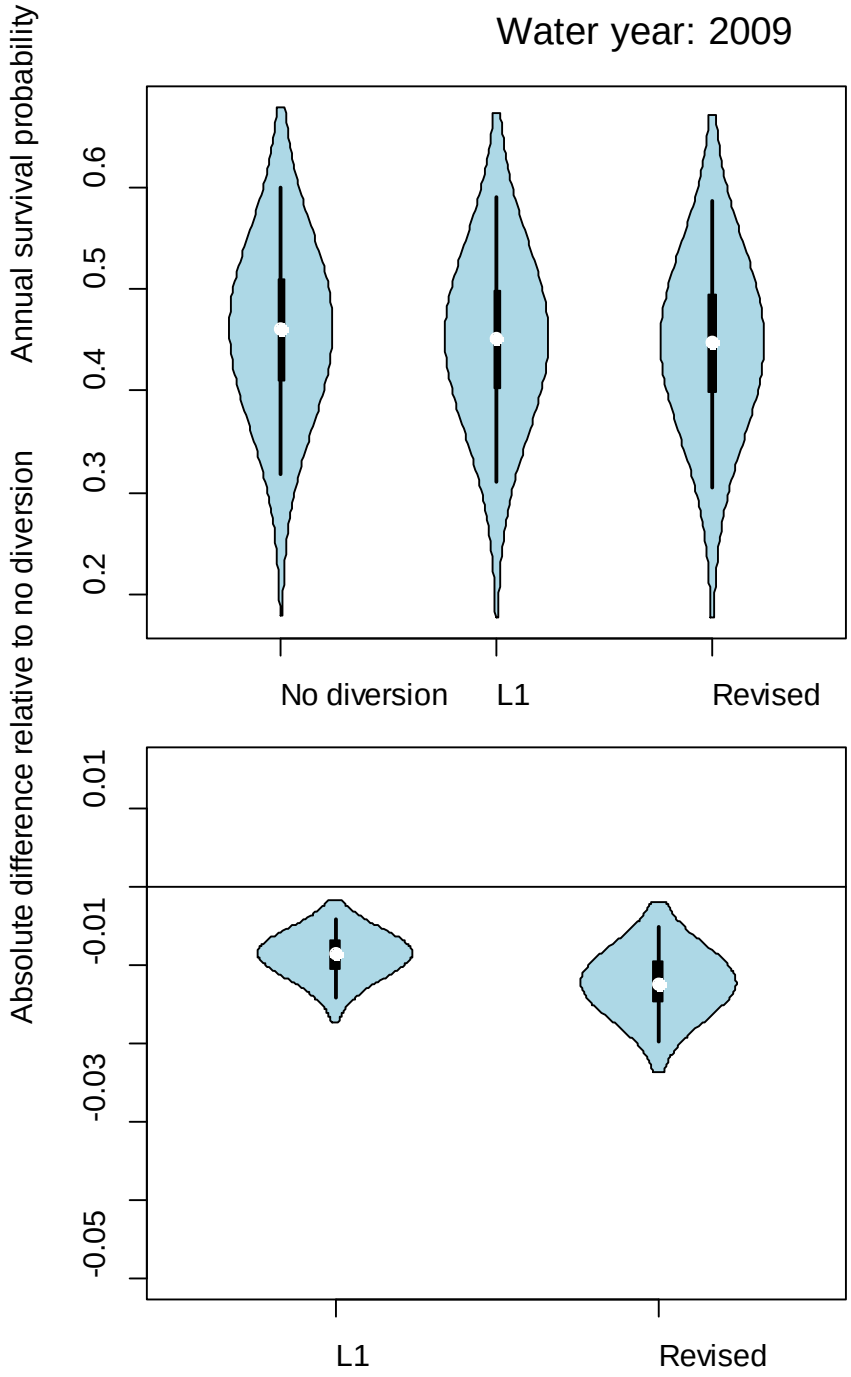

Figure 14. Violin plots for Water Year 2009 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25th-75th percentile, and the white dot shows the median.

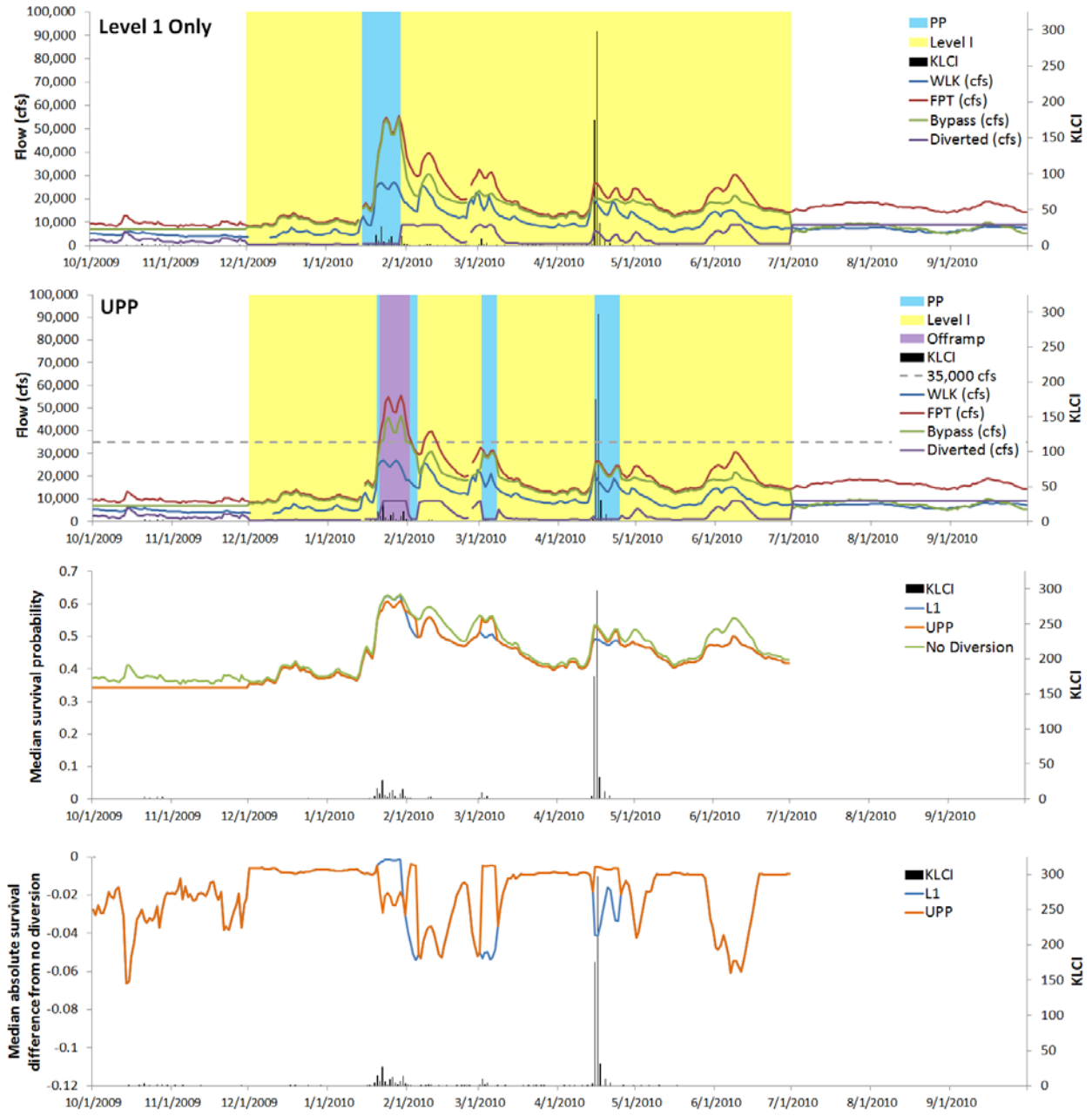

Figure 15. Summary for Water Year 2010 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

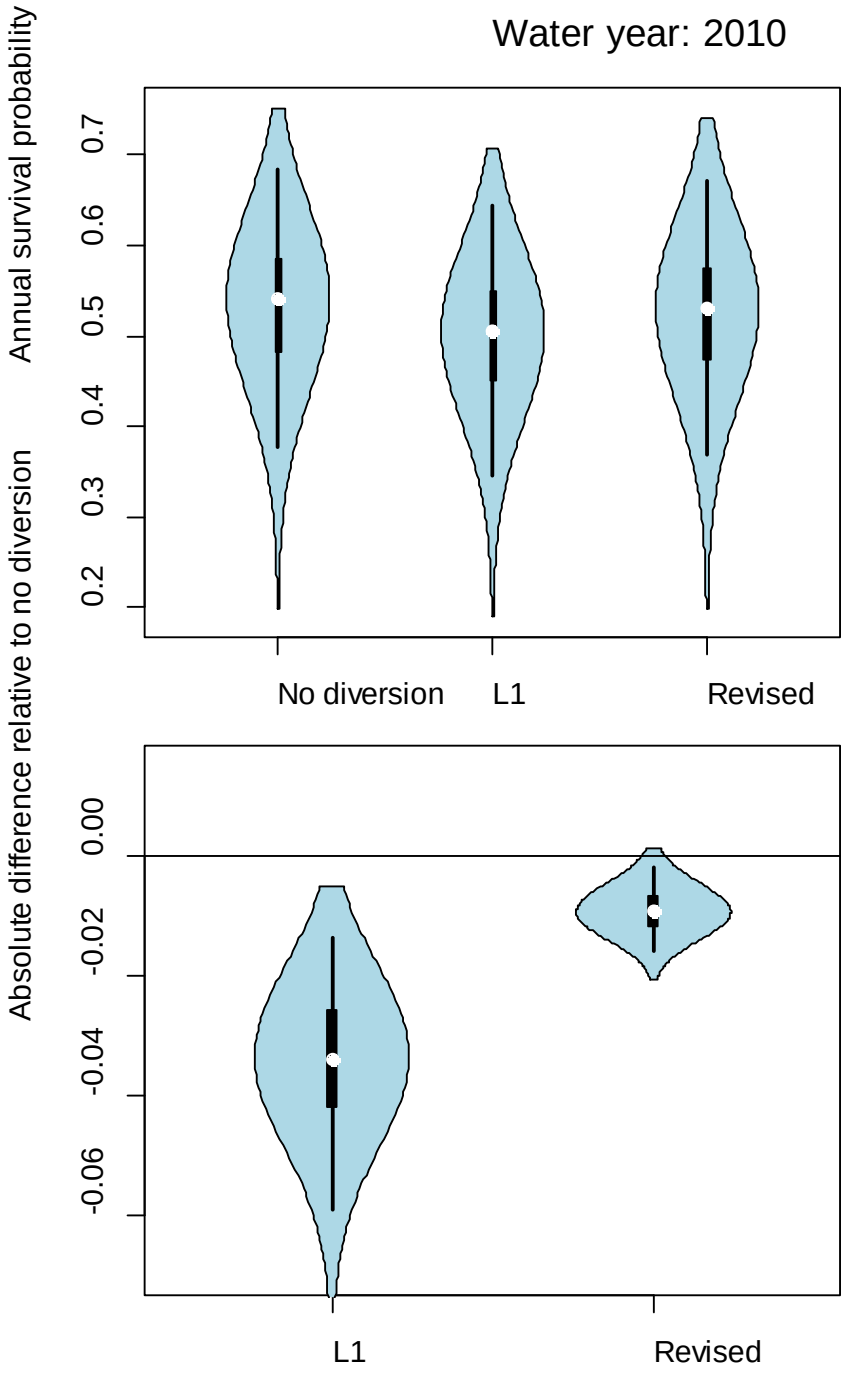

Figure 16. Violin plots for Water Year 2010 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25^{th}-75^{th} percentile, and the white dot shows the median.

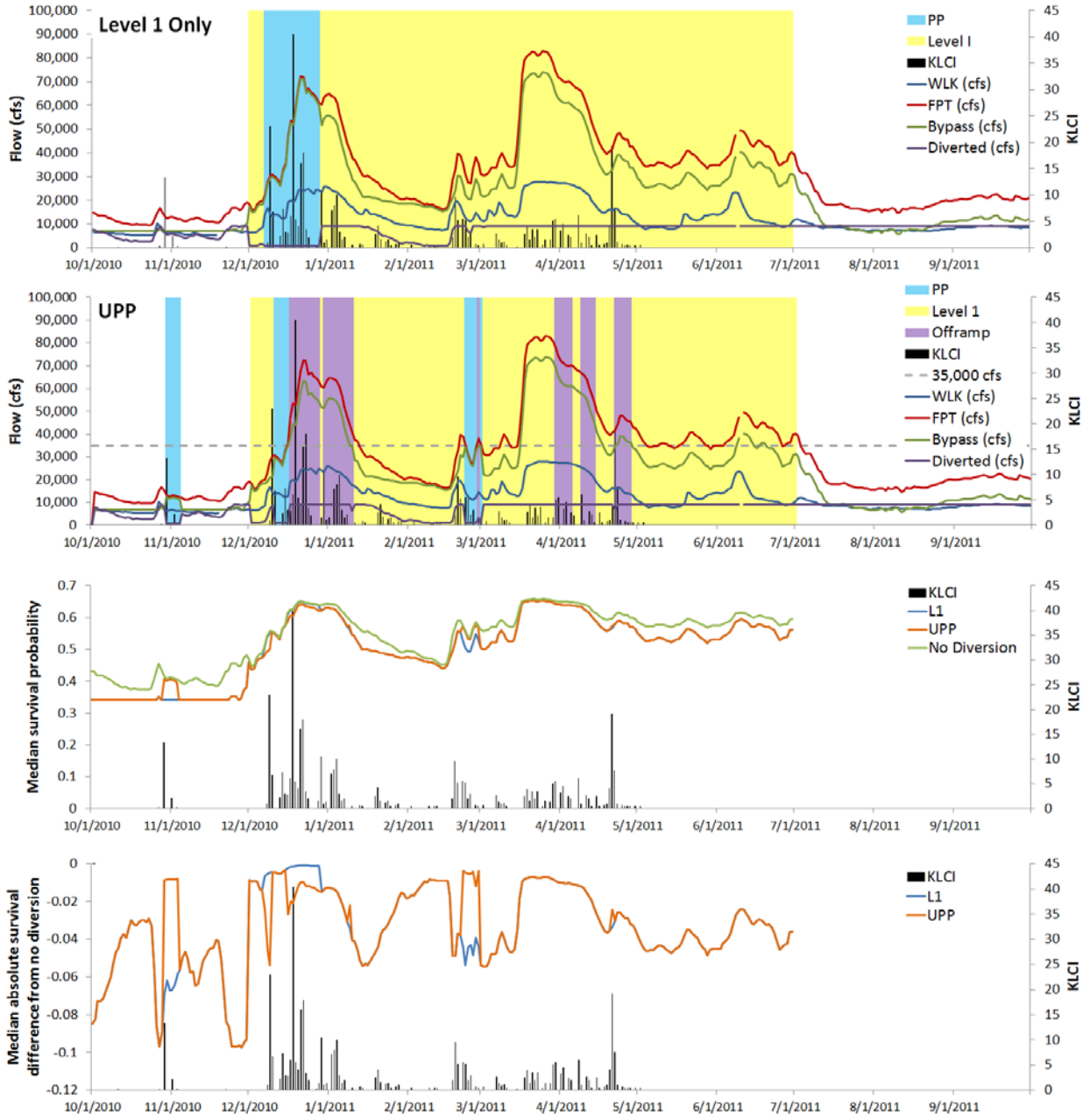

Figure 17. Summary for Water Year 2011 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

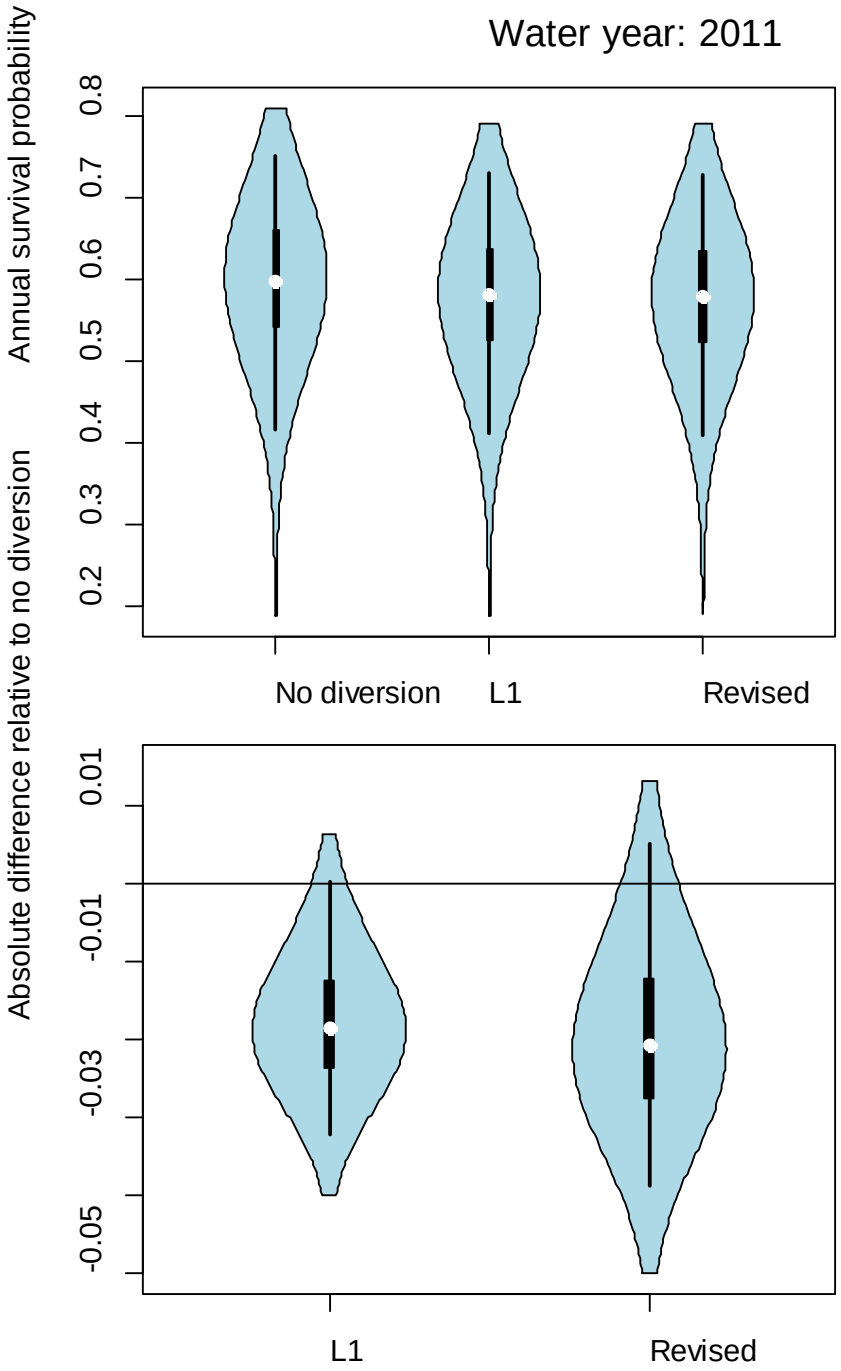

Figure 18. Violin plots for Water Year 2011 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25th-75th percentile, and the white dot shows the median.

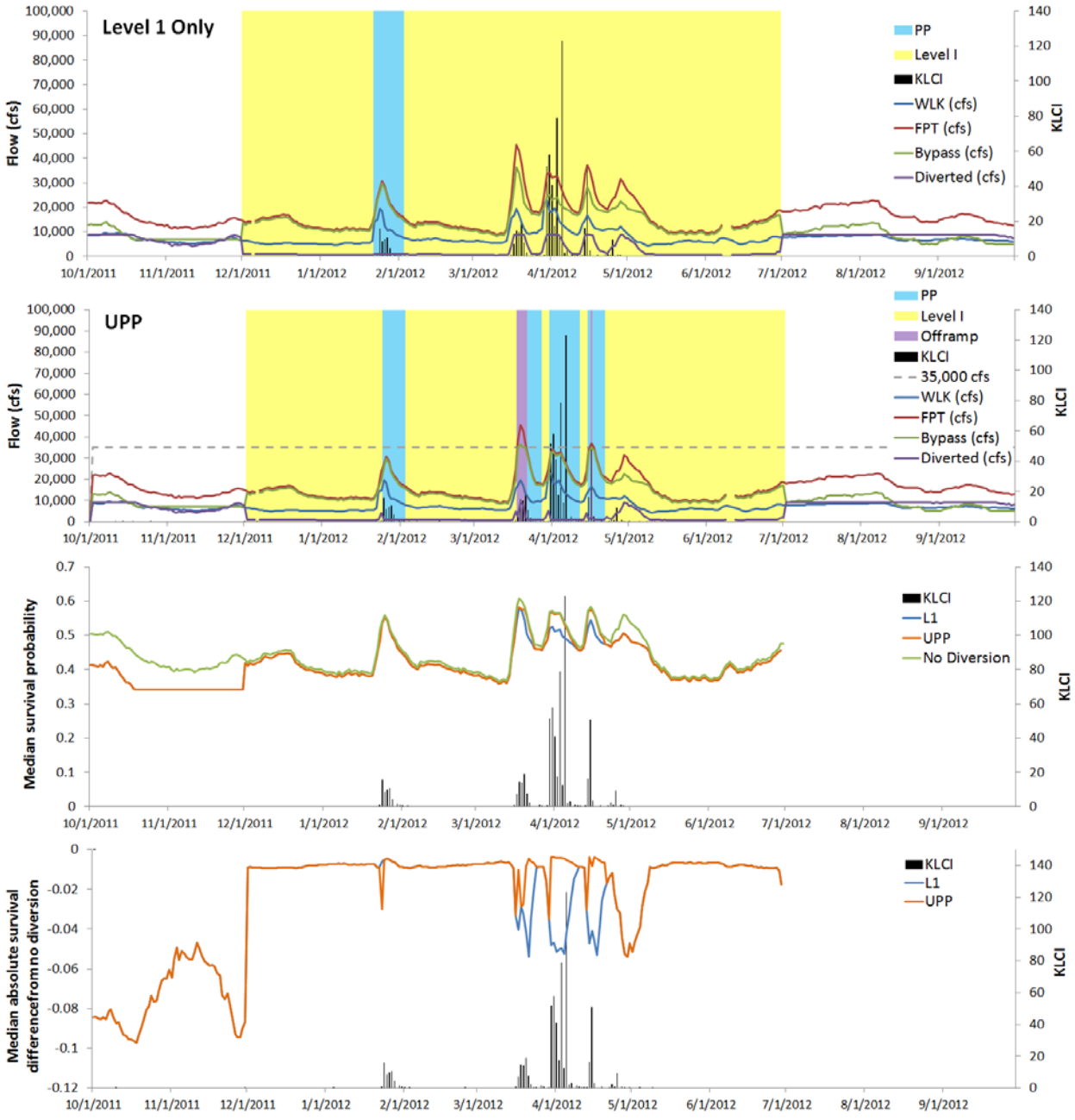

Figure 19. Summary for Water Year 2012 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

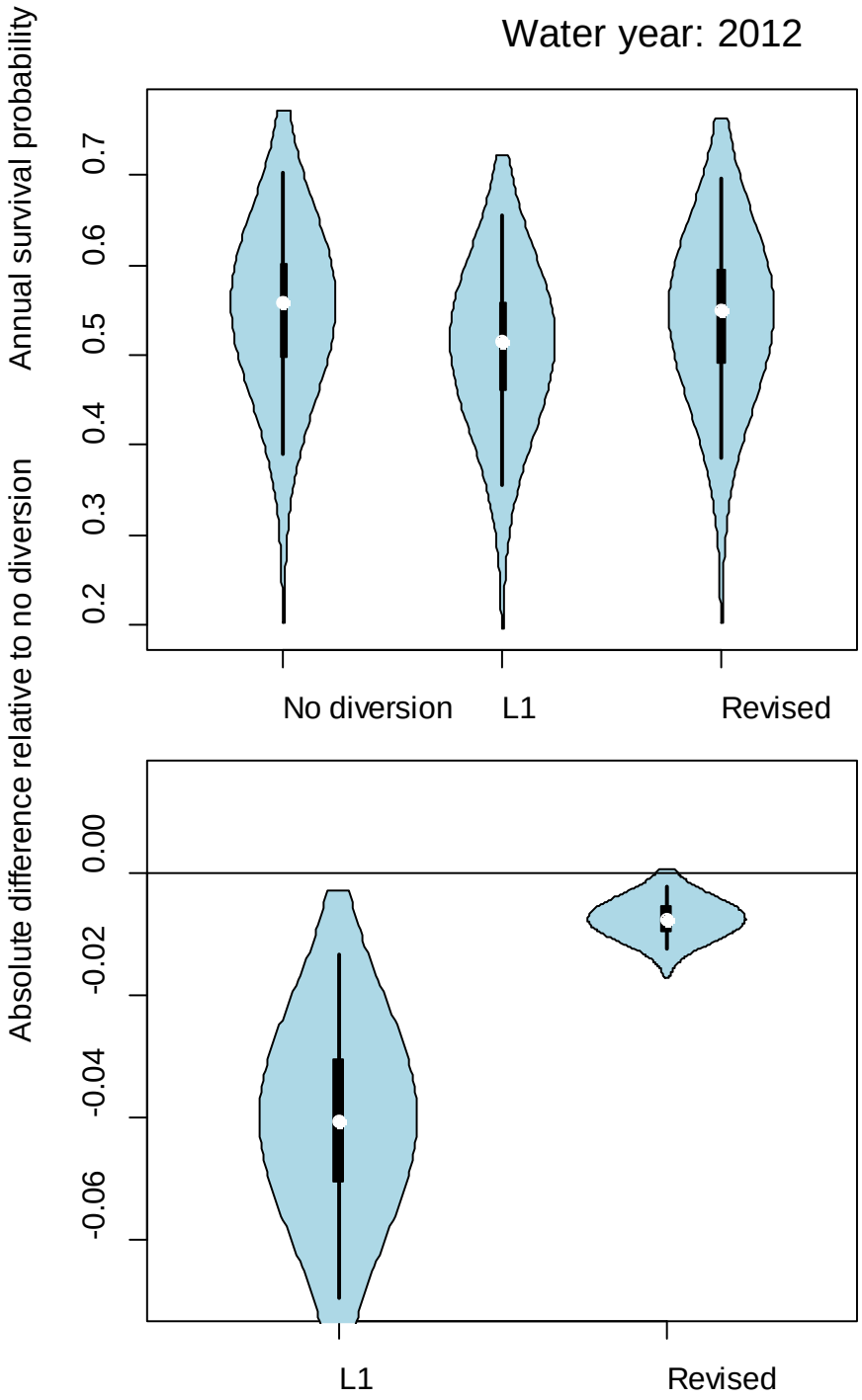

Figure 20. Violin plots for Water Year 2012 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25th-75th percentile, and the white dot shows the median.

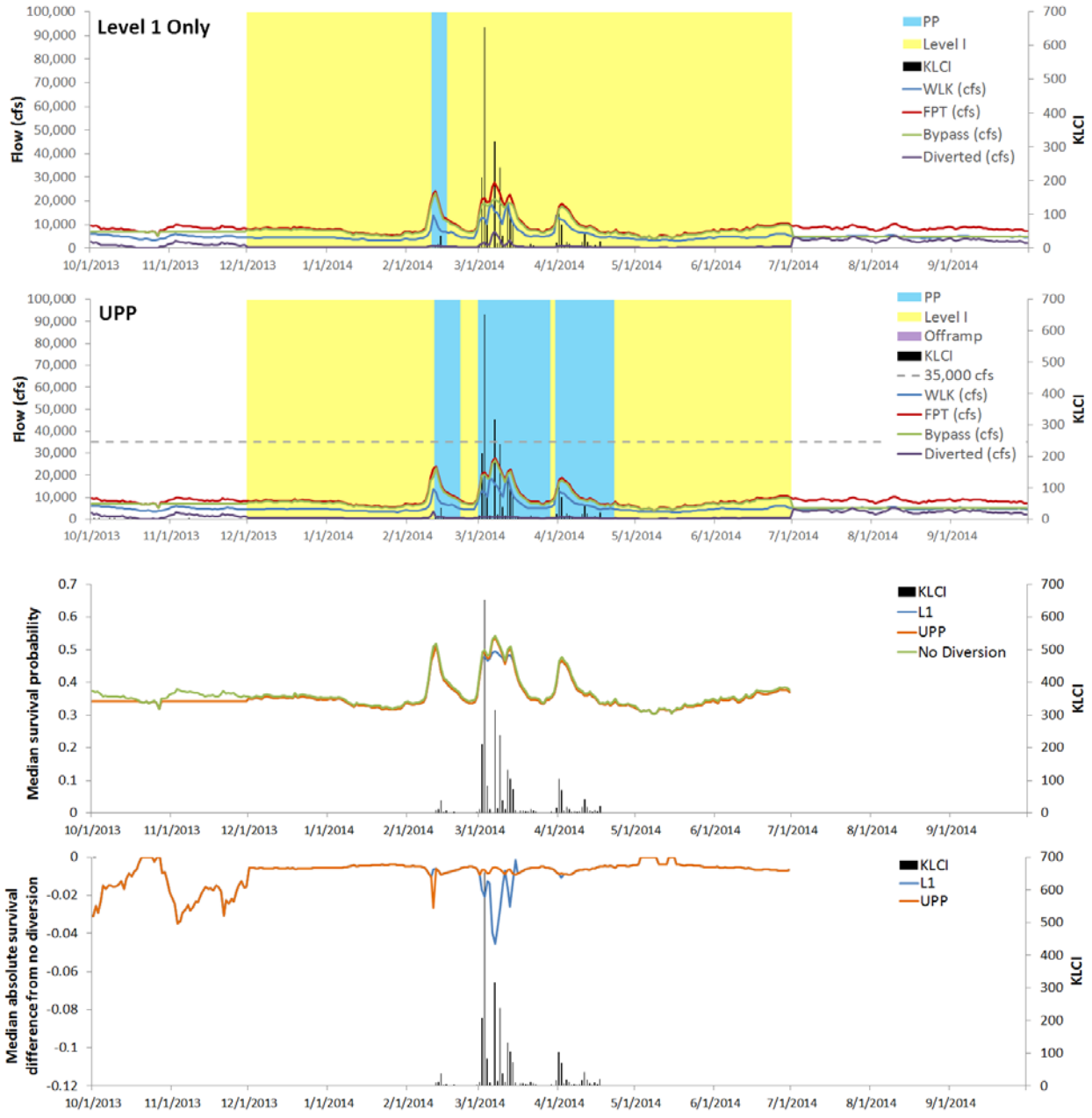

Figure 21. Summary for Water Year 2014 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

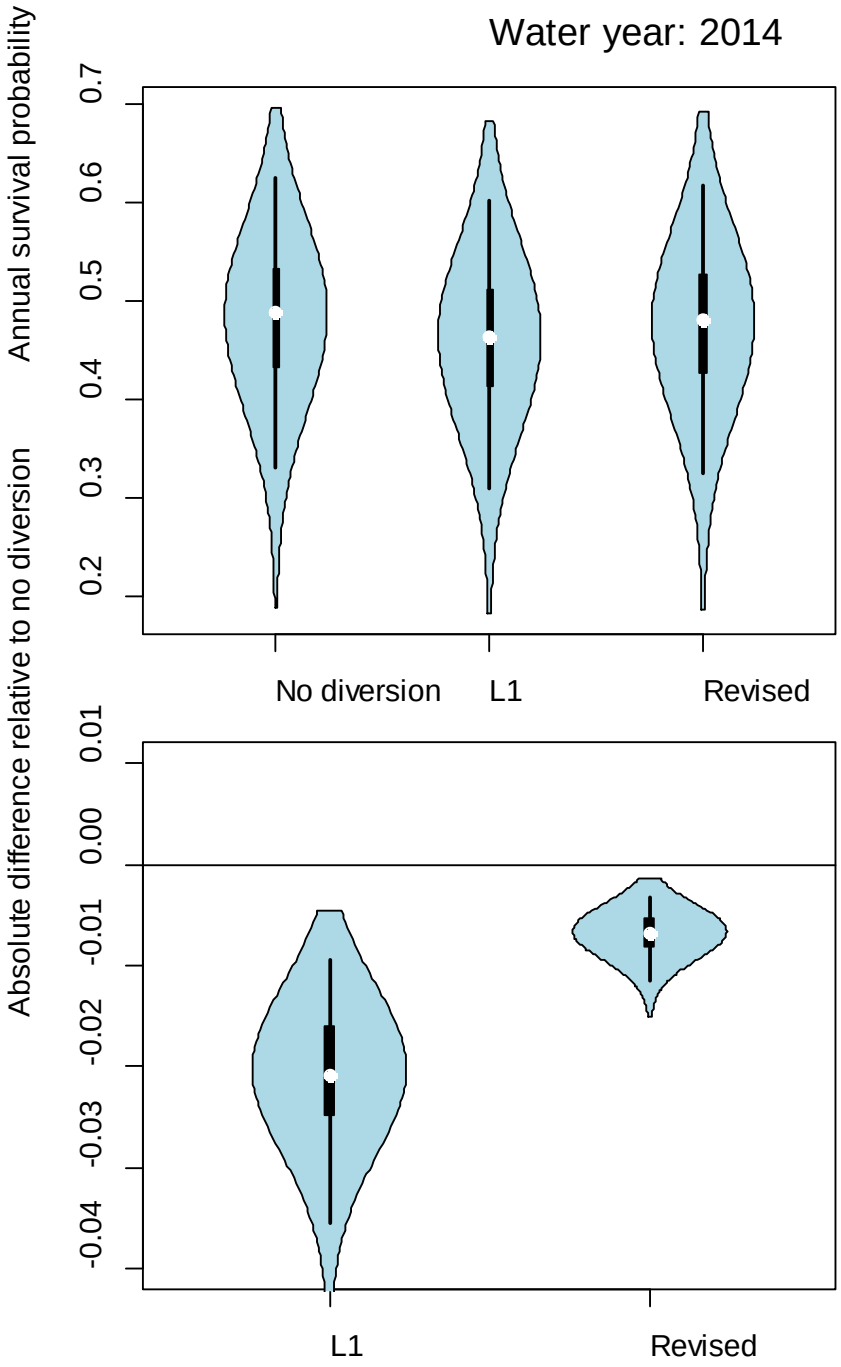

Figure 22. Violin plots for Water Year 2014 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25th-75th percentile, and the white dot shows the median.