Appendix M, Folsom Flow and Temperature

Attachment M.3 American River Weighted Usable Area Analysis

M.3.1 Model Overview

Weighted usable area (WUA) analysis is a method for estimating the availability of suitable habitat in rivers, streams, and floodplains under different flow conditions (Bovee et al. 1998). It has been used primarily for estimating spawning and rearing habitat of fish species. WUA is computed as the surface area of physical habitat available for spawning or rearing, weighted by its suitability. Habitat suitability is determined from field studies of the distributions of redds or rearing juveniles with respect to flow velocities, depths, and substrate or cover in the river or floodplain (Bovee et al. 1998). These data are used in hydraulic and habitat model simulations (e.g., PHABSIM or RIVER2D) that estimate the availability of suitable habitat in a portion of the river at a given flow. WUA curves showing suitable habitat availability versus flow are generated from the simulations. These curves facilitate evaluating how different flow regimes affect spawning and rearing habitat of important fish species.

M.3.2 Model Development

M.3.2.1 Methods

For this analysis, spawning WUA was estimated for fall-run Chinook salmon and California Central Valley steelhead in the American River. Fry and juvenile rearing WUA were not estimated because no reliable rearing WUA curves are available for Chinook salmon or steelhead in the American River. The principal study on which this analysis is based, Bratovich et al. 2017, determined spawning WUA in the American River but did not include rearing WUA investigations. The only rearing WUA information found for American River is old and potentially unreliable (U.S. Fish and Wildlife Service 1985).

Bratovich et al. (2017) provide spawning WUA curves for fall-run Chinook salmon and steelhead spawning habitat in the American River in eight sections of the American River. The eight sections lie within the approximately 10-mile river reach from Nimbus Dam downstream to Riverbend Side Channel, where most salmon and steelhead spawning occurs. Figure M.3-1 and Figure M.3-2 show composite spawning WUA curves from Bratovich et al. (2017) that combine the WUA results for the eight sections. For this effects analysis, CALSIM III flows at Nimbus Dam were used to determine fall-run and steelhead spawning WUA in the American River from the composite WUA curves for each month of the 93-year period of record.

For the Bratovich et al. (2017) study of spawning WUA in the American River, the Habitat Suitability Criteria (HSC) for fall-run Chinook and steelhead spawning were developed using depth, flow velocity, and/or substrate utilization data from previous studies on the American River and other rivers. The HSC were incorporated into a combination of available hydraulic/habitat models (including PHABSIM and RIVER2D) to estimate spawning WUA for different flows (Bratovich et al. 2017).

Mean spawning WUA under the baseline and the alternatives were estimated for the months of the spawning periods of each species (October through December for fall-run Chinook and January through March for steelhead) under each water year type and all water year types combined. Total spawning WUA for all months were compared after weighting the monthly results by the monthly weighting factors in Table M.3-1. These weighting factors were computed from tables of daily weighting coefficients provided by Bratovich et al. (2017), which were derived from redd survey and carcass survey results. No spatial weighting factors are required because, as noted above, the analyses are based on composite WUA curves that encompass all the spawning sections analyzed.

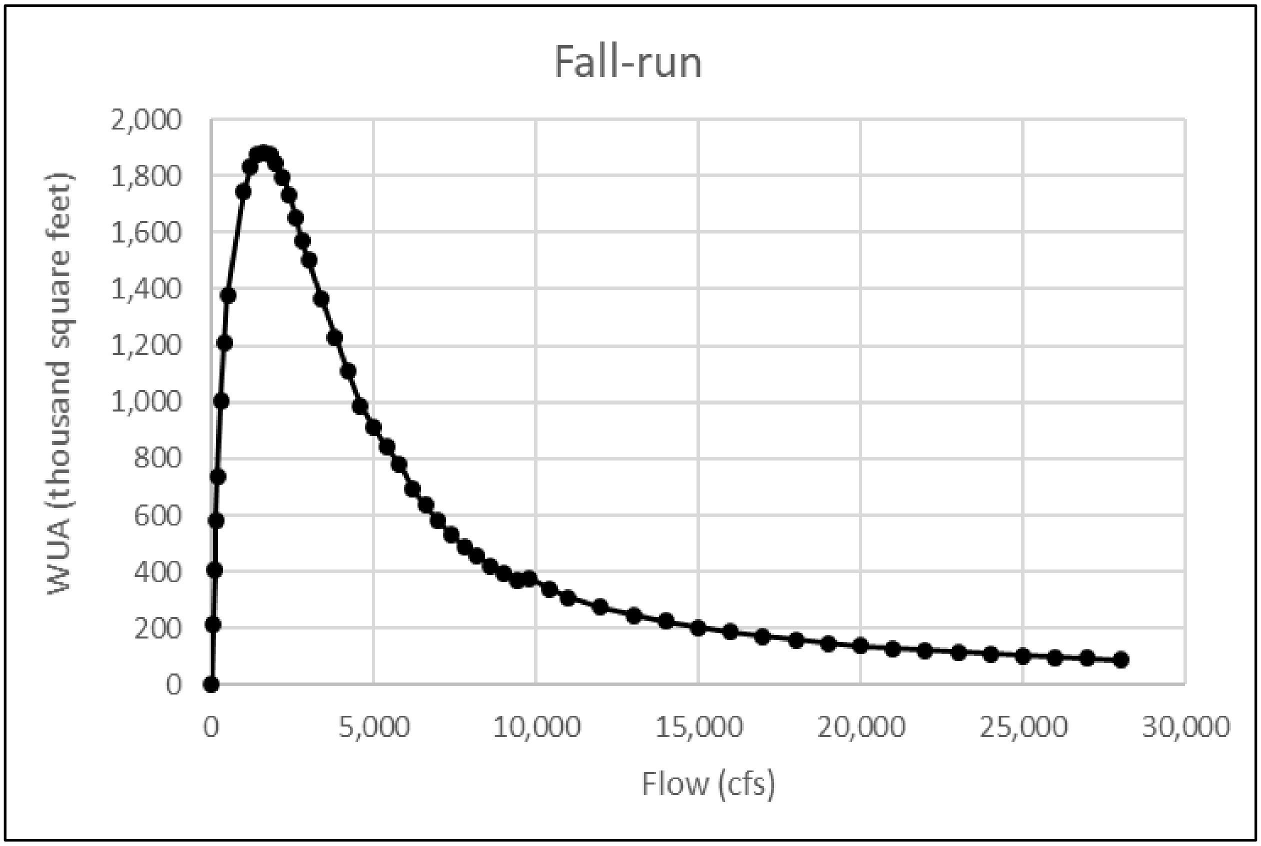

Figure M.3-1. Composite Spawning WUA for Fall-Run Chinook Salmon in the American River.

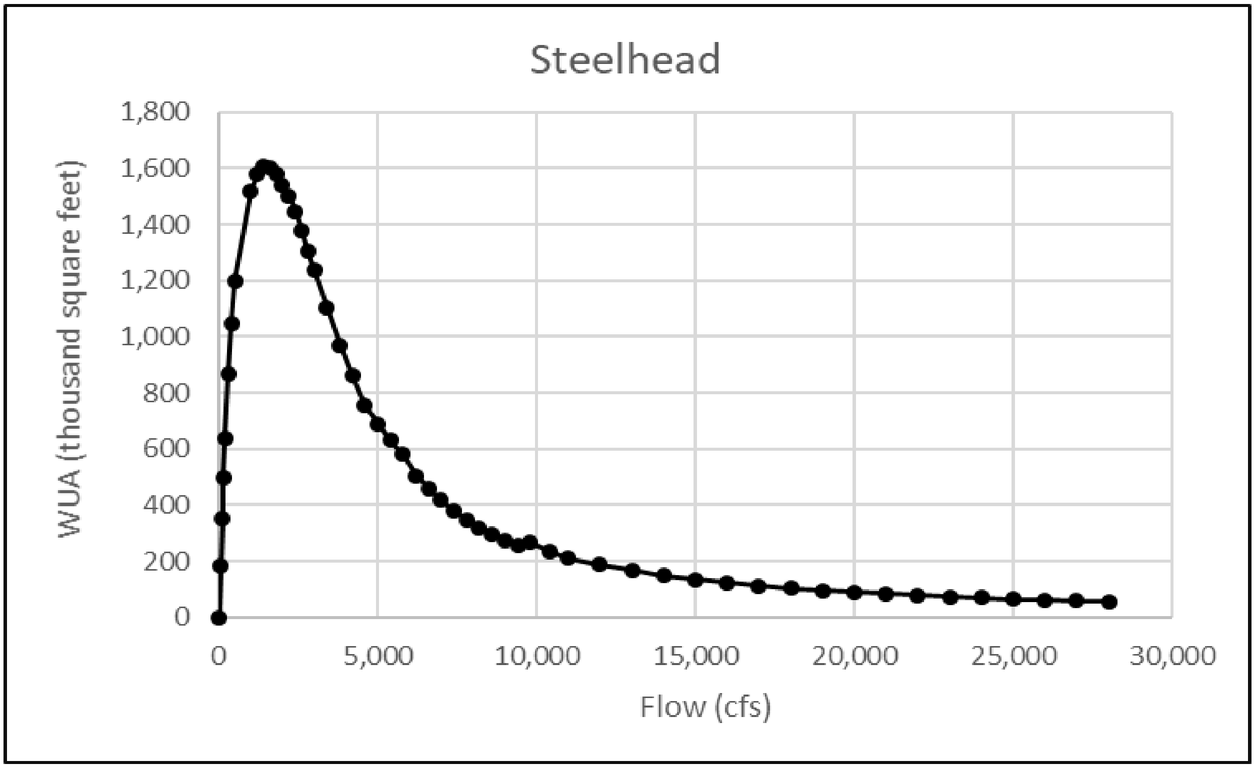

Figure M.3-2. Composite Spawning WUA for Steelhead in the American River.

Table M.3-1. Monthly Weighting Factors for American River Fall-run and Steelhead Spawning.

Month	Fall-run	Steelhead
October	0.07	
November	0.85	
December	0.08	
January		0.3
February		0.6
March		0.1

M.3.2.2 Assumptions/Uncertainty

This section includes two subsections. The first subsection provides a list of some important uncertainties and assumptions of the WUA analyses used for this analysis. The second subsection provides a more general discussion of the validity of WUA analysis, responding to concerns that have been raised in the scientific literature.

M.3.2.2.1 Important Uncertainties and Assumptions of the WUA Analyses Conducted for this Analysis

1. The CalSim 3 operations model that was used to estimate spawning WUA under scenarios uses a monthly timestep. Therefore, the WUA results should be treated as monthly averages. Monthly average WUA results faithfully represent the average conditions affecting the fish. Therefore, using monthly averages to compare WUA results is acceptable for showing differences in the effects of the different flow regimes under baseline and alternatives conditions. Weighting by the proportions in Table M.3-1 ensures that the comparisons account for differences in the amount of spawning occurring in each month, improving the validity of the results.

2. The suitability of physical habitat for salmon and steelhead spawning is assumed to be largely a function of substrate particle size, water depth, and flow velocity. Other unmeasured factors (e.g., flow vortices, water quality, etc.) could influence habitat suitability, contributing to uncertainty in the results.

3. Data used to develop the habitat suitability criteria for spawning included information from rivers other than the American River (Bratovich et al. 2017). The use of habitat data from rivers other than the American River adds some uncertainty to the spawning WUA results.

4. The output of the WUA analysis, Weighted Usable Area, is an index of habitat suitability, not an absolute measure of habitat surface area. In the literature, Weighted Usable Area is often expressed as square feet, square meters, or acres for a given linear distance of stream, which is misleading and can result in unsupported conclusions (Payne 2003; Railsback 2016; Reiser and Hilgert 2018).

5. WUA analyses assume that the channel characteristics of the river, such as proportions of mesohabitat types, during the years of field data collection for the Bratovich et al. 2017 report (1998-1999, 2009, 2011-2016) have remained in dynamic equilibrium to the present time and will continue to do so through the life of the Project. If the channel characteristics substantially changed, the shape of the curves might no longer be applicable.

M.3.2.2.2 Discussion Regarding Validity of Weighted Usable Area Analysis

WUA analysis is among the most widely used and recognized analytical tools for assessing effects of flow on fish populations (Reiser and Hilgert 2018). Procedures for quantifying WUA were developed and standardized by USFWS in the 1970s and they have since been widely adopted by researchers (e.g., Bourgeois et al. 1996; Beecher et al. 2010; Railsback 2016; Naman et al. 2020). However, WUA analysis has received some criticism from instream flow analysis practitioners, especially in recent years. Conclusions in this analysis regarding effects on fish of changes in flow resulting from operations are based on WUA analyses. Therefore, it is important to understand and evaluate the criticisms of WUA analysis and consider any potential limitations for assessing flow-related effects. Criticisms addressed in this attachment are primarily those relevant to spawning WUA analysis because, as discussed previously, no rearing WUA analyses were conducted for the American River.

Two frequent criticisms of WUA analysis that are most potentially relevant with regard to the results and conclusions of this analysis are: (1) WUA analysis fails to directly evaluate many factors that are known to be important to fish spawning, including water quality (especially temperature and dissolved oxygen), predation, and competition (including redd superimposition) (Beecher et al. 2010; Railsback 2016), and (2) the models employed to develop the WUA curves (especially PHABSIM) are antiquated, the field observations and measurements used to run the models are not sufficiently fine-grained to capture important highly localized factors, and the models do not adequately capture many dynamic properties of fish habitat use (Railsback 2016; Reiser and Hilgert 2018).

Regarding the first criticism, PHABSIM and the WUA curves they produce were never meant to address all factors affecting fish populations. As noted in a recent paper rebutting many of the criticisms of PHABSIM (Stalnaker et al. 2017): “PHABSIM is a component of instream flow incremental methodology (IFIM), which is a multifaceted decision support system that looks at riverine ecology for the purpose of making water management decisions.” The IFIM uses a suite of evaluation tools (including PHABSIM) and investigates water quality factors and other factors that affect fish in addition to the hydraulic-related habitat conditions analyzed using PHABSIM or other hydraulic habitat models (Beecher 2017). Analysis methods other than PHABSIM are used to evaluate the other factors, which may or may not be affected by flow. Conclusions regarding effects on a species are based on evaluations of the results for all the factors analyzed.

The second criticism is more specific to the modeling tools used for WUA analyses. Many of the limitations of PHABSIM cited by critics are acknowledged by its defenders (Beecher 2017; Stalnaker et al. 2017; Reiser and Hilgert 2018). Some of the cited shortcomings are common to any model that attempts to simulate complex ecological systems. Others reflect that PHABSIM is antiquated; newer, more powerful procedures have been incorporated into newer models. In fact, many studies have replaced or combined PHABSIM with more powerful tools in recent years, including the RIVER2D hydraulic and habitat model, which was included by Bratovich et al. (2017) in the models used to develop the American River spawning WUA curves used for this WUA analyses. The habitat variables included in hydraulic/habitat modeling have also been expanded and improved (Li et al. 2019). Such methods are promising, but they are not currently available for use in analyzing flow effects on fish populations in the American River.

Some biases are inevitable in any effort to model fish populations, but improvements in sampling and modeling techniques can be expected to lead to more accurate models for WUA analyses in the future. PHABSIM and similar models, despite their shortcomings, continue to be among the most used and useful analytical tools for assessing instream-flow-related issues (Reiser and Hilgert 2018).

M.3.2.3 Code and Data Repository

Code, input, and output files for this analysis can be found at: [TBD].

Results Table M.3-2 provides the spawning WUA results for American River steelhead under three baseline scenarios (EXP 1, EXP 3, NAA) and four management alternatives (ALT 2 v1 with TUCP, ALT2 v1 without TUCP, ALT 2 Delta VAs, and ALT 2 All VAs). The results are the means for all years analyzed, weighted by average frequency of spawning for each month (Table M.3-1). The results show an increase in mean WUA from wetter to drier water year types for all the baseline and management scenarios (Table M.3-2). Note that, as discussed under Assumptions/Uncertainties, WUA is typically expressed in square feet, but is not equivalent to standard surface areas.

M.3.3 Results

Table M.3-2 and Table M.3-3 below provide the spawning WUA results for American River steelhead and fall-run Chinook under a baseline scenario, NAA, and seven management alternatives (Alt 1, Alt 2 v1 with TUCP, Alt2 v1 without TUCP, Alt 2 Delta VAs, Alt 2 All Vas, Alt 3, and Alt 4). The results are the means for all 100 years analyzed, weighted by average frequency of spawning for each month (Table M.3-1).

The results for steelhead (Table M.3-2) show an increase in mean WUA from wetter to drier water year types for the baseline and all management scenarios, while the results for fall-run (Table M.3-3) show maximum or near-maximum WUA in above normal water year types and minimum WUA in wet water year types for all scenarios. Note, that as discussed under Heading 3, Assumptions/Uncertainties, WUA is typically expressed in square feet, but is not equivalent to standard surface areas.

Table M.3-2. Expected WUA[1] for Steelhead Spawning in the American River Downstream of Nimbus Dam for the Baseline Scenario, NAA, and Seven Management Alternatives.

Water Year Type	NAA	Alt1	Alt2v1 with TUCP	Alt2v1 without TUCP	Alt2 Delta VAs	Alt2All Watershed VAs	Alt3	Alt4
Wet	352,691	344,306	350,955	350,961	350,665	351,490	343,148	352,702
AN	701,524	661,544	688,328	688,780	682,699	678,966	682,659	688,054
BN	1,121,861	1,028,424	1,099,249	1,101,551	1,113,258	1,115,996	1,111,301	1,090,576
Dry	1,329,545	1,152,636	1,297,246	1,299,330	1,289,953	1,293,711	1,320,479	1,290,567
Critical	1,446,300	1,269,762	1,400,262	1,395,659	1,385,088	1,382,138	1,466,768	1,411,591
All	949,401	853,933	927,879	928,122	925,353	925,984	943,286	926,979

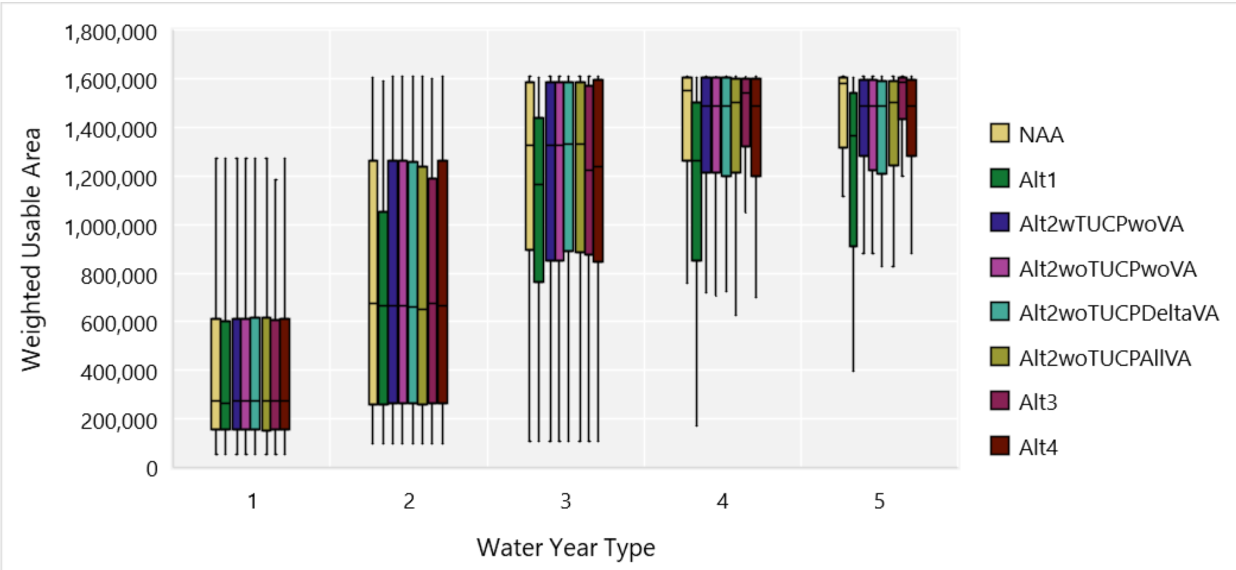

Figure M.3-3. Expected WUA for Steelhead Spawning in the American River Downstream of Nimbus Dam for the Baseline Scenario, NAA, and Seven Management Alternatives, January through March by Water Year Type.

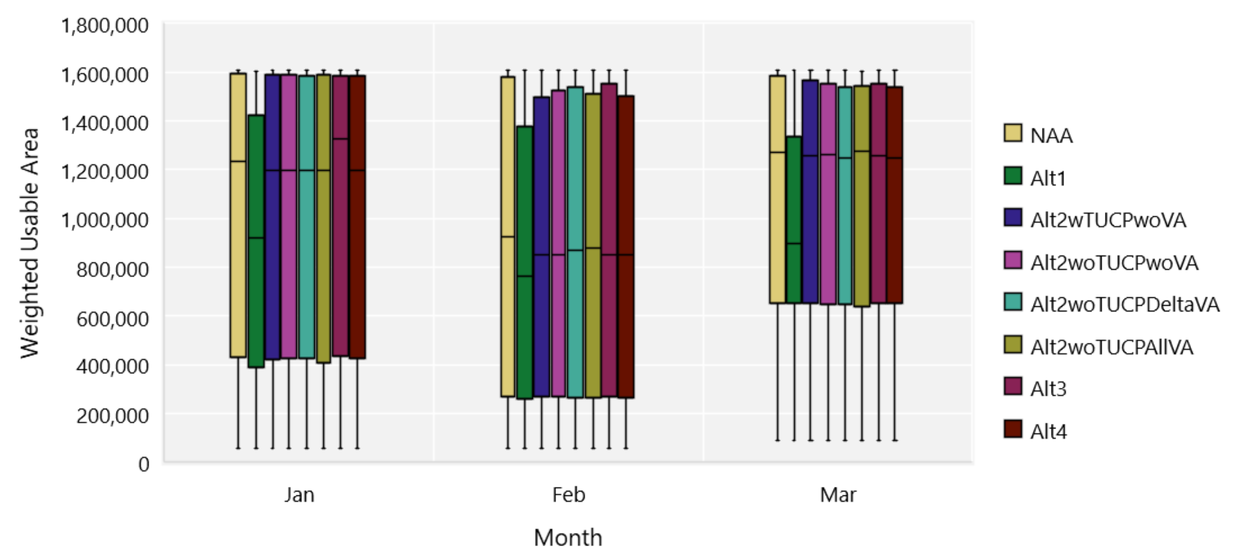

Figure M.3-4. Expected WUA for Steelhead Spawning in the American River Downstream of Nimbus Dam for the Baseline Scenario, NAA, and Seven Management Alternatives by Month

Table M.3-3. Expected WUA for Steelhead Spawning in the American River Downstream of Nimbus Dam for EXP1, EXP3, the NAA, and Four Versions of Alt2.

Water Year Type	EXP1	EXP3	NAA	Alt2v1 withTUCP	Alt2v1 withoutTUCP	Alt2 DeltaVAs	Alt2AllWatershedVAs
Wet	310,811	342,863	352,691	350,955	350,961	350,665	351,490
AN	607,924	657,341	701,524	688,328	688,780	682,699	678,966
BN	975,914	1,068,400	1,121,861	1,099,249	1,101,551	1,113,258	1,115,996
Dry	1,192,842	1,269,688	1,329,545	1,297,246	1,299,330	1,289,953	1,293,711
Critical	1,361,200	1,430,598	1,446,300	1,400,262	1,395,659	1,385,088	1,382,138
All	851,875	913,962	949,401	927,879	928,122	925,353	925,984

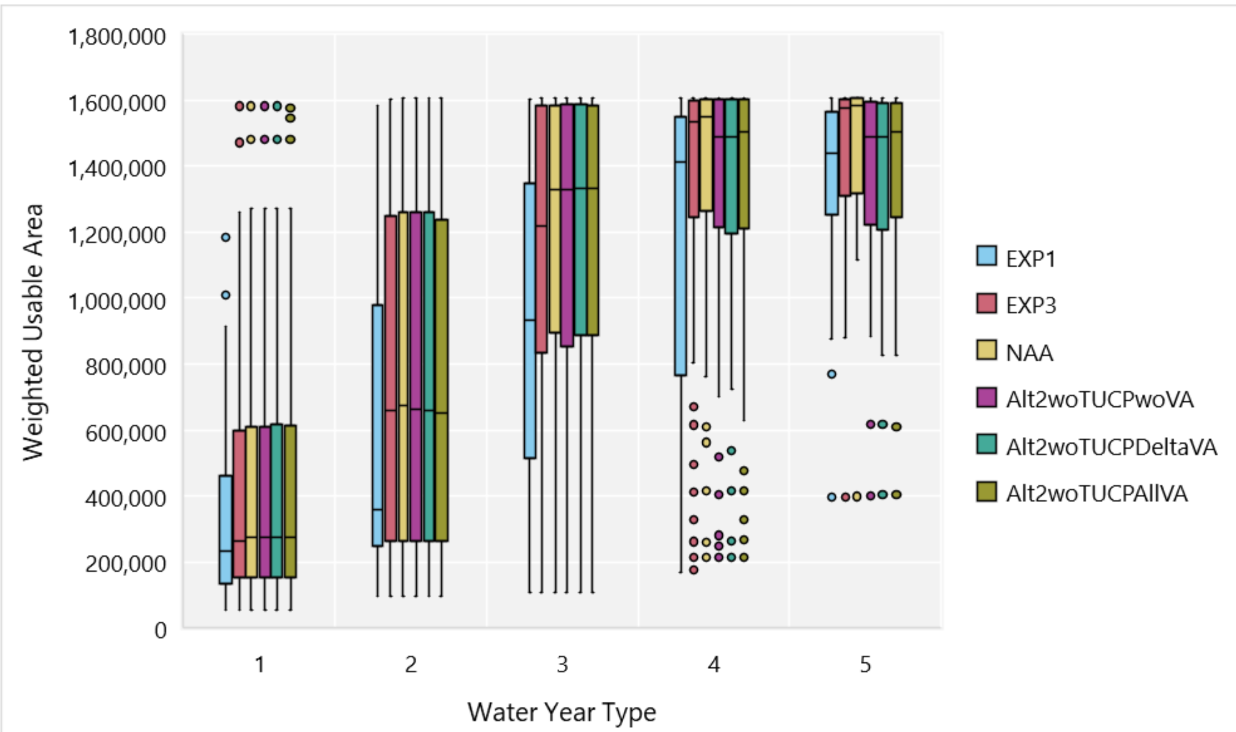

Figure M.3-5. Expected WUA for Steelhead Spawning in the American River Downstream of Nimbus Dam for EXP1, EXP3, the NAA, and Three Versions of Alt2 for January through March by Water Year Type.

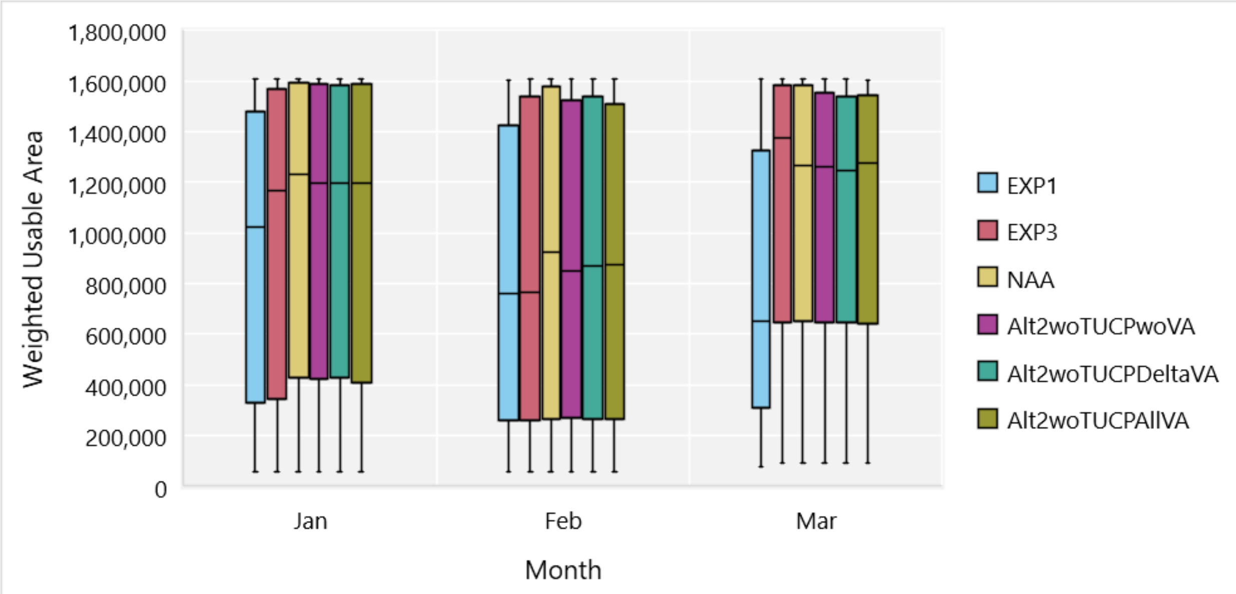

Figure M.3-6. Expected WUA for Steelhead Spawning in the American River Downstream of Nimbus Dam for EXP1, EXP3, the NAA, and Three Versions of Alt2 for by Month.

TableM.3-4. Expected WUA for Fall-run Chinook Spawning in the American River Downstream of Nimbus Dam for the Baseline Scenario, NAA, and Seven Management Alternatives.

Water Year Type	NAA	Alt1	Alt2v1 with TUCP	Alt2v1 without TUCP	Alt2 Delta VAs	Alt2All Watershed VAs	Alt3	Alt4
Wet	1,320,372	1,259,121	1,309,098	1,310,233	1,302,453	1,305,672	1,316,915	1,309,775
AN	1,686,947	1,482,441	1,677,742	1,678,060	1,672,558	1,675,677	1,644,017	1,678,994
BN	1,639,221	1,400,752	1,617,793	1,609,099	1,597,143	1,592,289	1,651,135	1,629,598
Dry	1,512,940	1,381,182	1,508,120	1,503,091	1,512,409	1,486,350	1,533,434	1,495,740
Critical	1,608,904	1,481,551	1,521,488	1,483,930	1,494,086	1,500,121	1,574,903	1,520,654
All	1,522,247	1,380,772	1,499,583	1,491,543	1,490,147	1,485,294	1,516,803	1,498,989

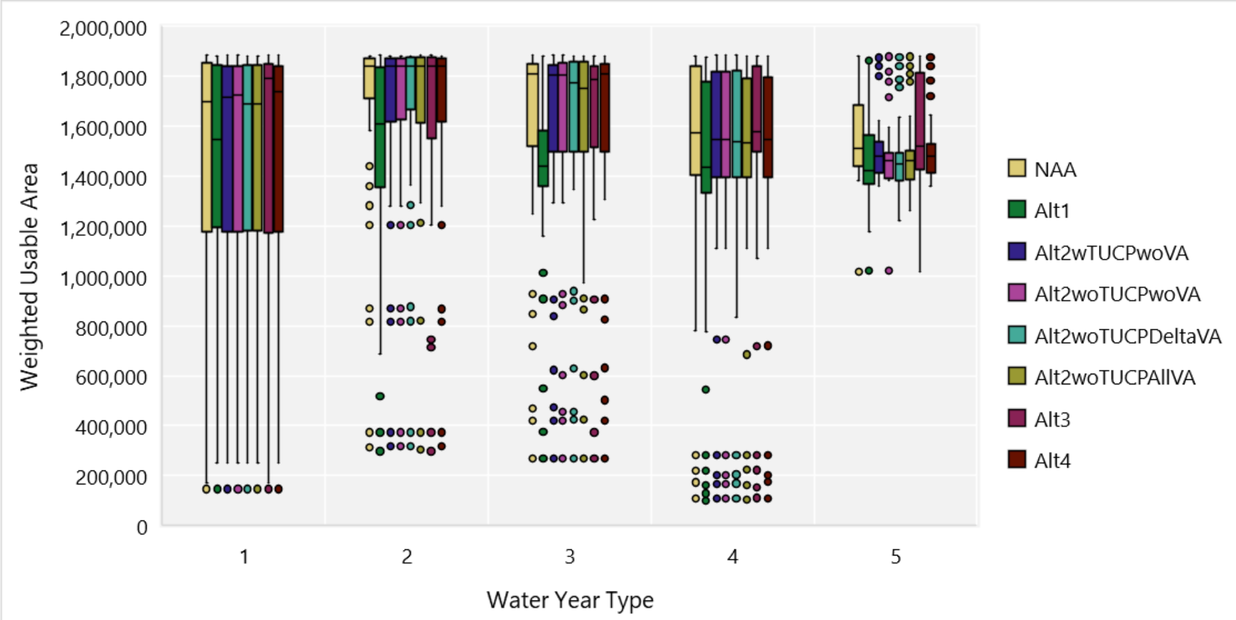

Figure M.3-7. Expected WUA for Fall-run Chinook Salmon Spawning in the American River Downstream of Nimbus Dam for the Baseline Scenario, NAA, and Seven Management Alternatives October through December by Water Year Type.

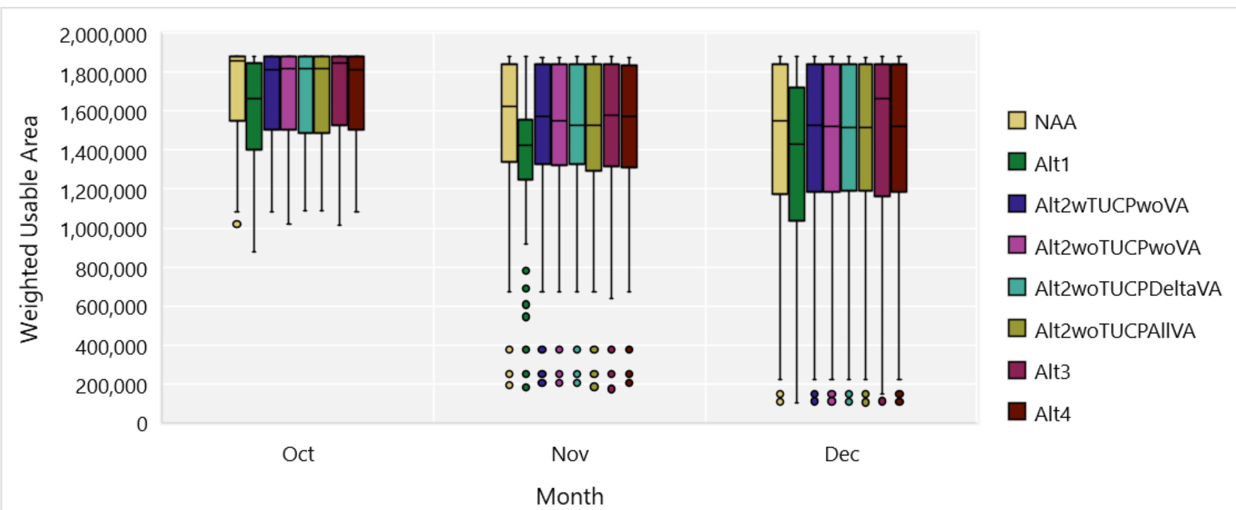

Figure M.3-8. Expected WUA for Fall-run Chinook Salmon Spawning in the American River Downstream of Nimbus Dam for the Baseline Scenario, NAA, and Seven Management Alternatives by Month

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