Draft Strategic Plan Appendix F: Non-Flow Measure Accounting

1 Introduction and Overview

This section is complementary to and builds on section 3.1.4 in the Draft Strategic Plan describing methods for Non-flow Measure Accounting. The following content adds detail to the accounting protocols that will compare pre- and post-implementation conditions in support of determining whether the Non-flow Measure commitments as detailed in the March 2022 Term Sheet have been met. Readers of this document should anticipate that this content will be brought into the Strategic Plan in the future, and that editorial changes will be made in the Draft Strategic Plan to ensure clarity between the general methods currently described in the Draft Strategic Plan and the more detailed protocols described here.

2 Tributary Non-flow Measure Accounting Protocols

The following habitat accounting protocols pertain to tributary spawning, in-channel rearing, and tributary floodplain rearing habitat enhancement measures outlined in Table 25. Design criteria and quantitative habitat accounting protocols for bypass floodplain and tidal wetland projects are presented in Sections 3 and 4 of this document.

Habitat accounting for tributary spawning, in-channel rearing, and tributary floodplain rearing habitat enhancement measures accounts for the acreage of implemented habitat enhancement measures based on design criteria for specific projects. Design criteria include water depth and water velocity, as well as substrate for spawning measures, and cover for tributary in-channel and tributary floodplain rearing measures (Tables 27 and 28), and inundation frequency for tributary floodplain rearing measures.

Habitat accounting is a site-specific assessment that will be conducted at the completion of each individual project construction and will serve as an incremental accounting step for whether parties have met their non-flow habitat total acreage commitments described in the March 2022 VA Term Sheet and applicable amendments. Area-specific Governance Entities (GEs), in coordination with the Science Committee, will build upon this methodological framework to develop detailed assessment protocols tailored to the specific habitat enhancement measures being implemented within their respective governance area. The habitat accounting framework presented below is intended to be applied at the individual project level.

2.1 Considerations for Habitat Accounting

Assessment of site-specific habitat implementation requires spatially explicit quantification of those areas within a project boundary (i.e., “footprint”) that conform with specified design criteria at design flows. The term “design flows” refers to the range of flows over which a habitat enhancement project is designed to create habitat. For the methodological steps identified below, the flows at which the “pre-project” and “as-built” conditions are evaluated must be the same to enable equitable comparisons, and for the project design flows to provide a meaningful basis for comparison.

Habitat accounting for tributary spawning habitat, in-channel rearing habitat, and tributary floodplain rearing habitat projects will be conducted over a range of design flows. The following section describes considerations regarding the identification of design flows for tributary habitat actions, as well as how design flows relate to habitat accounting for those actions.

The term "design flows" generally describes the range of flows over which habitat features constructed for a given project are intended to function (Copeland et al. 2001). For any given habitat enhancement project, design flows can vary based on a number of factors including: (1) the habitat objective(s) (e.g., spawning, in-channel rearing, tributary floodplain rearing); (2) the desired habitat features (e.g., perennial side-channel, seasonal side-channel, alcove, etc.); and (3) the biological objectives (e.g., increasing growth and survival for initial fry rearing, maintaining and promoting diversity of rearing and emigration life histories). In addition to these factors, design flows reflect the fluvial geomorphological interactions between site-specific topography and hydrology (Copeland et al. 2001; Flosi et al. 2010).

Habitat will be designed and constructed to meet water depth and velocity design criteria over a range of flows, and permit requirements relevant to habitat projects will ensure that design flows will be within the range of those typically observed and that habitat is available across a range of flows. Because of this, habitat accounting will include development (or revision) of habitat-flow relationships over a range of flows reflective of those assumed in the 2023 Final Draft Scientific Basis Report Supplement (SBRS) for each tributary. Development of these new or revised relationships will form the basis of a Consistency Assessment that will be designed to compare the availability of habitat over the range of applicable flows realized through implementation with the assumptions made in the SBRS.

2.1.1 Design Flows for Spawning Habitats

Despite the project- and feature-specific nature of design flows, certain generalities can be applied to the identification of design flows depending on the habitat objective. For example, tributary spawning habitat for salmonids would not be expected to be effective if located at elevations associated with flows greater than the bankfull channel flow. Redd construction and, more importantly, embryo incubation require sufficient duration of inundation that is typically not realized outside of the bankfull channel. Thus, a general range of flows appropriate for designing and implementing tributary spawning habitat is the range of flows extending from baseflow to the bankfull channel flow. Within this general range, it is appropriate to examine hydrological records (i.e., monitored flows) or hydrological model output to identify a narrower range of flows that typically occur, or are intended to be utilized during the spawning period relevant to the specific project site.

2.1.2 Design Flows for Tributary Floodplain and In-Channel Rearing Habitats

The identification of design flows for tributary rearing habitat is more complex because tributary rearing habitat occurs in two general forms: tributary floodplain rearing habitat and in-channel rearing habitat.

Design criteria for tributary floodplain rearing habitat include targets for inundation duration, intra-annual frequency, and inter-annual frequency, and a flow event meeting these targets is described as a "Meaningful Floodplain Event" ("MFE"). Specifically, tributary floodplain habitats will be designed with targets for inundation frequency and duration that are consistent with the intention of the MFE described in the SBRS[1], ensuring that tributary floodplain rearing habitat will be available over a range of flows. Additionally, for tributaries using a high resolution (i.e., daily timestep) hydrologic model, an example range of combined duration and frequency targets that may adhere to the rationale of the MFE has been identified, including:

- Inter-annual frequency: Inundation 2 out of every 3 years on average and within a range of 50% to 80% of years.
- If modeled duration of inundation is between seven and 18 days, floodplain projects should target at least two distinct inundation events in the February through June rearing period. Grosholz and Gallo (2006) recommend repeated flood pulses at intervals of 2- to 3-weeks to best support native fish.
- If floodplain projects are designed for duration of inundation greater than 18 days, a single inundation occurrence during the February through June rearing period will satisfy the intention of the MFE criteria.

The application of MFE targets necessarily restricts the range of potential design flows for tributary floodplain rearing habitat because they are directly tied to the hydrologic regime. For this reason, tributary floodplain projects will incorporate design flows in consideration of targets for inundation frequency and duration that are consistent with the intention of the MFE described in the SBRS. Other inundation designs consistent with the intention of providing suitable rearing habitat may also be developed for specific tributaries and projects. For example, a tributary-specific approach may include consideration of the actual flows that occur during qualifying MFEs in the identification of design flows. Each area-specific GE will identify appropriate design flows for tributary floodplain rearing habitat in coordination with the Science Committee. These intra- and inter-annual frequency and duration targets will be used to design and construct tributary floodplain rearing habitat that meets water depth and velocity design criteria over a range of flows, consistent with the intent of the SBRS.

For tributary in-channel rearing habitat, the range of design flows depends on the project- and site-specific biological objectives. For example, it may be desirable to design some project features (e.g., seasonal side channels) to provide in-channel habitat at a higher flow or over a broader range of flows than those associated with perennially inundated in-channel habitat. Other features within the same overall project footprint could be designed to provide in-channel rearing habitat within the perennially inundated channel elevation, and it also is possible to design in-channel habitat features to function over a range of flows that spans the perennially inundated channel elevation. As such, it may be appropriate to identify a range of design flows for each in-channel rearing habitat feature based on feature-specific geospatial boundaries associated with distinct topographical delineation, or by the project-specific elevation associated with the flow that activates off-channel inundation.

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[1] Design criteria for the Tuolumne River are pending development and will target consistency with the Tuolumne River Scientific Basis Report that is being prepared by the State Water Board.

2.1.3 Acreage Protocol for Tributary Spawning, In-channel Rearing, and Floodplain Rearing Habitats

Habitat accounting will be conducted at the time of project construction completion to evaluate whether the physical conditions at site-specific measures correspond with project specifications and design criteria.

The general methodology for evaluating the implementation of constructed tributary habitat measures for Chinook salmon spawning and rearing habitat consists of the following steps at the time of project construction completion and will be the methodology for comparing the realized acreage with the commitments of the Term Sheet to determine when the commitments have been met.

In addition to quantifying the area of implemented habitat meeting design criteria for habitat accounting, the methodology below also generates information (i.e., project-specific habitat-discharge relationships) that can be utilized for other, future Non-flow Measure assessments. These additional assessments will include a comparison of the additional acreage of suitable habitat resulting from Non-flow Measures with the acreage anticipated in the SBRS. These assessments can enable a comparison of realized acreage with initial estimates of SBRS[2] (i.e., a SBRS Consistency Assessment) and will be provided to the State Water Board as part of basin-wide suitability assessments anticipated in the Triennial Synthesis Reports and further described in the Science Plan.

2.1.3.1 "Pre-Project" Characterization

1. Accurately characterize "pre-project" physical conditions within specific habitat measure boundaries ("footprint"). Characterization of physical conditions[3] includes topography, substrate, and cover.
2. Create a digital elevation model (DEM) based on the pre-project topographical characterization and create substrate and cover rasters (see discussion of raster development below) for the project footprint.
3. Apply available two-dimensional ("2D") hydraulic models to calculate water depths and velocities within each computational pixel[4] within the project footprint at each modeled flow within the range of design flows.
4. Determine where design criteria (Table 27) are met at each modeled flow within the range of design flows for each computational pixel within the project footprint using hydraulic (e.g., water depth and velocity) and relevant non-hydraulic (e.g., substrate for spawning) criteria as binary functions. In other words, if a computational pixel corresponds with the hydraulic and

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[2] The Tuolumne River Scientific Basis Report Supplement is being prepared by the State Water Board and as such, the nature of any similar assessments specific to the Tuolumne River is under development, are subject to negotiation amongst the parties, and will be included in the Scientific Basis Report Supplement for the Tuolumne River.

[3] Topographical characterization can be developed through traditional surveying techniques, multibeam echo sounding bathymetry, and/or LiDAR data acquisition. Substrate and cover characterization can be developed through field survey mapping, geo-referenced aerial imagery (e.g., fixed-wing aircraft, unmanned aerial vehicles, satellite), and/or LiDAR data acquisition.

[4] Several factors contribute to the size of DEM and 2D model output mesh size, including the quality/density of LiDAR or other topographic data, computational ability, and desired accuracy of output. For high resolution results, a 3 ft. by 3 ft. DEM and 2D hydraulic model output mesh size is generally appropriate for the suite of habitat evaluations for the VA process.

applicable non-hydraulic criteria, then the area represented by that pixel is considered to meet design criteria.

5. Sum the area of all computational pixels within the project footprint that meet design criteria to identify the explicit area (acres) of habitat that meet design criteria at each modeled flow within the range of design flows.

2.1.3.2 "As-Built" Characterization

6. Modify characterization of the physical conditions[1] within the project footprint to reflect the constructed project features and develop a modified DEM as well as updated substrate and cover rasters (see discussion of raster development below).
7. Apply available hydraulic models to calculate water depths and velocities within each computational pixel within the project footprint at each modeled flow within the range of design flows.
8. Determine where design criteria (Table 27) are met at each modeled flow within the range of design flows for each computational pixel within the project footprint using hydraulic (e.g., water depth and velocity) and relevant non-hydraulic (e.g., substrate for spawning) criteria as binary functions (**Figure 1**, **Figure 2**).
9. Sum the area of all computational pixels meeting design criteria within the project footprint to identify the explicit area (acres) of habitat that meet design criteria at each modeled flow within the range of design flows.

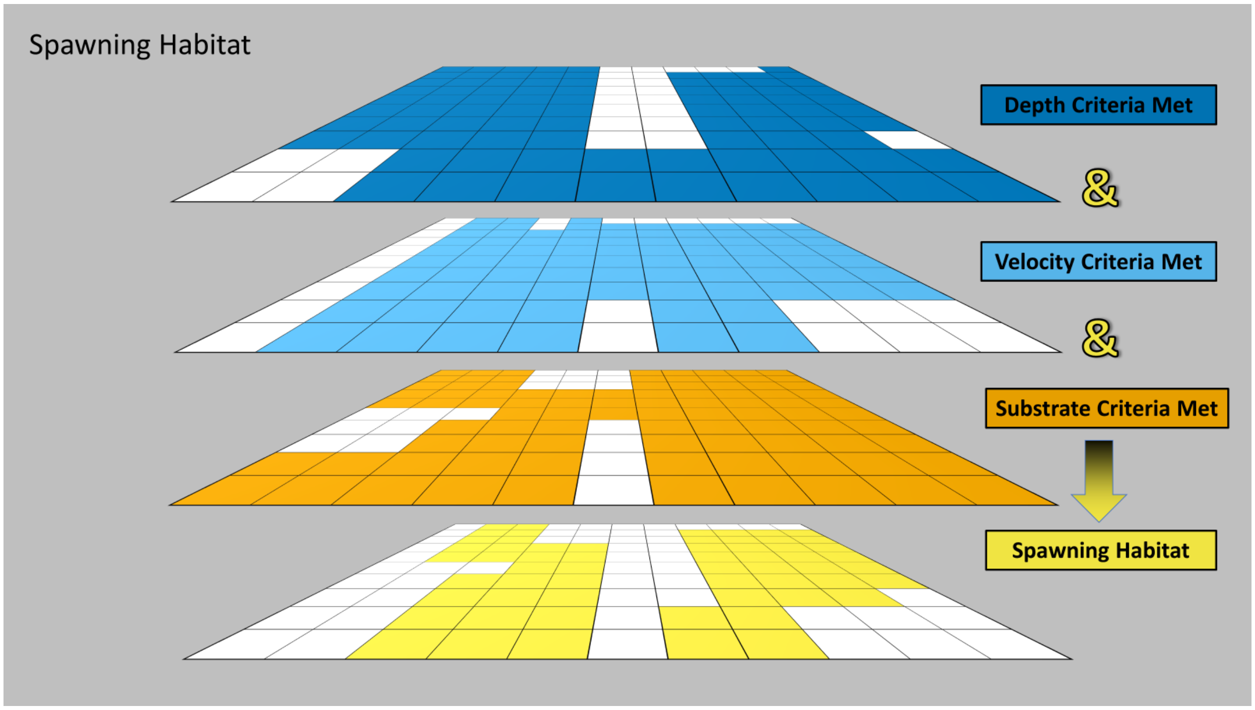


Figure 1. Conceptual representation of the determination of spawning habitat where design criteria (Table 27) are met at a modeled flow in the range of design flows for each computational pixel within the project footprint using hydraulic (water depth and velocity) and relevant non-hydraulic (substrate for spawning) criteria as binary functions. In other words, if a computational pixel corresponds with the hydraulic and applicable non-hydraulic criteria, then the area represented by that pixel is considered to meet design criteria. The same process is used for both "pre-project" and "as-built" conditions.

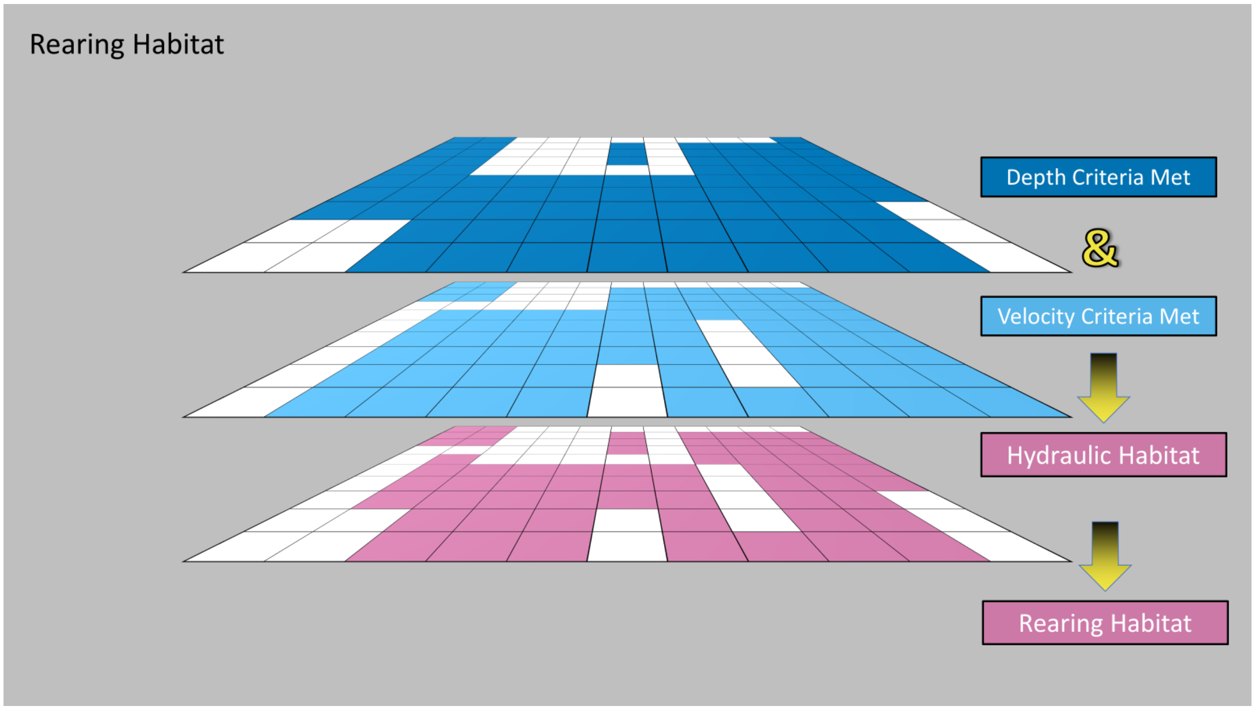


Figure 2. Conceptual representation of the determination of rearing habitat where design criteria (Table 27) are met at a modeled flow in the range of design flows for each computational pixel within the project footprint using hydraulic (water depth and velocity) criteria. Treated as binary functions, if a computational pixel corresponds with the hydraulic criteria, then the area represented by that pixel is considered to meet design criteria. The same process is used for both "pre-project" and "as-built" conditions.

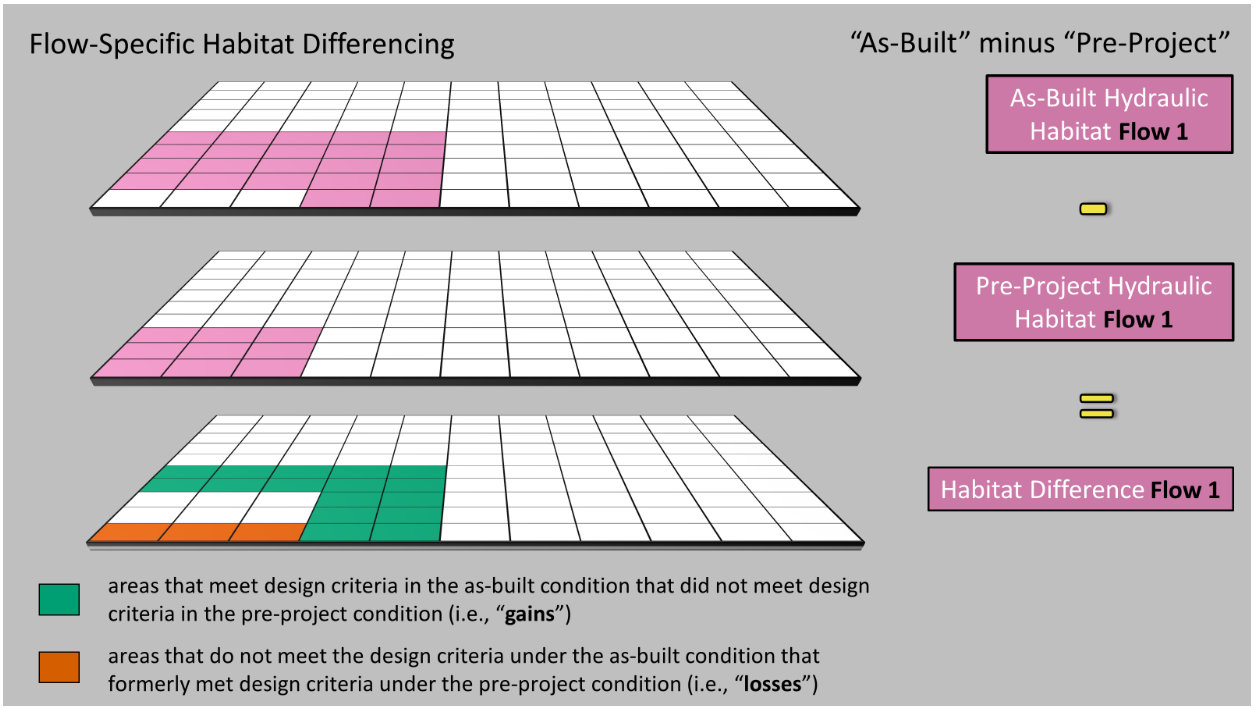
2.1.3.3 "Pre-Project" vs. "As-Built" Differencing

10. At each modeled flow within the range of design flows, identify spatially explicit areas that meet design criteria in the as-built condition that did not meet design criteria in the pre-project condition (i.e., "gains"), as well as the spatially explicit areas that do not meet the design criteria under the as-built condition but met design criteria under the pre-project condition (i.e., "losses", **Figure 3**).

2.1.3.4 Total Acreage of Unique Habitat Created Over the Range of Design Flows

Providing increases in habitat areas at different flows provides notable fisheries habitat benefits (e.g., more diverse rearing conditions across a range of flows, potential for improved juvenile life history diversity, etc.). Therefore, a quantitative metric was developed to account for the total areal extent of habitat gains and losses within the project footprint at each flow over the range of design flows. This metric is derived from the spatially explicit incremental gains and losses over the range of design flows, which shows the incremental amount of additional habitat gains and losses as flows increase from the lowest design flow up to the next higher modeled flow, without double-counting any areas.

To calculate the total amount of spatially explicit (i.e., unique) habitat gains and losses created at each modeled flow over the range of design flows relevant to the habitat objective (i.e., spawning, in-channel rearing, tributary floodplain rearing) being evaluated, the following steps will be undertaken.



🟩 areas that meet design criteria in the as-built condition that did not meet design criteria in the pre-project condition (i.e., “**gains**”)

🟧 areas that do not meet the design criteria under the as-built condition that formerly met design criteria under the pre-project condition (i.e., “**losses**”)

Figure 3. Example showing the differencing of the “as-built” and “pre-project” DEMs at a single flow in the range of design flows to identify the flow-specific areas of habitat gains (i.e., spatially explicit areas that meet design criteria in the as-built condition that did not meet design criteria in the pre-project condition; green cells) and habitat losses (i.e., spatially explicit areas that do not meet the design criteria under the as-built condition that formerly met design criteria under the pre-project condition; red cells).

11. Using the flow-specific difference rasters (“as-built” minus “pre-project”) generated in Step 10, identify the areas of habitat gains and losses at the lowest design flow.
12. At the next higher modeled flow, calculate the amount of habitat gains and losses additional to (i.e., not contained within the spatial extent) the areas identified in the previous step.
13. Repeat Step 12, increasing to the next higher modeled flow with each iteration, for all remaining modeled flows within the range of design flows.
14. Aggregate all areas of flow-specific habitat gains and losses identified in the previous steps to identify the overall areas of gains and losses over the range of design flows.

2.1.3.5 Application of Cover to Rearing Habitat Accounting

For each tributary in-channel and tributary floodplain rearing habitat enhancement measure, cover is a qualifying criterion such that if ≥20% of the area of a given rearing habitat type meeting hydraulic criteria also includes cover features (HSI≥0.5, Table 28), then the area meeting hydraulic criteria represents rearing habitat. If the ≥20% qualifying cover criterion is not met, then no newly constructed rearing habitat for a specific measure is counted. This qualifying criterion is applied to the total acreage of habitat gains calculated in Step 14 (detailed cover raster development is described below).

15. Calculate the difference between the total area of habitat gains and the total area of habitat losses to identify the total net area of habitat enhancement for habitat accounting.

Figure 4 provides an example of Steps 11 through 15 to illustrate the concept of identifying and aggregating spatially explicit habitat gains and losses associated with different flows over the range of design flows. As illustrated in Figure 4, this approach considers the entire areal extent of unique habitat gains and losses created across the range of design flows without double counting any areas.

2.1.3.6 Accounting for Multiple Habitat Objectives within a Single Project Footprint

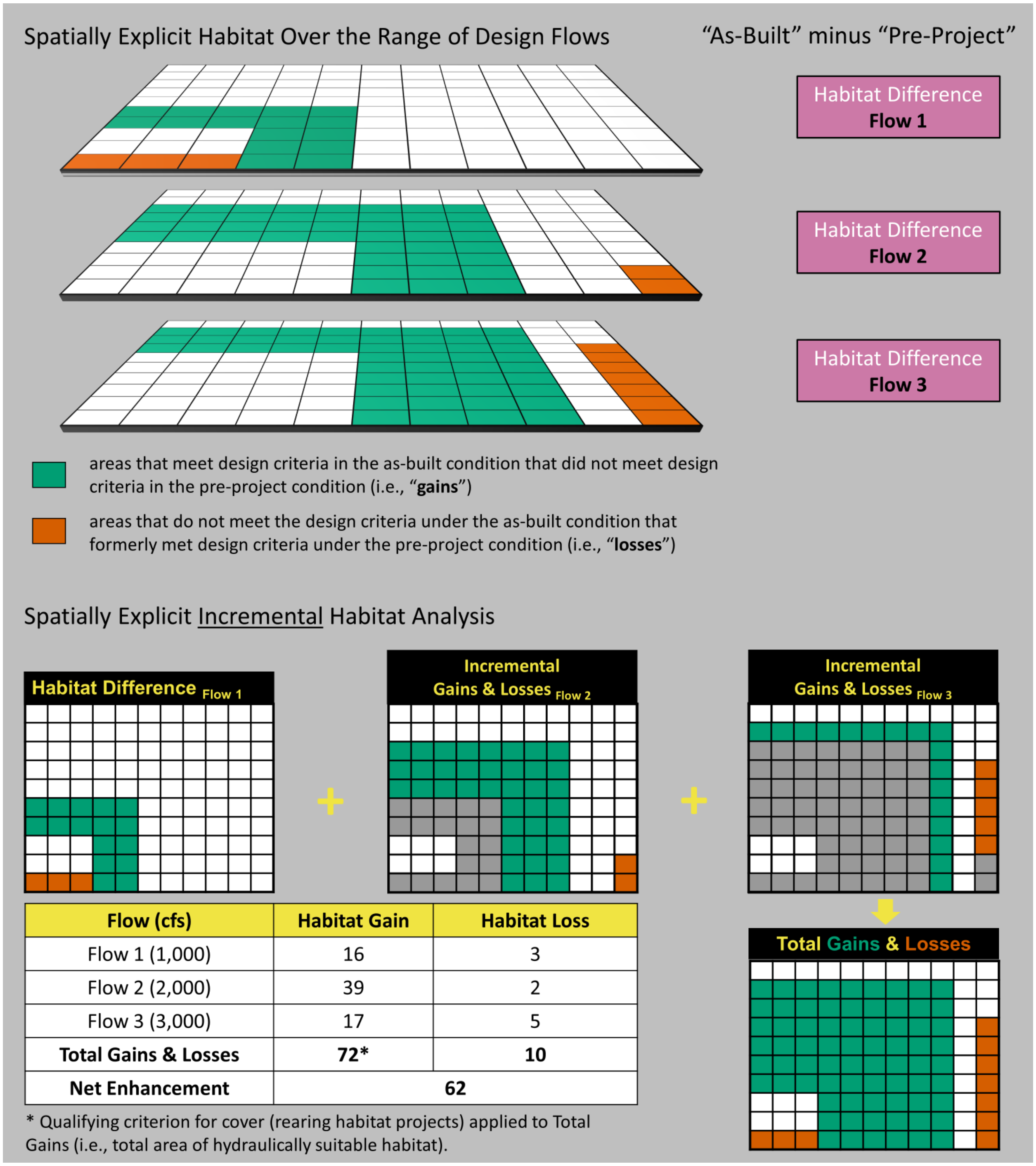
For instances where a single habitat enhancement measure contains more than one habitat objective (i.e., tributary spawning, in-channel rearing, tributary floodplain rearing) within the overall project footprint, habitat accounting must be able to quantify each habitat objective separately. In the case of a project that provides both spawning habitat and rearing habitat within the same spatial boundary, it is appropriate to quantify the habitat meeting each habitat objective separately for habitat accounting, even if there is spatial overlap between the two habitat objectives. This is because of the temporal distinction between the habitat objectives (i.e., the spawning period does not overlap with the rearing period), and the design criteria differ for the habitat objectives. In the case of a project that includes both in-channel rearing habitat and tributary floodplain rearing habitat within the same footprint, they will be distinguished by a feature-specific geospatial boundary associated with distinct topographical delineation, or by the project-specific elevation associated with the flow that activates off-channel inundation, such that there is no spatial overlap between these habitats for the habitat accounting assessment.

2.1.3.7 Calculation of Tributary Total Habitat

After all specific projects have been evaluated according to the relevant accounting approach (accounting approaches differ for early implementation projects; see below), then sum the amounts of newly constructed habitat meeting design criteria across all implemented projects within a GE area. Compare this amount with the amount of additional habitat specified in the MOU commitments to identify whether the commitments have been achieved.

2.1.3.8 Substrate Raster Development

Substrate within the project footprint is mapped, typically as polygon features where each polygon contains an area of substrate with a unique percent composition of grain size classes. For habitat accounting application, appropriate substrate for spawning habitat enhancement measures is characterized as having a dominant (>50%) grain size in the range of 0.75 in – 4.0 in as described in Table 27. Substrate polygons with dominant grain size classes in this range are identified and a shapefile is generated containing substrate polygons that meet design criteria. For building the spawning substrate raster, each raster pixel with a centroid that falls within the spawning substrate shapefile is identified as meeting the substrate criteria for spawning.



🟩 areas that meet design criteria in the as-built condition that did not meet design criteria in the pre-project condition (i.e., "**gains**")

🟧 areas that do not meet the design criteria under the as-built condition that formerly met design criteria under the pre-project condition (i.e., "**losses**")

Flow (cfs)	Habitat Gain	Habitat Loss
Flow 1 (1,000)	16	3
Flow 2 (2,000)	39	2
Flow 3 (3,000)	17	5
Total Gains & Losses	**72***	**10**
Net Enhancement	**62**	

* Qualifying criterion for cover (rearing habitat projects) applied to Total Gains (i.e., total area of hydraulically suitable habitat).

Figure 4. Example showing the identification and aggregation of flow-specific habitat gains (green cells) and losses (red cells) resulting from implementation of a project. The top portion of the figure demonstrates the flow-specific spatially explicit habitat difference rasters. The bottom portion of the figure demonstrates the incremental habitat gains and losses by flow across the range of design flows. In this example, if the habitat being evaluated is rearing habitat, the application of the qualifying criterion for cover would be applied to the overall area of habitat gains corresponding with the overall area meeting the hydraulic design criteria (i.e., water depth and velocity). The final step in habitat accounting is to calculate the difference between the overall area of habitat gains and the overall area of habitat losses to identify the total net area of habitat enhancement.

2.1.3.9 Cover Raster Development

For habitat accounting application, cover feature types must have a habitat suitability index (HSI) value of 0.5 or greater, described in Table 28. Cover features within the project footprint are mapped and a shapefile is generated in GIS containing the mapping data. Cover is typically mapped as point, line, or polygon features as appropriate to the cover feature type. Juvenile salmonids are often found within about 3 ft of a cover element (Moniz and Pasternack 2019; Hardy et al. 2006), which represents the burst distance for juvenile salmonids (Hardin et al. 2005). Consequently, each suitable non-cobble cover feature element in the shapefile will be buffered out by 3 ft (Moniz and Pasternack 2019). For building the cover raster, each raster pixel with a centroid that falls within the buffered cover shapefile is assigned that cover type (**Figure 5**).

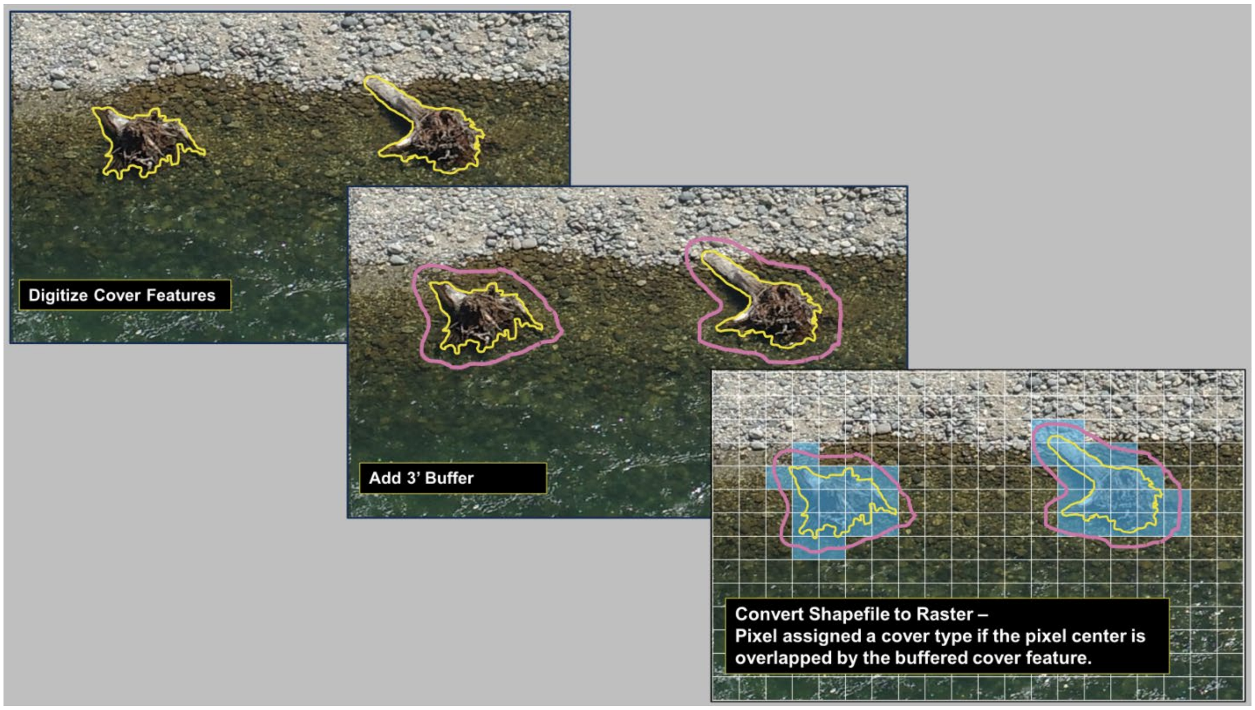


Figure 5. Example of digitizing cover features, applying a buffer to cover features (example of rootwads shown), and converting a cover shapefile to a cover raster. Note: the buffer also would be applied to estimated areas of vegetation at maturity.

Cover will be evaluated at project completion in accordance with final phases and/or full implementation of the project design (e.g., vegetation at maturity). For projects that incorporate riparian vegetation planting or planned recruitment into the project design, the expected resultant area of riparian vegetation in the mature condition should be a species-specific estimate of mature canopy size using, for example: (1) literature-based data or models for riparian vegetation recruitment, growth, size-at-maturation, or survival (e.g., HEC-RAS-RVSM (Riparian Vegetation Simulation Module; Zhang et al. 2019)); or (2) analyses of recruitment, growth, and size based on local observations of riparian vegetation. This estimated area of mature vegetation, including the buffer applied to the perimeter of the mature vegetation area estimate, will be incorporated into the quantification of cover (i.e., development of the cover raster) for assessing whether the cover qualifying criterion is met for rearing habitat accounting purposes on a project-specific basis. It is recognized that the actual realized area of riparian vegetation over time would be analyzed during habitat suitability analyses.

3 Acreage protocol for Bypass Floodplain Rearing Habitats

Bypass floodplain habitats can be inundated under baseline conditions. Therefore, bypass floodplain rearing habitat actions are intended to increase connectivity, and the frequency and duration of inundation within the project footprint. As such, acreages will be measured by those areas which demonstrate an incremental change in modeled inundation frequency and duration as a result of project implementation at design flows. As noted in the tributary acreage protocols, the term “design flows” refers to the range of flows over which a habitat enhancement project is designed to create habitat. The flows at which the “pre-project” and “as-built” conditions are evaluated must be the same to enable equitable comparisons.

“Pre-Project” Characterization

The existing frequency and duration of inundation over a range of water year types for a specific project footprint will be the baseline for the habitat accounting assessment. For example, a two-dimensional hydrologic model has been developed for the Yolo Bypass for the years 1997 to 2012 (DWR & USBR, 2019). A similar model has been developed for Sutter Bypass, Butte Sink and Colusa Basin for the years 2003, 2011, 2013, 2015 and 2019 (https://floodplainsreimagined.org/resources/reports-data/). A technical report describing this model is expected to be available in April 2024.

“As-Built” Characterization

The project-specific modeled change in inundation frequency and duration provided by the bypass floodplain rearing habitat action.

The project area which demonstrates a modeled increase in frequency and duration of inundation from ‘pre-project’ and meets the inundation frequency and duration ‘floodplain function’ (Table 27, described for tributary floodplains in the Draft Strategic Plan) will total the acreage provided by bypass floodplain rearing habitat actions. As stated in the Draft Strategic Plan, quantified design criteria for bypass projects are not provided due to the variety of fish species and life stages that are present in the bypasses. When design consideration for bypass habitat enhancements includes fish passage, connectivity is also expected to be incorporated into design. The ‘as-built’ models of fish passage enhancements will demonstrate that established species and life-stage specific guidelines have been integrated, such as NMFS 2023 and adult fish passage criteria previously developed for projects in Yolo Bypass (DWR & USBR, 2019).

4 Acreage Protocols for Tidal Wetland habitat actions

The tidal wetland habitat action acreage will be quantified as new wetted acres. Tidal wetland habitat actions may include transitional sites that have different habitat types, such as associated floodplain habitats adjacent to the main tidal wetland habitat project (Memorandum of Understanding, Appendix

2). For habitat accounting purposes, tidal wetland habitat actions' acreages will include these associated transitional sites' acreage. The acreage protocol for those associated habitats will adhere to the most applicable Non-flow Measure procedure.

"Pre-Project" Characterization

The existing habitat will be quantified by a DEM representing the pre-project topography. Wetted area will be defined by inundation levels relative to mean high-high water. If the site is not wetted or not tidal, a 'pre-project' characterization is not necessary, and all 'as-built' acreage will be additive.

"As-Built" Characterization

The post construction inundation levels will be determined by a site-specific tidal datum reflective of accurate tidal elevations at the project scale.

Acreages will be the result of the 'pre-project' DEM wetted area differenced from the 'as-built' DEM wetted area, with inundation levels relative to mean high-high water (Wheaton et al., 2009, Hensel et al., 2023). There is an expectation that access will be provided for estuarine species, and that the depth and width of the opening will be designed for full tidal exchange and the species and life stage expected to benefit. 'Full tidal exchange' is defined as a similar difference between high tides and low tides inside the opening of the site and outside the site. As noted in the Draft Strategic Plan, design criteria for tidal habitat restoration are not provided due to the wide variety of target species, life-stages, and types of habitat goals associated with tidal wetland restoration actions. Therefore, project specific design criteria for tidal wetlands are subject to the design criteria review process outlined in the Draft Strategic Plan.

5 References

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