STUDY REPORT W&AR-4
SPAWNING GRAVEL

ATTACHMENT D

METHODS FOR SUITABLE SPAWNING HABITAT AREA ESTIMATION

1.0 SPAWNING GRAVEL HYDRAULICS AND CRITERIA MAPPING

The Spawning Gravel in the Lower Tuolumne River Study Plan (November 2011), as modified by FERC's December 22, 2011 Study Plan Determination, addresses the following items relating to Chinook salmon spawning in the lower Tuolumne River from RM 52 to RM 24:

- characterize the current area, distribution, and use of spawning riffles in the lower Tuolumne River
- provide estimates of maximum spawning run sizes supported by spawning riffles under current conditions

This Spawning Gravel in the Lower Tuolumne River Study (W&AR-04) included field mapping of suitable spawning hydraulics within a subsample of riffle locations in the river, using spawning depth and velocity criteria developed for Chinook salmon and *O. mykiss*. The suitable spawning hydraulics data, in combination with mapping of suitably sized substrate areas, was used to derive a relationship between flow and spawning habitat area. This Attachment D to W&AR-04 describes the methods for selection of sample locations, field data collection, and data analysis used in the analysis of spawning habitat in the lower Tuolumne River.

Results from the analysis will supplement the W&AR-04 study and be used for population model input in conjunction with the Salmonid Synthesis Study (W&AR-05), the Chinook Population Model Study (W&AR-06), and the *O. mykiss* Population Model Study (W&AR-10).

1.1 Field Methods for Spawning Gravel Hydraulics and Criteria Mapping

The current listing of mesohabitat types mapped in September 2010 was used to identify riffle locations and boundaries from RM 52 to RM 24. A stratified random selection process was used to select representative types of riffles in the four spawning reaches identified in the W&AR-04 study based on percent occurrence (Table 1.1-1). The stratified random selection process was designed to sample approximately 25 percent of the available riffle habitat found throughout the river. Table 1.1-1 documents the spawning reaches, the total number of riffles found in each reach downstream of La Grange Dam, and the number of riffles selected in each reach for hydraulic mapping.

Table 1.1-1. Total number of riffle mesohabitats identified in reaches downstream of La Grange Dam along with the number of riffles selected for hydraulic mapping.

Total Riffles by Reach from RM 52.1 to RM 24.0					
	Reach 7 52.1–46.6	**Reach 6 46.6–40.3**	**Reach 5 40.3–34.2**	**Reach 4 34.2–24.0**	**Total**
Flatwater Riffles	8	1	3	12	24
Bar Complex Riffles	6	18	19	18	61
Total Riffles	14	19	22	30	85
Number of Riffles Selected for Hydraulic Mapping by Reach					
Flatwater Riffles	2	1	1	3	7
Bar Complex Riffles	1	5	5	5	16
Total Selected Riffles	3	6	6	8	23

Hydraulic field data were collected during the spawning season, from November 5 – 7, 2012 at a flow of approximately 175 cubic feet per second (cfs). Prior to field data collection, a series of base maps for each of the selected riffles was printed in 11x17 inch format, showing results of spawning gravel mapping conducted in August 2012. The maps included April 2012 aerial imagery overlays of the river at flows of approximately 320 cfs. Field crews, using a topset rod and Marsh-McBirney flow meter, systematically waded each of the riffle areas and delineated polygons onto the base maps showing areas of suitable depth and velocity over available spawning gravels. The polygons were converted to area coverages using ArcInfo GIS software techniques. The resulting areas were then used to extrapolate results to the entire reach as described in the next section.

Depth and velocity spawning suitability criteria used for hydraulic mapping were developed from existing criteria being used in the current IFIM study. Existing criteria curves were converted to a binary format appropriate for a "suitable/unsuitable" determination in the field that is necessary for calculation of actual spawning area (i.e., not a weighted "index") (Figures 1.1-1 and 1.1-2). Suitable spawning hydraulic conditions were defined as follows:

- Suitable depths ranging from 0.7 – 2.7 feet (ft)
- Suitable velocity ranging from 1.0 – 3.1 feet per second (fps)

These depth and velocity suitability criteria were used to map areas of suitable spawning hydraulic conditions within previously selected riffle habitats for both Chinook salmon and *O. mykiss*.

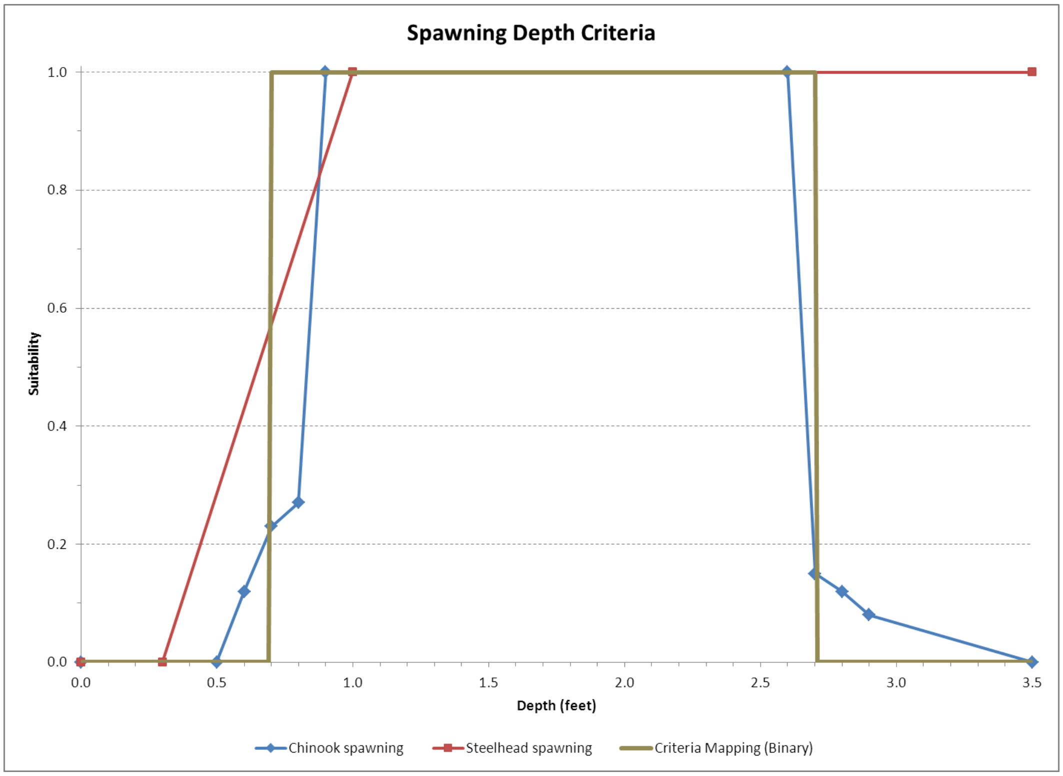

Figure 1.1-1. Spawning depth criteria used for lower Tuolumne IFIM and binary spawning habitat mapping.

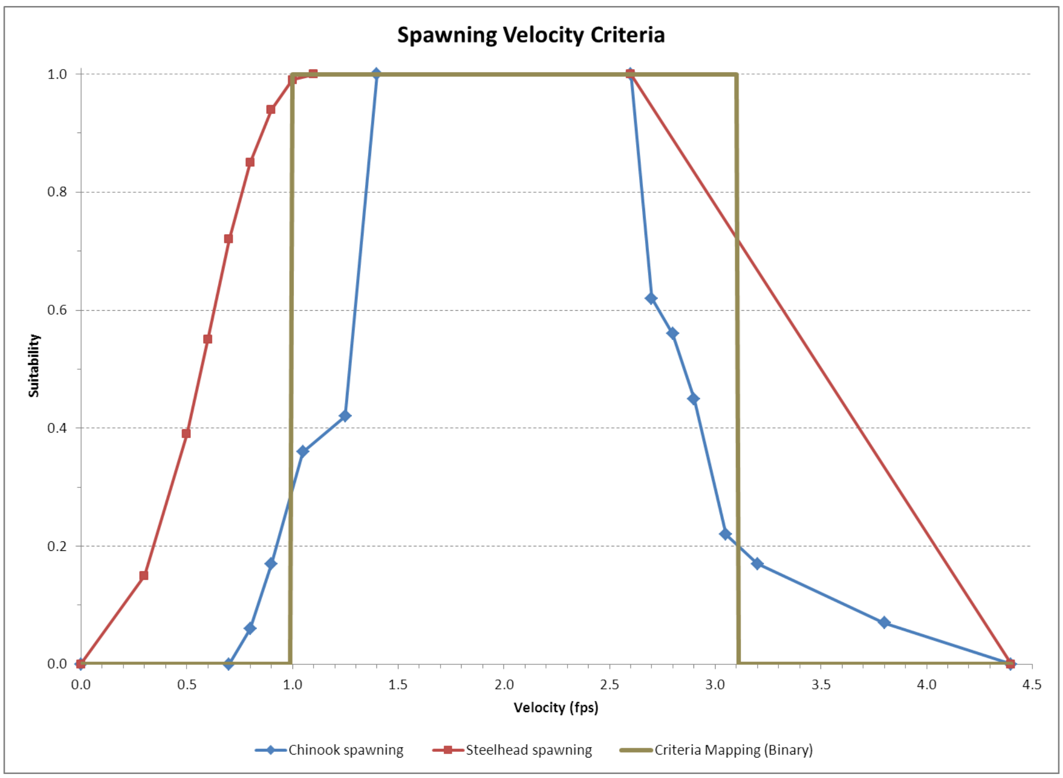

Figure 1.1-2. Spawning velocity criteria used for lower Tuolumne IFIM and binary spawning habitat mapping.

1.2 Analysis Methods for Spawning Gravel Hydraulics and Criteria Mapping

Areas of suitable spawning hydraulic conditions delineated over areas of suitable spawning gravels form the basis of the analysis. Suitable gravel areas were determined for both Chinook salmon and *O. mykiss* based on the D_{50} size ranges of the mapped gravel areas. As described in Kondolf and Wollman (1993), a D_{50} size range between 16 – 78 mm was used to define suitable Chinook salmon spawning gravels and a D_{50} size range between 10 – 46 mm was used to define suitable steelhead spawning gravels. The estimate of total suitable spawning area in the reach was calculated at the 175 cfs study flow using the following four steps:

Step 1 - Areas characterized by suitable spawning hydraulic conditions (i.e., depths and velocities) and suitable gravels were summed for each sampled riffle in the study to yield total suitable spawning area for sample riffles at the 175 cfs study flow. This suitable spawning area was then proportionally scaled to a flow of approximately 320 cfs (the flow at which recent river-wide aerial photo coverage is available) using PHABSIM model results for riffle habitats. This was accomplished by using the relationship of spawning Weighted Usable Area (WUA) as a function of flow predicted by the PHABSIM model (with the input data modified to include only riffle transects, and applying the same binary suitability criteria for depth and velocity indicated above). This resulted in an estimate of suitable spawning area at 320 cfs for all sampled riffles.

Step 2 - The proportion of suitable spawning area to total wetted spawning gravel area at 320 cfs was calculated for sampled riffles, using GIS data layers of wetted area at 320 cfs and spawning gravel distribution. This resulted in an estimate of wetted, suitable spawning area at 320 cfs for all sampled riffles.

Step 3 - The proportion calculated in Step 2 was applied to the known total wetted spawning gravel area for each reach at 320 cfs. This resulted in an estimate of total suitable spawning area at 320 cfs for all reaches.

Step 4 - Total suitable spawning area at other simulated flows (100 – 1,000 cfs) was calculated by scaling the results of Step 3 by the WUA spawning results (e.g., if spawning hydraulics per the WUA results are 10 percent greater at 400 cfs than 320 cfs, total suitable spawning area is 10 percent greater at 400 cfs).

Using the approach described above, total suitable spawning area for Chinook salmon and *O. mykiss* will be used as a basis for estimating maximum spawning run size over a range of simulated flows by simply dividing the total spawning area available by the average redd size for each species.

2.0 REFERENCES

Kondolf, G. M., and M. G. Wolman. 1993. The sizes of salmonid spawning gravels. Water Resources Research 29:2275–2285.