UPPER GUADALUPE RIVER
FLOOD RISK MANAGEMENT PROJECT
San José, California

Environmental Quality Analysis

Appendix C1

DRAFT INTEGRATED
GENERAL REEVALUATION REPORT
& SUPPLEMENTAL ENVIRONMENTAL ASSESSMENT

November 2022

US Army Corps of Engineers
San Francisco District

Valley Water

APPENDIX C1
Upper Guadalupe River Project Environmental Quality Analysis

Contents

1. Introduction

This appendix is intended to outline and summarize the habitat modeling approach and results for the Upper Guadalupe General Reevaluation Report (UGGRR). The modeling approach is designed to characterize net impacts to the Environmental Quality (EQ) account for a Flood Risk Management (FRM) study. It will evaluate impacts to existing habitat and benefits from creation of new habitat for aquatic and riparian species, while maximizing use of existing data and previously certified models. It combines two separate elements: 1) a hydraulic modeling based aquatic habitat suitability evaluation, and 2) a habitat suitability index (HSI) for the yellow warbler (Figure 1), used for quantifying changes in net average annual habitat units (AAHUs).

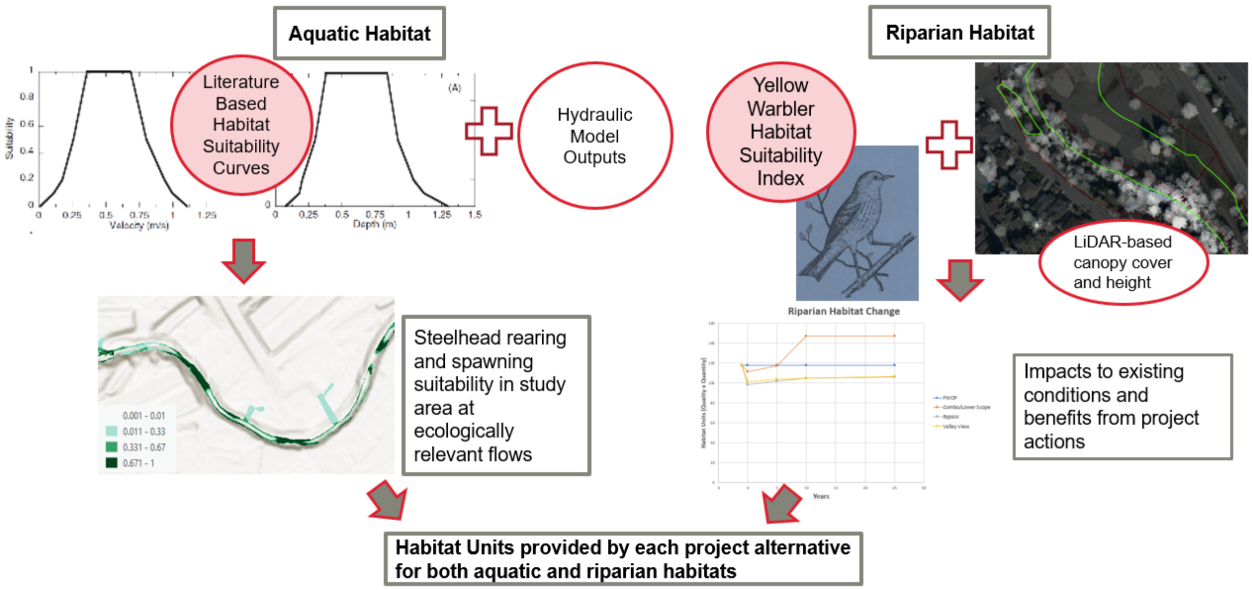

Figure 1. Generalized habitat modeling methodology schematic.

The yellow warbler HSI is an already certified model, and aquatic habitat suitability evaluation methodology was given single-use approval by the Ecosystem Restoration Planning Center of Expertise (ECO-PCX). The approval memo and technical memorandum documenting the methodology have been attached to this appendix. The aquatic habitat evaluation presented here is similar to that approved for the Yuba River Ecosystem Restoration Feasibility Study (approval memo dated 12 October 2017), revised to also include spawning suitability (Kammel et al. 2016) and to use rearing suitability curves more appropriate to the study area watershed (Holmes et al. 2014).

2. Background

The UGGRR is primarily intended to address flood risk in the Guadalupe River corridor in San Jose, CA. The plans to be evaluated in the report include the previously identified National Economic Development (NED) and Locally Preferred plans (LPP), termed Valley View and Bypass plans, respectively, from the original feasibility study and Limited Reevaluation Report (LRR), as well as two new alternatives formulated as part of this study process (known as the Combination plan and Lower-Scoped alternative). All alternatives include mitigation for impacts to the existing riparian forest, and the two new alternatives are expected to result in a net increase in area of riparian forest. The study area is located in a highly urbanized part of Santa Clara County and provides an important migration corridor for both aquatic and terrestrial species. The legacy of development, mining and urbanization in the watershed has degraded quality, quantity, and connectivity of aquatic and riparian habitat. The study team has been working with local stakeholders and resource agencies to formulate alternatives that provide some habitat benefit while achieving the primary study goal of providing improved flood risk management. This evaluation of habitat benefits is also in accordance with the comprehensive benefits evaluation memorandum (ASA-CW memorandum dated 5 January 2021).

Through an evaluation of various potential models, the project delivery team (PDT) chose to use a Habitat Evaluation Procedure (HEP) based assessment approach. The assessment approach utilizes HSI models to develop habitat units for key habitat types that are later combined into a single habitat output for each alternative. The PDT identified two key habitat types to represent anticipated ecosystem outputs of the focused array of alternatives: 1) riverine habitat and 2) riparian forest. Riverine habitat describes the wetted area and will vary with seasonal changes in flow. Riparian forest is broadly defined here as the shrubs and trees within the river corridor. The key habitat types selected for inclusion in this assessment approach are adequate to support evaluation of the full range of alternatives.

Representative evaluation species were selected for each habitat type based on several criteria: (1) species known to be sensitive to specific land- and water- use actions; (2) species that play a key role in nutrient cycling or energy flow; (3) species that utilize a common environmental resource; (4) species that are associated with important resource problems, such as anadromous fish and migratory birds; (5) species that have existing habitat response models suitable for the evaluation of proposed alternatives; (6) habitat data available or easily collected to support modeling; (7) species that provide relevant evaluation throughout the geographic range of proposed alternatives and across the broad range of effects of proposed alternative.

3. Model Selection

Based on the above criteria and approved HSI models, the representative species selected to evaluate habitat outputs for riparian forest was yellow warbler (*Dendroica petechia*) (Table 1). Given the above criteria and the fact that anadromous salmonids have been at the center of the discussion of habitat impacts in the watershed, the PDT chose to utilize steelhead (*Oncorhynchus mykiss*) rearing and spawning lifestages as a representative species to evaluate habitat output for riverine habitat (Table 1).

Table 1. Habitat Type, Species, and Habitat Variables.

Habitat Type	Evaluation Species	Habitat Variables
Riverine	rearing and spawning steelhead	Depth, Velocity, substrate and cover
Riparian Forest	yellow warbler	Percent canopy cover, average canopy height

Although approved HSI models are available for Chinook salmon and rainbow trout, these models are based on HSCs that do not appropriately relate to the types of benefits anticipated from the suite of proposed measures. The UGGRR is considering actions to address the degradation in the quality, quantity and connectivity of aquatic and riparian habitat commensurate with the study’s FRM authority. Proposed actions include floodplain benches and gravel augmentation that would provide both FRM and habitat benefits. Steelhead and yellow warbler were selected as the model species because they have potential to be affected by project actions and are representative of a wide range of species that use these habitats. The yellow warbler HSI and steelhead model curves were selected to be used with readily available vegetation cover data and hydraulic modeling outputs.

4. Terrestrial Habitat

Yellow warbler was one of the species used in the HEP analysis for the original 1998 Feasibility Study and Environmental Impact Statement. That modeling effort also introduced an additional variable to account for the percentage of canopy as tall trees, but that variable was not used for this study. Furthermore, all vegetation in the riparian corridor was assumed to be hydrophytic.

4.1. Data Processing Workflow

A Geographic Information System (GIS) was used to process data for the analysis. The project reaches were delineated as elsewhere in the UGGRR project area. Reaches include mainstem reaches 7 through 12 and Ross Creek and Canoas Creek. Reaches were further delineated to isolate maximum extent of the riparian corridor within the project area under existing and proposed conditions. A new reaches feature class was delineated based on current aerial imagery (Figure 2). The riparian corridor also includes the dense tree canopy areas adjacent to the channel and maximum width of grading footprint for the project action alternatives. The channel centerline was imported into the GIS and the riparian corridor reaches were further subdivided into 1000 ft increments along channel centerline to allow for more granular analysis.

Figure 2. Example of study reaches and riparian polygons used in the riparian habitat analysis.

To conduct the actual analysis, canopy height and canopy cover attributes were imported as raster datasets and trimmed to boundaries of riparian corridor feature class. These raster datasets were collected in 2020 as part of a countywide LiDAR data collection effort (https://pacificvegmap.org/data-downloads/). An example of these datasets is shown below in Figure 3.

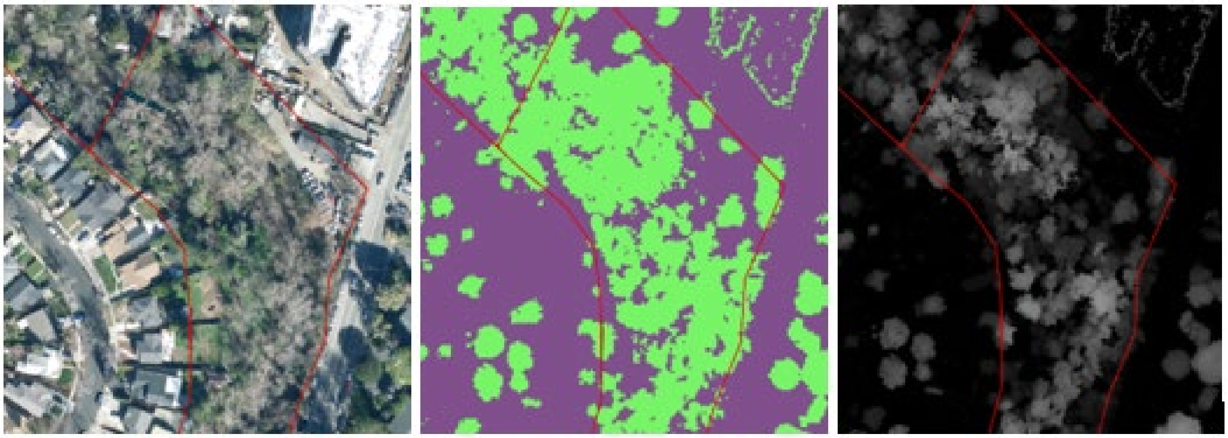

Figure 3. Lidar canopy cover and canopy height datasets shown alongside satellite imagery. Red lines across the images show the riparian polygon boundries.

Once the data were inputted into the GIS, a zonal statistics tool was used to average data values within the riparian calculation polygons. This tool takes the average value of all pixels within a polygon and reassigns the pixels that average value. The average heights and cover values were used with the Yellow Warbler HSI to produce habitat suitability values within the polygons. Figure 4, Figure 5, Table 2, and Table 3 below show the conversion from canopy cover and height to suitability index values.

Cover type	Variable	
DS,DSW	V_1	Percent deciduous shrub crown cover.

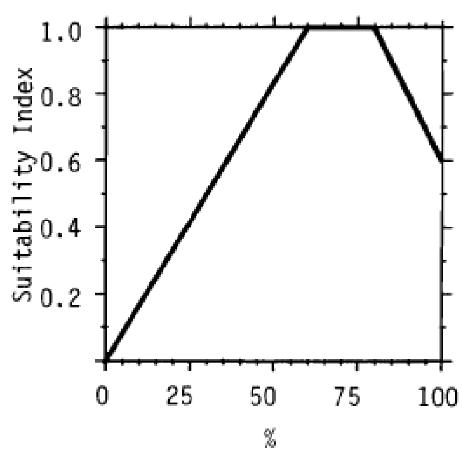

Figure 4. Cover habitat suitability index from Yellow Warbler model.

Table 2. Table form of the curve shown above in Figure 4, used to reclassify raster pixels.

Percent Crown Cover (%)		**Suitability Index**	**Slope**	**New Value (Reclass)**
Start	**End**			
3.4472 (minimum)	6.0	0	1.667	0
6.0	12.0	0.1	1.667	1
12	18	0.2	1.667	2
18	24	0.3	1.667	3
24	30	0.4	1.667	4
30	36	0.5	1.667	5
36	42	0.6	1.667	6
42	48	0.7	1.667	7
48	54	0.8	1.667	8
54	60	0.9	1.667	9
60	64.9568 (maximum)	1.0	0	10

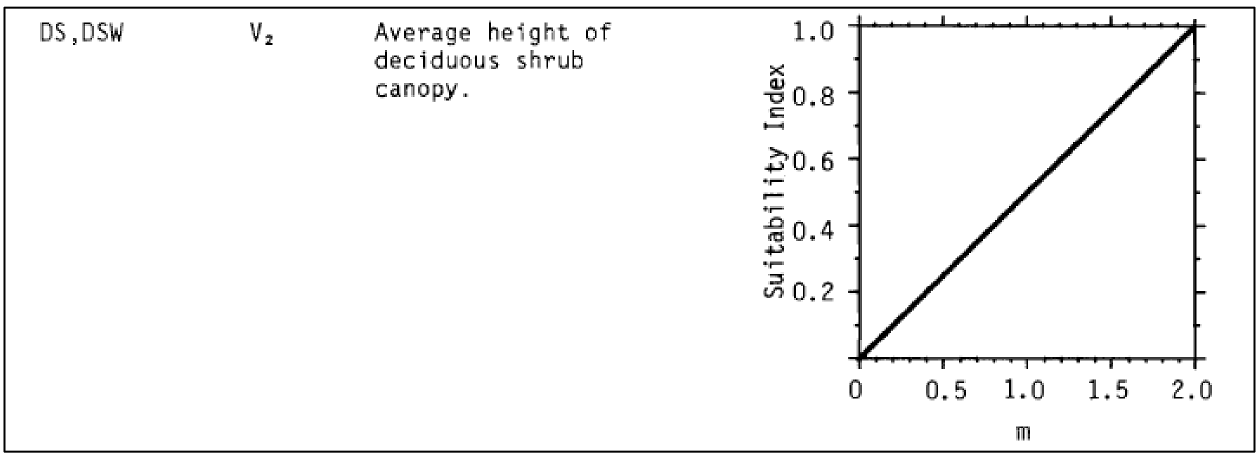

Figure 5. Canopy height habitat suitability index from Yellow Warbler model.

Table 3. Table form of the curve shown in Figure 5, used to reclassify pixels.

Mean Crown Height (ft)		**Suitability Index**	**Slope**	**New Value (Reclass)**
Start	**End**			
1.397486 (minimum)	1.97	0.2	0.5	0
1.97	2.62	0.3	0.5	1
2.62	3.28	0.4	0.5	2
3.28	3.94	0.5	0.5	3
3.94	4.59	0.6	0.5	4
4.59	5.25	0.7	0.5	5

Mean Crown Height (ft)		Suitability Index	Slope	New Value (Reclass)
Start	End			
5.25	5.91	0.8	0.5	6
5.91	6.56	0.9	0.5	7
6.56	28.76 (maximum)	1.0	0.5	8

Within each evaluation polygon, the mean of cover and height suitability values were taken to determine combined habitat suitability. This combined habitat suitability value was multiplied by the area of each evaluation polygon in acres to get an estimate of riparian habitat units. The existing conditions habitat suitability is shown for portion of the river in Figure 6 below.

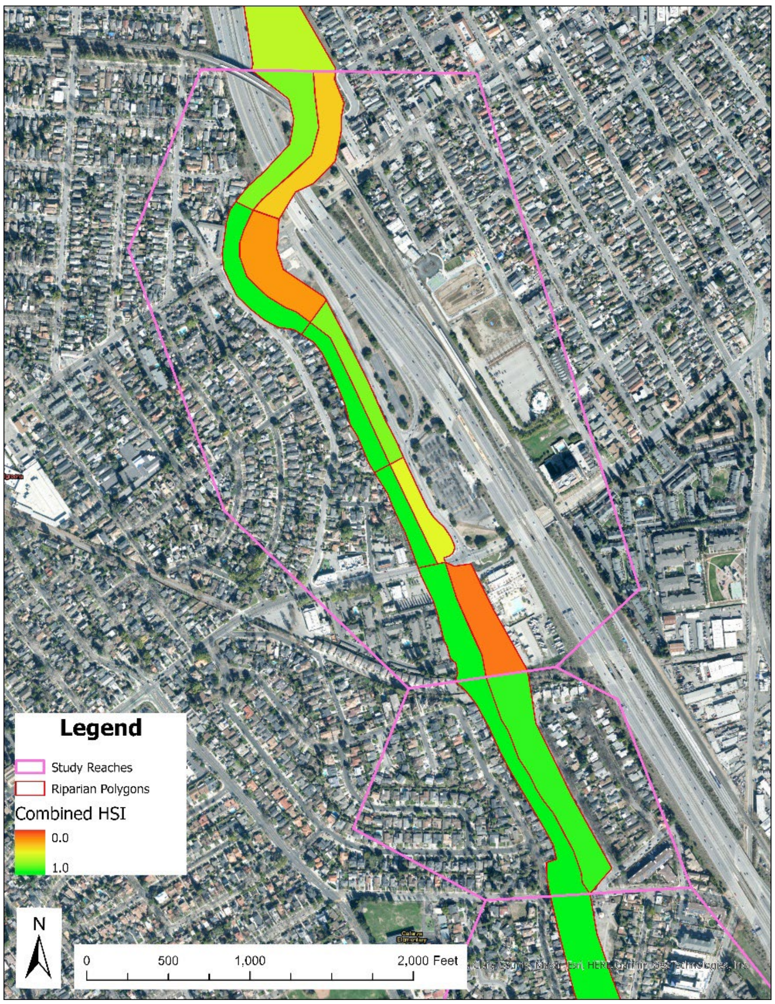

Figure 6. Combined habitat suitability for existing conditions.

Following the existing conditions analysis, this workflow was repeated for each of the action alternatives. For the with-project analysis, it was assumed that all vegetation within the grading footprint was cleared, and then planting polygons were laid out (Figure 7). Within the planting polygons, it was assumed that regrowth trajectories will follow what was observed in the Downtown Guadalupe project. The Downtown Guadalupe project monitored several mitigation sites, and found that native trees achieved the optimal cover from Figure 4 above within 10 years and reached optimal height or higher from Figure 5 above within 5 years. The procedure outlined in this section was followed with the imported planting polygons and assumed growth trajectories to arrive at riparian habitat units at each time step provided by each alternative.

Figure 7. Combination plan planting polygons (olive) shown with evaluation areas (red outline) and Combination plan grading footprint (light blue).

4.2. Results

This analysis found that the Combination and Lower Scope plans, which install a large floodplain bench in Reaches 7 and 8 in lieu of a bypass channel or conventional channel widening, result in a significant net increase in riparian habitat following project implementation (Figure 8). The Combination and Lower Scope plans are analyzed as a single plan in this context because the analysis focused on the mainstem of the Guadalupe River, where the vast majority of both impacts and benefits to vegetation is taking place, and where they employ the same measures. This net increase is a result of projected floodplain vegetation growth in places that are currently paved over (Figure 9).

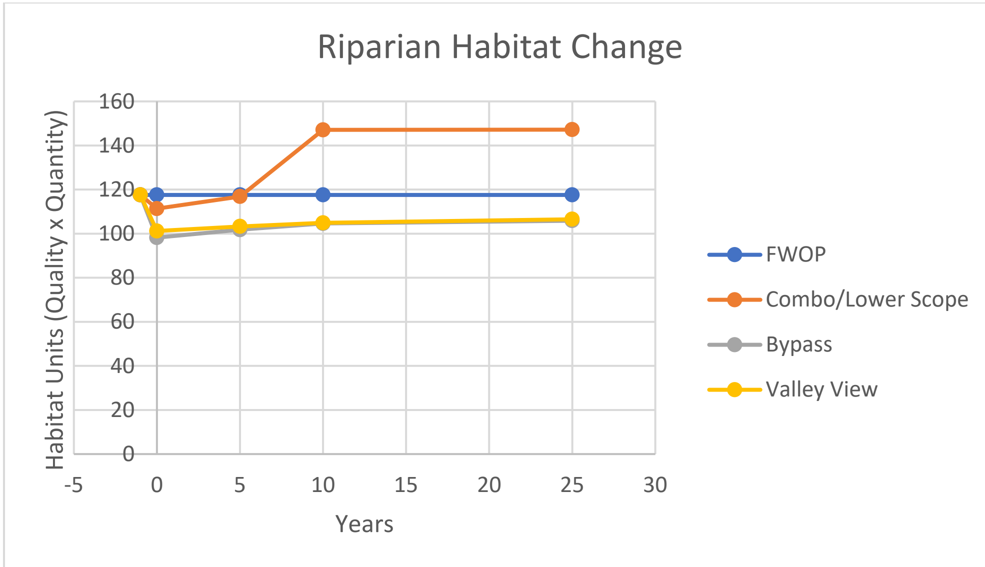

Figure 8. Riparian Habitat change from the project action alternatives.

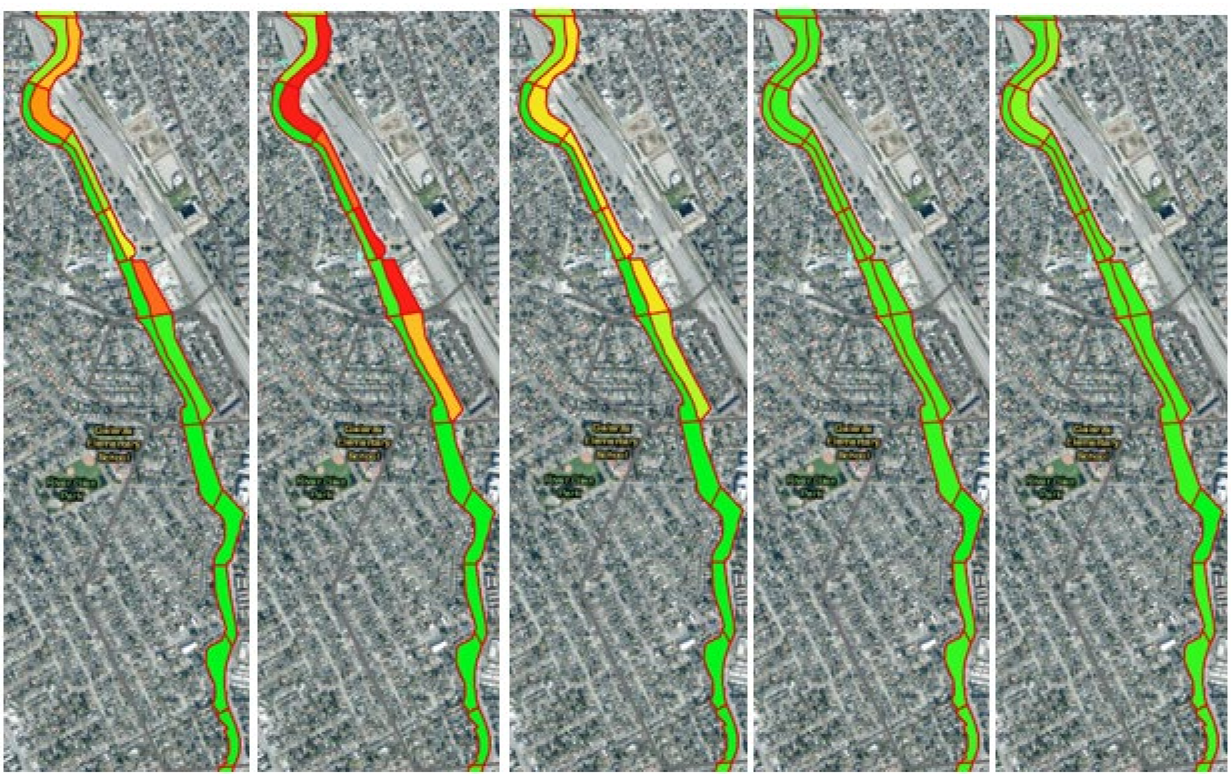

Figure 9. Panels showing average combined habitat suitability in each evaluation polygon at: pre-project, year 0, year 5, year 10, and year 25 for Combination Plan. Each panel shows an area approximately 3,000 feet wide and 9,000 feet long.

5. Aquatic Habitat

5.1. Data Processing Workflow

The background and scientific reasoning for the approach used in this analysis is described in the attached Single Use Waiver Technical Memorandum. Because of this, the explanation below is intentionally brief and focuses on illustrating the workflow and presenting results.

While the general approach is the same for both the Rearing and Spawning HSI calculations, there are some differences between the two in the specific workflow steps. Therefore, the ensuing explanation describes the Spawning and Rearing calculation processes separately.

5.2. Spawning

For each project alternative:

1) Run Hydrologic Engineering Center River Analysis System (HEC-RAS) hydraulic model for spawning flows
2) Develop Visual Basic programming code to convert HEC-RAS results (depth and velocity) into HSI values, according to the Habitat Suitability Curves (HSCs) described in the Single Use Waiver Tech Memo. The code functions as follows:
    a. For each pixel in the respective HEC-RAS results layer, the programming code converts flow depth to a depth HSI (DHSI) and flow velocity to velocity HSI (VHSI).
    b. The code then calculates the geometric mean of the DHSI and VHSI for each pixel.
    c. The code outputs a raster with each pixel value equal to the geometric mean of the DHSI and VHSI.

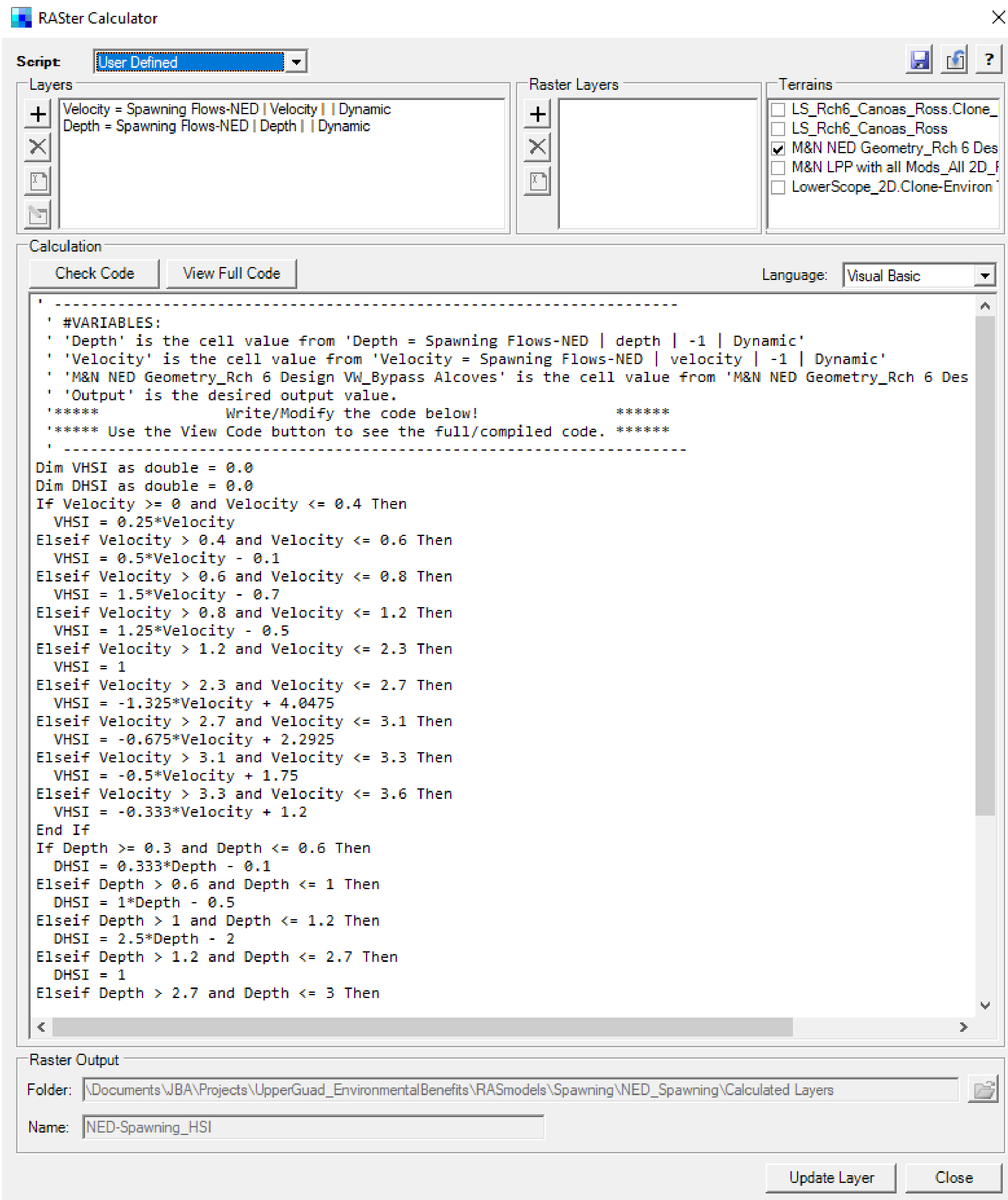

Figure 10: Screenshot of code for calculating Spawning HSI in the RASter Calculator interface.

3) Apply programming code to HEC-RAS simulation results using the RASter Calculator tool within RASMapper. This step produces the HSI raster within the RASMapper interface.

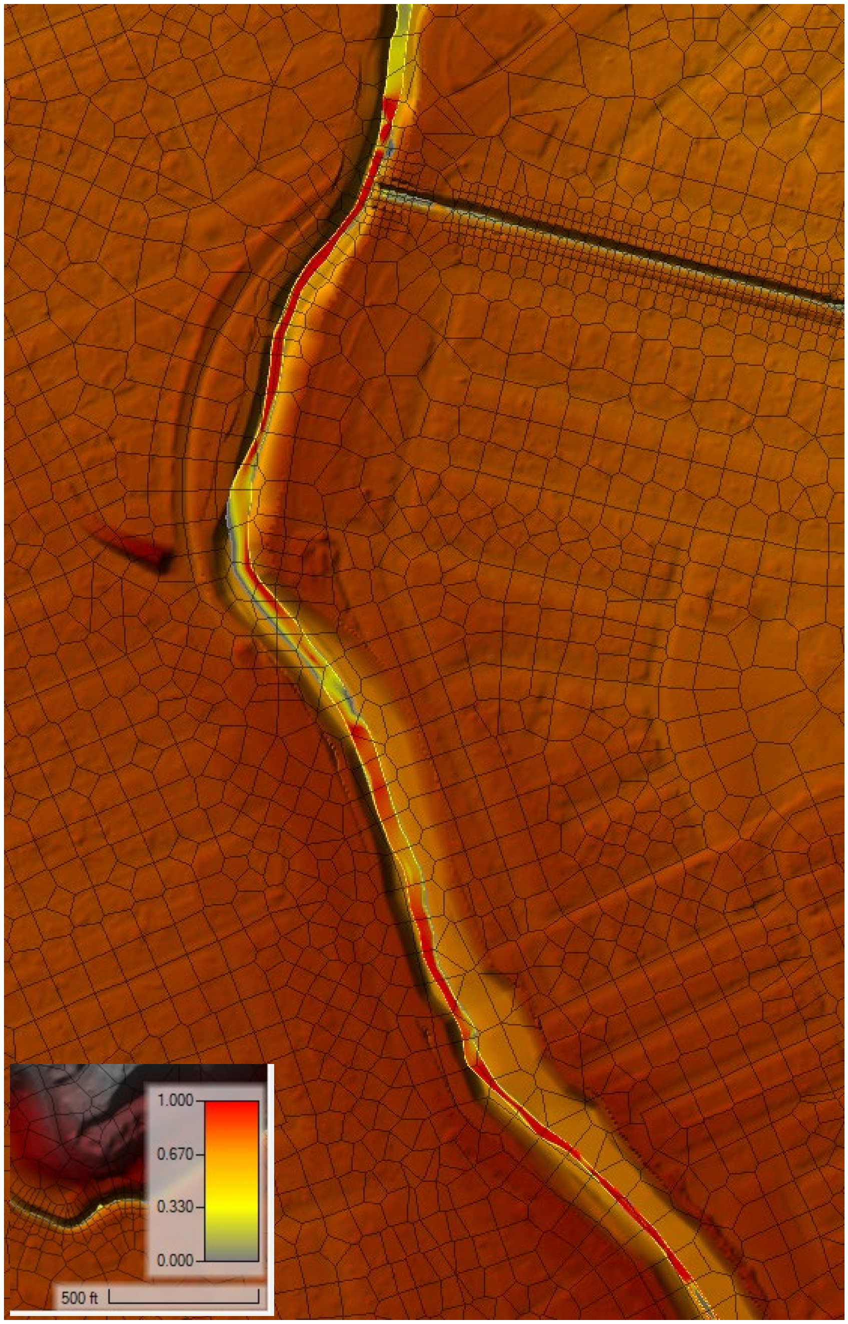

Figure 11: Screenshot of RASMapper showing the Spawning HSI raster calculated using the HSI code in RASter Calculator. Legend displays raw HSI values.

4) Export the HSI raster to a GIS (ArcGIS).
5) Using ArcGIS Geoprocessing tools:
    a. Reclassify the HSI raster into four classes of HSI according to Table 4. Hydraulic models have significant uncertainty, so the values are binned as shown to avoid creating a sense of false precision. This idea is explained further in the attached technical memorandum.

Table 4. Reclassification rules for determining habitat quality bin.

Raw HSI value range	**Reclassified value**	**Corresponding HSI category (i.e., habitat quality)**
0 to 0.01	0	None
0.01 to 0.33	1	Low
0.33 to 0.67	2	Medium
0.67 to 1	3	High

b. Once the raster was reclassified, it was converted to a polygon and intersected with the study reaches to calculate the amount of habitat in each habitat bin in each reach.

5.3. Rearing

For each project alternative:

1) Run HEC-RAS model for rearing flows
2) Develop Visual Basic programming code to convert HEC-RAS results (depth and velocity) into HSI values, according to the Habitat Suitability Curves (HSCs) described in the Single Use Waiver Tech Memo. Two different codes are used for the Rearing HSI calculations (as opposed to a single code in the Spawning case). The codes function as follows:
   a. Code 1 converts flow depth to a depth HSI (DHSI) for each pixel of the HEC-RAS results layer. The code outputs a raster with each pixel equal to the DHSI.

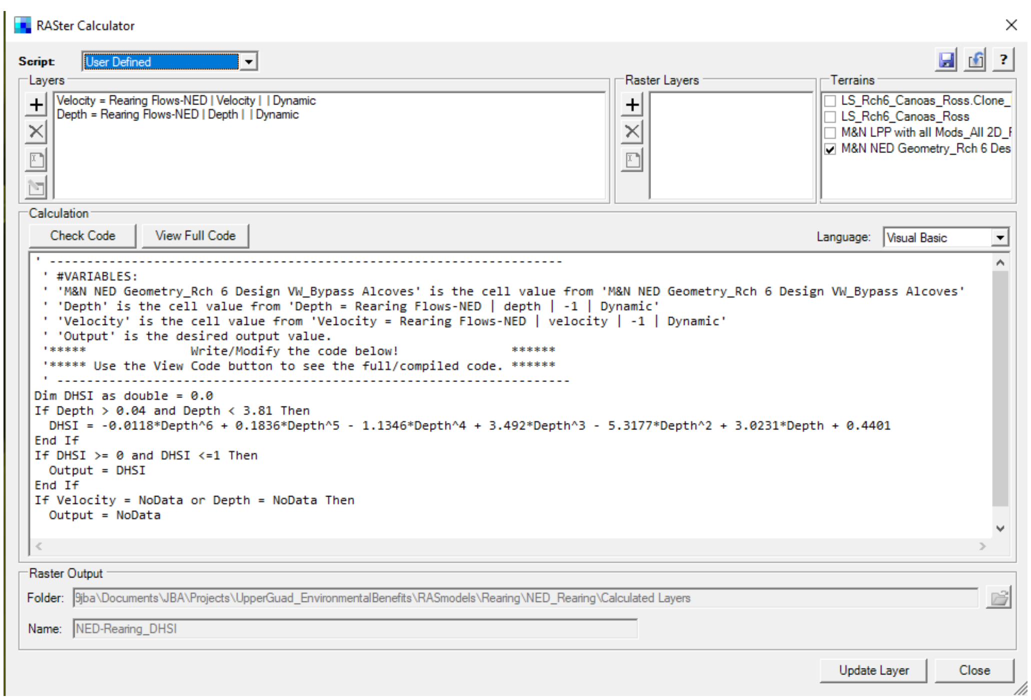

Figure 12: Screenshot of code for calculating Rearing Habitat DHSI in the RASter Calculator interface.

b. Code 2 converts flow velocity to a velocity HSI (VHSI) for each pixel of the HEC-RAS results layer. The code creates a raster with each pixel equal to the VHSI.

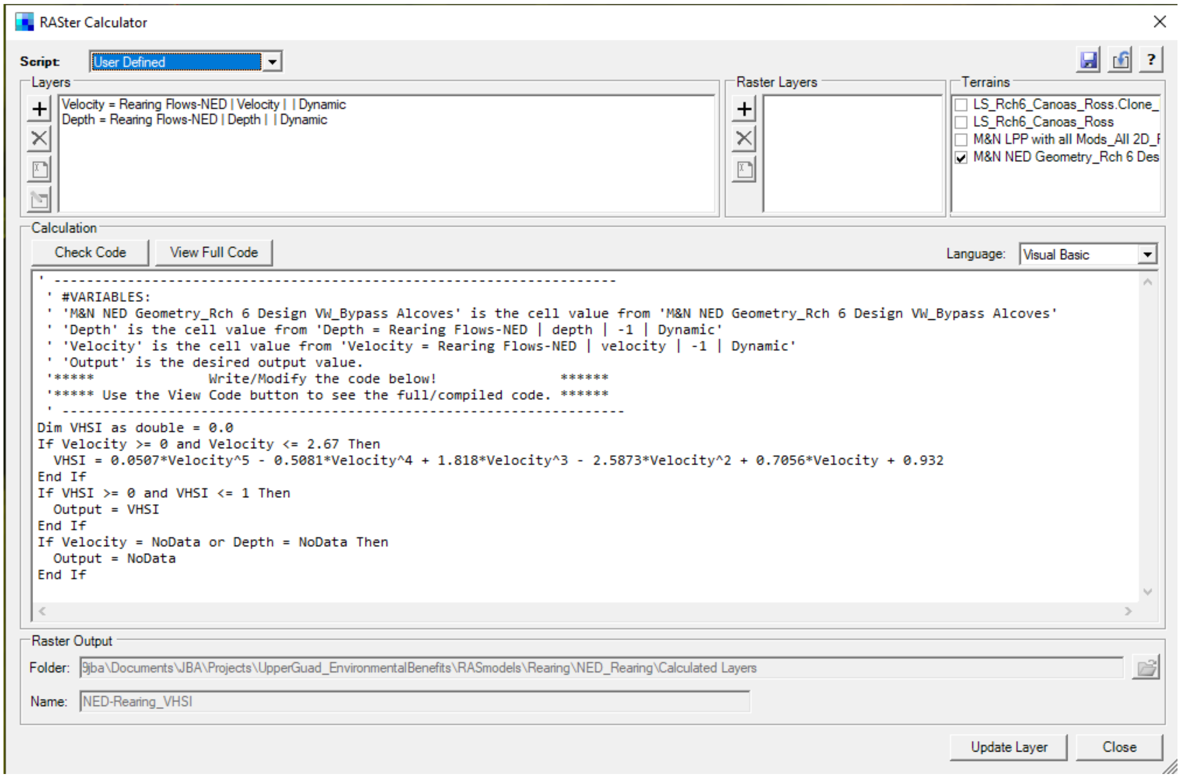

Figure 13: Screenshot of code for calculating Rearing Habitat VHSI in the RASter Calculator interface.

3) Apply programming codes to HEC-RAS simulation results using the RASter Calculator tool within RASMapper. This step produces the DHSI and VHSI rasters within the RASMapper interface.
4) Export the DHSI and VHSI rasters to ArcGIS.
5) Import the Substrate/Cover HSI polygon layer to supplement depth and velocity HSIs.
6) In ArcGIS, convert the Substrate/Cover HSI polygon to raster.
7) In ArcGIS, use the Raster Calculator geoprocessing tool to calculate the geometric mean of the three component HSI rasters – namely, VHSI, DHSI, and Substrate/Cover HSI. The resulting raster is the composite Rearing HSI raster.
8) Using ArcGIS Geoprocessing tools:
    a. Reclassify the Rearing HSI raster into four classes of HSI according to the same rule as Table 4.
    b. Once the raster was reclassified, it was converted to a polygon and intersected with the study reaches to calculate the amount of habitat in each habitat bin in each reach.

5.4. Results

5.4.1. Spawning

What follows are some summary tables of the HSI acreage totals and an example of the spatial distribution of spawning habitats.

Table 5: Summary of HSI acreage for Steelhead Spawning for each project alternative.

Acreage of Steelhead Spawning Habitat by HSI Class

	Low HSI (0.01 to 0.33)	Medium HSI (0.33 to 0.67)	High HSI (0.67 to 1)	Total acres of spawning habitat
No Action	7.82	4.72	9.10	21.65
Valley View	7.94	5.37	10.33	23.64
Bypass	8.78	5.15	9.51	23.44
Combination	7.57	4.95	9.01	21.53
Lower Scope	7.83	4.73	9.02	21.58

Table 6: Summary of HSI acreage for Steelhead Spawning in Project Reach 7.

Acreage of Steelhead Spawning Habitat by HSI Class in Reach 7

	Low HSI (0.01 to 0.33)	Medium HSI (0.33 to 0.67)	High HSI (0.67 to 1)
No Action	0.93	0.67	0.99
Valley View	0.79	0.75	0.98
Bypass	1.30	0.72	0.83
Combination	0.76	0.62	1.05
Lower Scope	0.90	0.67	0.99

Figure 14. Example of spatial distribution of spawning habitat in future without project conditions.

5.4.2. Rearing

Table 7 and Table 8 present a summary of the acreage calculation results for Rearing Habitat. It is noteworthy that the habitat acreages for the Rearing HSI are dominated by the Medium quality class of habitat (HSI between 0.33 and 0.67), in contrast to the Spawning HSI results where there is relatively more acreage in the High quality class. One major reason for this difference is the introduction of the third term into the HSI calculation for the Rearing Habitat. Namely, the Rearing HSI consists of the geometric mean of *three* component HSI values (flow depth, flow velocity, and substrate/cover), whereas the Spawning HSI consists of the geometric mean of just *two* component HSI values (flow depth and flow velocity). Much of the project area has a substrate/cover HSI value of 0.3. When that value of 0.3 is incorporated into the geometric mean calculation, it brings an otherwise "High" HSI value into the "Medium" range of HSI values.

Table 7: Summary of HSI acreage for Steelhead Rearing for each project alternative.

Acreage of Steelhead Rearing Habitat by HSI Class				
	Low HSI (0.01 to 0.33)	**Medium HSI (0.33 to 0.67)**	**High HSI (0.67 to 1)**	**Total acres of rearing habitat**
FWOP	6.58	11.25	3.29	21.12
Valley View	6.14	13.77	3.25	23.16
Bypass	6.00	12.77	3.27	22.04
Combination	6.26	12.01	3.47	21.73
Lower Scope	6.58	11.16	3.31	21.04

Table 8: Summary of HSI acreage for Steelhead Spawning in Project Reach 7.

Acreage of Steelhead Rearing Habitat by HSI Class in Reach 7			
	Low HSI (0.01 to 0.33)	**Medium HSI (0.33 to 0.67)**	**High HSI (0.67 to 1)**
FWOP	0.76	1.30	0.42
Valley View	0.89	1.11	0.30
Bypass	0.75	1.30	0.41
Combination	0.71	1.35	0.48
Lower Scope	0.75	1.23	0.44

6. Conclusion

In general, the riparian analysis found that the Combination and Lower Scope plans improve habitat, while the Bypass and Valley View plans cause some riparian habitat degradation over time. For the Combination Plan, there is some reduction in habitat with the initial clearing and grubbing, but this habitat comes back within 5 years and then is substantially improved after 10 years of vegetation growth.

For aquatic habitat, the analysis found that the alternatives generally perform somewhat similar to each other. The Bypass and Valley View plans provide the most habitat as analyzed here because they widen the low-flow channel throughout the study area. This appears favorable because the analysis used depths and velocities during relatively low flows (mean winter and mean spring flow for spawning and rearing, respectively) to evaluate habitat. There is significant opportunity to refine designs to improve the provision of aquatic habitat, particularly through the use of selective floodplain grading and pool-forcing large wood structures in Reaches 7 and 8. Structures like this have been discussed with resource agencies, but have not yet been designed in detail.

The Combination plan leads to the creation of a significant amount of additional riparian habitat, and while this analysis showed that it does not create as much spawning and rearing habitat as the Valley View and Bypass plans, there are significant opportunities to improve upon this as the study moves forward. The Combination plan, if implemented, will lead to significant improvement in the Environmental Quality of the project area. Table 9 below provides a rollup of final habitat numbers obtained for each plan with the analyses described in this appendix.

Table 9. Summary of riparian habitat at Year 25 and both types of aquatic habitat.

Plan	Riparian Habitat (habitat units)	High and Medium Quality Spawning Habitat (acres)	High and Medium Quality Rearing Habitat (acres)
No Action	117.5	13.82	14.54
Valley View	106.6	15.70	17.02
Bypass	105.9	14.67	16.04
Lower Scope	147.2	13.75	14.47
Combination	147.2	13.96	15.47

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION
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VICKSBURG MS 39180-3262

CEMVD-PDP 11 March 2022

MEMORANDUM FOR Commander, San Francisco District, U.S. Army Corps of Engineers (Attn: Mr. Thomas Kendall, CESPN-PMC)

SUBJECT: Single Use Approval of the Juvenile and Spawning Steelhead Habitat Suitability Index Model for the Upper Guadalupe General Reevaluation Report

1. References:
   a. Engineer Circular 1105-2-412: Assuring Quality of Planning Models, 31 March 2011.

   b. US Army Corps of Engineers. Assuring Quality of Planning Models - Model Certification/Approval Process: Standard Operating Procedures. Feb 2012.

   c. Memorandum to Directors of National Planning Centers of Expertise – Subject: Modification of the Model Certification Process and Delegation of Model Approval for Use, 04 December 2017.

   d. Memorandum from the Director of Civil Works to MSC Commanders – Subject: Delegation of Model Certification, 11 May 2018.

   e. Memorandum to Director of the Ecosystem Restoration National Planning Center of Expertise - Subject: Recommend Single Use Approval of the Juvenile and Spawning Steelhead Habitat Suitability Index Model for the Upper Guadalupe General Reevaluation Report, 10 March 2022.

2. An independent review team managed by the Ecosystem Restoration National Planning Center of Expertise evaluated the subject model. The model was found to be technically sound, computationally correct, usable for Civil Works planning, and policy compliant using appropriate functional assessment procedures.

3. The Juvenile and Spawning Steelhead Habitat Suitability Index Model is approved for single use for the Upper Guadalupe General Reevaluation Report. Independent technical review is complete, and the model meets the criteria contained in References 1.a. and 1.b. There are no unresolved issues stemming from the review.

for
Jodi K. Creswell
Acting Chief, MVD Planning and Policy and
Acting Director, Ecosystem Restoration
National Planning Center of Expertise

CF
CEMVD-PDP (Lawton, Mallard, Mickal, Miller)
CEMVP-PDP (Runyon)
CESPN-ET (Fertel)
CESPN-PME (Bilginsoy, Beagle)
CESPN-PMC (Kendall)
CESPN-ECE (Sanchez)

Upper Guadalupe General Reevaluation Study:

Juvenile and Spawning Steelhead Habitat Suitability Index

Technical Memorandum

Contents

1. INTRODUCTION

This single-use approval request is for the hydraulic habitat suitability component of the habitat modeling approach for the Upper Guadalupe General Reevaluation Report (UGGRR). The modeling approach is designed to characterize net impacts to the Environmental Quality (EQ) account for a Flood Risk Management (FRM) study. It will evaluate impacts to existing habitat and benefits from creation of new habitat for aquatic and riparian species, while maximizing use of existing data and previously certified models. It combines three separate elements: 1) the USACE General Salmonid Habitat Model (ERDC/EL TR-18-13), 2) a hydraulic modeling based aquatic habitat suitability evaluation, and 3) a habitat suitability index (HSI) for the yellow warbler (Figure 1). The USACE General Salmonid Habitat Model will primarily be used for identifying priority mitigation reaches, and the other two models will be used for quantifying changes in net average annual habitat units within the project area (AAHUs).

As the USACE General Salmonid Model and yellow warbler HSI are already certified models, this technical memorandum will focus on the aquatic habitat suitability evaluation. The habitat evaluation presented here is based on that approved for the Yuba River Ecosystem Restoration Feasibility Study (approval memo dated 12 October 2017), revised to also include spawning suitability (Kammel et al. 2016) and to use rearing suitability curves more appropriate to the study area watershed (Holmes et al. 2014). A more comprehensive description of the modeling methodology and results will be presented as an appendix to the UGGRR.

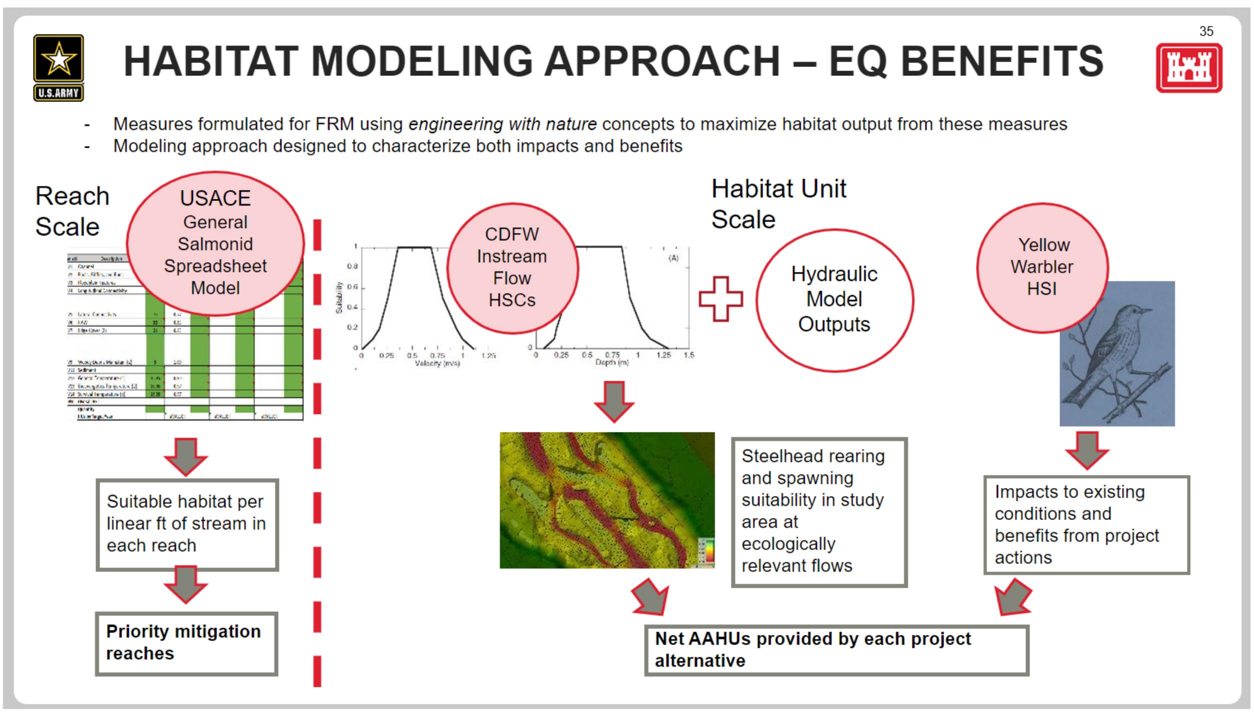

Figure 1. Habitat modeling approach schematic, from Oct 7th, 2021 IPR with vertical team.

2. BACKGROUND

The UGGRR is primarily intended to address flood risk in the Guadalupe River corridor in San Jose, CA. The plans to be evaluated in the report include the previously identified National Economic Development (NED) and Locally Preferred plans (LPP), termed Valley View and Bypass plans, respectively, from the original feasibility study and Limited Reevaluation Report (LRR), as well as two new alternatives formulated as part of this study process (known as the Combo plan and Lower-Scoped alternative). All alternatives include mitigation for impacts to the existing riparian forest, and the two new alternatives are expected to result in a net increase in area of riparian forest. The study area is located in a highly urbanized part of Santa Clara County and provides an important migration corridor for both aquatic and terrestrial species. The legacy of development, mining and urbanization in the watershed has degraded quality, quantity, and connectivity of aquatic and riparian habitat. Previous projects have worked to improve habitat connectivity in the watershed, and the nature-based features put forth in this study are meant to build on those efforts. The study team has been working with local stakeholders and resource agencies to formulate alternatives that provide some habitat benefit within the project reaches while achieving the primary study goal of providing improved flood risk management. This evaluation of habitat benefits is also in accordance with the comprehensive benefits evaluation memorandum (ASA-CW memorandum dated 5 January 2021).

Through an evaluation of various potential models, the project delivery team (PDT) chose to use a Habitat Evaluation Procedure (HEP) based assessment approach. The assessment approach utilizes HSI models to develop habitat units for key habitat types that are later combined into a single habitat output for each alternative. The PDT identified two key habitat types to represent anticipated ecosystem outputs of the focused array of alternatives: 1) riverine habitat and 2) riparian forest. Riverine habitat describes the wetted area and will vary with seasonal changes in flow. Riparian forest is broadly defined here as the shrubs and trees within the river corridor. The key habitat types selected for inclusion in this assessment approach are adequate to support evaluation of the full range of alternatives.

Representative evaluation species were selected for each habitat type based on several criteria: (1) species known to be sensitive to specific land- and water- use actions; (2) species that play a key role in nutrient cycling or energy flow; (3) species that utilize a common environmental resource; (4) species that are associated with important resource problems, such as anadromous fish and migratory birds; (5) species that have existing habitat response models suitable for the evaluation of proposed alternatives; (6) habitat data available or easily collected to support modeling; (7) species that provide relevant evaluation throughout the geographic range of proposed alternatives and across the broad range of effects of proposed alternative.

Based on the above criteria and approved HSI models, the representative species selected to evaluate habitat outputs for riparian forest was yellow warbler (*Dendroica petechia*) (Table 1). Given the above criteria and the fact that anadromous salmonids have been at the center of the discussion of habitat impacts in the watershed, the PDT chose to utilize steelhead (*Oncorhynchus mykiss*) rearing and spawning lifestages as a representative species to evaluate habitat output for riverine habitat (Table 1).

Table 1. Habitat Type, Species, and Habitat Variables.

Habitat Type	Evaluation Species	Habitat Variables
Riverine	rearing and spawning steelhead	Depth, Velocity, substrate and cover
Riparian Forest	yellow warbler	Percent canopy cover, average canopy height

Although approved HSI models are available for Chinook salmon and rainbow trout, these models are based on HSCs that do not appropriately relate to the types of benefits anticipated from the suite of proposed measures. The UGGRR is considering actions to address the degradation in the quality, quantity and connectivity of aquatic and riparian habitat commensurate with the study's FRM authority. Proposed actions include floodplain benches and gravel augmentation that would provide both FRM and habitat benefits. Steelhead and yellow warbler were selected as the representative species because they are likely to be affected by project actions. The yellow warbler HSI and steelhead model curves were selected to be used with readily available vegetation cover data and hydraulic modeling outputs.

3. UGGRR ASSESSMENT APPROACH

The primary consideration in developing an assessment approach for the UGGRR was to quantify net change in the EQ account in the comprehensive benefits analysis. In quantifying EQ benefits, it was determined that the assessment approach would need to (1) provide an equitable evaluation that adequately distinguishes between all actions, and (2) be based in 3x3x3 planning principals (leveraging existing resources and optimizing the level of detail of the analysis to complete the feasibility study in and efficient and effective manner).

The PDT determined that a HEP framework would provide a suitable multi-habitat/ multi-species assessment approach to evaluate and compare alternatives. The HEP framework was also beneficial in providing flexibility in the selection of modeling elements to leverage existing information and optimize the level of detail of analysis. The HEP is a process developed by the U.S. Fish and Wildlife Service (1980a and 1980b) to facilitate the identification of impacts from various types of actions on fish and wildlife habitat. The basic premise of HEP is that habitat quantity and quality can be numerically described. HEP can provide a comparison of habitat quality between different sites or between different times at one site (for example, pre-construction versus post-construction). A key assumption in HEP is that an individual species "prefers" (or survives/reproduces better) in habitats with certain physical characteristics that can be measured. For example, if yellow warblers typically nest in deciduous shrubs, then sites with greater deciduous shrub cover are more suitable for yellow warblers than sites which have little or no deciduous shrub cover.

An HSI utilized by HEP is a mathematical relationship between a physical, chemical, or biological habitat attribute and its suitability for a single species or assemblage of species. The HSI combines the effects of multiple variables into a single, unitless index that ranges from 0-1. Each individual variable is represented by a variable Suitability Index (SI), a unitless number between 0 and 1 that describes the requirements of a species for a specific attribute, such as cover, distance to foraging, water temperature, etc. A set of one or more SIs that represent key habitat requisites for the species during one or more life history stages are combined into an overall HSI by adding or multiplying the individual indices. The attributes are measured in the field or via GIS analysis, and their corresponding index values are inserted into the model to produce a score that describes existing habitat suitability. This index value can be multiplied by the area of the site to yield Habitat Units (HUs), or it can be used as an index score for a habitat quality comparison only.

Steelhead was selected as a representative species for the riverine key habitat type because it meets the criteria listed in the previous section and provides advantages over similar species. Anadromous salmonids, including steelhead are keystone species in the Guadalupe River watershed and play a key role in the nutrient cycling. Salmon and steelhead are at the center of many resource management and development decisions in the watershed and greater region. These have included improvements to habitat connectivity such as removing fish passage barriers throughout the watershed. Because the project is not proposing any further fish passage improvements, the focus of the analysis is on hydraulic variables that will be affected by the project alternatives. Steelhead are sensitive to habitat disturbance and rely on a wide variety of conditions for different life stage requirements. Steelhead are present throughout the study area and beyond. Steelhead are widely studied and a large body of information exists within and beyond the study area. The species also offers a practical advantage in that HSI models have been developed for use in nearby watersheds.

Yellow warbler was selected as a representative species for the riparian key habitat type because it also meets the criteria listed in the previous section. The yellow warbler is a migratory songbird that nests in riparian trees and shrubs and eats insects.

The assessment approach is summarized below to provide context for how the steelhead and yellow warbler HSIs will be applied. The assessment approach is a multi-species/ multi-habitat HEP approach that will evaluate ecosystem output of alternatives in area-based habitat units. The PDT identified key habitat types and representative species to support the multi-species / multihabitat HEP approach. Riverine and riparian habitats will be given equal weighting in this analysis. Defining key habitat types establishes clear guidelines by which the primary effects of each alternative can be categorized and evaluated and therefore provides for a simplified quantitative assessment of ecosystem outputs. Selecting representative species establishes the set of habitat-species relationships used to evaluate the quality of each key habitat type. The assessment approach can be summarized by the following major steps:

1. Apply HSI models to key habitat types to develop habitat units for both steelhead and yellow warbler for all future-without-project (FWOP) and future-with-project (FWP) conditions over 50-year period of analysis.
2. Calculate Average Annual Habitat Units (AAHUs) using the ecorest R package developed by ERDC. Ecosystem output will be calculated as the difference between FWOP and FWP condition AAHUs.
3. Compare ecosystem output AAHUs between different alternatives to evaluate performance in the EQ account.

4. INSTREAM FLOW HABITAT SUITABILITY MODEL

A. STEELHEAD HSI COMPONENTS AND INPUTS

HSIs for spawning and juvenile steelhead in the Upper Guadalupe River are based on habitat suitability criteria identified in habitat suitability studies conducted in the Yuba River (~130 mi north) and the Big Sur River (~75 mi south), respectively. HSIs from these rivers were selected for the similarities in the hydrologic and geomorphic conditions that influence habitat and the similarities of river run fish. Each lifestage has its own depth and velocity SIs.

SIs for spawning steelhead are sourced from a study conducted by Kammel et al. for the Lower Yuba River Management Team funded by the Yuba Water Agency to quantify the physical habitat conditions that influence spawning site selection (Figure 2). The study focuses on the lower Yuba River downstream of Englebright Dam. The Yuba River historically supported a steelhead population and the lower Yuba River currently supports a population of steelhead and resident rainbow trout (Kammel et al, 2016).

The SIs for spawning steelhead include depth and velocity as shown in Figure 2 and Tables 2 and 3 below. The spawning steelhead HSI for velocity is calculated in meters/second and converted to feet/second – ranging from 0 to 3.6 feet/second. Depth is similarly converted to feet and ranges from 0.3 to 4.3 feet. Kammel et al also use a spawning substrate SI, but this was not included here due to lack of high-quality substrate data. However, the project will be installing gravel nourishment in some of the alternatives, so spawning substrate will improve.

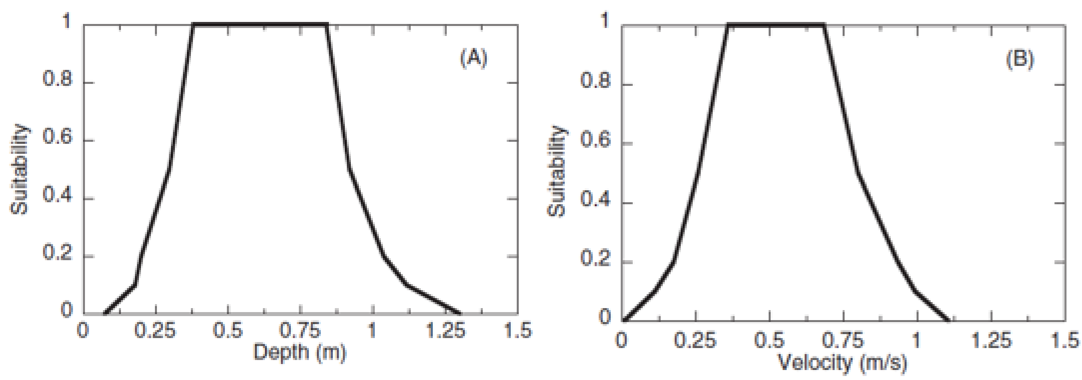

Figure 2. Spawning habitat suitability for velocity and depth in the Lower Yuba River, reprinted from Figure 3 in Kammel et al 2016.

Table 2. Spawning Steelhead Suitability Index for Velocity.

Velocity (m/s)	Velocity (ft/s)	Suitability Index Value
0	0.0	0
0.125	0.4	0.1
0.19	0.6	0.2
0.25	0.8	0.5
0.36	1.2	1
0.7	2.3	1
0.82	2.7	0.47
0.95	3.1	0.2
1	3.3	0.1
1.11	3.6	0

Table 3. Spawning Steelhead Suitability Index for Depth.

Depth (meters)	Depth (feet)	Suitability Index Value
0.085	0.3	0
0.19	0.6	0.1
0.32	1.0	0.5
0.375	1.2	1
0.83	2.7	1
0.92	3.0	0.5
1.03	3.4	0.2
1.12	3.7	0.1
1.3	4.3	0

The modeling approach uses SIs for rearing steelhead identified in a 2014 California Department of Fish and Wildlife study that prepared habitat suitability curves for habitat variables based on fish surveys conducted in the watershed (Holmes, 2014). SIs for water velocity and depth are based on Spring 2012 sampling. These habitat suitability curves are being used in favor of the rearing curves used in the Yuba Model because the Big Sur River has a more similar hydrologic regime (i.e. rain-dominated), watershed size and physiography to the Guadalupe River. The HSI for juvenile steelhead includes velocity and depth as shown in Figure 4 and Table 4 and 5 below. The juvenile steelhead SI for velocity is evaluated in feet/second and ranges from 0 to 3.61 ft/sec while depth is evaluated in feet and ranges from 0 to 3.81 feet. A third SI for substrate/cover is also included from the Yuba River steelhead rearing model to capture the benefits of replanting riparian vegetation, installing stream wood, and adding coarse sediment.

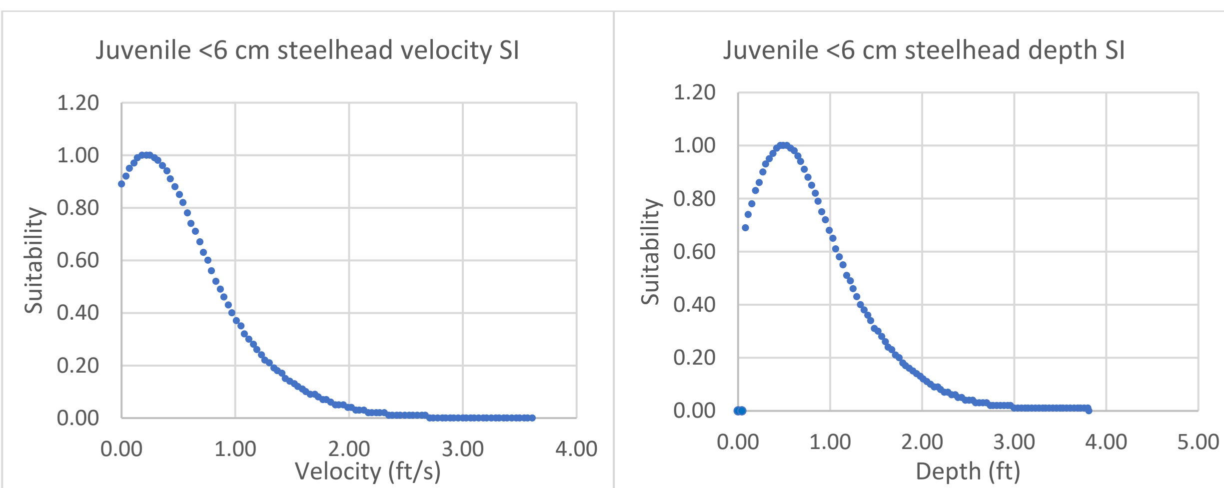

Figure 3. Left, Juvenile <6 cm steelhead velocity HSI curve. Right, Juvenile <6 cm depth HSI curve (Figures 122 and 123, respectively, from Holmes et al. 2014).

Table 4. Steelhead rearing habitat suitability for substrate/cover, from Yuba River model.

Substrate/cover	HSC Value
None	0.30
Cobble	0.50
Boulder/riprap	0.50
Riparian vegetation	1.00
Stream wood	1.00

Table 5. HSI values for rearing steelhead, reprinted from Table 16 in Holmes et al. 2014.

Velocity (ft/s)	Suitability Index Value	Velocity (ft/s)	Suitability Index Value
0.00	0.89	1.84	0.06
0.04	0.92	1.88	0.05
0.07	0.95	1.91	0.05
0.11	0.97	1.95	0.05
0.14	0.99	1.99	0.04
0.18	1.00	2.02	0.04
0.22	1.00	2.06	0.03
0.25	1.00	2.09	0.03
0.29	0.99	2.13	0.03
0.32	0.98	2.17	0.02
0.36	0.96	2.20	0.02
0.40	0.94	2.24	0.02
0.43	0.91	2.27	0.02
0.47	0.88	2.31	0.02
0.51	0.85	2.35	0.01
0.54	0.82	2.38	0.01
0.58	0.78	2.42	0.01
0.61	0.74	2.45	0.01
0.65	0.71	2.49	0.01
0.69	0.67	2.53	0.01
0.72	0.63	2.56	0.01
0.76	0.60	2.60	0.01
0.79	0.56	2.64	0.01
0.83	0.52	2.67	0.01
0.87	0.49	2.71	0.00
0.90	0.46	2.74	0.00
0.94	0.43	2.78	0.00
0.97	0.40	2.82	0.00
1.01	0.37	2.85	0.00
1.05	0.35	2.89	0.00
1.08	0.32	2.92	0.00
1.12	0.30	2.96	0.00
1.16	0.28	3.00	0.00
1.19	0.26	3.03	0.00
1.23	0.24	3.07	0.00
1.26	0.22	3.10	0.00
1.30	0.21	3.14	0.00
1.34	0.19	3.18	0.00
1.37	0.18	3.21	0.00
1.41	0.17	3.25	0.00
1.44	0.15	3.29	0.00
1.48	0.14	3.32	0.00
1.52	0.13	3.36	0.00
1.55	0.12	3.39	0.00
1.59	0.11	3.43	0.00
1.62	0.10	3.47	0.00
1.66	0.09	3.50	0.00
1.70	0.09	3.54	0.00
1.73	0.08	3.57	0.00
1.77	0.07	3.61	0.00
1.80	0.07		

Depth (feet)	Suitability Index Value	Depth (feet)	Suitability Index Value
0.00	0.00	2.09	0.10
0.04	0.00	2.13	0.09
0.08	0.69	2.17	0.09
0.11	0.74	2.20	0.08
0.15	0.78	2.24	0.07
0.19	0.83	2.28	0.07
0.23	0.86	2.32	0.06
0.27	0.90	2.36	0.06
0.30	0.93	2.39	0.05
0.34	0.95	2.43	0.05
0.38	0.97	2.47	0.04
0.42	0.99	2.51	0.04
0.46	1.00	2.55	0.04
0.49	1.00	2.58	0.03
0.53	1.00	2.62	0.03
0.57	0.99	2.66	0.03
0.61	0.98	2.70	0.03
0.65	0.96	2.74	0.02
0.68	0.94	2.77	0.02
0.72	0.91	2.81	0.02
0.76	0.88	2.85	0.02
0.80	0.85	2.89	0.02
0.84	0.82	2.93	0.02
0.87	0.79	2.96	0.02
0.91	0.75	3.00	0.01
0.95	0.72	3.04	0.01
0.99	0.68	3.08	0.01
1.03	0.65	3.12	0.01
1.06	0.61	3.15	0.01
1.10	0.58	3.19	0.01
1.14	0.55	3.23	0.01
1.18	0.51	3.27	0.01
1.22	0.49	3.31	0.01
1.25	0.46	3.34	0.01
1.29	0.43	3.38	0.01
1.33	0.40	3.42	0.01
1.37	0.38	3.46	0.01
1.41	0.36	3.50	0.01
1.44	0.34	3.53	0.01
1.48	0.31	3.57	0.01
1.52	0.30	3.61	0.01
1.56	0.28	3.65	0.01
1.60	0.26	3.69	0.01
1.63	0.24	3.72	0.01
1.67	0.23	3.76	0.01
1.71	0.21	3.80	0.01
1.75	0.20	3.81	0.00
1.79	0.18		
1.82	0.17		
1.86	0.16		
1.90	0.15		
1.94	0.14		
1.98	0.13		
2.01	0.12		
2.05	0.11		

B. MODELING TOOLS

The instream flow habitat suitability model is applied using hydraulic outputs the Hydrologic Engineering Center's (CEIWR-HEC) River Analysis System (HEC-RAS) that are post-processed in RASMapper and ESRI ArcMap to generate polygons of suitable habitat. This approach improves modeling of microhabitats when compared to spreadsheet models by providing a spatially explicit prediction of habitat area. As evidenced by the HSIs, the anticipated benefits of habitat and connectivity improvement measures are focused in shallow and or low velocity areas. An HSI applied through a spreadsheet model would result in an averaging of physical habitat indicator conditions over a defined project area. Averaging of depths, velocities, or cover across the full width of a riverine area could result in a single representative value that provides little or no habitat suitability value to the representative species. In other words, a broad scale application of an HSI model can result in a loss of the ability of the model to evaluate changes in microhabitat types. The steelhead HSI habitat suitability relationships describe a relatively narrow range of suitable depths and velocities. Although a spreadsheet application of the HSI model is not technically limited to a broad scale application, it is impractical to design a highly spatially detailed application of an HSI model without the support of a geographic information system (GIS) program to manage data.

HEC-RAS solves one- and two-dimensional hydrodynamic equations to arrive at a water surface elevation and flow velocity at each computational node at each timestep of the simulation. HEC-RAS outputs depths and velocities throughout the channel during flows of interest, which are then processed into grids of combined habitat suitability using HEC-RAS's RASMapper utility. ArcMap facilitates the evaluation of habitat suitability across a grid of fine scale, discrete locations, such that the anticipated ecosystem benefits that occur across a narrow range of habitat conditions would not be averaged out of consideration by areas of unsuitable habitat conditions. Furthermore, ArcMap would facilitate the added complexity by providing a framework for managing the large data sets and synthesizing that fine scale analysis in a single output.

C. METHODS

Step 1: Develop habitat suitability rasters for each variable

For this study, mean daily winter (December to February) flow will be used to evaluate spawning habitat suitability, and mean daily spring (March to May) flow will be used to evaluate rearing habitat suitability. In HEC-RAS, HSIs are applied to hydraulic outputs with a built-in raster calculator tool using equations based on the relationships shown above to produce depth and velocity suitability rasters. In this step, a raster layer representing the substrate/cover variable will also be added for the rearing habitat suitability calculation. These rasters are then combined using the geometric mean to arrive at combined habitat suitability rasters during flows of interest. The model does not require a specific cell size for each raster; however, finer scale (smaller cell sizes) will facilitate a more detailed evaluation of potential project effects. Subsequent calculations in this analysis require that cell size be uniform between all raster files. For HSI assessment, all rasters will be developed with a 3 ft cell size. The result of this step is a combined HSI raster in which each cell has a value from 0 to 1 representative of the habitat suitability at that location for rearing or spawning steelhead.

Step 2: Calculate habitat unit output

Within ArcMap, the combined habitat suitability rasters will be binned into low, medium, high-quality and non-habitat. Non-habitat is defined as anything with a combined habitat suitability value below

0.01, low-quality habitat consists of areas between 0.01 and 0.33, medium-quality between 0.33 and 0.67, and high-quality between 0.67 and 1. This approach is intentionally imprecise and is intended to get away from the false precision introduced by both hydrodynamic models and habitat suitability curves while still allowing for a comparison between different alternatives. The areas identified as habitat will be converted to polygons, and then mean suitability value (computed using zonal statistics) of the polygon will be multiplied by the area to arrive at habitat units for each life stage. Figure 4 shows a schematic of the workflow in ArcMap.

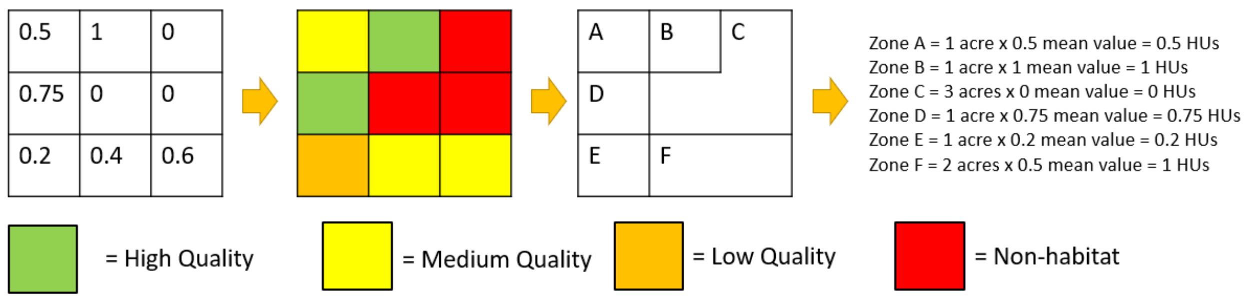

Figure 4. Schematic of GIS workflow to process habitat suitability rasters. In the first grid, the values are combined HSI values for each cell, and each cell represents one acre.

D. MODEL ASSUMPTIONS

- The intended use of the steelhead HSI model is to support the development of habitat units to facilitate an evaluation and comparison of net effects on EQ for proposed alternatives. The evaluation and comparison of proposed actions does not necessarily require an evaluation of absolute habitat value, but would be satisfied by a simpler, relative evaluation and comparison of alternatives. A relative evaluation compared to a comprehensive evaluation of habitat value can be completed through a much smaller effort with a reduced need for information. Given this consideration, the steelhead HSI model will focus on the relative improvement or lift to ecosystem value resulting from a given action.
- Historically, steelhead and chinook have been present in the Upper Guadalupe River. They continue to utilize the riverine ecosystem for spawning and rearing though the populations returning to the stream have dwindled. They are expected to serve as an appropriate surrogate for the general quality of riverine habitat. The use of a representative species as surrogate for the quality of affected key habitat types is appropriate within the HEP framework and provides a suitable level of detail for the UGGRR.
- Although the steelhead HSI models are limited in the type and range of habitat variables that it considers, the variables that are included provide a relevant evaluation of the types of effects anticipated from proposed actions. Therefore, while the steelhead HSI models may not provide a broad evaluation of riverine habitat, it will provide a suitable evaluation of the relative change resulting from a proposed action.
- The steelhead HSI models each use a single set of relationships for the entire study area. This level of detail meets the study's requirements and is consistent with other modeling aspects including hydraulic modeling, project designs, and application of other species HSI models utilized in the HEP framework.

- It is important to note that the application of the steelhead HSI model within the instream flow modeling approach may result in numerical levels of significance that are not real. Outputs will have many significant digits as a byproduct of program defaults. The fine scale application of the model on a 3ft x 3ft grid may also contribute to an impression of highly accurate results though the significance of results is largely dependent on the accuracy of input data. The results from this model should be considered significant only in their relative evaluation of potential effect of proposed actions. Accordingly, HSI values for FWOP and various alternatives will be binned relative to their distribution.

E. MODEL LIMITATIONS

- General limitations observed in the use of HEP and HSIs include: 1) many developed models have not been tested sufficiently to match observed "preferred" habitats by the various species or to match species experts' knowledge of optimal habitat; 2) high values generated from the HSIs do not necessarily match observed higher species diversity or abundance than sites with lower values; 3) difficulty in collecting sufficient data to use the models (particularly when models have numerous variables); 4) use of one species model to represent suitability for wider guilds or assemblages may not accurately represent those other species; and 5) lack of variables that describe landscape scale effects on species diversity and abundance.
- The steelhead HSI models applied in the project reaches of the UGGRR were developed for parts of the Yuba River and Big Sur River. These sites have similar but not identical stream conditions. The Yuba River spawning suitability data was used because it is relatively nearby in Northern California, is well-studied, and has readily available hydraulic habitat suitability data, but the hydrology and watershed size are significantly different from the Guadalupe River. More suitable spawning curves were not available at the time of this study. The Big Sur River has a more similar hydrology, physiography and watershed size to the Guadalupe River, but is notably different in the degree of urbanization. Despite this, the PDT determined that they are still suitable for characterizing relative differences between alternatives.

5. REFERENCES

ASA(CW). 2021. "POLICY DIRECTIVE – Comprehensive Documentation of Benefits in Decision Documents." Assistant Secretary of the Army for Civil Works.

CEMVD-PD-L . 2017. "Recommend Single Use Approval of the Yuba River Juvenile Steelhead Habitat Suitability Index Model." USACE Mississippi Valley Division.

Holmes, R., M. Allen, and S. Bros-Seeman. 2014. *Habitat Suitability Criteria Juvenile Steelhead BIG SUR RIVER, Monterey County*. Stream Evaluation Report. California Department of Fish and Wildlife.

Kammel, L. E., G. B. Pasternack, D. A. Massa, and P. M. Bratovich. 2016. "Near-census ecohydraulics bioverification of *Oncorhynchus mykiss* spawning microhabitat preferences." *Journal of Ecohydraulics*, 1 (1–2): 62–78. https://doi.org/10.1080/24705357.2016.1237264.