US Army Corps of Engineers®

Sacramento District
Planning Division

Yuba River Ecosystem Restoration Feasibility Study

Yuba County, California

Appendix A: Plan Formulation Appendix

October 2018

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Introduction

Ecosystem restoration is one of the primary missions of the U.S. Army Corps of Engineers (USACE) Civil Works program. The objective of ecosystem restoration is to contribute to National Ecosystem Restoration (NER) by restoring degraded ecosystem structure, function, and dynamic processes to a less degraded, more natural condition. Contributions to NER are increases in the quantity and/or quality of desired ecosystem resources. Contributions to NER are measured by improvements to habitat quantity and/or quality as expressed quantitatively in physical units or indexes (but not monetary units).

This approach requires a non-monetary indicator of ecological benefits that is applicable across alternative plans and scales of effort. For this study, a standard Habitat Evaluation Procedure (HEP) was performed to quantify the ecosystem benefits of potential restoration alternatives. HEP does not attempt to quantify all ecosystem benefits, but instead uses selected evaluation species to provide an indicator of the relative magnitude of ecological outputs that is used to compare the cost-efficiency of different measures or alternatives.

Per Engineer Regulation (ER) 1105-2-100, the plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with the Federal objective, shall be selected. The selected plan must be a cost effective plan for achieving the desired level of output and economically justified (determined to be worth its investment cost). The plan that meets these requirements shall be identified as the NER Plan. The following sections describe the evaluation, comparison, and selection process for the Yuba River Ecosystem Restoration Feasibility Study NER Plan.

Habitat Restoration Increments

As described in section 3.4.3 of the Feasibility Report, the initial screening process identified the Lower Yuba River Habitat Restoration measure as the most efficient and lowest risk measure to retain for further evaluation. For a more detailed analysis, the measure was divided into five geographic increments of habitat restoration, which became the building blocks of the final array of alternatives. The habitat increments are identified below and described in detail in section 3.5.

Habitat Increment 1

Upstream of Highway 20. Increment 1 includes 7.4 acres of riparian planting, 5.8 acres of side channel creation, and 6.1 acres of restored backwater area.

Habitat Increment 2

Upper Gilt Edge Bar and Unnamed Bar (near River Mile 17). Increment 2 includes 8.7 acres of riparian planting, 14 acres of floodplain lowering, 0.3 acre of restored backwater area, and 0.3 acre of bank scalloping.

Habitat Increment 3a

Lower Gilt Edge Bar, Hidden Island, First Island, Silica Bar, and Bar A. Increment 3a includes 28.7 acres of riparian planting, 13 acres of floodplain lowering, and 11.3 acres of side channel creation.

Habitat Increment 5a

Bar C. Increment 5a includes 21.3 acres of riparian planting, 13 acres of floodplain lowering, and 15.1 acres of side channel creation.

Habitat Increment 5b

Narrow Bar, River Mile 6.5, Bar E, and Island B. Increment 5b includes 29.7 acres of riparian planting, 7.7 acres of floodplain lowering, 9.2 acres of side channel creation, and 2.9 acres of restored backwater area.

Costs and Outputs of Habitat Increments

Each individual habitat increment was assessed to determine the cost of construction and the anticipated ecosystem benefits for evaluation species. Class 4 cost estimates were developed for each habitat increment based on early concept technical information. Class 4 estimates include major estimate assumptions in technical information and quantities, heavy reliance on cost engineering judgment, and a great deal of uncertainty relative to major construction components (ER 1110-2-1302). Ecosystem benefits were developed using a standard Habitat Evaluation Procedure (HEP). Appendix D, Attachment 8 provides detail on the selected species for HEP and the calculation of Habitat Units (HU). The costs and average annual gains in HUs for each habitat increment are shown below in Table 1. Average annual costs were calculated at the FY 2017 discount rate of 2.875%. The annual costs did not include interest during construction or operation, maintenance, repair, replacement, and rehabilitation costs because those costs would be proportional to the total project first costs for each increment and, as a result, would not affect plan selection.

Table 1. Costs and Outputs of Habitat Increments.

Increment	Total Project First Costs	Average Annual Costs	Acres	Average Annual Habitat Units Gained
1	$20,241,000	$768,107	19.2	3.62
2	$9,194,000	$348,895	23.3	14.32
3a	$31,610,000	$1,199,539	56.4	17.80
5a	$24,987,000	$948,209	49.3	19.36
5b	$23,608,000	$895,878	49.5	21.38

Combination of Habitat Increments

The Institute for Water Resources (IWR) Planning Suite is decision support software developed by USACE for the formulation and evaluation of ecosystem restoration alternative plans. Functionally, the software combines individual measures, or in this case, habitat increments, into alternative plans and identifies the relationship between changes in cost and changes in HUs. The software expedites the effort of testing each combination of increments and tabulating the resulting costs and environmental benefits. For this study, IWR Planning Suite generated all possible combinations of increments, for a total of 32 plans.

Cost Effectiveness Analysis

ER 1105-2-100 requires that the ecosystem benefits of potential restoration plans be evaluated through a detailed cost effectiveness and incremental cost analyses (CE/ICA). The cost effectiveness analysis is the first step in the CE/ICA, and compares the Average Annual Habitat Units (AAHUs) potentially achieved by each alternative to the cost of each alternative to generate a "cost per AAHU." This cost provides a means to compare the cost-effectiveness of each plan. A plan is considered cost effective if it provides a given level of output for the least cost.

Examining the cost per AAHU for each plan allows for the identification and elimination of economically inefficient plans. The three criteria used for identifying non-cost effective plans include (1) the same level of output could be produced by another plan at less cost; (2) a larger output level could be produced at the same cost; or (3) a larger output level could be produced at less cost. Non-cost effective combinations of plans are dropped from further consideration.

Based on cost per AAHU calculated for this study, IWR Planning Suite identified 23 of the 32 plans as non-cost effective. Those 23 plans were dropped from consideration.

Of the remaining 9 cost effective plans, 6 were identified as best buy plans. These 6 plans are the most efficient plans at producing outputs - they provide the greatest increase in outputs for the least increase in costs. Figure 1 displays the results of the cost effectiveness evaluation.

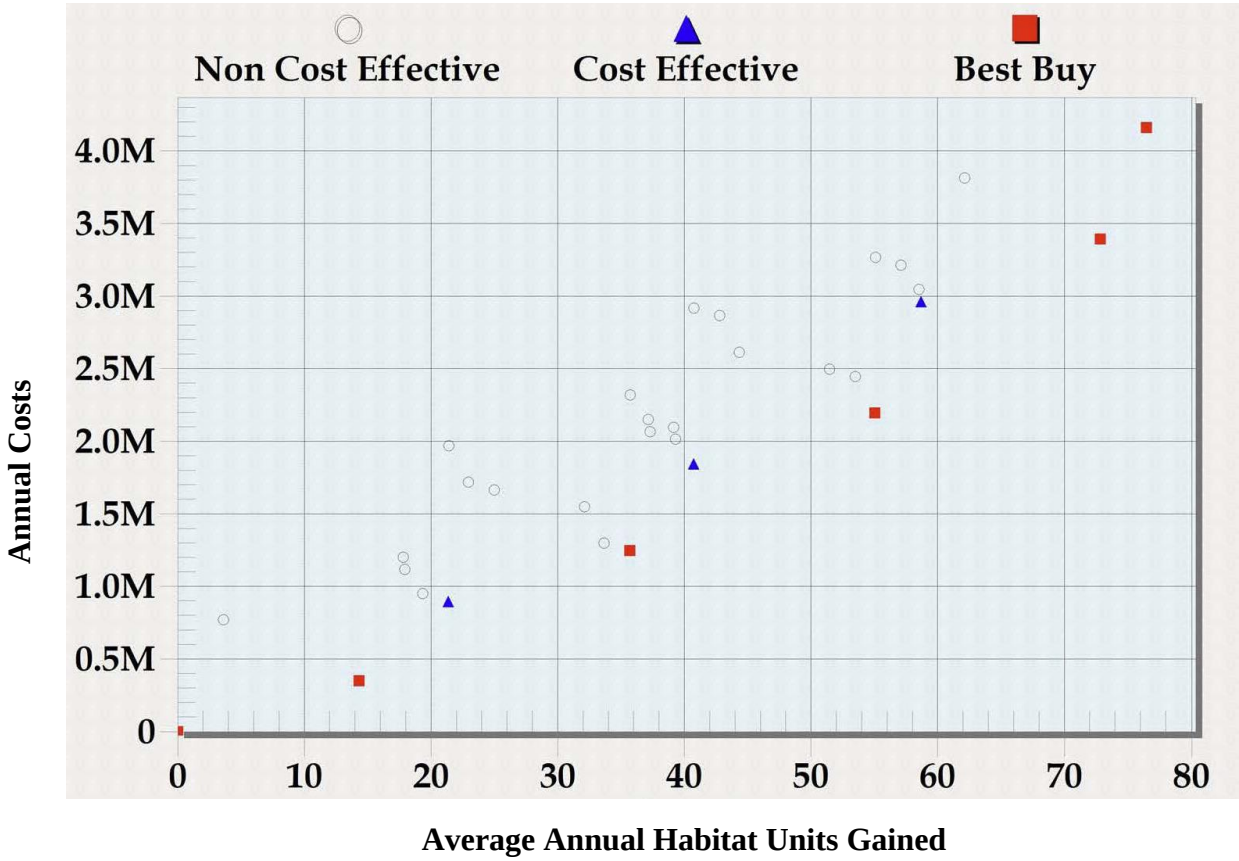

Figure 1. All possible combinations of habitat increments differentiated by cost effectiveness.

Final Array of Alternatives

The 6 best buy plans are the combinations of habitat increments that are both cost effective and the most efficient plans. For these reasons, they became the final array of alternatives for the Yuba River Ecosystem Restoration Feasibility Study. Table 2 details total costs and AAHUs of each alternative. The alternatives are also briefly described below. Detailed descriptions of the increments that make up the alternatives can be found in section 3.5 of the Feasibility Report.

Table 2. Incremental Costs and Outputs of Alternatives.

Alternatives	Total Project First Costs	Average Annual Costs	Acres	Average Annual Habitat Units (AAHU)	Incremental Annual Cost per AAHU	Total Annual Cost per AAHU
1 (No Action)	0	0	0	0	0	0
2 (Increment 2)	$9,194,000	$348,895	23.3	14.32	$24,364	$24,364
3 (Increments 2, 5b)	$32,802,000	$1,244,773	72.8	35.67	$41,905	$34,898
4 (Increments 2, 5b, 5a)	$57,789,000	$2,192,982	122.2	55.06	$48,980	$39,830
5 (Increments 2, 5b, 5a, 3a)	$89,399,000	$3,395,521	178.6	72.86	$67,386	$46,563
6 (Increments 2, 5b, 5a, 3a, 1)	$109,640,000	$4,160,628	197.8	76.48	$212,126	$54,402

Alternative 1 is the no action plan and assumes no action is taken as the result of this study.

Alternative 2 includes only increment 2 at Upper Gilt Edge Bar and Unnamed Bar, which would result in 23.3 acres of restored habitat by lowering the floodplain to facilitate inundation and planting riparian vegetation. The total cost of this alternative is $9.2 million.

Alternative 3 includes increments 2 and 5b at Upper Gilt Edge Bar, Unnamed Bar, Narrow Bar, River Mile 6.5, Bar E, and Island B, which would result in 72.8 acres of restored habitat by lowering the floodplain to facilitate inundation and planting riparian vegetation, as described above. The total cost of this alternative is $32.8 million.

Alternative 4 includes increments 2, 5b, and 5a at Upper Gilt Edge Bar, Unnamed Bar, Narrow Bar, River Mile 6.5, Bar E, Island B, and Bar C, which would result in 122.2 acres of restored habitat by lowering the floodplain to facilitate inundation and planting riparian vegetation, as described above. The total cost of this alternative is $57.8 million.

Alternative 5 includes increments 2, 5b, 5a, and 3a at Upper Gilt Edge Bar, Unnamed Bar, Narrow Bar, River Mile 6.5, Bar E, Island B, Bar C, Lower Gilt Edge Bar, Hidden Island, First Island, Silica Bar, and Bar A, which would result in 178.6 acres of restored habitat by lowering the floodplain to facilitate inundation and planting riparian vegetation, as described above. The total cost of this alternative is $89.4 million.

Alternative 6 includes increments 2, 5b, 5a, 3a, and 1 at Upper Gilt Edge Bar, Unnamed Bar, Narrow Bar, River Mile 6.5, Bar E, Island B, Bar C, Lower Gilt Edge Bar, Hidden Island, First Island, Silica Bar, Bar A, and Upstream of Highway 20, which would result in 197.8 acres of restored habitat by lowering the floodplain to facilitate inundation and planting riparian vegetation, as described above. The total cost of this alternative is $109.6 million.

Incremental Cost Analysis

The incremental cost analysis reveals and interprets changes in cost for increasing levels of environmental benefits. While each alternative/best buy plan provides the greatest increase in

outputs for the least increase in cost, the incremental cost analysis helps decision makers determine the most desirable level of output relative to costs. The analysis helps to identify and display variations in costs among alternative plans.

Figure 2 displays the 6 best buy plans/final array of alternatives for the Yuba River Ecosystem Restoration Study. Incremental costs per unit of output were used to identify major breakpoints in cost efficiency among the alternatives. Figure 2 shows that outputs increase as alternatives progress (1-6); however, these outputs are achieved at increasingly higher incremental costs. Alternative 2, while the lowest incremental cost per AAHU, is very small in scale and would not significantly contribute to the project objectives from a national perspective or maximize benefits relative to costs. Alternatives 3, 4, and 5, with the next lowest incremental costs per AAHU, are very similar in efficiency. Alternative 6 includes Increment 1, which is more than three times the cost per AAHU of the other increments, creating a clear breakpoint in the relative efficiency of the alternatives.

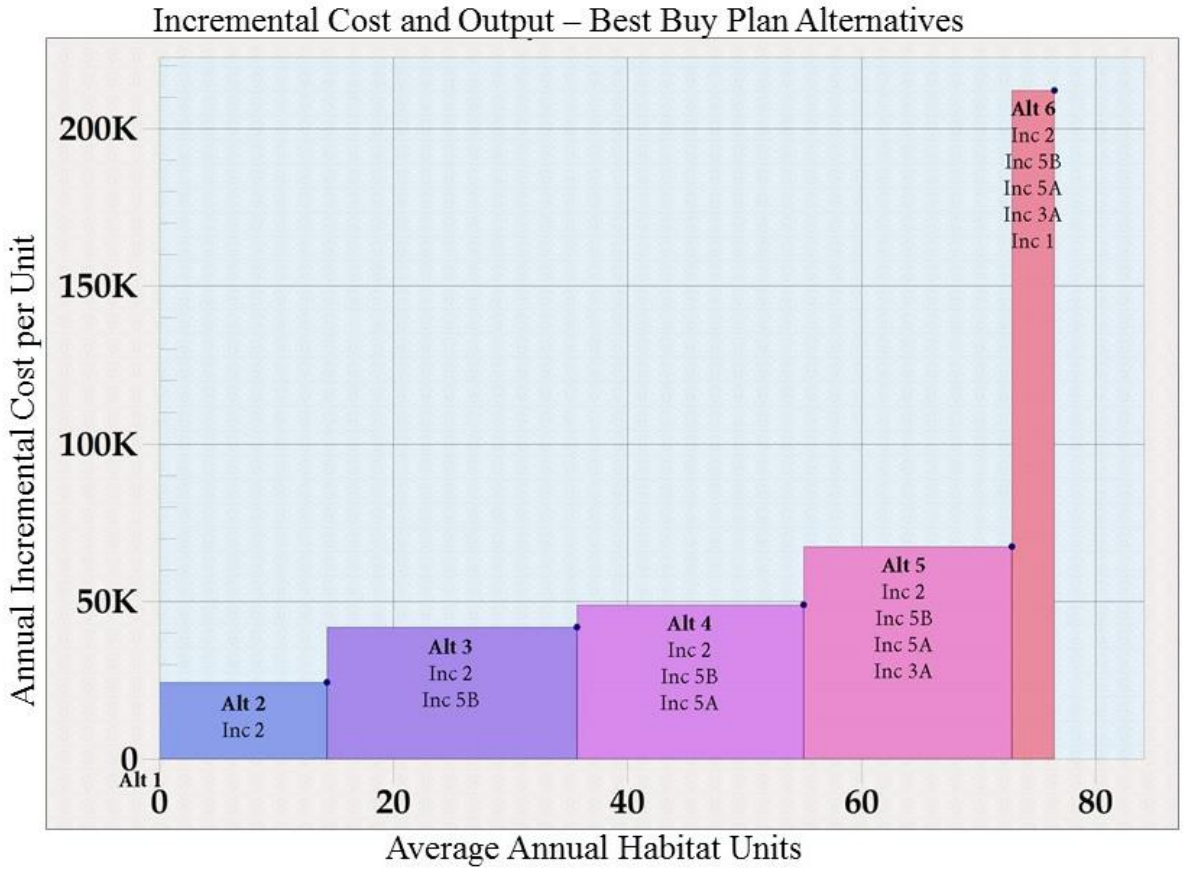

Figure 2. Incremental Costs and Outputs of Alternatives

Identification of the NER Plan

The results of the CE/ICA do not determine a discrete decision; rather they inform the selection of an alternative. For ecosystem restoration studies, the recommended plan should be the justified alternative and scale having the maximum excess of monetary and non-monetary beneficial effects over monetary and non-monetary costs. In addition to the CE/ICA, the alternatives for this study were compared on contributions to planning objectives, environmental factors, and evaluation criteria established in USACE guidance as described in section 3.8 of the Feasibility Report. The plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with the Federal objective, is identified as the NER Plan. In this case, Alternative 5 reasonably maximizes benefits relative to costs and is therefore the NER Plan and the recommended plan for the Yuba River Ecosystem Restoration Feasibility Study.

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Quantity of Habitat Restored Calculations				
Increment	**Method – Budgetary Guidance EC 11-2-206 Table C-2-4**	**River Reach**	**Calculations using Budgetary Guidance**	**Result**
Collect and Transport above New Bullards Bar	For fish passage projects other than complete dam removal, report length of mainstem river up to next fish passage impediment multiplied by the width of river immediately upstream of the impoundment and 0.25 and by the efficiency of the fish passage. The 0.25 multiplier represents the fact that fish are restored to the reach, but that fish only represent one component of the habitat. In the absence of project specific information on fish passage efficiency, use 0.9 for nature-like bypass, 0.8 for rock ramp, and 0.6 for fish ladders for the efficiency multiplier. Note - Does not include reservoir; existing habitat is not part of restored area calculations.	**North Yuba**: from New Bullards Bar reservoir high water to Loves Fall (33.7 miles)	(33.7 miles x 5280 ft/mile x 100 ft bankfull width)} x (0.25 habitat factor x 0.6 efficiency multiplier) / 43560 sqft/acre	61.3 acres
Collect and Transport above Englebright	For fish passage projects other than complete dam removal, report length of mainstem river up to next fish passage impediment multiplied by the width of river immediately upstream of the impoundment and 0.25 and by the efficiency of the fish passage. The 0.25 multiplier represents the fact that fish are restored to the reach, but that fish only represent one component of the habitat. In the absence of project specific information on fish passage efficiency, use 0.9 for nature-like bypass, 0.8 for rock ramp, and 0.6 for fish ladders for the efficiency multiplier.	**Middle Yuba River** (including above Our House Dam): from North and Middle Yuba River confluence to waterfall above Our House Dam (35.1 miles) **South Yuba River**: from confluence with Yuba River to waterfall (34.9 miles) **Yuba River above Englebright Reservoir**: from Englebright reservoir high water to New Bullards Bar Dam (9.8 miles)	[(35.1 miles x 5280 ft/mile x 69.25 ft bankfull width) + (34.9 miles x 5280 ft/mile x 101.5 ft bankfull width) + (2.3 miles x 5280 ft/mile x 56 ft bankfull width) + (5.8 miles x 5280 ft/mile x 107 ft bankfull width) + (1.7 miles x 5280 ft/mile x 153 ft bankfull width)] x (0.25 habitat factor x 0.6 efficiency multiplier) / 43560 sqft/acre	126.96 acres

	Note - Does not include reservoir; existing habitat is not part of restored area calculations.			
Englebright Fish Ladder	For fish passage projects other than complete dam removal, report length of mainstem river up to next fish passage impediment multiplied by the width of river immediately upstream of the impoundment and 0.25 and by the efficiency of the fish passage. The 0.25 multiplier represents the fact that fish are restored to the reach, but that fish only represent one component of the habitat. In the absence of project specific information on fish passage efficiency, use 0.9 for nature-like bypass, 0.8 for rock ramp, and 0.6 for fish ladders for the efficiency multiplier. Note - Does not include reservoir; existing habitat is not part of restored area calculations.	**Middle Yuba River** (including above Our House Dam): from North and Middle Yuba River confluence to waterfall above Our House Dam (35.1 miles) **South Yuba River**: from confluence with Yuba River to waterfall (34.9 miles) **Yuba River above Englebright Reservoir**: from Englebright reservoir high water to New Bullards Bar Dam (9.8 miles)	[(35.1 miles x 5280 ft/mile x 69.25 ft bankfull width) + (34.9 miles x 5280 ft/mile x 101.5 ft bankfull width) + (2.3 miles x 5280 ft/mile x 56 ft bankfull width) + (5.8 miles x 5280 ft/mile x 107 ft bankfull width) + (1.7 miles x 5280 ft/mile x 153 ft bankfull width)] x (0.25 habitat factor x 0.6 efficiency multiplier) / 43560 sqft/acre	126.96 acres
Englebright Removal	For dam removal, measure the length of impoundment under normal flow conditions, multiply by the width of river immediately upstream of impoundment. Also, report length of mainstem river up to next fish passage impediment multiplied by width used above and multiplied by 0.25. The 0.25 multiplier represents the fact that fish are restored to the reach, but that fish only represent one component of habitat.	**Englebright reservoir**: from Englebright Dam to Englebright reservoir high water (9 miles) **Middle Yuba River** (including above Our House Dam): from North and Middle Yuba River confluence to waterfall above Our House Dam (35.1 miles) **South Yuba River**: from confluence with Yuba River to waterfall (34.9 miles)	[(9 miles x 5280 ft/mile x 153 ft bankfull width)/ 43560 sqft/acre] + {{[(35.1 miles x 5280 ft/mile x 69.25 ft bankfull width) + (34.9 miles x 5280 ft/mile x 101.5 ft bankfull width) + (2.3 miles x 5280 ft/mile x 56 ft bankfull width) + (5.8 miles x 5280 ft/mile x 107 ft bankfull width) + (1.7 miles x 5280 ft/mile x 153 ft bankfull width)] x 0.25 habitat factor} / 43560 sqft/acre}	378.5 acres

		Yuba River above Englebright Reservoir: from Englebright reservoir high water to New Bullards Bar Dam (9.8 miles)		
Englebright Tram/Bypass	For fish passage projects other than complete dam removal, report length of mainstem river up to next fish passage impediment multiplied by the width of river immediately upstream of the impoundment and 0.25 and by the efficiency of the fish passage. The 0.25 multiplier represents the fact that fish are restored to the reach, but that fish only represent one component of the habitat. In the absence of project specific information on fish passage efficiency, use 0.9 for nature-like bypass, 0.8 for rock ramp, and 0.6 for fish ladders for the efficiency multiplier. Note - Does not include reservoir; existing habitat is not part of restored area calculations.	**Middle Yuba River** (including above Our House Dam): from North and Middle Yuba River confluence to waterfall above Our House Dam (35.1 miles) **South Yuba River**: from confluence with Yuba River to waterfall (34.9 miles) **Yuba River above Englebright Reservoir**: from Englebright reservoir high water to New Bullards Bar Dam (9.8 miles)	[(35.1 miles x 5280 ft/mile x 69.25 ft bankfull width) + (34.9 miles x 5280 ft/mile x 101.5 ft bankfull width) + (2.3 miles x 5280 ft/mile x 56 ft bankfull width) + (5.8 miles x 5280 ft/mile x 107 ft bankfull width) + (1.7 miles x 5280 ft/mile x 153 ft bankfull width)] x (0.25 habitat factor x 0.6 efficiency multiplier) / 43560 sqft/acre	126.96 acres
Daguerre Point Dam Bypass	For fish passage projects other than complete dam removal, report length of mainstem river up to next fish passage impediment multiplied by the width of river immediately upstream of the impoundment and 0.25 and by the efficiency of the fish passage. In the absence of project specific information on fish passage efficiency, use 0.9 for nature-like bypass, 0.8 for rock ramp, and 0.6 for fish ladders for the efficiency multiplier. Existing passage at DPD is achieved through fish ladder (0.6 efficiency multiplier). Improvement will be evaluated as relative improvement from existing condition (ie. FWP = bypass (assume benefit	**Lower Yuba River above Daguerre Point Dam**: from upstream of sediment impoundment to Englebright Dam (10.7 miles)	[(10.7 miles x 427 ft x 5280 ft/mile) x (0.25 habitat factor x 0.2 passage efficiency x 0.1 channel capacity)] / 43560 ft2/acre	2.77 acres

	equivalent to "rock ramp"/Step pools" 0.8; FWOP = ladder, 0.6; therefore use final efficiency multiplier of 0.8 - 0.6 = 0.2). Apply additional multiplier factor of 0.1 to account for partial channel capacity (10%) solution. Note - Does not include reservoir; existing habitat is not part of restored area calculations.			
Daguerre Point Dam Step Pools	For fish passage projects other than complete dam removal, report length of mainstem river up to next fish passage impediment multiplied by the width of river immediately upstream of the impoundment and 0.25 and by the efficiency of the fish passage. In the absence of project specific information on fish passage efficiency, use 0.9 for nature-like bypass, 0.8 for rock ramp, and 0.6 for fish ladders for the efficiency multiplier. Existing passage at DPD is achieved through fish ladder (0.6 efficiency multiplier). Improvement will be evaluated as relative improvement from existing condition (ie. FWP = rock ramp 0.8; FWOP = ladder, 0.6; therefore use final efficiency multiplier of 0.8 - 0.6 = 0.2). Note - Does not include reservoir; existing habitat is not part of restored area calculations.	**Lower Yuba River above Daguerre Point Dam**: from upstream of sediment impoundment to Englebright Dam (10.7 miles)	[(10.7 miles x 427 ft x 5280 ft/mile) x (0.25 habitat factor * 0.2 passage efficiency improvement)] / 43560 ft2/acre	27.7 acres
Daguerre Point Dam Removal	For dam removal, measure the length of impoundment under normal flow conditions, multiply by the width of river immediately upstream of impoundment. Also, report length of mainstem river up to next fish passage impediment multiplied by	**Daguerre Point Dam Impoundment**: The impoundment/reservoir of Daguerre Point Dam was considered equal to the	[(1.9 miles x 5280ft/miles x 427 ft) / 43560 ft2/acre] + [(10.7 miles x 427 ft x 5280 ft/mile) x (0.25 habitat factor) / 43560 ft2/acre]	236.79 acres

	width used above and multiplied by 0.25. The 0.25 multiplier represents the fact that fish are restored to the reach, but that fish only represent one component of habitat.	hydraulic/geomorphologic effect of the dam (1.9 miles) **Lower Yuba River above Daguerre Point Dam**: from upstream of sediment impoundment to Englebright Dam (10.7 miles)		
Habitat Increment 1*	Footprint acreage		N/A	19.3 acres
Habitat Increment 2*	Footprint acreage		N/A	23.3 acres
Habitat Increment 3*	Footprint acreage		N/A	108.5 acres
Habitat Increment 4*	Footprint acreage		N/A	15 acres
Habitat Increment 5*	Footprint acreage		N/A	104.3 acres

*Habitat increment acreages are original footprints; later in the planning process, the footprints were reduced (see Table 3-8).