Appendix 5.1

Accessibility Statement

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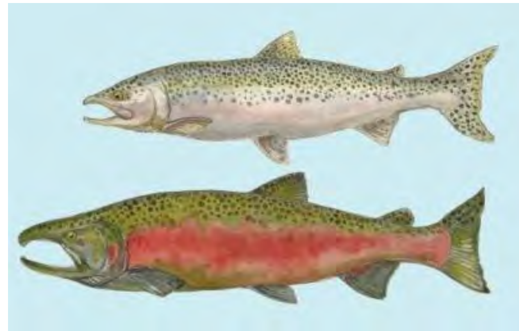
DRY CREEK FISH HABITAT ENHANCEMENT:
CONCEPTUAL DESIGN REPORT

Final Report • July 2012



DRY CREEK:
WARM SPRINGS DAM
TO THE RUSSIAN RIVER
SONOMA COUNTY, CA

PREPARED FOR

SONOMA COUNTY WATER AGENCY
404 AVIATION BOULEVARD
SANTA ROSA, CA 95403

SONOMA COUNTY WATER AGENCY

FINAL

DRY CREEK FISH HABITAT ENHANCEMENT FEASIBILITY STUDY: CONCEPTUAL DESIGN REPORT SONOMA COUNTY, CA

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DRY CREEK FISH HABITAT ENHANCEMENT FEASIBILITY STUDY: CONCEPTUAL DESIGN REPORT

EXECUTIVE SUMMARY

Introduction

Dry Creek is home to native threatened and endangered fish, including coho salmon, Chinook salmon, and steelhead trout. The National Marine Fisheries Service has determined that the operation of Warm Springs Dam could threaten the survival of coho salmon and steelhead trout in Dry Creek, and in 2008 issued a Biological Opinion requiring improvements to their habitat. In particular, key goals identified for habitat enhancement in Dry Creek include development of rearing and refugia habitat for Central California Coast (CCC) coho salmon (*Onchorhynchus kisutch*) and CCC steelhead trout (*O. mykiss*).

Habitat enhancement in Dry Creek is seen as a significant opportunity for the recovery of coho and steelhead in the region due to the relative abundance of cool water in the late summer months which is atypical of streams in the region. Late summer rearing conditions are considered a critical bottleneck for species recovery. Minimum habitat restoration goals are detailed more specifically in the Biological Opinion for Water Supply, Flood Control and Channel Maintenance Activities (RRBO: NMFS 2008).

The RRBO requires six miles of fish habitat enhancements to be implemented over the 13.9 mile long study reach. Generally, Dry Creek currently lacks high quality main channel and off-channel habitats which are critical for juvenile coho and steelhead rearing. The proposed habitat enhancements aim to directly address these deficiencies. The RRBO lays out a timeline for the habitat work, which will ultimately result in over six miles of habitat enhancement in Dry Creek implemented through three phases by 2020.

The Dry Creek Conceptual Design Report has been prepared to facilitate the implementation of fish habitat enhancement in Dry Creek in order to meet the requirements of the RRBO. Following the Feasibility Study Report (Inter-Fluve 2011a), this document presents conceptual designs for groups of off-channel and main-stem habitat enhancements throughout the study reach, and provides information to enable project evaluation, prioritization, selection, and planning for implementation of enhancements.

Summary of Conceptual Designs

Conceptual designs were developed based on the current understanding of geomorphic processes in Dry Creek, as described in the Dry Creek Feasibility Study Report (Inter-Fluve 2012).

Main-channel enhancements include riffle construction, pool enhancement, main channel remeandering, and logjam installation. Off-channel enhancements include backwater channel construction, side channel construction, and the creation of winter refuge habitat. The main channel and off-channel habitat enhancements prescribed for each enhancement subreach are presented in the subreach-scale concept design booklets (Appendices A – N), which include corresponding cost estimate information.

Spatial Organization

Dry Creek was stratified into three process-delineated segments in the feasibility study report (Inter-Fluve 2012). These include the upper segment (Warm Springs Dam to Pena Creek), the middle segment (Pena Creek to River Mile 3), and the lower segment (River Mile 3 to Russian River confluence). Within these three segments, the conceptual designs developed for lower Dry Creek include main channel and off-channel enhancements organized by the 16 habitat inventory reaches first delineated in the Dry Creek Current Conditions Report (Inter-Fluve 2010). These reaches were used to organize the field and analytical work accomplished in the current conditions and feasibility analysis phase. Within the 16 reaches are nested 25 'enhancement' subreaches, which are logical groupings of the off-channel and main-channel enhancement opportunities. In some cases, only one enhancement subreach fits into an inventory reach. In these cases, it is typically because the inventory reach was relatively short to begin with, or there was relatively limited enhancement potential. In other cases, the inventory reaches may be split into 2 or 3 enhancement subreaches. Each subreach may contain multiple off-channel and main-channel enhancements

Project Evaluation and Prioritization

Prioritization of enhancement subreaches for implementation includes two main phases: project ranking and project selection. In order to summarize potential habitat benefits to assist with project ranking, three evaluation metrics were assessed for each of the 25 enhancement subreaches. These metrics are based on 1) potential summer coho rearing habitat, 2) incremental winter rearing and refugia habitat, and 3) total potential enhanced habitat. Following application of the metrics, the enhancement subreaches were further organized into Tier 1 and Tier 2 within each study reach segment (lower, middle and upper). Over the three study reach segments, the ranking phase resulted in a total of sixteen Tier 1 enhancement subreaches (out of twenty-five total).

Project selection represents the second phase of project prioritization. In this phase, the results of the ranking phase will be evaluated alongside other critical factors such as access, cost, and overall distribution along Dry Creek. Project selection will be ongoing over the next several years as the Water Agency and its partners identify opportunities to implement habitat enhancement to meet the requirements of the RRBO.

Planning-level Conceptual Design Cost Opinions

Planning-level conceptual design cost opinions were prepared for comparison between alternative enhancement subreaches and for planning purposes. In the report, these estimates are summarized in terms of total costs and in terms of cost per unit habitat area.

ACKNOWLEDGEMENTS

We would like to acknowledge the following groups for their respective contributions to this study:

Sonoma County Water Agency Staff

Dry Creek Property Owners

Dry Creek Advisory Group Members

National Marine Fisheries Service Staff

California Department of Fish and Game Staff

U.S. Army Corps of Engineers Staff

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1. INTRODUCTION

Dry Creek, a major tributary to the Russian River, flows 32 miles from its source at Snow Mountain near Hopland, CA to its mouth near Healdsburg in Sonoma County, California (Figure 1). Warm Springs Dam (WSD) at river mile (RM) 13.9 divides the rugged terrain and steeper channel of the upper watershed from the relatively flat agricultural valley and lower gradient channel that is present below the dam. Since 1984, WSD is operated by the Army Corps of Engineers to control floods, and by the Sonoma County Water Agency (Water Agency) to supply potable water to 600,000 consumers in Sonoma and northern Marin Counties. The dam is one of multiple facilities that comprise the Russian River Water Supply and Flood Control Project (RRWSFC).

The current geomorphology of lower Dry Creek is a result of the interaction between watershed characteristics, including local geology, hydrology, and vegetation; the legacy of channel evolution and response to land management changes; and the ongoing influence of flow management. Lower Dry Creek is an incised, perennial, alluvial gravel bed stream that has responded to significant human induced hydrologic and geomorphic change over the past 150 years. Following base-level lowering, widespread systemic incision occurred which led to the development of an incised stream system flowing through a narrow active channel zone inset 10 – 30 feet below the adjacent agricultural valley floor. Modern hydrology in Dry Creek is characterized by greatly reduced flood peak magnitudes and elevated summer base-flows. Regulated hydrology has resulted in the establishment of dense riparian forest vegetation on bar features, and a reduced ability of the channel to erode vegetated floodplain surfaces due to a reduction of flood peak magnitudes by several hundred percent.

Dry Creek is home to ESA-listed native fish, including Central California Coast (CCC) coho salmon (Onchorhynchus kisutch; endangered) and steelhead trout (O. mykiss; threatened), and California Coastal (CC) Chinook salmon (O. tshawytscha; threatened). The National Marine Fisheries Service (NMFS) has determined that the operation of WSD could threaten the survival of coho salmon and steelhead trout in Dry Creek, and/or adversely affect their critical habitats. In 2008 NMFS issued the Biological Opinion for Water Supply, Flood Control and Channel Maintenance Activities for the Russian River Watershed (RRBO; NMFS 2008), which requires improvements to existing fish habitat in Dry Creek. In particular, key requirements focus on rearing and refugia habitat for coho and steelhead. Generally, Dry Creek currently lacks high quality main channel and off-channel habitats which are critical for juvenile coho and steelhead rearing. The proposed habitat enhancements aim to directly address these deficiencies.

Dry Creek is seen as a significant opportunity for recovery of coho and steelhead in the region due to the relative abundance of cool water in the late summer months which is atypical of streams in the region. Late summer rearing conditions are considered a critical bottleneck for species recovery. Habitat enhancement goals for Dry Creek are discussed later in this document and detailed more specifically in the RRBO (NMFS 2008). The RRBO lays out a timeline for the habitat work, which will ultimately result in six miles of habitat enhancement in Dry Creek by 2020. This Conceptual Design Report presents conceptual designs for over 4,000,000 ft^2 of enhancements spaced over the 13.9 mile project reach between WSD and the Russian River (hereafter referred to as 'lower Dry Creek'). The conceptual designs were developed specifically to meet the goals laid out by the RRBO.

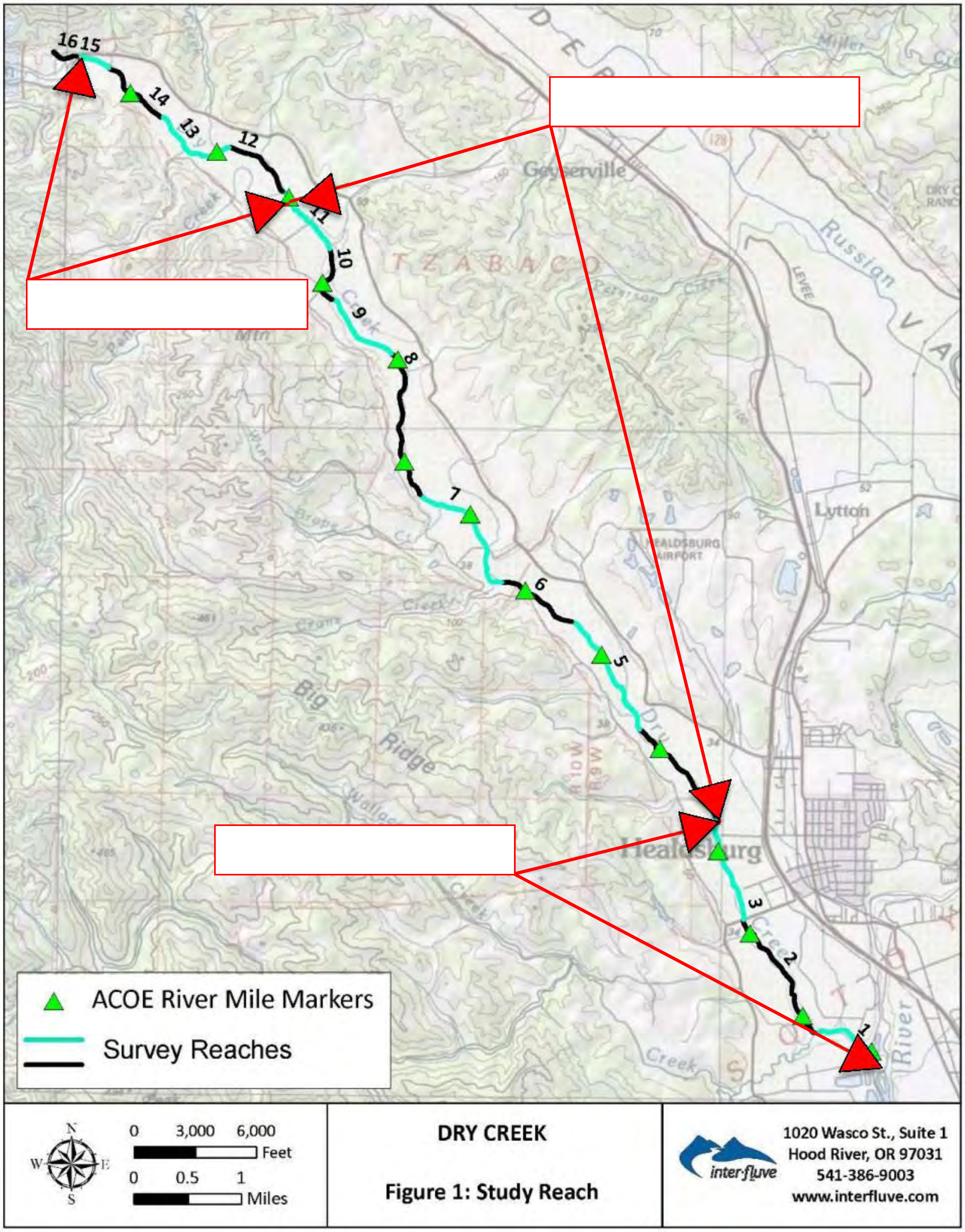

Figure 1. Map of Lower Dry Creek between Warm Springs Dam and the Russian River.

2. SCOPE OF WORK

The feasibility study is being conducted in three phases. Phase 1 included inventory and assessment of current conditions along Dry Creek between Warm Springs Dam and the confluence with the Russian River. Completed between the summer of 2009 and the spring of 2010, the final version of the Dry Creek Current Conditions Report was issued in December 2010 (Inter-Fluve 2010). Conducted between the summer of 2010 to the winter of 2011, Phase 2 included detailed feasibility assessment of habitat enhancement approaches. The Draft Feasibility Study Report was issued in April 2011 and finalized in July 2012.

The third phase of the feasibility study (the subject of this draft report), involved development of conceptual designs for habitat enhancement approaches deemed feasible as a result of the feasibility assessment. The conceptual design phase has included the following tasks:

- Development of conceptual designs for the study reach, based on the results of the feasibility assessment (Inter-Fluve 2012),
- Development of planning level cost estimates for the conceptual designs,
- Development and application of evaluation metrics to enable comparative review of project opportunities for which conceptual designs have been prepared, and
- Summarize the results of application of the evaluation metrics.

3. PREVIOUS STUDIES BY INTER-FLUVE

As noted above, the feasibility study has resulted in two reports which provide a foundation for the conceptual designs. These reports are summarized below:

- *Final Current Conditions Report, Dry Creek from Warm Springs Dam to the Confluence with the Russian River* (Inter-Fluve 2010): This report includes a summary of watershed context and hydrology, an assessment of stream geomorphology based on available data and field observations, and a detailed summary of the fish habitat inventory completed in summer 2009.
- *Final Habitat Enhancement Feasibility Study Report, Dry Creek from Warm Springs Dam to the Confluence with the Russian River* (Inter-Fluve 2012): This report includes additional quantitative assessment of stream geomorphology and trajectory, and assessment of the feasibility of fish habitat enhancement to meet the habitat goals of the RRBO on Dry Creek.

The reader is referred to the above reports for more detailed discussions of the results of the current conditions and feasibility assessments.

4. ENHANCEMENT GOALS, OBJECTIVES AND DESIGN CRITERIA

The following section describes the goals, objectives and assumed design criteria for the Dry Creek Habitat Enhancement Project which guided the development of the conceptual designs.

4.1 PROJECT GOAL

In the broadest sense, the goal of the Dry Creek Habitat Enhancement Project is to:

- Enhance channel and riparian conditions on lower Dry Creek to benefit juvenile life stages of ESA-listed coho salmon and steelhead trout, which will aid in their recovery within the region.

4.2 ATTENDANT OBJECTIVES

Attendant to the project goal, the following are the primary objectives for the Dry Creek Habitat Enhancement Project:

- Enhance summer rearing habitat for coho salmon and steelhead to 'near-ideal' conditions,
- Enhance summer rearing habitat for steelhead to 'near-ideal' conditions,
- Create refugia from winter high-flow releases for both coho salmon and steelhead,
- Enhance habitat, and to the extent feasible, minimize impacts on private property and infrastructure.
- Enhance habitat without adversely affecting Chinook salmon.

4.3 DESIGN CRITERIA

The RRBO lays out criteria which define high quality rearing habitat conditions for coho salmon and steelhead trout. These criteria were combined with additional considerations to constitute the preliminary design criteria for the project, summarized in Table 1. Although the RRBO is a 15-year guiding document, NMFS and CDFG will likely require the Water Agency to maintain functioning coho and steelhead habitat beyond this time frame. It is anticipated that the habitat enhancements will continue to provide habitat benefits and be maintained in approximately similar quantities for 25 years. The Water Agency, NMFS, and CDFG are engaged in an adaptive management planning process that will specify goals, objectives, and monitoring methods to verify the effectiveness and longevity of habitat enhancements (Porter et al. 2011).

Table 1. Dry Creek Fish Habitat Enhancement Design Criteria

Feature/Issue	Criteria	Remarks/Reference
Fish Habitat Design Criteria		
a. Target flow range	• 110 to 175 cfs	• Flow range outlined in RRBO
b. Pool Abundance	• 33% to 67% of all habitats	• RRBO
c. Pool : riffle ratio	• 1:2 to 2:1	• RRBO
d. Water depth	• 2 to 4 feet in pools	• RRBO
e. Velocity in rearing habitat	• < 0.2 ft/s • Reduced from present conditions to extent practicable	• RRBO • Primarily able to be met in off-channel habitats and shelter habitats associated with large woody debris • Local velocities in mainstem pool habitat
f. Cover	• >30% of habitat bottom obscured by cover	• RRBO • due to depth, surface turbulence, or presence of structures such as logs, debris piles, boulders, or overhanging banks and vegetation
g. Refugia habitat	• Should provide high quality shelter during high flow releases	• RRBO
h. Longevity of habitat	• 25 years in approximately similar quantities though adjustments will occur	• Water Agency
Large Woody Debris Stability		
i. Mobility of LWD	• 25 year event	• In most cases, stability requirements similar between Q2 and Q100-year events.
j. LWD Decay	• 15-25 year period	• Typical decay rates for coniferous species
Vertical Stability		
k. Design stability for riffles	• 25 year event	• In most cases, design substrate sizing is similar between Q2 and Q100 events
Lateral Stability		
l. Stream boundaries constructed inside the channel corridor	• 5 year event	• Relatively deformable boundary construction
m. Stream boundaries constructed along margin of the channel corridor	• 50-year event	• Less deformable boundary construction
n. Stream boundary construction techniques	• Employ techniques that also provide margin shelter and riparian habitat	• Biotechnical techniques

Table 1. Dry Creek Fish Habitat Enhancement Design Criteria

Feature/Issue	Criteria	Remarks/Reference
Planform Stability		
o. Avulsion into off-channel habitat	• None within first 5 years following construction, notwithstanding extraordinary hydrologic events • Future avulsion is acceptable provided habitat criteria continue to be met	• Address risk of avulsion through design overbank roughness created with LWD
Riparian Vegetation		
p. Invasive species	• Endeavor to eliminate invasive vegetation	
q. Native revegetation	• Encourage diverse, less dense native community	
Construction Period		
r. Impacts to existing resources	• Minimal	
s. Impacts to adjacent operations	• Minimal	
t. Impacts to infrastructure	• None	

5. GENERAL ENHANCEMENT APPROACHES

Fish habitat enhancements will emphasize natural stream characteristics, or those which evolve through a given stream's geomorphology. By using enhancement practices that emulate natural geomorphic effects, the benefits provided to juvenile coho and steelhead will be optimized by increasing the amount of high quality rearing habitat. Because these approaches occur within a dynamic system, they should not be expected to be static through time. However, they should provide approximately similar quantities of habitat through time within the project reach, and the planned adaptive management approach will assist with this. Design concepts have been developed based on our understanding of physical processes in each segment of Dry Creek. The Dry Creek Feasibility Report laid out the different processes occurring in the upper, middle and lower 'segments' of Dry Creek, each of which contain several of the 'inventory reaches' first delineated in the Current Conditions Report (Figure 1; Inter-Fluve 2010).

Channel processes and dynamics vary along the length of Dry Creek, which suggest tailoring the enhancement approach in each segment to match the prevailing fluvial processes at each location. In general, the approaches may fall in a range defined by strongly process-reliant at one end, and direct habitat construction at the other end. Accordingly, Lower Dry Creek has been split into three segments based on dominant physical processes and other shared characteristics: 1) upstream of Pena Creek (RM 11 to 13.7), 2) Pena Creek to the grade control sills (RM 3 to 11), and 3) from the grade control sills to the Russian River confluence (RM 0 to 3); see Figure 1. Generally, enhancement projects will be identified to include a series of main channel and off-channel enhancements which will provide continuity of juvenile coho and steelhead habitats through a given project reach.

The prevailing physical functions and implications for developing fish habitat of the desired character within each Dry Creek segment (upper, middle, lower) include the following:

- *Upper Segment:* Upstream of Pena Creek, construction of late-successional habitat was assessed to be feasible with low risk of the constructed habitat being compromised due to nuisance sediment deposition or other factors. Conversely, relying on channel processes to create the habitat was deemed to have low feasibility due to the lack of sediment supply and highly regulated hydrology. Generally, enhancement through direct habitat construction can be considered as having low risk of failure in this segment relative to other segments.

- *Middle Segment:* The middle segment stretching from RM 3 - 11 has greater sediment supply than the upstream reach due to the unregulated tributaries which enter Dry Creek below WSD. This increases the risk for nuisance sedimentation impacts to potential directly-constructed off-channel habitat. This risk can be mitigated through appropriate site selection and other considerations. In this segment, off-channel enhancements may shift in character due to channel processes, again dependent on the characteristics of each site. Conversely, several large off-channel opportunities may lend themselves to a more dynamic, process-focused approach, or combined approach. In summary, the preferred enhancement approach to each site is more variable in this segment than the other two segments, and careful consideration of the attributes of each proposed location will determine the corresponding advisable enhancement strategy.

- *Lower Segment:* In the downstream segment (RM 0-3), there is high risk that a direct habitat construction approach would be compromised by sedimentation due to the backwater influence of the Russian River (Figure 2). Conversely, enhancement that relies on a modified process-driven approach likely provides the best option in this segment. Based on observations of existing intact rearing habitats, it is possible that fluvial processes may be sufficiently intact to create target habitats over time provided the stage is set for habitat development to occur.

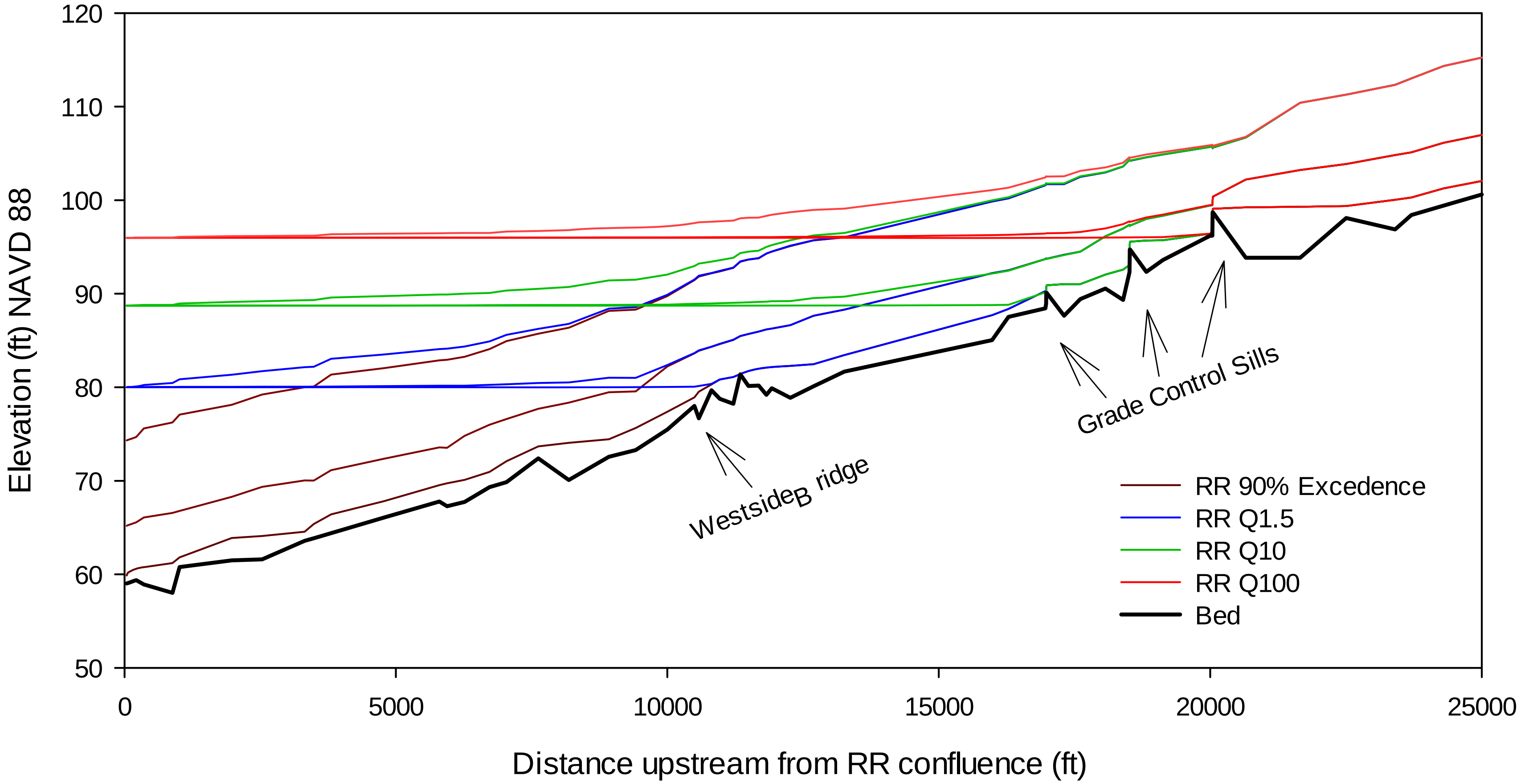

Figure 2. Model results predicting Dry Creek water surface elevations at 110 cfs, Q1 and Q10 in Dry Creek for 4 different flow levels in the Russian River, from Inter-Fluve 2012.

6. THE ENHANCEMENT TOOLBOX

Conceptual designs created for the enhancement subreaches emphasize natural stream characteristics, or those which evolve through a given stream's geomorphology. By using enhancement practices that emulate natural geomorphic effects, the benefits provided to juvenile coho and steelhead will be optimized by increasing the amount of high quality rearing habitat. Because these approaches occur within a dynamic system, they should not be expected to be static through time. However, they should provide approximately similar quantities of habitat through time within the project reach, and the planned adaptive management approach will assist with this. The following paragraphs describe the primary enhancement approaches applied to the conceptual designs included in Appendices A through N. See the Feasibility Study Report (Inter-Fluve 2012) for more detail on these approaches.

6.1 BACKWATER CHANNELS AND ALCOVES

Backwater channels, alcoves and ponds (Figure 3 and Figure 4) are areas off to the side of the stream that in summer connect to the main stream only at their downstream end. During this time, water backs into these areas, and has very low or no current. In addition to still water, logs that protrude into or float on the water, floating and submerged vegetation, and surrounding tall vegetation make these areas very attractive to juvenile fish. They use these areas to search for food, rest and to avoid predators. During winter periods, these areas will continue to have quiet water despite occasional high flows moving through them. In Dry Creek, this type of habitat will be primarily constructed in wider areas of the creek. This type of habitat provides the greatest opportunity to meet the target velocity criteria specified in the RRBO (Inter-Fluve 2012). Construction of these areas will include excavation to achieve desired grades relative to the summer water surface elevation and include placement of logs at appropriate locations, planting of aquatic vegetation and management of surrounding vegetation. The bottom grades for these areas have been set at 4 feet below the summer water surface elevations.

Based on repeat observations of backwater habitats in Dry Creek and assessment of the response of these habitats to high flow events, and monitoring of constructed side channels on other streams, Inter-Fluve (2012) developed guidelines to inform design of this habitat type on Dry Creek (Table 2). The primary challenges to the longevity of constructed backwater habitats are nuisance sedimentation and downstream changes in the main channel affecting the hydraulic control for the backwater habitat. Of the backwater channels reviewed on Dry Creek to date, those whose upstream ends were located a moderate distance from the active channel, and/or with a section of hydraulically rough floodplain between the upstream channel and the habitat were substantially less affected. These considerations will promote the longevity of the constructed habitat. Nevertheless, some degree of sedimentation in these areas will be unavoidable, and this issue should be tracked through the adaptive management program. Over the length of Dry Creek, there will be variability between the constructed backwater channels in terms of sedimentation and adjustment to flood flow. These responses can be expected to varying degrees over the 25-year horizon assigned to the project.

Figure 3. Conceptual depiction of backwater channel and alcove.

Figure 4. Conceptual depiction of backwater pond feature.

Table 2. Considerations for design of backwater channels on Dry Creek, based on field observations of similar habitats on Dry Creek, and observations of constructed side channel evolution on other project sites.

Consideration	Relevant Failure Mode
Outlets should not be located in depositional zones (e.g., riffles)	Nuisance sedimentation
Moderate distance from the active channel at the upstream end, and/or	Nuisance sedimentation
Hydraulically rough zone between active channel and upstream end	Nuisance sedimentation
A robust control on channel grade should be located downstream of the outlet (e.g., riffle)	Abandonment by loss of hydraulic control.

Substantial volumes of large woody debris will be installed in the backwater habitats. These installations will be overtopped by the full range of flood flows. In order to remain in the enhancement areas over a prolonged period to continue to provide habitat value, the large woody debris must either be large enough that it cannot be transported by the stream, or be ballasted to prevent its mobilization. Because it is not realistic to supply the size of large woody debris that would be self-stable in the reach (i.e., old growth logs), the large woody debris installed in Dry Creek will be ballasted to emulate the stability characteristics of much larger logs. Large woody debris will be ballasted through a range of techniques which will include partial burial, and cabling to other logs, existing mature trees, timber piles, snags, and/or boulders.

6.2 Side Channels

Side channels run parallel to the main stream and connect at both ends, including during the summer (Figure 5). The flow of the stream is split between the two channels. This serves to reduce the stream current, which in combination with pools and logs in the water, make these areas attractive to coho salmon and steelhead trout. The fish use these areas to search for food, to rest and to avoid predators. In Dry Creek, this type of habitat will also be primarily constructed in wider areas of the creek. In some of these areas, old abandoned channels may be excavated to provide enhanced side channels. Construction of these areas will entail excavation to form the channel, riffles and pools; placement of logs at appropriate locations, and management of the surrounding vegetation.

Based on repeat observations of backwater habitats in Dry Creek and assessment of the response of these habitats to high flow events, and monitoring of constructed side channels on other streams, Inter-Fluve (2012) developed guidelines to inform design of this habitat type on Dry Creek (Table 3).

Figure 5. Conceptual depiction of side channel.

Table 3. Consideration for design of side channels on Dry Creek, based on observations of similar habitats on Dry Creek following a high water event, and observations of constructed side channel evolution on other project sites.

Consideration	Relevant Failure Mode
Inlets and Outlets should not be located in depositional zones (e.g., riffles)	Nuisance sedimentation
Side channel inlet alignment should be oblique to upstream main channel alignment	Nuisance sedimentation, debris blockage
Sediment competency should be balanced with the main channel	Nuisance sedimentation
A robust control on channel grade should be located downstream of the outlet (e.g., riffle)	Abandonment by loss of hydraulic control.

6.3 LOG JAMS

A log jam is an accumulation of logs that may be constructed in an area where it would be beneficial to initiate or stabilize a turn or fork in the channel (Figure 6). The log jam serves to anchor the stream's location by being an immobile object along one or both banks, acting similar to a bridge abutment or a natural bedrock outcrop. Deep pools may form next to log jams through the interaction of the logs and flowing water, creating excellent fish habitat. To create a log jam, an area is excavated and then logs are stacked and knit together with boulders and "snags" (trunks of dead trees that remain standing vertical to the horizon). This combination stabilizes the log jam during floods. Similar to the descriptions above for large woody debris in backwater and pool habitats, large woody debris in log jams will be ballasted through a range of techniques to enhance its longevity in the reach.

Figure 6. Conceptual depiction of a log jam.

6.4 RIFFLE CONSTRUCTION AND POOL ENHANCEMENT

Riffles are areas where the streambed is steeper and the current is swift (Figure 7). Riffles play a key role in controlling the elevation of the streambed and releasing the stream's energy so that the current flowing through adjoining pools is slower during the summer period. They are also important for food production. Riffle habitat was found to be relatively lacking during the 2009 habitat inventory, which leads to long flatwater and pool habitat units with swifter than desired velocities and that lack complexity (Inter-Fluve 2010). Riffle habitat is lacking because Dry Creek has evolved to a condition where it is very efficient at transporting the sediment that is supplied to the stream downstream of WSD (Inter-Fluve 2012).

Pools are deeper areas of the stream which in a healthy stream provide key habitat for young fish because currents are slow, the flow patterns are diverse, and fish can hide beneath logs that project into the water (Figure 8). Proposed pool enhancement in the enhancement areas will act to increase the complexity and diversity of habitat for young fish, and create areas that have sheltered currents that young fish prefer. This will be accomplished with selected grading of existing pool features and the installation of large woody debris along the pool margins. Additionally, as described above, pool velocities will be reduced due to riffle construction.

Construction of riffles is proposed to provide key grade control for backwater habitats and to improve the quality of the adjoining pools for fish. The riffles are designed to backwater the adjacent upstream pool in the summer operational discharge range, which will flatten the water surface through the pool and lead to reduced stream velocity. Although the riffles will reduce stream velocity through the existing pools, the primary locations in these habitats where the target velocity criteria specified in the RRBO will be met will be in shelter habitats associated with large woody debris and along the channel margins. Riffles are constructed with a well-mixed layer of small boulders, cobbles, gravel and sand across the stream, and entail excavation of portions of the existing streambed to prepare suitable subgrade conditions.

Figure 7. Conceptual depiction of riffle construction.

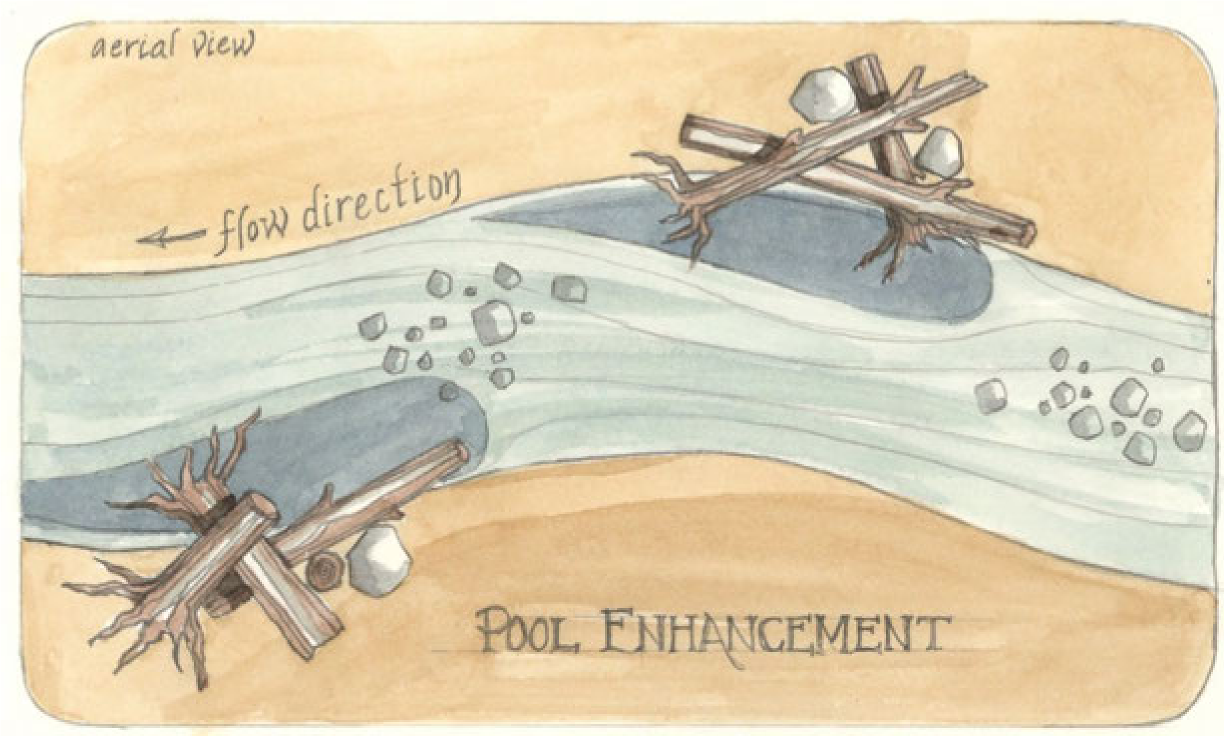

Figure 8. Conceptual depiction of pool enhancement.

6.5 WINTER REFUGE HABITAT

Winter refuge zones are areas where fish can escape high velocities in the main stream channel during elevated winter flows (Figure 9). Winter refuge habitats are floodplain areas that become inundated during frequent winter flow events. Juvenile fish have been shown to use inundated floodplain habitats and benefit from seasonal access to terrestrial food sources, such as insects that live in the soil, and terrestrial vegetation. Winter refuge habitats are created by lowering certain portions of the floodplain in order to increase the frequency of inundation. LWD will be placed in winter refuge habitats in order to provide additional cover, and enhance the flood refuge for juvenile salmonids. In addition to lowering floodplain areas to create winter refuge habitat, constructed backwater channels will provide winter refuge over a large range of flows.

Figure 9. Conceptual depiction of winter refuge habitat.

6.6 VEGETATION MANAGEMENT

Dry Creek has extensive vegetative growth along the channel, which includes many non-native or invasive weed species. In some areas, overly dense stands of vegetation impair stream function by channelizing the flow of the creek and acting like a levee, which forces energy into the creek bed, and results in pools that are too long, with water that moves too swiftly (Figure 10).

In general, the vegetation within the project area does not display the range of different successional classes indicative of a dynamic, properly functioning riparian system. Plant communities within intact riparian systems typically consist of a variety of vegetation communities that represent a range of different age classes and structural types. This pattern is largely a function of active floodplain evolution which is currently suppressed in the project reach.

Riparian vegetation management will include selective thinning of existing vegetation, removal of invasive weeds, and in some cases, replanting of native vegetation (Figure 11). A palette of native plants to be used in revegetation activities would be developed in consultation with the Sonoma County Stream Maintenance Program Manual (Horizon Water and Environment 2009).

Figure 10. Conceptual depiction of riparian vegetation before treatment.

Figure 11. Conceptual depiction of riparian vegetation after treatment.

6.7 STREAMBANK CONSTRUCTION

Streambank construction techniques may be applied at select locations to prevent the creek from migrating into high terraces, where graded slopes are steeper than 3 horizontal to 1 vertical, or where the main channel planform is adjusted. The technique used in a given location will depend on shear stresses acting on the bank, substrate, slope, and other factors. Potential streambank construction areas will be evaluated in greater detail once project reaches are selected.

6.8 DYNAMIC PROCESS-BASED FLOODPLAIN ENHANCEMENT

In the lower segment of Dry Creek, highly dynamic channel processes are present due to the supply of water and sediment from unregulated tributaries, and the influence of the Russian River which creates a backwater profile upstream into Dry Creek during floods. In this section of Dry Creek, the construction of late-successional habitats will not provide lasting habitat benefits due to the risk for sedimentation or other impacts on enhancements. A different approach was developed to utilize construction techniques designed to set the stage for the enhancement to be dynamic and continue to provide habitat benefits over time. In the lower two miles of Dry Creek, lateral floodplain surfaces and bars are perched high above the main channel. This approach would reconnect floodplain processes by shaving down lateral bars and excavating terraces to "reset" the connectivity between the channel and its floodplain which are not currently accessed frequently during storm events. Excavation, grading, and construction of logjams in strategic locations set the stage for a diverse suite of habitats to evolve and change over time (Figure 12).

This approach relies on both heavy construction techniques and natural processes to drive the evolution of habitats over time. This approach is based on the function of natural floodplain systems. In naturally-functioning channels, lateral, or off-channel, habitats may be short lived habitat types in floodplain systems. Alcoves and backwater channels may be destroyed and recreated as channels migrate across their floodplains, but the quantities or availability of off-channel and main channel habitat remains relatively stable. Although these habitats are constantly being created and destroyed over time, they typically offer high quality habitat and are responsible for a significant portion of juvenile coho productivity in many river systems. Juvenile coho utilize these lateral habitats to seek out terrestrial and aquatic food sources, to find refuge from the main channel, and avoid predators.

Dynamic process-based floodplain restoration in the lower segment will utilize a combination of floodplain grading, logjam construction, and excavation of off-channel habitats. Substantial excavation of the floodplain will serve to increase the frequency of inundation and create large areas of "Pilot Winter Refuge Habitat." Additionally, the excavation of "Pilot Off-Channel Habitat" will provide immediate summer habitat function, but this habitat is expected to change over time and potentially soon after construction. Logjams will be installed in strategic locations in order to encourage planform development in response to flood flows and sediment supply. Over time, pilot off-channel habitat will be become main channel habitat, and vice-versa.

Reconnecting the channel to its floodplain will allow for main channel and floodplain habitats to be dynamic over time.

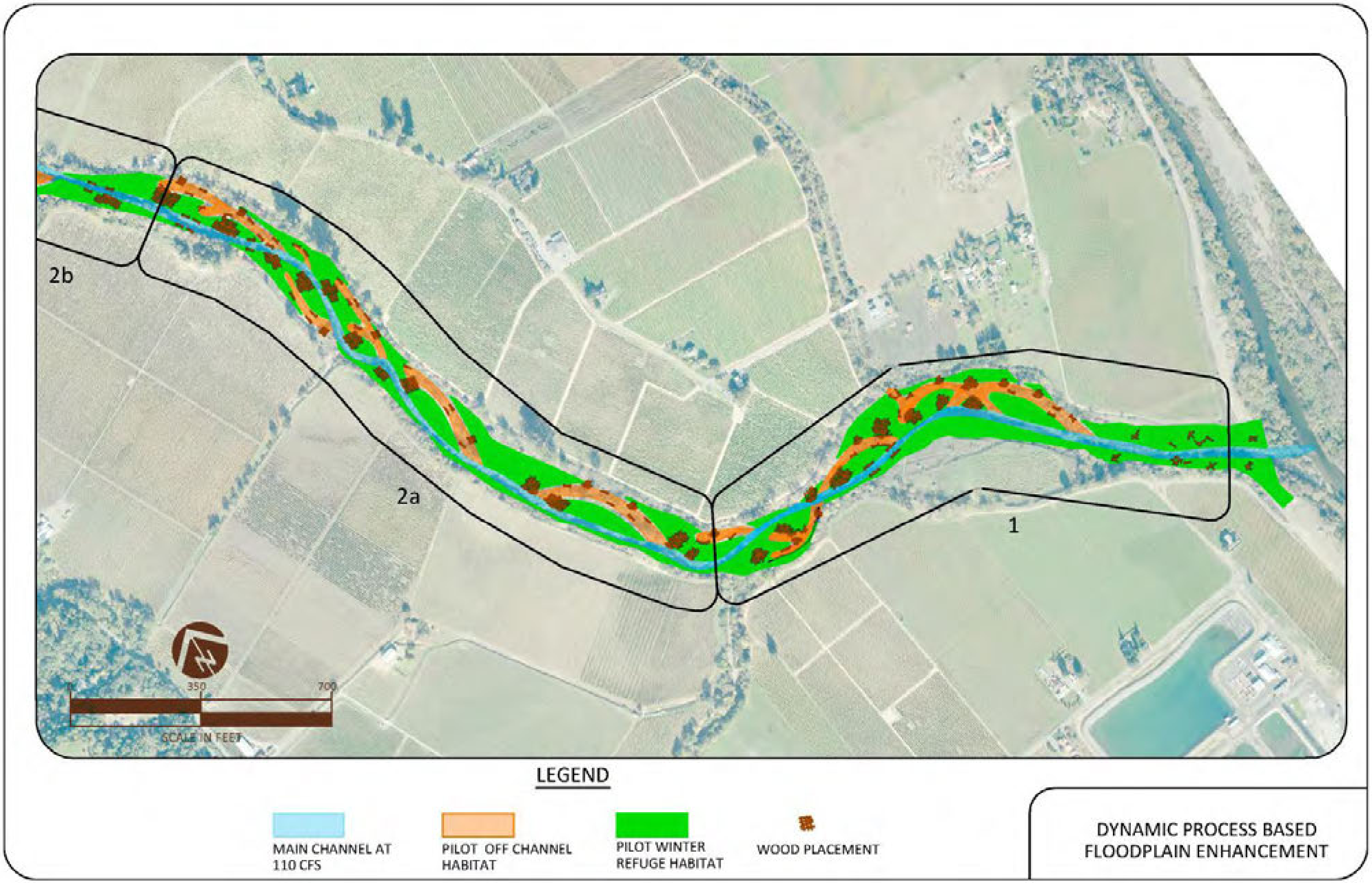

Figure 12. Depiction of dynamic, process-based enhancement in enhancement subreaches 1 and 2.

7. SPATIAL ORGANIZATION OF CONCEPTUAL DESIGNS

Habitat enhancements described in this report are organized based on the sixteen 'inventory reaches' first established in the Dry Creek Current Conditions Report (Figure 1, Table 4 : Inter-Fluve 2010). In order to organize the conceptual designs and to facilitate the project evaluation and prioritization process, the 16 inventory reaches have been further sub-divided into 25 'enhancement subreaches' (Figure 13). Each enhancement subreach contains multiple 'enhancement sites', which refer to groupings of individual habitat features such backwater channels, pools, riffles, log jams, etc[1]. This organization approach was implemented in order to result in a manageable number of potential alternate conceptual designs, which are at the scale that enhancements would be advanced towards implementation.

Within this report, the conceptual designs are presented in the form of conceptual design booklets, found in Appendices A-N. Each of these appendices describes the conceptual designs contained within a single inventory reach. The general outline for these design briefs includes a general overview of the inventory reach, and then one or more subsections that are dedicated to each enhancement subreach found within the inventory reach. The treatment of each enhancement subreach includes narrative description, conceptual plans, estimation of habitat benefits, and planning-level cost estimate.

It should be noted that inventory reaches 15, 11, 6, and 1 were not divided into enhancement subreaches due to either limited reach length, or lack of enhancement opportunities, within the reach. Additionally, conceptual designs are not presented for inventory reach 7, as this constitutes the one-mile demonstration reach that has been advanced towards implementation on an accelerated timeline. See the Demonstration Reach design report (Inter-Fluve 2011) for further detail on the enhancement approach in the Dry Creek demonstration reach.

In some cases the inventory reach boundaries did not match up perfectly with the enhancement concept locations for a given enhancement subreach. For example, the backwater channel at the lower end of reach 8 would necessarily be constructed paired with a riffle that is actually located at the upstream end of reach 7. In a case such as this, the grouping of the backwater channel and riffle into the same subreach was maintained, even though technically one of the features would fall into the adjacent inventory reach. In this way, in a few cases habitat units from outside of a given inventory reach or enhancement subreach were grouped with projects in an adjacent reach/subreach in order to employ a consistent methodology for grouping enhancement sites.

It is recognized that the exact groupings of enhancement sites selected for implementation may not precisely match the groupings of the concept designs as presented in this report. Appendix O provides a summary table of cost information at the individual site scale. This may facilitate contemplation of alternate groupings of projects during the evaluation and prioritization phase.

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[1] For example, 0.5 mile long Sub-Reach X may consist of a series of riffle/pool enhancements, one backwater channel, and one side channel. Cost estimates are developed to represent the cost associated with all of the enhancement "features" in Sub-Reach X. Predicted habitat benefits are reported assuming that all enhancement sites in Sub-Reach X are constructed together.

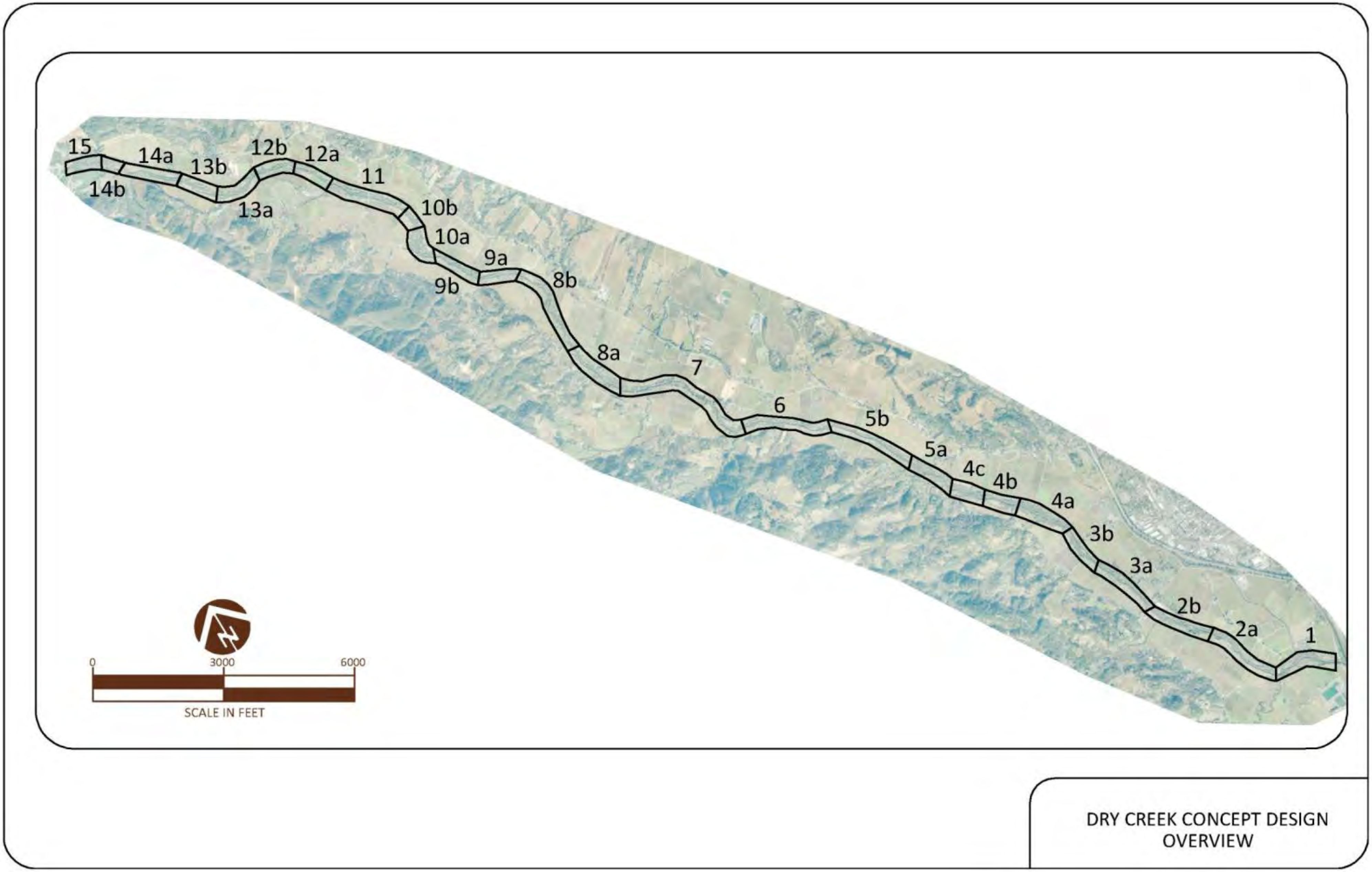

Figure 13. Overview of the 25 reaches and sub-reach for the conceptual design report. Note: Reach 7 is the demonstration reach, and is not included in the conceptual design report.

Table 4: Inventory reach and enhancement subreaches for lower Dry Creek.

Inventory Reach	Enhance-ment Subreach	DS end (RM)	DS end (landmark)	US end (RM)	US end (landmark)	Length (ft)
1	1	0.0	Dry Creek Mouth	0.7	Mill Creek	3550
2	2a, 2b	0.7	Mill Creek	2.0	Westside Road	7000
3	3a, 3b	2.0	Westside Road	3.0	Fault lineament 1150' DS Sill 1	5500
4	4a, 4b, 4c	3.0	Fault lineament 1150' DS Sill 1	4.1	1600' US Sill 3, US end check dam impoundment	5460
5	5a, 5b	4.1	1600' US Sill 3, US end check dam impoundment	5.3	Fault lineament, 150' DS Kelley Ck	6850
6	6	5.3	Fault lineament, 150' DS Kelley Ck	6.1	Bedrock outcrop, 475' DS Crane Ck	4150
7 *Demonstration Reach*	7	6.1	Bedrock outcrop, 475' DS Crane Ck	7.4	Bedrock outcrop, 950' US Grape Ck	6940
8	8a, 8b	7.4	Bedrock outcrop, 950' US Grape Ck	8.9	Change in relative confinement	7630
9	9a, 9b	8.9	Change in relative confinement	9.7	Change in relative confinement, and fault lineament	4190
10	10a, 10b	9.7	Change in relative confinement, and fault lineament	10.3	Tributary location	3390
11	11	10.3	Tributary location	11.0	Pena Ck	3755
12	12a, 12b	11.0	Pena Ck	11.7	Gradient shift, 700' DS Dutcher Ck	3670
13	13a, 13b	11.7	Gradient shift, 700' DS Dutcher Ck	12.4	Steep riffle	3930
14	14a, 14b	12.4	Steep riffle	13.3	Schoolhouse Creek confluence	4021
15	15	13.2	Schoolhouse Creek confluence	13.6	Bord Bridge	1980
16	16	13.6	Bord Bridge	13.9	Dam Outlet	1340

**Conceptual designs for the "Demonstration Reach", reach 7 are not included in this report.*

***It is not feasible to enhance Reach 16, as it is the dam tailwater channel. Therefore conceptual designs were not created for this reach.*

8. ASSUMPTIONS

The Conceptual Design Report and associated design development is based on ongoing planning-level and detailed hydraulic modeling and analysis of Dry Creek, as described in Inter-Fluve 2010, 2011, 2012. The conceptual designs that are presented reflect the best available information about the reaches and subreaches discussed in this report. The current versions of the planning-level and detailed hydraulic models have been developed from a combination of ground survey and LiDAR[2] data (Inter-Fluve 2011, 2012). The same data are implicit in the development of the design concepts and associated cost estimates, which reflect excavation volumes based on the same combination of data. Due to the nature of LiDAR data collected in the forested riparian zone along Dry Creek, it is likely that earthwork estimates contained in the cost estimates are conservative. As individual groupings of projects are prioritized and selected, future site-specific ground surveys will improve the precision and enable refinement of enhancement designs, and associated hydraulic modeling and cost estimates.

The earthwork associated with each off-channel enhancement site was estimated based on preliminary grading plans developed at each site with the data sets described above. The criteria that were used to develop the preliminary grading plans are summarized in Table 5.

Table 5. Criteria assumed for development of grading plans in off-channel enhancement areas.

Design Criteria Description	**Design Criteria Utilized**
Distance between project footprint and active channel	50 - 60 ft, minimum
Target wetted width for backwater channel grading	20 ft minimum
Target width for side channel grading	40 ft minimum
Side-slope assumptions	3 horizontal : 1 vertical, or flatter
Target invert elevation for off-channel habitat	4 ft below 110 cfs WSE
Target invert elevation for winter refuge	WSE @ 1000 cfs
Target invert elevation for pilot off-channel habitat (reaches 1 and 2)	4 ft below 110 cfs WSE
Target invert elevation for pilot winter refuge (reaches 1 and 2)	WSE @ 500 cfs

[2] LiDAR, also known as Light Detection And Ranging, is derived from data collected using a specialized aircraft-mounted instrument which can collect high precision topographic data over large areas. In some cases, densely vegetated areas can produce topographic data which over-estimates ground elevations. Furthermore, current LiDAR surveys are unable to obtain elevations covered by water.

9. PROJECT EVALUATION

In total, conceptual designs were created along more than 12.5 miles of lower Dry Creek. Twenty-five separate groupings of projects (enhancement subreaches) were developed and are detailed in Appendices A through O. The conceptual designs include a variety of off-channel and main channel enhancements aimed at meeting habitat enhancement objectives laid out in the RRBO. In order to facilitate evaluation of the relative benefits and enable prioritization of alternate enhancement subreaches, the following section describes the methodology used to estimate associated habitat benefits, and describes development and application of three project evaluation metrics to each subreach. It is anticipated that these metrics will support the project prioritization process as depicted in Figure 14.

9.1 ANALYSIS OF PROPOSED HABITAT BENEFITS

The habitat benefits resulting from the proposed enhancements are reported in Appendices A through N for each enhancement subreach. The estimated benefits are summarized and organized by anticipated seasonal utilization (i.e. summer coho rearing), and overall fish habitat benefit. Table 6 summarizes the methodology used to estimate the additional habitat benefits resulting from the enhancement work.

It should be noted that alcove/backwater habitats will provide winter rearing and refuge areas in addition to summer rearing, as they continue to offer low velocity off-channel habitat during typical winter flow conditions and during flood events. Additionally, most main channel LWD placements will provide winter rearing and refuge over a portion of the typical flow range, depending on their location in the channel. However, to avoid double-counting of habitat benefits, the habitat areas included in the Incremental Winter Refuge category include only winter refuge specific projects (which consist of lowering overbank areas – see Section 6.5), plus the additional area of alcove/backwater channel projects that are inundated between 110 and 1000 cfs. Both incremental winter refuge and summer rearing habitats are incorporated into the Total Enhanced Habitat calculation and score (see Section 9.3).

Although off-channel LWD-margin habitat is proposed, only main channel LWD-margin habitat areas are reported in the habitat metrics to prevent double-counting of habitat improvements. Aside from LWD-margin habitat, main channel habitat enhancements included in the Total Enhanced Habitat calculation and score are largely conversions of one habitat type to another (i.e. flatwater to pool resulting from riffle construction). Main channel re-meander projects are exceptions where total main channel habitat area would change based on the conceptual design (i.e., a net increase in total main channel habitat area due to newly created habitat area in the main channel).

Table 6. Methodology used to calculate enhanced habitat benefits.

Habitat Category	Included Habitats	Basis of Area Estimate
Summer coho rearing habitat	Alcove/backwater channel	Area within habitat inundated at 110 cfs.
	Main-channel LWD-margin	Area of LWD in the channel + 3 foot extension of hydraulic influence into the channel
	Side Channel	2/3 of habitat inundated at 110 cfs.
	Pilot off-channel	• 100% of pilot backwater habitats inundated at 110 cfs • 2/3 of pilot side channel habitats inundated at 110 cfs
Incremental winter refuge habitat	Winter Refuge	Area of habitat inundated at 1000 cfs
	Pilot winter refuge	80% of overbank area inundated at 500 cfs
	Alcove/backwater channel	Additional area within grading inundated between 110 and 1000cfs
Total enhanced habitat	Alcove/backwater channel	Area within habitat inundated at 110 cfs.
	Main-channel LWD-margin	Area of LWD in the channel + 3 foot extension of hydraulic influence into the channel
	Side Channels	Area of habitat inundated at 110 cfs
	Winter Refuge	Area of habitat inundated at 1000 cfs
	Pilot winter refuge	Area of habitat inundated at 500 cfs
	Pilot off-channel	Area of habitat inundated at 110 cfs
	Riffle	Area of habitat inundated at 110 cfs
	Pool	Area of habitat inundated at 110 cfs

9.2 Evaluation Metrics

Four evaluation metrics were developed for application to each enhancement subreach. The first and second metrics address the inherent summer and incremental winter refuge habitat development potential, while the third metric addresses the total habitat development potential, and the fourth metric addresses the predicted continuity of habitat benefits, for each enhancement subreach.

The habitat-based metric scores were derived from the quantity of additional summer coho rearing, incremental winter refuge, and total enhanced habitat area created by the proposed enhancements in each subreach. Scoring criteria for the habitat metrics are summarized in Table 7. The "continuity" score is largely based on the current understanding of fluvial processes in different locations along Dry Creek, as described in the Feasibility Study Report (Inter-Fluve 2012), in addition to subreach-specific channel and floodplain characteristics.

Table 7. Habitat enhancement scoring criteria used to evaluate reaches and sub-reaches in Dry Creek.

Score	Summer coho rearing habitat based criteria*	Incremental winter refuge habitat based criteria**	Total habitat based criteria***
Low	< 20,000 ft^2	< 30,000 ft^2	< 80,000 ft^2
Medium	20,000 - 80,000 ft^2	30,000 - 90,000 ft^2	80,000 - 150,000 ft^2
High	>80,000 ft^2	>90,000 ft^2	>150,000 ft^2

*Includes low water areas of backwater channels, LWD-margin habitat, side-channels and pilot off-channel habitat based (see Table 6)

**Includes high flow area of backwater channels, winter refuge habitat, and pilot winter refuge habitat (see Table 6)

***Includes all habitat enhancements, including backwater channels, LWD-margin habitat, side channels, pilot off-channel habitat, riffles, enhanced pool area, winter refuge habitat (see Table 6)

9.3 Evaluation Results

Table 8 summarizes the scores resulting from application of the evaluation metrics to each enhancement subreach. Detailed summaries of conceptual designs can be found in Appendices A through N, which provide a synthesis of proposed habitat and cost estimates for conceptual designs created for the lower 13 miles of Dry Creek.

The results for the continuity metric for reaches 1 and 2 should be taken within the context of the different philosophical approach applied in this area. The final scoring will have to take into account the dynamic nature of the approach devised for these two reaches. It has not yet been decided how habitats that change over time will be treated in the evaluation of enhancements (Porter et al 2011).

Table 8. Summary of enhancement subreach scoring and associated additional habitat enhancement areas based on the conceptual designs created for the lower 13 miles of Dry Creek.

Enhancement Subreach	Summer Coho Rearing Habitat Potential	Incremental Winter Refuge Habitat	Total Habitat Potential Score	Enhancement Continuity Score	Enhanced Summer Coho Habitat (ft²)	Incremental Winter Refuge Habitat (ft²)	Total Habitat Enhancements (ft²)
15	Medium	Low	Low	High	38600	9550	63950
14b	Medium	Low	Low	High	56150	15350	77400
14a	High	Medium	High	High	89800	31050	169150
13b	Medium	Medium	Medium	High	59900	36200	130050
13a	Low	Low	Low	High	11000	0	29850
12b	Low	High	Medium	High	7000	96150	131350
12a	Low	Low	Low	High	4000	0	16600
11	Low	Medium	High	Medium	8000	64100	163850
10b	Medium	Low	Medium	Medium	47900	0	83300
10a	Medium	Low	Medium	High	74950	15650	146300
9b	Low	Medium	Low	Medium	6000	50950	69300
9a	Low	Low	Low	Medium	3000	0	27000
8b	High	Medium	High	Medium	87300	45900	211600
8a	Medium	High	High	High	59000	181900	253400
6	Low	High	High	Medium	8000	95100	158900
5b	Medium	Medium	High	Medium	37000	46450	168950
5a	High	Low	High	Medium	93650	24500	151650
4c	Medium	Low	Low	High	57650	8050	69550
4b	High	Low	Medium	Medium	108500	15050	134450
4a	High	Low	High	High	107850	24450	182500
3b	Medium	Low	Medium	Medium	65950	20350	121500
3a	Medium	Low	Medium	Medium	44250	18850	95050
2b	High	High	High	Low	103800	254280	367180
2a	High	High	High	Low	151800	296900	463000
1	High	High	High	Low	113150	360200	498400

9.4 ENHANCMENT SUBREACH RANKING AND PROJECT SELECTION

Results of the project evaluation will support prioritization of enhancement subreaches in lower Dry Creek. Represented conceptually by Figure 14, the prioritization process includes two primary phases: 1) Project Ranking, and 2) Project Selection. In the ranking phase (represented by the left half of Figure 14), the enhancement subreaches were ranked within the upper, middle and lower segments of the study reach based on their summer coho rearing, incremental winter rearing and refuge, and total habitat scores.

Within each study reach segment, the enhancement subreaches were further classified into Tier I and Tier II groups to help summarize their relative potential for habitat enhancement(Table 9). The results show that there are a total of 16 Tier I subreaches distributed across the upper, middle and lower segments of Dry Creek.. Table 9 also shows the enhancement continuity score for each enhancement subreach for reference, although this score was not taken into account in the ranking process. This factor will be considered in the project selection phase, discussed below.

Project selection represents the second phase of project prioritization, depicted as the right half of Figure 14. In this phase, the results of the ranking phase will be evaluated alongside other factors that are critical considerations for implementation of habitat enhancement in lower Dry Creek. These implementation considerations include critical factors such as access, cost, and overall distribution along Dry Creek, among other factors. Project selection will be ongoing over the next several years as the Water Agency and its partners identify opportunities to implement habitat enhancement to meet the requirements of the RRBO.

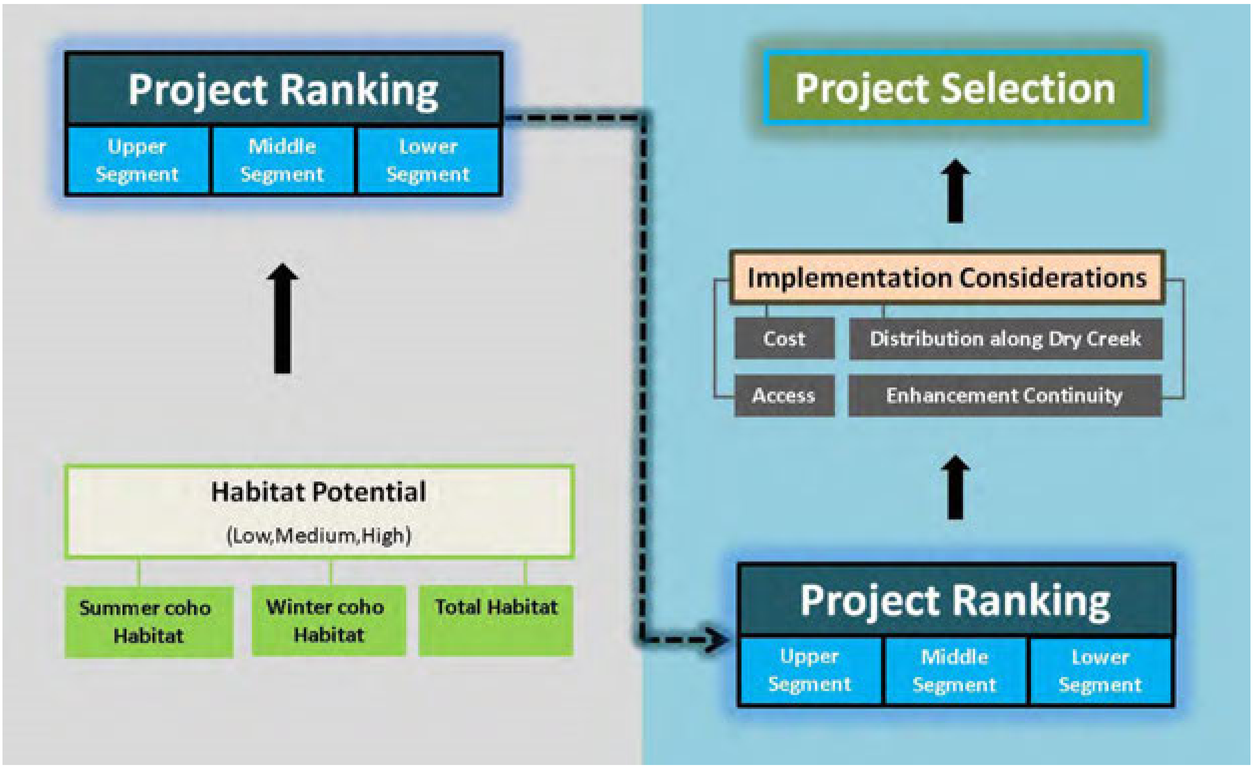

Figure 14. Conceptual depiction of project prioritization approach. The left side of the figure represents the first phase of the prioritization process, which includes ranking of the enhancement subreaches based solely on their inherent potential for habitat enhancement. The second phase, project selection, will factor in implementation considerations such as access, distribution, and cost to result in selection of the enhancement subreaches that are advanced to design and implementation.

Table 9. Ranking of enhancement subreaches in Dry Creek organized by Upper, Middle and Lower segments.

Segment	Ranking Tier	(Sub) Reach	Coho Potential Coho Rearing Habitat Score	Winter Refuge & Rearing Habitat Score	Total Potential Habitat Score		Predicted Continuity Score
Upper	Tier I	**14a**	High	Medium	High		High
		13b	Medium	Medium	Medium		High
		15	Medium	Low	Low		High
		14b	Medium	Low	Low		High
	Tier II	**12b**	Low	High	Medium		High
		13a	Low	Low	Low		High
		12a	Low	Low	Low		High
Middle	Tier I	**8b**	High	Medium	High		Medium
		4a	High	Low	High		High
		5a	High	Low	High		Medium
		4b	High	Low	Medium		Medium
		8a	Medium	High	High		High
		5b	Medium	Medium	High		Medium
		10a	Medium	Low	Medium		High
		10b	Medium	Low	Medium		Medium
		4c	Medium	Low	Low		High
	Tier II	**6**	Low	High	High		Medium
		11	Low	Medium	High		Medium
		9b	Low	Medium	Low		Medium
		9a	Low	Low	Low		Medium
Lower	Tier I	**2b**	High	High	High		Low
		2a	High	High	High		Low
		1	High	High	High		Low
	Tier II						
		3b	Medium	Low	Medium		Medium
		3a	Medium	Low	Medium		Medium

10. CONCEPTUAL DESIGN COST OPINIONS

Planning-level conceptual design cost opinions were prepared for comparison between alternative enhancement subreaches and for planning purposes. These estimates are summarized in Table 10 in terms of total costs and various factors describing cost per unit habitat area. The cost opinions are detailed in the individual reach-scale conceptual enhancement design booklets (Appendices A-N) for each enhancement subreach. The cost opinions are presented in 2011 dollars.

These should be considered order-of-magnitude cost opinions assuming design-bid-build public works procurement, and given the current level of design development concept-level cost contingencies have been included. The cost opinions would be considered Class 4 (study or feasibility level) according to standards established by the Association for the Advancement of Cost Engineering. As these are planning estimates, project delivery costs (permitting, engineering design, contract administration) have also been included. Detailed quantity takeoffs made for the excavation work items were computer-generated (and independently checked) using the surfaces described in Section 7 and represent neat-line quantities. In preparation of the concept-level cost opinions, several global factors or criteria were applied across all enhancement subreaches. These factors are summarized in Table 11.

Additional cost estimate information has been provided in Appendix O in order to provide flexibility in creating groups of projects for future implementation of habitat enhancement in Dry Creek, which may vary from the groupings assumed in this report for the 25 enhancement subreaches detailed in Appendices A-N. To do so, each enhancement subreach was split into its component enhancement sites, and associated costs were broken out for these smaller groupings. For example, a smaller scale grouping of enhancement sites would include a backwater channel with the associated downstream riffle that would be constructed together.

The opinions of estimated construction cost presented are based on information developed for this report and market conditions at the time of preparation (December 2011) of the estimates. Construction cost was estimated with the use of a combination of unit prices from published, internally-developed and maintained historical databases, vendor quotes, and other consultations, factored for location and other project specific criteria.

Lastly, various limitations should be considered in the use of the cost opinions contained herein. These limitations include the potential for changes in technology, methods and construction applications, the impact of short-term economic cycles and other market fluctuations, the time-lag of reporting databases, and other factors. Any estimate of unit prices is not intended to predict the actual outcome of hard dollar results from open and competitive bidding. The cost estimation efforts described herein were conducted in a manner consistent with the standard of care ordinarily applied as the state of practice in the profession, given the amount of design information presently available.

Table 10. Cost estimate and cost metrics based on the conceptual designs created for the lower 13 miles of Dry Creek. Cost/ft² of summer coho rearing habitat includes backwater channels, qualifying portions of side channels and pilot off-channel habitat, and LWD-margin habitat. Cost/ft² of winter refuge and rearing habitat includes summer habitats plus winter refuge, pilot winter refuge, and area of backwater/alcove inundated between 110 and 1000 cfs. Cost/ft² of all habitat enhancements includes winter habitat plus enhanced pool habitat, and riffle habitat.

(Sub) Reach	**Total cost**	**Summer Coho Rearing** ($/ft²)	**Cumulative Winter Rearing & Refuge*** ($/ft²)	**All Habitat Enhancements** ($/ft²)
15	$4,624,000	120	96	72
14b	$3,790,000	67	53	49
14a	$7,614,000	85	63	45
13b	$8,640,000	144	90	66
13a	$1,700,000	155	N/A	57
12b	$5,596,000	799	54	46
12a	$692,000	173	N/A	42
11	$4,063,000	508	56	25
10b	$6,390,000	133	N/A	77
10a	$10,897,000	145	120	78
9b	$5,457,000	910	96	79
9a	$681,000	43	N/A	25
8b	$12,224,000	140	92	58
8a	$13,693,000	232	57	54
6	$7,007,000	876	68	44
5b	$9,964,000	269	119	59
5a	$8,402,000	90	71	55
4c	$3,904,000	68	59	56
4b	$6,456,000	60	52	48
4a	$8,656,000	80	65	47
3b	$4,866,000	74	56	40
3a	$4,060,000	92	64	43
2b	$9,123,000	88	25	21
2a	$11,934,000	79	27	26
1	$11,526,000	102	24	23

*Cumulative winter rearing and refuge habitat area includes summer coho rearing and incremental winter rearing and refuge areas.

Table 11. Global assumptions applied for preparation of conceptual cost opinions.

Cost Item	Assumptions
Vegetation Management	• Area calculated based on the channel corridor width from vineyard grade to vineyard grade, with channel and off-channel enhancement areas excluded from calculation • Estimated based on the 10-yr flood inundation extent
Clear and Grub	• Calculated area includes off-channel enhancement impact areas plus a multiplier (5% of impact area) for development of temporary access.
Floodplain Roughness Logs	• Number estimated at 130 pieces/acre • 30% with rootwads
Backwater Habitat Logs	• Number estimated at 130 pieces/acre • 30% with rootwads
Pool Enhancement Logs	• Number estimated at 8 pieces per individual pool enhancement location • 30% with rootwads
Log Jams – Reaches 15-3	• Number estimated at 40 pieces/each log jam • 30% with rootwads
Log Jams – Reaches 1-2	• Individual log jams: number estimated at 50 pieces/individual jam • Clustered log jams; number estimated at 0.03 pieces/ft2 of area of coverage • 30% with rootwads
Riffles	• Riffles assumed to be 100' in length. • For riffle enhancements, assume 1.5' of depth. • For riffle construction, assume 3' of depth. • Assume width of riffle to be 1.2 * average channel width of 50 ft
Appendix O Costs	• 'Earthwork' lumps clearing and grubbing with common excavation. • Direct costs each grouped set of sites is based on a ratio of the indirect costs and total direct costs

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11. APPENDICES