LOWER DEER CREEK FLOOD AND ECOSYSTEM IMPROVEMENT PROJECT – 2D HYDRODYNAMIC MODEL PROJECT ALTERNATIVES RESULTS ADDENDUM

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PURPOSE

This is an addendum to the Lower Deer Creek Flood and Ecosystem Improvement Project 2D Hydrodynamic Model technical memorandum (April 2019). The purpose of this addendum is to document model results for the 12 project alternatives created for the Lower Deer Creek Flood and Ecosystem Improvement Project. Six of the 12 project alternatives presented here have been carried through to the project description of the Lower Deer Creek Flood and Ecosystem Improvement Project Draft Environmental Impact Statement/Environmental Impact Report (DEIS/EIR).

MODEL SCENARIO DESCRIPTIONS

PROJECT ALTERNATIVES

A total of 12 project alternatives were modeled for the Lower Deer Creek Flood and Ecosystem Improvement Project (Table 1). These alternatives included six separate setback options combined with two Stanford-Vina Ranch Irrigation Company (SVRIC) Diversion Dam improvement options. Other design measures include levee improvements, levee setbacks, bank stabilization, flood easements, and Red Bridge (Leininger Road) improvements—all common elements to the 12 alternatives (Figure 1).

TABLE 1: SUMMARY DESCRIPTIONS OF PROJECT ALTERNATIVES

Alternative	SVRIC Dam Structure	Setback Option	Setback Acres
1a	No changes	A	72
2a	Lowered (roughened rock ramp)	A	72
1b	No changes	B	67
2b	Lowered (roughened rock ramp)	B	67
1c	No changes	C	55
2c	Lowered (roughened rock ramp)	C	55
1d	No changes	D	42
2d	Lowered (roughened rock ramp)	D	42
1e	No changes	E	30
2e	Lowered (roughened rock ramp)	E	30
1f	No changes	F	0
2f	Lowered (roughened rock ramp)	F	0

The hydrodynamic model geometry was modified from the baseline conditions to simulate the project alternatives in the following ways (organized by location from upstream to downstream):

- Upstream of Red Bridge
    - Project levee setback on the right bank
    - Project levee raised on left bank
- Red Bridge to the SVRIC diversion dam
    - Red Bridge structure removed (to simulate bridge replacement with a clear-span bridge that does not obstruct flow)
    - Project levees raised and setback on both left and right banks
    - Four feet of floodplain lowering in setback areas
    - Roughness coefficient set at dense riparian value (n = 0.07) in setback areas
    - Southern diversion canal high flow cutoff structure added with embankment and road raising
    - Alternative 2 plans lower SVRIC diversion dam structure based on current roughened rock ramp design
    - Alternative 2 plans include sediment removal and grading upstream of SVRIC diversion dam
- SVRIC diversion dam to Highway 99
    - Non-Project levee and berm removal
    - Project levee raised on left bank
- Downstream of Highway 99
    - Deflection levee added on left bank
- China slough
    - Landcover roughness coefficient set to sparse riparian (n = 0.045)

Alternative Setback Options

Figure 2 shows the six separate setback configurations (A through F) modeled as part of this effort. Setback options A through E include four feet of floodplain lowering on the river side of the levees. Option F does not include floodplain lowering.

FIGURE 1: DEER CREEK PROJECT ELEMENTS

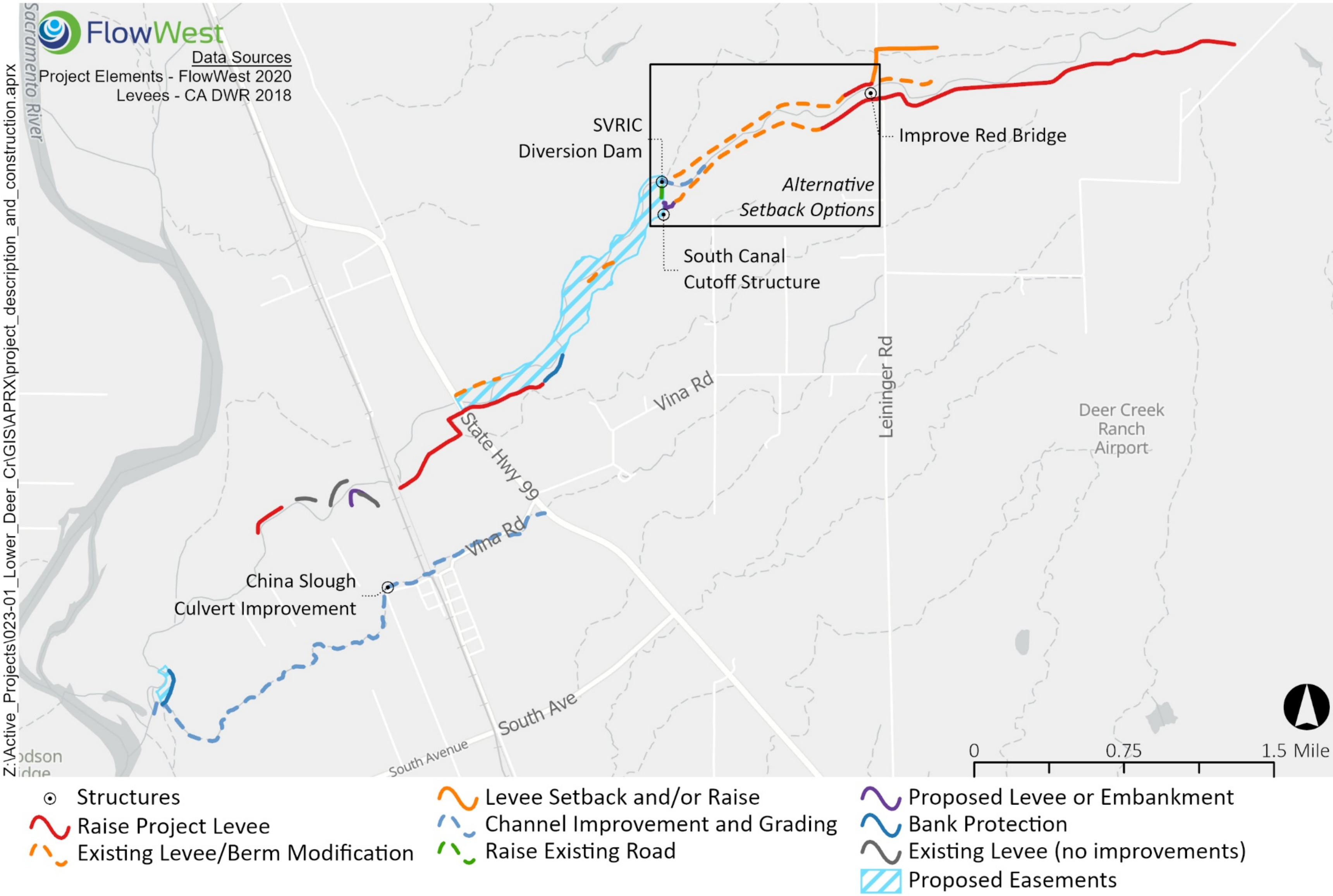
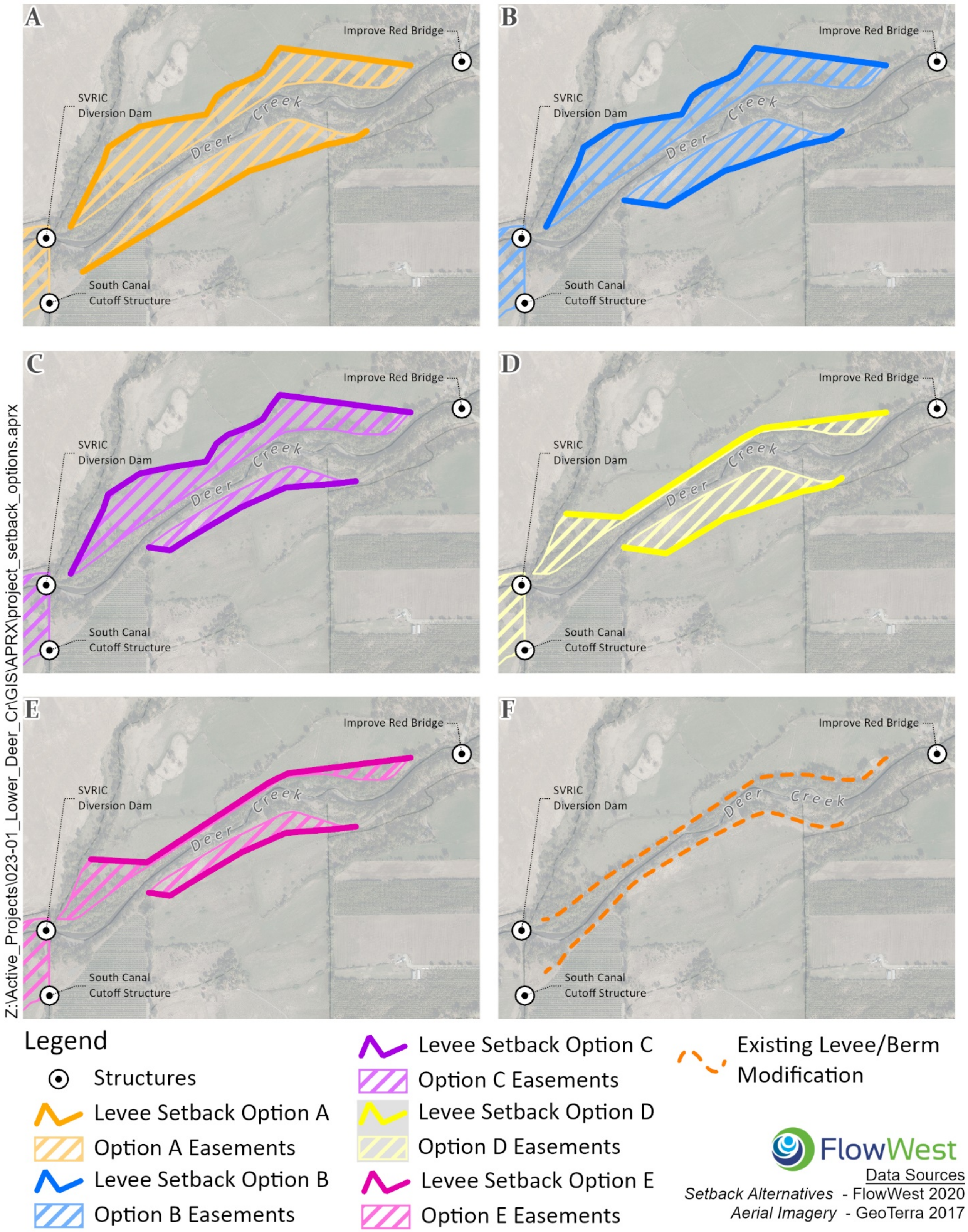


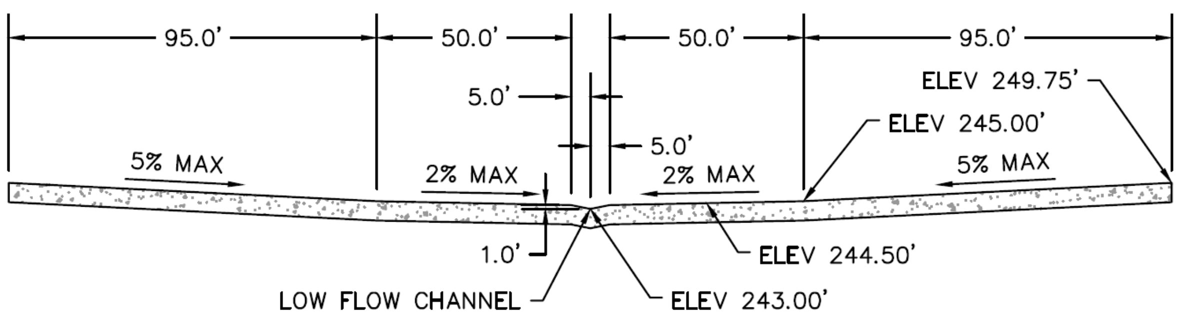
FIGURE 2: ALTERNATIVE SETBACK OPTIONS A THROUGH F



Stanford-Vina Ranch Irrigation Company (SVRIC) Dam Passage Improvement Options

The Stanford Vina Fish Passage Planning and Design Project Technical Advisory Committee is currently developing a set of alternatives to improve fish passage at the dam. The preliminary set of design alternatives includes elements such as partial replacement with an operable (Obermeyer) gate, a roughened rock ramp, boulder weirs, and fish ladders. Since alternatives for fish passage improvements at the dam have not been finalized; for the purposes of this analysis, we evaluated two options that the TAC believes are the most feasible at this time—improvements to the fish ladders on the existing dam (Alternative 1), and replacement of the dam with a roughened rock ramp (Alternative 2). Alternative 1 is modeled with no changes to the existing dam. Alternative 2 is modeled as a new structure with a 4-ft lower, 10-ft wide low flow channel that increases elevation based on a preliminary design cross-section (Figure 3). This option also includes sediment removal extending approximately 1,200 feet upstream to establish a new creek bed profile controlled by the lowered dam crest elevation.

FIGURE 3: ROUGHENED ROCK RAMP PRELIMINARY DESIGN CROSS-SECTION



This section summarizes results for low flow habitat suitability, as well as, high flow design, freeboard, and shear stress. Results of these analyses are presented in the sections that follow.

Suitable Fish Habitat

Analyses presented in this section consider two aspects of riverine physical habitat suitability—flow depth and velocity. These variables, coupled with species-specific suitability curves, have widely been used as bases for evaluating habitat suitability as they are easily extracted from hydrodynamic model results (SFEI 2020, Gard 2019, cbec 2020). However, habitat use and suitability depend on many other factors including accessibility, sediment continuity and quality, water quality, and predation. Therefore, depth and velocity suitability are two parameters out of many that can quantify the expected habitat benefits offered by each project alternative.

For this analysis, the depth and velocity suitability criteria shown in Table 2 were combined with outputs from the hydrodynamic model to compare suitable fish habitat at a range of relevant flows under Existing Conditions and the 12 project alternatives. Species criteria analyzed include Fall, Late-Fall, and Spring Run Chinook Salmon; Steelhead; and Hardhead. Since results showed no significant differences between Alternative 1 and Alternative 2, suitable acres of habitat for only Alternative 1 (existing dam) are presented in the sections that follow.

TABLE 2: SUITABLE DEPTH AND VELOCITY CRITERIA

Habitat and Life Stage	Species	Depth (ft)	Velocity (ft/s)	Source
Instream Juvenile Rearing	Spring Run Chinook, Steelhead	0.21 - 5.59	0.00 - 5.54	Gard et. al. 2019
Instream Juvenile Rearing	Fall Run, Late-Fall Run Chinook	0.41 - 5.31	0.00 - 3.07	Gard et. al. 2019
Instream Spawning	Fall Run, Late-Fall Run Chinook	0.41 - 6.69	0.09 - 6.30	Gard et. al. 2019
Floodplain Juvenile Rearing	Spring Run, Fall Run, Late-Fall Run Chinook, Steelhead	0.50 - 5.20	0.00 - 4.00	cbec 2020
All	Hardhead	1.65 - 8.85	0.00 - 3.75	NID and PG&E 2011

Instream Habitat

Instream habitat suitability results showed little to no change from Existing Conditions for the species and criteria evaluated (Figure 4, Figure 5, and Figure 6). The largest differences occurred for Spring Run Chinook and Steelhead rearing at 3,000 cfs (approximately 4 acres, Figure 4), as well as for Fall Run and Late-Fall Run Chinook spawning at 5,000 cfs (approximately 5 acres, Figure 6). All setback alternatives provided relatively similar instream habitat suitability gains. Alternative 1f performed similar to Existing Conditions.

FIGURE 4: CHINOOK AND STEELHEAD INSTREAM REARING SUITABILITY

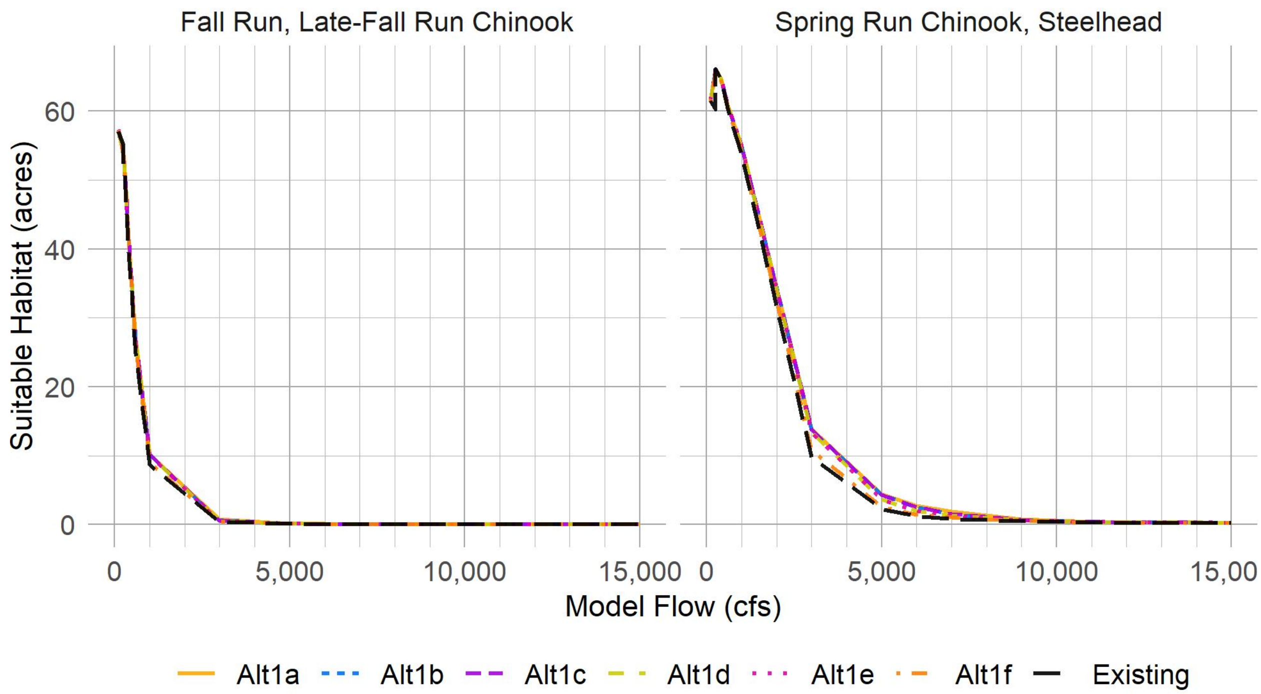


FIGURE 5: CHINOOK INSTREAM SPAWNING SUITABILITY

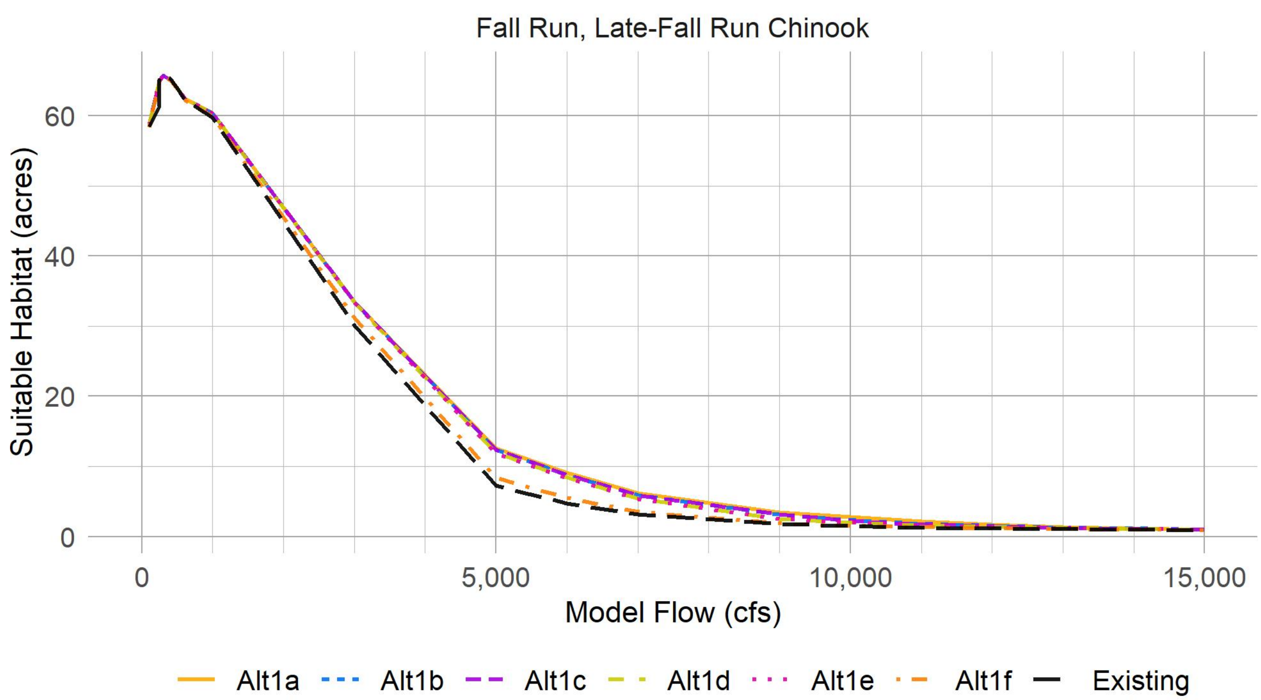
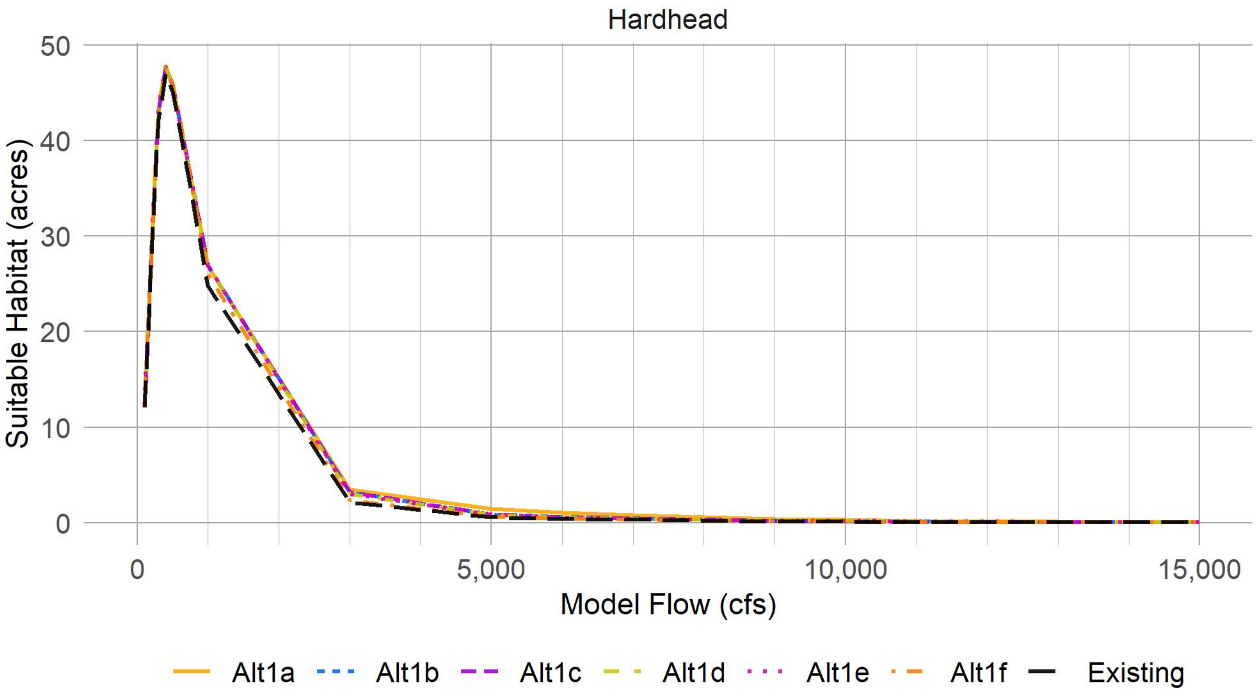


FIGURE 6: HARDHEAD INSTREAM REARING AND SPAWNING SUITABILITY

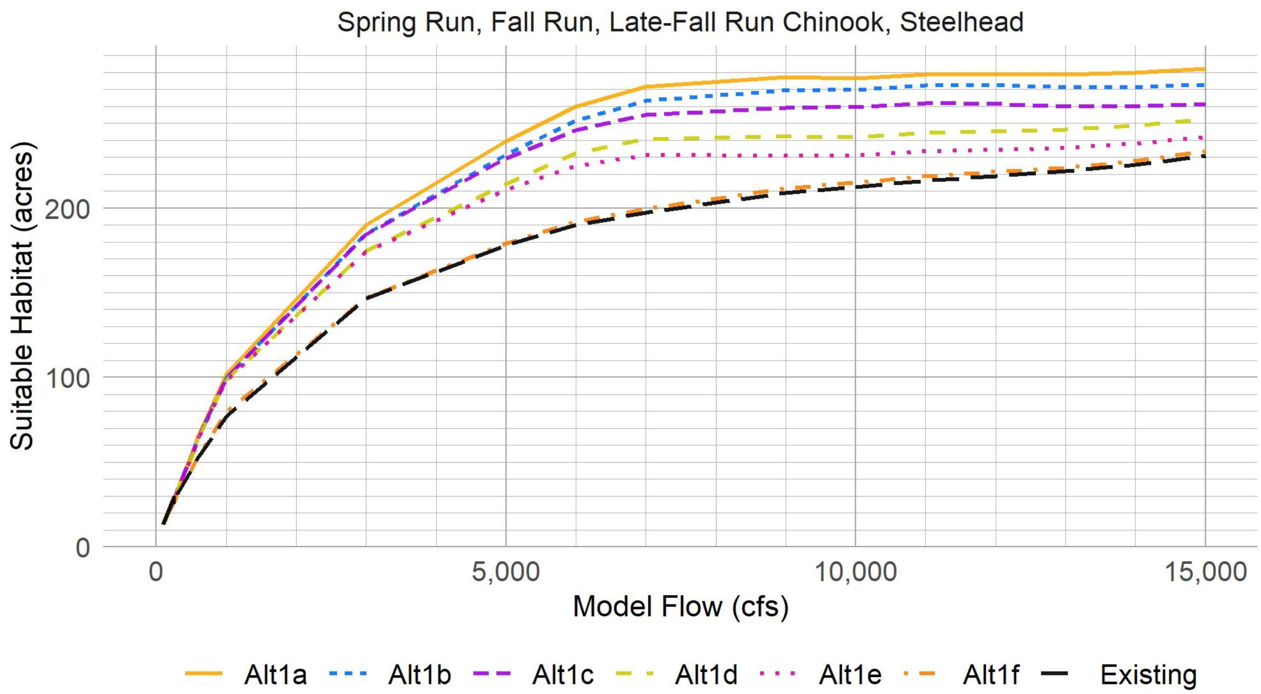


Floodplain Habitat

Results show all project setback alternatives (1a through 1e) would increase suitable floodplain habitat for all species and criteria evaluated relative to Existing Conditions (Figure 7, Figure 8). Alternative 1f shows some floodplain habitat gains, but is generally consistent with Existing Conditions.

Figure 7 shows some project alternatives have similar Chinook and steelhead floodplain rearing habitat suitability at flows below 5,000 cfs (e.g., Alternatives 1d and 1e), but start to diverge thereafter. Alternative 1a yields the most suitable floodplain rearing acres at all flows, followed by Alternative 1b, Alternative 1c, Alternative 1d, Alternative 1e, and Alternative 1f, respectively.

FIGURE 7: CHINOOK AND STEELHEAD FLOODPLAIN REARING SUITABILITY



Hardhead floodplain rearing habitat suitability curves show groupings of project alternatives that have similar suitable acres at flows lower than approximately 10,000 cfs. This can be seen in the trendlines for Alternatives 1b and 1c, as well as for Alternatives 1d and 1e. At flows greater than 10,000 cfs, the acres of suitable habitat among these alternatives diverge. In general, Alternative 1a yields the most suitable habitat, followed by Alternative 1b, Alternative 1c, Alternative 1d, Alternative 1e, and Alternative 1f, respectively.

FIGURE 8: HARDHEAD FLOODPLAIN REARING SUITABILITY

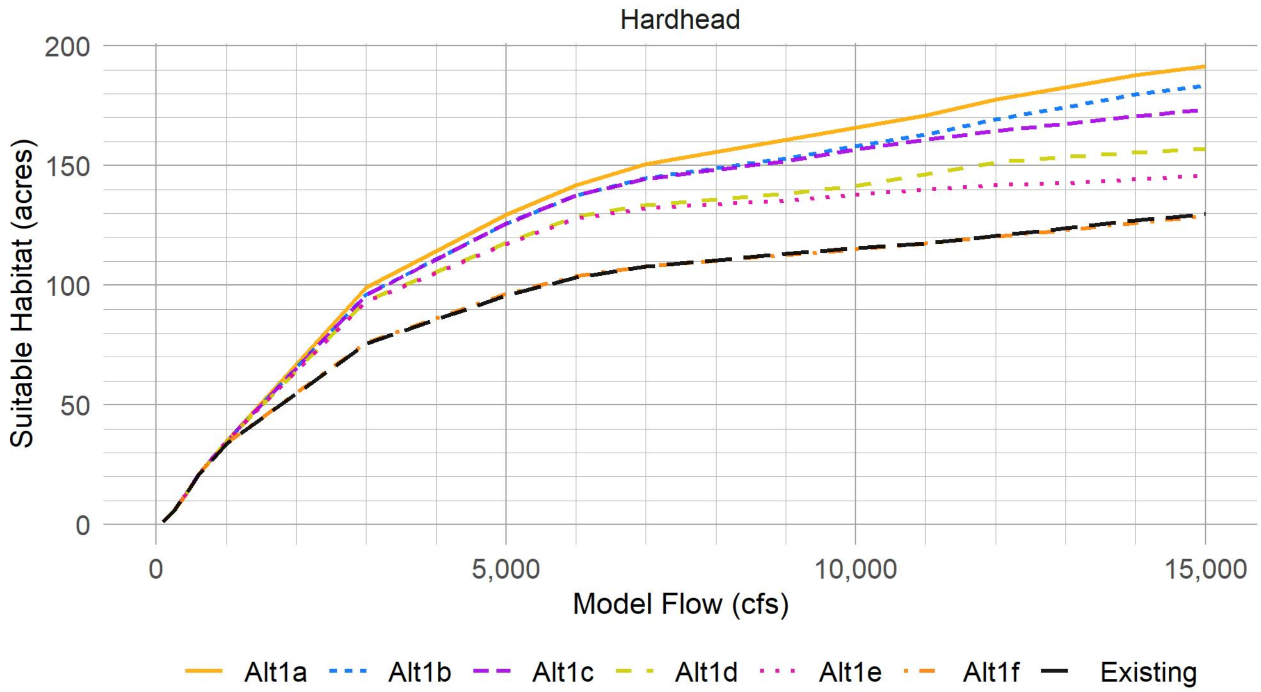


Table 3 summarizes acres of suitable floodplain rearing habitat by alternative at the 2-year and 5-year return interval flows (5,500 cfs and 9,900 cfs, respectively). As discussed previously, several of the alternatives show similar suitable habitat acres around the 2-yr flow, after which they start to diverge. These groups of similar floodplain habitat have been designated by group number in Table 3.

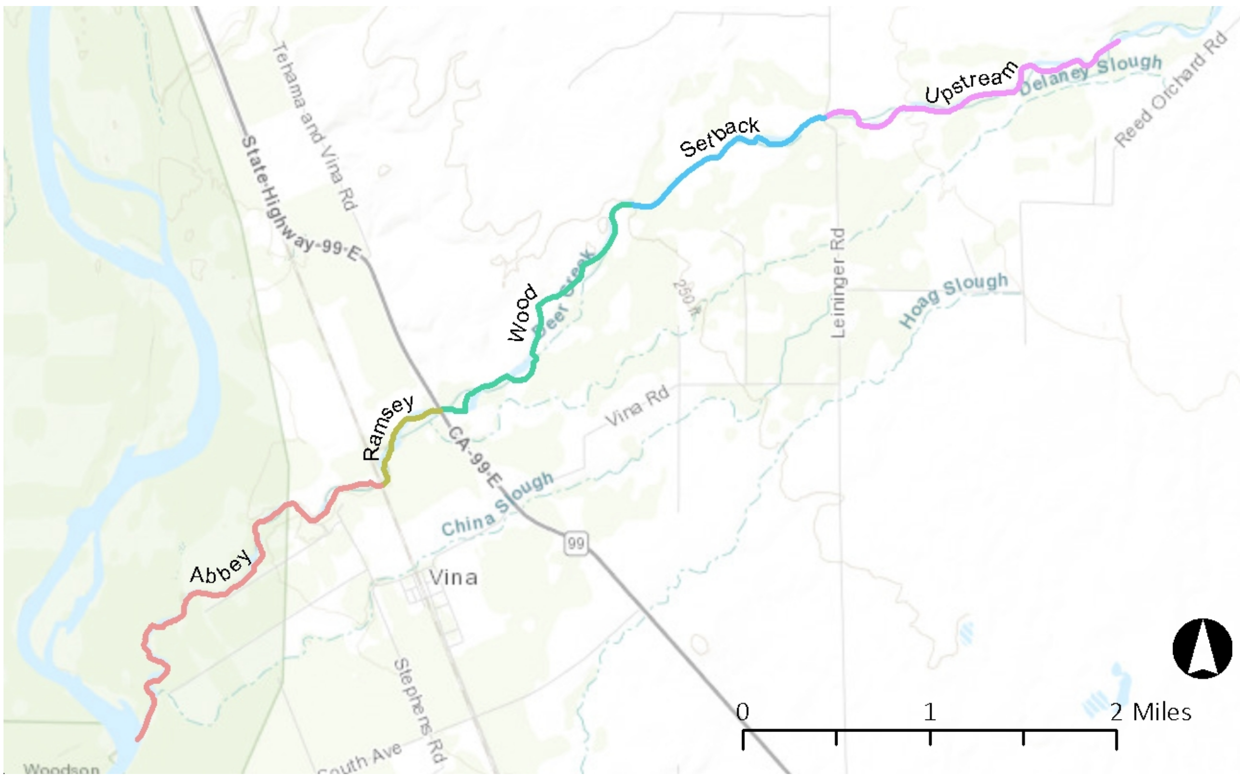
TABLE 3: ACRES OF SUITABLE FLOODPLAIN HABITAT BY ALTERNATIVE

Group	Alternative	Chinook and Steelhead Suitable Acres (2-yr flow)	Chinook and Steelhead Suitable Acres (5-yr flow)	Hardhead Suitable Acres (2-yr flow)	Hardhead Suitable Acres (5-yr flow)
1	1a	249.6	276.8	135.6	165.3
2	1b	241.6	269.7	131.7	157.6
2	1c	237.7	259.4	131.5	156.3
3	1d	223.2	241.9	123.3	141.1
3	1e	217.9	230.9	122.6	137.6
4	1f	185.5	214.5	100	114.7
4	Existing	183.8	212.0	99.5	115.3

DESIGN FLOW WATER SURFACE ELEVATIONS

Effects of the project alternatives on existing water surface elevations were analyzed using the 50-yr return interval flow and presented based on the reaches shown in Figure 9. The 50-yr flow corresponds to the original USACE design flow for the Deer Creek Flood Control Project. Results for the 50-yr return interval flows are discussed below and results for Alternative 1a are shown in Appendix C inundation maps (Figure C-1 through Figure C-4). Although water surface elevations differ between the alternatives, inundation extent only differs in the Setback Reach and is determined by the orientation of the 6 setback options. Therefore, we opted to create one set of inundation maps for the alternative with the largest inundation extent (Alternative 1a) rather than one set for each alternative.

FIGURE 9: DEER CREEK MODEL REACHES



Model results show that the Alternative 1 options (those with no changes to SVRIC dam elevations) and Alternative 2 options (those with SVRIC dam replaced with lowered roughened rock ramp) are identical except for within the 2,500 ft upstream of SVRIC dam. As shown in Figure 10, these two alternatives differ by a maximum of 1 ft at the dam and differences diminish to zero in the upstream direction. With this in mind, presentations and analyses within this section have been limited to Alternative 1 options in an effort to simplify and facilitate discussion.

FIGURE 10: ALTERNATIVE 1A AND ALTERNATIVE 2A 50-YR WATER SURFACE ELEVATION DIFFERENCES IN THE VICINITY OF SVRIC DAM

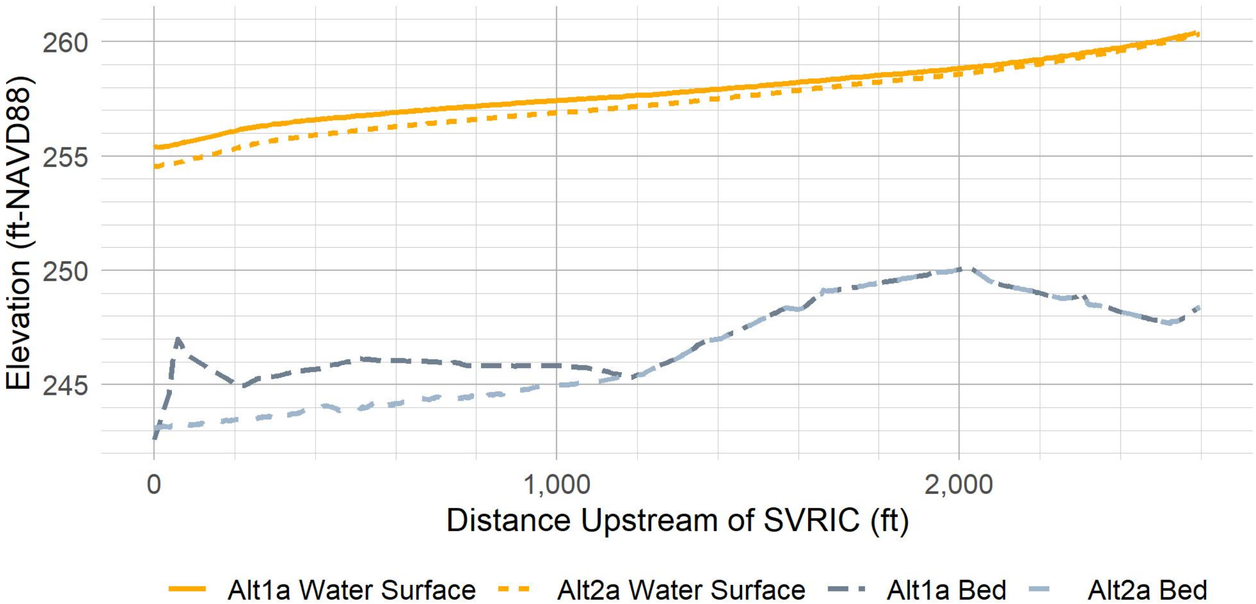
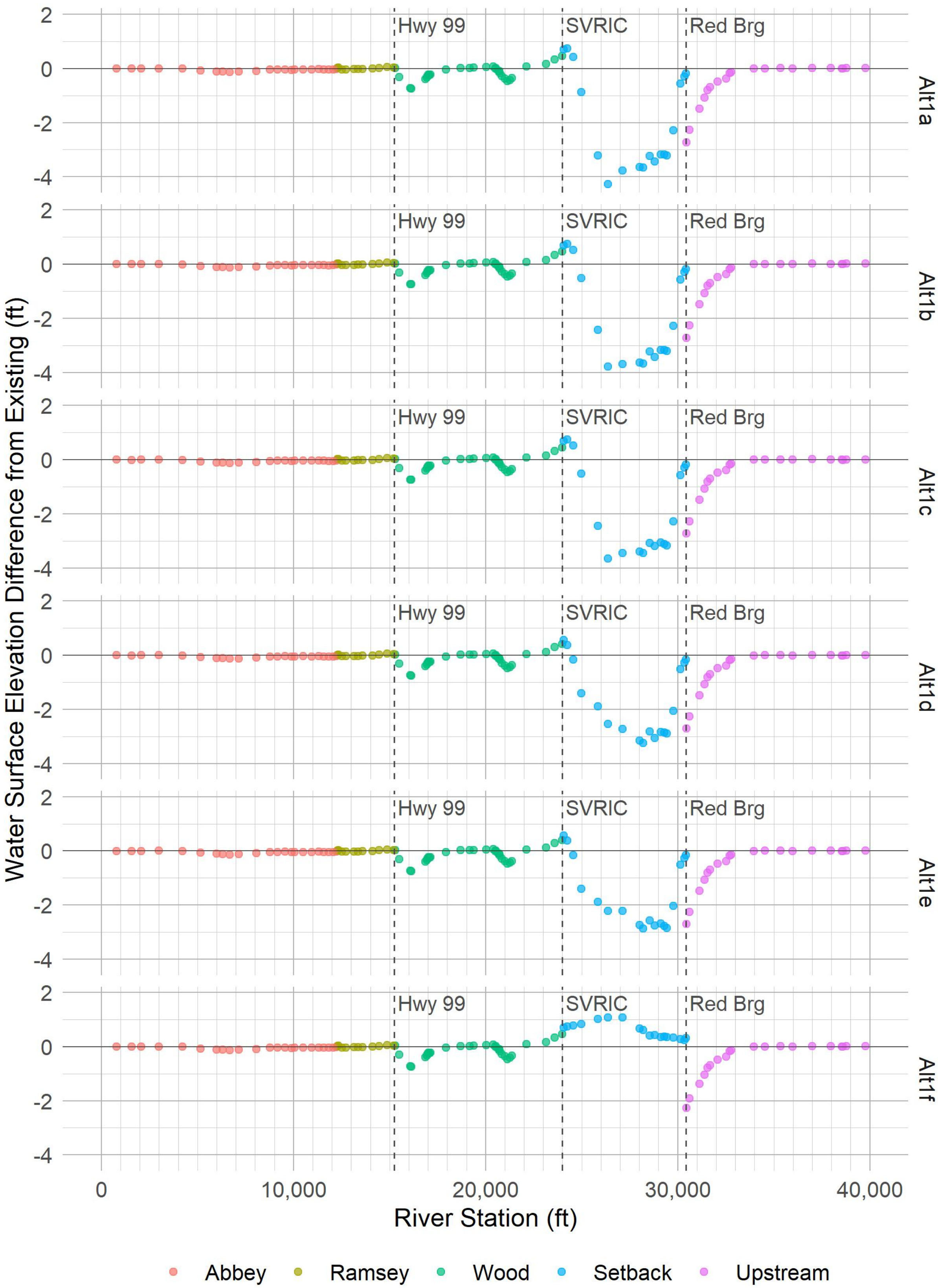


Figure 11 shows how each alternative affects water surface elevations compared to Existing Conditions. All alternatives show nearly identical influences on water surface elevations outside of the Setback Reach—with most locations being lower or unchanged. The most significant reductions outside the Setback Reach occur upstream of Red Bridge and at two locations between SVRIC dam and Highway 99 (the Wood Reach). These reductions align with the proposed improvements at Red Bridge and Wood Reach private levee and berm removals, respectively. The discontinuity in water surface elevation change shown for all alternatives at Red Bridge is due to the backwater effect the current bridge causes at higher flows. With the proposed realignment and widening of Red Bridge, the backwater effect would be eliminated for all alternatives resulting in steep water surface elevation decreases upstream of the bridge as compared to existing conditions.

Within the Setback Reach, influences of alternative setback options can be seen. Setback Option A shows the largest reductions in water surface elevations (corresponding to the largest setback area) and setback Option E shows the lowest reductions (corresponding to the smallest setback area). Setback Option F (the no-setback option) would increase water surface elevations in the Setback Reach.

Water surface increases exist in the vicinity of SVRIC dam for all setback options—a side effect of preventing levee overtopping in the Setback Reach. However, the increases shown upstream of the dam would be eliminated if SVRIC dam is replaced with a lowered roughened rock ramp (Alternative 2).

FIGURE 11: ALTERNATIVE EFFECTS ON DESIGN FLOW WATER SURFACE ELEVATIONS



Freeboard

Levee height increases required to meet freeboard are summarized in Table 4 and shown graphically in Figure 12. This analysis was done by subtracting existing levee elevations from design water surface elevations and adding 3 feet of freeboard. If an existing levee elevation would already meet or surpass the freeboard requirement, zero height increase is needed. The exception to this occurs in the Setback Reach where existing levees are to be removed and replaced with setback levees. In this case, reductions in existing levee heights are shown.

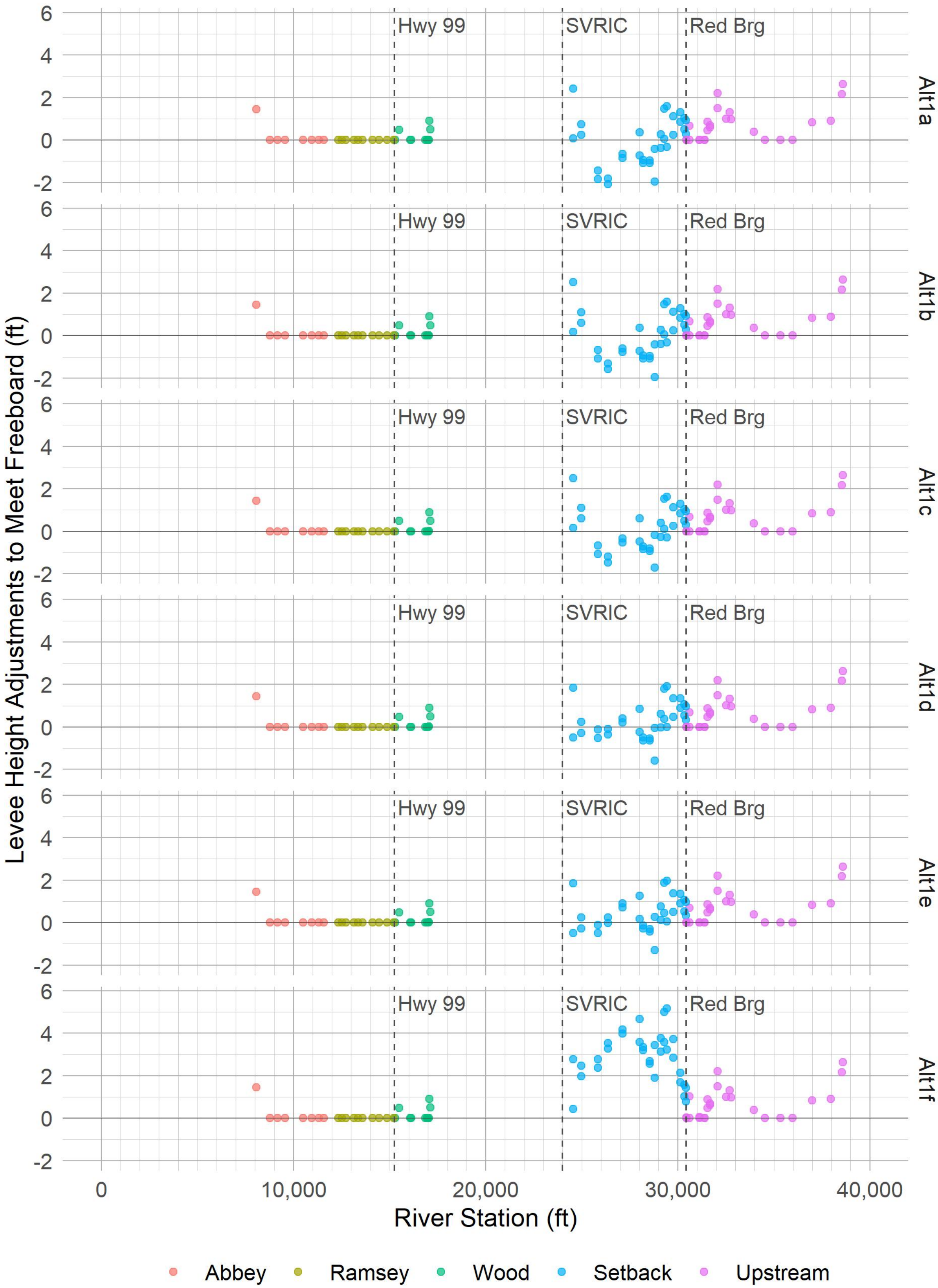
In the Abbey Reach and Ramsey Reach, since results show that project alternatives do not significantly influence water surface elevations (Figure 11), nearly all levees within these reaches would continue to meet freeboard for all alternative setback options (Figure 12). The only exception is at the downstream end of the most downstream project levee on river right (shown as a red line for “Raise Project Levee” in Figure 1), where the levee would need to be raised by 1.4 ft to meet freeboard (Table 4). Within the Wood Reach, project alternatives lower water surface elevations (Figure 11), but levee elevations would need to be increased at some locations up to a maximum of 0.9 ft to meet the freeboard requirement (Figure 12, Table 4). The project alternatives would also reduce water surface elevations in the Upstream Reach (Figure 11), but levee heights would still need to be increased at some locations to meet the freeboard requirement (Figure 12). The median levee height increase needed to meet freeboard would be 0.6 ft and the maximum increase would be 2.6 ft (Table 4).

Levee height requirements differ by alternative setback option within the Setback Reach (Figure 12, Table 4). In general, the larger the setback area, the lower the new levees need to be. However, there are some exceptions to this rule. Model results show a localized influence of the setback alignment on water surface elevations (and levee heights). This can be seen in the higher maximum increase requirements calculated for Option B and Option C compared to Option D and Option E (Table 4). This is because the largest levee height increases are needed near SVRIC dam (Figure 12) where Option D and Option E have a locally wider setback as compared to Option B and Option C (Figure 2). Option F (the no-setback option) requires levee height increases throughout the setback reach ranging from 0.4 ft to a maximum of 5.2 ft with a median increase of 3.0 ft (Table 4).

TABLE 4: SUMMARY OF LEVEE HEIGHT INCREASES REQUIRED TO MEET FREEBOARD

Setback Option	Reach	Median Increase (ft)	Maximum Increase (ft)
All	Abbey	0.0	1.4
All	Ramsey	0.0	0.0
All	Wood	0.0	0.9
Option A	Setback	0.1	2.4
Option B	Setback	0.1	2.5
Option C	Setback	0.1	2.5
Option D	Setback	0.2	1.9
Option E	Setback	0.3	2.0
Option F	Setback	3.0	5.2
All	Upstream	0.6	2.6

FIGURE 12: LEVEE HEIGHT ADJUSTMENTS REQUIRED TO MEET FREEBOARD



Shear Stress

Shear stress is the primary driver of sediment transport capacity (i.e., the rate of sediment transport caused by flows greater than the flow required to mobilize sediment) in a river. Higher shear stress at a given flow results in higher sediment transport capacity for that flow, and lower shear stress at a given flow results in lower sediment transport capacity for that flow. To better understand how project alternatives could change sediment transport processes, shear stress changes resulting from the levee setback alternatives were analyzed—primarily in the reach upstream of SVRIC diversion dam where sediment deposition, vegetation recruitment, and channel migration have been an ongoing maintenance issue (NHC 2021, page 32). Although the channel migration and change in this part of Deer Creek are the result of normal fluvial processes, the artificially reduced bed slope and backwatering imposed by the SVRIC diversion dam causes local reductions in shear stress and sediment transport capacity—accelerating the natural processes and expanding the affected area. It is estimated that SVRIC diversion dam reduces bed slope over a length of 2,500 ft upstream of the dam, and that the majority of sediment deposition and migration caused by the dam is occurring over a length of approximately 1,000 ft (NHC 2021, page 30).

For this analysis, the critical shear stress range (i.e., the shear stress required to mobilize creek bed sediments) was determined from the reported median bed particle size (i.e. the D50, or particle diameter at which 50% are finer) collected within the area of interest (Tompkins, Falzone, and Kondolf 2005, page 21). The D50 ranged from 63 mm to 99 mm (2.5 in to 4 in), corresponding to small and large cobbles. From this, the critical shear stress range was determined to be 1.1 lb/sf to 2.3 lb/sf, respectively (Fischenich 2001, Table 1). Figure 13 and Figure 14 show shear results at the 2-yr flow (commonly referred to by geomorphologists as the channel forming flow) for Existing Conditions and the various setback alternatives. Existing Conditions results show the majority of the bed is likely fully mobile at the 2-year flow (i.e. at shear stresses greater than 1.1 lb/sf, symbolized by the darker purple colors). All setback alternatives would reduce shear stress in the area of interest, with the exception of Alternative F (i.e., the non-setback alternative). The most significant differences in shear stresses occur within 2,500 ft upstream of SVRIC dam (the length over which the dam reduces bed slope). The reduced shear would likely change sediment transport dynamics in this zone, specifically, by reducing the frequency with which the bed and bars would become fully mobile. Although the magnitude of channel change cannot be determined with this analysis alone, possible outcomes are accelerated bar formation and meander migration rate in this area. Neither of these processes are expected to significantly increase water surface elevations during high flows.

For alternatives that include a 4-ft lower dam invert, model results show significant shear stress increases relative to keeping the dam at its current elevation. Figure 15 shows a comparison between Alternative 1a (full setbacks with dam at current elevation) and Alternative 2a (full setbacks with 4-ft lower dam invert). Alternative 2a increases shear stress throughout the 2,500-ft area of interest and narrows the potentially immobile zone by approximately 400 ft relative to Alternative 1a. Based on the model results, a lowered dam is expected to increase shear stresses upstream of the dam for all setback options. However, the extent to which this will lessen or eliminate the sediment deposition and channel migration issues upstream of

SVRIC diversion dam cannot be quantified by this analysis. It is extremely important to note that accelerated channel migration and change has been occurring upstream of SVRIC dam for at least the past 20+ years even though shear stress modeling for the 2-year flow shows a fully mobile bed under the existing conditions confined between the levees. Therefore, while shear stresses and resulting sediment transport could change with levee setback alternatives, it is not expected that this will cause new maintenance issues. It is expected that final design of setback levees will include a factor of safety that allows ongoing channel changes at the dam without impinging on minimum required freeboard.

FIGURE 13: SHEAR STRESS RESULTS AT 2-YR FLOW (ALTERNATIVES 1A THROUGH 1C)

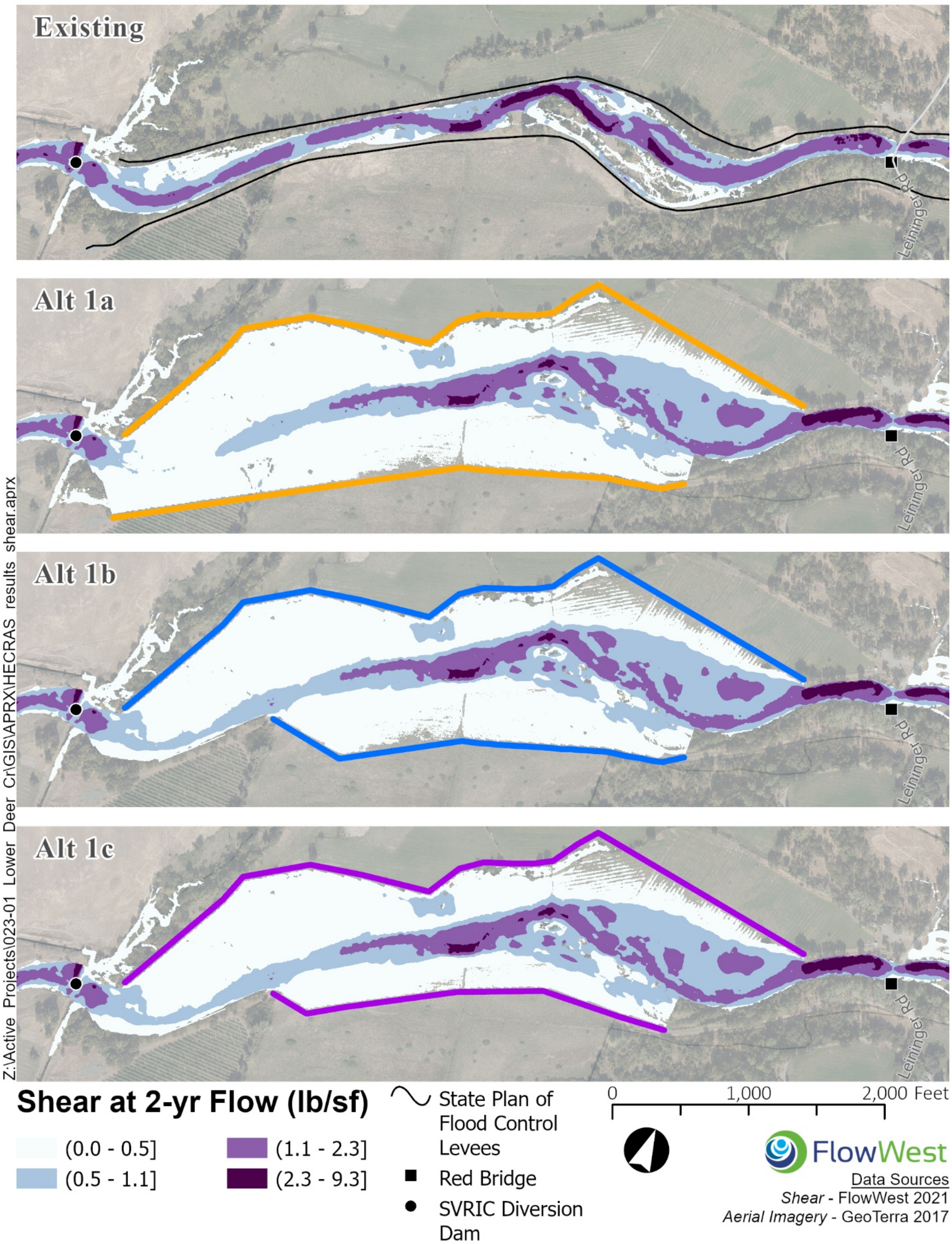


FIGURE 14: SHEAR STRESS RESULTS AT 2-YR FLOW (ALTERNATIVES 1D THROUGH 1F)

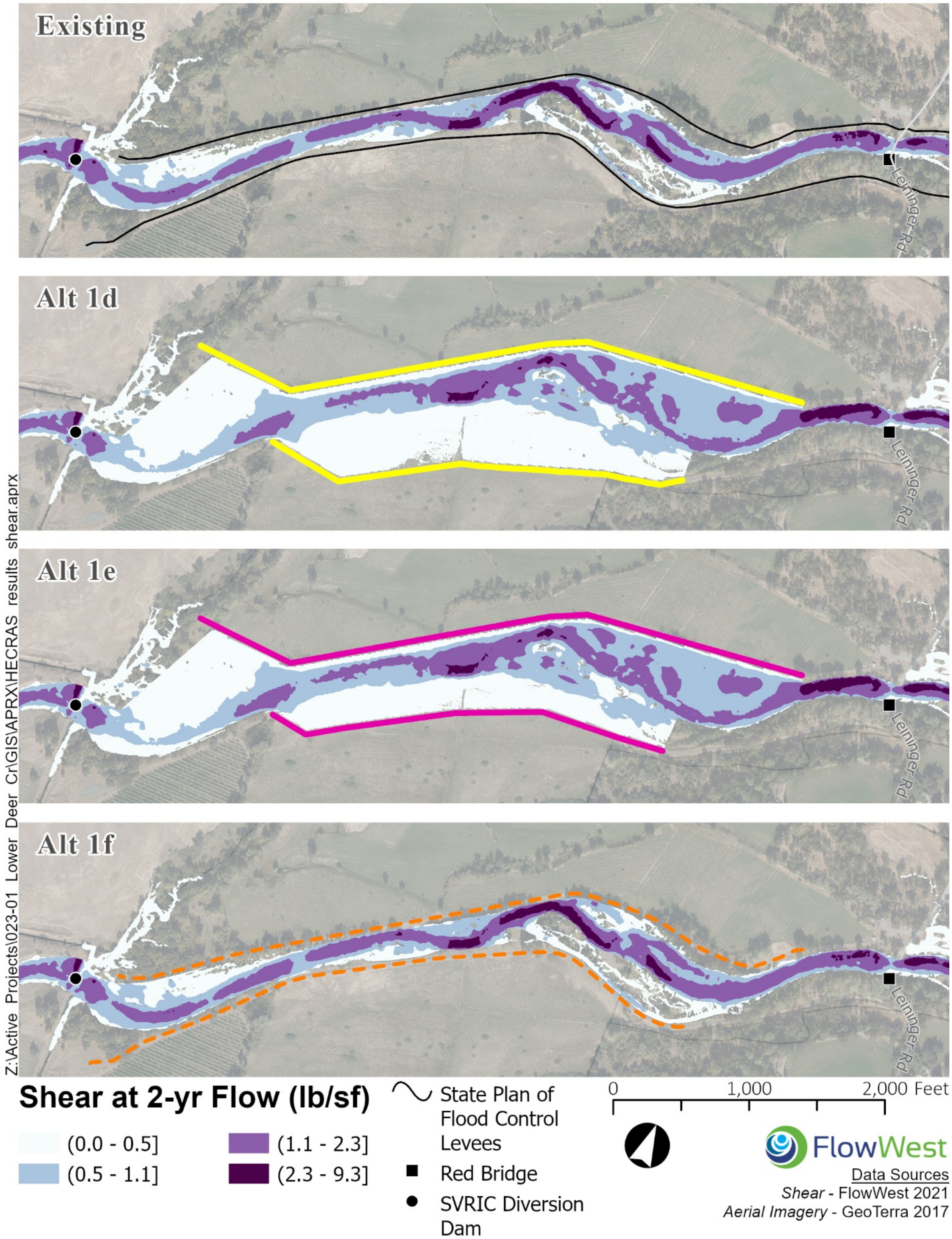
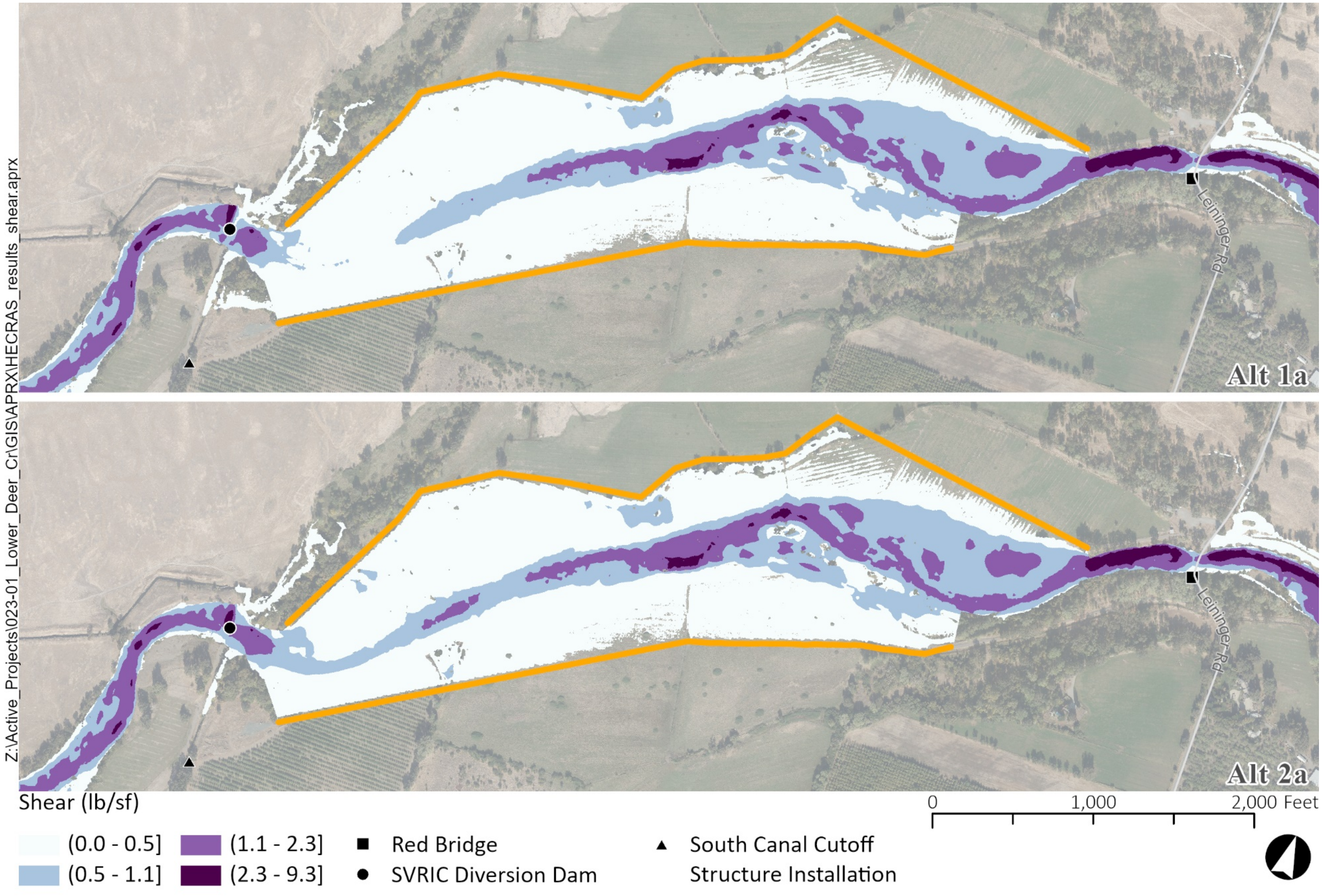


FIGURE 15: ALTERNATIVE 1A AND 2A SHEAR STRESS RESULTS AT 2-YR FLOW



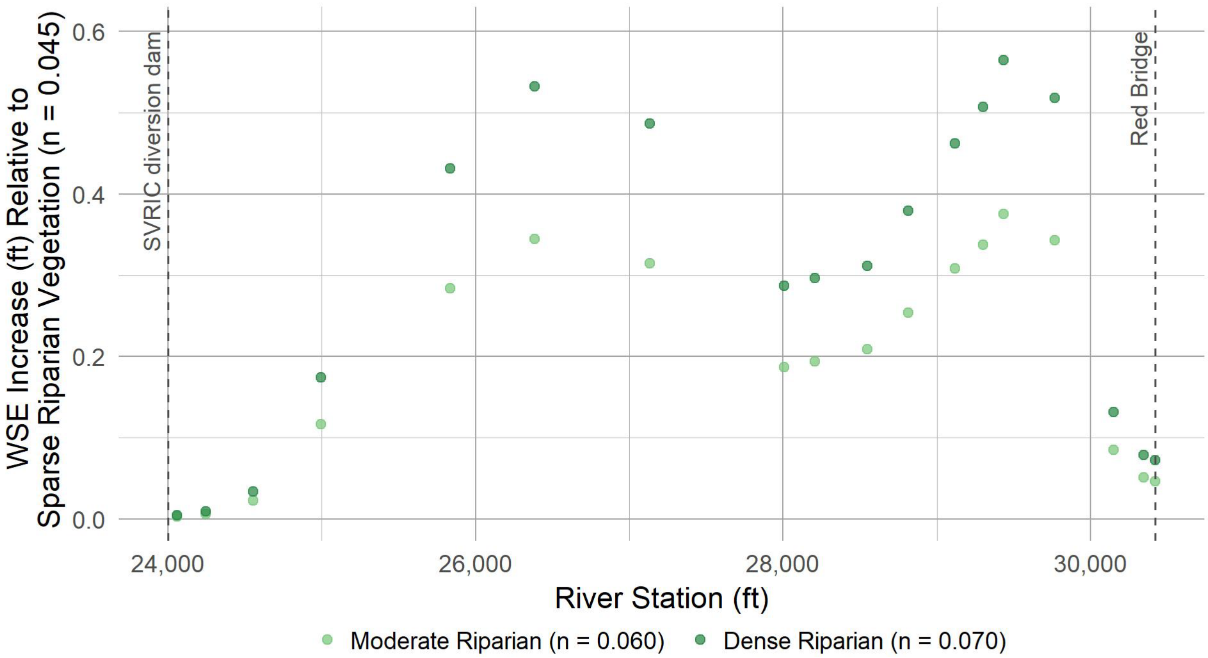
Sensitivity to Setback Roughness Coefficient

Sensitivity analysis is the process of investigating how variability in model input parameters affects model outcomes. These analyses provide insight into model uncertainty, assist with interpretation of model results, and ultimately improve project success. In this section, model sensitivity to Manning's roughness coefficients in the levee Setback Reach is discussed as a means to investigate how the representation of riparian vegetation density might impact water surface elevations (and required levee elevations) at the design flow (21,000 cfs).

Figure 16 shows the results of the sensitivity model runs—water surface elevation increases as vegetation density and roughness increase from sparse riparian (n = 0.045) to moderate (n = 0.060) and dense (n = 0.070) riparian in the Setback Reach. These increases mostly range between 0.2 ft (2.4 inches) and 0.6 ft (7.2 inches). Smaller increases occur where the setback areas taper and decrease in width, especially at the extremities near Red Bridge and SVRIC diversion dam.

Because this project has both flood risk reduction and ecosystem improvement goals, it was determined that hydrodynamic modeling of project alternatives would better inform these objectives using higher roughness values (corresponding to more densely vegetated conditions). On the flood risk reduction side, a higher roughness coefficient results in a higher modeled water surface elevation and higher levee design heights. It also provides an added buffer to account for model uncertainty. On the ecosystem improvement side, assuming a higher vegetation density and roughness coefficient reduces expected vegetation maintenance requirements in the floodplain in the levee setback areas. This reduces potential environmental impacts associated with these activities (and reduces costs associated with maintenance). As a result, the setback roughness coefficients for all project alternatives were set to emulate dense riparian vegetation conditions (n = 0.070).

FIGURE 16: INFLUENCE OF VEGETATION DENSITY ON WATER SURFACE ELEVATIONS IN SETBACK REACH



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APPENDIX C

Lower Deer Creek Flood and Ecosystem Improvement Model Alternative 1a inundation depth maps at 21,000 cfs. This is the design flow for the Deer Creek Flood Control Project (USACE 1957).

NOTE: Appendix C has been superseded by Appendix D, which is included as an attachment in the "Lower Deer Creek Flood and Ecosystem Improvement Project – 2D Hydrodynamic Model North Canal Cutoff Results Addendum" (Addendum 2 of Appendix G).