East Fork Lewis River Ridgefield Pits Restoration

Basis of Design Report Preliminary Design:

Attachment 3 – Hydraulic Model Analysis

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Contents

1.1 OVERVIEW

LCEP developed a 2D hydrodynamic model using the Tuflow FV modeling engine (Tuflow FV 2020, 2013) developed by the University of Queensland in Australia (and currently owned by British Maritime Technologies) to evaluate surface hydraulics along the East Fork Lewis River (EFLR) and its floodplain throughout the project site. The model is an upstream extension of an original model that was calibrated and applied as part of the EFLR La Center Wetlands project. The hydraulic model was used to evaluate existing hydraulic conditions and aid in the selection of preferred restoration design alternatives. Hydraulic model outputs also provide input to sediment and water quality modules used to evaluate geomorphic changes and water temperatures (see main report sections 2.5 and 2.6, respectively). A summary of the modelling process and model results are presented here. The model uses a metric coordinate system (UTM) and thus simulation results are output in metric units accordingly. Conversion to Imperial units has been done in this report where it is convenient and useful for the reader, however many of the data plots do retain metric units.

1.2 MODEL EXTENT AND ELEVATION DATA SOURCES

The model extent is shown in Figure 1. We derived model grid elevations from 2010 U.S Army Corps of Engineers LiDAR; 2018 bathymetric soundings collected by Inter-Fluve (see main report Attachment #1); 2018 RTK-based topo/bathy points collected by Inter-Fluve and LCEP (see main report Attachment #1); and 2018 UAV-derived imagery collected by LCEP.

Figure 1. Hydrodynamic model grid, illustrating model extent and upstream/downstream boundary forcing locations.

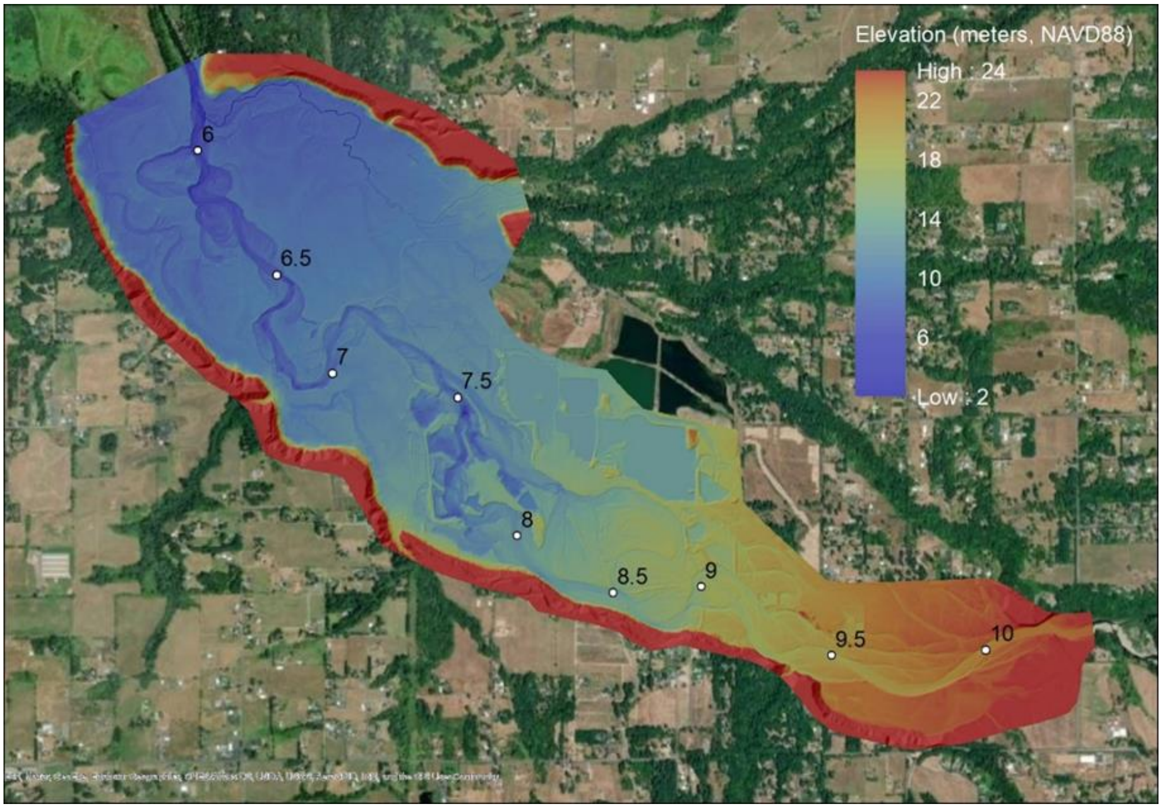


Figure 2. Hydrodynamic model topography in meters. Markers indicate EFLR miles.

Changes in river planform are occurring rapidly in the Project reach, and survey data collected for the model may no longer be accurate in some areas. Figure 2 illustrates the extent of change that has occurred between 2010 (when Corps of Engineers LiDAR data was collected) and 2017 near River Mile 8, where a significant northward migration of the river channel can be seen. It is recommended that for these areas especially, and possibly the entire reach, a new elevation survey be conducted for future design phases to ensure that the model and design surfaces reflect current conditions.

Figure 2. Change in river planform at river mile 8 between 2010 (indicated by the yellow line) and 2017 (shown in image).

1.3 MODEL BOUNDARIES AND BOUNDARY CONDITION FORCING

Model forcing is applied at the upstream boundary near river mile 10 (just upstream of Daybreak Park) and at the downstream boundary near river mile 6 (just downstream of the Mason Creek confluence). EFLR discharge is applied at the upstream boundary, with corresponding river stage applied at the downstream boundary. A range of discharge values have been applied in steady state simulations, covering the approximate 1,2,5,10 and 100-year flood recurrence interval magnitudes (Table 1) and lower flows covering the summer-fall base flow period. Downstream stage values corresponding to each discharge value are obtained from a stage-discharge relationship that was established using the earlier, calibrated model developed for a downstream project at La Center Wetlands. Figure 3 shows predicted stage at the upstream boundary of that model (which corresponds to the downstream boundary of the Ridgefield Pits model) for the range of discharge values that were applied, and the resulting stage-discharge curves (for overbank and in-channel flow separately) that were derived. Figure 4 shows the extent and overlap of the earlier La Center Wetlands model and the Ridgefield Pits model.

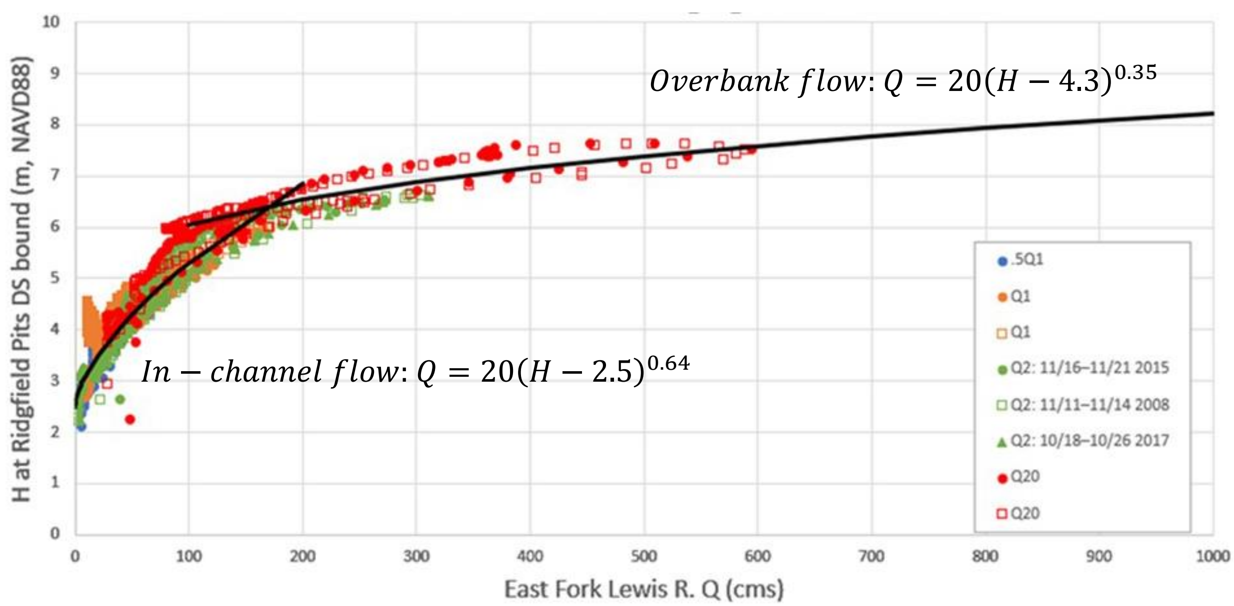


Figure 3. Established stage (H) - discharge (Q) relationship between upstream flow and downstream water level for the Ridgefield Pits model, obtained from outputs of downstream La Center Wetlands model simulations.

Table 1. Steady-state discharge values in cubic feet per second (cfs) that have been applied at the project upstream boundary for hydraulic and temperature modeling.

Discharge (Q), cfs	Applied Models	Note		Discharge (Q), cfs	Applied Models	Note
35	Hydraulic/Temp.	approx. lowest flow recorded		5,000	Hydraulic	approx. Q_1
80	Hydraulic/Temp.			10,000	Hydraulic	approx. Q_2
150	Hydraulic/Temp.			15,000	Hydraulic	approx. Q_{10}
500	Hydraulic			22,000	Hydraulic	Approx. Q_{50}
1,000	Hydraulic			28,000	Hydraulic	Approx. Q_{500}
3,000	Hydraulic	approx. bankfull				

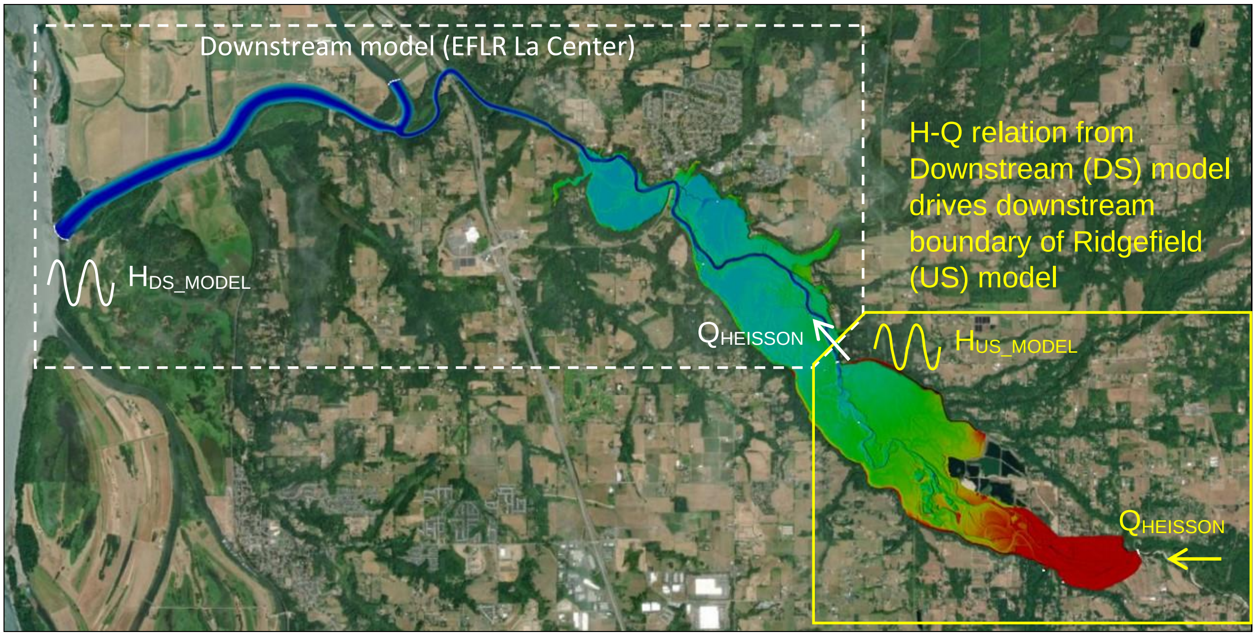


Figure 4. Full extent and overlap of the downstream La Center Wetlands and upstream Ridgefield Pits hydrodynamic models.

1.4 EXISTING CONDITIONS (EC) CHANNEL GEOMETRY

Longitudinal bed profiles and channel cross section profiles of the main channel in the Existing Condition (EC) model surface are shown in Figures 5 and 6. Metric profiles output directly from the model surface are shown in Figure 5 while imperial unit profiles have been included as Figure 6, for interested users and for direct comparison to other studies. Average slope of the project reach above the Ridgefield Pits is ~0.00364. Average slope through the Ridgefield Pits Reach decreases to ~0.00167. Large variations in depth occur through this section, which are indicative of both limited resolution of the bathymetric data source as well as gravel pits in various stages of recovery from accumulation of sediment over the past several decades.

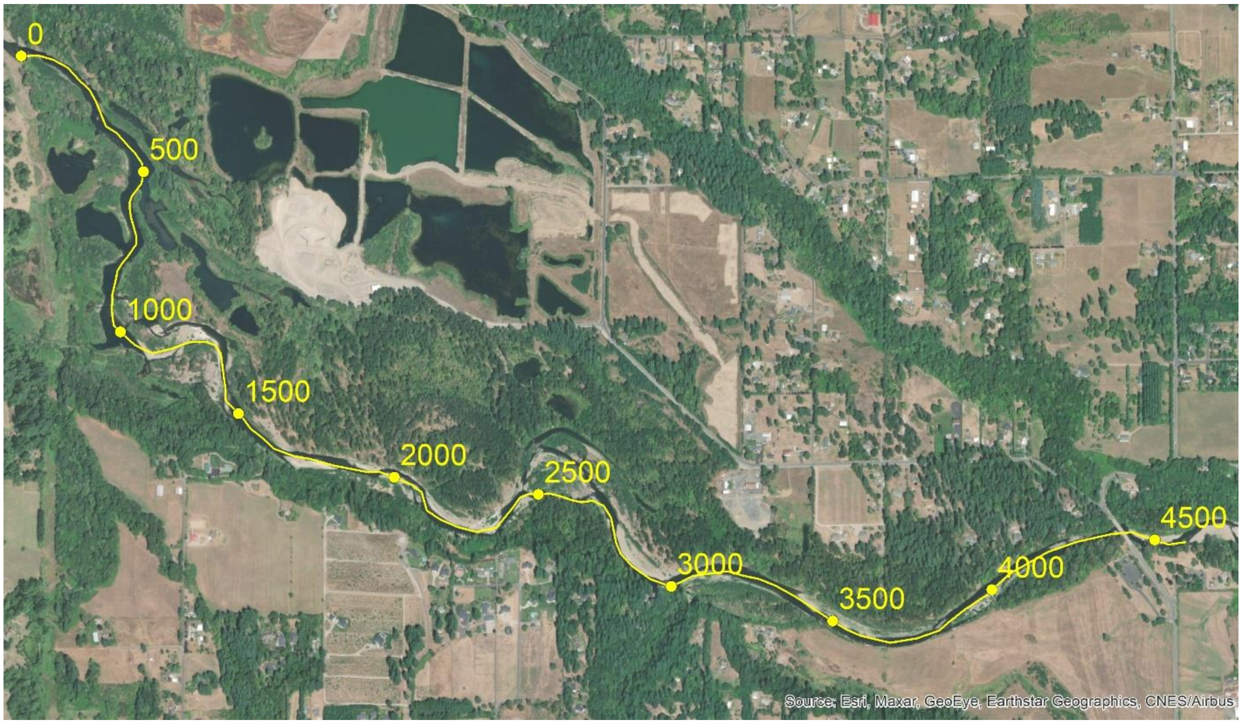


Figure 5a. Longitudinal track along main EFLR channel used to generate bed profile shown in Figure 4b. Metric units.

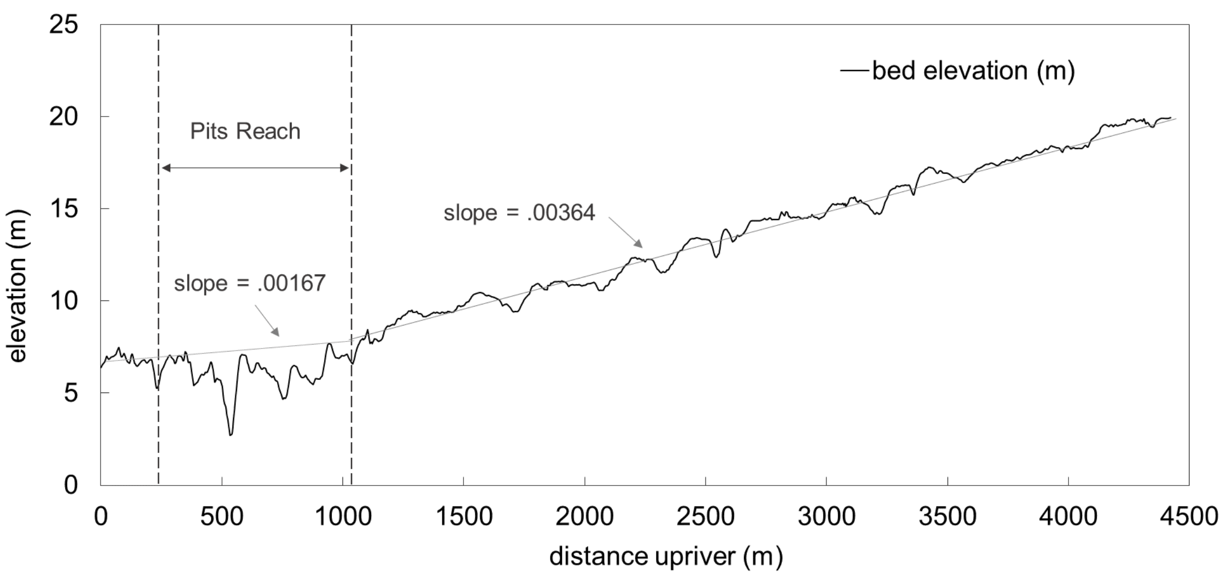


Figure 5b. Longitudinal bed profile of main EFLR channel along track shown in Figure 4a, derived from the EC model surface. Metric units.

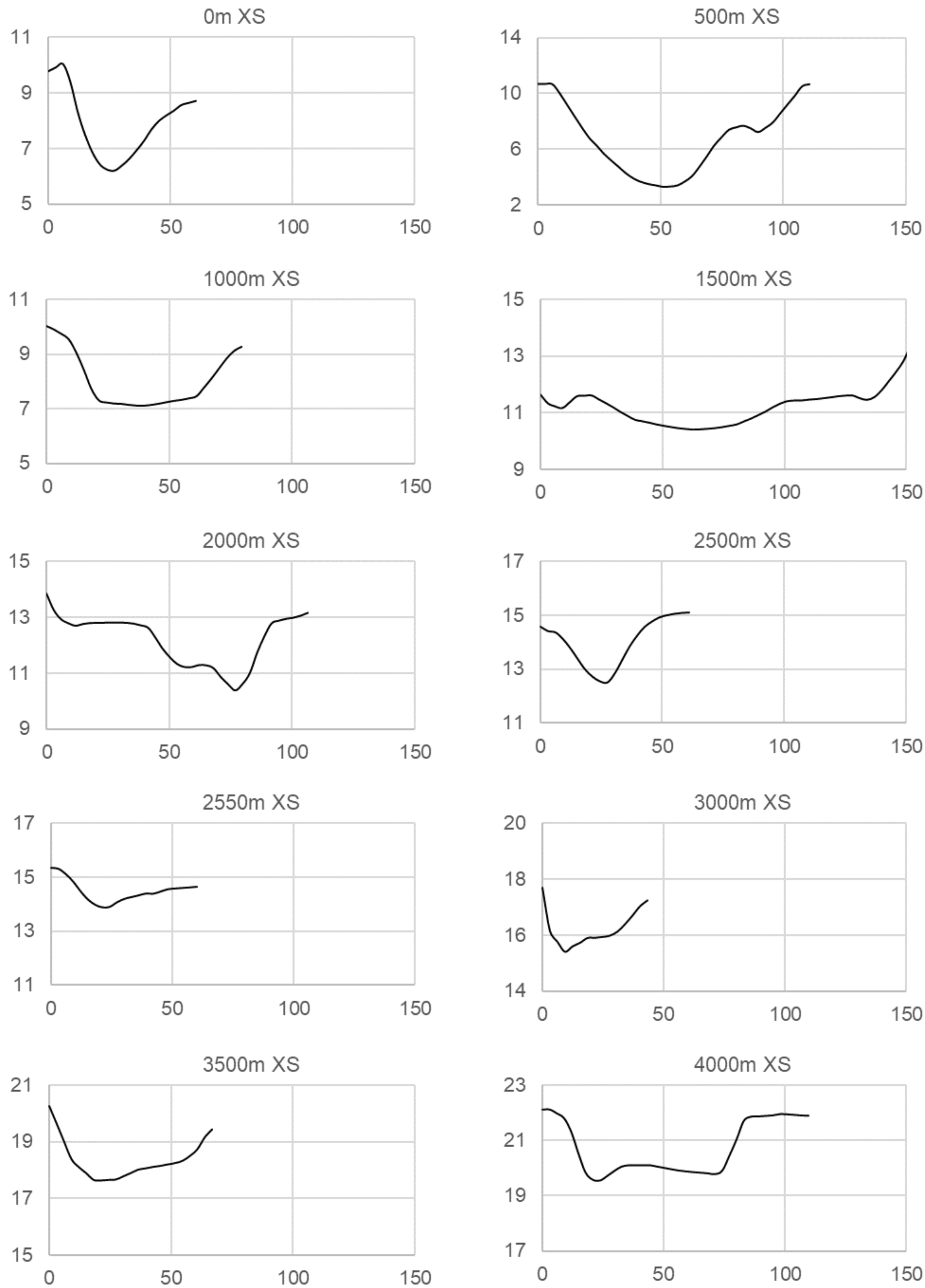


Figure 5c. EFLR main channel cross sections at point locations shown in Figure 4a, derived from the EC model surface. For all plots: X axis = distance along cross section in meters; Y axis = elevation in meters.

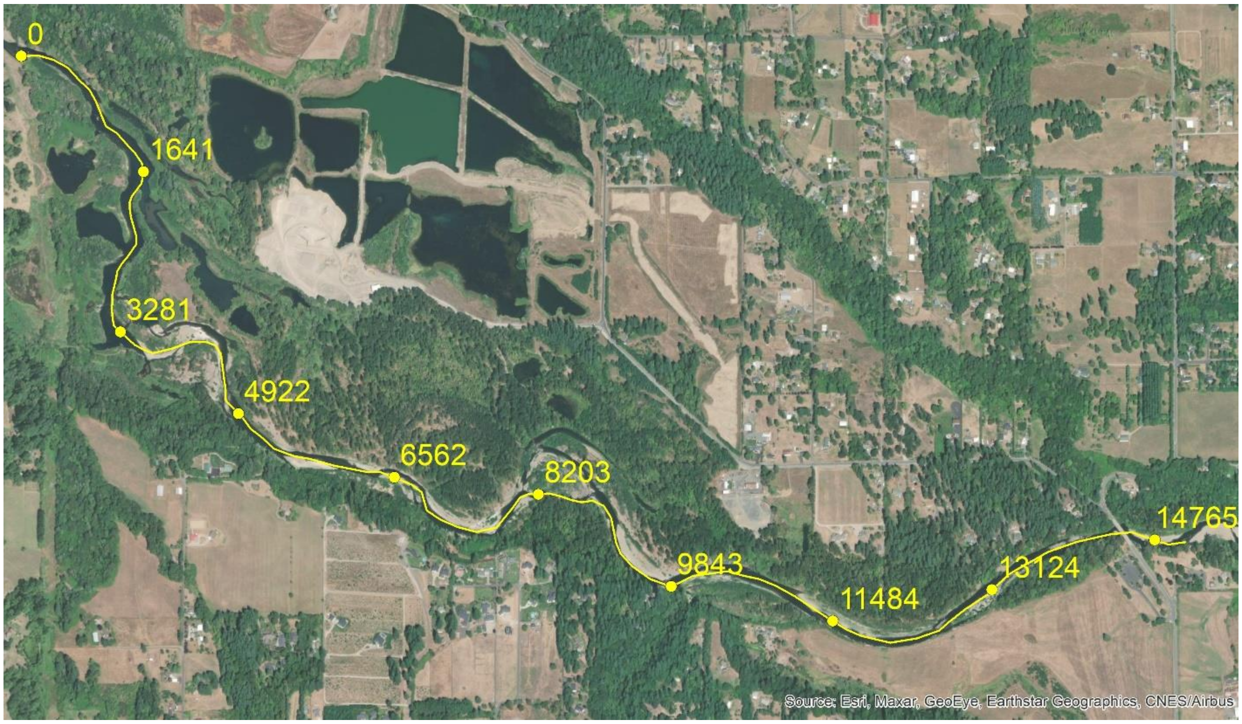


Figure 6a. Longitudinal track along main EFLR channel used to generate bed profile shown in Figure 5b. Imperial units.

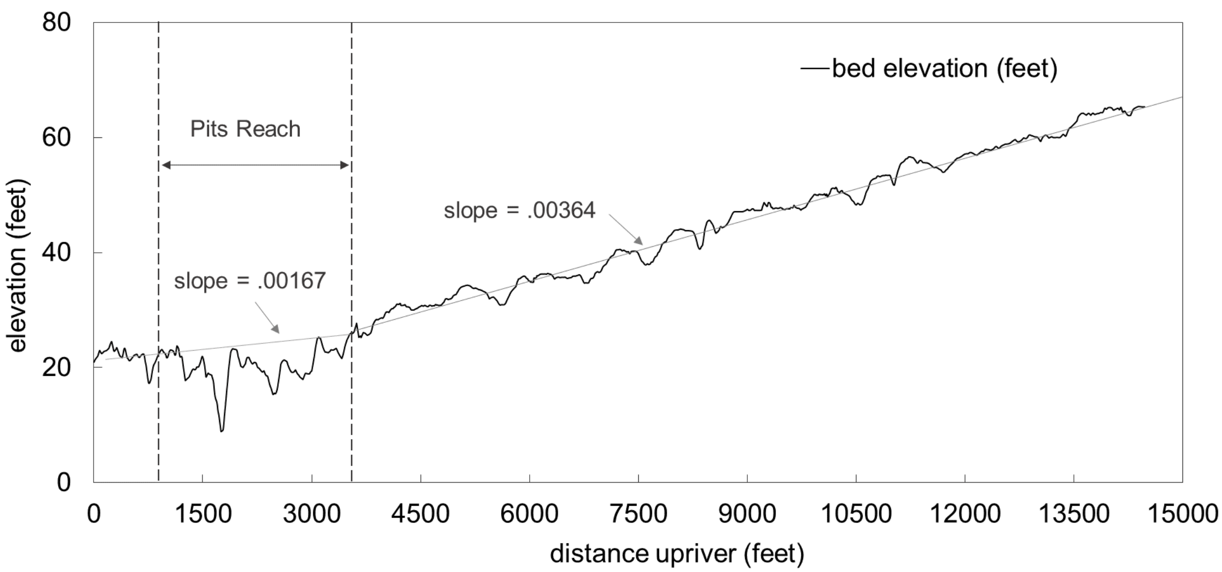


Figure 6b. Longitudinal bed profile of main EFLR channel along track shown in Figure 5a, derived from the EC model surface. Imperial units

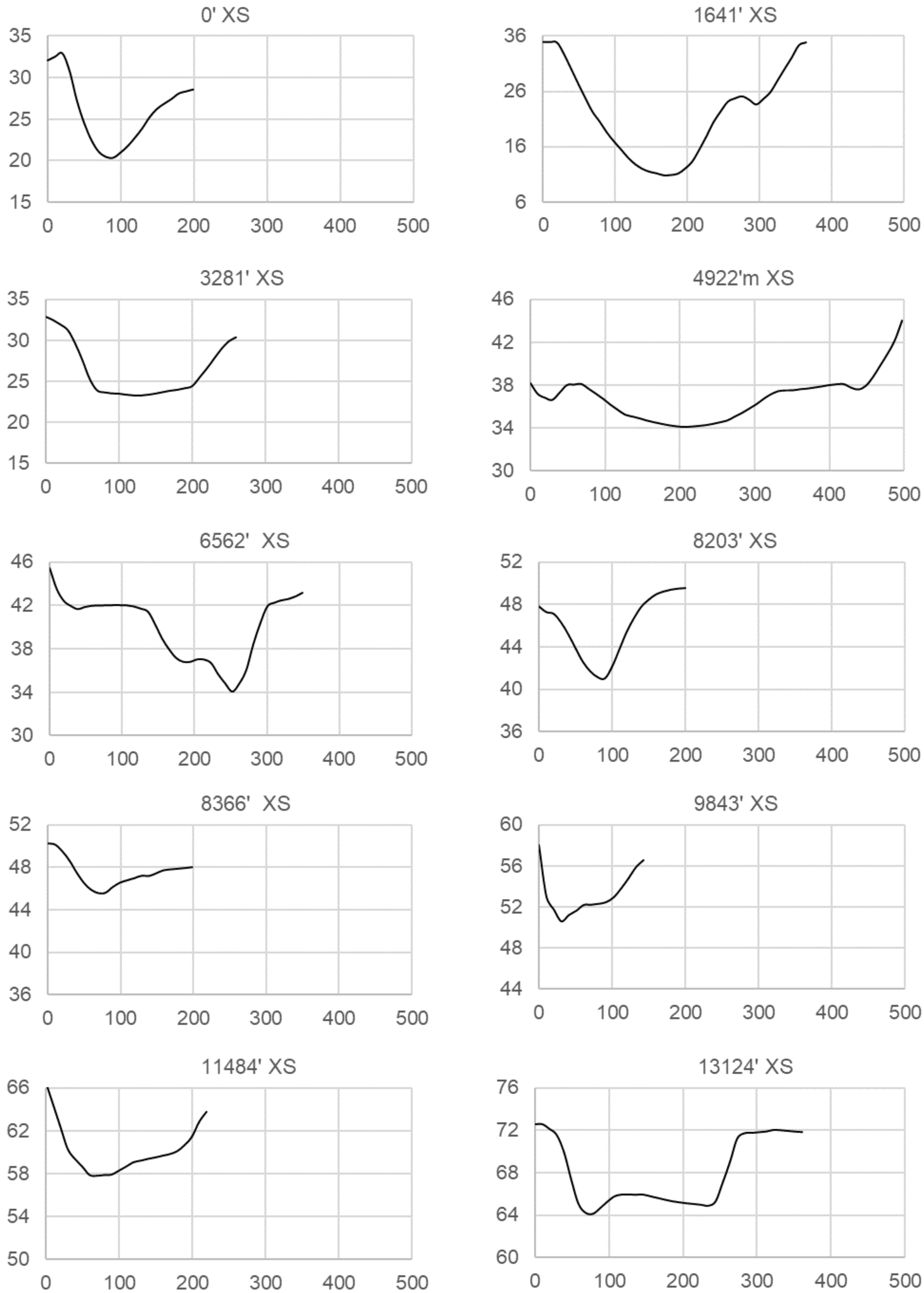


Figure 6c. EFLR main channel cross sections at point locations shown in Figure 5a, derived from the EC model surface. For all plots: X axis = distance along cross section in feet; Y axis = elevation in feet.

1.5 MODEL SURFACE COMPOSITION AND MANNING'S FRICTION COEFFICIENTS

Bed friction momentum terms are calculated in the Tuflow 2D hydraulic model using a Manning's roughness coefficient, η, specified for the bed surface material. The surface materials and assigned Manning's values that are used in the model are shown in Table 2. Values were estimated using the USGS Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains (Arecment and Schneider, 1989) as well as values applied in the calibrated Downstream La Center model. The East Fork Lewis River channel takes on many different bed forms through the project area, ranging from a surface armored with large cobble throughout some sections to finer sands and gravels in slower flowing, lower gradient reaches, particularly through the Ridgefield Pits.

Table 2. Surface materials used in the hydraulic model, and their assigned Manning's η values.

Surface Material	Assigned Manning's η value
High-gradient straight channel, armored	.03
Low-gradient straight channel, armored	.032
Low-gradient straight channel, no armor	.028
Low-gradient winding channel, armored	.04
Low-gradient winding channel, no armor	.035
Deep pools, gravel pits	.04
Sand (floodplain)	.025
Grasslands (floodplain)	.038
Light shrub (floodplain)	.05
Dense shrub/forest (floodplain)	.06
Gravel shoals	.045
Bare, compacted (floodplain)	.025

1.6 MODEL GRID RESOLUTION

Tuflow FV is a flexible mesh modeling engine that allows for a varied grid size throughout the model domain. This allows for higher resolution modeling in areas that require it due to small-scale topographic variations, whereas in other areas with greater spatial homogeneity a larger grid size can be used, thereby minimizing the number of grid cells and associated processing time. The model developed for the Ridgefield Project reach uses a fixed cell size of approximately 5 square meters throughout the areas where restoration alternatives were evaluated. While not as computationally efficient as the variable size solution discussed above, this was done to keep the model grid consistent for the different channel geometries that were evaluated, thereby eliminating the potential for any grid biases when comparing simulation results for these different alternatives. This is most important regarding performance of the morpho-dynamic module used to evaluate sediment transport, which is discussed in Section 2.5 and Attachment #4 of the main report. The 5-meter cell size was selected as a balance between resolving the minimum channel widths to be modeled while keeping the grid to a reasonable size based on the available computing power. Figure 7 shows the model grid cells within the Ridgefield Pits reach, for the EC and the initial multi-thread hybrid alternative that was evaluated.

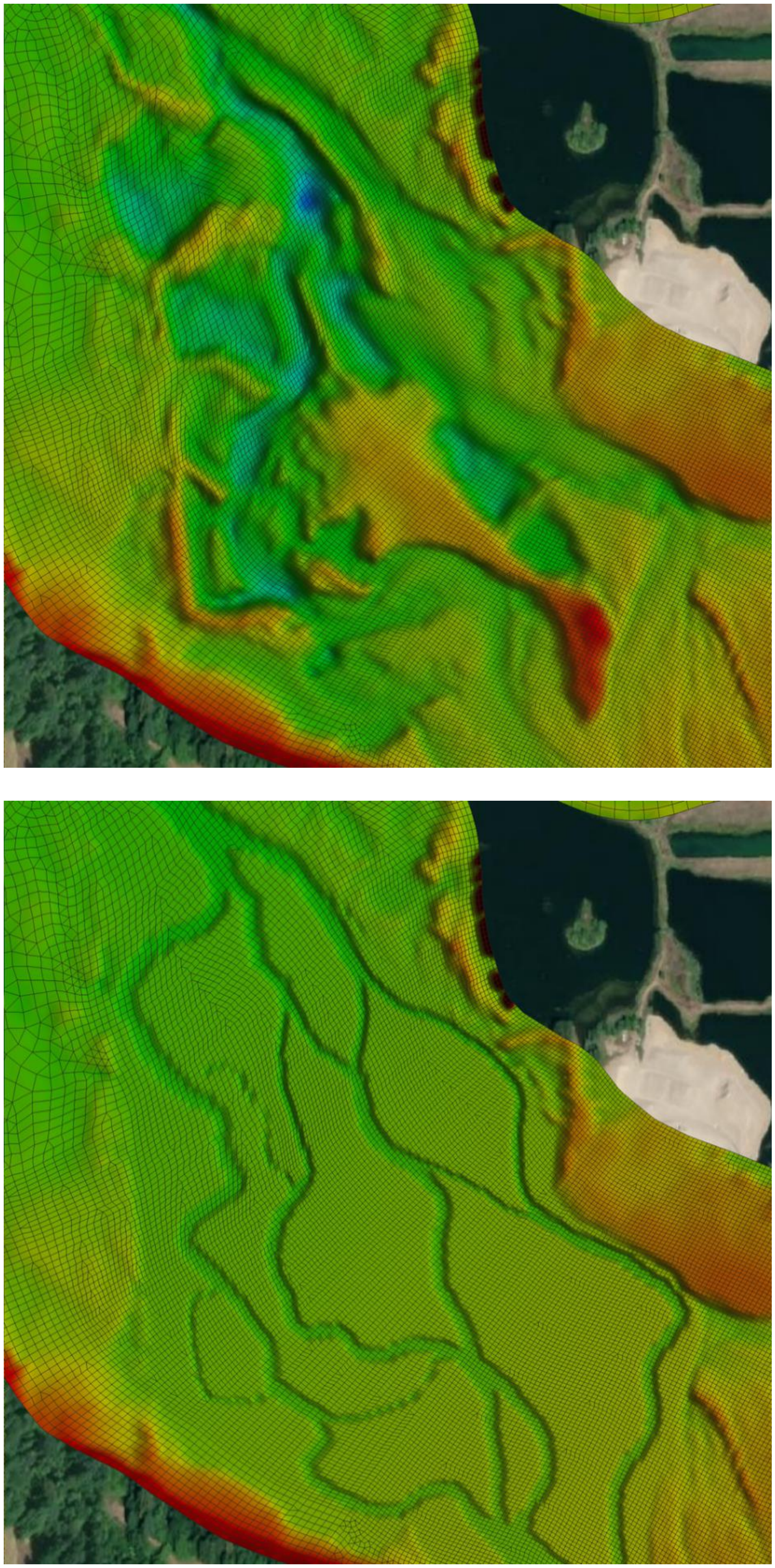


Figure 7. Model grid illustrating the grid cell resolution and fixed cell size in the vicinity of the Ridgefield Pits reach. Top: EC. Bottom: initial multi-thread Alternative 3.

1.7 MODEL SIMULATIONS COMPLETED

The hydraulic model was run for the range of flows listed in Table 1, for the EC and selected restoration alternatives that include significant changes to channel geometries and resulting hydraulics. From the list of developed alternatives in described in Section 3.1 of the main report, those which were modeled are listed in Table 3.

Table 3. Restoration Alternatives for which hydraulic modeling was applied to evaluate performance.

Restoration Alternative
[1]Alternative 1 – No action; passive recovery of Pits Reach (EC)
[2]Alternative 2 – Relocate main channel within Pits Reach into pre-avulsion channel location (single-thread)
[3]Alternative 3 – Full pits re-grade (multi-thread channel network)
[4]Alternative 5 – Mill-Manley confluence high-flow channel.

Alternative 1. This is the EC. Simulations results are compared to those for other Alternatives in the Ridgefield Pits reach, which include Alternatives 2 and 3. Performance of each is weighed against the Goals and Objectives included in Section 4.1 of the main report.

Alternative 2. This modeling is still in progress. The design team did not initially intend to model this Alternative based on the low score it received during the initial screening process, however the TOG has expressed additional interest in reviewing the results. The team is currently working to generate the results and compare to those for the EC and Alternative 3.

Alternative 3. The design team modeled two separate Alternative 3 multi-thread channel networks. The initial layout consisted of several channels of varied size with crossing paths. The second layout consisted of a 3-channel 'hybrid' network which included alcoves in existing areas. This iterative process is discussed in Section 4.2.1 of the main report and ultimately the 'hybrid' layout was selected as the preferred for the reasons discussed within. Model results shown in this section are included for the 3-channel hybrid alternative only.

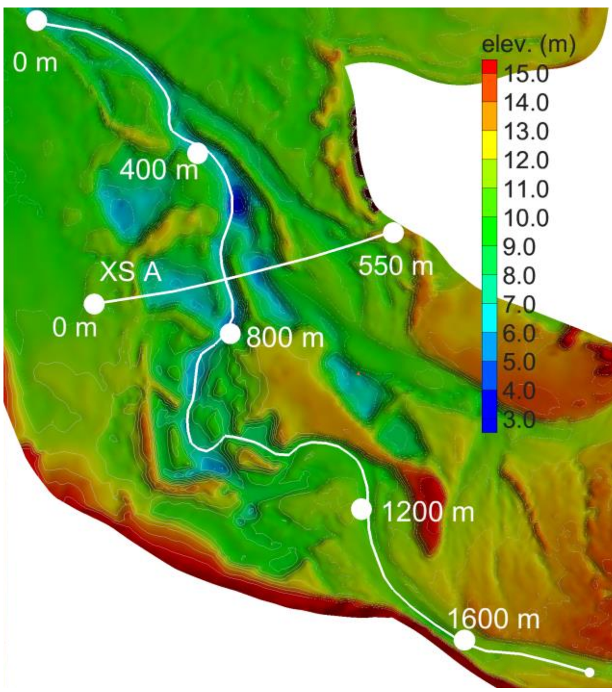
Alternative 5. Multiple restoration concepts were proposed at the Mill-Manley confluence however the overflow channel was the only one that involved significant channel re-work requiring hydraulic model evaluation. Results were compared to the EC, to evaluate the capacity for high flows delivered by the overflow channel to the confluence zone to create adequate scour to remove sand and gravels that typically deposit in this area and reduce available cold-water habitat.

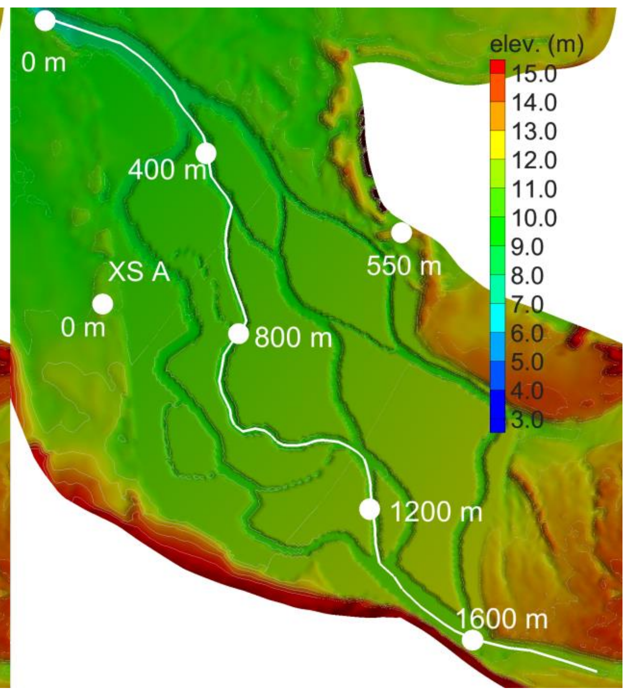
1.8 MODEL RESULTS: ALTERNATIVES 1 AND 3 (EC COMPARED TO MULTI-THREAD)

- Alternative 3 channel geometry

Channel profiles for the EC and iterations of the Alternative 3 multi-thread are shown in Figure 9, for the respective longitudinal and cross-sectional profiles shown in Figure 8. Evolution of the Alternative 3 channel configuration was guided by the following design objectives, as discussed in Section 4.2.1 of the main report: maintaining an acceptable cut-fill balance; the desired bankfull flow; the desired number of channels as determined by the Technical Oversight Group.

The amount of external fill required (i.e. the amount of fill that would need to be imported to the site to fill the Ridgefield Pits and grade the floodplain to the desired slope) was reduced from ~400,000 cy to ~44,000 cy through the iteration process. This was accomplished by lowering the overall elevation and adjusting the longitudinal slope of the floodplain through the Ridgefield Pits reach, as can be seen in Figure 9. In going from the initial multi-thread surface to the initial 3-channel hybrid (Fig. 8 top right to bottom left) a net cut (i.e. material needing to be removed from the site) of 72,000 cy resulted. The floodplain elevation was then raised back up slightly, resulting in the revised 3-channel hybrid surface (i.e. the proposed Alternative 3 surface, as shown in Fig. 8, bottom right) with a net fill of ~44,000 cy. This was considered an acceptable cut-fill balance for the current design level and will be further adjusted as necessary during final design.





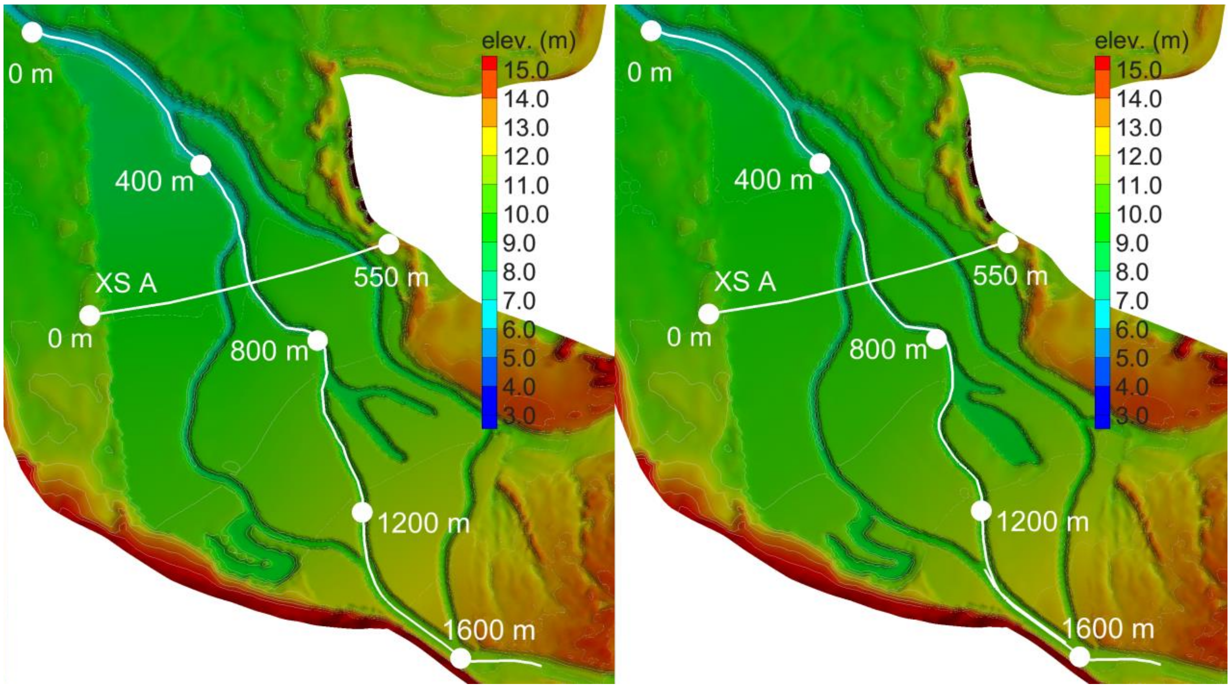
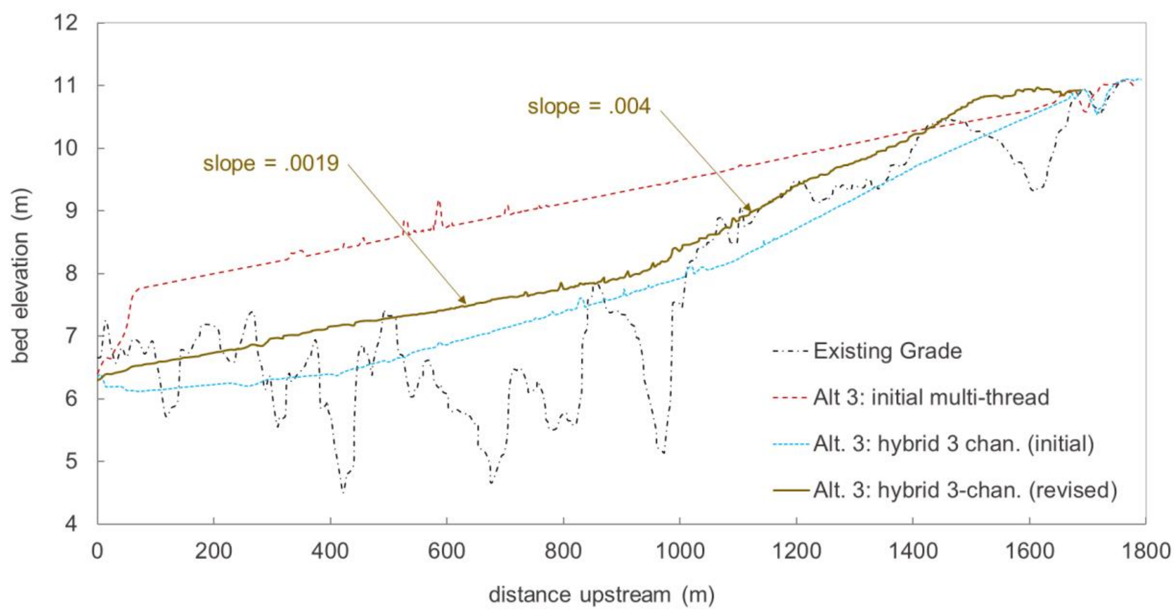


Figure 8. Model topography and elevation profile paths for the EC and Alternative 3 multi-thread iterations. Top Left: EC; Top Right: initial multi-thread; Bottom Right: initial 3-channel hybrid; Bottom Left: revised 3-channel hybrid. Respective longitudinal and cross-sectional elevation profiles are shown in Figure 9 below.



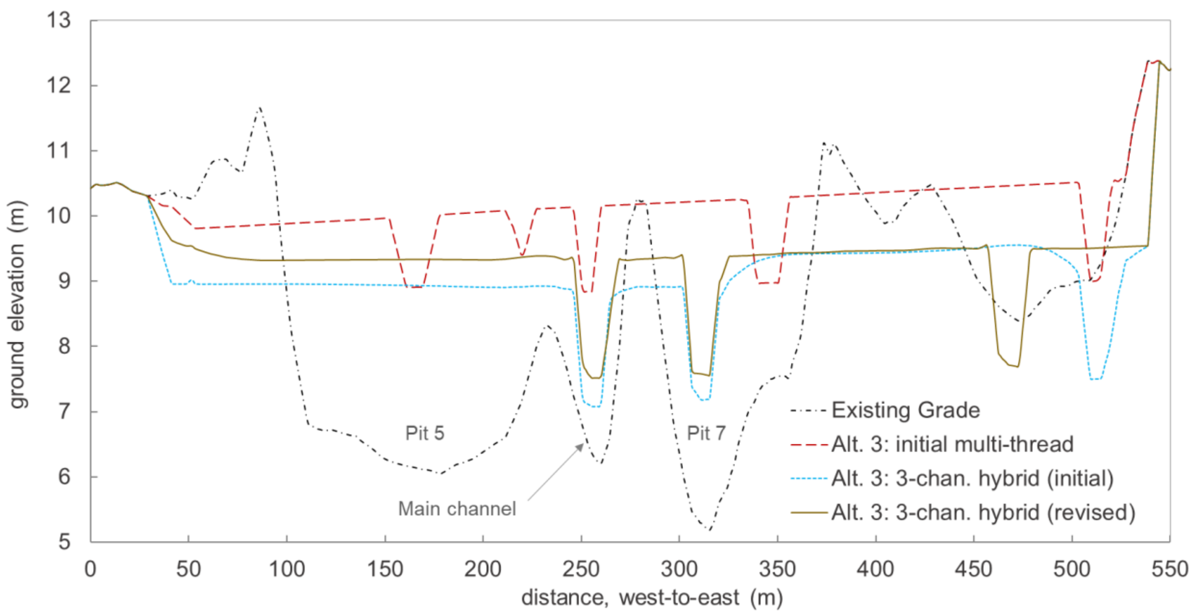


Figure 9. Model elevation profiles along the profile paths shown in Figure 8 above. Top: longitudinal profiles for selected channels; Bottom: cross-sectional profiles along cross section A (XS A in Figure 7).

Longitudinal bed slope of the Alt3 hybrid 3-channel network is close to that of the EC channel. Both exhibit a grade break at approximately 1,000m upstream, with higher slope upstream (0.0036 for the EC, versus 0.004 for Alt.3) and lower slope downstream (0.0017 for the EC versus 0.0019 for Alt. 3) of the break. Maintaining this existing floodplain grade helps to optimize the cut fill balance for the Alt. 3 design and allows preservation of intact, high elevation vegetation that currently exists upstream of the grade break.

Geometries (channel widths and depths) for the Alt. 3 hybrid 3-channel network were determined using standard Manning's calculations for trapezoidal channels, based on the desired bankfull depth of 1.8 m (5.9') and approximate bankfull flow of 2,600 cfs for the project reach (see Section 4.2.1 of the main report). Measured values for channel geometry parameters taken from the model surfaces are shown in Table 4 below, along with calculated bankfull flow, flow velocity, width-to-depth ratio, and shear stress values. For the Alt. 3 hybrid 3-channel preferred alternative shown in the left column, measured values differed slightly from targeted design values because of limitations imposed by the model grid cell size (~5 meters). Channel parameters for the EC model are also included in Table 4 for comparison. The EC consists of a single channel through most of the Ridgefield Pits reach.

For the given parameters, channel overtopping is predicted to occur at 1,267 cfs for the Alt. 3 hybrid 3-channel design, which corresponds to an upstream discharge of 3,801 cfs (3 x 1,267 cfs) entering the project reach. This value is higher than the initial design guideline of 2,600 cfs. Modeling time constraints did not allow for a further revision of channel geometry to reduce the bankfull flow to the targeted value during the present design phase, and so this will be done in later phases when the channel layouts are looked at in greater detail.

Results of the trapezoidal channel calculations shown in Table 4 suggest improvements in hydraulic conditions for the preferred Alternative 3 compared to the EC. These include reduced channel velocities and reduced shear stress at the bankfull condition, as well as reduced channel width to depth ratios which should improve temperature performance at lower flows, by maintaining greater water depths (except for in the Ridgefield Pits proper, where water depths are currently high at all flows).

Table 4. Channel geometry parameters and associated bankfull flow, flow velocity, and shear stress calculated using Manning's trapezoidal channel formula, for the Alternative 3 hybrid 3-channel model and the EC model.

	Alternative 3 hybrid 3-channel network, individual channel parameters	EC, single channel parameters
Channel bottom width (m / ft.)	9.0 / 29.5	36 / 118.1
Side slope (x/y)	3	4.5
Manning's η-value	0.035	0.035
Chan slope, upstream section	0.004	0.0036
Chan slope, downstream section	0.0019	0.0017
Flow Depth (m / ft.)	1.75 / 5.7	2.7 / 8.9
Channel top width (m / ft.)	19.4 / 63.6	60.3 / 197.8
Flow conveyance area (m^2 / ft^2)	24.9 / 268.4	130.0 / 1399.4
Wetted perimeter (m / ft.)	20.1 / 65.8	60.9 / 199.8
Hydraulic Radius (m / ft.)	1.2 / 4.1	2.1 / 7.0
Bottom Width/Depth ratio	5.1	13.3
Calculated flow velocity, upstream section (m/s / ft./s)	2.1 / 6.9	2.8 / 9.3
Calculated flow velocity, downstream section (m/s / ft./s)	1.4 / 4.7	2.0 / 6.4
Calculated bankfull flow, Q, upstream section (m^3/s / $ft.^3$/s)	52 / 1,839	369.5 / 13,048
Calculated bankfull flow, Q, downstream section (m^3/s / $ft.^3$/s)	35.9 / 1,267	253.9 / 8,967
Calculated Shear stress, upstream section (N/m^2 / pd./$ft.^2$)	48.7 / 1.0	75.4 / 1.6
Calculated Shear stress, downstream section (N/m^2 / pd./$ft.^2$)	23.1 / 0.5	35.6 / 0.7

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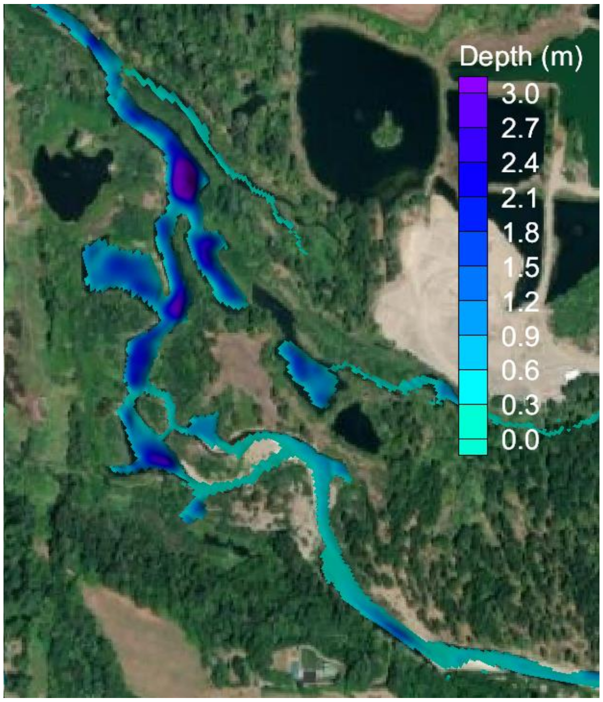
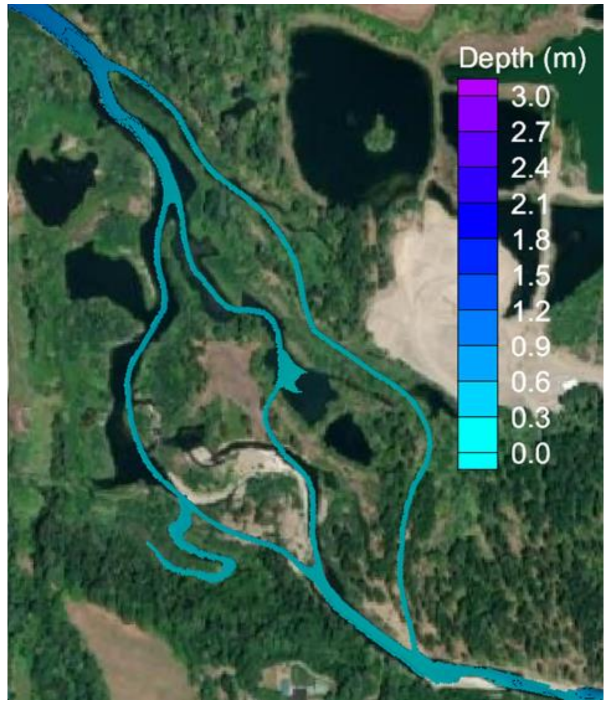
- Model steady-state simulation outputs: Water Depth

Steady-state simulation water depth profiles are shown in Figure 10 for the EC and Alternative 3 hybrid 3-channel network model surfaces. Channel depths and flows for the individual channels of the Alt.3 hybrid 3-channel network are shown in Table 5 for input flows less than and up to the design bankfull flow. Depths for the EC model are not included because water depth is highly variable throughout the Ridgefield Pits reach, making comparison to the Alt 3 results difficult.

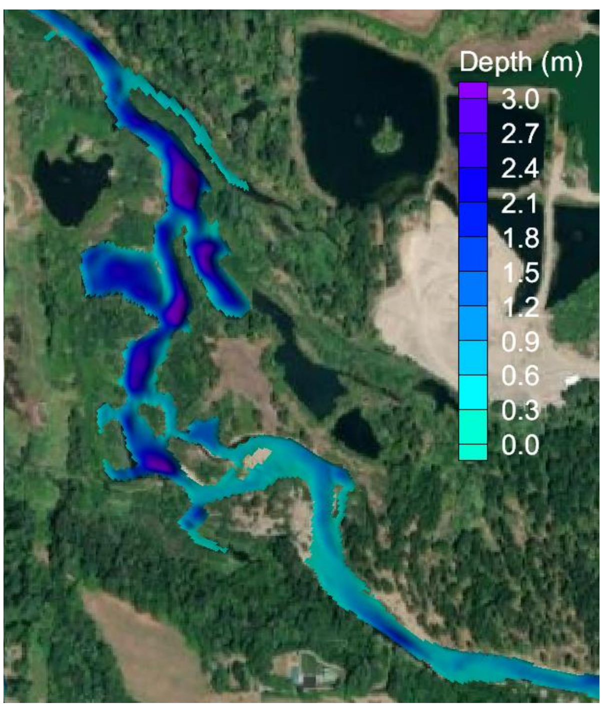
EC, Q = 35 cfs



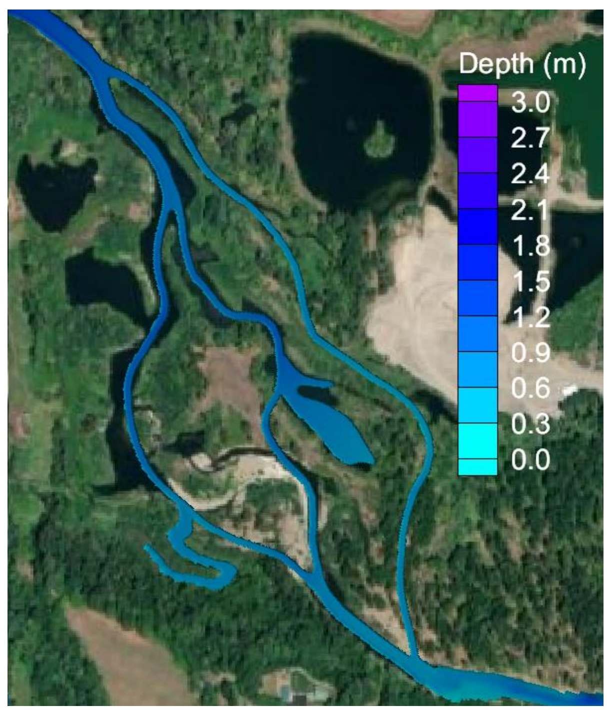
Alt 3, Q = 35 cfs



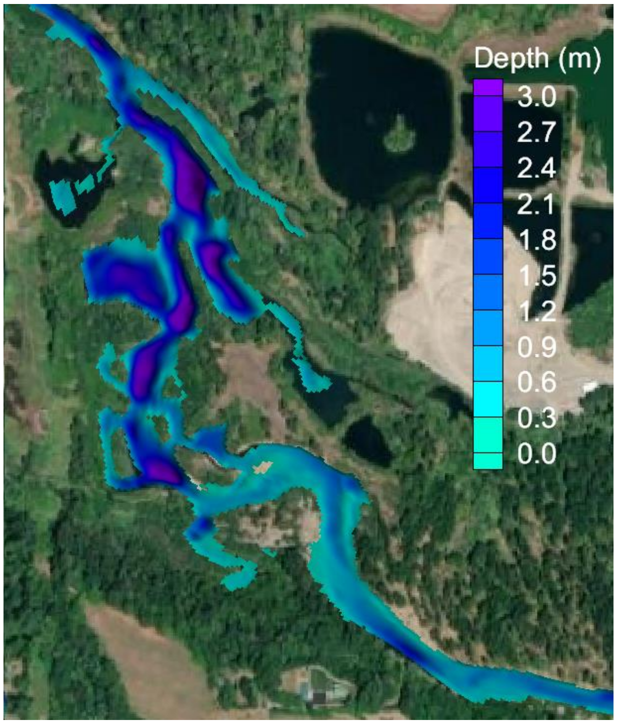
EC, Q = 500 cfs



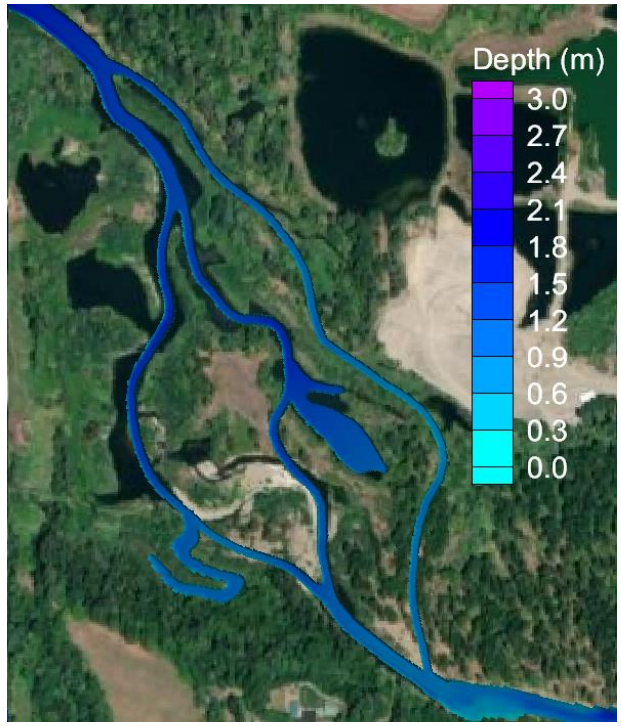
Alt 3, Q = 500 cfs



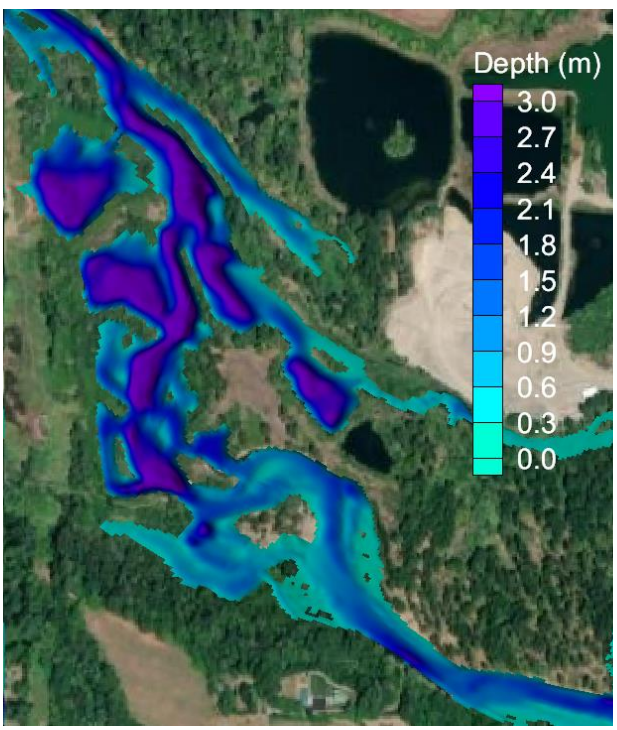
EC, Q = 1,000 cfs



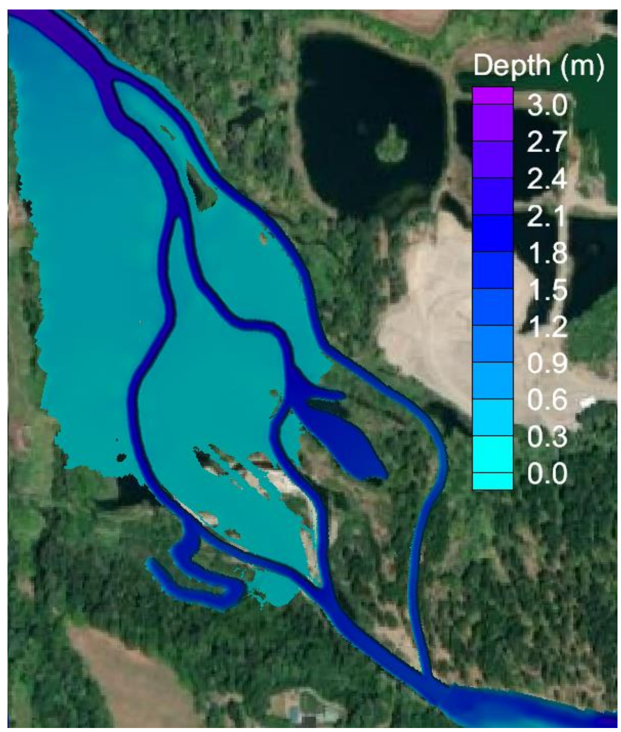
Alt 3, Q = 1,000 cfs



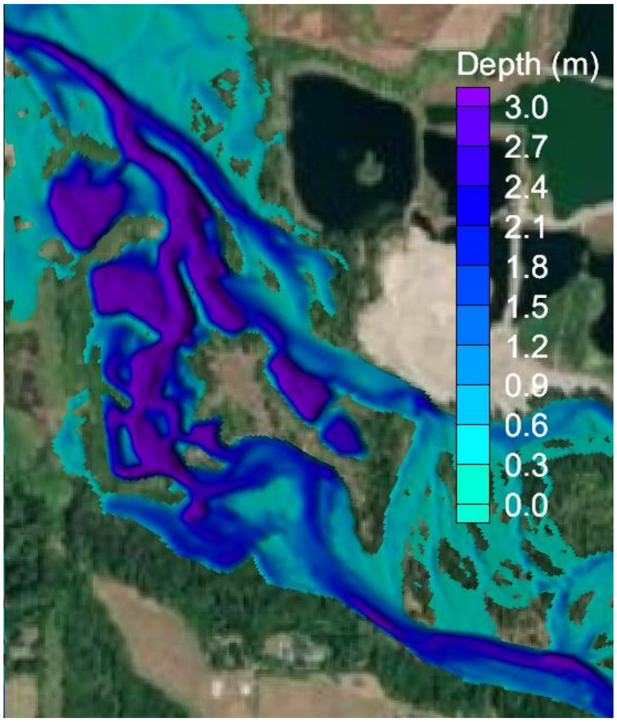
EC, Q = 3,000 cfs



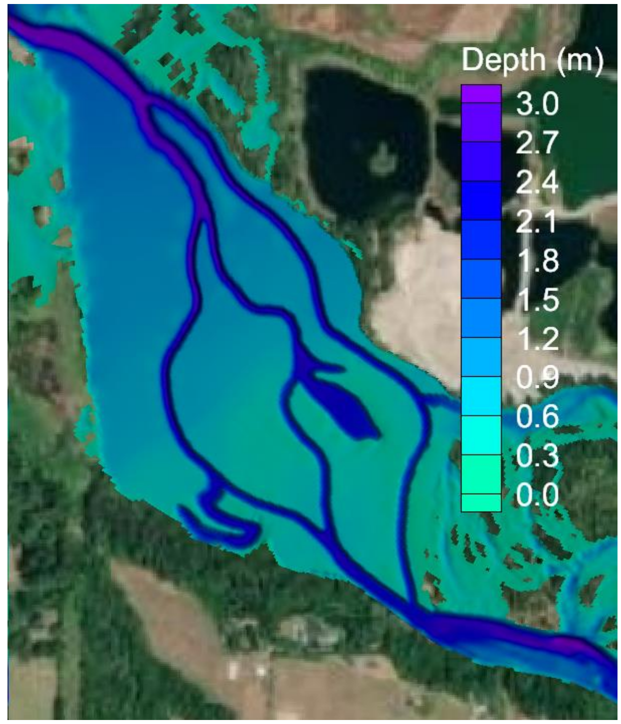
Alt 3, Q = 3,000 cfs



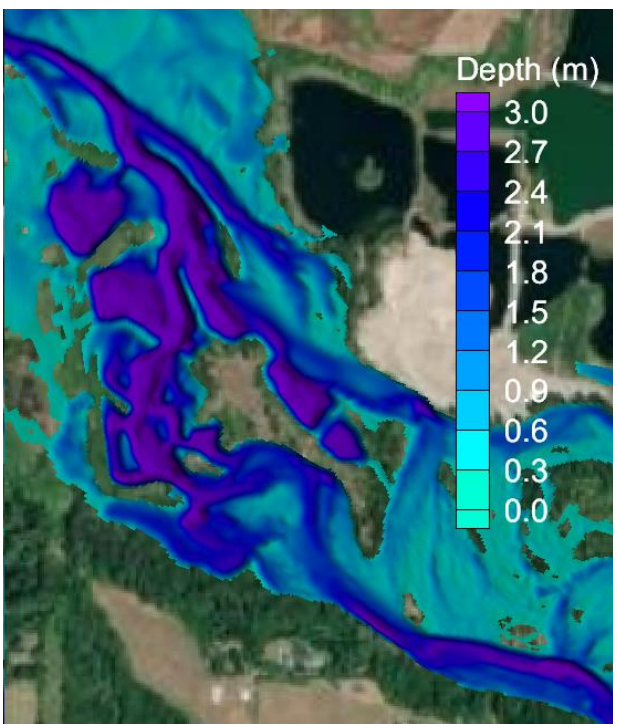
EC, Q = 10,000 cfs



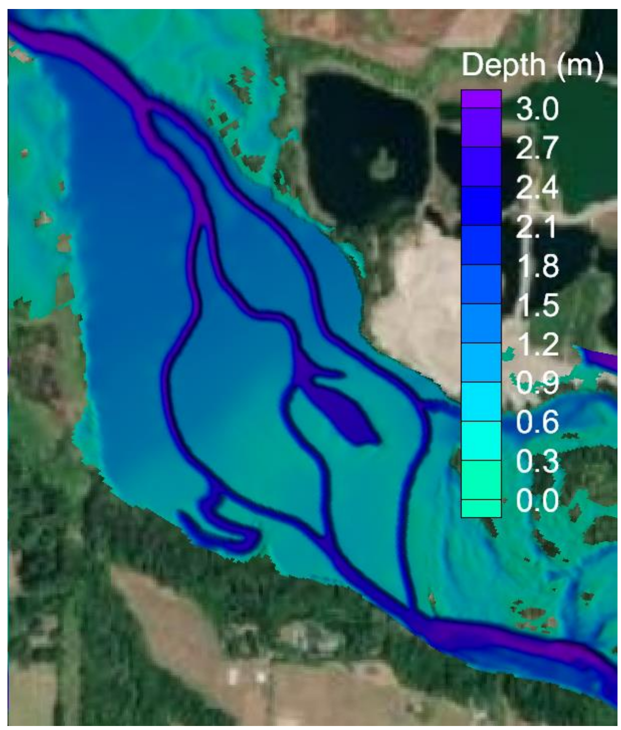
Alt 3, Q = 10,000 cfs



EC, Q = 15,000 cfs



Alt 3, Q = 15,000 cfs



EC, Q = 28,000 cfs   Alt 3, Q = 28,000 cfs

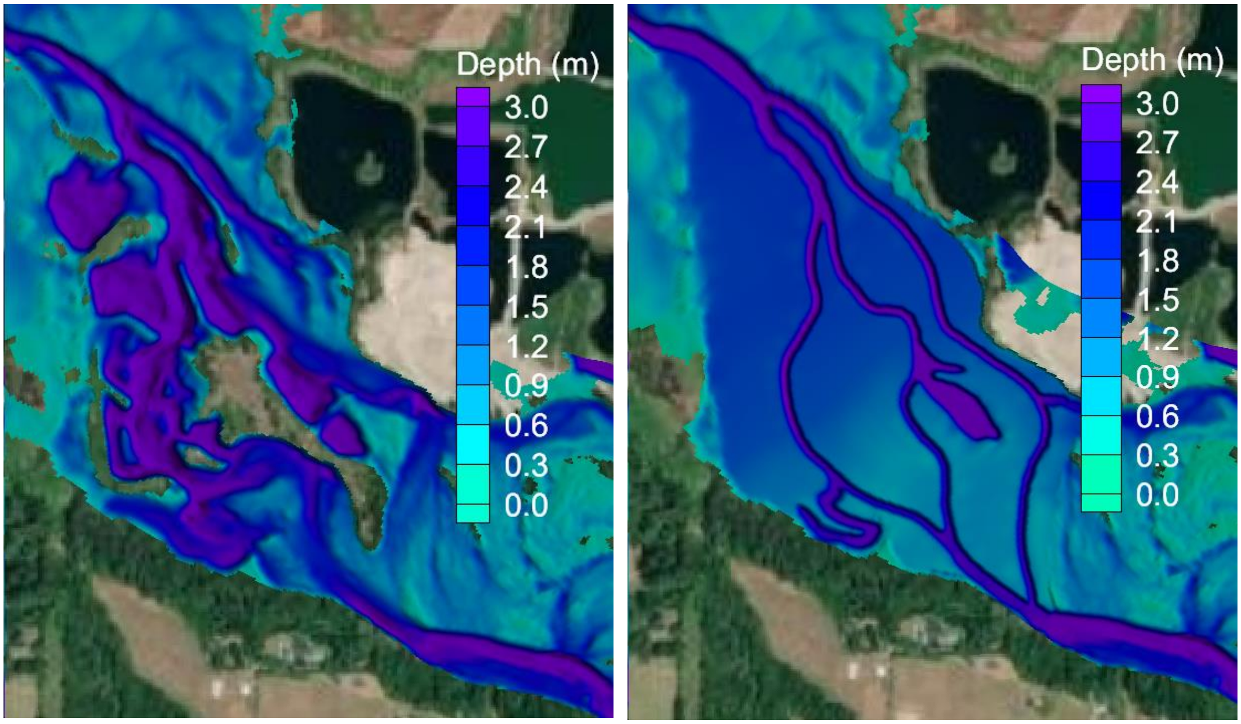


Figure 10. Water depth plots for model steady-state simulations covering the full range of ELFR discharge values: base flow – 500-year flood event. Left column: depths for the EC model. Right column: depths for the 3-channel hybrid Alternative model.

Table 5. Minimum and maximum water depths, and relative flow magnitudes, for the individual channels of the Alt. 3 hybrid 3-channel network. Values are included for the minimum simulated input flow of 35 cfs, up to the approximate design bankfull flow of 3,000 cfs.

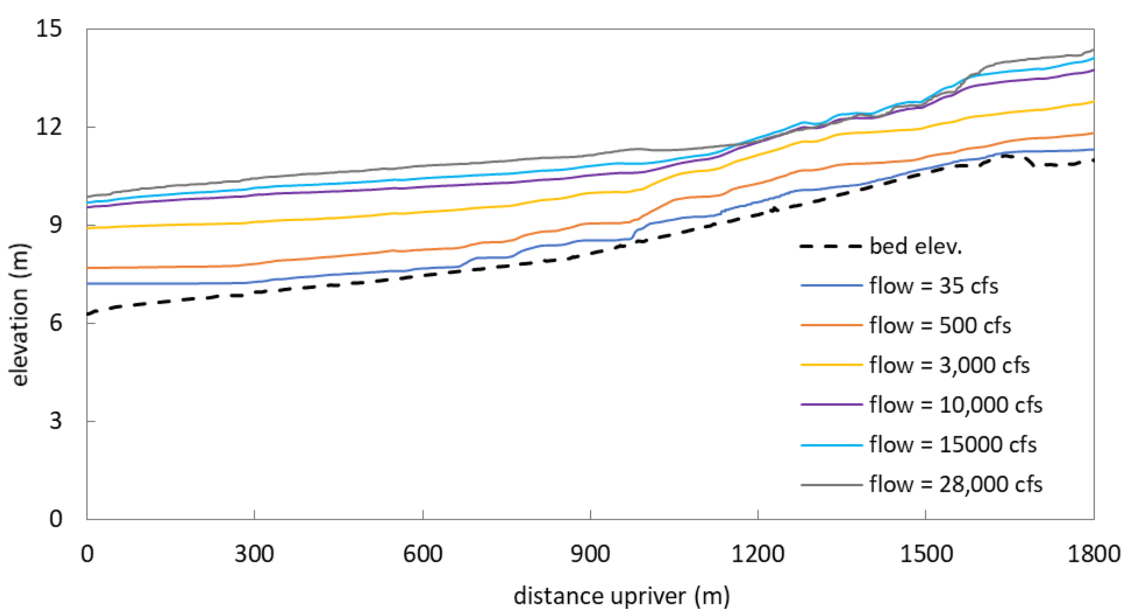
	@ Q = 35 cfs	@ Q = 500 cfs	@ Q = 1,000 cfs	@ Q = 3,000 cfs
West channel min./max. depth (ft)	0.42 / 0.9	1.45 / 3.2	2.0 / 4.6	3.9 / 6.6
Middle channel min./max. depth (ft)	0.2 / 0.5	1.7 / 3.0	3.0 / 4.1	4.9 / 6.2
East channel min./max. depth (ft)	0.2 / 0.4	1.2 / 2.0	1.7 / 3.2	3.5 / 6.1
West Channel flow (cfs) / % of total flow	17 / 50%	199/ 40%	400 / 40%	1,208 / 40%
Middle channel flow (cfs) / % of total flow	10 / 29%	183 / 36%	370 / 37%	1,035 / 35%
East channel flow (cfs) / % of total flow	8 / 21%	118 / 24%	230 / 23%	872 / 29%

As illustrated in Table 5, flow is not evenly distributed between the individual channels in the Alt. 3 hybrid 3-channel network. Most flow (and resulting greater water depth) Is concentrated in the western channel, with the middle and eastern channels receiving successively less flow. The effect is most pronounced at the lowest input flow of 35 cfs, with flows evening out somewhat as the input flow increases to the approximate bankfull design flow. The uneven distribution may be due in part to a slight westward tilt of the floodplain surface, which is evident in the cross-sectional bed profile seen in Figure 9 above. Channel geometries may be adjusted in future design phases however some amount of flow concentration may be desirable, to maintain greater water depth in at least one of the channels during low-flow periods.

Filling of the pits with material, proposed in the Alternative, results in significant decrease in water depth throughout the pits reach. Currently, under the EC, water depths exceed 15 feet in some of the Ridgfield Pits even under the lowest flow conditions. At bankfull, depths exceed 25 feet in many areas. Alternative 3 channel depths range from 0.3 feet at the minimum input base flow of 35 cfs, up to 6.6 feet at just over bankfull flow of 3,000 cfs.

Model simulations for Alternative 3 show the channel banks overflowing at the 3,000 cfs input flow level, consistent with the design goal of 2,600 cfs. We did not run a simulation at the design bankfull input of 2,600 cfs, however water depths for the 3,000 cfs simulation are in the range of 6.1–6.5 feet. This being slightly higher than the design bankfull elevation of 5.9 feet indicates that the banks are overtopping at flows close to what was targeted in the design. It was noted earlier that channel overtopping as calculated by the Manning's trapezoidal channel formulas was predicted to occur at 3,801 cfs, which is somewhat higher than what the model results show. Discrepancies may be due to two factors: 1) inability of the model cell resolution to fully capture exact channel dimensions; and 2) a lack of field observations to fully calibrate and validate the model over the full range of input flow. Calibration and validation will be done prior to future design phases and design parameters will be adjusted accordingly.

Longitudinal water surface plots through the Ridgefield Pits reach for the steady-state simulations are shown in Figure 11. These illustrate the reduction in water depths for the Alternative 3 multi-thread channel network (Fig. 11, top) relative to the EC (Fig. 10, bottom). Water surface slopes are also generally reduced for the Alternative, particularly at flows less than or equal to the bankfull flow, resulting in reduced erosive potential (shear stress) and current velocity through the reach.



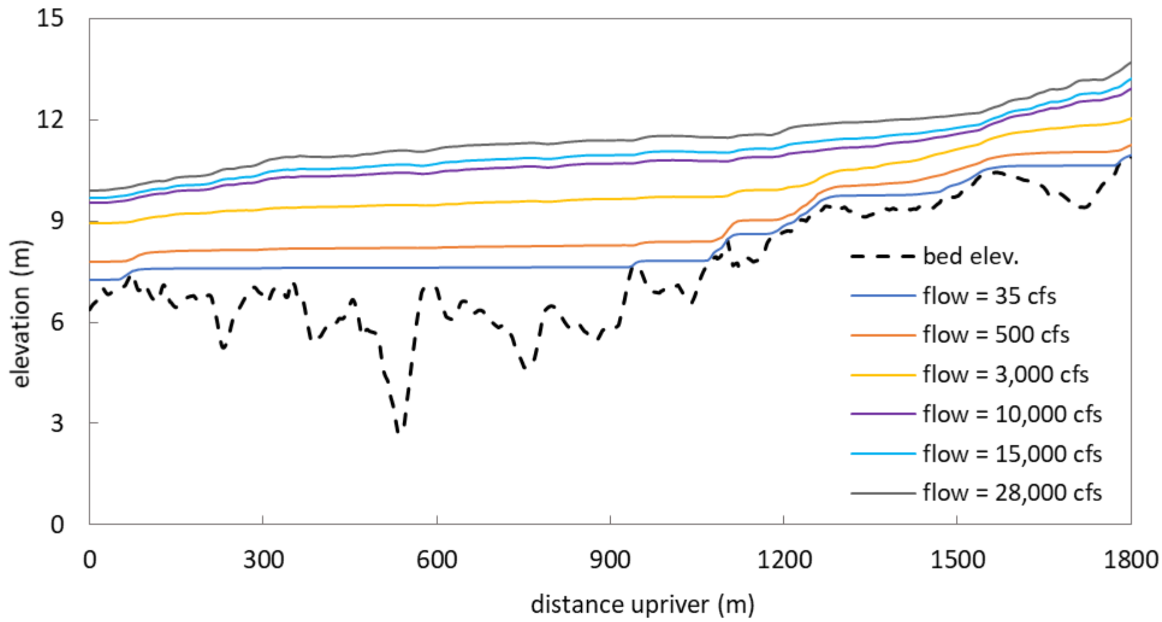


Figure 11. Longitudinal water surface profiles through the Ridgefield Pits reach for the steady-state model simulations. Top: Alternative 3 hybrid 3-channel network (middle channel). Bottom: EC.

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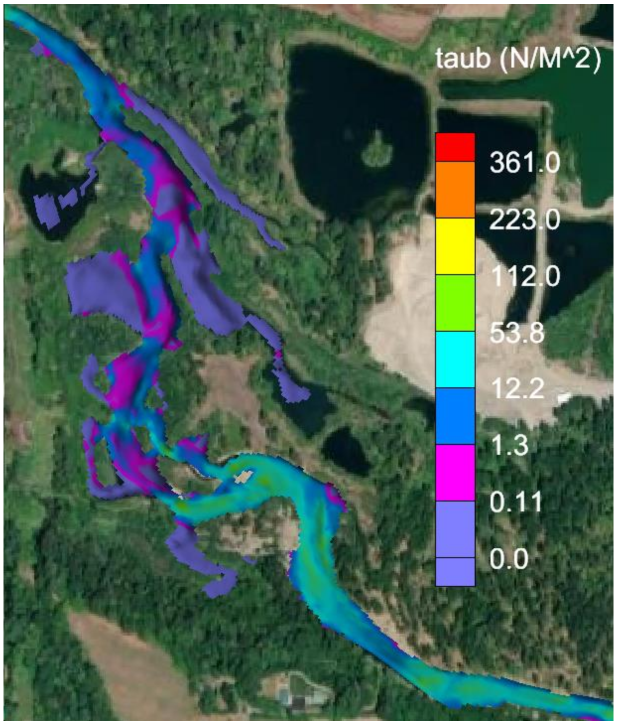
- Model steady-state simulation outputs: Bed shear stress (τ_b)

Steady-state simulation bed shear stress (τ_b) profiles are shown in Figure 12 for the EC and Alternative 3 hybrid 3-channel network model surfaces. Plots are included for higher flow conditions only, as erosive conditions are not present at flows less than approximately 1,000 cfs. Plots are binned according to critical shear stress values (τ_c) required to move various grain size, as shown in Table 6. For example, in areas colored pink, sand (0.0625–2.0 mm grain size) and finer sediments would be transported under the given flow condition. In areas colored green, small cobble (64–128 mm grain size) and finer materials would be transported, etc.

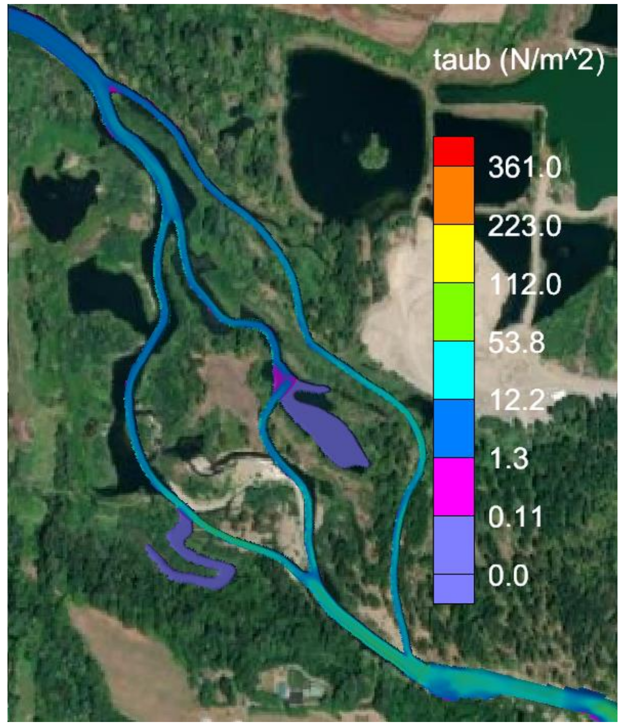
Table 6. Grain diameters and associated critical shear stress values. Source: USGS Scientific Investigations Report 2008-5093 (https://pubs.usgs.gov/sir/2008/5093/table7.html)

Particle class	Range of particle diameters		Critical bed shear stress (τ_c)
	mm	inches	(N/m^2)
Large Cobble	128 – 256	5 – 10	112 – 223
Small Cobble	64 – 128	2.5 – 5	53.8 – 112
Coarse Gravel	16 – 64	0.6 – 2.5	12.2 – 53.8
Fine Gravel	2 – 16	0.1 – 0.6	1.3 – 12.2
Sand	0.0625 – 2	0.0025 – 0.1	0.11 – 1.3
Silt and Fines	0 – 0.0625	0.0000 – 0.0025	0 – 0.11

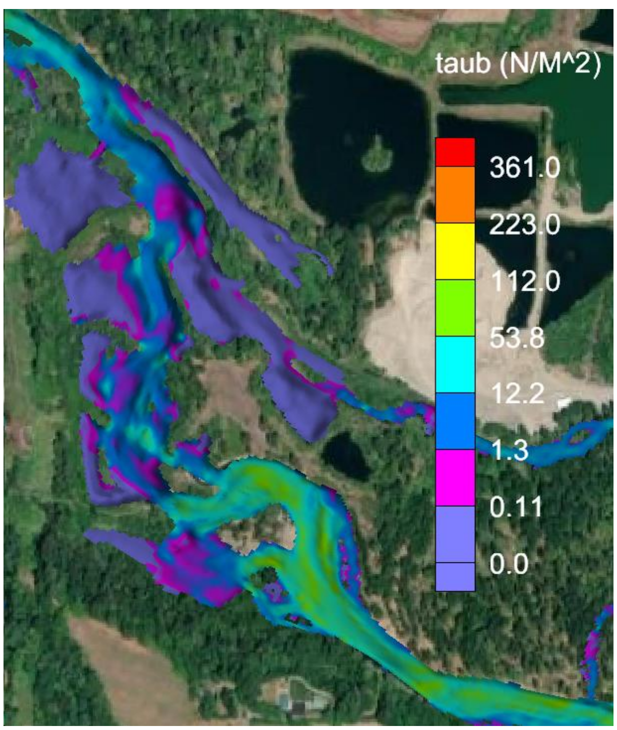
EC, Q = 1,000 cfs



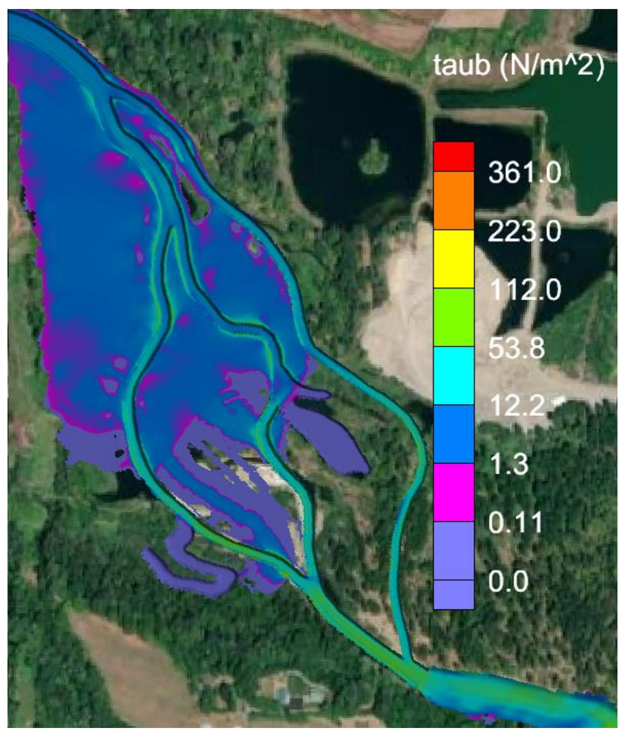
Alt 3, Q = 1,000 cfs



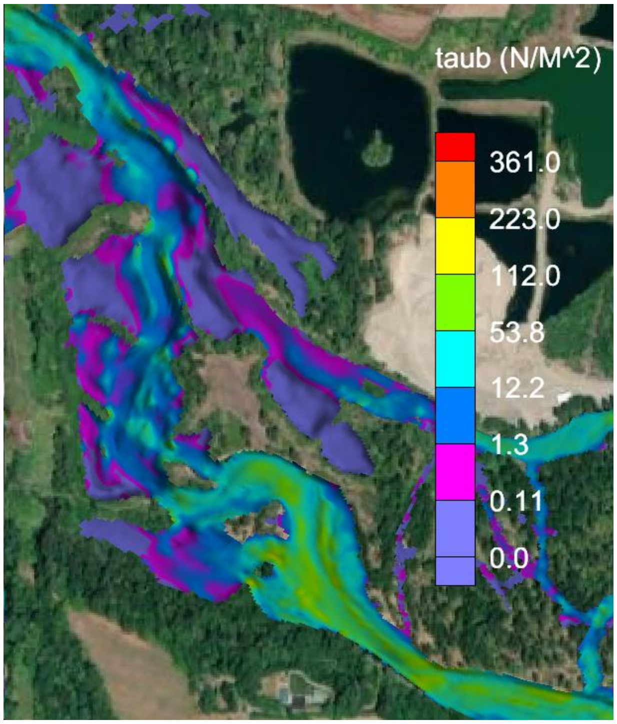
EC, Q = 3,000 cfs



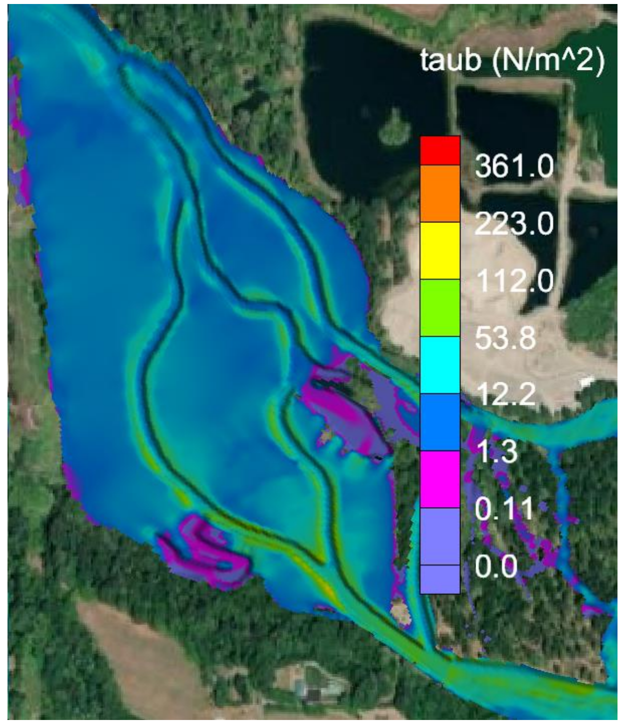
Alt 3, Q = 3,000 cfs



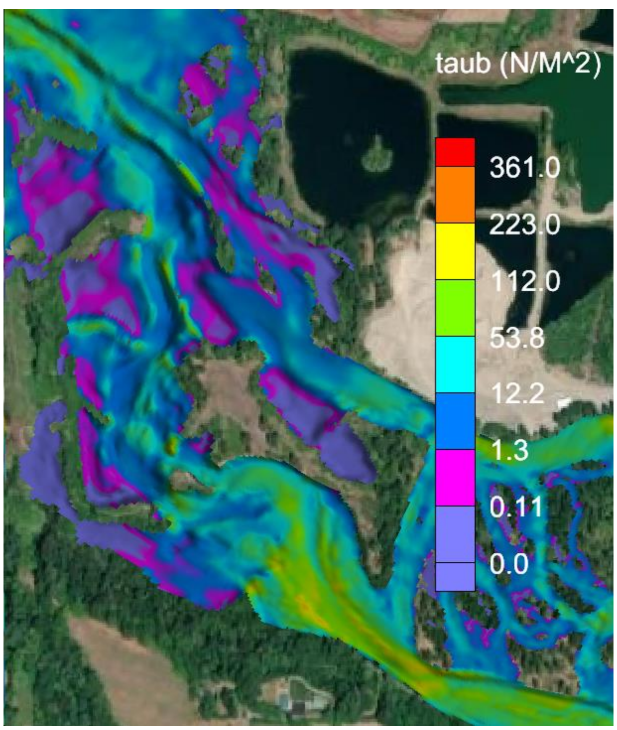
EC, Q = 5,000 cfs



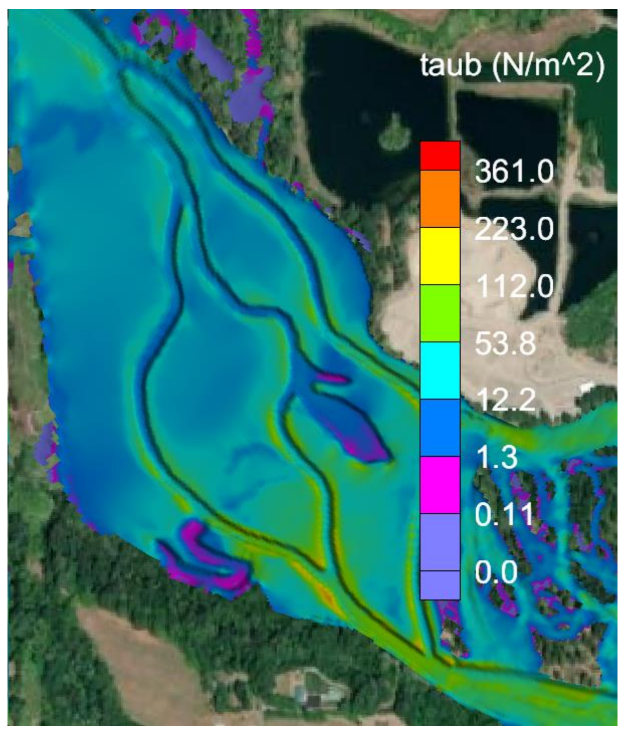
Alt 3, Q = 5,000 cfs



EC, Q = 10,000 cfs



Alt 3, Q = 10,000 cfs



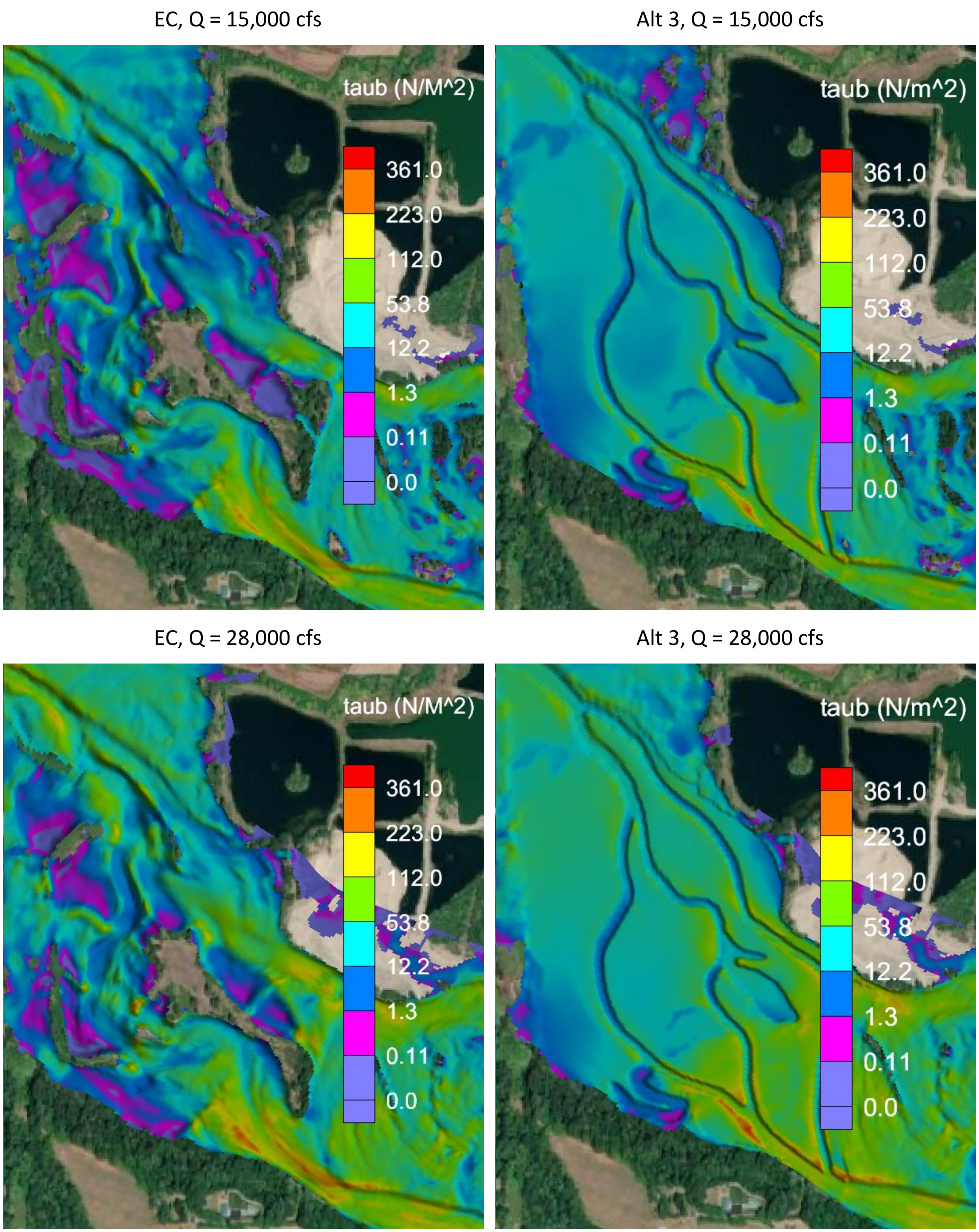


Figure 11. Bed shear (τ_b) plots for model steady-state simulations covering the range of higher ELFR discharge values from 1,000 cfs up to the 500-year flood event. Left column: τ_b for the EC model. Right column: τ_b for the 3-channel hybrid Alternative model.

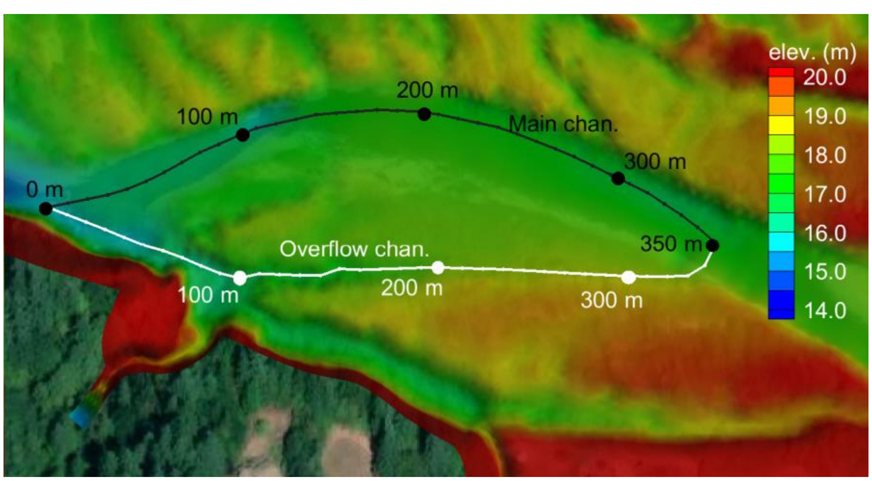
Plots in Figure 11 show a general reduction of channel bed shear stress values at the upstream end of the Ridgefield Pits reach for the Alternative 3 hybrid multi-thread compared to the EC, at bankfull, 1-year (~5,000 cfs) and 2-year (~10,000 cfs) input flows. This reduction should increase channel stability in this portion of the reach, which has shown significant channel instability throughout the past several years. Over this same flow range, low-shear areas currently present in the deep pits are eliminated in the Alternative model. Combined with more uniform shear stresses overall for the Alternative model, at magnitudes large enough to move gravels, sediment transport through the reach is expected to improve significantly compared to the EC.

1.9 MODEL RESULTS: ALTERNATIVE 5

Multiple restoration concepts were proposed at the Mill-Manley confluence however the overflow channel was the only one that involved significant channel re-work requiring hydraulic model evaluation. The objective of creating the Alternative 5 overflow channel is to increase flow to the Mill/Manley confluence zone during high flow events to induce scour of sand and gravel material that currently concentrates here and degrades cold water habitat conditions. This Alternative was proposed early in the TOG process, however due to various factors identified in subsequent meetings its potential effectiveness was called into question. These factors include: 1) increased sediment load from Mill Creek due to upper watershed impacts; 2) risk of impacting existing cold water habitat in the beaver ponds at the Manley Creek confluence; and 3) risk of increasing erosion along the severely eroded south bank immediately downstream of Mill Creek. Despite the decision to no longer pursue this Alternative the TOG requested the modeling to proceed, and so results are included here.

- Alternative 5 channel geometry

Channel profiles for the Existing Condition (EC) and iterations of the Alternative 5 overflow channel are shown in Figure 13, for the respective longitudinal profiles shown in Figure 12 for the overflow and main channels. A second iteration of the overflow channel was created after model results for the first iteration did not result in increasing scour at the confluence zone (see results below).



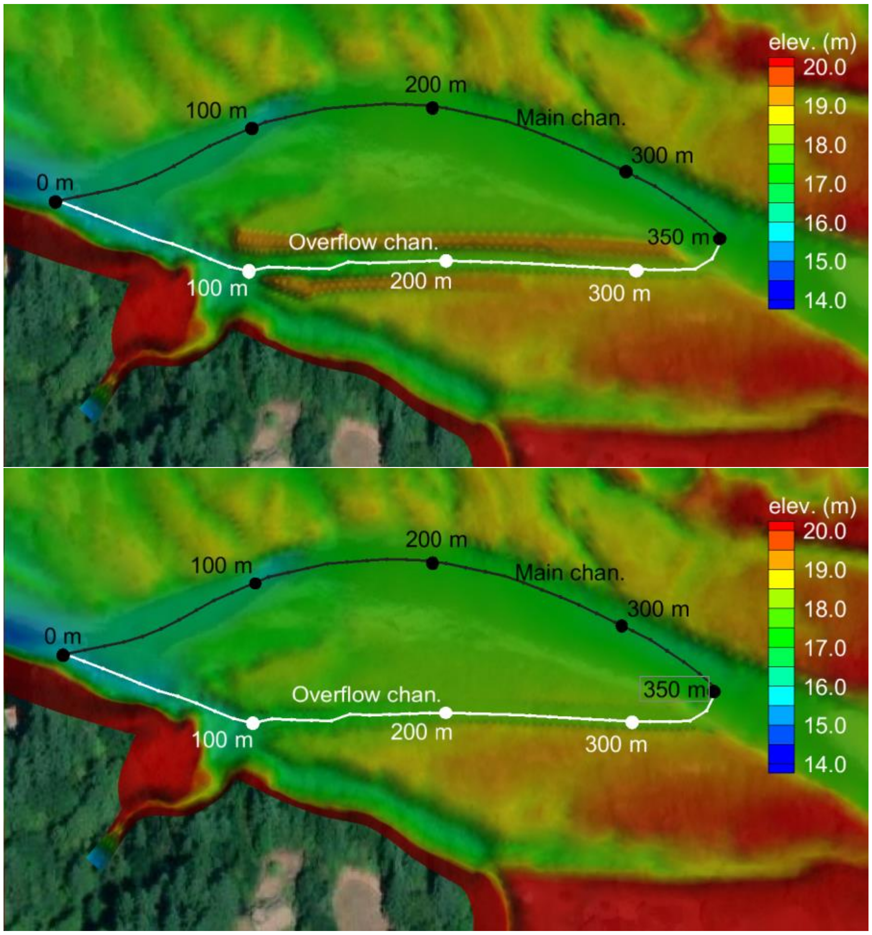


Figure 13. Model topography and longitudinal elevation profile paths for the EC and Alternative 5 overflow channel at the Mill/Manley confluence zone. Top: EC; Middle: initial Alt. 5 overflow channel; Bottom: Alt. 5 overflow channel, 2nd iteration. Respective longitudinal elevation profiles are shown in Figure 13 below.

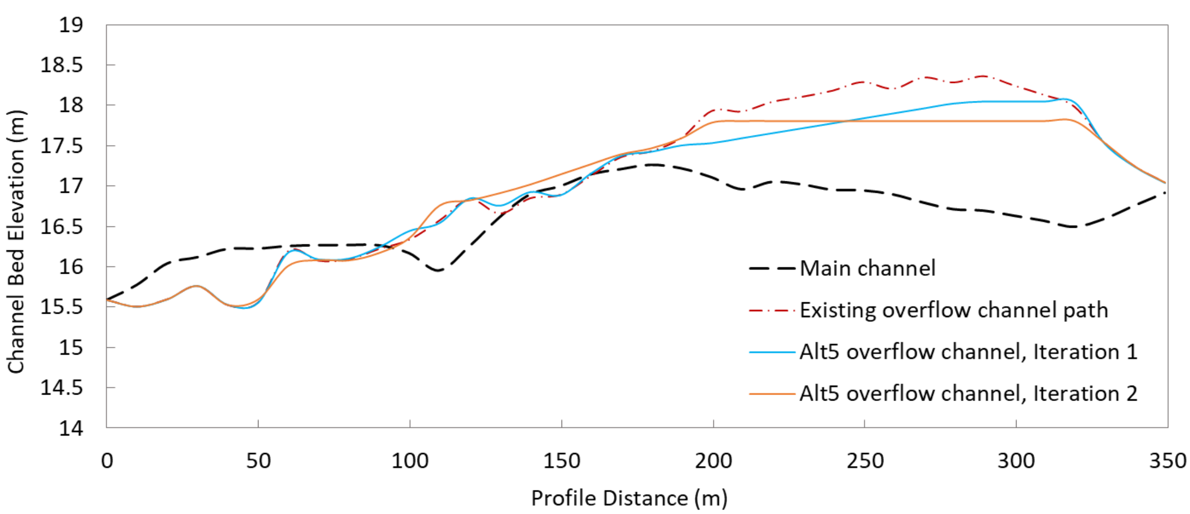


Figure 13. Model elevation profiles along the longitudinal profile paths shown in Figure 12 above.

- Model steady-state simulation outputs: Bed shear stress (τ_b)

Steady-state simulation bed shear stress profiles are shown in Figure 14 for the EC and Alternative 5 overflow channel model surfaces, over the input flow magnitudes of interest. Plots are binned according to the same critical shear stress values required to move various grain size, as were described above in Table 6. Relative difference in bed shear between the overflow channel model and the EC model are shown in Figure 15. Yellow, red, and orange shades indicate an increase in bed shear for the overflow channel condition whereas blue shades indicate a decrease, relative to the EC. The area enclosed by the white circle encompasses the Mill/Manley confluence area of interest. The objective of Alternative 5 is to increase bed shear in this zone during the flow period of interest, to promote sediment scour and maintain water depths that are suitable for use by salmonids seeking thermal refuge.

The initial overflow channel was modeled with berms to help concentrate flow in the channel. Model results showed no advantage with these structures present, with bed shear values decreasing relative to the EC (Fig. 15, left side images). These berms were removed, and the overflow channel was re-graded, for the 2nd and final iteration (see profiles in Fig. 13). Bed shear values for this final iteration show a slight increase in the zone of interest relative to the EC (Fig 15, right side images), however increased scour potential is also introduced further upstream in the overflow channel, which could potentially deliver additional sediment to the confluence zone. Bed shear does not show any increase along eroding EFLR bank immediately downstream of the Mill/Manley confluence zone, however this was not studied in detail for this analysis since this Alternative has been deemed generally unfavorable by the TOG.

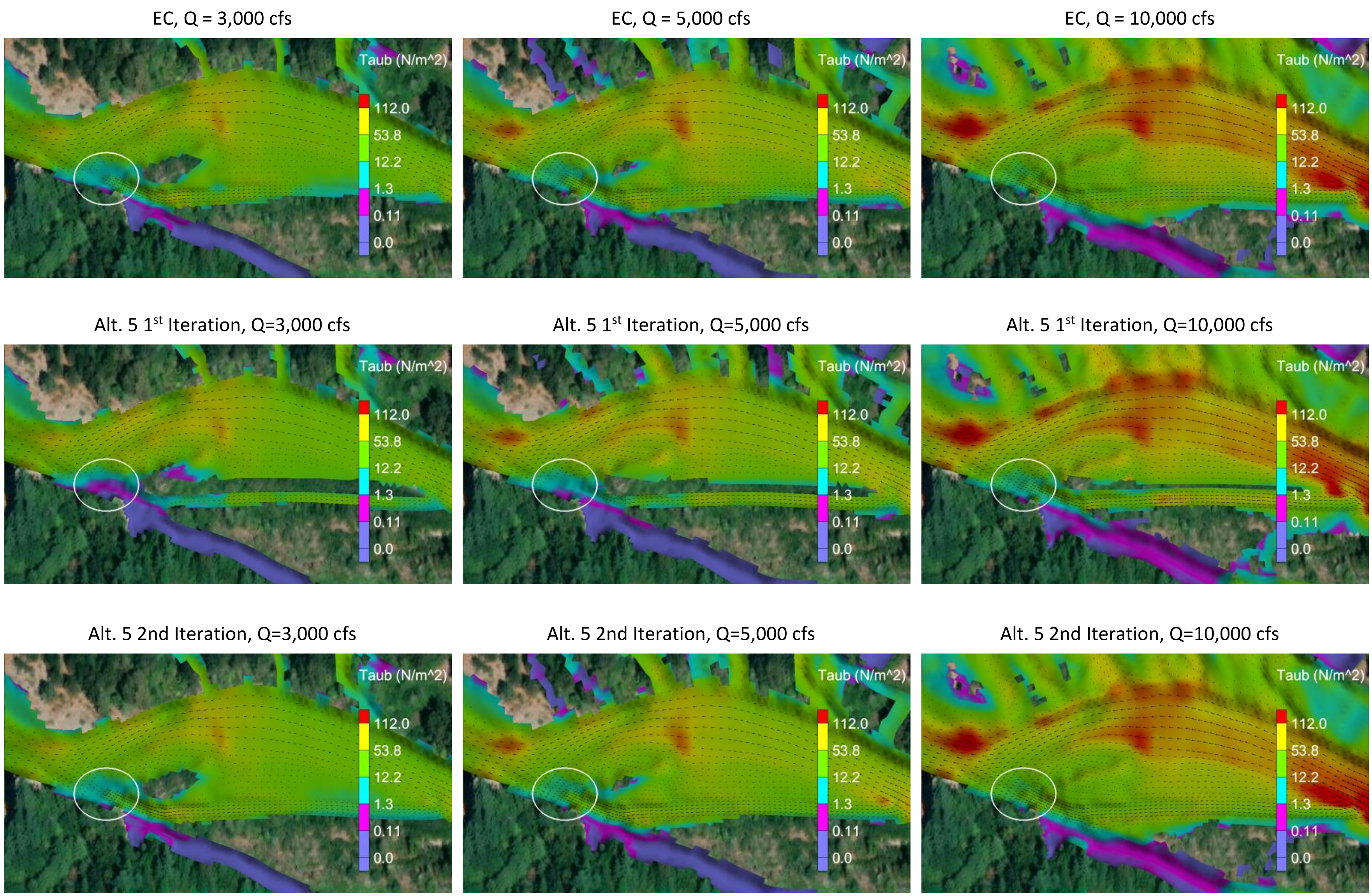


Figure 14. Bed shear (τ_b) plots for model steady-state simulations covering the typical winter EFLR flows up to the approximate 2-year flood event. Left column: τ_b for the EC model. Middle column: τ_b for the Alt 5. Model, initial iteration. Right column: τ_b for the Alt 5. Model, final iteration.

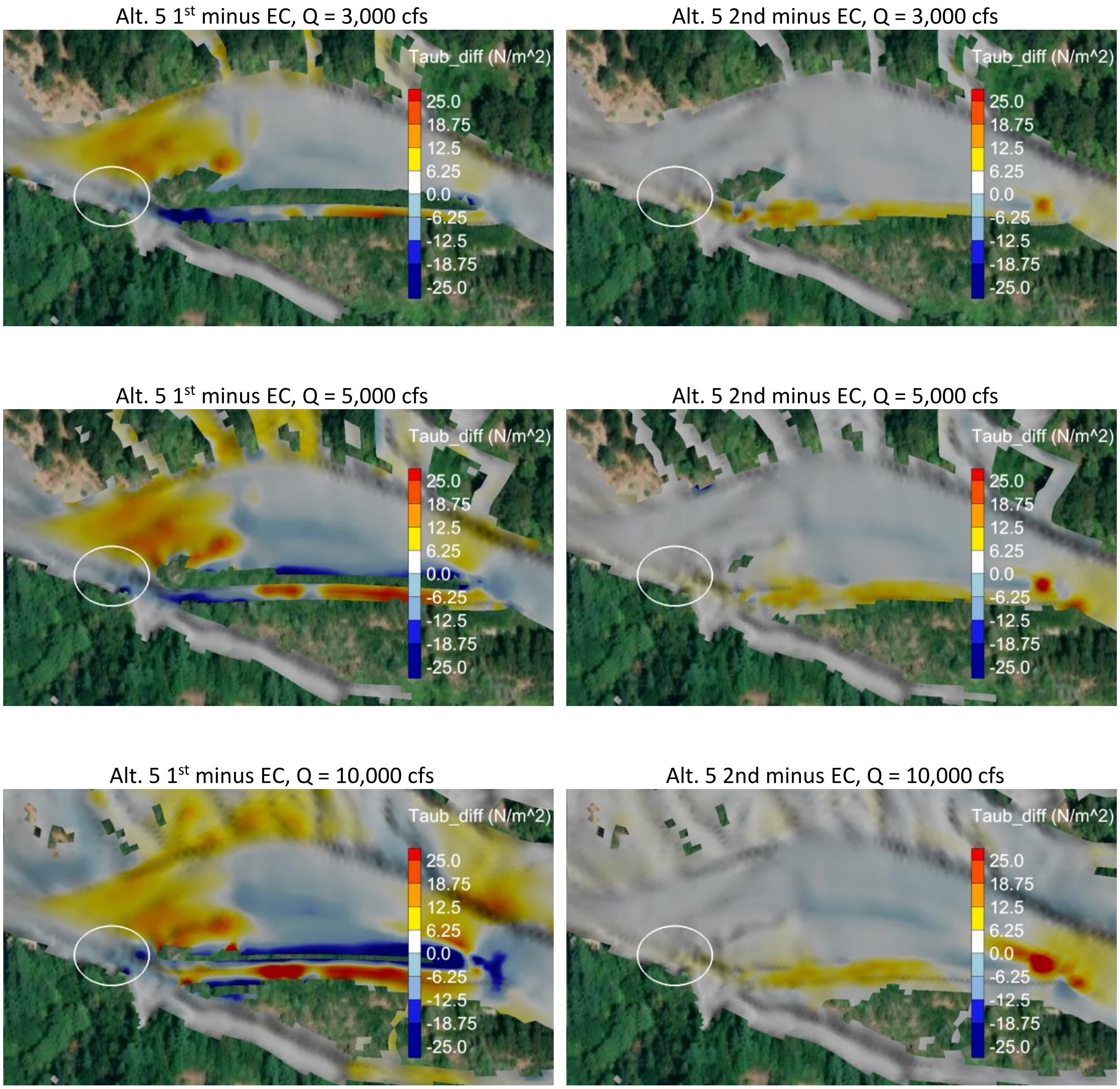


Figure 15. Bed shear (τ_b) difference plots for model steady-state simulations covering the typical winter EFLR flows up to the approximate 2-year flood event. Left column: τ_b (Alt. 5 iteration 1) - τ_b (EC). Right column: τ_b (Alt. 5 iteration 2) - τ_b (EC).

1.10 HYDRAULIC MODELING SUMMARY AND NEXT STEPS

The Ridgefield Pits hydraulic model was used to help evaluate restoration Alternative 3 – within the Ridgefield Pits reach proper, and restoration Alternative 5 – the proposed overflow channel upstream of the Mill/Manley confluence with the EFLR. The model also serves as input for extended analyses of sediment transport and water temperature, using add-on modules within the Tuflow modeling package. These analyses are described in Sections 2.5 and 2.6 of the main report, although sediment modeling has not been fully completed at this time. Inputs to the Ridgefield Pits model were derived from an initial model covering the entire EFLR downstream of the project reach, that was developed for the La Center Wetlands restoration project. That model was fully calibrated and validated, however this process has not yet been completed for the Ridgefield Pits model because required field observations are still being collected.

Model simulations of the preferred restoration Alternative 3 for the Ridgefield Pits reach generally show improved hydraulic conditions for the 3-channel hybrid network relative to the Existing Condition (EC). Bed shear and water surface profiles suggest improved sediment transport and channel stability through this reach for the 3-channel network. Currently, the reach shows significant channel instability, and a continued lack of sediment conveyance, as the reach continues to slowly adjust to the 1996 channel avulsion event. Bankfull flow occurrence as predicted by the model is somewhat less than what was predicted by channel calculations for the given channel design parameters. This is expected, as the model is not fully calibrated, and the model grid cell resolution is limited in the ability to fully resolve the relatively small channel widths incorporated in the design. Further grid refinements, and model calibration, will be incorporated into the next design phase to resolve these issues.

Model simulations of the overflow channel proposed in Alternative 5 at the Mill/Manley confluence did not show a significant improvement over the EC, relevant to the restoration objective of promoting scour at this confluence zone. A minor increase in bed shear was obtained after some refinement of the channel geometry, however increased bed shear upstream, as well as other potential concerns associated with this action that were expressed by the TOG, have generally deemed this restoration alternative unfavorable.

1.11 REFERENCES

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