US Army Corps of Engineers ®
Walla Walla District

LOWER SNAKE RIVER CHANNEL MAINTENANCE IMMEDIATE NEED DREDGING FOR COMMERCIAL NAVIGATION ENVIRONMENTAL ASSESSMENT

TIERED FROM THE LOWER SNAKE RIVER PROGRAMMATIC SEDIMENT MANGEMENT PLAN FINAL ENVIRONMENTAL IMPACT STATEMENT DATED AUGUST 2014

Appendix C

Hydraulic Evaluation of the Bishop Bar Disposal Site

US Army Corps of Engineers ®
Walla Walla District

LLA – FY22 Navigation Channel Maintenance

Bishop Bar Hydraulic Evaluation

P2#474948

Appendix C

CENWW-ECH

June 2022

Table of Contents

Table of Figures

1 BLUF

The U.S. Army Corps of Engineers (USACE) Walla Walla District (CENWW) proposes to dredge accumulated sediment out of the Snake River federal navigation channel and berthing areas near the confluence of the Snake and Clearwater Rivers and below the Ice Harbor Lock and Dam navigation lock near Pasco, Washington. All dredged sediment would be disposed of at an in-water location near Bishop Bar located at River Mile (RM) 118 on the lower Snake River in Washington State. This is the proposed action and may be referred to as such or the “immediate need dredging action” through-out this document.

The proposed unconfined in-water disposal site is an existing submerged mid-depth bench located in a low velocity area of the Lower Granite reservoir near Snake RM 118, about three miles upstream from the previous disposal site at Knoxway Canyon (RM 116) last used in 2015. The new disposal site was selected for its proximity to dredging locations while meeting various engineering and biological criteria identified in USACE 2019. The site constitutes approximately 30 acres of a larger mid-depth bench on the right bank adjacent to Bishop Bar (Figure 1-1).

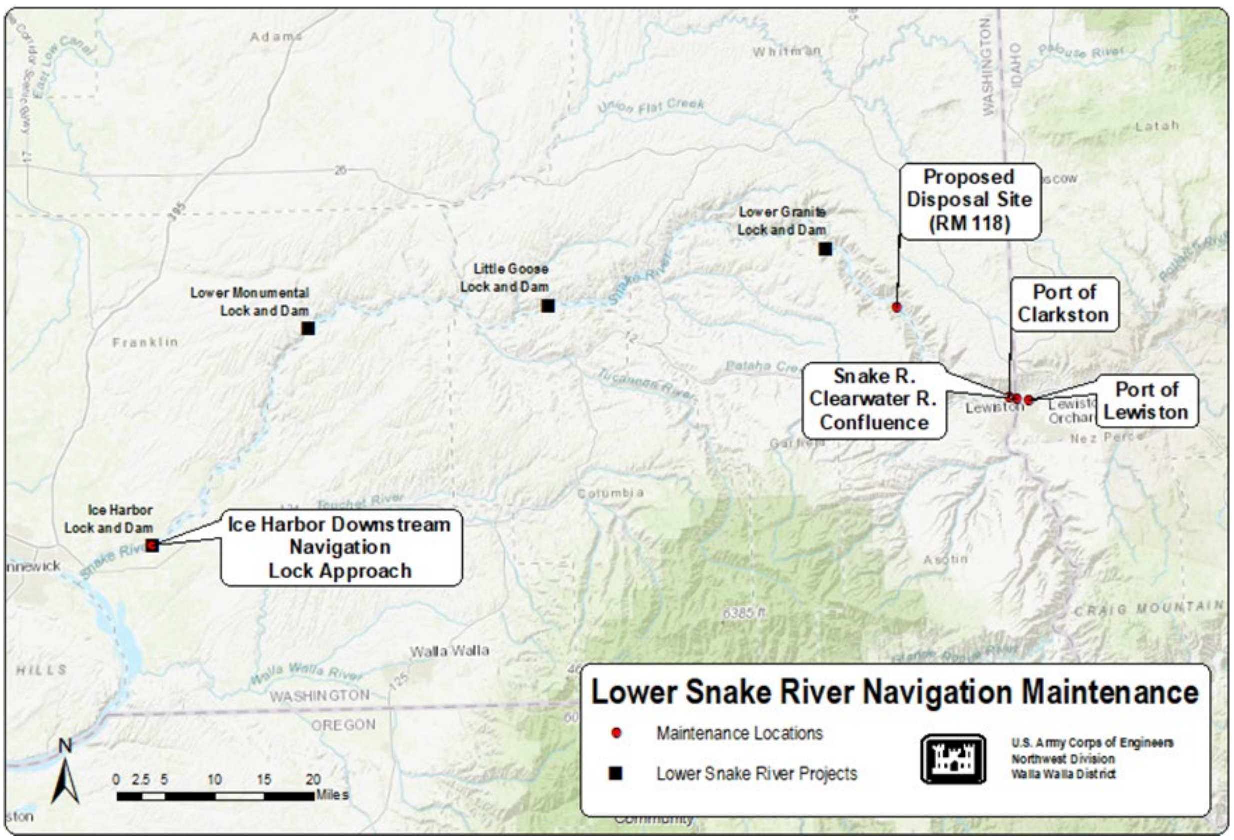

Figure 1-1. Vicinity Map depicting the confluence dredging site and the proposed RM 118 disposal site.

A numerical hydraulic model and sediment mobility study was conducted to evaluate conditions at the Bishop Bar in-water disposal site over a range of regulated flood conditions. As discussed in Section 4, results indicate that most of the placed dredged material is expected to remain dynamically stable, except for areas of increased turbulence and recirculation near the flow separation and reattachment zones.

2 Approach & Methods

The scope and approach for this evaluation was developed in accordance with ER-1110-2-8153 (USACE 1995) to characterize hydraulic and sediment mobility conditions over a range of potential regulated flood conditions for the Bishop Bar site. This included defining the hydraulic frequency within the regulated reach to load a detailed two-dimensional numerical hydraulic model. Results from the hydraulic model simulation were used to estimate critical sediment sizes for bedload transport and suspended load transport within the water column for comparison with dredge material properties.

2.1 Hydrologic Boundary Conditions

Two sets of hydrologic boundary conditions were used for this analysis, (1) annual exceedance flood discharges, and (2) dredging construction period flow duration.

2.1.1 Flood Frequency Hydrology

The annual peak discharge exceedance used for this analysis were taken from Table F-29 of the 2014 Programmatic Sediment Management Plan (PSMP) which were based on a coincident flood frequency analysis (FFA) of the Snake and Clearwater Rivers. The annual exceedance flows ranged from 160 kcfs for the 50% AEP, to the Standard Project Flood (SPF) of 420 kcfs. Per the Lower Granite (LLA) Water Control Manual (WCM), flood management operations utilize a hinge pool. For peak flows between 120 kcfs and 300 kcfs, the maximum Lower Granite Forebay at RM 107.5 is interpolated between 734 and 725 feet NGVD 29 (737.4 and 728.4 feet NAVD88) respectively, and for the standard project flood, the maximum LLA forebay is 724.0 feet NGVD29 (727.4 feet NAVD88).

Table 2-1. Summary of Flood Frequency Index Sets evaluated.

Return Period (years)	Annual Exceedance Probability (%)	Flow (kcfs)	LLA Forebay Stage (feet NAVD 88)
2	50%	160.423	733.78
5	20%	214.082	732.00
10	10%	245.988	730.66
25	4%	282.788	729.32
50	2%	307.995	728.40
100	1%	331.562	728.21
250	0.40%	360.629	727.98
500	0.20%	381.603	727.81
1000	0.10%	401.569	727.60
SPF	SPF	420.000	727.40

2.1.2 Construction Period Hydrology

To evaluate potential hydraulic conditions at the Bishop Bar disposal site for the dredging construction period, a flow duration curve was developed for the 75-day hydroperiod between 15-December and 01-March. The flow duration curve for the dredging construction period was computed based on the 80-year simulated dataset of mean daily inflows to Lower Granite Dam representing the preferred alternative from the 2020

Columbia River System Operations (CRSO) EIS (USACE 2020). This input represents a synthetic hindcast of historical watershed variability from 1929 to 2008 regulated to the CRSO preferred alternative. The downstream stage for the LLA forebay was set at the minimum operating pool (MOP) of 736.4 feet NAVD88 (733.0 feet NGVD29) for all flows < 120 kcfs. Note that Navigation Objective Reservoir Operations (NORO) deviations from MOP (e.g., MOP+1, etc.) essentially raise the LLA tailwater which flattens the grade line further dampening hydraulic response in the Bishop Bar reach.

Table 2-2. Summary of 80-year duration series for 15-December to 01-March hydroperiod.

15-Dec to 01-Mar Duration Exceedance (%)	Flow (kcfs)
1	110.631
5	75.626
10	60.939
25	45.134
50	29.905
75	21.755
90	18.072
95	16.847
99	15.282

2.2 Hydraulic Methods

The hydraulic modeling methods used for this evaluation included a two-dimensional depth-averaged model of the RM118 study reach that was linked to the regional regulated hydraulics of the Lower Granite Dam reservoir using a standard one-dimensional backwater model. All hydraulic modeling was conducted on the NAVD88 vertical datum using hydrologic loading defined in Section 2.1 above.

2.2.1 Regional Modeling

The LLA project at ~RM107 is operated to regulate upstream inflows from the Snake and Clearwater Rivers which join at Snake RM 139 near Clarkston, WA and Lewiston, ID. To transfer the regional inflows and downstream backwater to the Bishop Bar site, an existing one-dimensional HEC-RAS model was used. The 1D HEC-RAS model was based on Iteration 4 of the Reach 09/10/11 CRT/CRSO model dated October 2017 (USACE 2020) with a calibrated Manning's roughness coefficient of 0.0225 for the active channel. Because only steady index flow sets were used for this evaluation, the RAS 1D model was cropped at the confluence to remove both upstream Reach 10 on the Clearwater and Reach 11 on the Snake.

Tie-in locations between the one-dimensional and the more detailed two-dimensional Bishop Bar reach model were at R09_RS115.512 downstream and R09_RS120.869 upstream respectively. Note that these river stations (RS) are based on the CRSO Reach 9 RAS1D model schematic, and the stationing is slightly different from the historical Snake River miles used for the 2014 PSMP and this related evaluation of Bishop Bar.

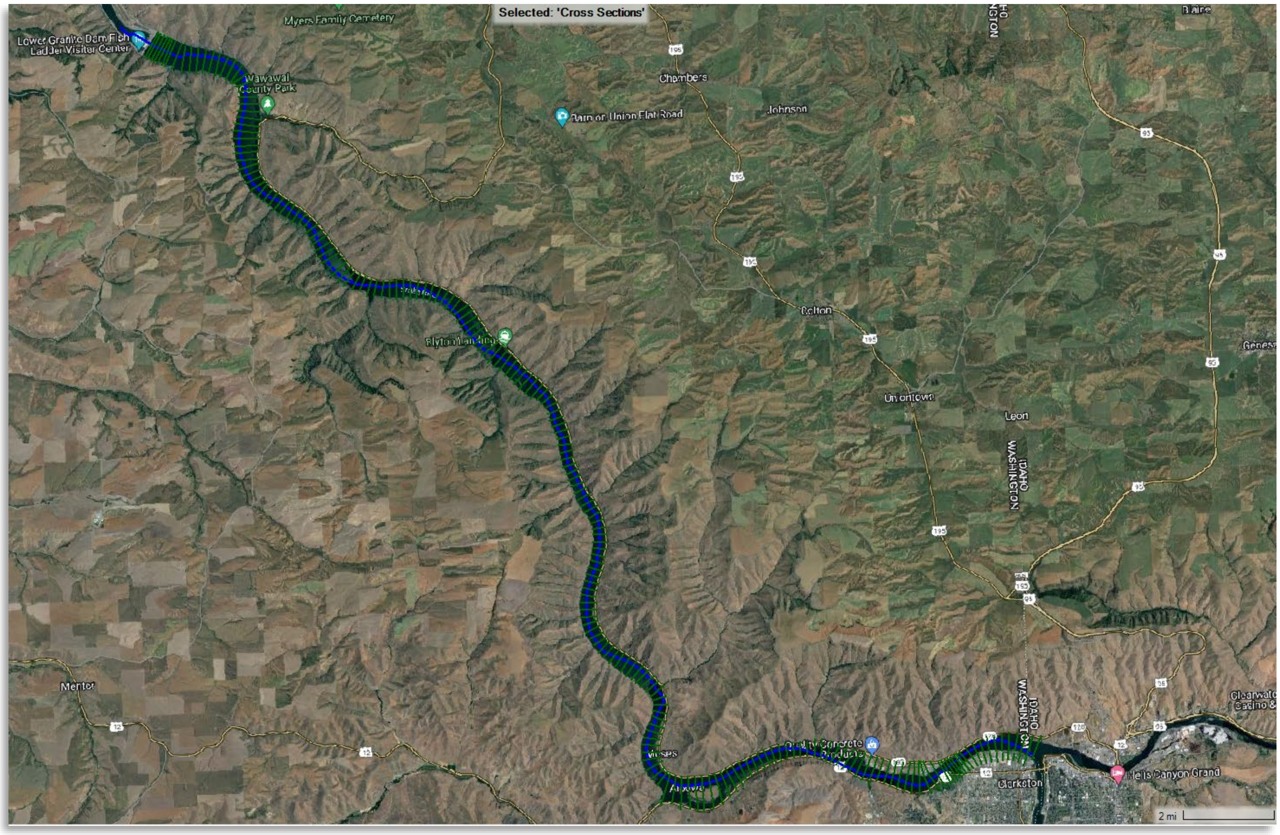

Figure 2-1. HEC RAS 1D model schematic for Snake River R09 between RM107 and RM139. *Flow direction is from lower right to upper left.*

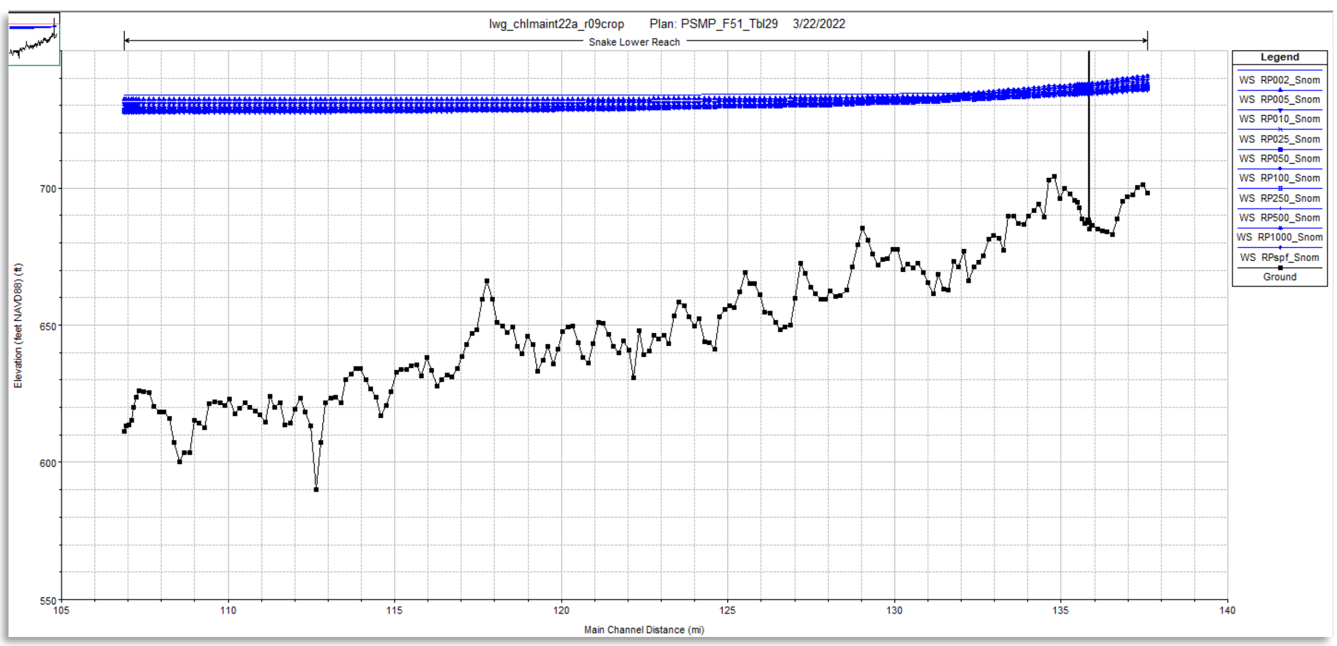

Figure 2-2. HEC-RAS 1D water surface profiles upstream of LLA for the 10 flood frequency index sets evaluated.

2.2.2 Reach Modeling

To assess the hydraulic conditions within the Bishop Bar reach, a two-dimensional depth-averaged model was developed using HEC-RAS. The 2D model domain extent spanned ~5 river miles from RM116 downstream to RM 121 upstream with lateral extents set slightly beyond the water edge at a nominal elevation of 750 feet (NAVD 88). This longitudinal buffer distance equates to ~6 bankfull widths upstream and ~6 downstream which allowed the 2d flow patterns to equilibrate to a quasi-steady-state. Tie-ins to the regional 1D RAS model (Section 2.2.1) were at R09_RS115.512 downstream and R09_RS120.869 upstream.

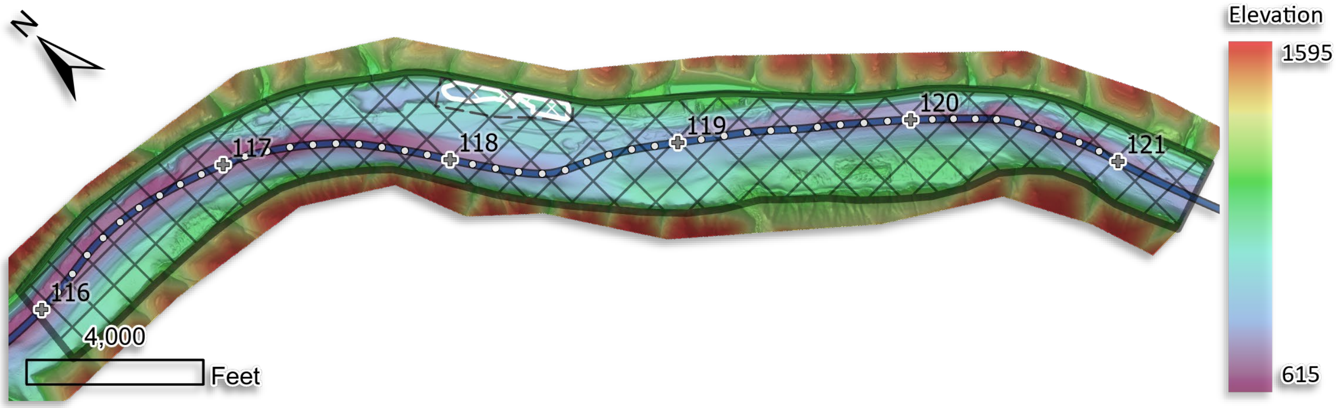

Figure 2-3. Overview of RAS2D domain modeled for the Bishop Bar reach

Terrain for the Bishop Bar reach model utilized an updated multibeam bathymetry collected for CENWW on 12-Dec-2021 by David Evans and Associates (DEA Inc., 2021). The modeling bathymetry was extended to the upstream and downstream model extents using multibeam collected for the PSMP (USACE 2014) in September 2011. Overbank lidar data from 2010 was merged with the two bathymetric datasets for the composite model terrain. All terrain data and hydraulic models utilized the NAVD88 vertical datum. For consistency with the LLA hinge pool elevations presented in the WCM (USACE 2006) and PSMP Appendix F (USACE 2014), a datum conversion factor of +3.40 feet was used to shift LLA forebay elevations in the WCM from NGVD29 to NAVD88. Note that this datum shift is slightly different than the +3.44 feet shift reported by NGS NCAT (https://www.ngs.noaa.gov/NCAT/) at the LLA forebay.

An orthogonal mesh with a nominal cell size of 16 feet (~5 meters) was used for the two-dimensional RAS model, resulting in ~235k cells with an average area of ~250 square feet. The RAS2D mesh Manning's roughness coefficient was set to 0.025 (approximately 11% rougher than the RAS 1D roughness), resulting in an index set stage calibration of <0.1% relative to the regional water surface profile from the RAS 1D model. Figure 2-4 below depicts the RAS2D mesh, the Bishop Bar disposal site between ~RM 117.9 and ~RM 118.6, and the catch limits for the proposed shallow in-water placement of 2022 dredge materials.

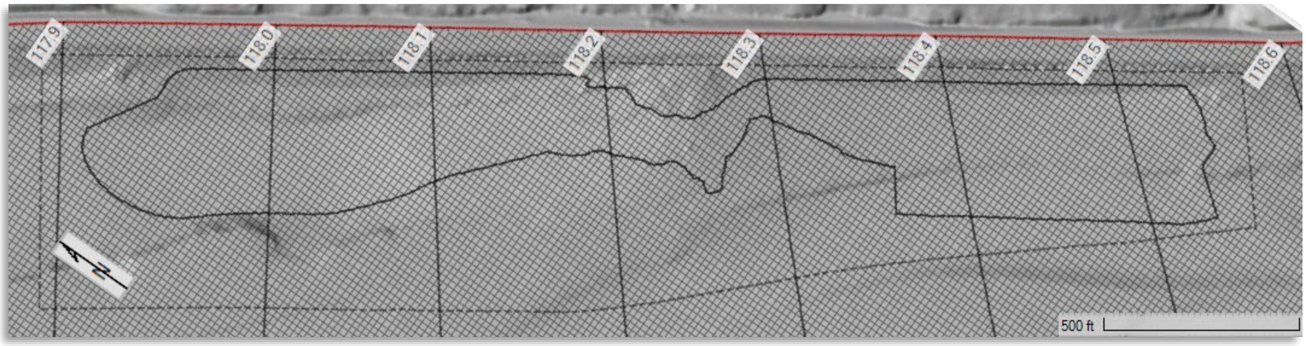

Figure 2-4. Overview of RAS2D mesh for the Bishop Bar disposal site.

For this run-of-river reservoir reach with a very flat energy grade slope of <1.5 feet per mile, the shallow water (Saint Venant) equations were used as flow acceleration and turbulence can influence local hydraulic response more than boundary friction and gravity. Simulation of flow separation and recirculation zones was accommodated using a parabolic turbulence model with anisotropic coefficients. Preliminary model simulations were evaluated to maximize turbulent mixing without introducing numerical instability. Nominal turbulence coefficients of 0.1 and 0.05 were used for the longitudinal and transverse mixing respectively with a Smagorinsky coefficient of 0.05 which resulted in realistic flow separation and recirculation zones without introducing numerical instability. Model sets were initialized over 12-24 hours from a static downstream tailwater and an upstream approach slope of ≥0.001 and then executed with a 1 second timestep for an addition 12-24 hours to convergence.

2.3 Sediment Mobility Methods

The simulated hydraulic force components from the 2D model were used to estimate the hydraulic capacity to transport sediment along the channel bed and in suspension using standard force thresholds methods. An important distinction to note is that hydraulic capacity to move a particular sediment size does not account for the available supply of that sediment (Bagnold, 1966). If a given size is not present in the inflowing sediment load and cannot be eroded from the channel margin (bed and banks), then it would not be in transport despite sufficient hydraulic capacity to move it. This simplified threshold approach is typically referred to as incipient motion/suspension and was deemed appropriate for this evaluation in accordance with ER 1110-2-8153 (USACE 1995). The actual sediment transport rate is dynamic and depends on balance between the hydraulic force and the available sediment supply and is typically averaged or accumulated over a duration of sufficient length (e.g. tons/day).

2.3.1 Sediment Size and Characterization

Because sediment grain sizes can span such a large range, a convenient measure is to use a doubling ($\log_2$) based scale to define equal intervals from very fine to very coarse sediments and is used herein. A simple way to conceptualize this is as a sieve stack whereby the coarsest sieves are at the top (large ψ) incrementally transitioning to finer sieves (small ψ) at the bottom (Figure 2-5). Of interest for this evaluation is the bed material load, which is comprised of sediment sizes larger than 31μm (coarse silt) that deposit within (and will be dredged from) the confluence FNC. The compliment to bed material load is washload, representing finer size classes that transport predominately in suspension due to settling velocities that are much lower than the stream velocity.

Grain Class	ψ_{lower}	ψ_{upper}	$\varnothing_{si}$	$\varnothing_{bg}$	
MB	9	10	512mm	20.2in	Medium Boulder
SB	8	9	256mm	10.1in	Small Boulder
LC	7	8	128mm	5.0in	Large Cobble
SC	6	7	64mm	2.52in	Small Cobble
VCG	5	6	32mm	1.26in	Very Coarse Gravel
CG	4	5	16mm	0.63in	Coarse Gravel
MG	3	4	8mm	0.315in	Medium Gravel
FG	2	3	4mm	0.157in	Fine Gravel
VFG	1	2	2mm	79mil	Very Fine Gravel
VCS	0	1	1mm	39mil	Very Coarse Sand
CS	-1	0	0.5mm	20mil	Coarse Sand
MS	-2	-1	0.25mm	10mil	Medium Sand
FS	-3	-2	0.125mm	5mil	Fine Sand
VFS	-4	-3	62.5μm	2.5mil	Very Fine Sand
CM	-5	-4	31.2μm	1.2mil	Coarse Silt
MM	-6	-5	15.6μm	0.62mil	Medium Silt
FM	-7	-6	7.8μm	0.31mil	Fine Silt

Figure 2-5. Log_2 based stack of sediment grain size classes

Physical and chemical characterization of the sediment to be dredged from the Snake and Clearwater confluence areas was completed in September and October of 2019 under Task Order# W912EF19F9002 (Shannon & Wilson, 2020). Samples were collected at numerous sites including 21 Dredged Material Management Units (DMMU), and the Ports of Clarkston, WA and Lewiston, ID. The grain size distribution of the samples was determined by mechanical methods per ASTM D6913 on a nominal 1/2ψ scale using sieve sizes: 2-, 1.5-, 1-, ¾-, ½-, and ⅜-inch and #4, #8, #10, #16, #20, #30, #40, #60, #80, #100, #140, #200, and #325.

In general, the DMMU samples contained mostly sand, with the inner quartile range of the D_{50} spanning fine sand to medium sand (darker shading in Figure 2-6). Nearshore samples on the Snake River (Port of Clarkston Recreation Dock, Grain Elevator, and Cruise Dock) had higher fines (silts and clays <62.5μm) content than other sample locations. The fines content of near-shore areas ranged from 7.2% to 74%. On a volumetric basis, sediment dredged from nearshore locations will be very low relative to the remaining DMMUs to be dredged.

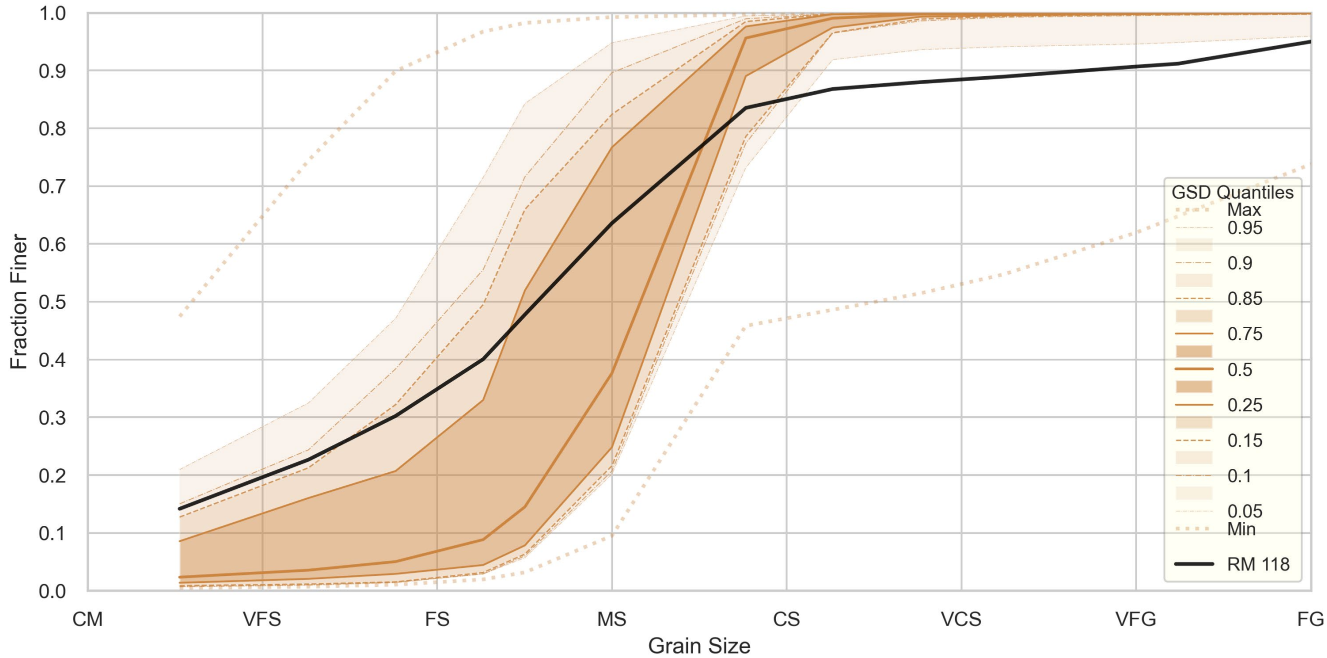

Figure 2-6. Grain Size distribution quantiles of dredged sediment to be disposed at Bishop Bar site and the composite gradation at the RM 118 Bishop Bar site.

For comparison, the grain size distribution of a composite grab sample collected at the RM 118 Bishop Bar site, is plotted over the DMMU GSD quantiles. Of note is that a majority of the RM118 composite distribution (up to the D_{84}) is finer than that of the DMMU sediments to be dredged which supports the premise that the placed materials which are coarser will remain stable at the Bishop Bar site. For the sediment disposal strategy, it is recommended that material dredged from lenses finer than sand (<62.5µm) be strategically placed within the nearshore areas at the Bishop Bar site and be covered with at least 2 feet of graded sand to minimize the potential for fines resuspension after the project is complete. As an additional countermeasure, dredged lenses of coarser sands could be strategically placed as toe material for improved stability near the hydraulic separation eddyline with the active channel.

2.3.2 Critical Bedload Sediment Size

To evaluate the potential for the movement of coarse bed material load along the channel bed in the Bishop Bar reach, a competence-based approach was applied whereby grain mobility was computed as a force balance between applied and resisting forces. For gradually varying flow in a wide channel, the applied force results from the hydrodynamics of the flow while the resisting force is related to the submerged weight of a non-cohesive sediment grain. The seminal work of Shields (1936) used a similarity approach to derive the critical grain size as:

$$d_c = \frac{\tau'}{\tau_c^* \left(\gamma_s - \gamma_w\right)}$$

where, τ' represents the fraction of the bed shear stress acting on the sediment, $(\gamma_s - \gamma_w)$ represents the submerged unit weight of the sediment, and d_c represents the critical sediment grain diameter. Shields described the fundamental process of sediment mobility by establishing that at the threshold of sediment movement, the critical Shields stress (τ_c^*) is a function of the critical grain Reynolds number with an empirically derived envelope between 0.03 and 0.06 for non-laminar conditions as illustrated in the traditional Shields curve as shown below (Figure 2-#)

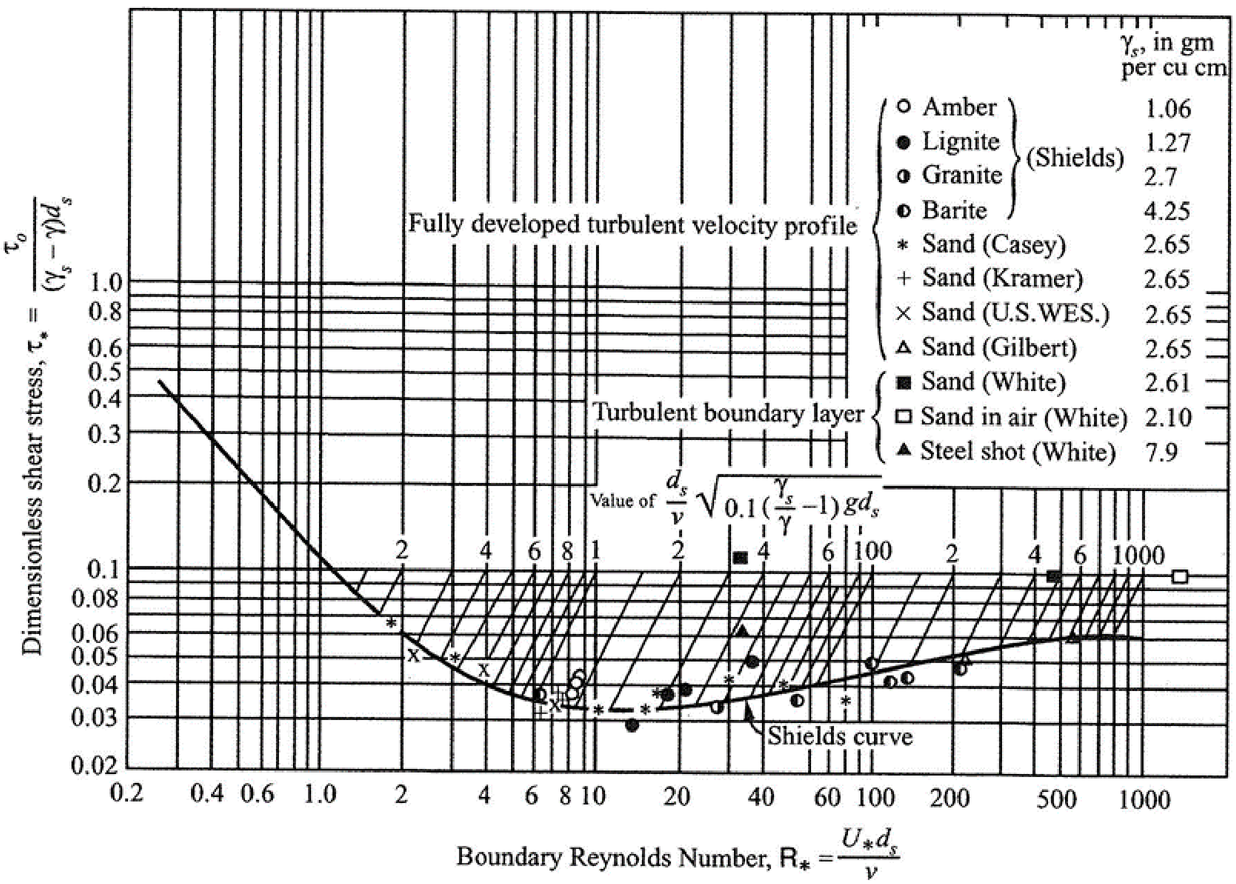

Figure 2-7. Shields Diagram for Sediment Grain Mobility. *Source: ASCE Manual of Practice 54, Figure 2.43*

The critical bedload grain size represents the upper bound for incipient motion, where finer grain sizes would also be mobile, and coarser grain sizes would not. Coarse bedload sediments typically move in lagged pulses along the channel bed as a function of tractive force at transport rates significantly lower than those for suspended sands. Sands also move along the bed in pulses and can form various bed features such as dunes depending on the hydraulic regime.

2.3.3 Suspended Sediment Size

To evaluate the potential for the suspension and transport of fine grain sizes at the Bishop Bar disposal site, a competence-based approach was applied whereby grain suspension is an assumed function of flow stratification that scales with the ratio between settling and shear velocity. At the Bishop Bar disposal site, the source sediment would be located at the channel bed, with hydraulic turbulence effectively diffusing sediment from this deeper zone of high concentration toward a lower concentration zone near the water surface.

The suspended sediment within the water column can generally be represented as a concentration profile (Figure 2-8) that varies with depth according to the general Rouse equation which calculates the sediment concentration (C) at an elevation y above the bed relative to the near bed (a=0.05=lower 5% of depth) concentration Ca, for flow depth D, and scaling parameter z. Also known as the Rouse number, the parameter z defines this force balance as a ratio between a characteristic sediment fall velocity and the boundary layer shear velocity, a hydraulic surrogate that is proportional to the lift velocity acting on sediment at the channel bed.

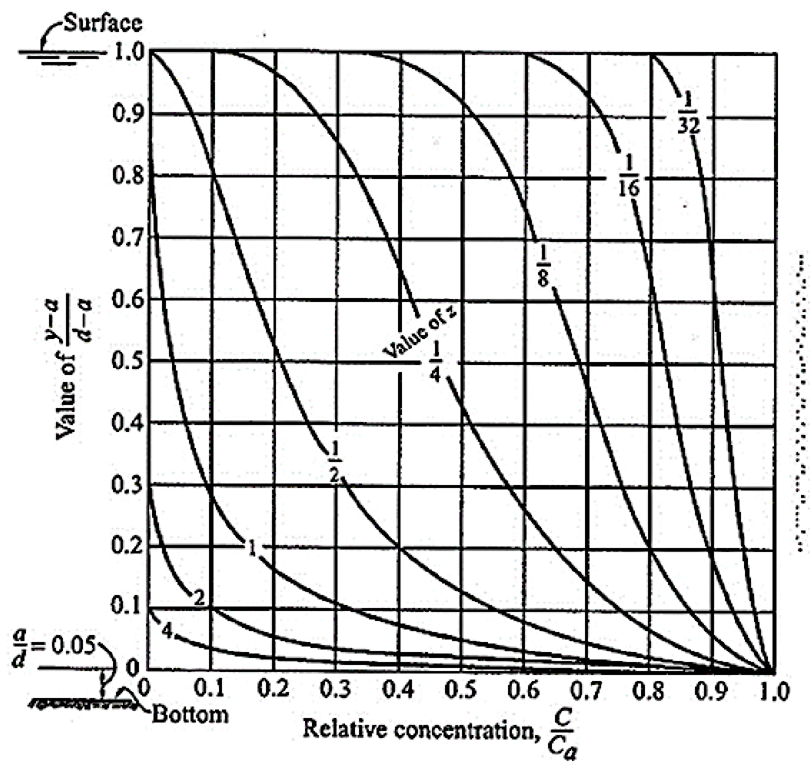

Figure 2-8. Standard Rouse Profile *Source: ASCE Manual of Practice 54, Figure 2.32*

3 Results

Results of the numerical hydraulic simulation and subsequent sediment mobility calculations are presented in Section 3.

3.1 Hydraulic Evaluation

Downstream of the confluence with the Clearwater River, the Snake River valley cuts deeply into the Columbia River Basalt Plain. From Silcott Island downstream to LLA, the Snake River planform is relatively confined, with an average width-to-depth ratio of 20 and median <10. With the Snake River valley predominately inundated by the LLA backwater, hydraulic patterns within the study reach are relatively uniform and dampened with a nominal slope of <0.5 foot per mile. Flow conveyance within this run-of-river reservoir reach is generally proportional to depth, tracking with the inundated historical thalweg.

3.1.1 Depth

Depth within this run-of-river reservoir reach is directly related to the downstream stage at LLA and upstream inflows from the Snake and Clearwater Rivers. Within the Bishop Bar reach, thalweg depths exceed 100 feet. As depicted in Figure 3-1, the approach thalweg follows the right side of the channel, transitioning away from exposed bedrock at RM 118.9 through the symmetrical centerline at RM 118.7. Adjacent to the Bishop Bar site (between RM 118.3 and 117.3), the thalweg is on the left side of the channel and transitions back to the right side of the channel downstream to RM 116.

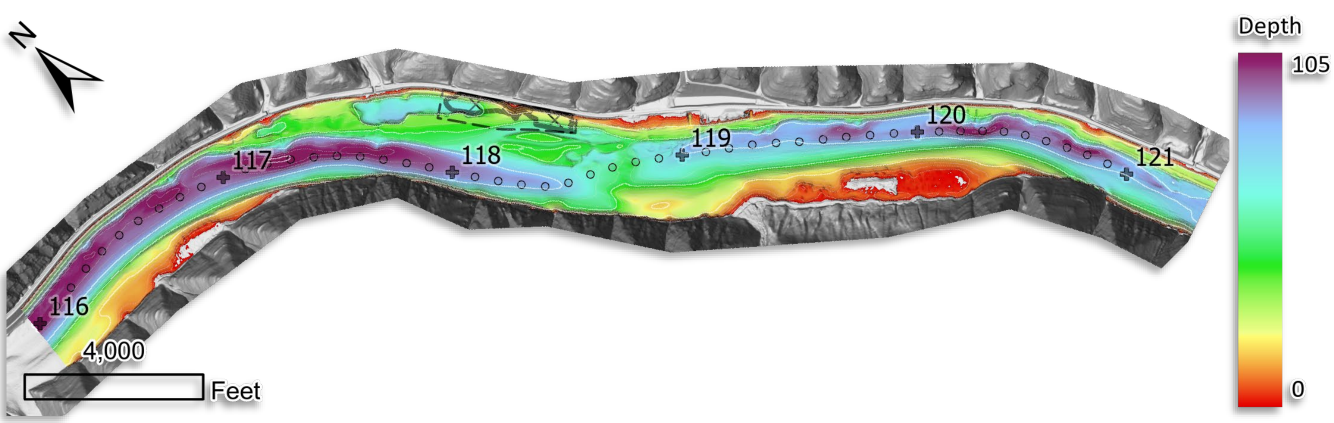

Figure 3-1. Reach Depth (feet) for 1% AEP (331.6 kcfs). *Flow direction is from right to left.*

At the thalweg crossover location, there is a ~10+ foot high mound in the channel bed between RM 118.8 and RM 118.7. From the 2022 bathymetry, this mound is roughly 5 acres in size (~600 feet wide cross-stream by ~250 feet long) and appears to be a submerged relic top of riffle feature of boulders inundated with sand. The difference between the 2022 and 2011 bathymetry indicates this feature is stable under current operations with an elevation difference < 1 foot. The location of this feature coincides with the upstream end of the Bishop Bar side channel and a localized increase in hydraulic response at the thalweg crossover (Figure 3-2).

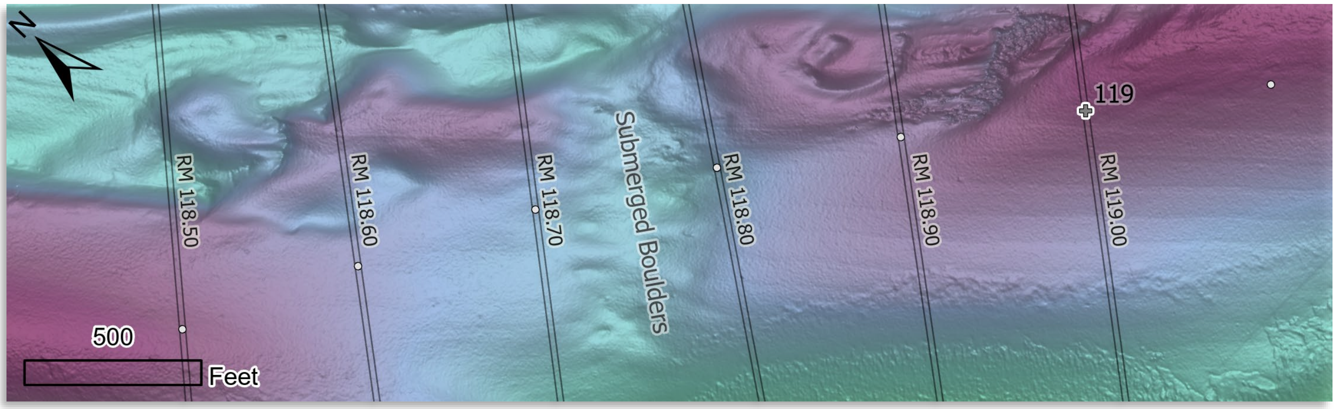

Figure 3-2. Submerged boulders feature at RM 118.7. *Flow direction is from right to left.*

The Bishop Bar site is characterized by a submerged relic channel bar and ~275 foot wide side channel between RM 118.2 and RM 118.6 (Figure 3-3). Local depths in the submerged side channel are on the order of 60+ feet, transitioning onto a submerged bench with depths of ~30 feet. Immediately downstream of the disposal site is a submerged pool following the right bank from ~RM 118.1 to ~RM 117.5 that is ~25 feet deeper than the adjacent channel bed with a nominal area of ~36 areas. It is unknown if this is a natural feature or if the area had been excavated prior to inundation by the LLA reservoir after 1974.

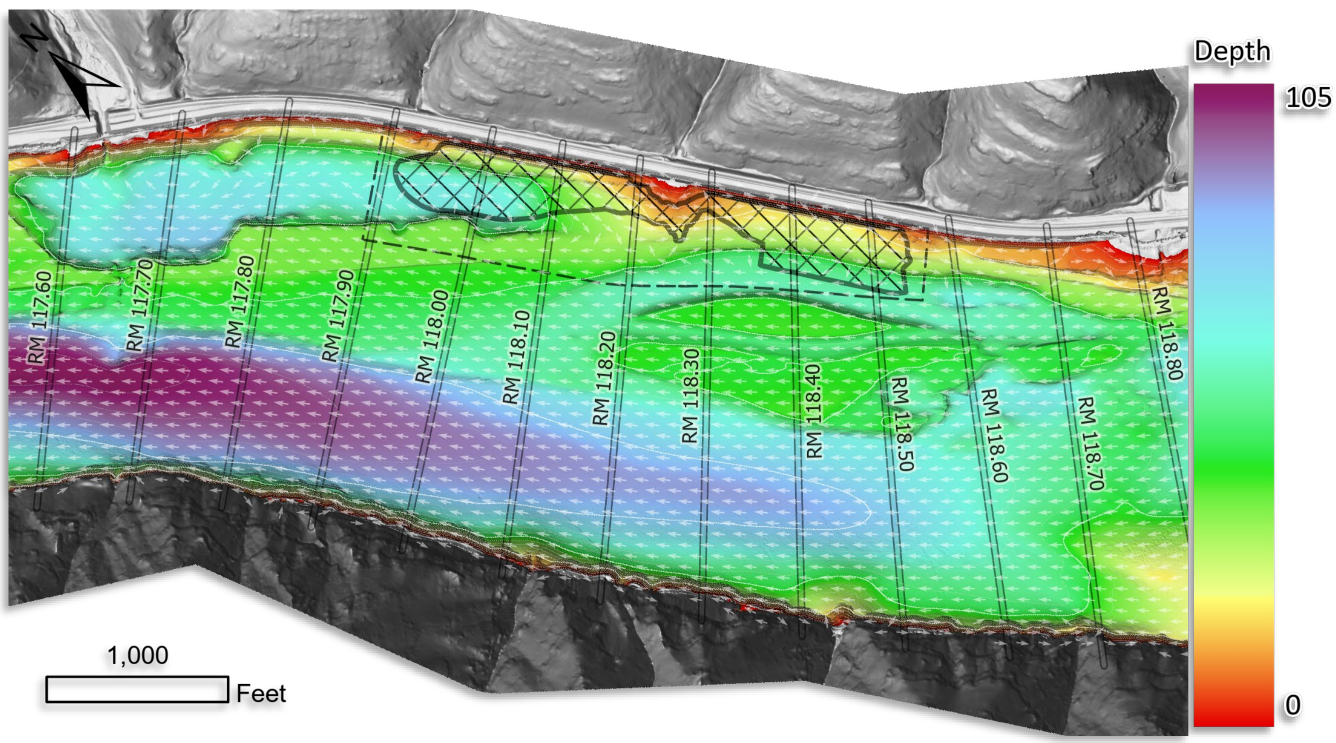

Figure 3-3. Site Depth (feet) for 1% AEP (331.6 kcfs). *Flow direction is from right to left.*

Simulated depth results for a sample line through RM 118.4 depicts the riverine depth trends for the flood frequency index sets (Figure 3-4). Of note is that due to the LLA flood risk management hinge pool operation, simulated depths incrementally decreased from the 2-year (50% AEP) event to the SPF over a range of ~10 feet. Within the 2022 disposal limits footprint, the distribution of baseline depth spanned from ~10 feet to ~70 feet with median values near 40 feet (Figure 3-5).

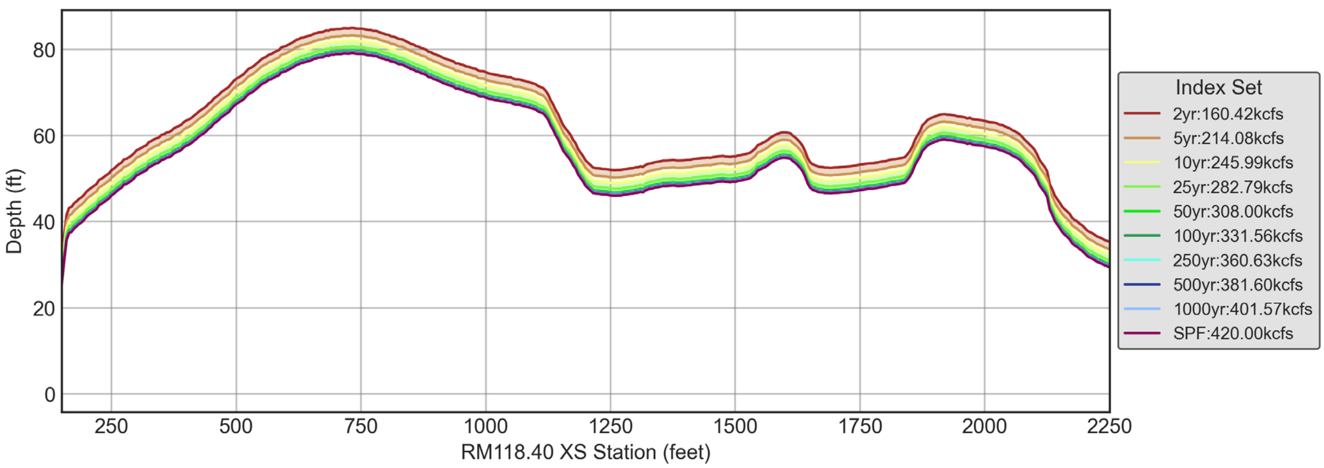

Figure 3-4. Depth at RM 118.40 for flood frequency index sets.

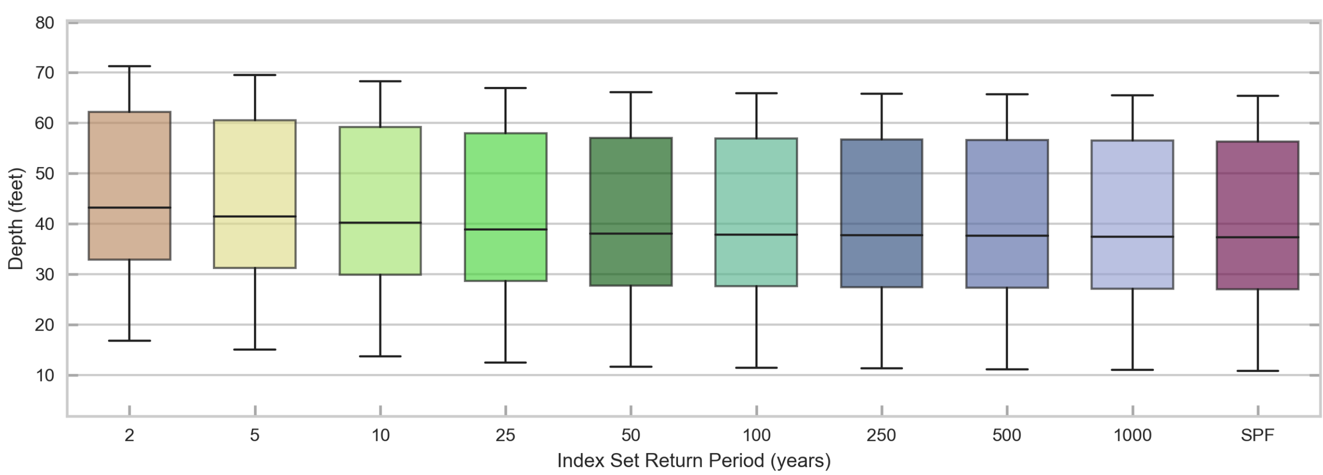

Figure 3-5. Depth distribution within 2022 disposal limits for flood frequency index sets

3.1.2 Velocity

As a run-of-river reservoir, channel velocities through the Bishop Bar reach are relatively low considering the flow magnitude. The backwater effects from the downstream stage at LLA effectively dampen the maximum channel velocities to ~5.2 feet/second at the SPF of 420 kcfs to <2 feet/second for the 50% AEP of 160.4 kcfs.

As illustrated in Figure 3-6 below, the upstream approach velocity at RM 121 is comparatively high due to the slightly narrower channel width of approximately a quarter mile. The simulated active channel velocity reached peak values around RM 120, gradually decreasing in the downstream direction with another localized peak at the RM 118.7 thalweg crossover location. Downstream of the thalweg crossover location, the active channel gradually widens by up to ~40%, resulting in slightly lower relative velocities concentrated to the thalweg.

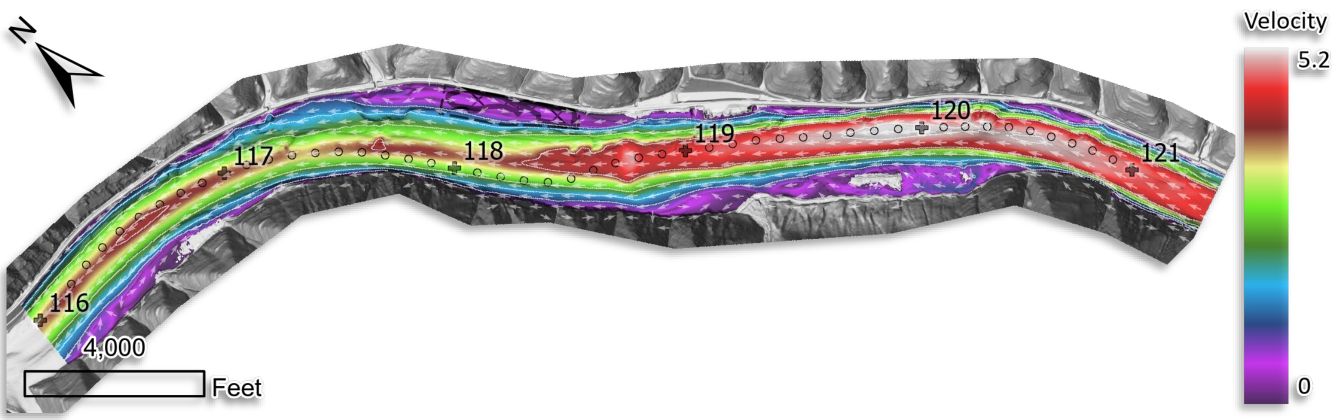

Figure 3-6. Reach Velocity (ft/sec) for 1% AEP (331.6 kcfs). *Flow direction is from right to left.*

Flow separation and recirculation was simulated at multiple locations in the reach. On the left side of the active channel across the river from Blyton Landing (between RM 118.9 and RM 120.4), the river inundates a ~1.5 mile long shallow bench with limited flow separation and recirculation positively correlated to depth. The downstream end of the left bank shallow bench and the upstream end of a second low energy area on the right bank (downstream from Blyton Landing) both coincide with the RM 118.7 thalweg crossover (Figure 3-6 and Figure 3-7).

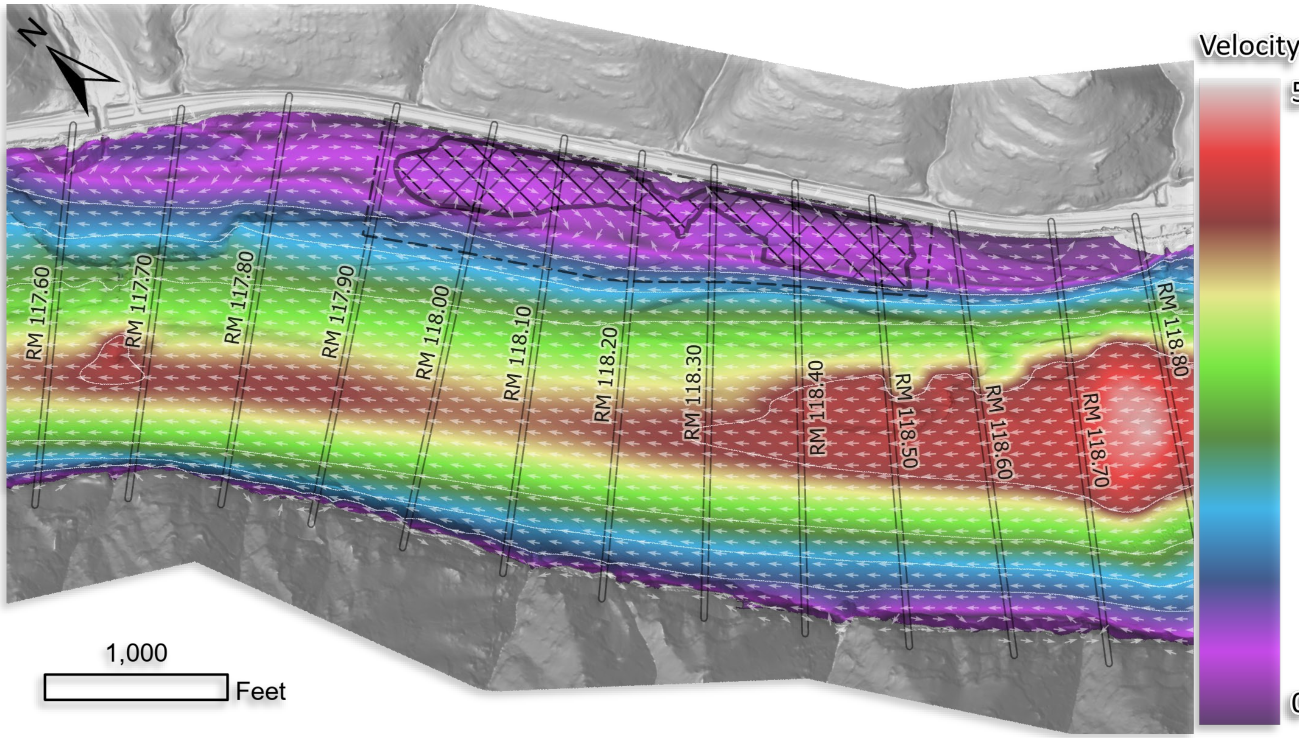

Figure 3-7. Site Velocity (ft/sec) for 1% AEP (331.6 kcfs). *Flow direction is from right to left.*

On the right side of the active run-of-river channel, the simulation identified flow separation starting at ~RM 118.8 immediately downstream in the hydraulic shadow created by Blyton Landing. The separation eddyline extends downstream for approximately one mile, creating a ~60 acre sheltered zone of lower energy on the northeast side towards the landward right bank. This eddyline feature was simulated to occur and remain stable over the range of flow sets evaluated. At the upstream end of the site, the flow separation zone coincides with the submerged side-channel that is approximately 20 feet deeper than the adjacent toe of the near shore bench. Downstream of ~RM 117.7, the flow separation reattaches, and the flow streamlines transition back towards the active channel. Within the low energy right bank area between RM 118.6 and RM 117.9 is the Bishop Bar in-water dredge material disposal site. Within the low energy right bank area between RM 118.6 and RM 117.9 is the Bishop Bar in-water dredge material disposal site. At the Bishop Bar site, unsteady low velocity flow recirculation patterns were also present in the simulation across all flows. These transient features were characterized by two or three major recirculation zones ~3-10 acres in size with nominal longitudinal diameters of ~500-1500 feet and a transverse (cross-stream) diameter factor of ~0.25 (Figure 3-8).

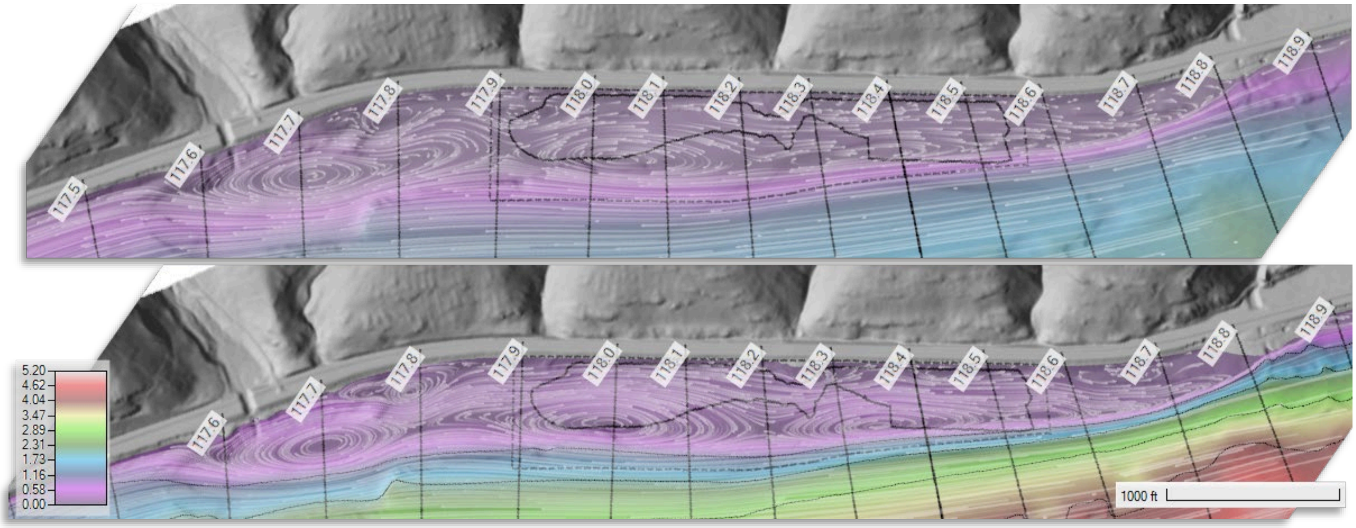

Figure 3-8. Transient flow recirculation patterns at the Bishop Bar site. Top: 50% AEP (160.4 kcfs); Bottom: 1% AEP (331.6 kcfs). Color coding is velocity magnitude up to 5.2 feet/second. *Flow direction is from right to left.*

A sample line at RM 118.4 depicts the simulated velocity magnitude for the flood frequency index sets (Figure 3-9), illustrating the low velocity area extending out from the right bank. As previously noted for depth, the LLA FRM hinge pool operation lowers the downstream stage to increase the conveyance, resulting in an incremental increase in peak channel velocity with decreasing flood frequency. Within the 2022 disposal limits footprint, the velocity distribution was < 0.5 feet/second with median values < 0.2 feet/second (Figure 3-10).

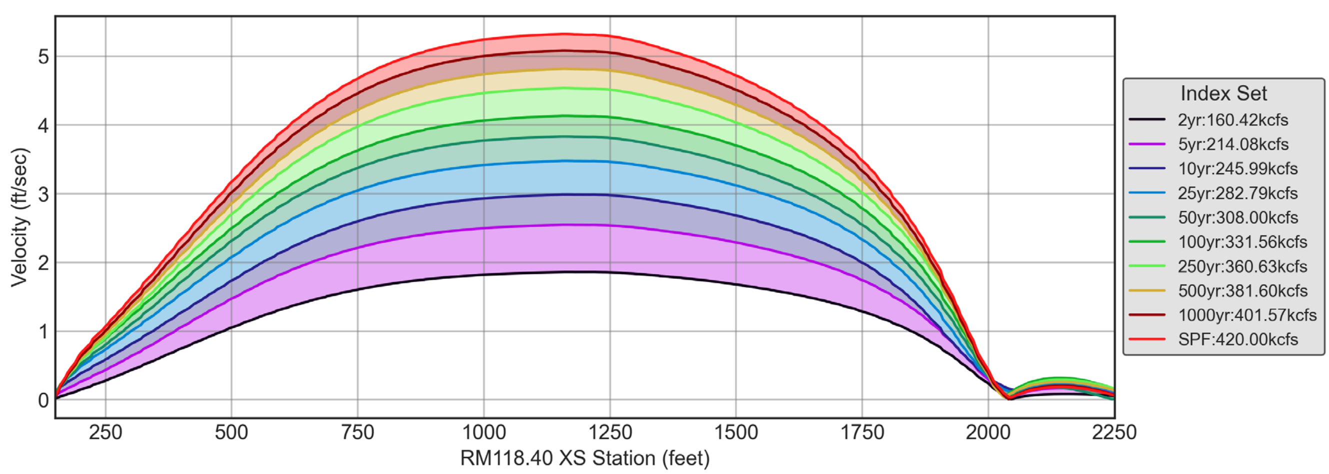

Figure 3-9. Velocity at RM 118.40 for FFA series.

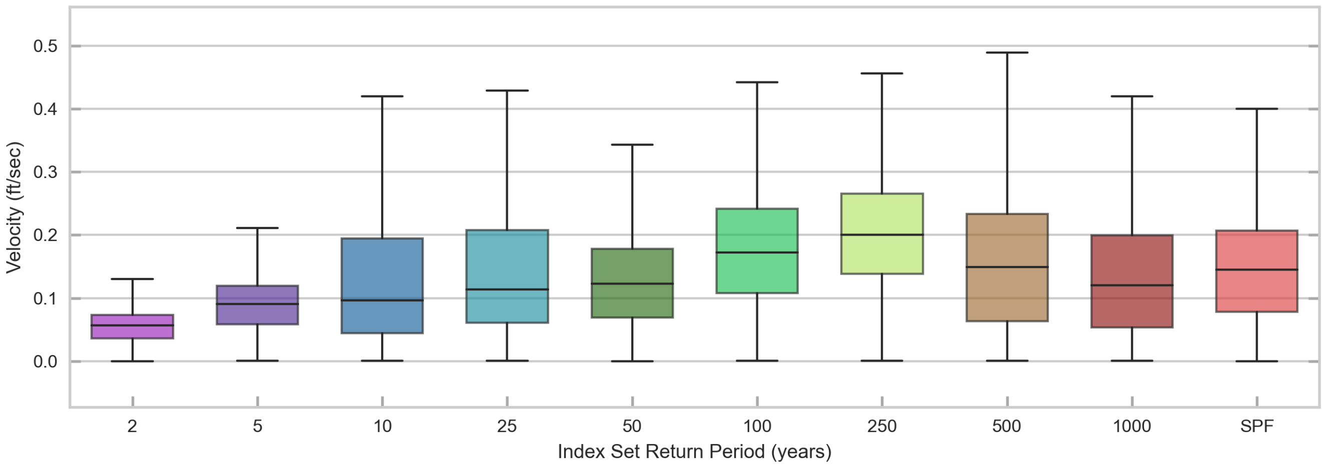

Figure 3-10. Velocity distribution within 2022 disposal limits

To evaluate potential hydraulic conditions at the Bishop Bar disposal site during the dredging construction period, two indices were selected from the flow duration curve developed for the 75-day hydroperiod between 15-December and 01-March. The upper index simulated was the 5% exceedance flow of 75.6 kcfs and the second index simulated was the 50% exceedance flow of 29.9 kcfs (see Table 2-2). The simulation confirmed that the flow separation and recirculation patterns also observed for the flood index sets could be present during the dredging construction period, however simulated velocity was relatively low (<0.25 feet/second) and is not expected to impact the disposal and placement of dredged materials at the Bishop Bar site.

An additional consideration regarding recirculating flows is the positioning of daily water quality monitoring stations for background and compliance during the placement of dredged materials. Although the low-velocity flow recirculation zones at the Bishop Bar site can be present during this period, they are still an unsteady transient feature with a dynamic adaptation length. As such and considering the slender aspect ratio for the Bishop Bar site, it is recommended that the background monitoring station be located just outside the flow separation eddyline and slightly upstream (relative to the active channel) from the work area compliance station in accordance with applicable regulatory criteria for this action.

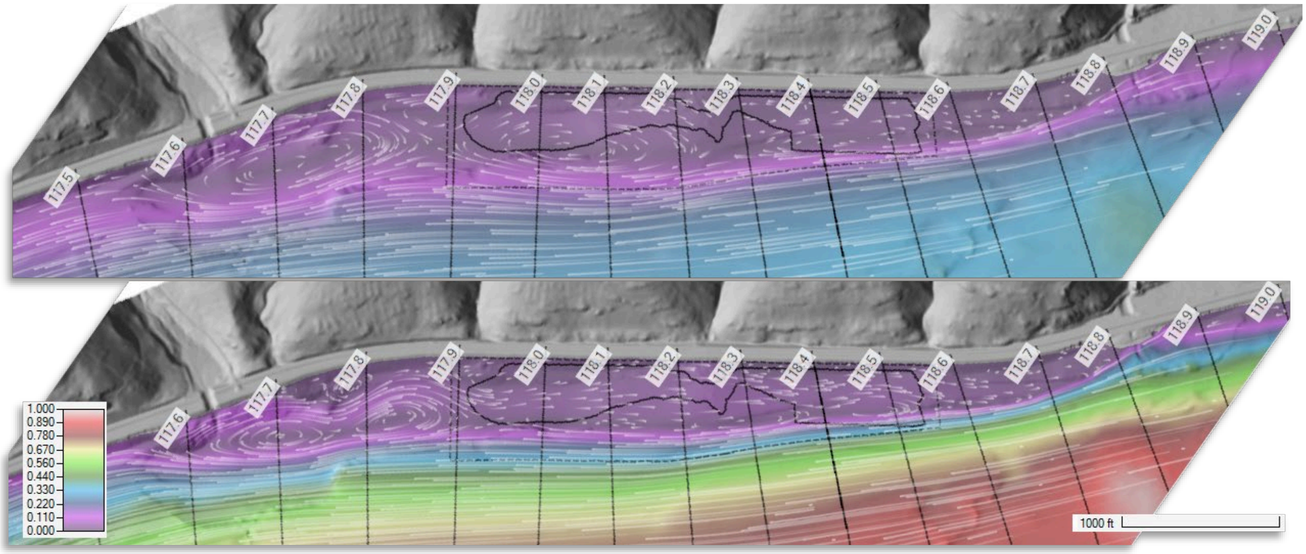

Figure 3-11. Simulated velocity magnitude (ft/sec) and flow patterns at RM118 during 15-Dec to 01-Mar construction period. Color coding is velocity magnitude up to 1.0 feet/second. Left: 5% exceedance (75.63 kcfs), Right: 50% exceedance (29.91 kcfs). *Flow direction is from right to left.*

3.1.3 Shear Stress

Derived as a function of depth, velocity and slope, simulated boundary shear stress in the reach followed a similar pattern to velocity. As would be expected, the largest shear stress values coincided with depth in the thalweg with peak values < 0.14 lbf/ft^2 for the SPF. At the Bishop Bar site on the landward side of the flow separation eddyline, the simulated shear stress values decreased by multiple orders of magnitude, approaching near-zero values <0.001 lbf/ft^2 with median values ≤0.0002 lbf/ft^2 across the index flow sets considered.

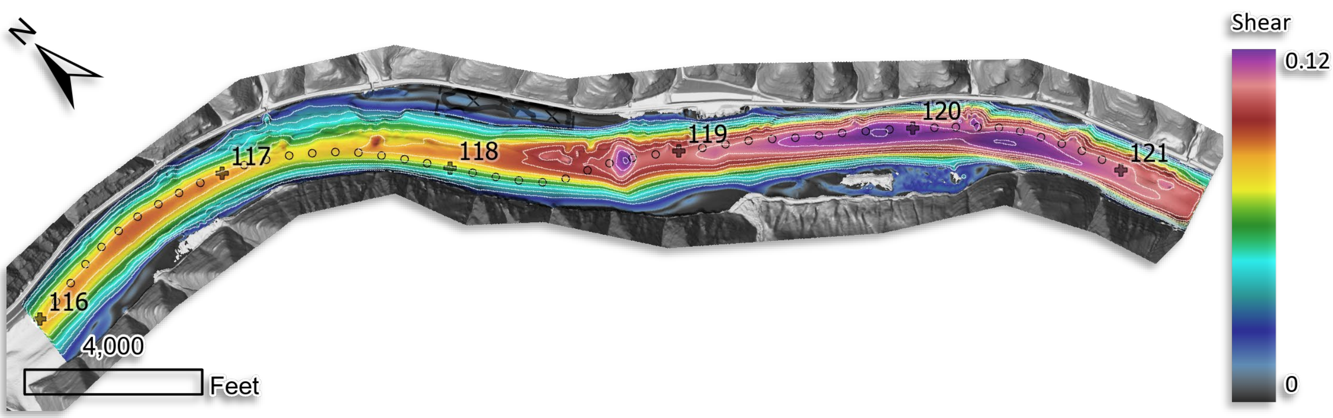

Figure 3-12. Reach Shear Stress (lbf/ft^2) for 1% AEP (331.6 kcfs). *Flow direction is from right to left.*

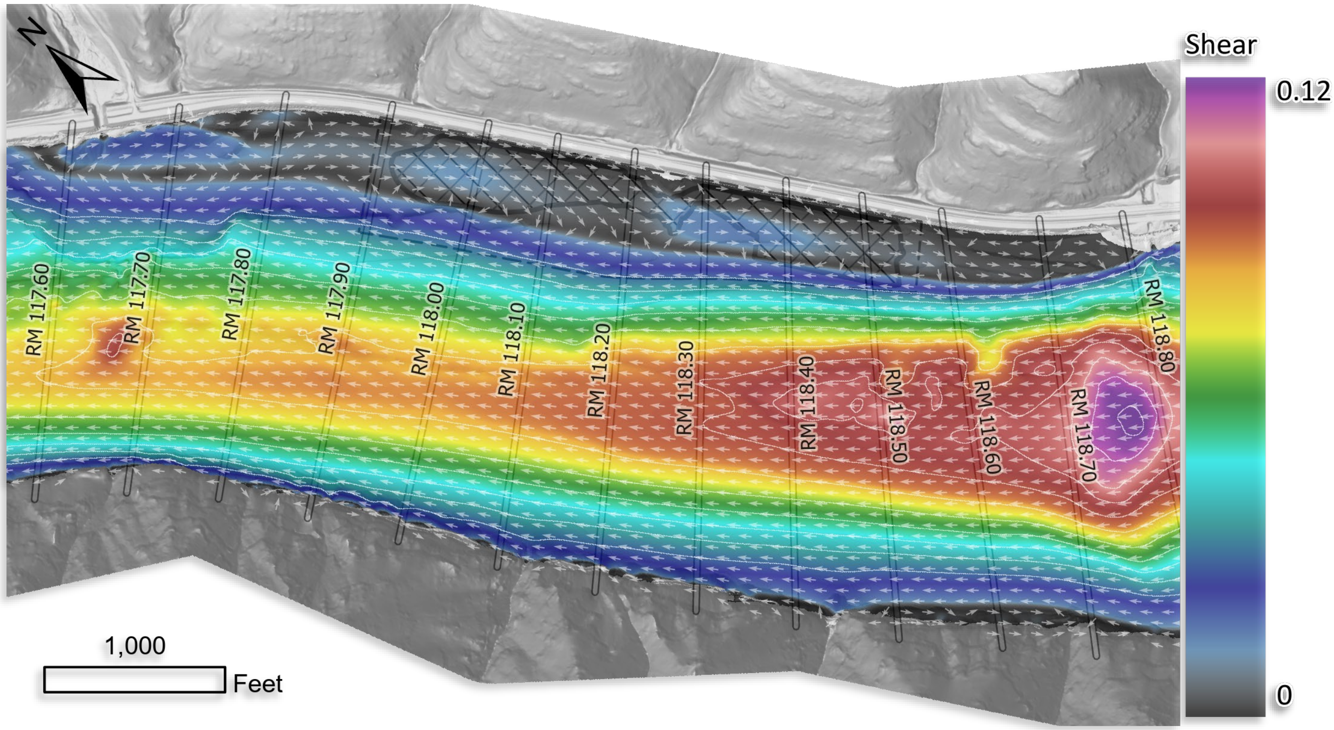

Figure 3-13. Site Shear Stress (lbf/ft^2) for 1% AEP (331.6 kcfs). *Flow direction is from right to left.*

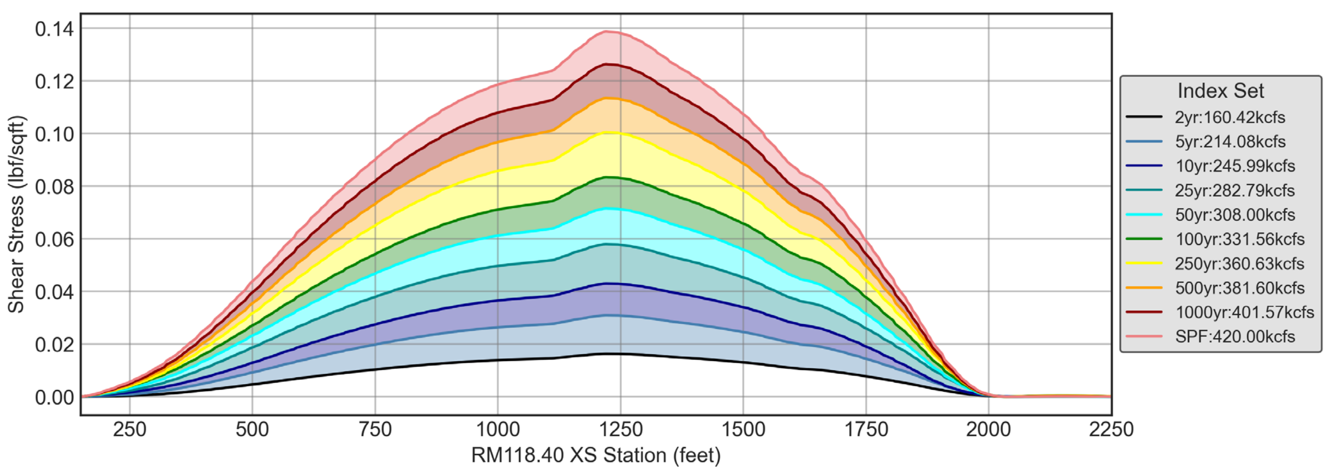

Figure 3-14. Shear Stress at RM 118.40 for FFA series.

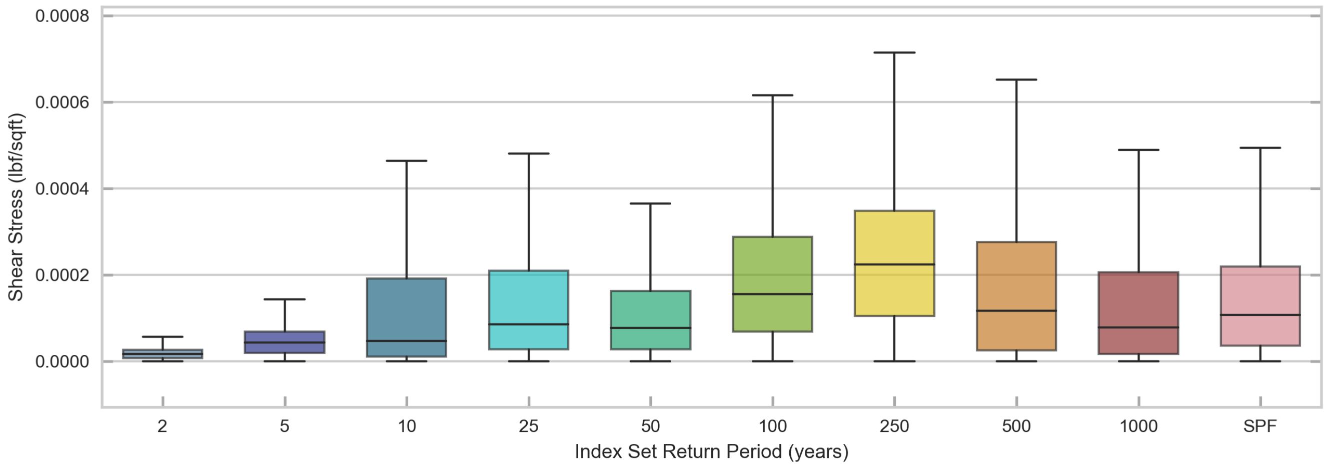

Figure 3-15. Shear Stress distribution within 2022 disposal limits.

3.2 Sediment Mobility Evaluation

The simulated hydraulic force components from the 2D model were used to estimate the hydraulic capacity for bed material load (sediment sizes larger than coarse silt: 31μm) to be mobilized and suspended using standard force thresholds methods. As summarized in Section 2.3.1, the gradation of the 2022 dredged material is predominately sands (0.625mm to 2.0mm diameter) which can transport both along the channel bed and advect at much larger rates in suspension. The smaller/finer fractions (silts and clays) predominately transport in suspension as washload, requiring very low energy conditions to settle out of the water column and deposit.

Figures 3-16 through 3-20 depict the reach critical bedload and suspended sediment sizes for the 1% AEP index flow. Of note is that while there is sufficient energy within the active channel to mobilize sediment sizes finer than medium gravels, gravels are not a large component of the upstream sediment supply (relative to sand volume) and are prone to deposition within the Snake and Clearwater confluence reach upstream. Further, gravels have not been observed downstream of Silcott Island ~RM 130 (USGS 2012) and are not expected to be present in this reach despite sufficient hydraulic capacity to transport as bedload. For suspended sediment mobility, hydraulic capacity within the active channel is sufficient to readily transport sands inversely proportional to their grain size. At a 50% reference concentration, the critical suspended grain size within the active channel extents is fine sand, gradually tapering to fines < 62.5μm at the channel margins.

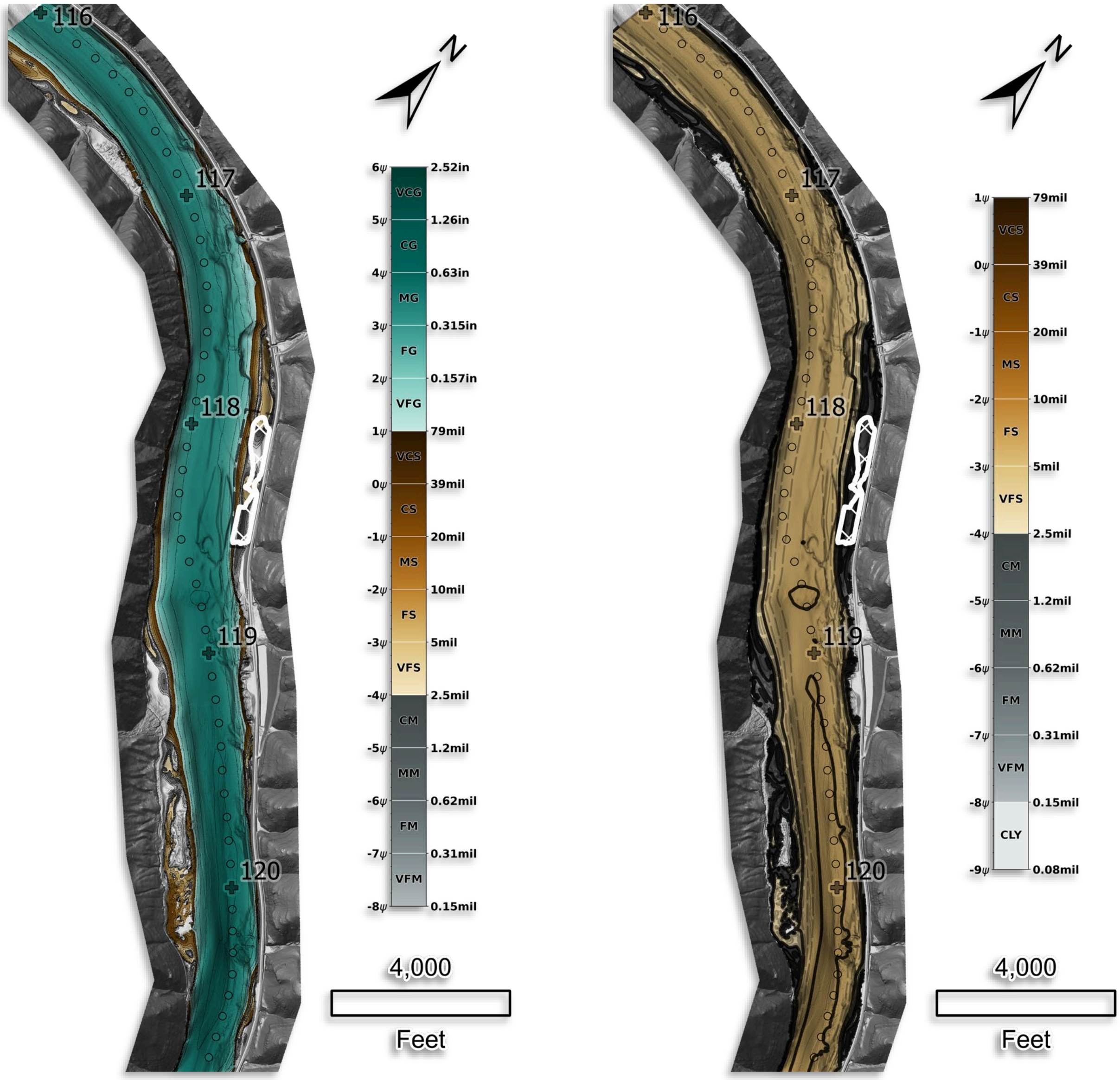

Figure 3-16. Reach Sediment Mobility for 1% AEP (331.6 kcfs). Left: Critical bedload grain size, Right: Critical suspended grain size at 50% concentration. Contours are on a 1/2ψ interval. *Flow direction is from bottom to top.*

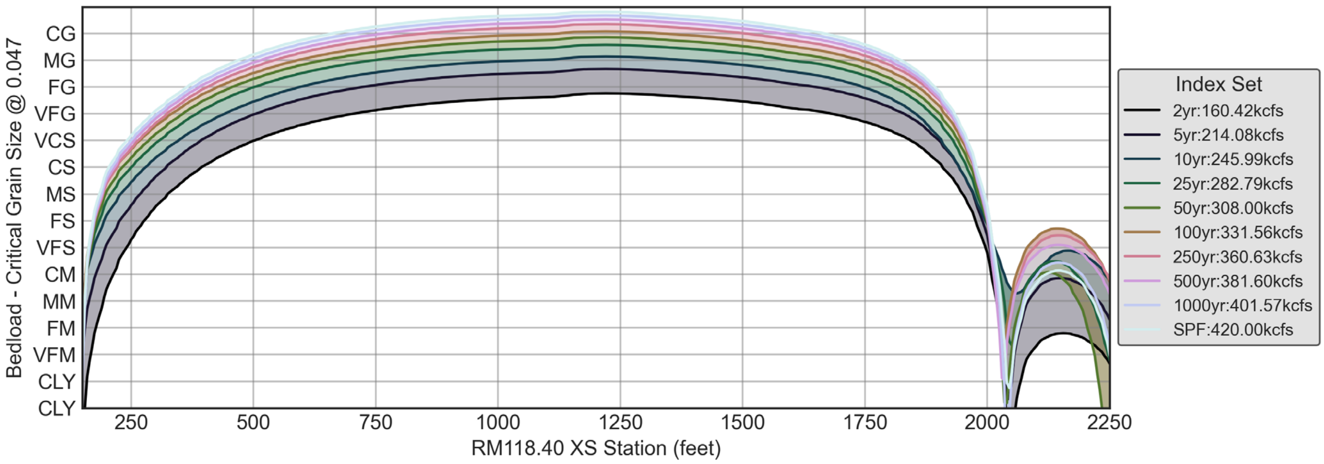

Figure 3-17. Critical bedload grain size at RM 118.40 for FFA series.

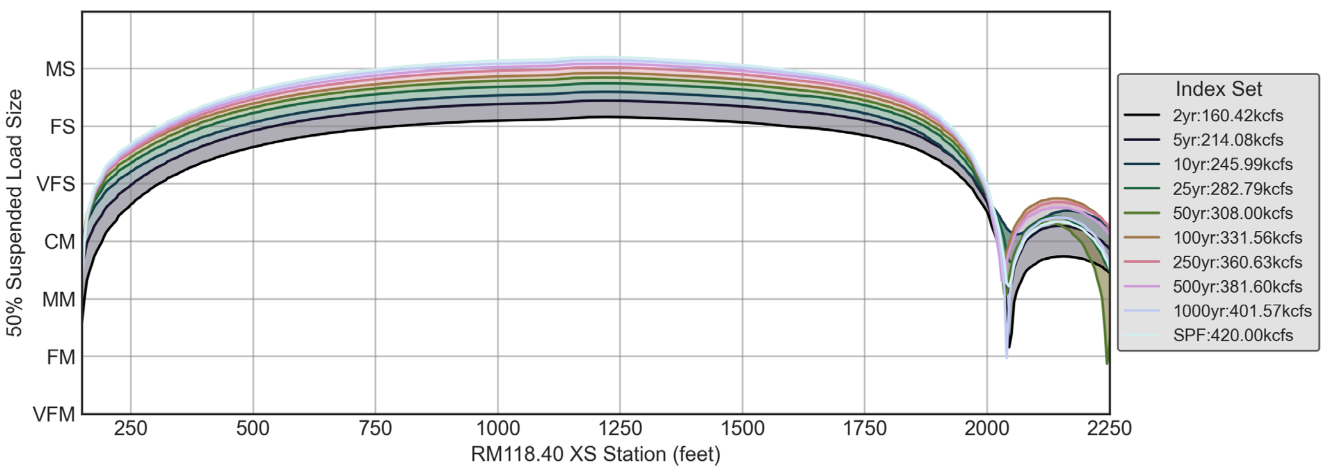

Figure 3-18. 50% Suspended load concentration size at RM 118.40 for FFA series.

Located to the landward side of the flow separation zone between RM 118.8 upstream and 117.6 downstream, the Bishop Bar in-water disposal site is characterized by relatively quiescent hydraulics and a corresponding low degree of sediment mobility and suspension. Figures 3-19 and 3-21 illustrate the spatial distribution of critical grain size within the nearshore low velocity recirculation zones which is generally limited to localized transport of silts and fine sands. Along the flow separation eddyline and in the deeper area of the submerged side channel, medium to coarse sand can be mobilized as bedload at channel elevations <680 feet (NAVD88). The inter-quartile-range for critical bedload grain size within the disposal catch limits was ≤VFS with upper tails of the distribution mobilizing up to coarse sands where the toe material is adjacent to the eddyline and submerged side channel.

Similar to the critical bedload grain size, within the Bishop Bar site, the critical suspended load grain size at a 50% reference concentration is limited to silts except for the transition near the flow separation eddyline where very fine sand can be suspended (Figure 3-19). As depicted in Figure 3-20, the median and inter-quartile-range for critical suspended load grain size fall within the silt size class across all FFA index sets.

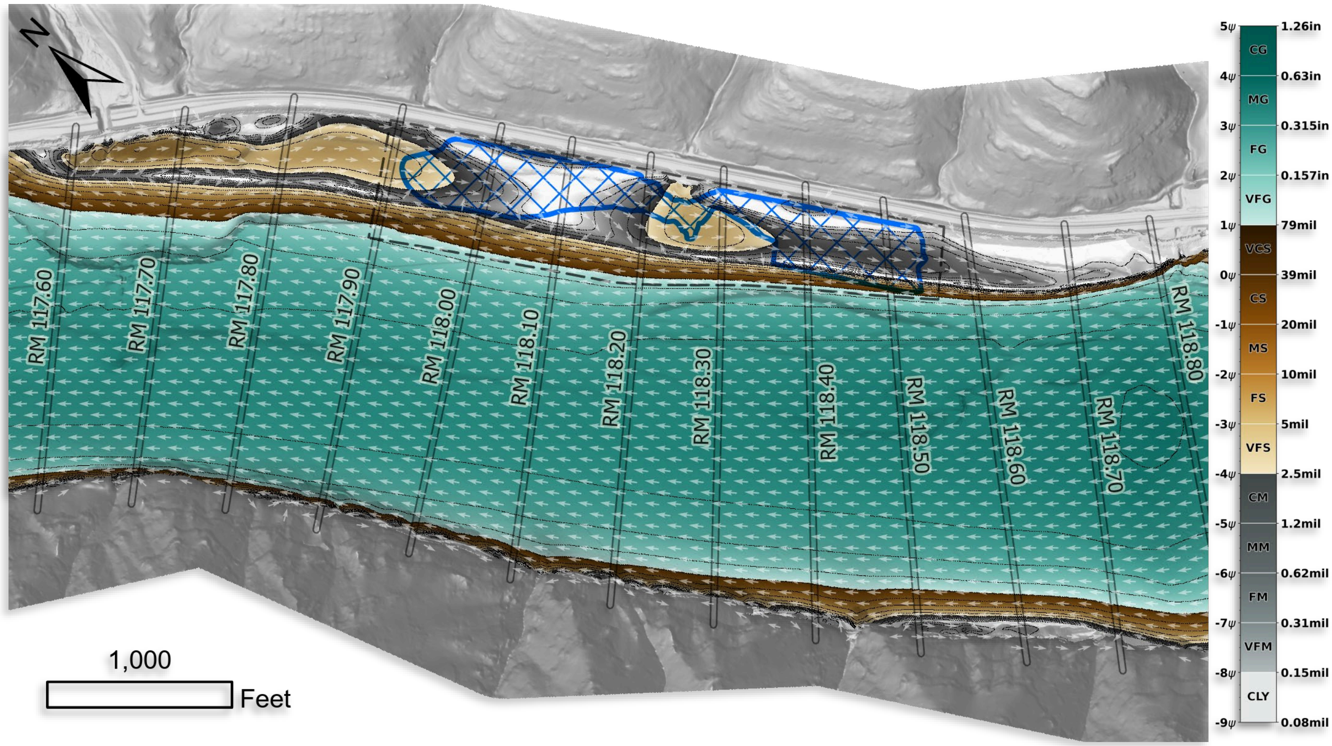

Figure 3-19. Site critical bedload grain size for 1% AEP (331.6 kcfs). *Flow direction is from right to left.*

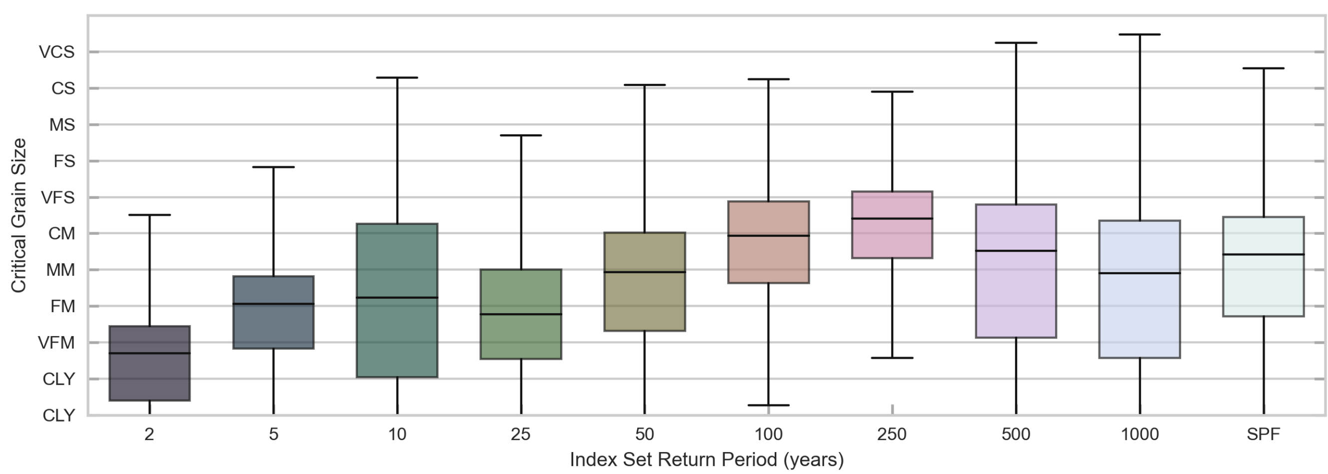

Figure 3-20. Critical bedload grain size distribution within 2022 disposal limits

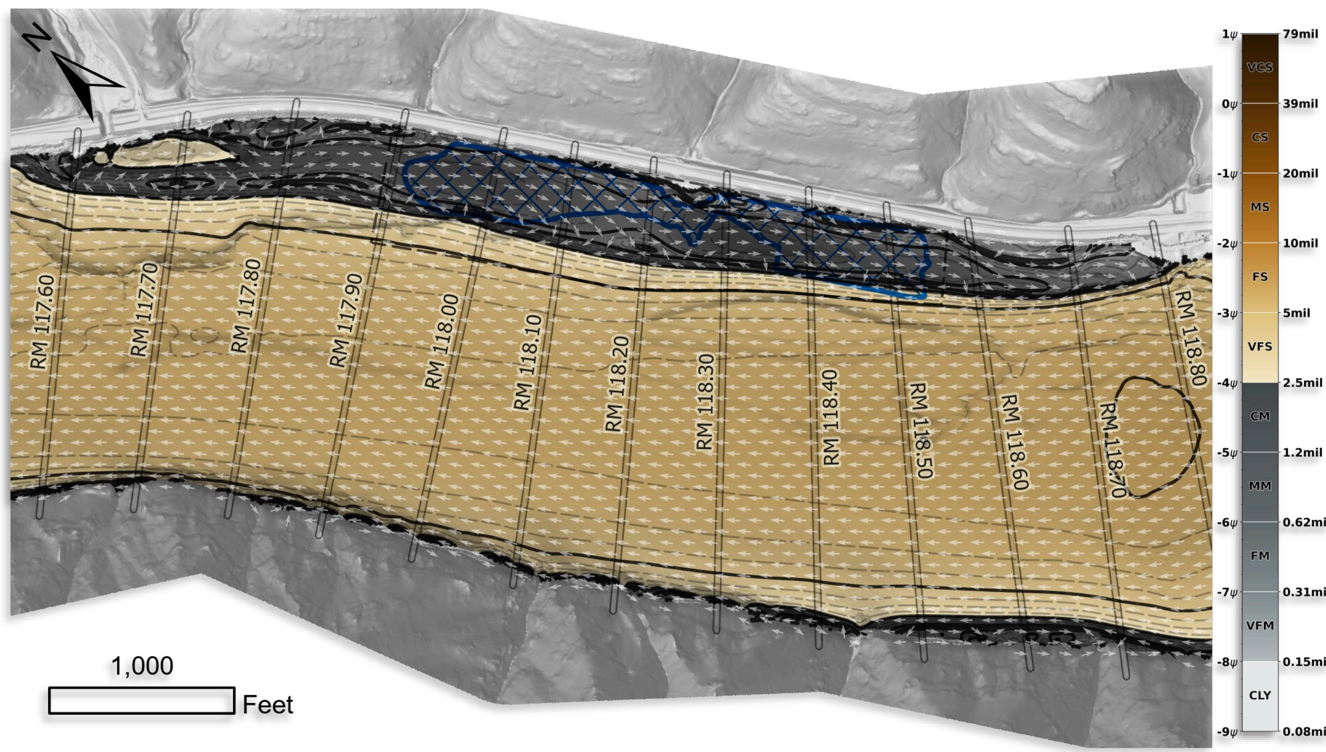

Figure 3-21. Site critical suspended grain size at 50% concentration for 1% AEP (331.6 kcfs). *Flow direction is from right to left.*

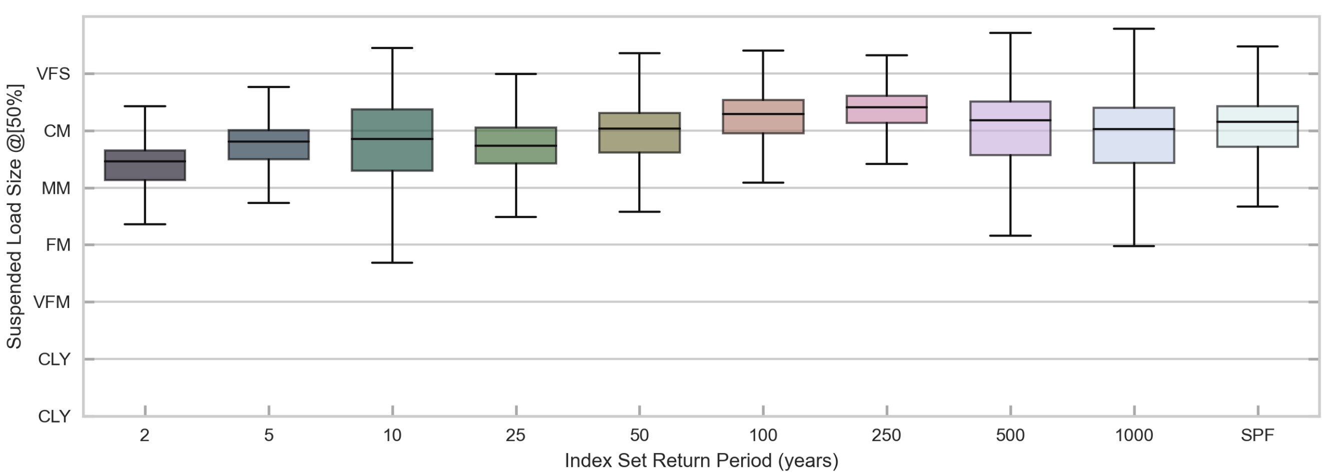

Figure 3-22. Suspended load size distribution at a 50% reference concentration within 2022 disposal limits

4 Summary

A hydraulic model study was conducted for the Bishop Bar in-water disposal site located on the right bank of the Snake River at RM118 over a wide range of regulated LLA seasonal and flood risk management operations. Results from the hydraulic simulation identified a persistent flow separation zone extending approximately one-mile downstream, sheltering a relatively shallow ~60 acre area at the Bishop Bar site located in the hydraulic shadow of Blyton Landing. Transient recirculating velocity zones within this low energy area were identified in the simulation ~3-10 acres in size.

Sediment mobility and suspension calculations, indicate that while the nearshore area is hydraulically sheltered, turbulence near the shear layer and reattachment zones could mobilize medium or finer sands on the bed, and entrain fine silts and clays as washload. In addition, higher washload (silts and clays) concentrations following the increased spring flows may persist longer within transient recirculation zones than for a uniform channel with similar low velocities. However, considering the relatively low velocities over a wide range of regulated discharges up to the SPF, and the confirmation that fine sediment is already present at the Bishop Bar in-water disposal site, this is not considered to be a significant risk. Further, if some of the placed sand or silt dredge material were to mobilize and be transported into the active channel, the consequences would be minimal as it would advect in the water column in proportion to velocity, readily diluting the suspended sediment concentration profile.

Based on a comparison between the computed sediment mobility thresholds and the gradation for the dredged material most of the placed dredged material is expected to remain dynamically stable under the range of regulated flows at the Bishop Bar site. It is recommended that fine material dredged from nearshore areas such as ports be strategically placed within the nearshore areas at the Bishop Bar site and be covered with at least 2 feet of coarser graded sand to minimize the potential for fines resuspension after the project is complete. As an additional countermeasure, coarse material dredged from navigation locks or lenses of coarser sand could be strategically placed as toe material if needed for improved stability near select areas of hydraulic turbulence.

5 References

- Bagnold RA. 1966. An approach to the sediment transport problem from general physics. USGS Numbered Series. U. S. Govt. Print. Office, Available online from: http://pubs.er.usgs.gov/publication/pp422I
- David Evans and Associates Inc. December 2021. 2021 Hydrographic Navigation Condition Surveys. Multibeam Hydrographic Survey Report. Contract No. W912EF-21-D-0001, Task Order No. W912EF21F9701
- Einstein, H. A. 1950. The Bedload Function for Sediment Transport in Open Channel Flows. Technical Bulletin 1026. U.S. Department of Agriculture, Soil Conservation Service. Washington, D,C.
- Garcia, M. H. 2007. ASCE Manual of Practice 110-Sedimentation Engineering: Processes, Measurements, Modeling, and Practice.
- NGS 2022. NCAT Coordinate Conversion and Transformation Tool: https://www.ngs.noaa.gov/NCAT/
- Rouse, H. 1937. "Modern Conceptions of Mechanics of Fluid Turbulence." Transactions of the American Society of Civil Engineers 102(1):463¬–505. http://cedb.asce.org/CEDBsearch/record.jsp?dockey=0288088
- Shannon & Wilson. 2020. Lower Snake/Clearwater River 2019 Channel Maintenance Report Sampling and Analysis Results. Prepared for USACE-NWW, Task Order# W912EF19F9002
- Shields, A. F. 1936. *Anwendung der Aehnlichkeitsmechanik und der Turbulenzforschung auf die Geschiebebewegun, Mitt. Preuss. Versuchsanst. Wasserbau Schiffbau*, 26, 26, 1936. (uuid:61a19716-a994-4942-9906-f680eb9952d6). English translation by W. P. Ott and J. C. van Uchelen. U.S. Department of Agriculture, Soil Conservation Service Cooperative Laboratory, California Institute of Technology. Pasadena, CA.
- USACE 2021. HEC-RAS River Analysis System. Hydraulic Reference Manual version 6.0. May 2021. CPD-69.
- USACE 2022. 2022/2023 Lower Snake River Channel Maintenance Immediate Need Dredging For Commercial Navigation Environmental Assessment
- USACE 2022. Lower Snake River Dams, Navigation Channel Maintenance 2022 Plans and Specifications. Solicitation# W912EF22B0005.
- USACE 2020. Columbia River System Operations Environmental Impact Statement. Northwest Division.
- USACE 2019. Sampling and Analysis Plan for Lower Snake and Clearwater Rivers Proposed 2019/2020 Channel Maintenance Dredging. Walla Walla District.
- USACE 2014. Lower Snake River Programmatic Sediment Management Plan Final Environment Impact Statement. Walla Walla District. Walla Walla, WA.
- USACE 2006. Lower Granite Reservoir Water Control Manual
- USACE 1995. ER 1110-2-8153: Sedimentation Investigations
- USACE 1995. EM 1110-2-4000: Sedimentation Investigations of Rivers and Reservoirs
- USACE 1977. Lower Granite Lock and Dam. Operational and Maintenance Manual. Lewiston Levees.
- USGS 2012. Grain-Size Distribution and Selected Major and Trace Element Concentrations in Bed-Sediment Cores from the Lower Granite Reservoir and Snake and Clearwater Rivers, Eastern Washington and Northern Idaho. SIR 2012-5219.
- Vanoni, V. A. 2006. Sedimentation Engineering. ASCE Manual of Practice No. 54. Reston, VA.
- Whipple, K. 2004. "IV. Essentials of Sediment Transport." 12.163/12.463 Surface Processes and Landscape Evolution: Course Notes. MIT Open Courseware.