SEDIMENT WEDGE STUDY

Study Goals and Objectives

The Sediment Wedge Study was designed to experimentally evaluate the capacity of sediment wedges to create or enhance local cold-water refuge habitats in tributaries to the Chehalis River during the warm season to benefit native cold-water adapted aquatic species. Sediment wedging restoration is intended to enhance cold-water refugia via accumulations of cobble and gravel upstream of an engineered in-channel obstruction (e.g., large wood). During summer low flows, stream water is expected to percolate into these sediment accumulations, cooling water as it flows through the subsurface stream channel and resurfacing downstream.

This report documents progress on pre-implementation monitoring intended to address the following research questions:

- Do sediment wedge structures reduce downstream water temperature?
- Do sediment wedge structures increase thermal refugia opportunities?
- Do sediment wedge structures alter hyporheic exchange dynamics?
- What is the net change in substrate associated with sediment wedge structures over time?
- What affect do sediment wedge structures have on fish movement?

Only pre-implementation monitoring has occurred to-date.

Methods / Study Design

This study will be performed on two geographically independent stream reaches within the Chehalis Basin. We used landscape analysis tools to inform site selection and identified potential study sites with high restoration and water storage potential. After establishing landowner willingness, we identified two sites for inclusion in the study: Delezene Creek (Weyerhaeuser Company) and Schafer Creek (Green Diamond Resources Company; **Figure 1**). Both sites are located on private industrial forestlands managed primarily for timber harvest. Delezene is a low-gradient, fifth-order tributary located in the Central Lowlands ecological region of the lower Chehalis River. Schafer is a low- moderate-gradient third-order tributary of the Wynoochee River located in the Olympic ecological region. Both streams were historically alluvial channels that have evolved to bedrock as a result of historic logging and wood removal.

Our monitoring design allows us to evaluate the effects of sediment wedge structures on water temperature, creation of thermal refugia for aquatic and semi-aquatic native species, hyporheic exchange, sediment accrual, and fish movement during the pre- and post-treatment periods in a Before-After Control-Impact (BACI) study. We started pre-treatment monitoring in summer 2022 and will continue through summer 2024 until sediment wedge construction. Post-treatment monitoring will begin after construction and continue through a minimum of two full water years until October 2026. To accommodate the BACI sampling design, each study site is comprised of an upstream control reach, treatment reach, and downstream reach positioned longitudinally adjacent to one another (**Figure 2**).

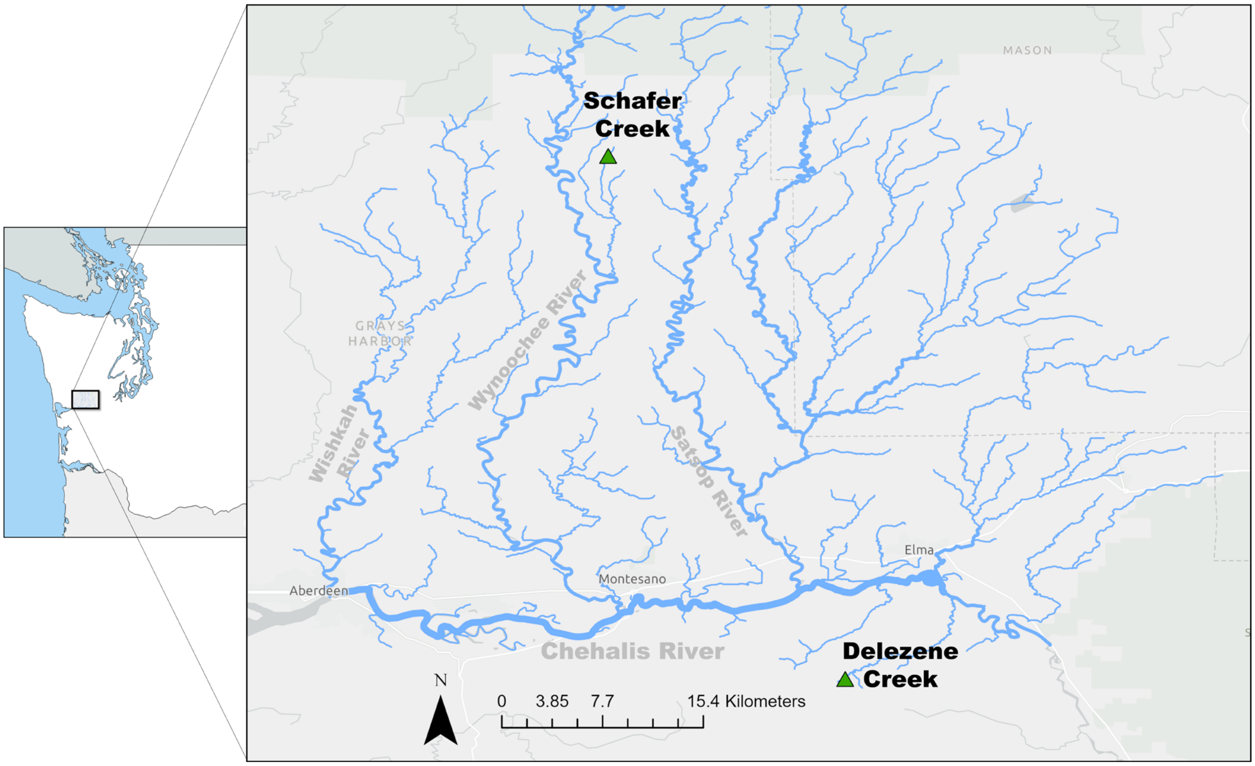

Figure 1. Map of the two study site locations included in the Sediment Wedge Study.

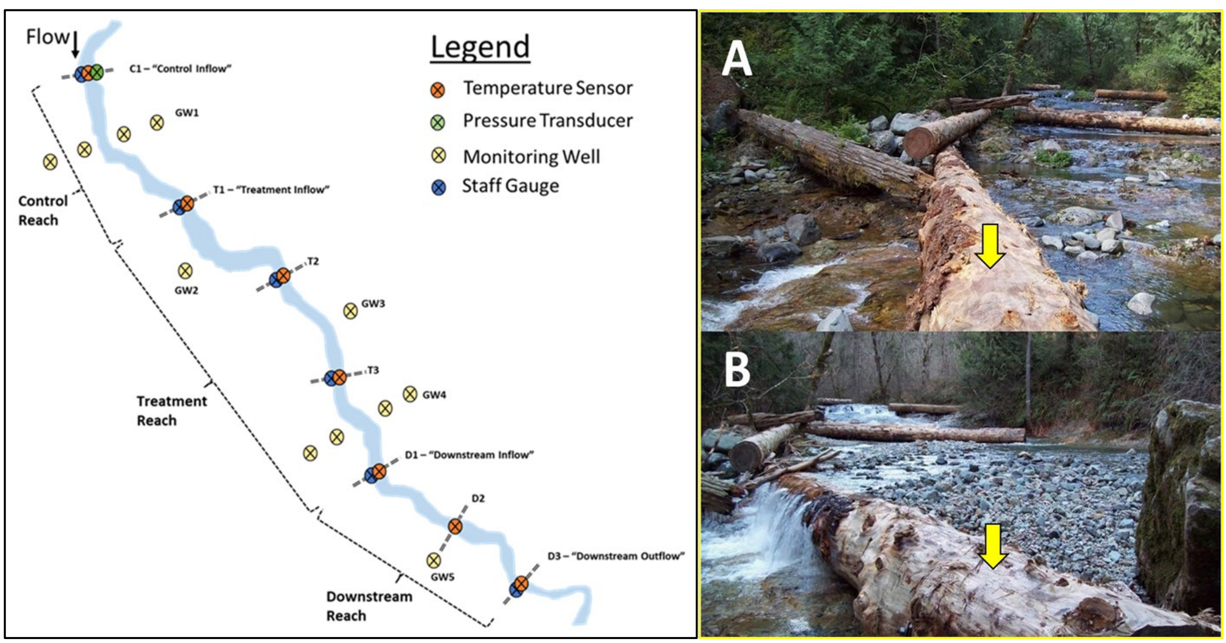

Figure 1. Left: Conceptual site map illustrating the sampling locations and study site layout. Treatment reaches range from approximately 200 to 480 meters in length. Right: Example Sediment Wedge, note that structures in this study will be designed to allow for fish passage.

Water Temperature: To evaluate the net stream water temperature change we deployed multiple temperature sensors in well-mixed areas of the stream thalweg at each site, with sensors positioned throughout the control, treatment, and downstream reaches and recorded temperature year-round at 30-minute intervals. We download sensors at least every two months.

Thermal Refugia: To evaluate the presence of discrete cold-water patches more than 1°C cooler than the adjacent ambient water temperature, we surveyed each study reach during the summer low-flow period (July-August) using a handheld digital thermometer with a 1m probe (Model 35200K ±0.1 °C, response rate < 1 s; Cooper-Atkins Corp.).

Hyporheic Exchange: To evaluate stream stage, we deployed continuously logging pressure transducers at the control, treatment, and downstream inflows. Stage is recorded year-round at 30-minute intervals. We also launched a single barometric pressure transducer that logs at 30-minute intervals near the approximate mid-section of each study site to allow for barometric corrections of stream water level loggers. We co-located staff gauges with pressure transducers. We made 4-5 discharge measurements annually across the recession period (approximately monthly) to capture the range of hydrologic variability across the spring and summer study period.

We took monthly manual measurements of alluvial water level at well locations from April to October, and approximately every one to two months from November to March. Alluvial water monitoring transects were positioned perpendicular to flow, with one transect approximately mid-way between the inflows of the control and another within the lower 30% of the treatment reach. Each transect consisted of four monitoring wells spanning the valley floor and bisected by the stream. We placed additional monitoring wells on each side of the stream in an alternating fashion. Each well was installed to a depth assumed to be below the lowest mean annual water table elevation.

Substrate: We conducted pebble counts in each reach and cross-sectional surveys in the control and treatment reaches annually during the summer low-flow period.

Fish Movement: We evaluated pre-treatment fish use with anadromous fish spawning surveys and three-pass electrofishing removal surveys within each of the control, treatment and downstream reaches. The electrofishing effort was made possible by the in-kind support of Weyerhaeuser, who donated two full days of their crew time to survey both study sites. Without their support these surveys would not have been possible.

Summary of Results

This report covers preliminary observations from the pre-implementation (i.e., treatment) monitoring period beginning June 2022. Sediment wedge construction is planned for summer of 2024. We provide a brief summary of channel and stream characteristics for each site in **Table 1** which are similar between the sites.

Table 1. Aggregate mean values across all study reaches (control, treatment, and downstream) of channel and stream characteristics for the first year of pre-treatment monitoring at two Sediment Wedge study sites. Values represent average conditions across each study site during the low-flow period of measure unless otherwise noted.

Metric	Delezene	Schafer
Wetted Width (m)	3.40	3.16
Bankfull Width (m)	4.74	4.86

Depth (cm)	0.22	0.21
Measured Discharge (cfs), May - November	2.82 (n = 21)	3.04 (n = 20)
Mean daily maximum (°C), July - August	16.0	14.1
Number cold-water patches in Treatment	7	1

Water Temperature: We deployed 12 water temperature sensors at Delezene and 11 sensors at Schafer. Mean daily maximum July and August temperatures across sites ranged from 14.1 to 16.0 °C (Table 1).

Thermal Refugia: We identified cold-water patches at both sites in August 2022. The number of discrete cold-water patches across treatments ranged from 1 to 7 (Table 1).

Hyporheic Exchange: We did not deploy instream piezometers at either site due to limiting conditions of bedrock and shallow alluvium along the study reaches. We assume minimal vertical exchange along the bedrock mediated reaches and limited losses to deep groundwater through bedrock fractures, as indicated by bi-monthly seepage runs across the control and treatment reaches at both sites. We deployed 12 riparian monitoring wells and 3 stream gauges across each study site to infer the direction and timing of lateral groundwater-surface water exchange. Bi-monthly flow measurements were taken throughout the recession and summer low-flow period to improve understanding of the timing and flow conditions that mediate connectivity between the stream and shallow riparian aquifer water levels.

Substrate: We conducted a pebble count and evaluated dominant substrate within a series of channel cross-sections at each site during summer low-flow of 2022. At Schafer the dominant substrate was bedrock. At Delezene, the dominant substrate was dominated by fines, sand and gravel-sized substrates. Distributions of shallow alluvium were mapped at both sites to understand the proportion of bedrock to alluvium.

Fish Movement: We found evidence of anadromous fish using the downstream, treatment and control reaches of both sites in the pre-treatment period. We documented five coho salmon (*Oncorhynchus kisutch*) redds at Schafer in 2022: one in the downstream reach, zero in the treatment reach, and one in the downstream reach. Unfortunately, we were unable to conduct pre-treatment spawning surveys at Delezene in 2022 because at the time our landowner access permit had expired, and it took us a couple of months to gain reapproval for access from the landowner. It will be priority to conduct spawner surveys at Delezene in 2023. The dominant species detected at Delezene with electrofishing were reticulated sculpin (*Cottus perplexus*) and coho salmon, which were detected in all reach types (downstream, treatment and control). The dominant species detected at Schafer was reticulated sculpin, also in all reach types. Coho salmon was also detected at Schafer, but in fewer numbers than reticulated sculpin. Cutthroat trout (*O. clarkii*) and torrent sculpin (*C. rhotheus*) were detected at both sites. Other species detected included a single long-nose dace (*Rhinichthys cataractae*) at Delezene, and a single Pacific lamprey (*Entosphenus tridentatus*) and many steelhead trout (*O. mykiss*) at Schafer.

Discussion

Monitoring is on track to inform study objectives related to water temperature, thermal refugia, hyporheic exchange, substrate and fish movement. Our study sites cover a range of stream habitat conditions representative of many medium tributaries in the Chehalis Basin. Delezene largely lacks riparian overstory canopy and the streamside vegetation is dominated by reed canary grass. Stream substrate is largely fines, sand and small gravel, and summer stream temperature averages higher than Schafer. The riparian area at Schafer is dominated by mature conifers and receives much less direct solar radiation (though the canopy is fairly open and allows a fair amount of light to reach the stream). Bedrock is the dominant stream substrate and summer stream temperature averages lower than at Delezene.

A predominance of bedrock, impermeable hardpan, and discontinuous shallow alluvium precluded our ability to directly measure hyporheic exchange at study sites. Instead, we infer that hyporheic exchange and streamflow losses to long flow paths through fractured bedrock is limited at both sites. We mapped the distribution of bedrock and discontinuous shallow alluvium to record the pre-treatment proportion of bedrock to alluvium. We also validated our assumption of minimal losses to groundwater by performing bi-monthly seepage runs across each study reach. We utilize riparian monitoring wells and stream gauges in combination with direct measurements of flow to improve understanding of the timing and flow conditions that facilitate connectivity between the stream and riparian areas. We anticipate the ability to directly measure hyporheic exchange in the post-treatment period after sediment wedges have been installed.

Because biotic response was removed from the Project Effectiveness Program, we are working with Weyerhaeuser to ensure that we collect pre-treatment fish use data necessary to evaluate potential sediment wedge effects to fish movement. Fish use was noted in all reaches at both sites during summer 2022 electrofishing surveys. Of note, the project has also benefitted tremendously from in-kind support from Tristan Weiss, a Research Scientist with the WDFW Habitat Program Water Science Team.

Adaptive Management

The need for an experimental evaluation of sediment wedges as a restoration tool was a priority identified by the Prioritization and Sequencing (P&S) subcommittee of the Chehalis Basin Aquatic Species Restoration Plan (ASRP) Science Review Team (SRT) (ASRP SRT memo to the Steering Committee dated March 18, 2021). As an experimental restoration action with a strong monitoring focus, the Sediment Wedge Study was designed, in part, as a proof-of-concept intended to identify the feasibility of successful restoration outcomes. The P&S further clarified that initial efforts to apply sediment wedges needed to be *experimental* because the "…magnitude of any temperature-reduction and accessory ecological service responses need to be verified…". Additionally, the P&S recommended the experimental evaluation of *pre-filled* sediment wedges, to minimize the time required for the maximum downstream response in an effort to quickly evaluate sediment wedging as a viable restoration option for the Chehalis Basin.

We anticipate that results from this study will inform Steering Committee decisions relative to the utility and effectiveness of sediment wedging as a restoration option in the Chehalis Basin. Study results will allow an evaluation of sediment wedge restoration relative to other restoration options in its ability to provide cool-water refuge for aquatic and semi-aquatic species in the Basin, as well as inform site-specific considerations relative to sediment wedging effectiveness for a particular site based on its characteristics. As such, this research informs both the Science and Policy feedback loops.