COUNTYLINE LEVEE SETBACK PROJECT

YEAR 5 MONITORING REPORT (2022)

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Executive Summary

What is this report about?

This report documents Year 5 (2022) post-construction monitoring results from the Countyline Levee Setback Project on the lower White River. The project aimed to reduce flood risk and provide ecological benefits through reconnecting the White River to its floodplain. Completed in fall 2017, actions included removing portions of an existing levee, building a setback levee protected by a biorevetment and 8 engineered log jams, and installing nearly 60,000 native plants.

Is the project meeting its objectives?

The project continued to meet the majority of its ecological objectives, including all measured Year 5 performance standards under U.S. Army Corps of Engineers Permit No. NWS-2011-211 except for large wood abundance (Table ES1).

How is the river responding?

After project construction, a perennially wetted side channel developed and has persisted through Year 5. Since Year 1, several channels in the floodplain have deepened, and the active channel area has decreased since Year 2. A second low-flow connection point between the mainstem and floodplain is developing, and the abundance of channel connection points (nodes) are continuing to increase over time. Future channel dynamics and habitat formation will depend on future hydrology and continued flow regulation at Mud Mountain Dam, and the resulting movement of sediment and wood.

How has habitat changed?

The reconnected floodplain provides large areas of side channel and low velocity edge habitat year-round for juvenile salmonid rearing. Nearly 46 acres was observed to be inundated within the project area during high flows in 2022, providing refuge habitat for fish. Aquatic habitat complexity metrics like channel nodes have increased over time, and habitat dynamism has been observed as bars and banks continue to shift. Native vegetation cover has exceeded performance standards in planted areas, and naturally recruited seedlings are continuing to establish and grow along floodplain gravel and sand bars. Large wood loading in the project area was greater in Year 4 than Year 1, but still did not meet the National Marine Fisheries Service target. Beavers are maintaining an 11-acre beaver pond within the project area; the pond provides foraging and breeding habitat for waterfowl and amphibians, and overwintering habitat for coho salmon.

How has flood risk changed?

The project continues to provide sediment storage for the lower White River, with net deposition of sediment observed in the project reach between Years 4 and 5. Analysis of water surface elevations along the mainstem channel over time suggest that the reconnected floodplain continued to provide flood risk reduction benefits despite ongoing sediment deposition along the alluvial fan in this reach of the lower White River. Downstream water surface elevations at the 8th Street bridge have remained similar to pre-project levels.

How is the site being adaptively managed?

Plantings have been maintained by manual and chemical control of invasive vegetation, irrigation during the first 3 years post-installation, and replanting selected areas. Most performance standards for Year 5 were met and no additional adaptive management actions beyond ongoing vegetation management are recommended at this time.

Table ES1. Summary of indicators evaluated, and project performance compared to permit-associated performance standards for Year 5.

Indicator	Year 5 Performance Standard	Year 5 Status	Details
Channel dynamics	New channel(s) form outside of the pre-project active channel.	ACHIEVED	The floodplain side channel with multiple braids outside of the mainstem channel persisted through Year 5, with a new channel connection point observed in 2022.
Native vegetation cover	Cover by installed trees and shrubs, including cover by volunteers of desirable native woody species, in Year 5 is at least 40%	ACHIEVED	Percent cover of trees and shrubs averaged 73% across transects in planted areas.
Invasive vegetation cover	Less than 10% invasive cover (non-regulated noxious weeds and weeds of concern) in planted areas (5% for King County class A noxious weeds, bindweed, knotweed). Less than 25% reed canary grass on site.	ACHIEVED	An average of 4% cover of non-regulated invasive weeds was found across monitored transects. Knotweed and bindweed were present but infrequent. Reed canarygrass cover averaged 0.4% across planted transects.
Floodplain inundation	On average over years 1, 3, 5, 7, and 10, wetted area in the floodplain between Feb 1 – Mar 31 is 32.5 acres.	ACHIEVED[1]	The average of Year 1, 3, and 5 inundation estimates was 53.4 acres, meeting performance standard for early termination of this monitoring requirement.
Low velocity edge habitat	Sum of slow-water (<1.5 ft/sec) bar, bank, backwater, and side channel area increases by >50%, relative to baseline condition.	ACHIEVED	Slow-water habitat availability remained far greater than at baseline; at ~1500 cfs low-velocity habitat area has maintained a 960% increase compared to baseline.
Fish habitat use	Juvenile salmonid frequency of occurrence is highest in backwater and side channels, compared to other edge types.	ACHIEVED	Side-channel habitat in the reconnected floodplain was frequently used by juvenile Chinook. Backwater habitat was not sampled adequately to compare fish use with other habitat types in Year 5.
Fish habitat capacity	Habitat capacity at median rearing flows is increased by ≥ 50% compared to baseline.	ACHIEVED	Habitat capacity for Chinook and coho increased by 325% and 242% respectively in Year 5 compared to baseline.
Large wood	Wood loading (natural and placed) on site meets or exceeds NMFS recommendation for properly functioning condition (>80 key pieces/mile).	NOT ACHIEVED	Wood loading in the project reach was 38 key pieces/mile in Year 4 (2021), which is improved from Year 1 but did not meet the NMFS target. High-flow events needed to recruit large wood have been limited since construction.
Flood hazard	No significant damage to engineered structures, adjacent flood facilities/infrastructure. Channel migration contained within project area.	ACHIEVED[2]	Engineered structures are intact. Extents of channel migration are contained within project area. Flood risk as measured by mainstem water surface elevation at high flows is reduced from pre-project conditions despite ongoing sediment deposition.

[1] Performance standard associated with Natural Resources Damages Assessment (NRDA) consent decree; performance standard under NWS-2011-211 only specifies that inundation will increase as measured between Feb 1 – Mar 31. [2] Performance standard is not associated with NWS-2011-211.

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I. Project Summary

Project Setting and Goals

The Countyline Levee Setback Project (project) is on the Lower White River within the City of Sumner, City of Pacific, and unincorporated Pierce County, and is so named because it spans the King-Pierce County boundary (Figure 1). The reach is bounded by the A Street SE and Burlington Northern Santa Fe (BNSF) Railway bridges at the upstream end (River Mile 6.3) and the 8th Street East (or Stewart Road SE) Bridge at the downstream end (RM 5.0). The project is situated in a naturally depositional area on a large alluvial fan, where the White River avulsed from discharging north to the Green River to discharging south to the Puyallup River in 1906. The USGS estimates that the Countyline project area is lower than the same channel location prior to the avulsion by up to 8 meters (approximately 26 feet), inducing deposition of sediment to equilibrate the channel slope (Anderson and Jaeger, 2019). In response to the deposition, the lower White River was channelized, dredged and confined in the 1900s. These actions led to reduced channel capacity and substantial loss of aquatic habitat, creating a need for flood risk reduction and habitat restoration along this reach. A more complete history of the White River can be found in the *Countyline Levee Setback Year 1-2 Report* (2020).

The project **reconnected approximately 120 acres of floodplain to the White River channel, with the goals of reducing flood risk, restoring natural river processes, and improving fish habitat through creating off-channel juvenile rearing habitat for salmonids.** The habitat restoration goal and related objectives of the Countyline Levee Setback Project are:

Goal: Restore riverine processes and functions to the extent practicable to the lower White River and its floodplain within the project area to enhance salmonid rearing habitat, in particular for spring and fall Chinook, coho, and steelhead.

Objectives:

1. Allow natural channel movement within the project area by removing and setting back the existing levee along the left bank.
2. Encourage the formation of off-channel rearing habitat, through installation and future natural recruitment of large wood, that will promote the return of the complexity, diversity, and morphology found in an unconstrained floodplain.
3. Provide off-channel flood refuge for salmonids by allowing a more natural frequency of inundation of the floodplain complex during flood events within the project boundaries.
4. Protect existing mature riparian buffer areas and restore a corridor of mature riparian vegetation within the project boundaries to provide shoreline and stream channel shading, invertebrate prey supply, and large wood recruitment.

Other project goals included: (1) prevent an increase in flood and geomorphic hazards outside of the project area and, if possible, reduce existing hazards, and (2) design and construct a project that best meets the project goals and objectives using the most cost-effective means.

Project Actions

The approach to resolving existing flood risks focused on increasing capacity for flood flows and sediment load. The strategy was two-fold: (1) acquire land rights (fee or easements), and (2) implement capital improvements to modify levees and retrofit revetments to reconnect the river to its floodplain. In addition to flood risk benefits, returning the lower White River to a more naturally functioning floodplain was expected to improve aquatic and wildlife habitat. Levees were reconstructed along an alignment set back from the previous active channel and a biorevetment incorporating large wood was constructed to protect the setback facility (Figure 1). Large wood structures were also installed in the floodplain to disperse adversely erosive flows and provide opportunities for complex habitat formation. Native vegetation was planted along riparian banks and on top of large wood structures to provide healthy riparian buffer functions in the long term.

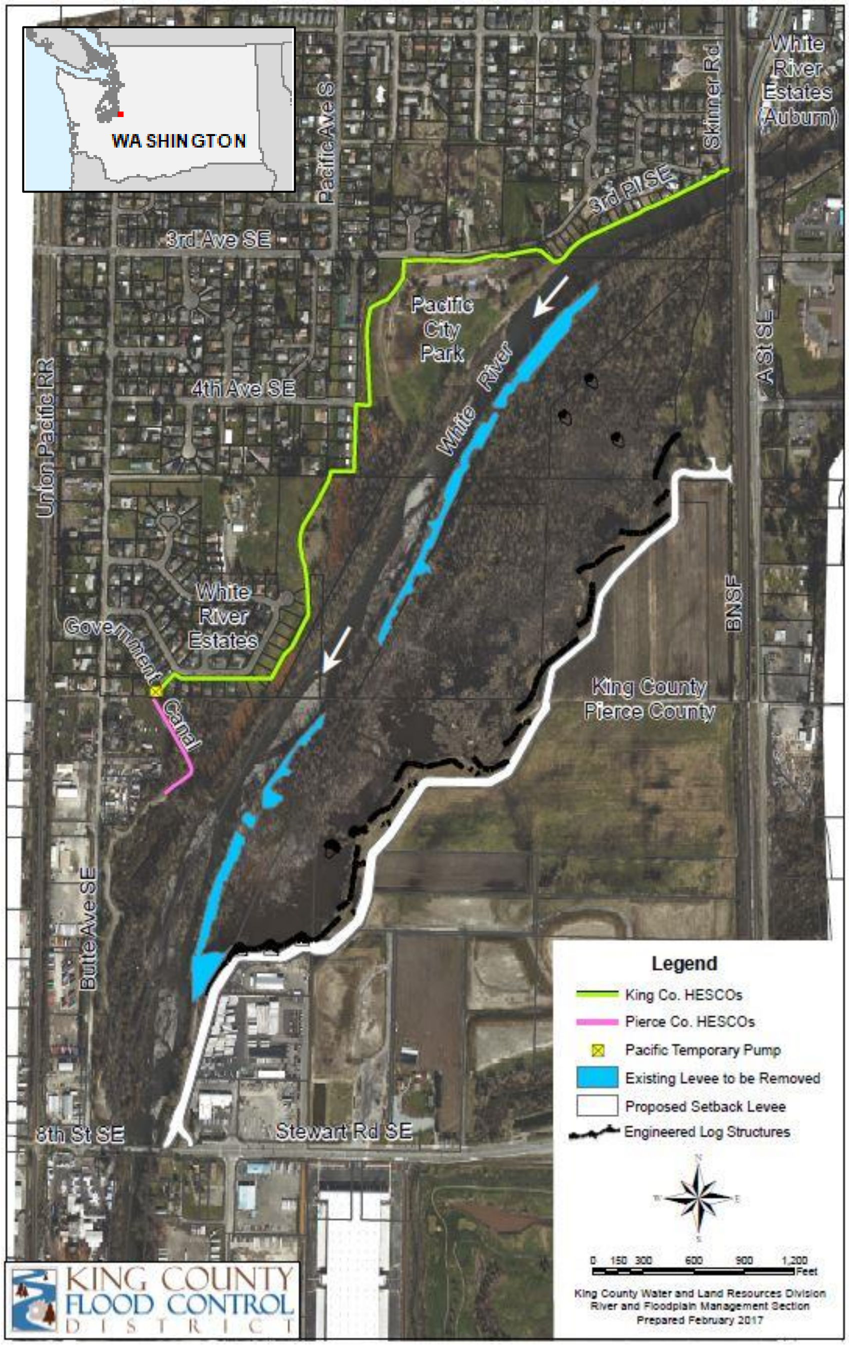

Figure 1. Countyline Levee Setback project area prior to construction with major project design features shown. White arrows show pre-project mainstem flow direction. Aerial imagery from 2015.

Performance Standards

Monitoring objectives and performance standards were designed to determine project effectiveness (Appendix A). Many ecological and habitat indicators were included as requirements under NWS-2011-211.

II. Monitoring Focus

Ongoing project monitoring focuses on whether project actions had the intended effects on habitat conditions, riverine processes, and threatened fishes (effectiveness monitoring), in order to improve future project design and construction practices, and ongoing maintenance (adaptive management). This report focuses on habitat monitoring, although flood risk reduction analyses are also presented. Changes between baseline (2011-2017) and Year 5 (2022) post-construction are evaluated in this document, to determine whether the project is effectively meeting the stated habitat and flood risk goals, objectives, and performance standards, as well as the need for adaptive management actions. Additionally, changes between earlier post-implementation monitoring years and Year 5 are documented to track ongoing site evolution. The relationship between project goals, objectives, and actions and monitored indicators is outlined in Table 1.

Table 1. Links between monitoring indicators and project goals, objectives, and actions.

Goal	Objective	Actions	Indicator
Restore riverine processes and functions	1. Allow natural channel movement within the project area.	Removed and set back the existing levee along the left bank.	• Channel dynamics
	2. Encourage the formation of off-channel rearing habitat and promote the return of the complexity, diversity, and morphology found in an unconstrained floodplain.	Installed large wood, constructed engineered log jams, set back the existing levee to encourage natural recruitment of wood.	• Channel dynamics • Aquatic habitat • Fish use • Wood
	3. Provide off-channel flood refuge for salmonids by allowing a more natural frequency of inundation of the floodplain complex during flood events within the project boundaries.	Set back the existing levee.	• Aquatic habitat • High-flow floodplain inundation
	4. Protect existing mature riparian buffer areas and restore a corridor of mature riparian vegetation within the project boundaries to provide shoreline and stream channel shading, invertebrate prey supply, and large wood recruitment.	Installed native riparian vegetation, with ongoing maintenance.	• Native riparian cover • Invasive cover

Table 1. continued

Goal	Objective	Actions	Indicator
Prevent increased flood risk and reduce flood risk if possible	Increase flood storage within the project, which should benefit flood elevations in the project vicinity (particularly the right bank).	Constructed setback levee, biorevetment structure, and engineered log jams.	• Structural stability • Flood elevations • Channel dynamics • Sediment conditions

The primary audiences for implementation and effectiveness monitoring results include King County staff (to inform future project design and adaptive management needs), regulatory agencies (to determine compliance with performance standards), funding agencies and stakeholders (to determine compliance with funding agreements and priorities), and the scientific community (to build on research into efficacy of levee setbacks for habitat restoration and flood risk reduction in depositional riverine environments). Monitoring methodology is described in Appendices A and B.

III. Monitoring Results and Discussion

Channel Dynamics and Sediment Conditions

Channel Dynamics

Year 5 Performance Standard	Year 5 Status	Details
New channel(s) form outside of the pre-project active channel.	ACHIEVED	The side channel with multiple braids outside of the mainstem channel persisted through Year 5, with a new channel connection point observed in 2022.

The active channel area, defined as those areas observed in aerial photography that include water, banks, unvegetated gravel bars, and bars without perennial vegetation, along the alignment of the primary side channel has decreased over time. Perennial vegetation has established on gravel bars and channels have deepened and incised through earlier sediment deposits (Figure 2). The active channel area remains similar along the mainstem and near the primary side channel inlet at the north end of the project yet remains dynamic. A new perennial low-flow connection point between the mainstem and floodplain side channel was observed in 2022, with flow moving through a floodplain wetland complex located approximately in the middle of the project and floodplain (Figure 3). The 9.1-acre beaver pond in the northeast portion of the project is shown as active channel in 2022 in Figure 3, given its connectivity with the floodplain side channel; this was not mapped as active channel in previous years but had some degree of connectivity at high flows with the side channel in previous years as well. For consistency across monitoring years, the beaver pond was not included in total active channel area in any monitoring year.

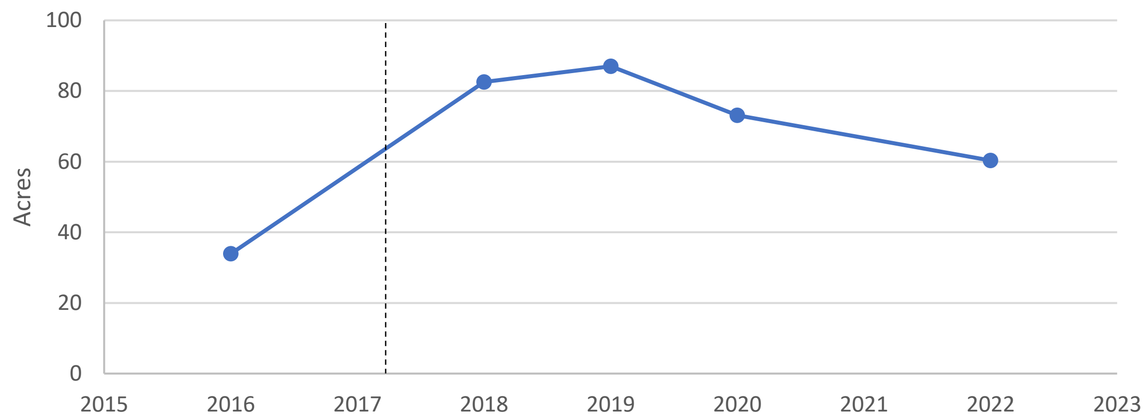

Figure 2. Active channel area over time. Dotted line shows timing of project construction.

All other channel complexity metrics were also substantially higher in Year 5 compared to the baseline condition, with greater side and braided channel length and number of nodes observed. Total side channel length and number of side channel nodes continued to trend up from Year 3 to Year 5, in part due to new channel connection points but also due to conversion of some channels from braided channels to side channels as vegetation became more established between Year 3 and Year 5 (Figure 4, Figure 5). Total braided channel length in Year 5 was similar to Year 3 but the number of braided channel nodes increased from Year 3, possibly due to continued channel dynamism near the side channel inlet (Figure 4, Figure 5). We note that the analysis for Year 3 (2020; 1030 cfs) used imagery flown at a lower discharge than Year 5 (2022; 1950 cfs) and the Year 5 imagery has more vegetation

Table 2. Change in active channel area, channel length, and channel nodes between baseline and Years 1, 2, 3, and 5. Active channel area in 2022 does not include beaver pond area.

	Baseline (2016) 1800 cfs	Year 1 (2018) 2400 cfs	Year 2 (2019) 2860 cfs	Year 3 (2020) 1030 cfs	Year 5 (2022) 1950 cfs
Active Channel area (acres)	33.9	82.6	87.0	73.1	60.3
Side Channel total length (ft)	5,745	14,644	17,170	20,364	33,676
Number of side channel nodes	20	24	46	49	113
Side channel:Mainstem channel ratio	1.056	1.65	2.25	2.92	4.84
Number of braided channel nodes	30	74	44	98	161
Braided Channel total length (ft)	7,437	11,733	15,790	9,072	10,609
Braided channel:Mainstem channel ratio	0.816	2.06	2.45	1.30	1.52

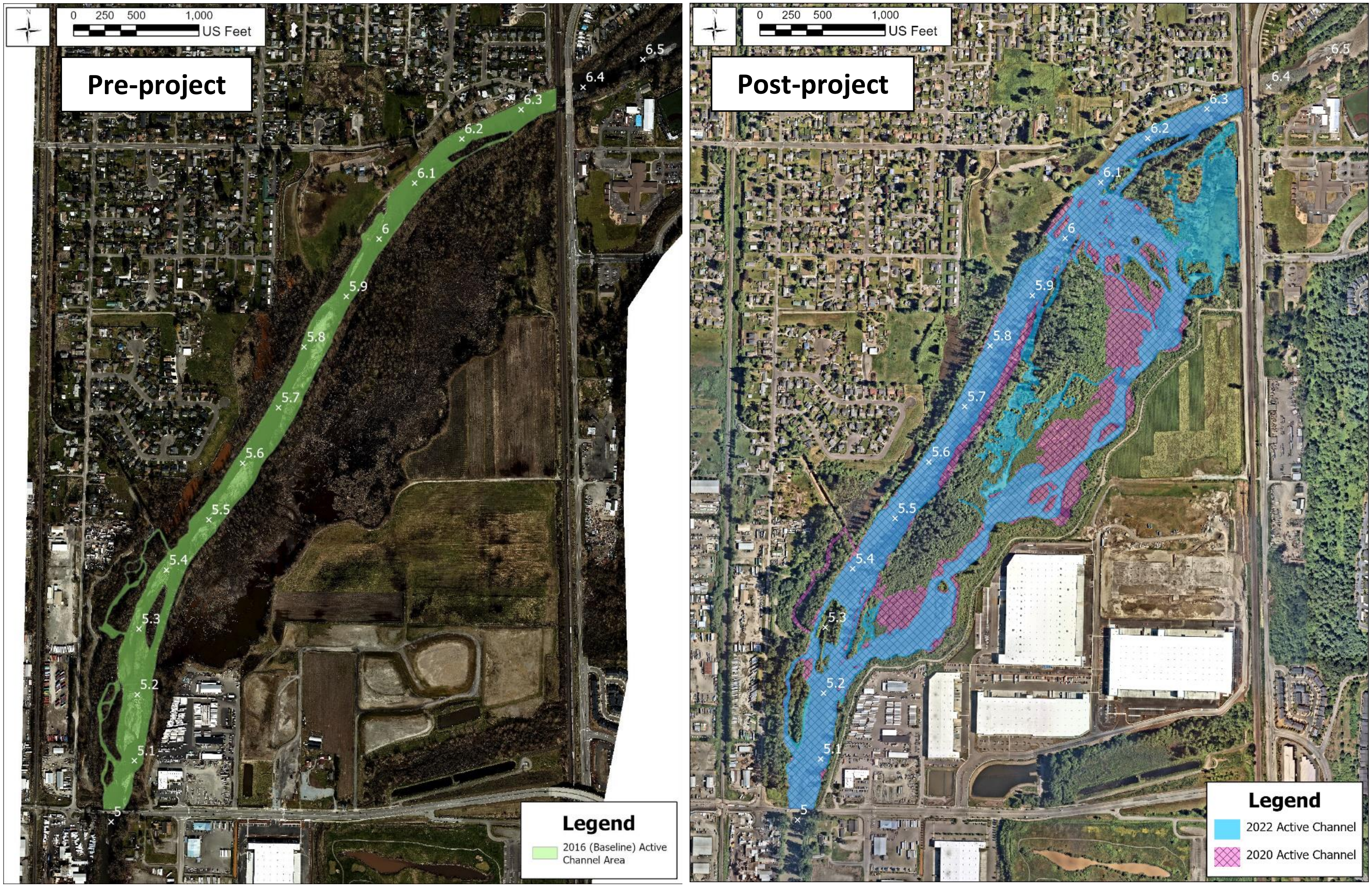

Figure 3. Change in active channel area between baseline (2016), Year 3 (2020), and Year 5 (2022). River miles shown with x symbols. Beaver pond in the northeast portion of the project was also present in 2020 but is not shown because of a lack of direct connection to the mainstem channel. New low-flow channel connection point can be seen in 2022 at river mile 5.9.

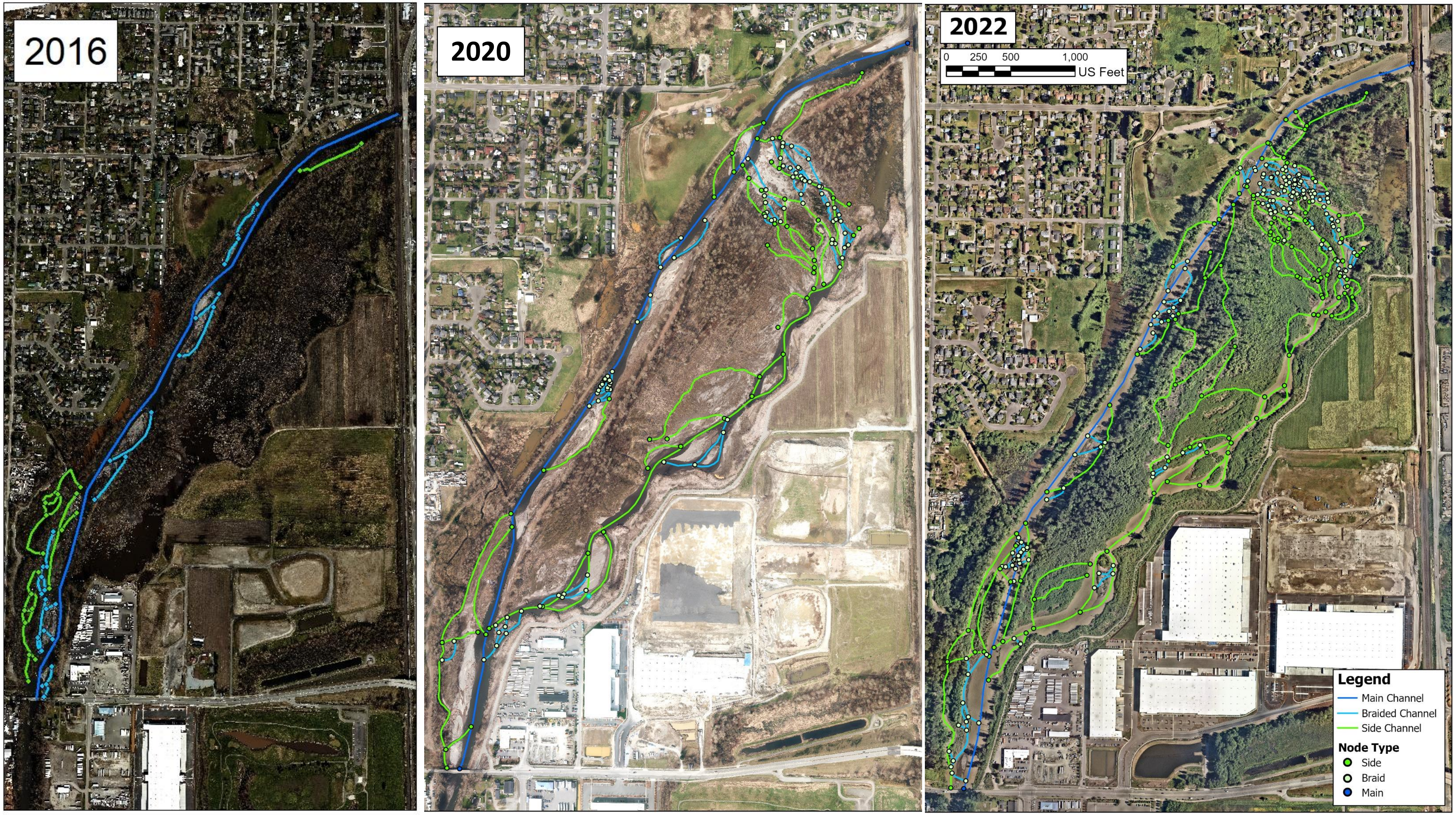

Figure 4. Change in braided and side channel length and nodes between baseline (2016), Year 3 (2020), and Year 5 (2022).

obscuring channel features. Therefore, the data may not be fully comparable between Years 3 and 5 given that braided channel (and side channel) presence is sensitive to discharge (as gravel bars are exposed or covered by water) and may be obscured by annual and emergent vegetative cover. However, Year 5 and baseline channel length and node analyses were conducted using imagery at very similar flow (baseline at 1800 cfs; Year 5 at 1950 cfs) and so may be more directly comparable. Complexity metrics were generated by different observers between years, which could result in additional variability between years (Beechie et al. 2017), however observers were given similar training and data was reviewed and field validated by a constant set of reviewers across years, so difference in flow and vegetative cover is likley a greater source of variability in this data.

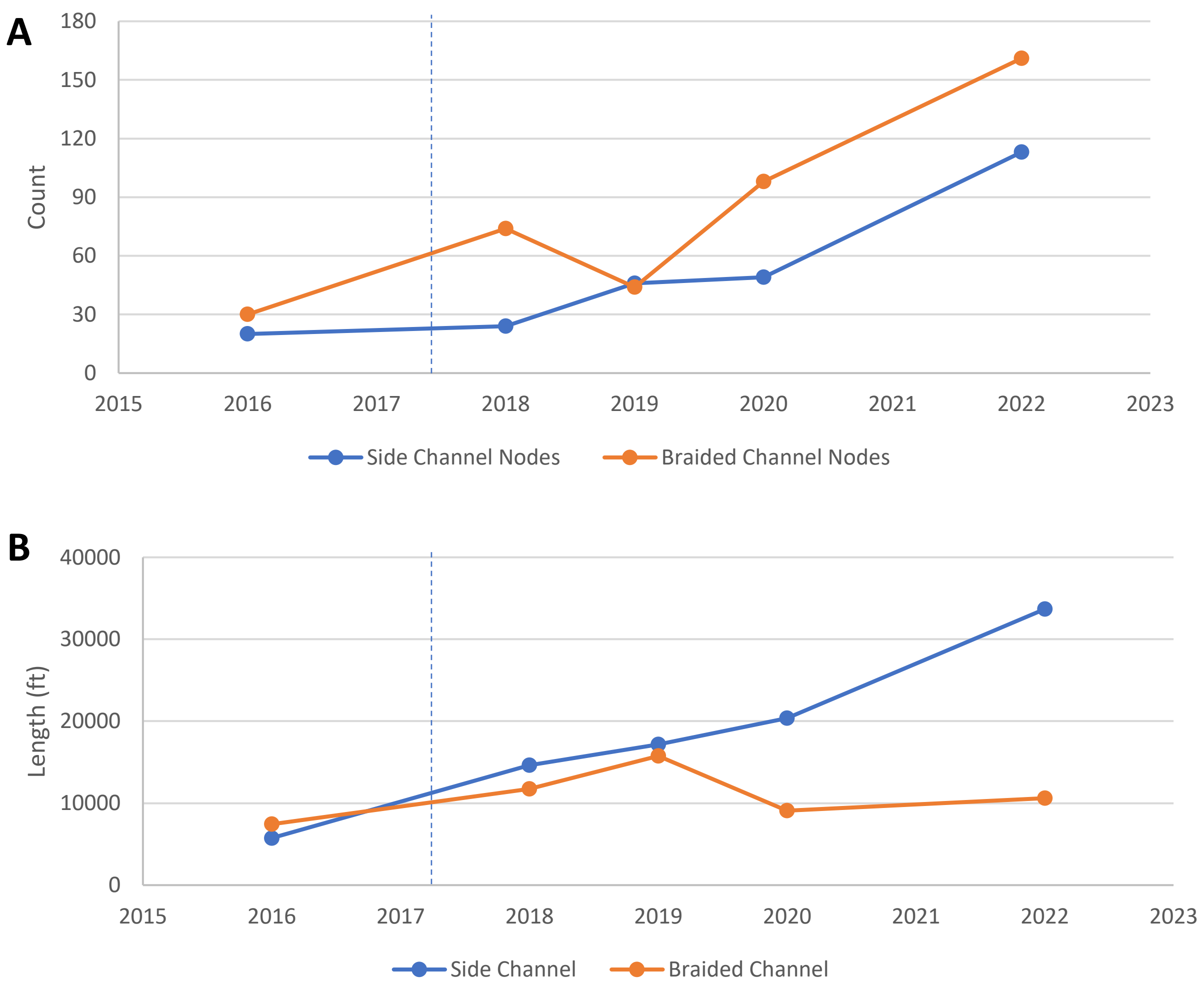

Figure 5. Side channel and braided channel nodes (A) and total length (B) across the project area over time. 2016 Data represents pre-project conditions, dotted line shows timing of project construction.

Selected cross sections derived from LiDAR revealed that the average elevation across most cross sections increased between 2020 and 2022 (Table 2). Notably, the average channel bed elevation across the side-channel inlet (cross section 6.071) was higher than the average channel elevation in the mainstem just upstream of the side channel inlet (cross section 6.077), suggesting that the flow split between the mainstem and side channel has likely changed at low flows, with more flow remaining in the mainstem. This is supported by field observation. This could mean that some floodplain habitats used by salmonids are no longer wetted at low flow and potential loss of floodplain habitat in some areas, but it may also increase low velocity habitat in portions of the side channel that were previously too fast for very small salmonids. Additionally, new low flow connection points between the mainstem and floodplain are developing and so this change in flow split may be more indicative of habitat dynamism than habitat loss (see Low Velocity Habitat section below). Channels have been particularly dynamic in the side channel inlet area, as sediment and wood have been deposited and mobilized over time (Figure 7). Along the mainstem, growth of gravel bars was observed along several cross sections, and within the floodplain sediment deposition was observed in many areas (Figure 6).

Table 3. Channel bed elevations (feet) averaged across selected cross sections. Cross sections are labeled by river mile. Numbers in parentheses are values excluding voids in LiDAR when present. Horizontal datum: NAD 1983 HARN Washington State Plane Coordinate System North Zone. Vertical datum: NAVD 88

Cross-section	Year 3 (2020)	Year 5 (2022)	Difference (ft)
XS 6.145	83.23 (83.64)	82.96 (83.15)	-0.27 (-0.49)
XS 6.077	81.84	81.89	+0.06
XS 6.071	82.18	82.33	+0.14
XS 5.93	76.50	77.23	+0.72
XS 5.920	77.31	78.12	+0.81
XS 5.7449	74.86	75.43	+0.57
XS 5.3929	71.38	71.52	+0.14
XS 5.041	66.96 (67.24)	67.44	+0.48 (+0.20)

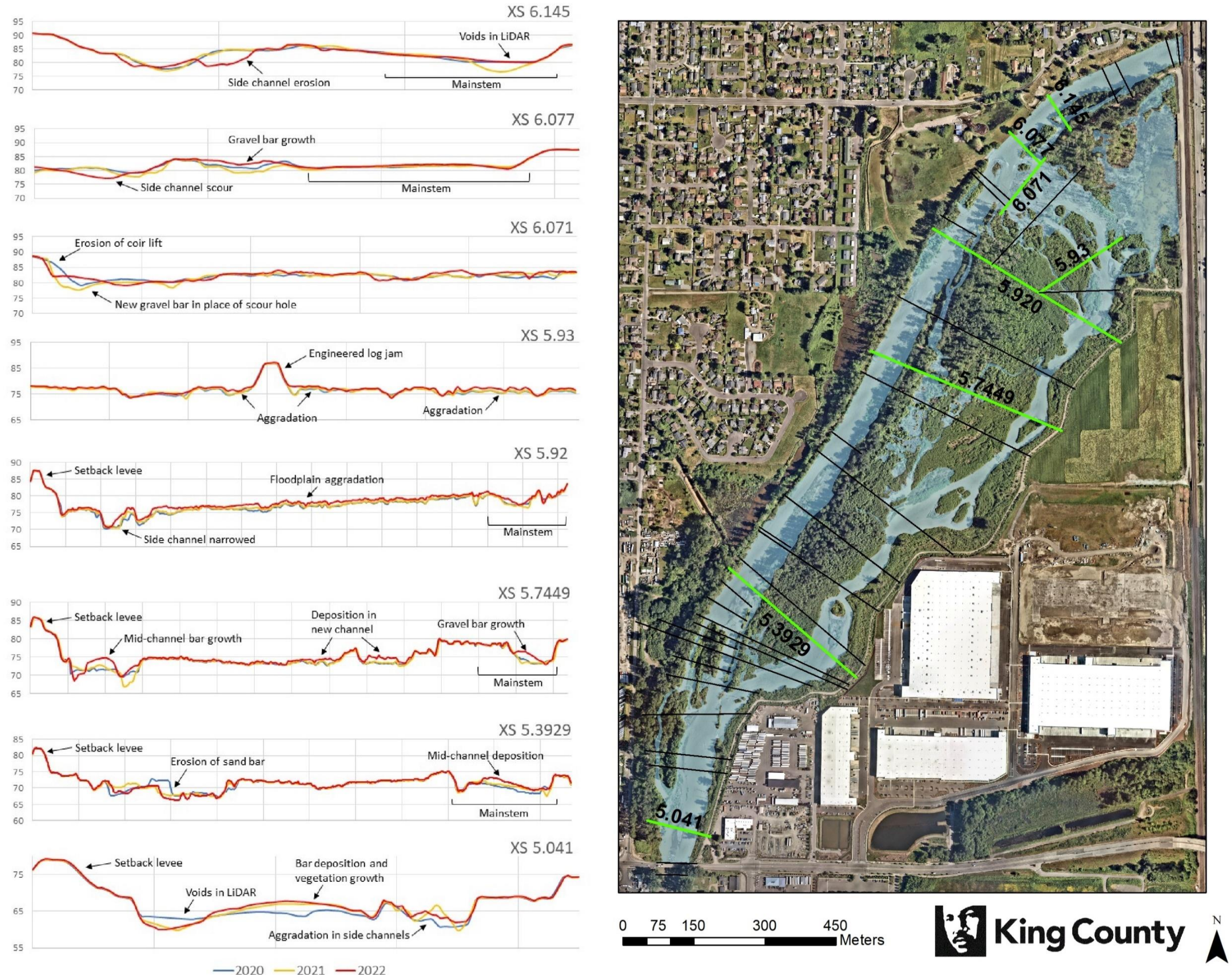

Figure 6. Cross sections comparing 2020, 2021 and 2022 channel bed elevations, viewed looking downstream with mainstem on the right side of cross sections. Scaling varies in order to accentuate features, vertical grid lines along x-axis represent 100-foot increments. At right, selected cross sections highlighted in green, active channel shown in blue polygon.

Feb 26, 2018
1,220 cfs

Oct 25, 2019
1,340 cfs

Mar 7, 2020
1,700 cfs

Oct 15, 2021
650 cfs

April 28, 2022
1,260 cfs

Figure 7. Side channel inlet, looking north.

Sediment Conditions

Indicator	Year 5 Performance Standard	Details
Sediment	None specified	A net 85,292 cubic yards of sediment deposition was estimated between 2020 and 2022 across the reach; net deposition was estimated in most of the mainstem and upstream floodplain areas and net erosion in downstream floodplain areas.

Between 2020 and 2022, a net total of 85,292 cubic yards of sediment deposited within the reach as calculated from LiDAR. Most of the deposition occurred near the side channel inlet into the floodplain (Zone 8, Figure 10), and within the floodplain along the new side channel through the center of the floodplain (Zone 10, Figure 10; Figure 9). This is consistent with fluvial geomorphic processes, that a crevasse splay deposit forms immediately downstream of the location of a levee breach, natural or otherwise.

Deposition was also observed in several places along the mainstem where gravel bars grew and/or shifted over time. It is interesting to observe in Figure 9 that many areas that experienced erosion in one year experienced deposition the next, indicating a highly dynamic sediment transport regime out of equilibrium.

Net erosion was observed in a handful of locations within the mainstem where channels have migrated, as well as along the downstream half of the floodplain side channel where channels are incising and near the side channel inlet where channel locations have shifted (Figure 10). One explanation for sediment mobilization in downstream project areas is that deposition where the channel widens at the side-channel inlet could have increased channel gradient and resulted in increased water velocity, causing sediment export downstream.

Observed sediment deposition and erosion patterns are consistent with channel response predictions made during project design. These observations also are consistent with mechanisms of bedload sediment transport involved in the process of incremental head-cutting where the low area at the tail of a headcut (pool) will be filled from sediment mobilized at the nick point at the top of the headcut slope (Fryirs and Brierley, 2013). Anderson and Jaeger (2019) demonstrated through sediment flux analysis that the lower Canyon Reach (RM 12 to 17) is the source of sediment deposited in the Countyline Reach and that the nick point where erosion changes to deposition is at about RM 9. Multiple high flow events occurred between LiDAR flights that would have mobilized upstream sediments (Figure 8) and contributed to patterns of overall deposition observed at the project.

Table 4. Net change in sediment volume (cubic yards) from 2020 to 2022. Zones correspond to those shown in Figure 10.

Zone	Net volume change (cubic yards)	Zone	Net volume change (cubic yards)
1	4,466	11	5,523
2	4,466	12	4,221
3	10,561	13	-948
4	5,836	14	-161
5	5,069	15	757
6	4,046	16	-972
7	1,442	17	59
8	11,249	18	-79
9	4,870	19	-245
10	9,331	20	15,799

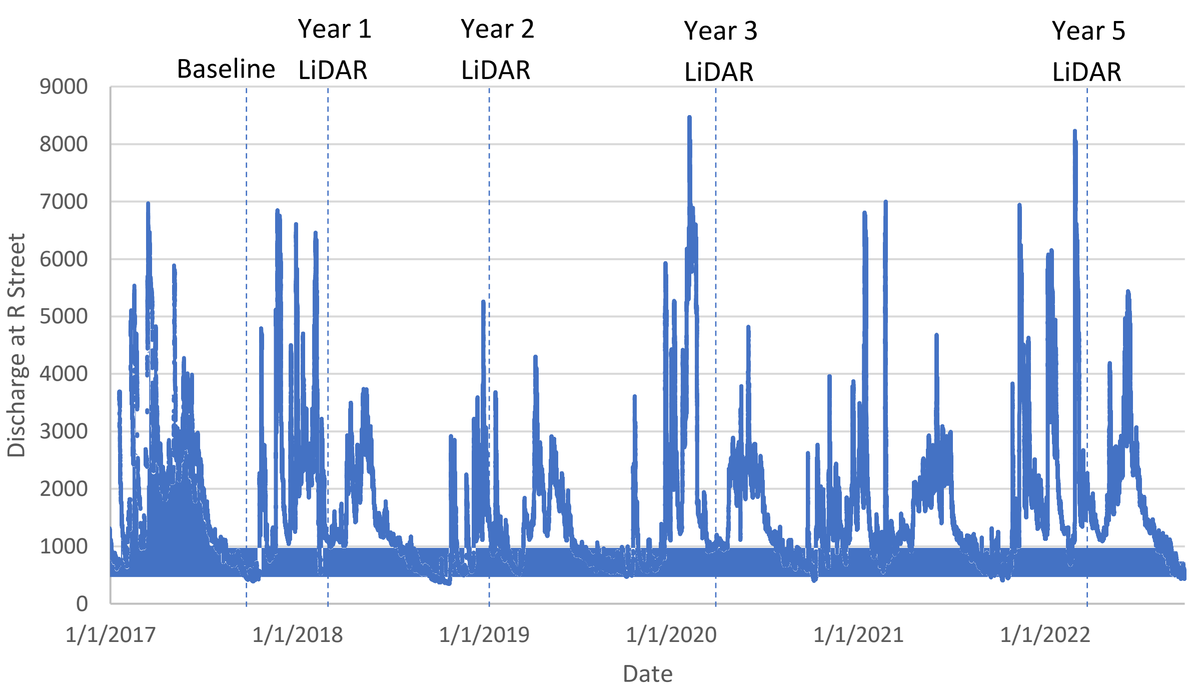

Figure 8. Hydrology (USGS White River at R Street) since January 2017. Dates of LiDAR flights (which provided digital ground models used in analyses) are shown with dotted lines.

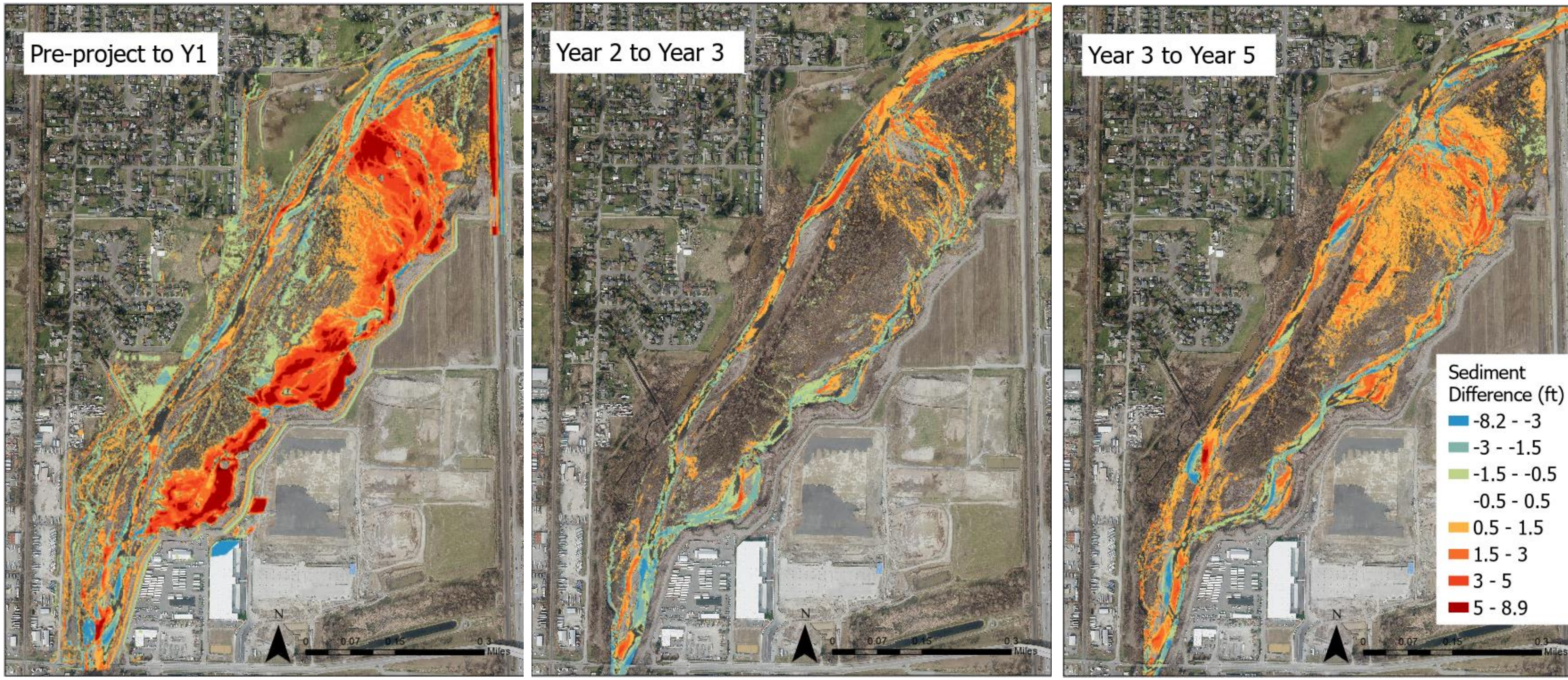

Figure 9. Elevation change in the project area between pre-project (baseline) to Year 1 (2016 – 2018; left), Year 2 to 3 (2019 – 2020; center), and Year 3 to 5 (2020 – 2022; right).

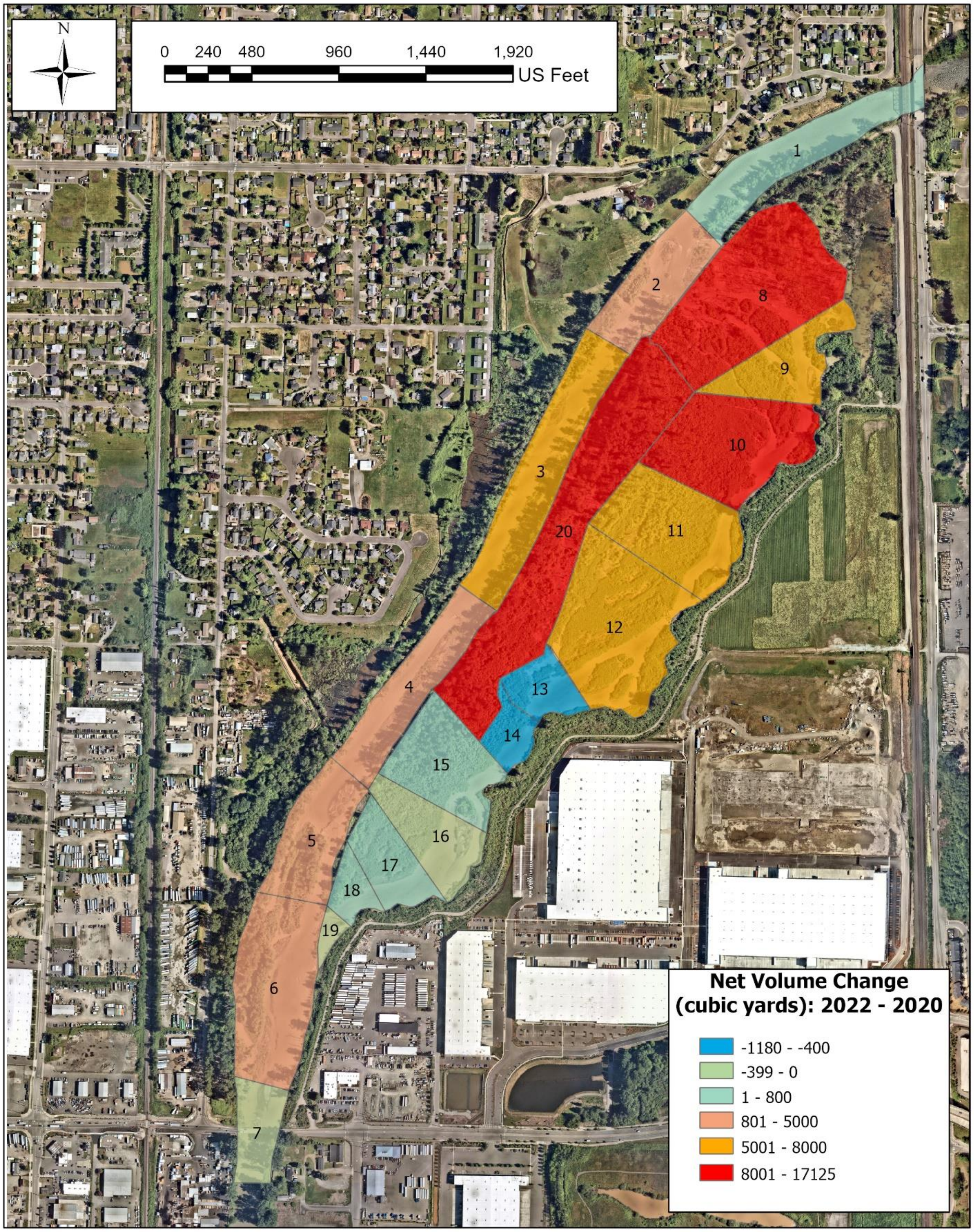

Figure 10. Zones within mainstem and floodplain areas for which change in sediment volume was calculated in Table 4.

Habitat

Aquatic Habitat

High-flow Floodplain Inundation

Year 5 Performance Standard	Year 5 Status	Details
On average over years 1, 3, 5, 7, and 10, wetted area in the floodplain between Feb 1 – Mar 31 is 32.5 acres. If inundated area exceeds 48.8 acres in three consecutive monitoring events, this requirement will be fulfilled with no further inundation monitoring required.	ACHIEVED	The average of Year 1, 3, and 5 inundation estimates was 53.4 acres, meeting performance standard for early termination of this monitoring requirement.

Monitoring inundated area in the floopdlain within a monitoring window relevant to salmonid rearing and flood refuge (Feb 1 – Mar 31) was required as part of a funding agreement. Monitoring for this metric primarily focused on inundated area during high flows, so this metric is related to off-channel flood refuge. Not all calculated inundated areas may serve as refugia from high velocities, however, since velocities in the primary flow path within the side channel may be high. In Year 5, the area of inundated floodplain was 45.7 acres at 6,080 cfs (Figure 11). The average inundated area in the project over Year 1, 3, and 5 was 53.4 acres, which exceeded the 48.8-acre performance standard for early termination of this monitoring requirement as outlined by funding agreements.

Table 5. Acres of floodplain inundated at baseline and after construction.

Measurement period	Date	Flow at Auburn (cfs)	Visual Delineation Method (acres)	MLC or NDWI method (acres)
Baseline	3/18/2016	1800	7.8	--
Year 1	2/6/2018	6060	63.3	56.8
Year 1	4/9/2018	2400	21	24
Year 2	4/9/2019	2860	28	22.2
Year 2	4/12/2019	4050	56	--
Year 3	2/8/2020	6620	--	57.6*
Year 5	3/2/2022	6080	--	45.7*

*Imagery was analyzed using the normalized difference water index (NDWI) instead of maximum likelihood classification (MLC), as it was found to provide a better visual match to known inundated areas in the imagery.

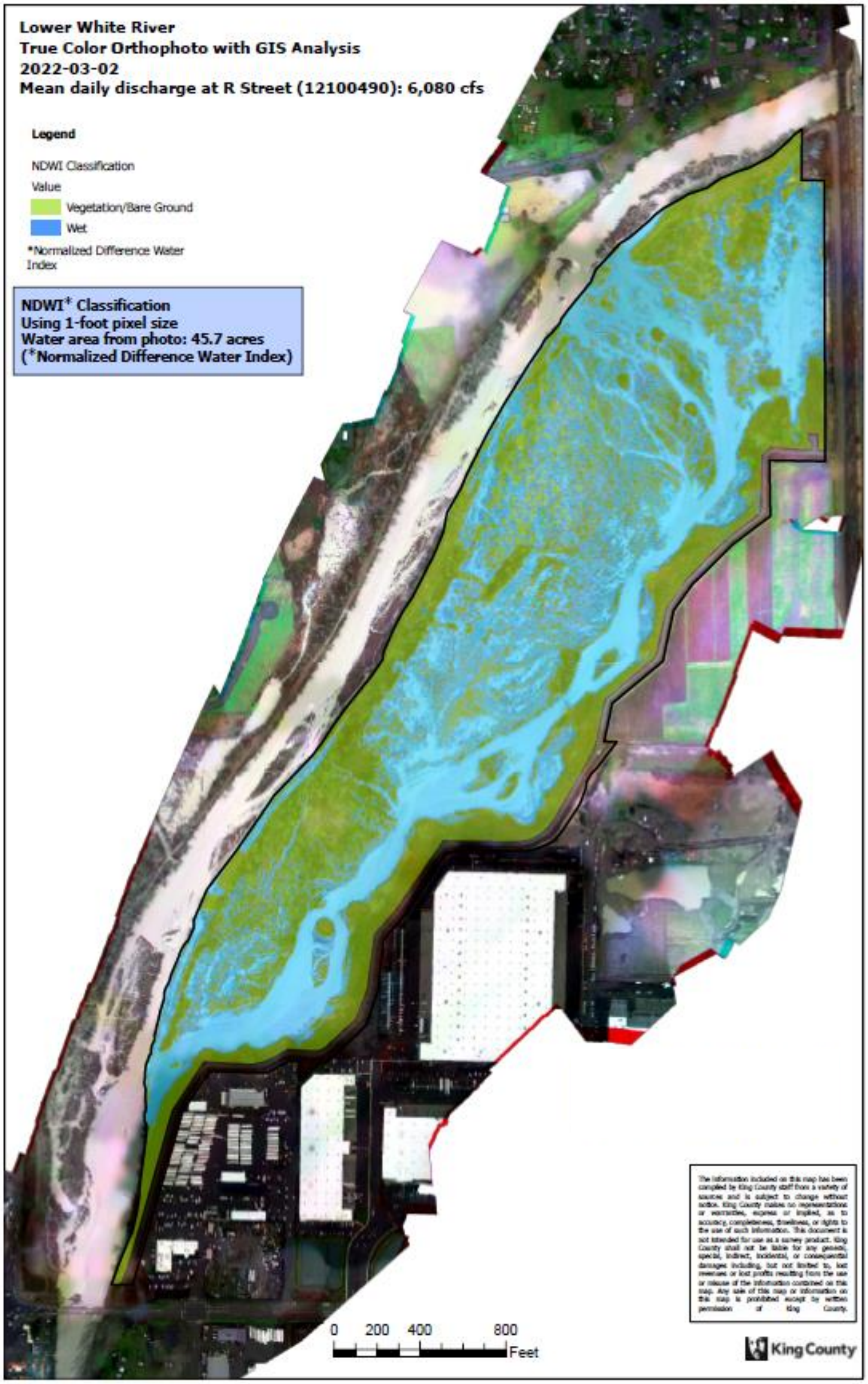

Figure 11. High-flow inundated areas at Year 5.

Low Velocity Habitat

Year 5 Performance Standard	Year 5 Status	Details
Sum of slow-water (<1.5 ft/sec) bar, bank, backwater, and side channel area increases by >50%, relative to baseline condition.	ACHIEVED	Slow-water habitat availability remained far greater than at baseline; at ~1500 cfs low velocity habitat area has maintained a 960% increase compared to baseline.

Slow-water habitat types were field categorized based on methods modified from Beechie et al. (2005) to quantify distinct habitat types at the reach scale that juvenile salmonids are known to use. These habitat categories are based on the bank-type and focus on slow-water adjacent to shore. The following habitat types were included: bar, unarmored bank, armored bank, backwater, side channel, and beaver pond (See Appendix B for definitions). It is important to note that side channels are inclusive of all habitats present, and may include a variety of micro-habitats that include bars or banks.

In Year 5, 25.3 acres of low velocity habitat were available at 1430 cfs (sampling date: 7/18/2022), including 15.2 acres (61,665 m^2) of side channel habitat, 0.3 acres (1,306 m^2) of backwater habitat, 0.6 acres (2,229 m^2) of bar habitat, 0.4 acres (1,699 m^2) of bank habitat, and an 8.8-acre (35,432 m^2) beaver pond. When compared with low velocity habitat available under baseline conditions, this represents a 961% increase in habitat per km surveyed, though bar and backwater habitat per river km decreased (-59% and -19%) while bank and side channel habitat increased (1686% and 2321%).

The total area of low velocity habitat is very similar to that observed at a similar flow in Year 1 (2018), though the spatial distribution is different as the site has evolved (Figure 14). Flow around the area near the side channel inlet has become more concentrated in more defined channels, and so less low velocity habitat is found in this area. While some channel braids and side channels have become inundated less frequently in the primary side channel through the floodplain, a new connection point between the mainstem and floodplain side channel has formed, creating a large new patch of side channel habitat that runs through a wetland complex at the center of the site (Figure 12, Figure 14). This new side channel remains connected at summer low flow. The beaver pond at the north end of the site has also enlarged from 6.3 acres in 2018 to 8.8 acres in 2022. Similar to Year 1, most low velocity habitat is side channel, though less backwater habitat was present in Year 5 compared to Year 1 (Figure 13, Table 6).

Table 6. Low velocity habitat area (m^2 per km surveyed) by type at baseline, Year 1, and Year 5 at 1400-1500 cfs.

	Bar	Bank	Backwater	Side Channel	Beaver Pond	Total
Baseline (3/19/2015)[a]	2,538	45	763	1,202	0	4,548
Year 1 (11/5/2018)[b]	255	194	2,727	32,958	12,086	48,219
Year 5 (7/18/2022)	1,051	802	616	29,087	16,713	48,269

[a] Values reported in area per km surveyed, but only 0.85 km surveyed at baseline so values are greater than what was observed.

[b] In Year 1, bar and bank habitat in the floodplain was characterized as side channel habitat.

Figure 12. New channel between mainstem and side channel floodplain (May 2022).

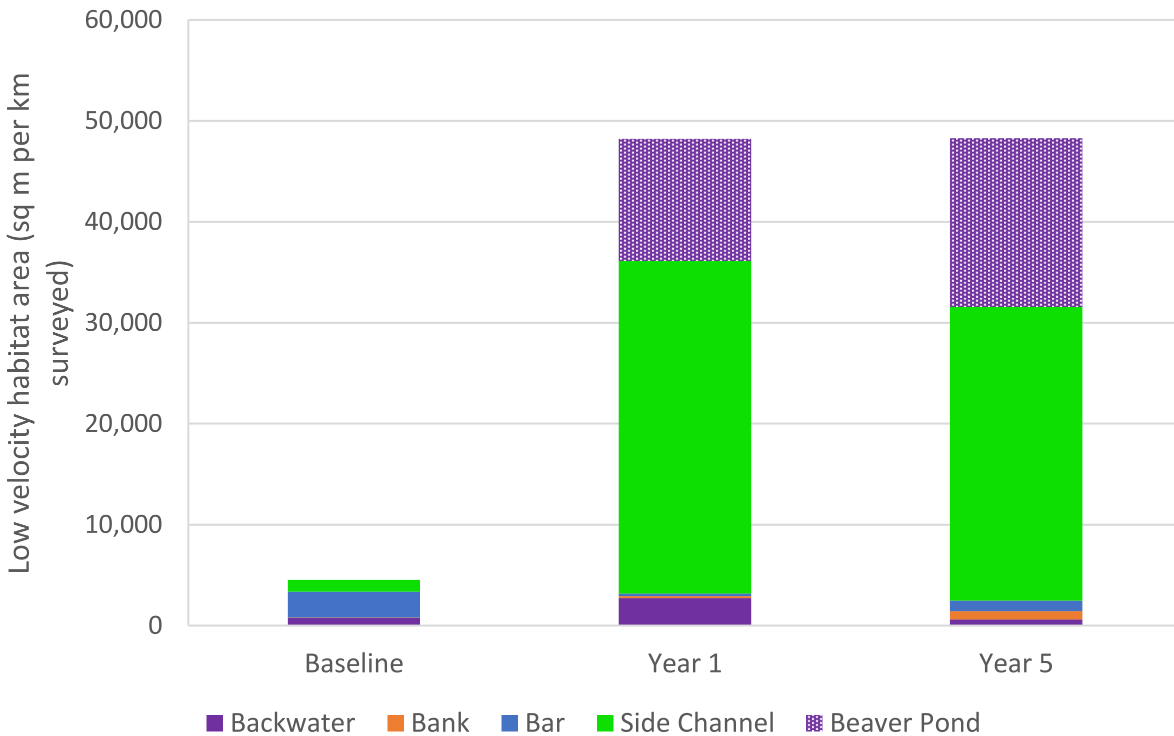

Figure 13. Slow-water habitat by type at baseline (3/19/2015), Year 1 (11/5/2018), and Year 5 (7/18/2022) at approximately 1400-1500 cfs. Side channel habitat in Year 1 includes bar and bank habitat within the floodplain side channel.

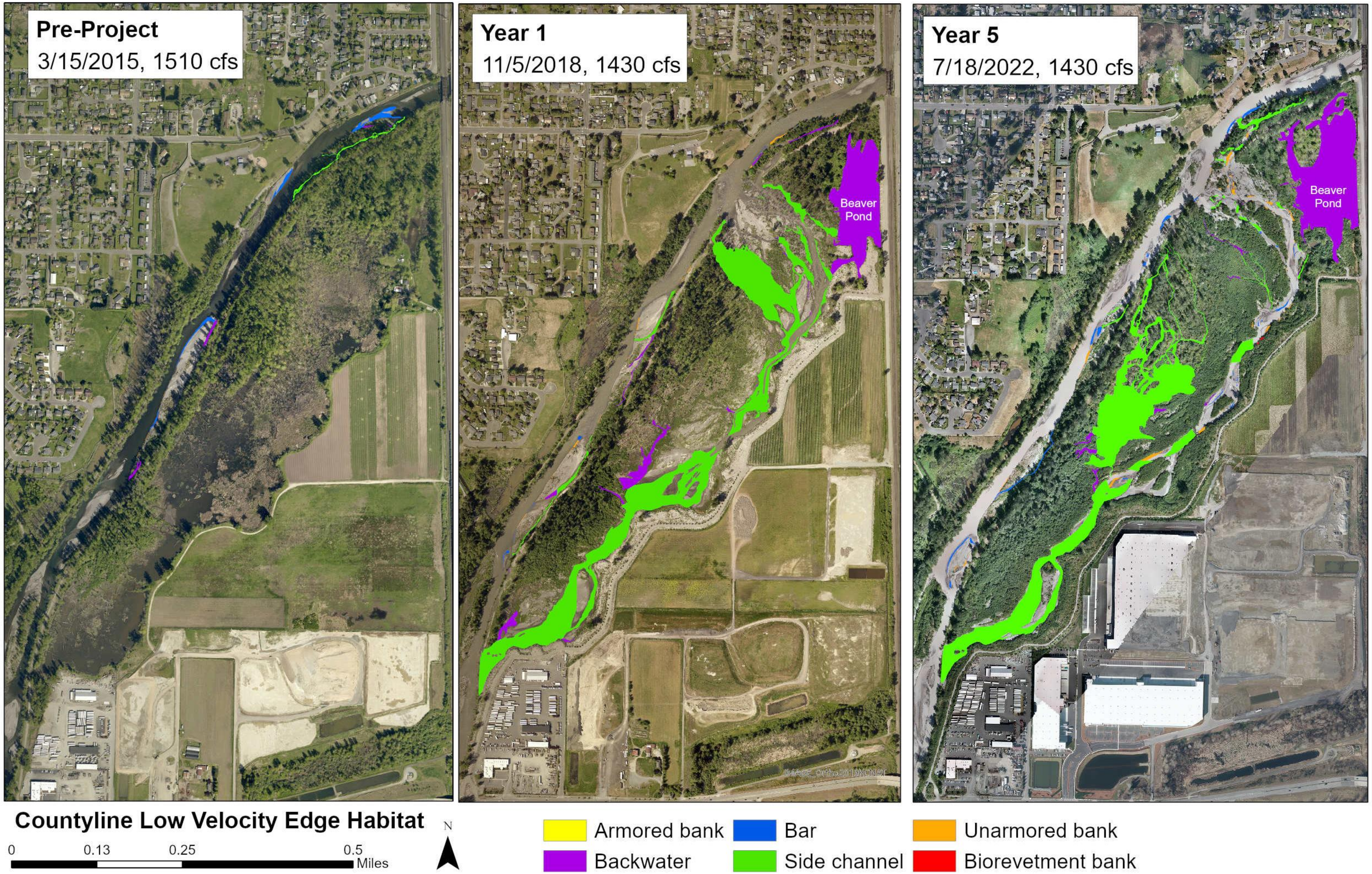

Figure 14. Comparison of baseline, Year 1, and Year 5 low velocity habitat areas.

Plotting low velocity habitat area versus discharge at the USGS R Street gage revealed a positive relationship under both baseline and post-project conditions (Figure 15), likely because side channels and backwater habitats became engaged at higher flows but were dry or disconnected at lower flows. Plotting post-project habitat data by habitat type supports this explanation, as only side channel habitat showed a positive relationship with discharge (Figure 16). Across all post-construction years, more low velocity habitat was present at low flows compared to baseline, indicating the project has created habitat that has persisted over time. Very high flood flows were not sampled due to safety and so the nature of the relationship between habitat area and discharge at higher flows than sampled is unknown; as discharge increases further we hypothesize that low velocity habitat availability would increase as floodplain inundation increases, but would eventually decrease after floodplain inundation was complete since the river remains confined between levees. Low velocity area at these very high flows would still likely be higher than at low flows.

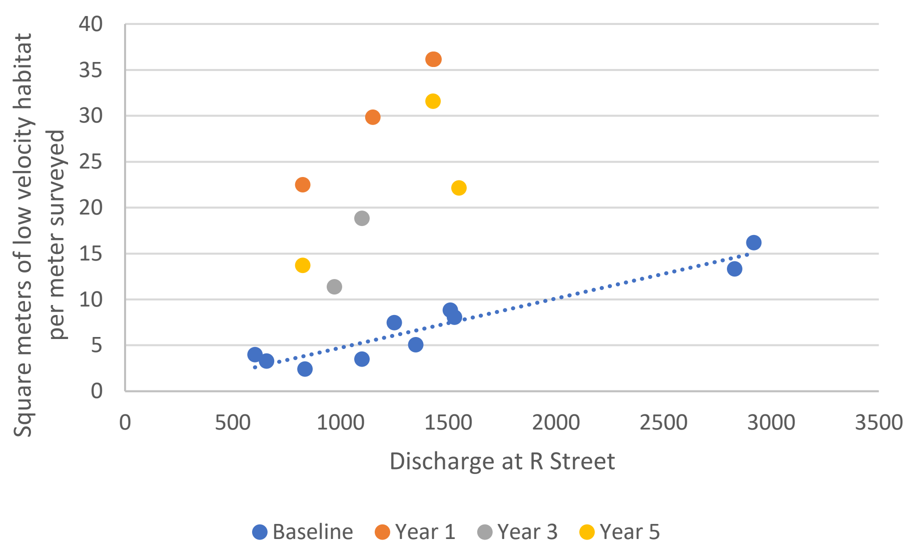

Figure 15. Low velocity habitat area versus discharge at R Street gage. All habitat types combined. Linear trend for baseline data shown.

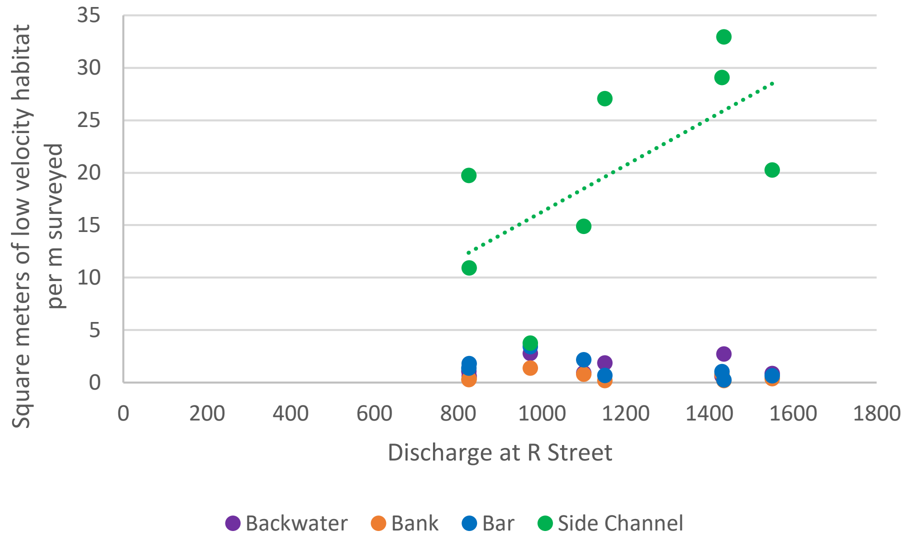

Figure 16. Post-project low velocity habitat area by type versus discharge at the R Street gage. All post-project surveys shown. Linear trend for side channel habitat shown.

Fish Use

Year 5 Performance Standards	Year 5 Status	Details
Juvenile salmonid frequency of occurrence is highest in backwater and side channels compared to other edge types.	ACHIEVED	Side channel habitat in the reconnected floodplain was used by juvenile Chinook. Backwater habitat was not sampled adequately to compare fish use with other habitat types.
Habitat capacity at median rearing flows is increased by ≥ 50% compared to baseline.	ACHIEVED	Habitat capacity for Chinook and coho increased by 325% and 242% respectively in Year 5 compared to baseline.

Fish using the project area were sampled by seine, and sampled units included low-velocity side channel, bar, bank, and backwater habitat units in the floodplain and mainstem. Sampling was conducted quarterly at dawn and was intended to evaluate differences in relative abundance across season and habitat types (both low velocity unit types and mainstem versus floodplain).

In total, 359 juvenile Chinook salmon, 28 juvenile coho salmon, 176 juvenile pink salmon, 2 juvenile chum salmon, and 2 trout were captured in 2022. Other species encountered included sculpin, dace (*Rhinichthys spp.*), large scale sucker (*Catostomus macrocheilus*), minnows (*Cyprinidae spp.*), and mountain whitefish (*Prosopium williamsoni*). Of Chinook captured, 257 were captured in a single set and were likely primarily hatchery fish given their relatively uniform size. This set was excluded from remaining analyses since these fish were likely migrating downstream and therefore did not represent patterns of habitat use for rearing. Other Chinook captured on the same day >64mm FL were also excluded, as a distinct cutoff was observed in size between wild and hatchery fish on this date; this left 23 Chinook considered in the analyses below.

In addition to seining, traps were deployed in the large beaver pond at the north end of the site during winter to detect presence of overwintering juvenile salmonids. On December 22, 2021, 16 coho salmon were captured (average fork length [FL] = 77.1mm) and on February 3, 2022, 45 coho were captured (average FL = 83.9mm). One young-of-year Chinook was captured on February 3 (FL = 36mm). Other species encountered included pumpkinseed sunfish, three-spine stickleback, red sided shiner, and bullfrog tadpoles.

Chinook Salmon

Most juvenile Chinook were captured in spring and summer, following patterns observed in Year 1 (2018) and across baseline sampling years (2011, 2012, 2013, 2015) (Figure 17), but overall non-hatchery Chinook catch was very low. High flows in March 2022 likely flushed out many juveniles from the lower White River (Andrew Berger, personal communication). Catch per unit effort (count per second fished; CPUE) was highly variable, but average spring-time Chinook CPUE was higher in Year 1 (2018) compared to Year 5 (2022) or baseline averages, mirroring a pattern of higher abundance of outmigrating Chinook observed in 2018 than 2022 (Andrew Berger, personal communication).

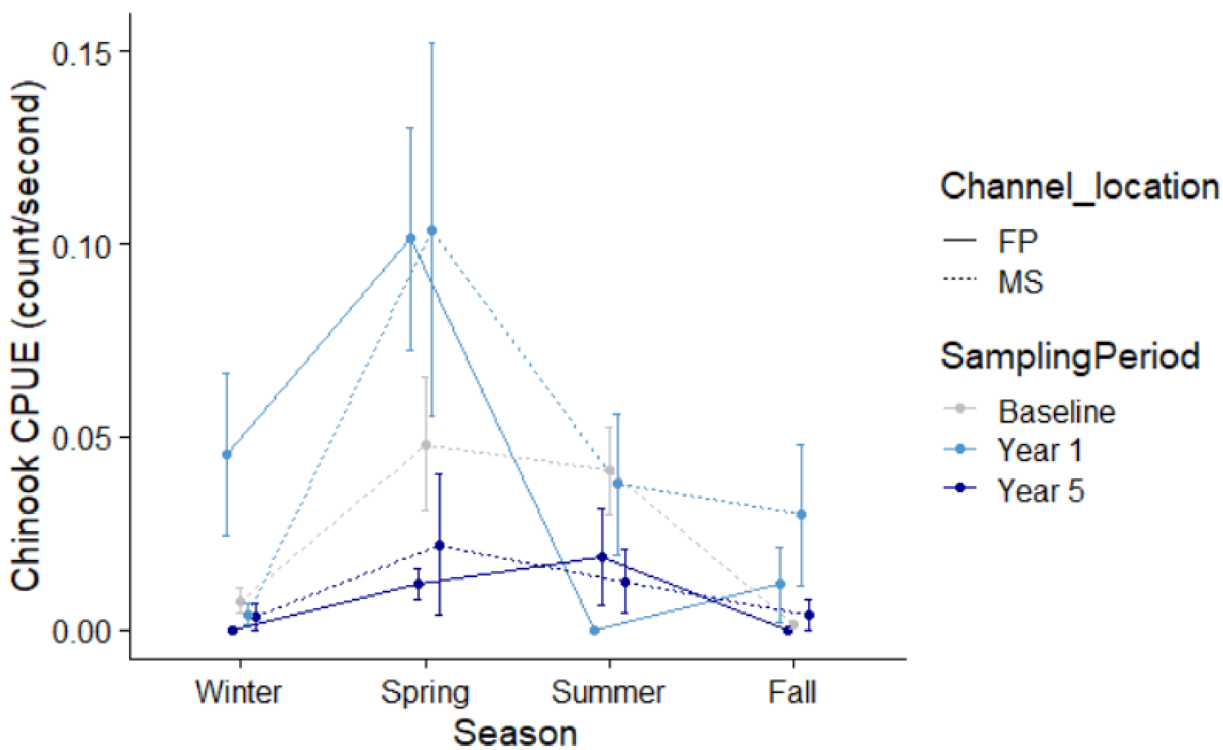

Figure 17. Catch per unit effort of juvenile Chinook salmon (by seconds fished) in floodplain (FP) and mainstem (MS) habitats. Data from all baseline years (2011, 2012, 2013, 2015) combined. Error bars depict standard errors.

Catch of Chinook in spring was low across habitat unit types, but was highest in mainstem bars (0.07 Chinook/sec) (Table 7), although backwater habitats were not sampled in spring. Across seasons, 10 Chinook were captured in the floodplain and 13 were captured along the mainstem, and Chinook ranged in size from 48mm to 103mm FL (Figure 18). Chinook captured in spring in the floodplain tended to be slightly larger (mean = 71.7 mm FL, n = 10) compared to those captured in the mainstem (mean = 71.2 mm FL, n = 13); we might hypothesize that fish captured in the floodplain would be larger if food availability and habitat conditions allowed for more rapid growth, as in other systems (Sommer et al., 2001), however the size difference between floodplain and mainstem fish was not statistically significant by one-tailed t-test (p=0.34).

Table 7. Average Chinook catch per unit effort (fish count/second fished) across habitat types and season in 2022. Standard error presented in parentheses.

Channel Location	Season	Side Channel	Bar	Bank	Backwater
Mainstem	Winter	0 (0)	0 (0)	0.01 (0.01)	--
	Spring	0 (0)	0.07 (0.07)	0.01 (0.01)	--
	Summer	--	0.03 (0.01)	0 (0)	--
	Fall	--	0 (0)	0.01 (0.01)	--
Floodplain	Winter	0 (0)	--	--	--
	Spring	0.01 (0.01)	0.02	0.02	--
	Summer	0.02 (0.01)	--	--	--
	Fall	0 (0)	--	--	0

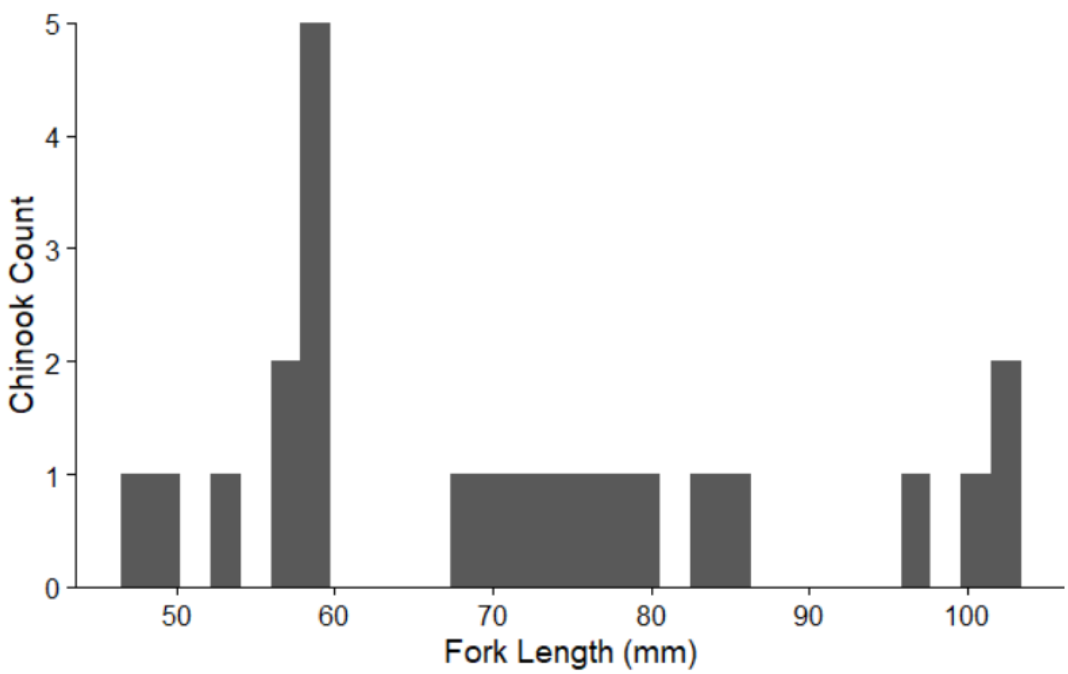

Figure 18. Histogram of juvenile Chinook fork lengths measured across all sampled units in 2022.

Coho Salmon

Catch of juvenile coho salmon was also low in Year 5 sampling, with highest CPUE also in spring (Figure 19). Year 5 (2022) coho CPUE was lower than at baseline or in Year 1 sampling (Figure 19), however backwater habitat, which has slower and sometimes deeper habitat preferred by coho (Quinn 2018), was not sampled in spring 2022 when highest CPUE of coho had been observed in spring of Year 1. Of habitats sampled in spring, highest catch was observed within low velocity bar habitat in the mainstem (Table 8). Across seasons, 12 coho were observed in the floodplain and 14 were observed in mainstem habitats, ranging in size from 53mm to 104mm FL (Figure 20). Nearly all were age-1+ fish (n= 24, average FL = 91.7mm). By comparison, 16 coho were caught in the beaver pond on one day in December (12/22/2021) and 45 were caught on one day in February (2/3/2022).

Table 8. Average coho catch per unit effort (fish count/second fished) across habitat types and season in 2022. Standard error presented in parentheses.

Channel Location	Season	Side Channel	Bar	Bank	Backwater
Mainstem	Winter	0 (0)	0 (0)	0 (0)	--
	Spring	0 (0)	0.15 (0.15)	0 (0)	--
	Summer	--	0 (0)	0.01 (0.01)	--
	Fall	--	0 (0)	0 (0)	--
Floodplain	Winter	0 (0)	--	--	--
	Spring	0.05 (0.02)	0	0.02	--
	Summer	0.01 (0.01)	--	--	--
	Fall	0.02 (0.02)	--	--	0

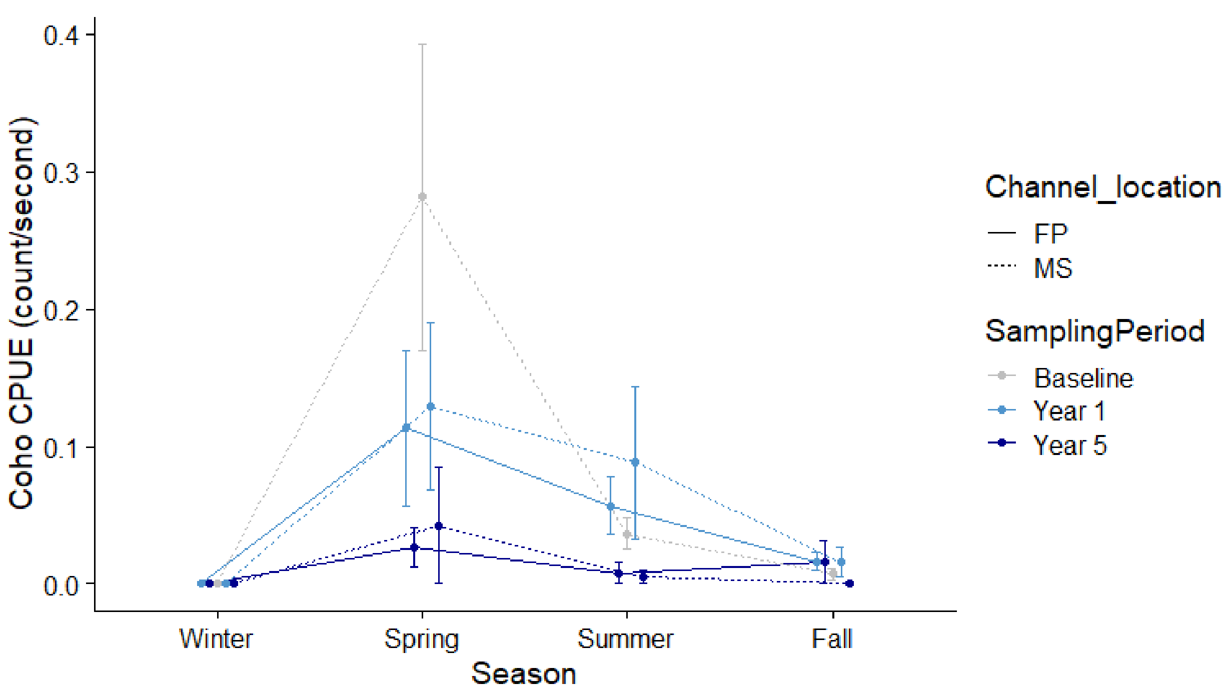

Figure 19. Catch per unit effort of juvenile coho salmon (by seconds fished) in floodplain (FP) and mainstem (MS) habitats. Data from all baseline years (2011, 2012, 2013, 2015) combined. Error bars depict standard errors.

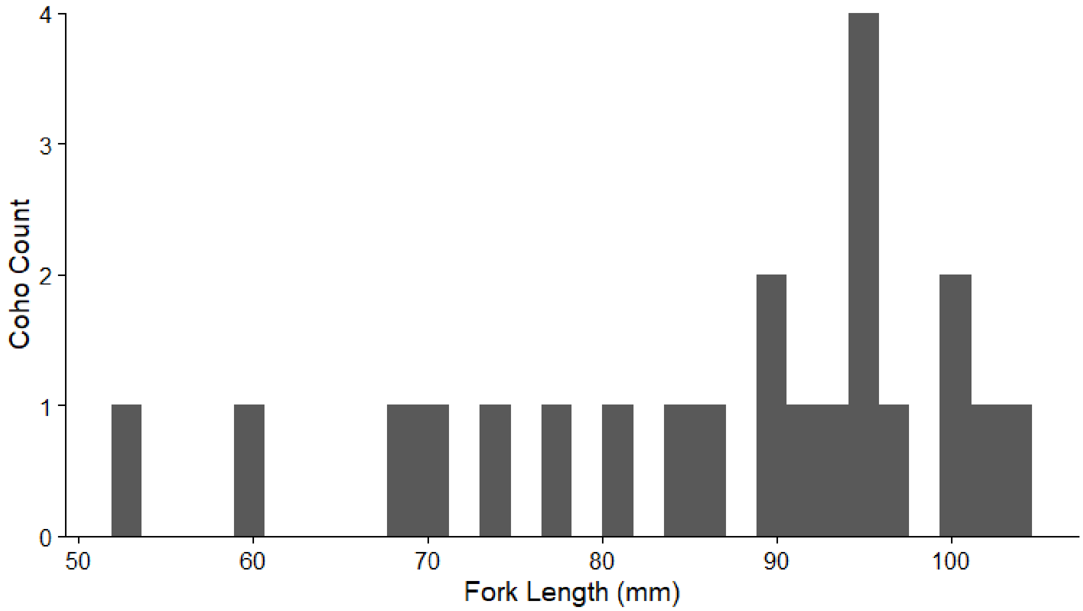

Figure 20. Histogram of juvenile coho fork lengths across all sampled units in 2022.

Habitat Capacity

The calculated habitat capacity index for juvenile Chinook and coho salmon multiplies observed low velocity habitat area by observed fish densities in a subset of those habitat areas, and so can be thought of as a way to weight observed habitat by the relative “value” of that habitat for fish use (whereby value is assigned by fish density). We caution against interpreting habitat capacity as an extrapolation of fish abundance to the entire site, given the relatively few fish density observations available and because units sampled for fish did not capture the full variability in habitat conditions across the site. It is also not a true “habitat capacity” in the sense that fish densities used in the calculation do not represent densities of saturated habitat (i.e., densities that the maximum number of fish that could be supported): this is especially important given that for the current calculation, we used average Year 5 spring densities in mainstem and floodplain habitats, which were low compared to other years sampled. Nevertheless, the index can still be useful in providing a method of quantitatively evaluating relative change in habitat for juvenile salmonids over time. The habitat capacity index used here is presented in units of fish per km of river surveyed, using average floodplain and mainstem fish densities observed in Year 5 and multiplying them by low velocity habitat areas observed at baseline, Year 1, and Year 5 at similar flows. See Appendix B for more details on this calculation.

Compared to baseline conditions, in Year 5 the habitat capacity index for juvenile Chinook in spring increased by 325% and for juvenile coho in spring by 242% at approximately 1500 cfs, dramatically exceeding the performance standard of at least a 50% increase. In Year 1, habitat capacity indices for Chinook and coho were even greater (Table 9), due to a relatively greater area of low velocity habitat in Year 1 compared to Year 5. These increases are similar in magnitude to the increases in modeled suitable habitat for juvenile Chinook and steelhead estimated by Roni et al. (2023).

Table 9. Habitat capacity for juvenile Chinook and coho salmon at 1400-1500 cfs. Capacity was calculated by multiplying total observed floodplain or mainstem low velocity habitat by average observed wild fish densities in spring 2022 in floodplain or mainstem habitat.

	Juvenile Chinook		Juvenile coho	
	Capacity per km	% Increase from baseline	Capacity per km	% Increase from baseline
Baseline	37	--	105	--
Year 1	227	510%	505	379%
Year 5	158	325%	361	242%

Wildlife

Year 5 Performance Standard	**Details**
None specified	Numerous bird species continue to use floodplain habitat, and beaver activity has steadily increased over time. Northwestern salamander breeding was observed in the large beaver pond during spring-time amphibian surveys.

Through Year 5, the site continued to provide habitat for a variety of terrestrial and amphibious species, including bald eagles (a nest present at baseline remained active through 2022), great blue herons, red wing blackbirds, Canada Geese, red-tailed hawks, a number of duck species, deer, mink, and opossum. A beaver dam complex in the northeast area of the project has expanded and remained active as of the date of this report, and multiple smaller dams have become established in the floodplain (Figure 22). Beaver browse was also regularly observed on site (Figure 21) and appeared to be more abundant in Year 5 than in previous post-project monitoring years, possibly due to the abundance of preferred vegetation that has established on site.

Amphibian breeding surveys were conducted monthly from February through May 2022 for comparison with baseline observations. Surveys focused on the large beaver pond in the northernmost area of the project, as well as within a floodplain wetland located mid-project, given that these were the primary locations where habitat may be suitable for breeding. In 2022, 11 distinct northwestern salamander (*Ambystoma gracile*) egg masses were observed in the large beaver pond wetland (Figure 23). One northwestern salamander egg mass was observed in the floodplain wetland. Egg mass survival was not quantified, but anecdotal observations from repeat surveys suggest that survival was high, as egg masses were observed maturing over time and were hatched-out by the final survey. Compared to baseline surveys conducted in 2011 and 2012, egg mass abundance was far less; in 2011 and 2012, 270 and 419 northern salamander egg masses were observed respectively across 5 surveyed wetland sampling areas. Pacific treefrog egg masses (*Pseudacris regilla*) were also observed in one surveyed wetland in 2011. The difference in egg mass abundance is largely due to a smaller survey area; wetland area suitable for amphibians decreased substantially post-construction.

Figure 21. Beaver browsed willow sending out roots along a floodplain sand bar (left; May 2022). One of several small beaver dams in the floodplain (right; July 2022).

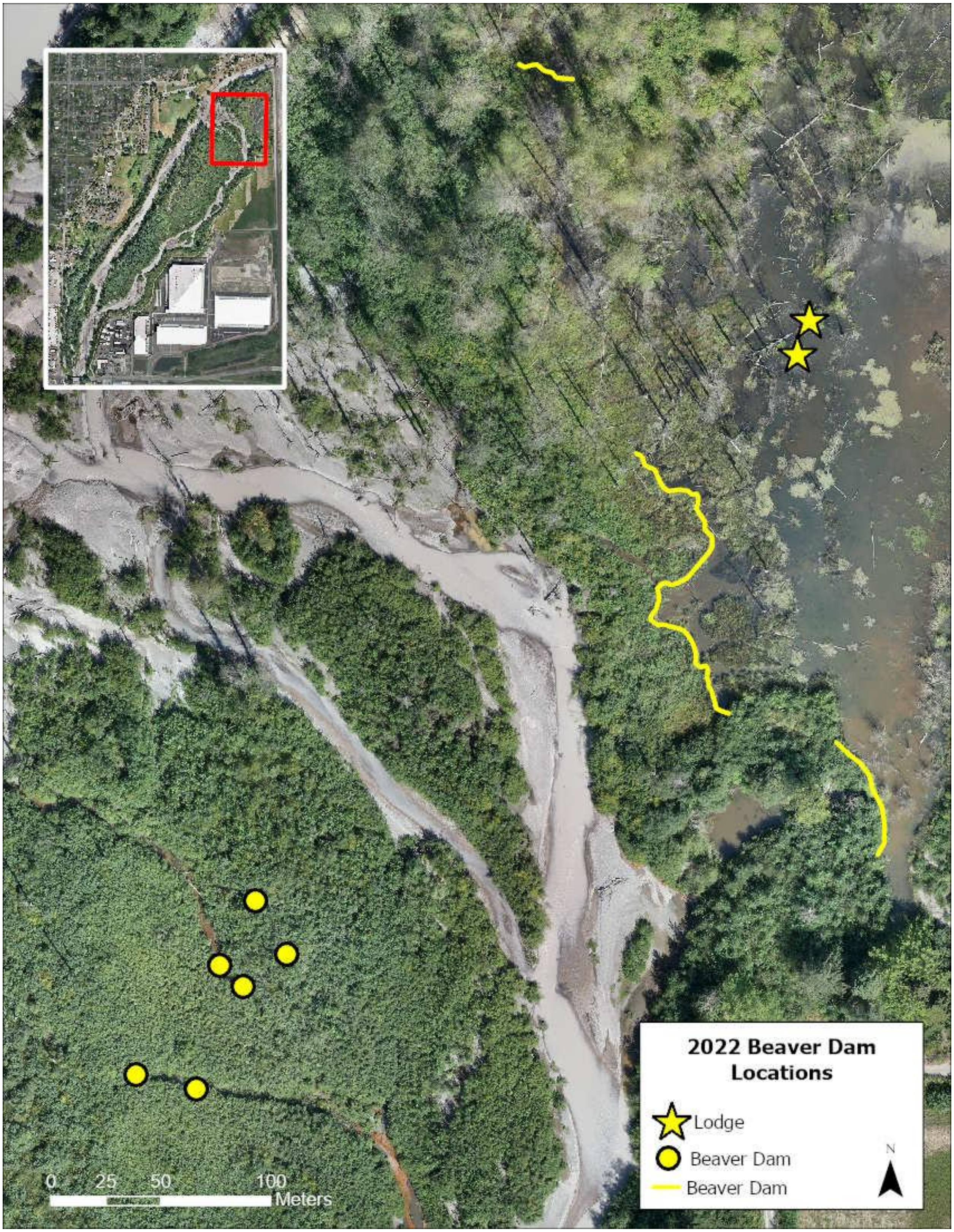

Figure 22. Known beaver dam and lodge locations as of July 2022.

At baseline, one adult red legged frog (*Rana aurora*), one adult Pacific treefrog, and one adult bullfrog (*Rana catesbeiana*) were observed during surveys; by comparison no adult amphibians were observed during Year 5 surveys, however subadult and adult bullfrogs have been observed in several locations within the project (primarily at the same beaver pond), and bullfrog tadpoles were also captured during overwintering fish sampling in the large beaver pond.

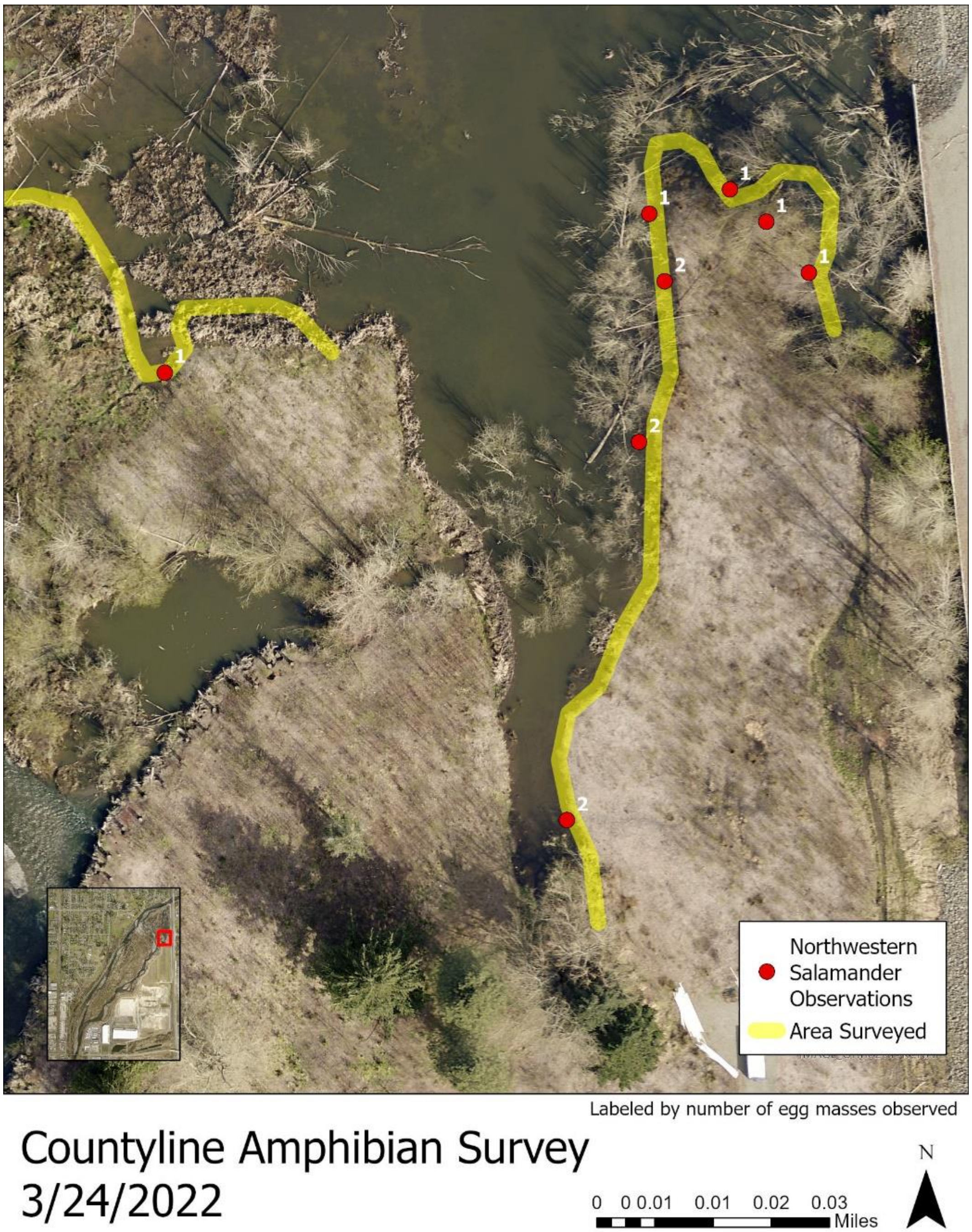

Figure 23. Northwestern salamander egg mass observations.

Large Wood

Year 5 Performance Standard	Year 5 Status	Details
Wood loading (natural and placed) on site meets or exceeds NMFS recommendation for properly functioning condition (>80 key pieces/mile)	NOT ACHIEVED	Wood loading in the project reach was 38 pieces/mile in Year 4 (2021), which is improved from Year 1 but did not meet the NMFS target. High-flow events that recruit large wood have been limited since construction.

Wood abundance was documented using Year 4 imagery rather than Year 5 due to availability of leaf-off imagery for remote sensing delineation. Both naturally occurring and placed wood were included in wood counts and volume calculations; only the exposed portions of placed wood are included. In total, 2,860 individual large wood pieces (>2m in length and 0.1 m in diameter, natural and placed) were documented in the project reach in Year 4, compared to 1,852 pieces at baseline (2017; but note that wood count methodology differed between baseline and Year 4 data, see Appendix B). In addition, 264 jams (>3 pieces of large wood; volume: 14,203 m^3) were observed in Year 4. Since project construction, wood has been observed moving into and transporting out of the project reach, particularly in the mainstem and near the side channel inlet area in the floodplain. Some pieces have been covered partially by aggrading sediment.

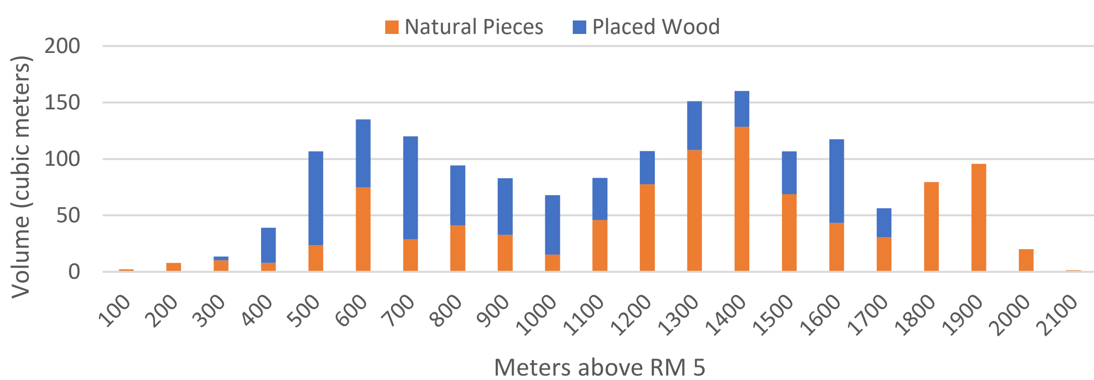

Figure 24. Volume of naturally occurring and placed large wood pieces in 2021. Data does not include pieces found within jams.

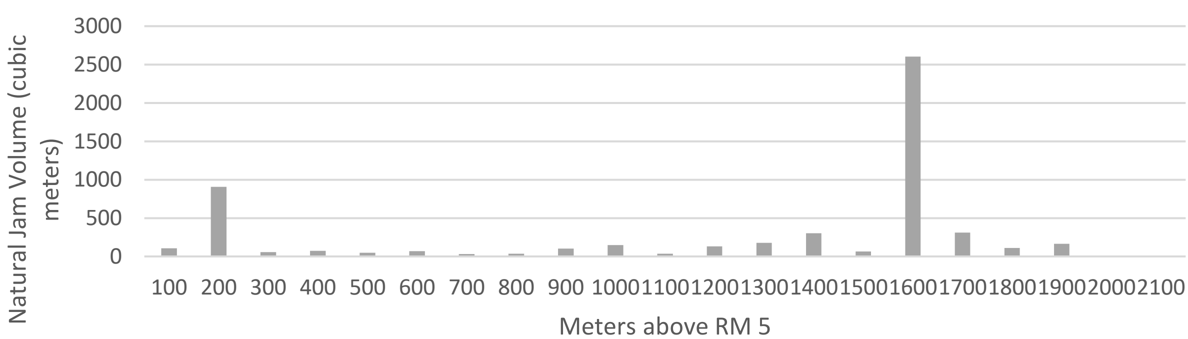

Figure 25. Volume of naturally occurring log jams in 2021.

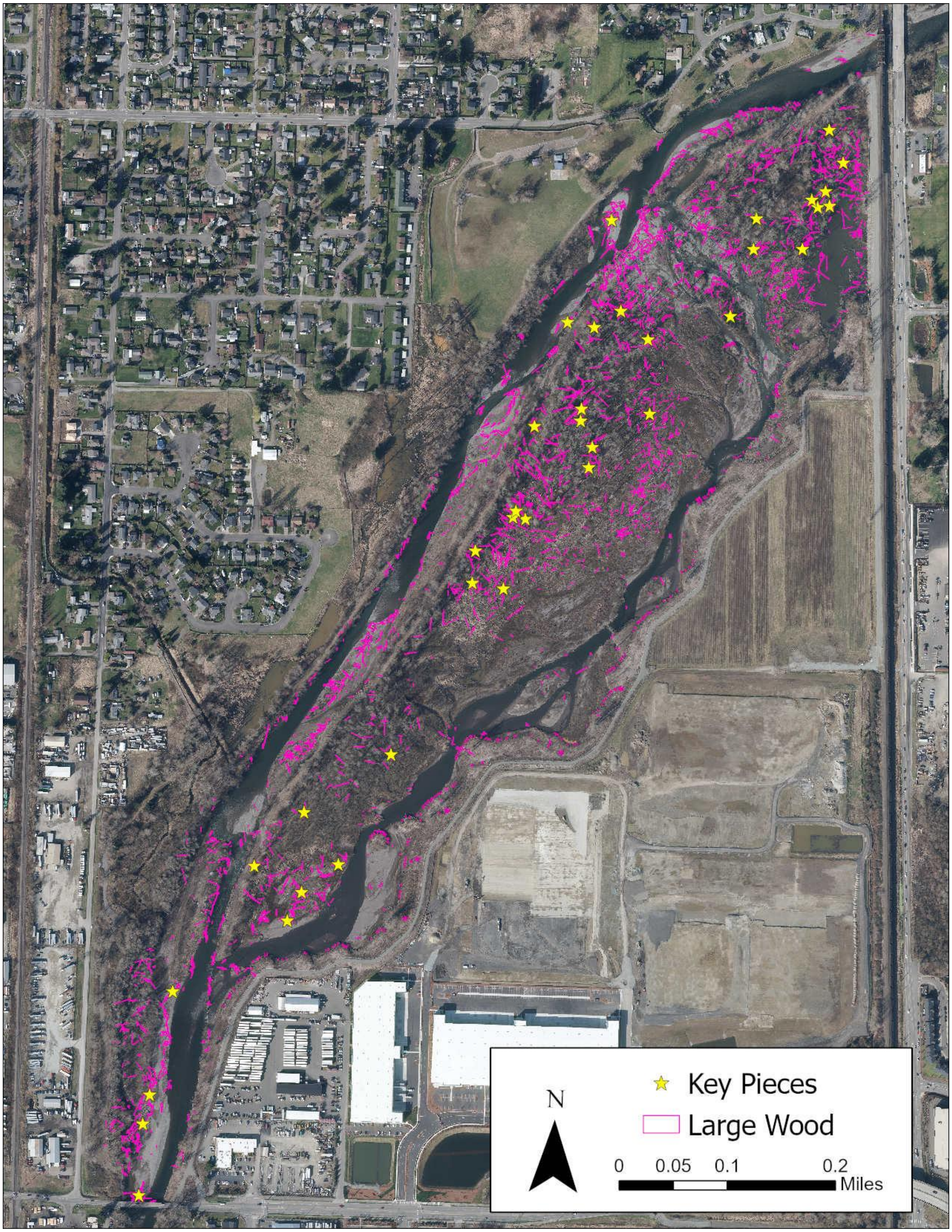

Figure 26. Map of all large wood (pieces and jams, naturally occurring and placed) in the project reach in 2021. See Table 10 for Key Piece definition.

By volume, the vast majority (95%) of observed wood in Year 4 was naturally occurring (6,440 m^3) compared to placed (704 m^3). More wood pieces were observed in the middle of the reach compared to at the project boundaries near the A Street and Stewart Road bridges where the channel is more constrained (Figure 24). Small jams were found throughout the project reach, and very large jams were observed on the right bank less than 200m upstream of the Stewart Road bridge and at the upstream end of the project at the entrance to the floodplain side channel (Figure 25).

Throughout the project reach, 49 key pieces (>15.2 m long, 0.6m diameter) were observed either as individual pieces or within a log jam (Figure 26). This was an increase in key piece count from baseline and Year 1 conditions, but key piece count still fell short of targets set both by the National Marine Fisheries Service (NMFS 1996) and Fox and Bolton (2007) for key piece abundance (Table 10, Figure 27). Non-quantitative field observation suggested more wood may have been present in the reach in Year 4 than Year 5 and so counts may not accurately reflect Year 5 conditions. However, since Year 4 conditions did not meet large wood targets, and likely overestimate wood what would have been present in Year 5, we can conclude that Year 5 would not have met wood abundance targets either.

Large wood abundance in the project area continues to fall short of the targeted 80 pieces per mile (15.2 m long and 0.6 ft diameter), likely because high flow conditions that recruit and transport wood have largely not occurred since construction. Wood targets for the project were based on study results that suggested on average 79 pieces meeting this size threshold would be transported to the project area annually (King County 2011). However, this analysis assumed flow conditions would remain similar into the future; instead, flow releases from Mud Mountain Dam have been limited to less than 7,000 cfs since 2009 (compared to 17,600 cfs authorized under the Water Control Manual, and a flow target of 12,000 cfs when feasible). Wood recruitment to the project area is likely to continue to be limited by water management practices.

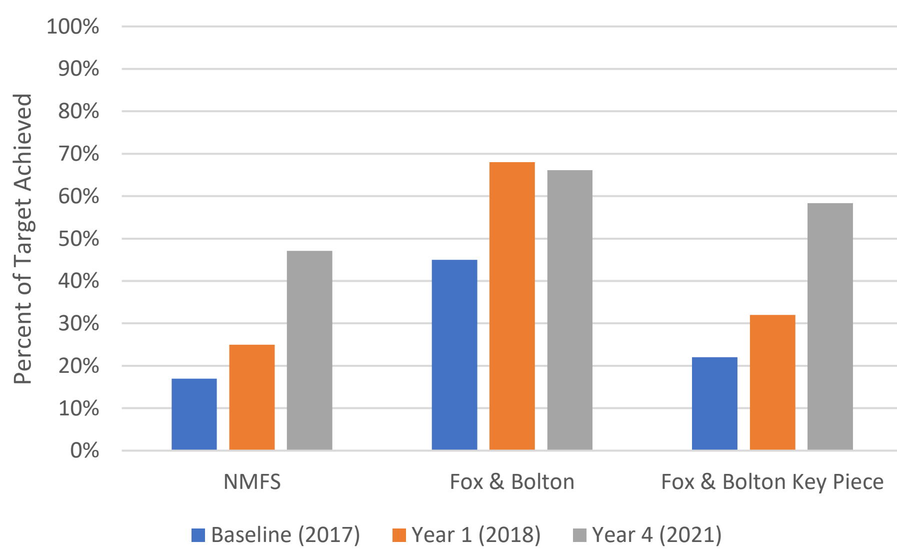

Figure 27. Percent of large wood target guidelines achieved at baseline, Year 1, and Year 5. Placed wood pieces are included in the Fox & Bolton target, but not the NMFS or Fox and Bolton Key Piece targets.

Table 10. Comparison of large wood counts with established large wood targets.

Source	Minimum Size Criteria	Target	2017 Observed	2018 Observed	2021 Observed
National Marine Fisheries Service	15.2 m long and 0.6 m diameter	>80 pieces per mile	13.8 per mile	20 per mile	38 per mile
Fox & Bolton*	2 m long and 0.1 m diameter	>206 pieces per 100m	93 pieces per 100 m (average)	140.8 pieces per 100 m (average)	136 pieces per 100 m†
	Key Piece: 15.2 m long and 0.6 m in diameter, volume is 10.75 m^3 or more	>4 pieces per 100 m	0.9 pieces per 100 m	1.3 pieces per 100 m	2.3 pieces per 100 m

* The 75th percentile from Fox & Bolton (2007) used for both targets.
† Value does not include pieces found within jams, and so underestimates loading.

Vegetation Cover

Year 5 Performance Standard	Year 5 Status	Details
Cover by installed trees and shrubs, including cover by volunteers of desirable native woody species, in Year 5 is at least 40%	ACHIEVED	Percent cover of trees and shrubs averaged 72% across transects in planted areas.
Less than 10% invasive cover (non-regulated noxious weeds and weeds of concern) in planted areas (5% for King County class A noxious weeds, bindweed, and knotweed). Less than 25% reed canary grass on site as a whole.	ACHIEVED	An average of 4% cover of non-regulated invasive weeds was found across monitored transects. Knotweed and bindweed were present but infrequent. Reed canarygrass cover averaged 0.4% across planted transects.

Transect Sampling

Average tree and shrub cover across all sampled transects (including unplanted gravel bars) was 72% in Year 5. In planted areas, combined average shrub and tree cover was 73%, exceeding the Year 5 performance standard of 40% cover of native woody species in planted areas, nearing the Year 10 performance standard of at least 75%.

Cover of native woody species continued to vary across planted areas and across transects within planted area types; average cover was 72% (standard deviation (SD) = 37%) in levee slope (LS) areas, 70% (SD = 33%) in riparian buffer (RB) areas, 71% (SD = 33%) in unplanted gravel bars (GB), and 78% (SD = 29%) in engineered log jam (ELJ) areas. When evaluating performance of each planted area compared to the Year 5 performance standard, all planted areas significantly exceeded the standard of 40% ($p<0.05$).

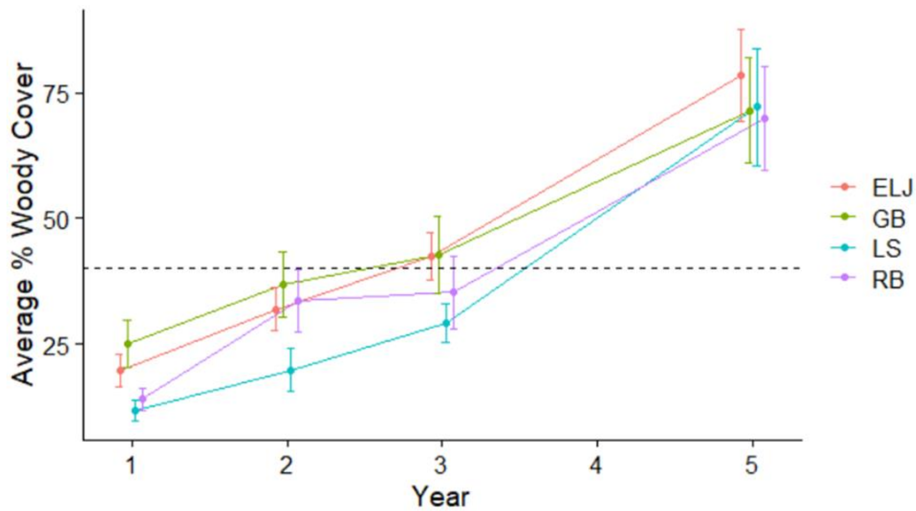

Figure 28. Percent cover of woody species in years 1, 2, 3, and 5, averaged across sampling transects, by planting area. Engineered Log Jam (ELJ), unplanted gravel bar (GB), levee slope (LS), and riparian buffer (RB). Error bars denote standard errors, and dashed line shows the Year 5 performance standard of 40% cover.

Conservative estimates of percent cover of woody species by planting area (i.e., calculated using the lowest value of each cover class range, rather than mid-point), indicate that at minimum, 48% cover was observed in ELJ areas, 45% in LS areas, and 47% in RB areas.

Average cover of native woody species has increased each year for all vegetation area types (Figure 28), and by Year 5 cover of woody species in all vegetation area types is similar. Vegetation establishment has exceeded expectations so far, possibly resulting from appropriate soil preparation and plant selection, natural recruitment, and regular watering delivered by the extensive irrigation system used on site for the first 3 years. Analyses done by Roni et al. (2023) indicated that riparian shading over the wetted channel has increased since construction, resulting from the increase in the areal extent of canopy cover.

A native wildflower seed mix was spread along the top couple feet of the levee slopes in 2018; riverbank lupine (*Lupinus rivularis*) has been particularly successful, with most species establishing in 2019 and 2020 during the second or third growing season. Successful perennial wildflowers included self heal (*Prunella vulgaris*), western yarrow (*Achillea millefolium*), Canada goldenrod (*Solidago canadensis*), riverbank lupine, bigleaf lupine (*Lupinus polyphyllus*), fireweed (*Chamaenerion angustifolium*), western columbine (*Aquilegia formosa*), and wooly sunflower (*Eriophyllum lanatum*) (Figure 29). Several annual species have also re-seeded and persisted over time, including Douglas meadowfoam (*Limanthes douglasii*) and wine cup clarkia (*Clarkia purpurea*).

An average of 0.03% cover of field bindweed (*Convolvulus arvensis*) was observed across all planted area transects; bindweed was observed in one ELJ transect of 30 sampled. No Japanese knotweed (*Polygonum cuspidatum*) was observed in planted area transects, but a small quantity of knotweed (0-5% cover) was observed in two unplanted gravel bar plots. No bindweed was observed in gravel bar transects.

Figure 29. Canada goldenrod (left) and yarrow, self heal, wooly sunflower, and riverbank lupin (right) in 2020.

Non-regulated weed cover was 4% across sampled planted transects, which is below the performance standard of <10% cover. An average of 0.4% cover of reed canarygrass was observed across all planted transects (just one ELJ plot contained 25-50% cover), which is below the performance standard of <25% of reedcanarygrass. A small quantity of reed canarygrass (<5% cover) was also observed in another 6 additional gravel bar plots. No butterfly bush, Queen Anne's lace, English Holly, spotted jewelweed, yellow flagged iris, or bittersweet nightshade was observed in planted area plots. However spotted jewelweed, yellow flagged iris, and bittersweet nightshade are known to be present on site in small quantities. Vegetation maintenance in planted and floodplain areas is ongoing to manage for undesirable species.

Site-wide Cover Estimate

Remote sensing analysis using a Normalized Difference Vegetation Index (NDVI) found that across the entire planted area, percent cover was 82%, up from 63% in Year 3 (Figure 30). The NDVI method uses multispectral imagery to characterize vegetation, and a field verification exercise done at this site in 2021 found that the NDVI method may produce greater estimates of cover compared to transect data collected in the field. We did not expect that the NDVI method and transect sampling would produce identical or directly comparable estimates of percent cover, since the NDVI estimate includes all vegetation, (including non-native species, whereas data reported above from transects separate out native and non-native cover and include woody species only), and methodology limitations differ (e.g., cover class bins for field collected data, soil color influences on spectral reflectance for remotely sensed data) which may under or overestimate cover in some areas.

Figure 30. Remotely sensed vegetation in planted areas (bright green) as calculated by NDVI. Boundary of planted areas shown in white polygons.

Native Recruitment

Natural recruitment of native tree species was dominated by willow species, red alder, and black cottonwood. Unplanted gravel bars had much higher rates of natural recruitment of these species than planted areas but declines in recruit counts over time were also more substantial (though cover remained high; Figure 28), likely due to competition and thinning as recruits established (Figure 31).

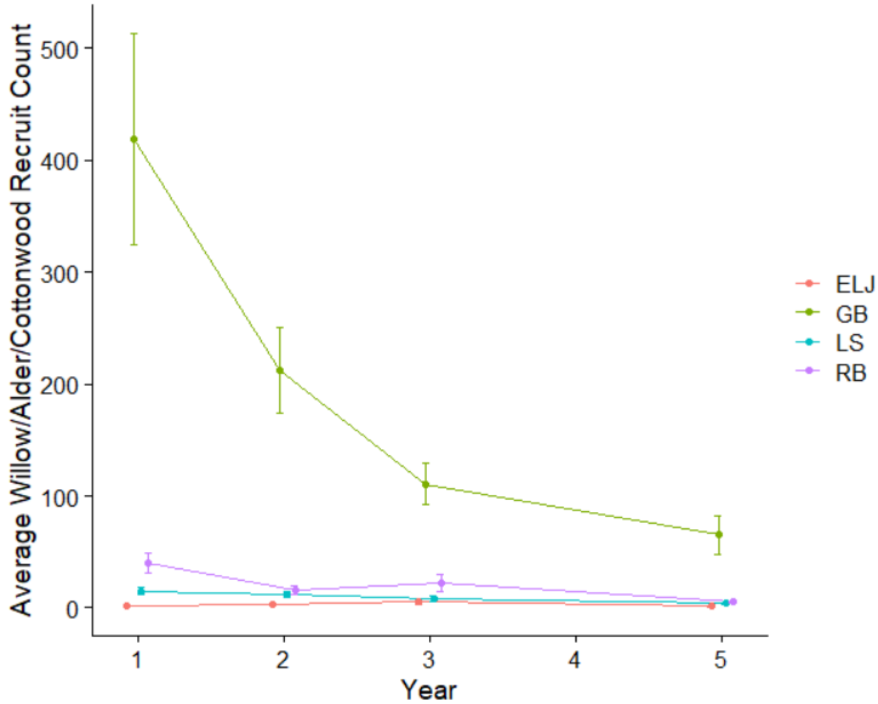

Figure 31. Combined count of willow, alder, and cottonwood natural recruits by vegetation area; engineered log jam (ELJ), gravel bar (GB), levee slope (LS) and riparian buffer (RB).

On gravel bars, most natural recruits were willow and cottonwood; small numbers of alder were observed. Recruitment was generally high across gravel bar transects, but not all gravel bars showed high recruitment. The four gravel bar transects with the highest initial recruitment counts were all located on the right bank of the floodplain side channel, nearest to the mature cottonwoods located along the old levee alignment (Figure 32a). By Year 5, the highest recruit counts on sampled gravel bars were along two transects with more recent disturbance but are located on the left bank of the side channel; GB10 was located on a sand bar that eroded away after Year 1, but re-established in Year 5.

Along riparian buffer transects, recruits were mostly alder and cottonwood. Some transects showed increases in recruit counts in Year 2 or 3 compared to previous years, suggesting that ongoing recruitment may be occurring (Figure 32b). Along levee slopes, recruits were primarily cottonwood although some alder recruits were present (Figure 32c). Along engineered log jam transects, recruitment rates were by far the lowest observed. Of recruits observed, most were cottonwood and alder. Counts along several transects were higher in Year 2 or 3 compared to previous years (Figure 32d), which could also suggest ongoing recruitment or a delay in recruitment, possibly due to different soil conditions, more compacted soil on top of the ELJs, or differences in hydrology that may influence species (especially cottonwood) recruitment and establishment.

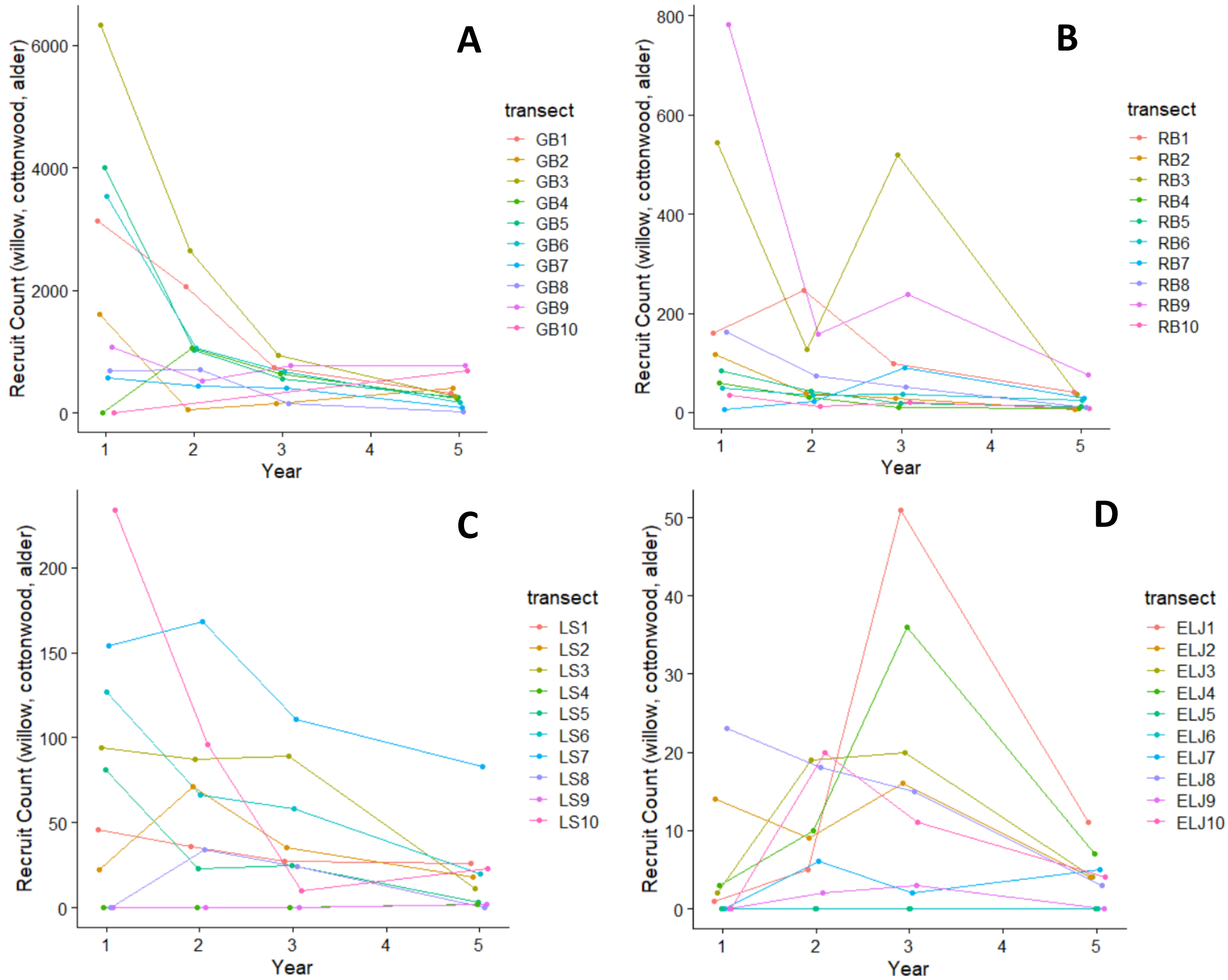

Figure 32. Count of naturally recruited willow, cottonwood, and alder by (A) gravel bar (GB), (B) riparian buffer (RB), (C) levee slope (LS) and (D) engineered log jam (ELJ) transect. Note the scale of y-axis varies by panel.

Figure 33. Vegetation establishment on top of an apex engineered log jam (top left), along levee slopes (top right), within riparian buffers (bottom left), and along unplanted gravel bars (bottom right) in 2022.

Flood Hazard

Year 5 Performance Standard	Year 5 Status	Details
No significant damage to engineered structures, adjacent flood facilities/infrastructure. Channel migration contained within project area.	ACHIEVED	Engineered structures are intact. Extents of channel migration are contained within project area. Flood risk as measured by mainstem water surface elevation at high flows is reduced from pre-project conditions despite ongoing sediment deposition.

No substantial damages to engineered structures throughout the project reach were observed during the first five years post-construction. Several areas continue to be monitored, including approximately 120 feet of biorevetment that has experienced some scour and erosion along approximately 20 ft of the coir lifts near the floodplain side channel inlet. Inspections and channel cross sections confirmed that lateral migration into the left bank has been effectively resisted by the biorevetment and levee and with channel movement limited to within the project area. The project has not created damages to adjacent facilities or infrastructure.

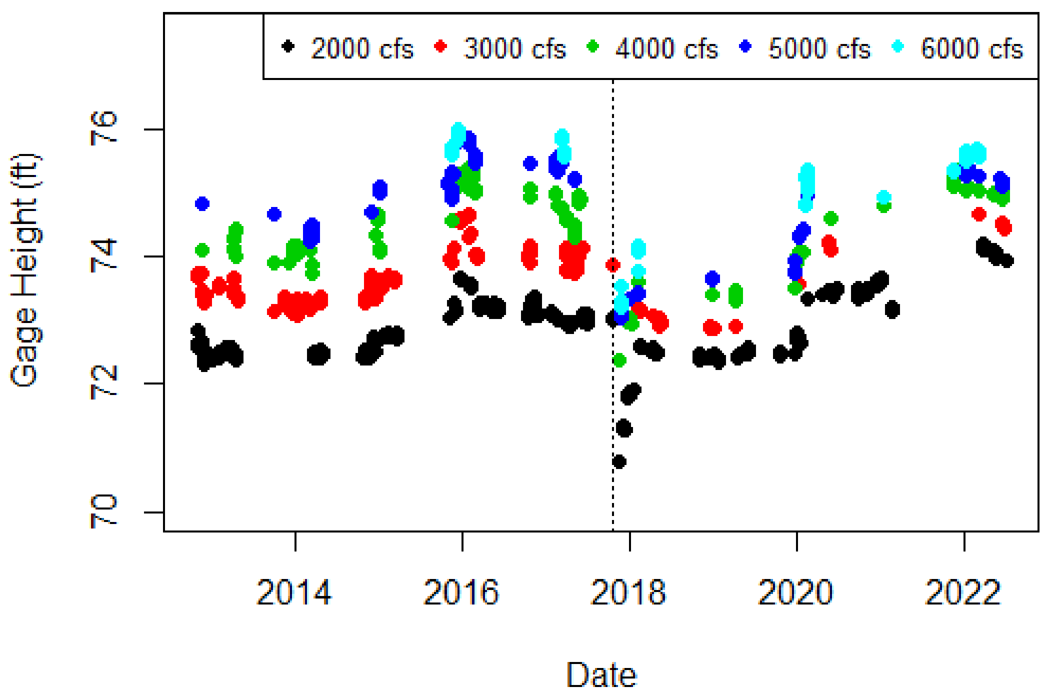

Figure 34. Water surface elevation at USGS 12100498 White River at Pacific, WA. The river initially breached the lowered levee on October 21 2017 (dashed line).

Flood flows since October 2017 and through October 2022 were conveyed through the Countyline project area, as expected. Water surface elevations (WSE) in the mainstem White River at USGS gage 12100498 at Pacific initially decreased at a given discharge, particularly immediately after the river initially breached the berm left along the old levee alignment in October 2017 (Figure 34). As sediment began depositing within the floodplain, WSEs rose again in the mainstem over the first year post-construction, though throughout the first flood season more flow was directed into the floodplain than mainstem and WSE remained lower than pre-project. Subsequent patterns of sediment deposition in the floodplain through the end of 2019 redirected the majority of flow back into the mainstem White River.

Ongoing sediment deposition throughout the alluvial fan along the lower White River was expected to increase WSEs at a given discharge over time, which has been observed; mainstem WSE at lower flows of approximately 2000 cfs have increased over time (Figure 34). Aggradation at the side channel inlet following high-flow events in February 2020 and March 2022 resulted in additional changes in the flow split. By 2022, average channel bed elevation across the side channel inlet (cross section 6.071) was higher than the average channel bed elevation nearby in the mainstem (cross section 6.077; Table 3).

As of October 2022, at higher flows (i.e., 6000 cfs) mainstem WSEs have returned to approximately the same elevation as pre-project elevations at the same discharge, however the range of WSEs across discharges was reduced in 2022 compared to pre-project (Figure 34); this indicates that at higher flows water is still being conveyed through the floodplain rather than increasing mainstem stage, therefore the project continues to provide reduced flood risk.

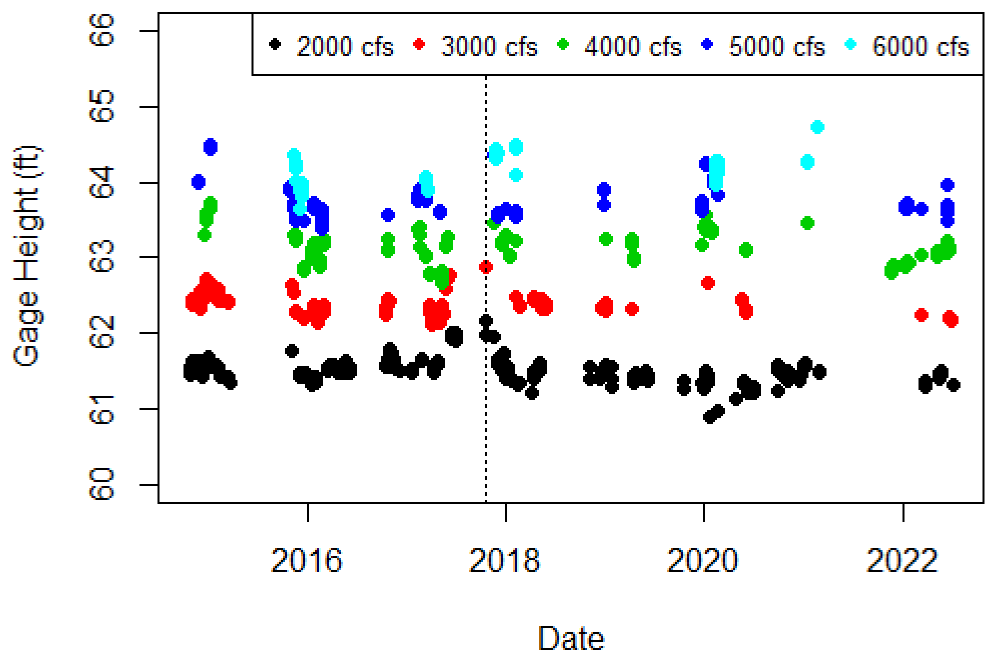

Figure 35. Water surface elevation at USGS 12100500 White River near Sumner, WA (at the 8th Street bridge). The river initially breached the lowered levee on October 21 2017 (dashed line).

A stage-discharge analysis using data from USGS gage 12100500 White River near Sumner, WA at the downstream end of the project site revealed that water surface elevations have remained unchanged in this location (Figure 35). This indicates that the project has not increased downstream flood risk in this location and points towards the sediment storage function of the project.

IV. Adaptive Management

Adaptive management actions have primarily focused on vegetation management, removal of illegally dumped items, and site security measures. Vegetation maintenance has included manual and chemical control of undesirable vegetation in planted areas and unplanted floodplain areas, regular watering of planted areas in summer months from 2018 to 2020 with an irrigation system and municipal water supply, and installation of additional plantings in Years 1 and 2. Descriptions of maintenance actions are found in Table 11. Undesirable controlled vegetation species included yellow flag iris, Himalayan blackberry, bindweed, thistles, bittersweet nightshade, reed canary grass, tansy ragwort, common tansy, poison hemlock, purple loosestrife, bird's foot trefoil, Scotch broom, and Japanese knotweed.

Table 11. Site maintenance activities.

Year	Maintenance Activities
2018	• Undesirable species removal (manual and chemical control) • Irrigation of planted areas 1-3x per week by irrigation system • Replant 800 live stakes, 2800 trees, and 4,250 shrubs
2019	• Undesirable species removal (manual and chemical control) • Irrigation of planted areas 1x per week by irrigation system • Replant landward levee slopes with 20 Western red cedar and 30 Douglas fir.
2020	• Undesirable species removal (manual and chemical control) • Irrigation of planted areas 1x per week by water truck
2021	• Undesirable species removal (manual and chemical control)
2022	• Undesirable species removal (manual and chemical control)

V. Conclusions

The Countyline Levee Setback Project continued to meet the overall project goal of restoring riverine process and function as measured by increased channel complexity, ongoing channel dynamism, floodplain inundation, and ongoing riparian vegetation establishment. Salmonids, amphibians, waterfowl, beaver, and other wildlife have been observed using reconnected floodplain habitats. The project is also meeting the goal of reducing flood risk as measured by mainstem water surface elevations at higher flows. Large wood targets were not met in either Year 1 or Year 5, possibly due to ongoing flow regulation by Mud Mountain Dam that limits natural hydrological variability and wood recruitment. Ongoing vegetation maintenance is recommended, although no other adaptive management actions are recommended at this time.

Appendix A. Monitoring Objectives, Metrics and Performance Standards

Each indicator is associated with a performance standard (objective), method, and metric (output) which will be monitored on a rotating schedule over the 10-year monitoring period (Table A1; King County, 2014).

Table A1. Monitoring objectives, methods, and outputs.

Category	Indicator	Performance Standard	Task	Monitoring Method	Timing (Years)	Output
Project Implementation	As-built condition	As-built condition satisfies design objectives.	1	Manage construction to ensure project satisfies design objectives; Produce record drawings.	Immediately post-construction	Record drawings
Channel Dynamics	Movement	New channel(s) form outside of the present (pre-project) active channel.	2	LiDAR, aerial photography, and field survey	1, 3, 5, 10 (timing may be adjusted based on high flow events)	Mapped channel forms
Habitat Benefit	Aquatic habitat	Sum of slow-water (<1.5 ft/sec) bar, bank, backwater and side channel area increases by >50%, relative to baseline condition.	3	Map slow water areas on channel margins at flows representing 50th, 75, and 90th percentile flows during Jan-Jun	1, 3, 5, 10	Change in edge habitat area relative to baseline
		Floodplain inundation within the project area will increase after project construction, as measured between February 1 and March 31 utilizing aerial photography.	4	Georeferenced aerial photography and field ground-truthing	1, 3, 5, 7, 10; additional photography may be collected during and following high flow events	Georeferenced photograph of inundated area
	Wood	Wood loading (natural and placed) on site meets or exceeds NMFS recommendation for properly functioning condition (>80 pieces/mile; NMFS 1996).	5	Object-based image analysis (based on LiDAR and orthophotos) and field survey	1, 5, 10	Estimates of wood loading
	Riparian cover	80% survival[2] at end of Year 1 growing season for all installed trees and shrubs (excluding stakes)[3].	6	Fixed plots	1, 2, 3, 5, 7, 10	Percent survival of installed plants
		Cover by installed trees and shrubs, including cover by volunteers of desirable native woody species: Year 2 at least 15%, Year 3 at least 20%, Year 5 at least 40%, Year 7 at least 60%, and Year 10 at least 75%.	7	Fixed plots	1, 2, 3, 5, 7, 10	Percent cover of native installed and volunteer woody vegetation (trees and shrubs)
		Average vegetated riparian buffer width of 75 feet.		See task 4	1, 5, 10	Minimum, average, and maximum buffer width
	Invasive cover	Less than 10% invasive cover (non-regulated noxious weeds and weeds of concern) in planted areas (5% for KC Class A noxious weeds, bindweed, and knotweed). Less than 25% reed canary grass on site as a whole.		See task 7	1, 2, 3, 5, 7, 10	Percent cover of invasive plants
	Wetlands	1.08 acres temporary impacts in Wetlands A and B restored to aquatic habitat condition.		See task 4	1	Wetted area
Fish use	Habitat preference	Juvenile salmonid density (or frequency of occurrence) is highest in backwaters and side channels, compared to other edge types.	8	Sample juvenile salmonids in edge habitat during rearing period	1, 3, 5, 10	Relative abundance of juvenile salmonids in discrete habitat types
	Habitat capacity	Habitat capacity at project site – estimated as the product of the average density of juvenile salmonids in edge habitats and the area of edge habitat (by type) at median rearing flows increased by >50% compared to baseline.		See tasks 3 and 10	1, 3, 5, 10	Change in habitat capacity

Appendix B. Monitoring Methods

Channel Dynamics

Channel complexity was characterized by:

- Number of side channel nodes and ratio of side channel to main channel length (Stefankiv et al. 2019). Side channel nodes mark the start and end of a side channel that is connected to the mainstem (or another side channel) at one end.
- Number of braid channel nodes (Stefankiv et al. 2019). Braid channel nodes mark the start and end of a smaller channel within the active channel across or between gravel bars. Braid channels are distinguished from side channels by lack of established vegetation.
- Total active channel area (sum of area of water, banks, unvegetated gravel bars, and bars without perennial vegetation) (Collins and Montgomery 2011; Konrad 2015)
- Floodplain connectivity and continuity (Konrad 2015). Area of floodplain inundated at high flow between February 1 and March 31.
- Channel cross section changes reflecting areas of deposition, side channel development, and floodplain connection.

Channel complexity metrics were calculated using GIS measurements taken from high-resolution orthoimagery captured before project construction (April 2016, 1800 cfs at USGS White River at R Street) and post-project at the most comparable flow available (April 2018, 2400 cfs; April 2019, 2860 cfs; August 2020, 1030 cfs; May 22 2022, 1950 cfs). The flow rate at the time of imagery collection is noted as water surface elevation may affect side channel and braid channel engagement, and so imagery at the most comparable flow available was used; we note that imagery available in 2020 was collected at a lower flow than baseline (2016) or Year 5 (2022) imagery, which could influence our observations of channels and channel braids in the imagery. Previously established channel cross section locations were used to evaluate bed elevation changes between 2020 and 2022 LiDAR datasets.

Sediment Conditions

To evaluate ongoing changes in sediment volume and to estimate quantities of sediment deposited in and eroded from the project area, the change in surface elevation was calculated in GIS from LiDAR data collected at Year 3 in 2020 and Year 5 in 2022 (Williams 2012). The elevation difference between the two surfaces was calculated to get an elevation change and reveal areas of deposition and erosion and then multiplied by cell area (9 square feet) to estimate a volume. A net volume for entire project area was estimated by summing all volume cells. Calculated values were rounded to reflect the accuracy of the estimates.

Aquatic Habitat

High-flow Floodplain Inundation

Inundated area was estimated using aerial imagery during one pre-project (March 2016, 1800 cfs) period, and six post-project periods over a range of flows. In addition to true color (RBG) imagery, unmanned aerial vehicles (UAVs) also collected imagery that included near infrared (NIR) spectra during two collection events in 2018, one in 2019, two in 2020, and one in 2022. Collection of NIR spectra allows water surfaces to be distinguished from vegetation and bare ground because of the high contrast in the spectral absorption in the NIR band.

In 2018 and 2019, a maximum likelihood classification (MLC) method was used to distinguish inundated area, calibrated against the spectral properties of areas known to be wet or otherwise (i.e., dry or obscured by vegetation). Comparison of these MLC classified areas with a field-verified wetted edge indicated that some wetted areas were obscured by vegetation and so these estimations may have underestimated the actual inundated area. In 2020 and 2022, the area of inundation was estimated using a Normalized Difference Water Index (NDWI), another remote sensing technique for water body mapping (Ma et al. 2019, Mukherjee et al. 2018) that uses the relationship between NIR and green bands to distinguish between water, vegetation, or soil signatures. Areas completely obscured by vegetation would still be underestimated using the NDWI method to measure inundation, however it appeared to perform better than the MLC method in areas with partial vegetation obstruction. Pre-project inundated area was calculated by visually delineating wetted areas using the true color orthoimage, given that NIR data was unavailable. Although the methods differ, baseline and year 1, 2, 3, and 5 estimates are presented in this report for a rough comparison.

Low-Velocity Habitat

Juvenile salmonids rely heavily on shallow, relatively slow moving waters for rearing (Bjornn and Reiser 1991, Beechie et al. 2005), therefore we surveyed the availability of this habitat in the project reach. The margins of low-velocity habitat were located by visually determining the shear line (water velocity was approximately <0.45m/sec), and the slow-water boundary was mapped using a Trimble Geo7X GPS. Low velocity habitat was categorized into backwater, bar, bank, and side channel habitat types based on methods modified from Beechie et al. (2005). Low-velocity habitat was only mapped if the habitat unit area was greater than the accuracy of the GPS (typically 1-3 feet). Habitat types included:

- Bar: low-gradient depositional habitat generally consisting of sand, gravel, and cobble.
- Unarmored bank: vertical or nearly vertical erodible shore with no artificial bank stabilization.
- Armored bank: vertical or nearly vertical shore with placed riprap or other bank stabilization.
- Backwater: partially enclosed slack-water area separated from the main flow path and often found at the downstream or upstream end of a disconnected side channel or braid. Backwaters also form at the downstream end of bars between the bar and a bank edge.
- Side channel: secondary channel separated from the main flow path by an island that extends above the bank-full level or that includes mature vegetation. Habitats categorized as side channels were those flow paths where the entire cross-sectional width of flow was slow-water (<1.5ft/sec). It is important to note that side channels are inclusive of all habitats present, and may include a variety of micro-habitats that include bars or banks.
- Beaver pond: Inundated slow-water habitat within the floodplain that is controlled by the presence of a beaver dam or other beaver activity and is characterized by little to no flow and water extending over the banks of the pre-existing channel.

Low velocity habitat was surveyed multiple times per year to quantify the relationship between flow and low velocity habitat availability. Prior to project construction, twelve surveys were conducted in three habitat sampling areas along the mainstem. These areas were considered representative of available habitat conditions and channel morphology present pre-project throughout the entire reach. Several pre-project surveys limited habitat collection to along the left bank in 2011 and 2012 due to logistical constraints (Table B1). Post-project surveys conducted in 2018, 2020, and 2022 included the entire left bank mainstem as well as the entire reconnected floodplain.

In the current report, before and after low velocity habitat data collected at approximately 1400-1500 cfs (about the median flow from February – March) are compared. Since only a portion of the mainstem was sampled during baseline efforts (0.85 km long reach, versus 2.12 km in Year 1 and 3), data was standardized by length of mainstem river sampled for comparison across sampling periods. Only habitat along the left bank and left bank floodplain are included in analyses. The beaver pond in the northeast project area was considered separately from other backwater habitats in interannual comparisons.

Table B1. Low flow habitat sampling events.

Project Phase	Date	Flow (cfs)	Areas Sampled
Pre-project	4/13/11	1530	ULB, MLB
Pre-project	10/3/11	657	ULB, MLB
Pre-project	1/31/12	2830	ULB, MLB, URB
Pre-project	5/8/12	2920	ULB, MLB
Pre-project	11/6/12	1350	MLB
Pre-project	2/19/13	1100	ULB, MLB
Pre-project	**3/19/15**	**1510**	**ULB, MLB, URB**
Pre-project	5/20/15	1080	ULB, MLB
Pre-project	7/22/15	806	ULB, MLB, URB
Pre-project	9/3/15	603	ULB, MLB, URB
Year 1	2/26/18	1150	Entire site, no right bank
Year 1	**11/5/18**	**1430**	**Entire site, no right bank**
Year 1	7/31/18	825	Entire site, no right bank
Year 3	3/23/20	972	Entire site, no right bank
Year 3	7/27/20	1110	Entire site, no right bank
Year 5	2/22/22	825	Entire site
Year 5	5/2/22	1550	Entire site
Year 5	**7/18/22**	**1430**	**Entire site**

Bolded rows highlight the data compared in this report.
ULB = upper left bank; MLB = middle left bank; URB = upper right bank

Fish Use

Habitat Use

Fish sampling aimed to evaluate pre- and post-construction juvenile salmonid use of low velocity habitats. Fish were captured by one pass of a seine (1/8" mesh size) in subsets of low velocity habitat units to determine relative abundance across side channel, bar, bank, and backwater habitat types in the mainstem and reconnected floodplain. Some habitat types were not present (or were very rare) during some sampling periods due to variation in flow, so selection of habitat units aimed to be representative of the habitat types available during the sampling event. Sampling was conducted close to dawn to coincide with periods of increased fish activity (although some sets occurred approximately 40 minutes before sunrise and up to 5 hours after sunrise).

Habitat units were sampled by dragging both ends of the seine through a unit, so area sampled was not consistent across sets. In 2022, the area sampled was mapped using a hand-held GPS unit and the duration of net deployment was recorded. In all other years, only the set duration was recorded, so comparisons of catch per unit effort across years used seconds fished as the measure of effort. Fish were identified to species, anaesthetized and measured for fork length prior to release.

Table B2. Dates of fish sampling by seine by season. Flow at R Street included in parentheses.

Project Phase	Year	Winter	Spring	Summer	Fall
Pre-project	2011	--	4/20 (1530 cfs)	7/12 (3000 cfs)	10/4 (657 cfs)
Pre-project	2012	2/1 (2830 cfs)	5/8 (2920 cfs)	7/25 (3210 cfs)	11/6 (1350 cfs)
Pre-project	2013	2/20 (1000 cfs)	--	--	--
Pre-project	2015	--	3/19 (1270 cfs) 5/20 (1120 cfs)	7/22 (836 cfs) 9/3 (584 cfs)	--
Year 1	2018	2/27 (1200 cfs)	5/9 (3160 cfs)	8/1 (950 cfs)	11/6 (1410 cfs)
Year 5	2022	2/23 (830 cfs)	5/3 (1760 cfs)	7/19 (1410 cfs)	11/2 (800 cfs)

In addition to sampling by seine, in Year 5 traps were deployed once in December (Dec 22 2021) and once in February (Feb 3 2022) in the large beaver pond at the north end of the project site to evaluate presence of overwintering salmonids. In December both one fyke net and several minnow traps were deployed; in February two fyke nets were deployed after results from December showed that minnow traps were not as effective at capturing salmonids. Traps were deployed in the evening and checked the next day. All fish captured were identified and measured.

Habitat Capacity

Habitat capacity indices for Chinook and coho salmon was calculated using average Chinook or coho densities (count per square meter seined) across all floodplain units sampled and all mainstem units sampled in spring 2022. All habitat types within floodplain or mainstem areas were combined for these averages because not all habitat types were sampled (i.e., no backwater habitat was sampled in spring). We multiplied the total low velocity area (m^2) observed by the average fish density (fish/m^2) observed in both the mainstem and floodplain, and combined the two for a total site-wide fish capacity (unit of measure = fish). Beaver pond areas were not included since fish density was not sampled in ponds. To compare Year 5 to baseline and Year 1 conditions, a total site-wide fish capacity was similarly calculated using baseline or Year 1 observations of low velocity area at a similar flow (1400-1500 cfs) and using Year 5 fish density data (Year 5 data was used for previous years because it was the only year in which area sampled was recorded, and also because this methodology eliminates differences in capacity due to interannual variability in fish abundance). Because habitat sampling varied in effort between baseline and post-project conditions (0.85 km of river surveyed at baseline, compared to 2.12 km of river surveyed post-project), the habitat capacity index was standardized by river km surveyed (final units = fish / km).

This habitat capacity index essentially weights habitat areas by the relative “value” of floodplain versus mainstem habitat for juvenile salmon, using observed fish densities to assign relative value. We caution against interpreting habitat capacity as an extrapolation of fish abundance to the entire site, given the relatively few fish density observations available and because units sampled for fish did not capture the full variability in habitat conditions across the site as seining is not effective in all habitat units (e.g., areas with obstructions or wood). It is also not a true “habitat capacity” in the sense that fish densities used in the calculation do not represent densities of saturated habitat (i.e., densities that represent the maximum number of fish that could be supported). Nevertheless, the index can still be useful in providing a method of quantitatively evaluating relative change in habitat for juvenile salmonids over time.

Wildlife

Amphibian breeding surveys were conducted monthly during the breeding season (on Feb 11, Mar 24, Apr 22, and May 19 2022) by a team of three to four biologists. Two transects were established in the large beaver pond at the northernmost area of the project, along the pond edge where shallower water provided suitable breeding habitat (Transect 1 and 2; Figure B1). An additional transect was established in a floodplain wetland near the center of the project (Transect 3; Figure B1). Transects were generally shallow (<1 m deep) and a 2-m wide area along the transect was surveyed for egg mass presence. Surveys were conducted on foot by wading along the transects, and also walking along the shore in the case of the beaver pond transects. Surveys were not conducted in rain or high winds to maximize visibility. Egg masses were identified by species and egg mass locations were marked with a GPS.

Beaver and bird observations were made opportunistically during field visits. Beaver dam locations were identified and delineated both in the field and using aerial imagery from 2022.

Figure B1. Amphibian breeding survey transects.

Large Wood

Wood totals presented in this report include all naturally occurring and placed wood from the Stewart Street Bridge to north of A-Street at RM 6.2. Naturally occurring large wood pieces and log jams were remotely delineated from true color leaf-off low-flow orthoimagery from Year 4 (imagery collected March 17, 2021). Year 4 imagery was selected because leaf-off orthoimagery was not available in Year 5; anecdotal observations suggest that more wood may have been present in the reach in Year 4 than Year 5 and so counts may not accurately reflect Year 5 conditions. However, since Year 4 conditions did not meet large wood targets, and likely overestimate wood that would have been present in Year 5, we can conclude that Year 5 would not have met wood abundance targets either.

Large wood was defined as pieces at least 2 m long and 0.1 m in diameter. Jams were defined as having at least 3 overlapping pieces of large wood. Volumes were calculated using a predictive model that estimates wood volume in jams and pieces from aerial imagery-delineated wood area, which was derived from data on the Cedar River (Scott, *in prep*):

$$\text{Wood volume (ft}^3\text{)} = e^{-1.7733}(\text{wood area(ft}^2\text{)})^{1.2792}$$

Since installed wood has not changed in location or quantity since construction, counts and volumes of placed large wood pieces were used from 2018 analyses.

Baseline (2017) and Year 1 (2018) wood loading was documented using field surveys following methods specified by Montgomery (2008) to map individual pieces. Pieces that were not accessible to field survey were counted and size-classed using GIS measurements taken from high-resolution 2017 and 2018 orthoimagery (image dates: April 21, 2017 and March 29, 2018). Log jam heights and perimeters in the mainstem were field surveyed using GPS during baseline (2017) and Year 1 (2018) data collection. To quantify individual pieces within mapped log jams (collection of ≥3 pieces of wood) at baseline and in Year 1, aerial counts were combined with lidar-derived jam heights and a piece-size distribution was calculated using volumetric and porosity metrics. Log jam porosity was assumed to be 75%.

To quantify placed wood, the volume of wood exposed in engineered log structures (jams and biorevetments) was calculated from record drawings, and included both logs installed horizontally as well as vertical log piles. Placed racking wood was assumed to be 24 inches in diameter, and length was based on the exposed portion of logs (excluding the portion of logs concealed within the structure). Root wad volumes were calculated as 10% of the entire log. Placed wood has not mobilized as of Year 4 or 5, and so the same calculated volumes were used for both Year 1 and Year 4.

Vegetation Cover

Transect Sampling

Forty monitoring transects were established in disturbed areas to evaluate the success of planted vegetation and estimate the rate at which trees colonize bare ground. Ten transects were established within each of four strata: naturally-formed gravel bars, fill on top of engineered log jams, riparian buffers, and levee slopes (Figure B2). Transects did not cross strata and locations were randomly chosen within the appropriate strata. All transects were 30-m long, except for those on engineered log jams which were 15-m long due to the smaller area of fill on top of these structures. One gravel bar transect established in Year 1 was not surveyed in Year 2 and 3 because it was underwater, but a sandbar reformed in its location by Year 5 and so this transect was reestablished and surveyed.

Within each transect, percent cover of native and invasive tree, shrub, and groundcover species was measured within 1-m radius circular plots. Percent cover was measured by cover class within five plots along each 30-m transect (riparian buffer, levee slope, gravel bar transects), evenly spaced at 6-m intervals, and within 3 plots spaced every 5-m along each 15-m transect (engineered log jam transects). Cover classes were 0-5%, 5-25%, 25-50%, 50-75%, 75-95%, and 95-100% (Daubenmire 1959). Mid-points of each cover class were used to calculate averages. Recruitment was also measured within the same 1-

m radius plot; all volunteer vegetation was identified to species and counted. Photos were taken from the start and end of each transect, angled along the transect, for a visual record of vegetation establishment over time. This field data was collected on Aug 27-30, 2022.

Site-wide Cover Estimate

Transect sampling allows for species-specific evaluation of vegetation performance and cover in a subset of the project area. To evaluate site-wide vegetative cover, remote sensing data were used to calculate a Normalized Difference Vegetation Index (NDVI). NDVI is typically used to characterize vegetation growth or vigor, and is defined as the normalized ratio of the red and near infrared spectral bands (Xue and Su 2017). Multispectral imagery collected by drone during peak vegetation growth on August 23, 2022 captured red and near infrared (NIR) spectra, allowing for calculation of NDVI to identify areas with vegetative cover. NDVI ranges between -1 and 1, with values closer to 1 displaying spectral characteristics most similar to vegetation; based on visual comparison with true color imagery collected at the same time, a threshold value to distinguish between vegetation and non-vegetation was determined. The resulting raster was used to calculate the vegetative cover within the entire 18-acre planted area. Unlike field-collected data, this method does not distinguish between native and non-native cover.

To explore differences in field versus remotely sensed methodology, we compared field-measured and remotely-sensed percent cover at 20 randomly selected 1-m radius circular plots throughout planted areas in 2021 (Year 4). Remotely-sensed percent cover within those plots was generated in GIS using NDVI calculated from August 2021 imagery, and field-measured percent cover was collected within 2 days of the aerial imagery collection, such that vegetation conditions were the same. Field estimation of percent cover was binned by 10% cover classes (e.g., 0-10%, 10-20%). Results indicate that remotely sensed cover using NDVI overestimates vegetative cover compared to field data, particularly in plots with intermediate cover values (Figure B3). This non-linear relationship between vegetative cover and NDVI, and saturation of NDVI in areas with denser vegetation, has also been found by others (Jiang et al. 2006). Other methods of calculating the percent cover from NDVI, as described in Jiang et al. (2006), minimally or did not improve the relationship between field-measured and remotely-sensed data. Despite this observed non-linear relationship, tracking NDVI over time can be useful in quantifying site-wide change in vegetation cover (recognizing is it an over-estimate), and/or in measuring other vegetation metrics such as health and density.

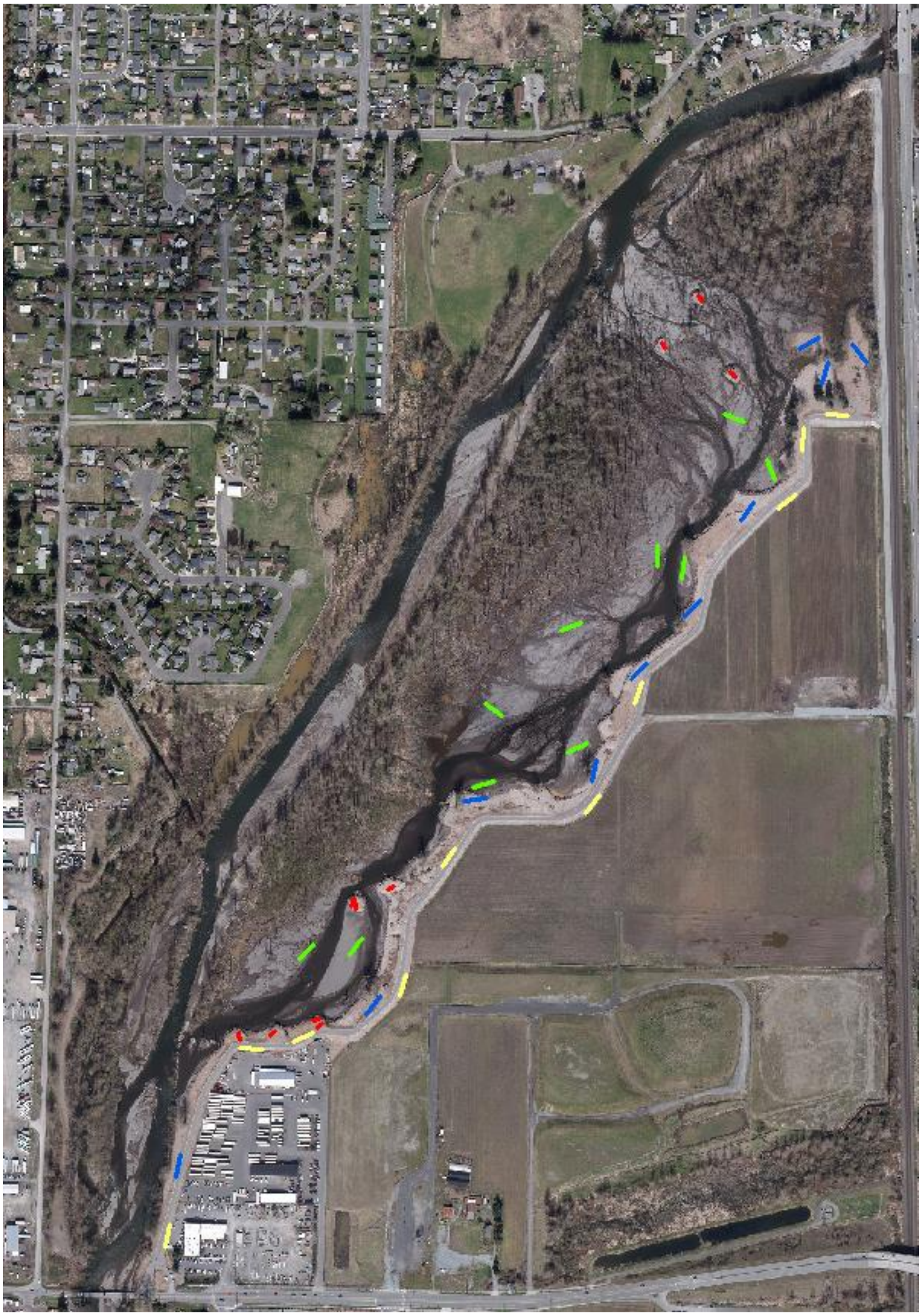

Figure B2. Vegetation sampling transects. Transects were stratified by planting area, with 10 transects within each area: riparian buffer (blue), levee slope (yellow), engineered log structures (red), and unplanted gravel bars (green).

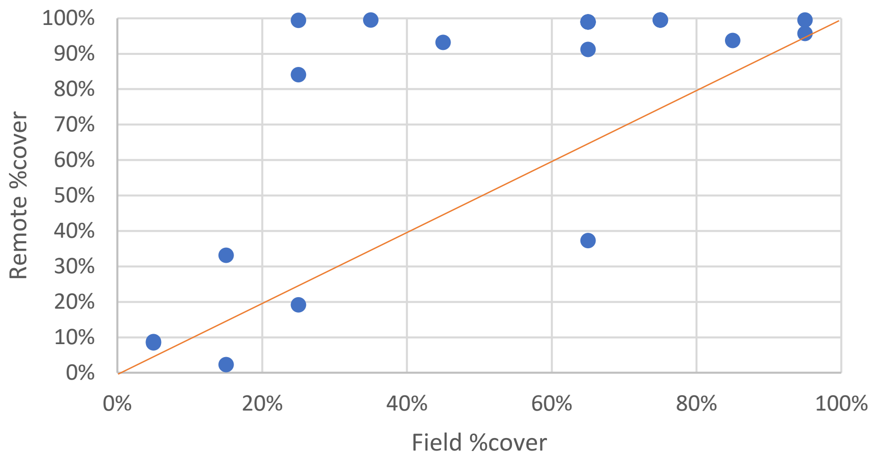

Figure B3. Percent cover as measured in the field versus remotely by NDVI. Orange line represents 1:1; points above the line are plots where NDVI overestimated cover compared to field data, points below the line are plots where NDVI underestimated compared to field data.

Flood Hazard

The structural stability of the setback levee was inspected by the project design engineers during and following high flow events in February 2021, November 2021, and March 2022, as well as during the low flow period (Sept 2022). Areas of concern were noted and follow-up monitoring was conducted where needed. The ongoing impact of the project on flood elevations was also evaluated by observation during high flow events, as well as by evaluating water surface elevations at the USGS 12100498 White River at Pacific gage from October 2016 through 2022 at flow intervals of 1000 cfs from 2,000 to 6,000 cfs as measured by the USGS 12100490 White River at R Street gage. Lateral migration of the mainstem and side channels within the project area was monitored using cross sections derived from both survey and LiDAR, as described in the Channel Dynamics section above, as well as by inspection.

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