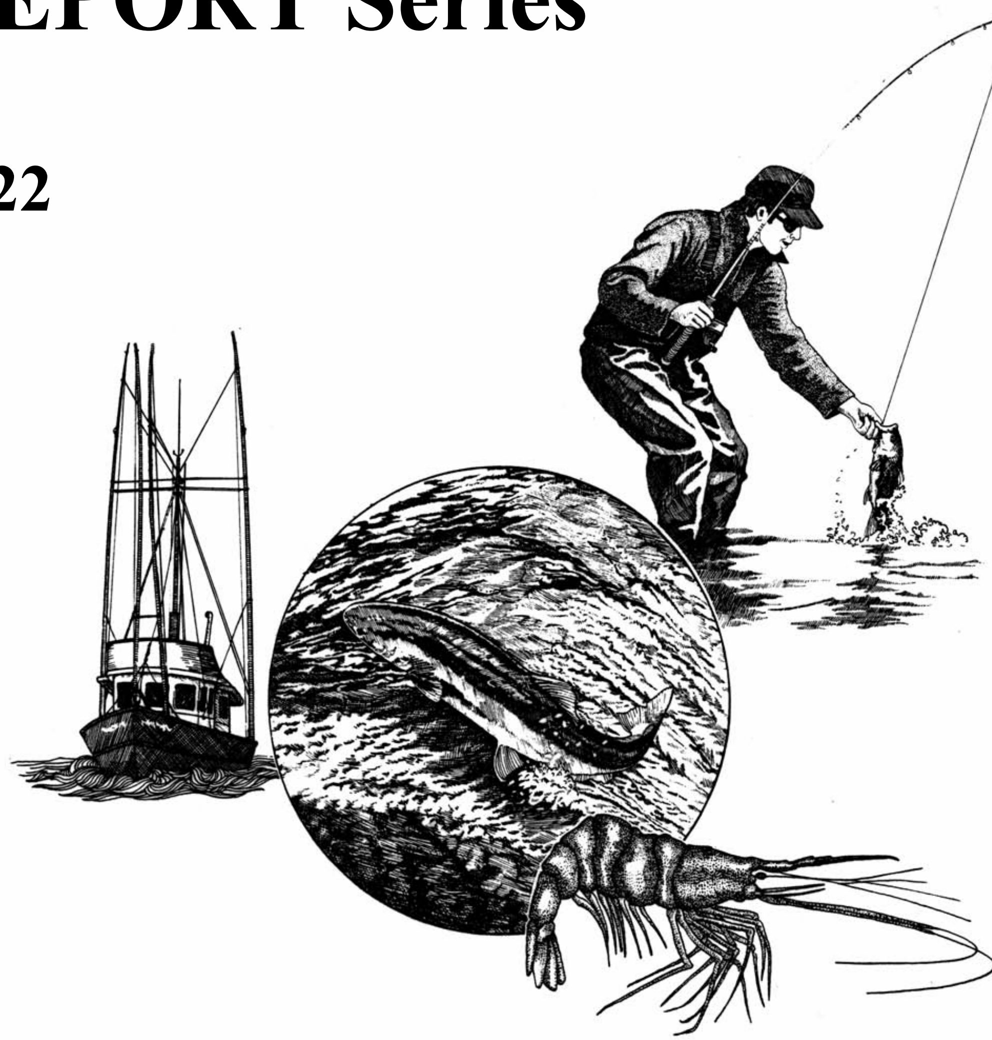
# ODFW PROGRESS REPORT Series

## 2022



## Oregon Department of Fish and Wildlife

2021- Monitoring Report for the Clackamas Focused Investment Partnership.

Number OPSW-ODFW-2022-07
Aquatic Inventories Project

# PROGRESS REPORT FISH RESEARCH PROJECT OREGON

PROJECT TITLE: 2021 Monitoring Report for the Clackamas Focused Investment Partnership

PROJECT NUMBER: OPSW-ODFW-2022-7

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# ABSTRACT

The Oregon Department of Fish and Wildlife's Aquatic Inventories Project (AQI) and UAS (Unoccupied Aircraft System) operations have been tasked by the Clackamas Focused Investment Partnership (FIP) to provide habitat restoration monitoring throughout the Clackamas River basin in support of the Clackamas Partnership Strategic Plan to improve and enhance the river and stream habitat for native fish and wildlife. In 2020 ODFW crews surveyed the entirety of the mainstem Clackamas River to establish a pre-restoration reference. ODFW incorporated several novel technologies to aid with the complexities of monitoring a large-scale non-wadeable river. On-the-ground foot and boat surveys, snorkel surveys, a UAS, and Side Scan Sonar (SSS) were employed to capture and describe habitat conditions at a watershed scale. In 2021 ODFW surveyed eight individual sites; three post-restoration treatments, two proposed for upcoming restoration, and three control sites that will be used to compare the restoration sites. UAS and physical habitat ground surveys were conducted to capture typical high-water conditions during the winter. At the end of the summer, we used UAS to capture the lowest water stream conditions and snorkel surveys to identify fish use and assemblage. Native fish observations in 2021 were less frequent throughout the basin compared to those in 2020, while warmer water temperatures and non-salmonid species were present at nearly every site. In addition, non-native species were observed within our current, furthest downstream sites in the basin (Lower Control Channel and Riverbend). We used a simple linear regression to show the UAS surveys adequately described winter habitat area ($R^2 = 0.97$, p-value < 0.05), and t-tests showed differences in winter habitat area when compared to summer habitat area in those sites with the most secondary channels or off-channel habitat types (p-value < 0.05). Sites that were dominated by a single, primary channel did not show a significant habitat area change between seasons (p-value > 0.05). Across all sites where restoration occurred and control sites, t-test results by habitat attribute showed change was not significant one-year post-restoration (p-value > 0.05). The HabRate model suggests habitats across surveyed locations were generally fair for all life history types. Comparisons of the metrics collected from the mainstem Clackamas River, the pre-and post-restoration sites, and the control sites will allow an evaluation of habitat changes and effectiveness resulting from restoration efforts.

# BACKGROUND

The Oregon Department of Fish and Wildlife's Aquatic Inventories Project (AQI) and UAS operations provide monitoring support for the Clackamas Focused Investment Partnership (FIP) to describe the quality and quantity of restored or enhanced habitat. Proposed restoration sites, control channels, and mainstem river surveys will be used to evaluate restoration influence and effectiveness at the individual site, reach, and basin scale. In the Spring of 2020, ground-based habitat surveys and Side Scan Sonar (SSS) surveys were conducted on the mainstem Clackamas River to establish a pre-restoration baseline, along with ground-based surveys on proposed restoration sites. Mainstem surveys will occur again after a five-year interval to document any habitat change associated with restoration treatment across defined reaches and within the basin.

In 2021, habitat surveys were conducted within proposed restoration sites, primarily in March and April, before prescribed restoration. Snorkel surveys were conducted in July. UAS aerial surveys occurred in March, September, and October. The use of a Side Scan Sonar was not practical for surveying the proposed restoration sites as those sites were primarily composed of side channels and tributaries. However, the Side Scan Sonar will be used in the five-year post-restoration mainstem surveys to capture and quantify substrates and depths.

This report aims to provide a background for monitoring habitat and to describe the methods used to assess the varying habitat types. Data provided should be viewed as a base condition for control channels and primary river habitat or pre-treatment conditions for those sites proposed for restoration activity. For each surveyed area within this report, we describe; (1) reach boundaries and general habitat characteristics, (2) channel area and depth profiles, (3) structure and complexity, and (4) general fish species composition.

# METHODS

## Ground Surveys

This report discusses findings from a survey design developed for both wadeable and non-wadeable habitat types. Due to the nature and size of the channels and habitat characteristics, the Aquatic Inventories Project adhered to protocols developed by Moore et al. (2007) within wadeable areas. Attributes collected and summarized at the reach level described channel morphology, substrate composition, instream wood, and fish species. The ground survey summarized results described habitat quality through the HabRate model (Burke et al. 2010). The model generates habitat ratings (1-poor, 2-moderate, or 3-good) for each life stage of anadromous salmonids present in the Clackamas River basin (coho, steelhead, cutthroat trout, and Chinook salmon). Assessments of fish presence were conducted by snorkel surveys and adhered to methods described in Constable et al. (2012).

## UAS Surveys

UAS surveys were used to supplement ground surveys and sonar data. Structure from Motion with Multi-View Stereo (SfM-MVS) reconstruction in Agisoft Metashape was used to create point clouds, Digital Elevation Models (DEM), and orthorectified photo mosaics. DEMs were created from the dense point cloud filtered to only ground points, which could sometimes provide topographic information when obscuring vegetation was present in the orthomosaic. Measurements and counts were made in Agisoft Metashape and ESRI ArcGIS Pro.

## Methods Comparison

We used R software (R Development Core Team 2006) for all analyses. A simple linear regression was used to assess whether habitat area ($m^2$) from winter ground surveys differed from habitat area ($m^2$) generated from winter UAS survey imagery.

$$Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i$$

We then used paired t-tests to describe whether a difference exists between winter habitat area derived from ground surveys and summer habitat area derived from UAS imagery.

## Restoration Assessment

Paired t-tests were also used to assess differences between pre-restoration and post-treatment across habitat metrics.

## STUDY AREA

Three mainstem Clackamas River side-channels (Eagle Creek Complex, Kingfisher, and Riverbend) and one tributary (North Fork Deep Creek) were established for restoration and monitoring below River Mill Dam. Three control sites were selected at distinct locations within the Clackamas basin to monitor secondary channels not associated with prescribed restoration. Three tributary streams of the Willamette River were also included in the restoration and monitoring effort: Lower Johnson Creek, Abernethy Creek, and Newell North Stream (Figure 1).

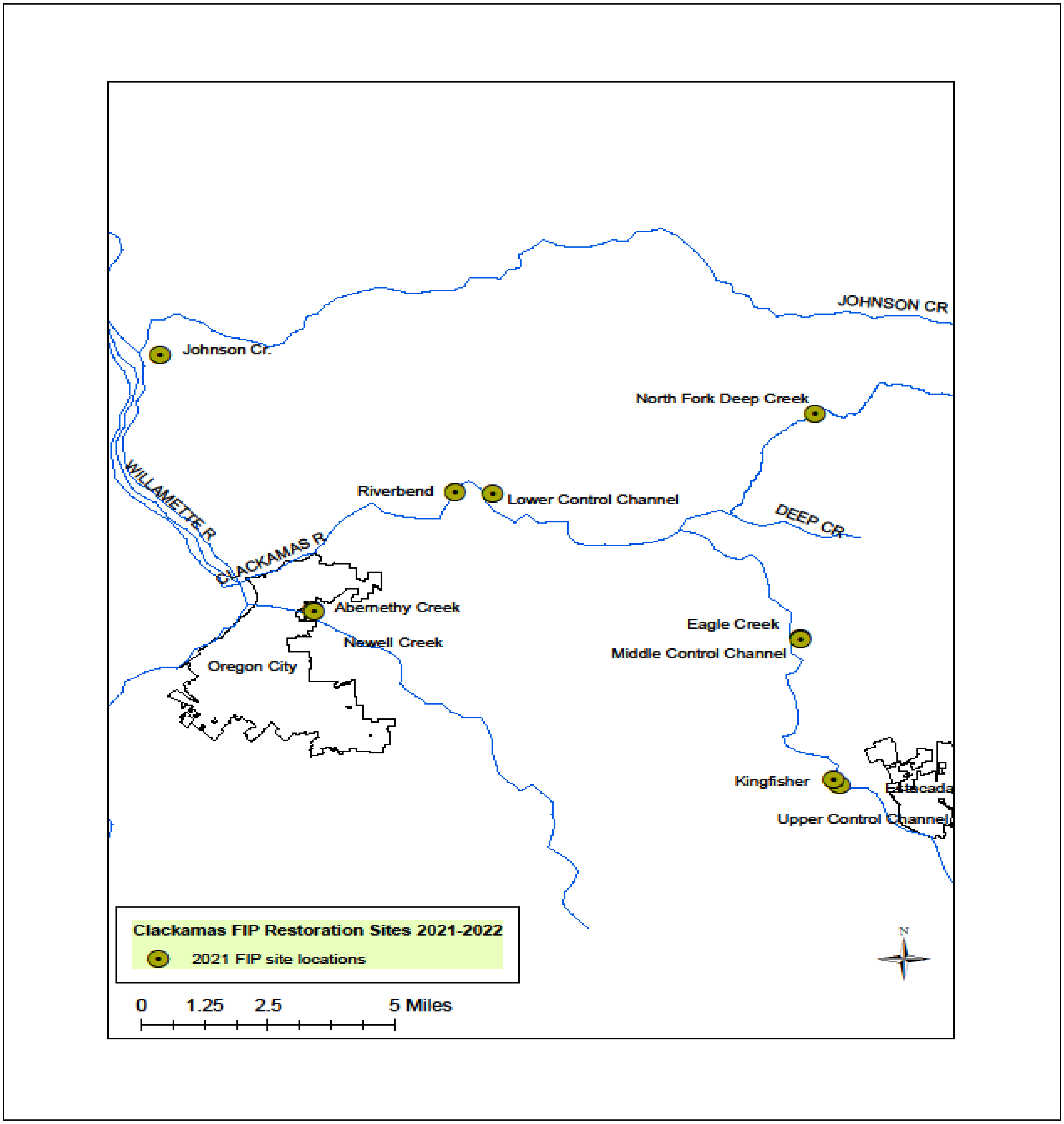


Figure 1. Clackamas FIP study area and monitoring sites.

## Kingfisher Side-Channel

The Kingfisher Side Channel is located on the west side of the Clackamas River main channel, immediately adjacent to the Upper Control Channel. Figures 2 and 3 show the Kingfisher Side Channel during the winter and summer of 2021. The Kingfisher Side Channel flows north 534 meters, begins approximately 400 meters downstream of the mouth of Dog Creek, and is accessed through Milo McIver State Park. The Kingfisher Side Channel is constrained to its current channel location due to constraining terraces on either side of the channel. A valley width index (VWI) suggests the active channel could potentially move 20 times between hillslope toes.

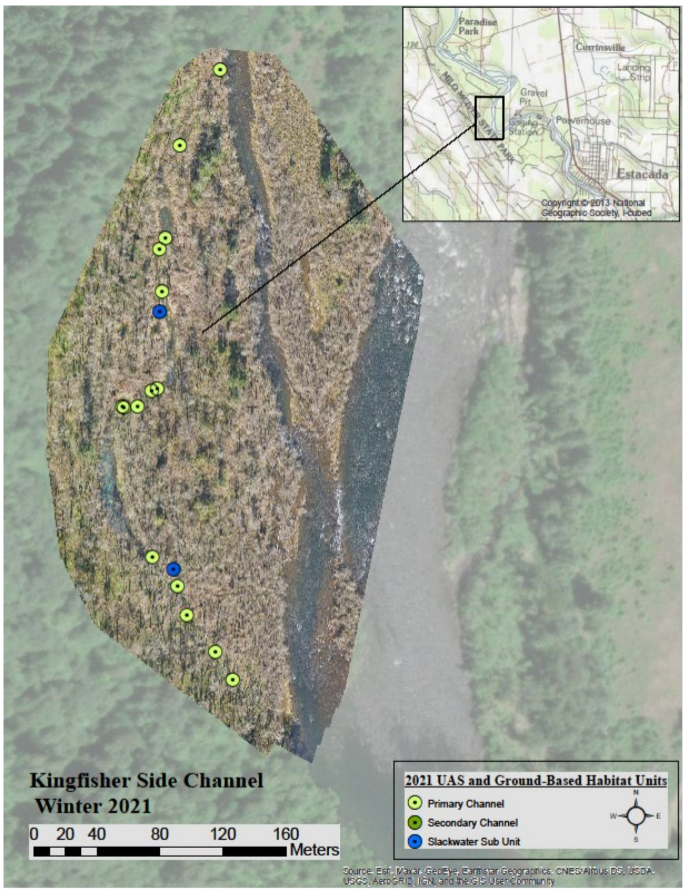


Figure 2. Kingfisher side-channel. Winter 2021 UAS imagery and ground-based survey points pre-restoration.

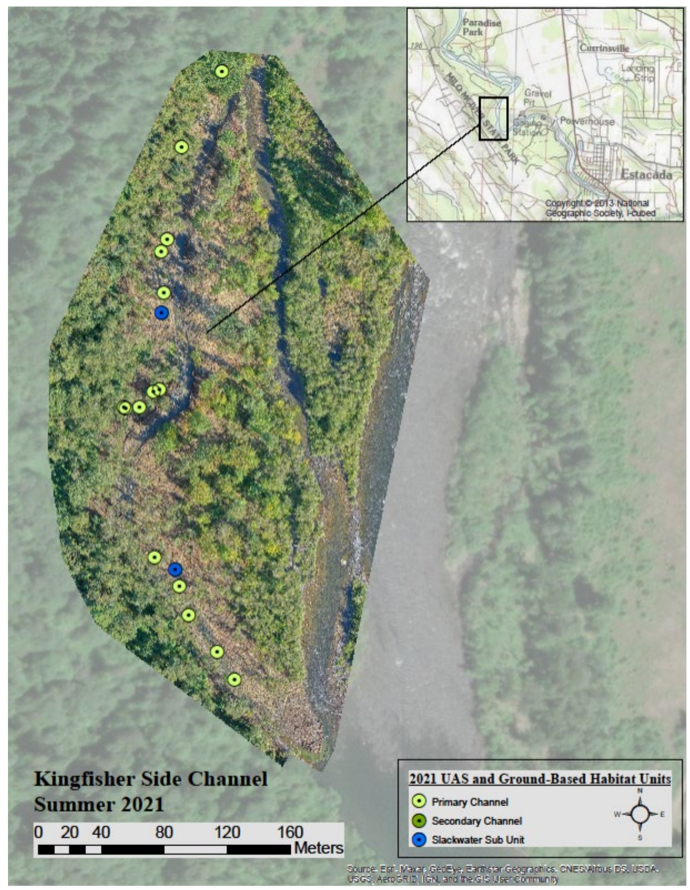


Figure 3. Kingfisher side-channel. Summer 2021 UAS imagery and ground-based survey points post-restoration.

## Upper Control Channel

The Upper Control Channel is located on the east side of the Clackamas River main channel, immediately adjacent to the Kingfisher Side Channel. Figures 4 and 5 show the Upper Control Channel during the winter and summer of 2021. The Upper Control Channel flows north 164 meters and begins approximately 400 meters downstream of the mouth of Dog Creek and is accessed through Milo McIver State Park. The Upper Control Channel is primarily constrained to its current channel location due to a high constraining island terrace to the west and a steep hillslope on the east. These features limit the available lateral movement of the channel to 30 meters.

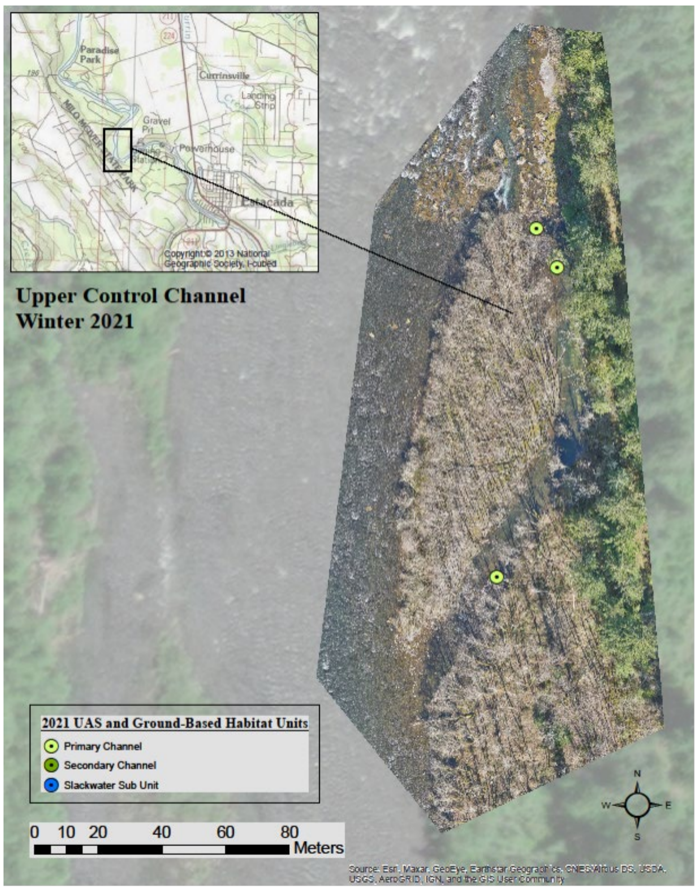


Figure 4. Upper Control Channel. Winter 2021 UAS imagery and ground-based survey points.

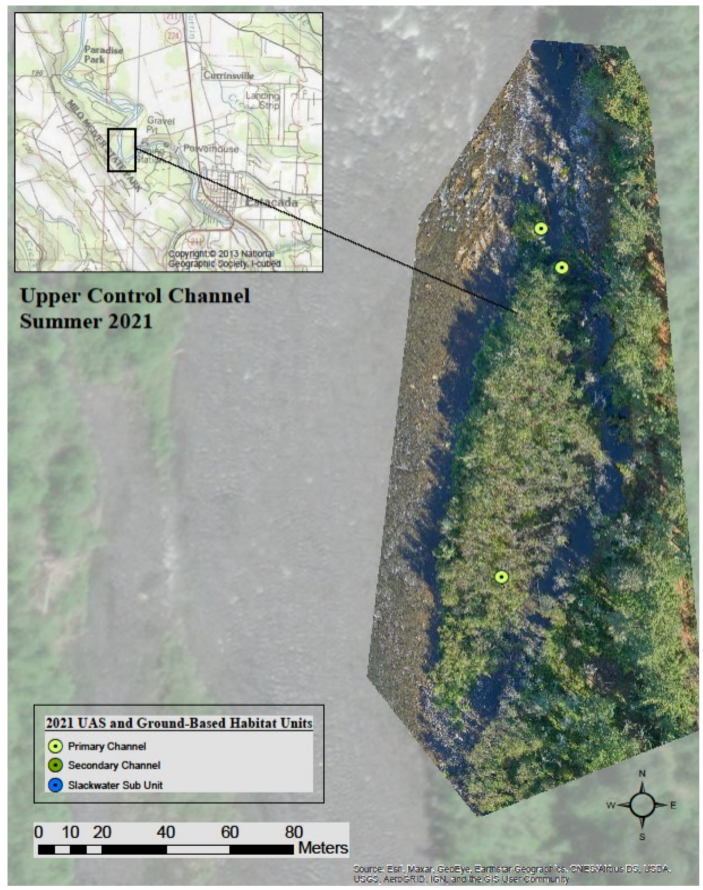


Figure 5. Upper Control Channel. Summer 2021 UAS imagery and ground-based survey points.

## Eagle Creek Complex

The Eagle Creek Complex started at the confluence with the Clackamas River and extended approximately 0.5 kilometers upstream to an endpoint just west of a bridge at SE Dowty Road. The primary channel flowed westerly and entered a secondary channel of the Clackamas River in the southwest section of the study area; two secondary channels split off and flowed primarily northwest and entered the same Clackamas secondary channel further downstream in the northwest section of the study area. The entire complex occurs entirely within Bonnie Lure State Recreation Area (Figures 6 and 7). The Eagle Creek Complex is constrained mainly by terraces, and the primary channel could move approximately 200 meters across the valley floor.

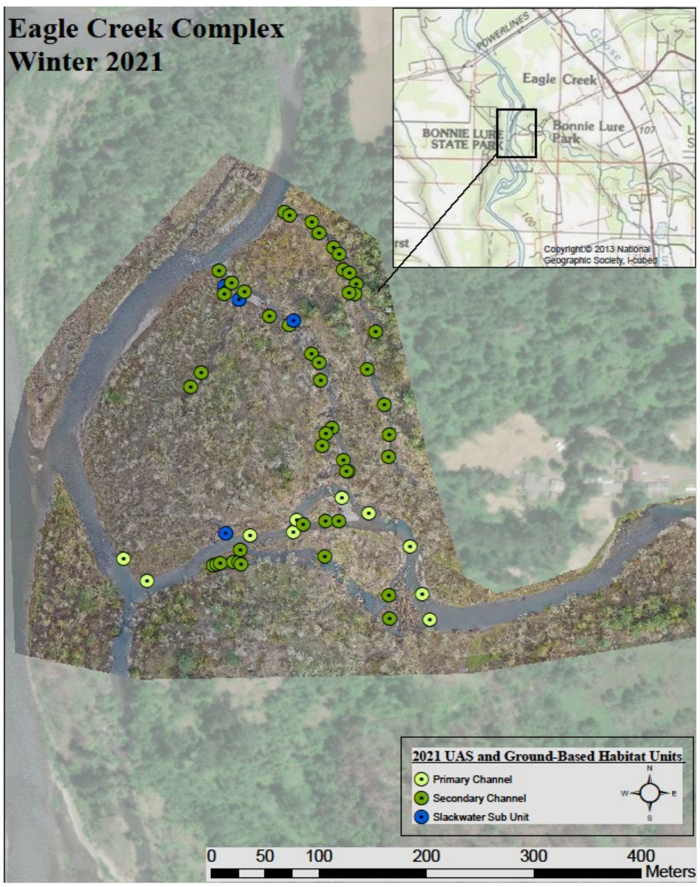


Figure 6. Eagle Creek Complex. Winter 2021 UAS imagery and ground-based survey points pre-restoration.

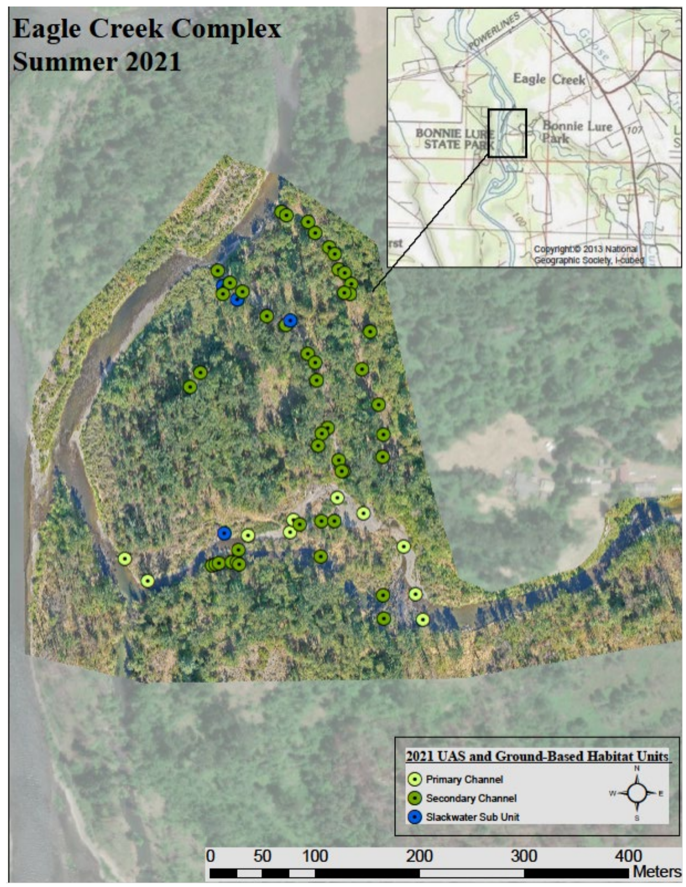


Figure 7. Eagle Creek Complex. Summer 2021 UAS imagery and ground-based survey points post-restoration.

## Middle Control Channel

The Middle Control Channel is located on the east side of the Clackamas River main channel and flows north 318 meters to form the southwest boundary of the Eagle Creek Complex. Figures 8 and 9 show the Middle Control Channel during the winter and summer of 2021. The Middle Control Channel flows entirely within Bonnie Lure State Recreation Area. Potential movement of the Middle Control Channel is restricted to 220 meters of movement between the main channel of the Clackamas River to the west and the hillslope to the east.

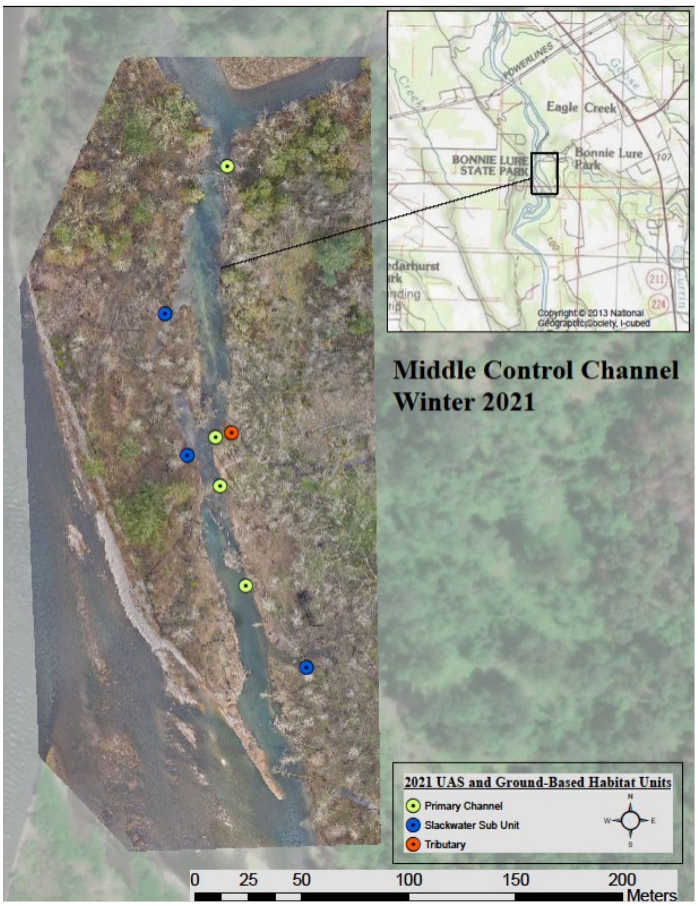


Figure 8. Middle Control Channel. Winter 2021 UAS imagery and ground-based survey points.

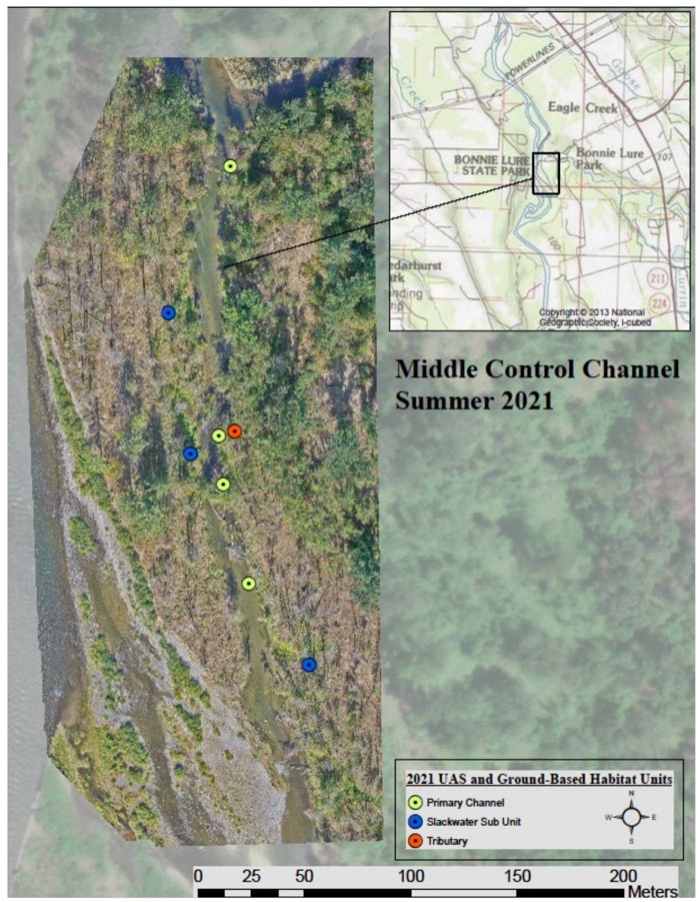


Figure 9. Middle Control Channel. Summer 2021 UAS imagery and ground-based survey points.

## Riverbend Side Channel

Riverbend Side Channel is located on the west bank of the Clackamas River between Carver Park and Riverside Park. The top end of the Riverbend Side Channel is approximately 1.5 kilometers downstream of the Lower Control Channel. Figures 10 and 11 show the Riverbend Side Channel during the winter and summer of 2021. The primary channel flows southwest for 620 meters. The Riverbend Side Channel is unconstrained with a broad flood plain and can be inundated by high flow events. A valley width index (VWI) suggests the active channel could potentially move 20 times between hillslope toes.

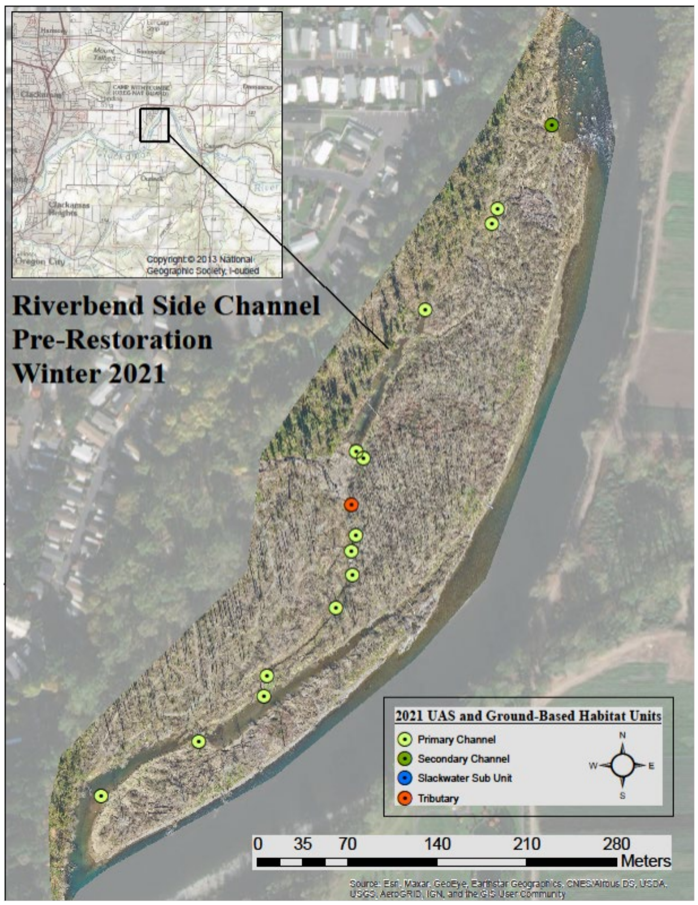


Figure 10. Riverbend Side-Channel. Winter 2021 UAS imagery and ground-based survey points.

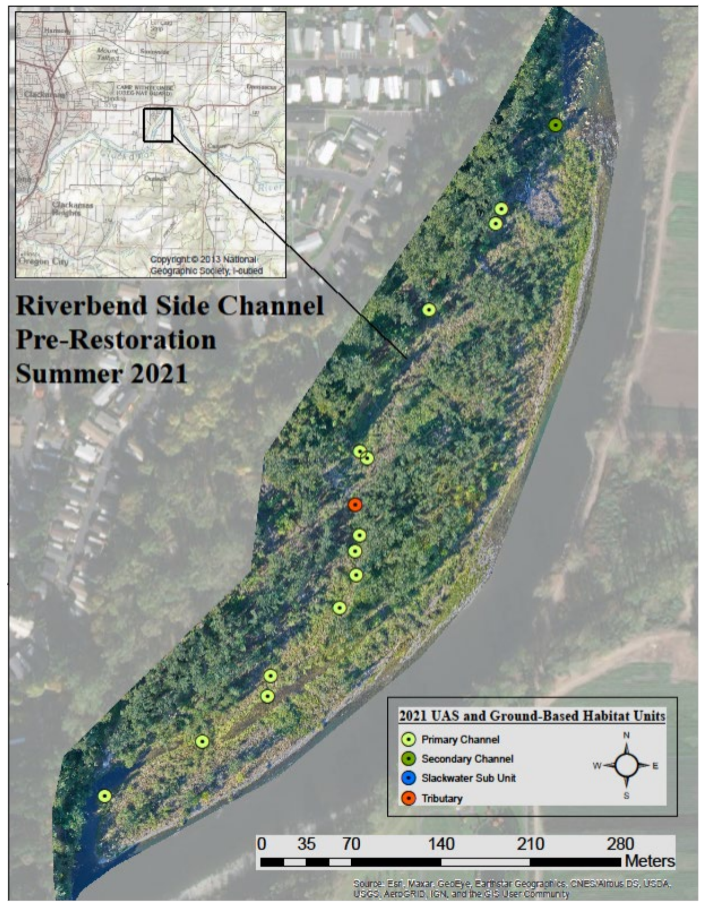


Figure 11. Riverbend Side-Channel. Summer 2021 UAS imagery and ground-based survey points.

## Lower Control Channel

The Lower Control Channel is located approximately 1 kilometer downstream of the Carver Bridge on the southwest side of the Clackamas River primary channel. Figures 12 and 13 show the Lower Control Channel during the winter and summer of 2021. Most of the Lower Control Channel flows northwest into a large alcove, while a single, small secondary channel flows northeast back to the Clackamas main channel. Potential movement of the Lower Control Channel is limited to 80 meters between a high constraining terrace on the west bank and the main channel of the Clackamas River.

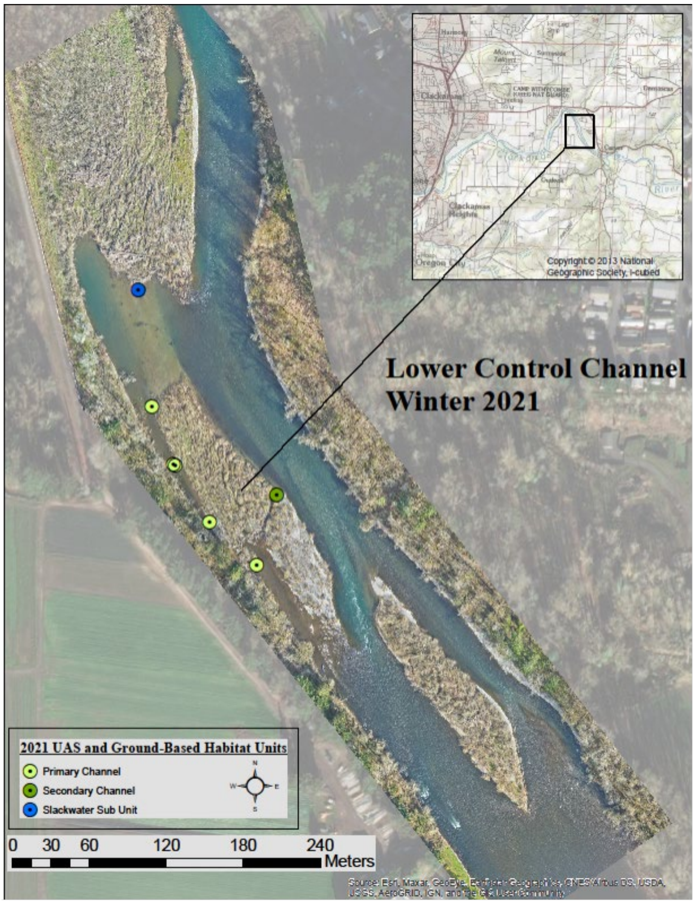


Figure 12. Lower Control Channel. Winter 2021 UAS imagery and ground-based survey points.

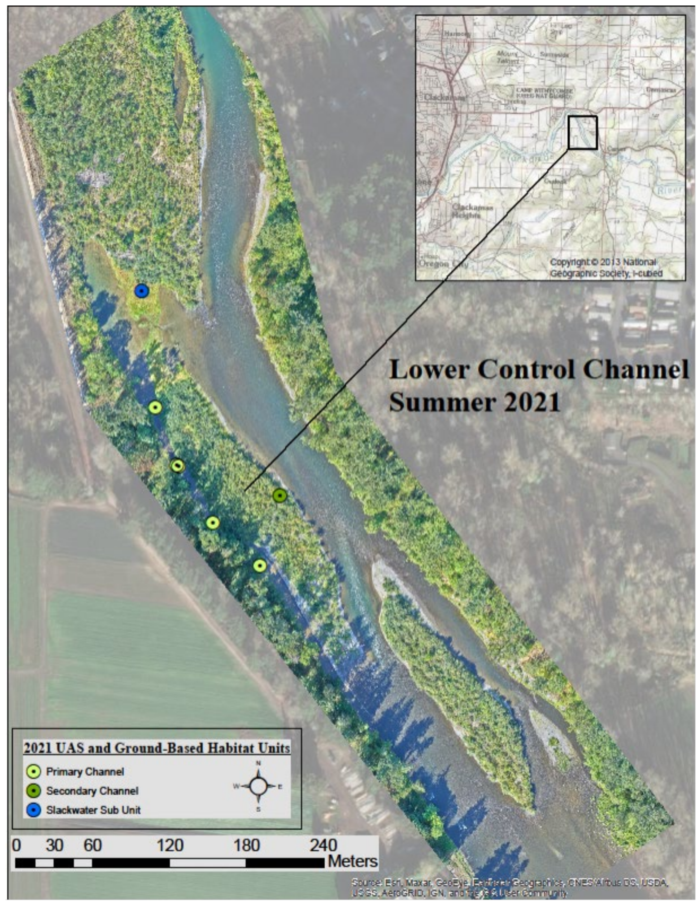


Figure 13. Lower Control Channel. Summer 2021 UAS imagery and ground-based survey points.

## Johnson Creek

The Lower Johnson Creek Habitat Enhancement site is located within the city of Milwaukie. Johnson Creek flows south for 228 meters within the site boundaries and is bound to the east by Highway 99. Figures 14 and 15 show Johnson creek during the winter and summer of 2021. The site is crossed by Highway 224 near the beginning of the survey. High terraces on each bank constrain the Johnson Creek channel. A valley width index (VWI) suggests the active channel could potentially move more than 20 times between hillslope toes. Current land use and existing structure will likely keep Johnson Creek in its present channel location.

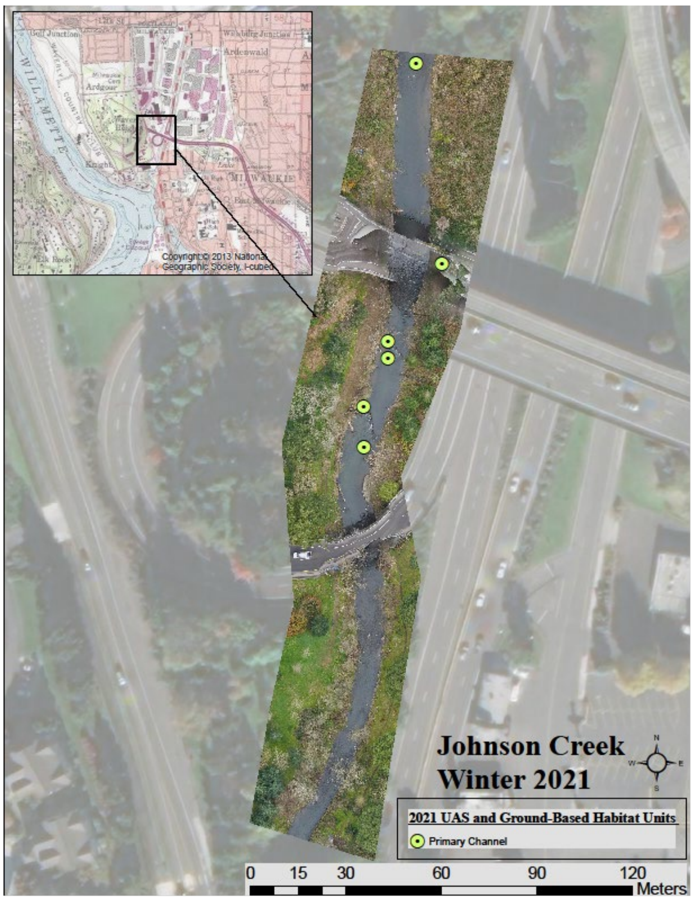


Figure 14. Johnson Creek. Winter 2021 UAS imagery and ground-based survey points.


Figure 15. Johnson Creek. Summer 2021 UAS imagery and ground-based survey points.

## Abernethy Creek

Abernethy Creek is a tributary of the Willamette River. It is located outside Oregon City and is part of the North Newell Stream restoration effort (Figure 16). Abernethy Creek flows west for 522 meters within the site boundaries and is bound to the north by South Redland Road. The site is crossed by Highway 213 near the beginning of the survey. Abernethy Creek is constrained to its current channel location due to constraining terraces on either side of the channel. A valley width index (VWI) suggests the active channel could potentially move 14 times between hillslope toes. However, this is unlikely due to current land use and surrounding infrastructure.

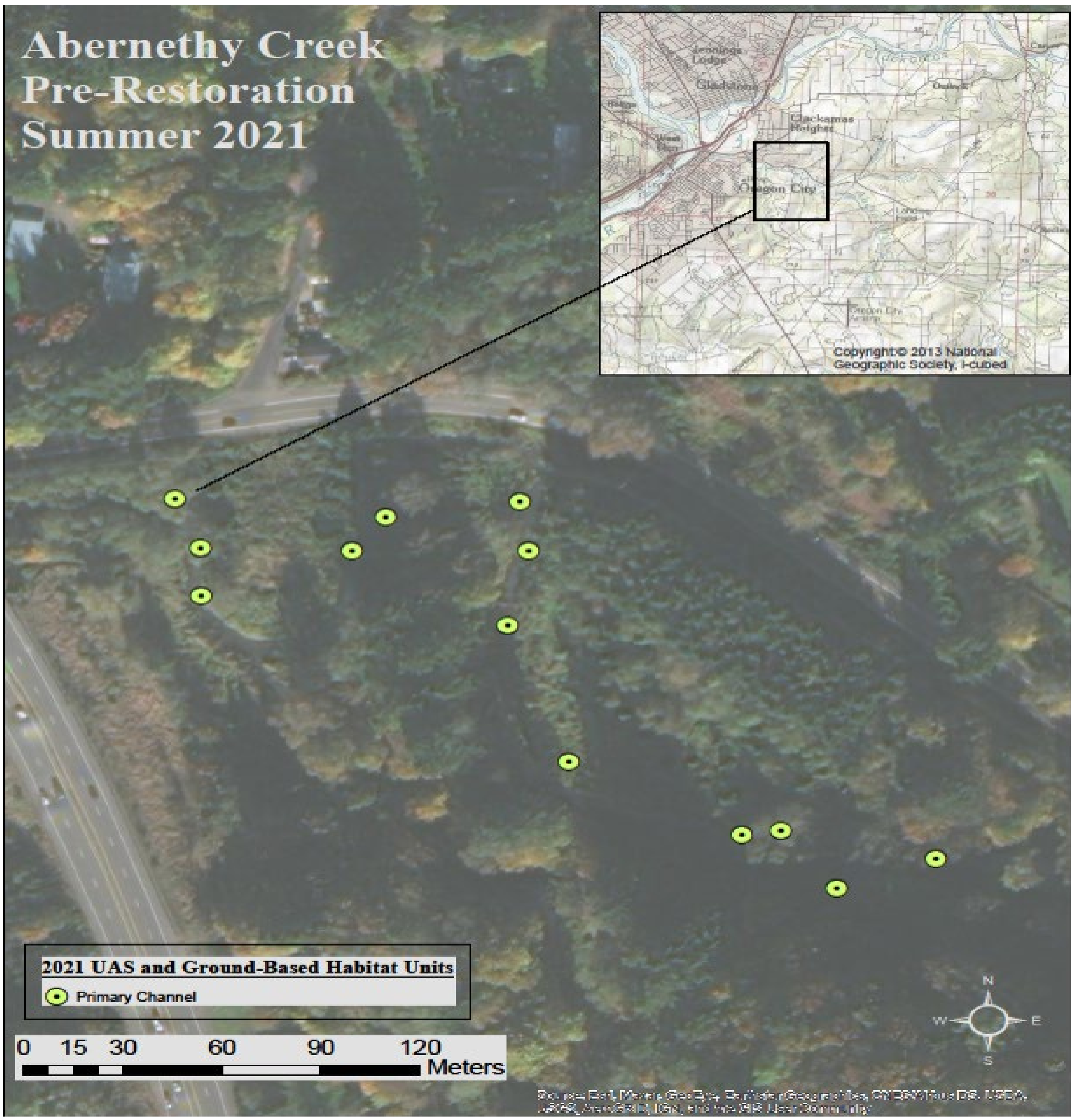


Figure 16. Abernethy Creek. Winter 2021 ground-based survey points. (ESRI World Imagery).

## Newell Creek North Stream

Newell Creek is a tributary of Abernethy Creek. Within the site, the creek flows 1,439 meters in a northerly direction. Newell Creek is bound to the west by Highway 213 (Figure 17). Newell Creek is constrained to its current channel location due to constraining terraces on either side of the channel. A valley width index (VWI) suggests the active channel could potentially move 8.3 times between hillslope toes.

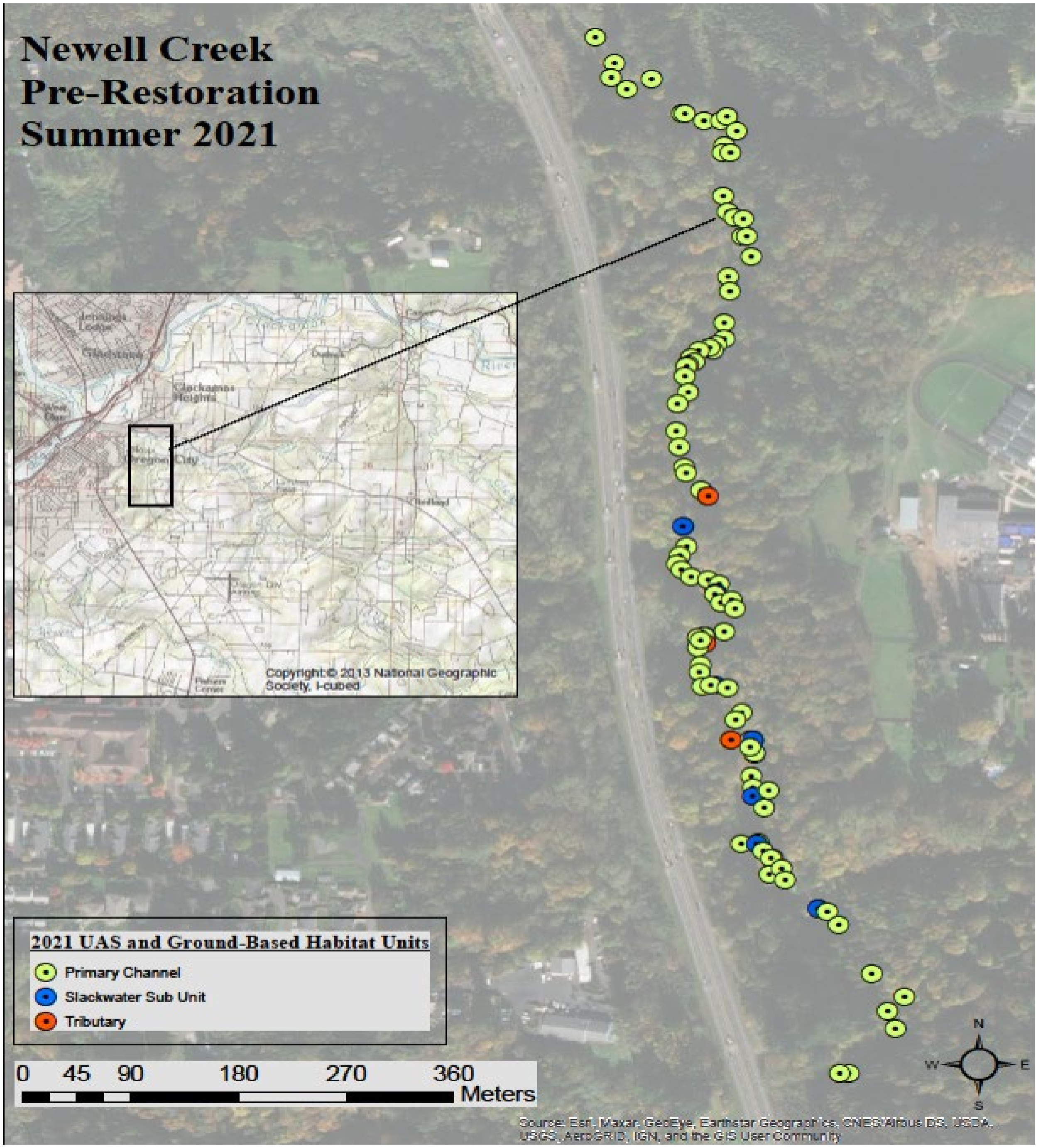


Figure 17. Newell Stream North. Winter 2021 ground-based survey points. (ESRI World Imagery).

## Cazadero (North Fork Deep Creek)

The Cazadero North Stream and Wetland Restoration Project are within the North Fork of Deep Creek. The site occurs entirely within land owned by Portland Metro and flows southwest within the upper extent of the site, bound by a culvert under Richie Rd (Figure 18). The west side of the site is bordered by the Cazadero Trail adjacent to the town of Boring, OR. High terraces on each bank constrain the Cazadero site. A valley width index (VWI) suggests the active channel could move 16 times between hillslope toes, although this is highly unlikely due to current land use and existing structure.

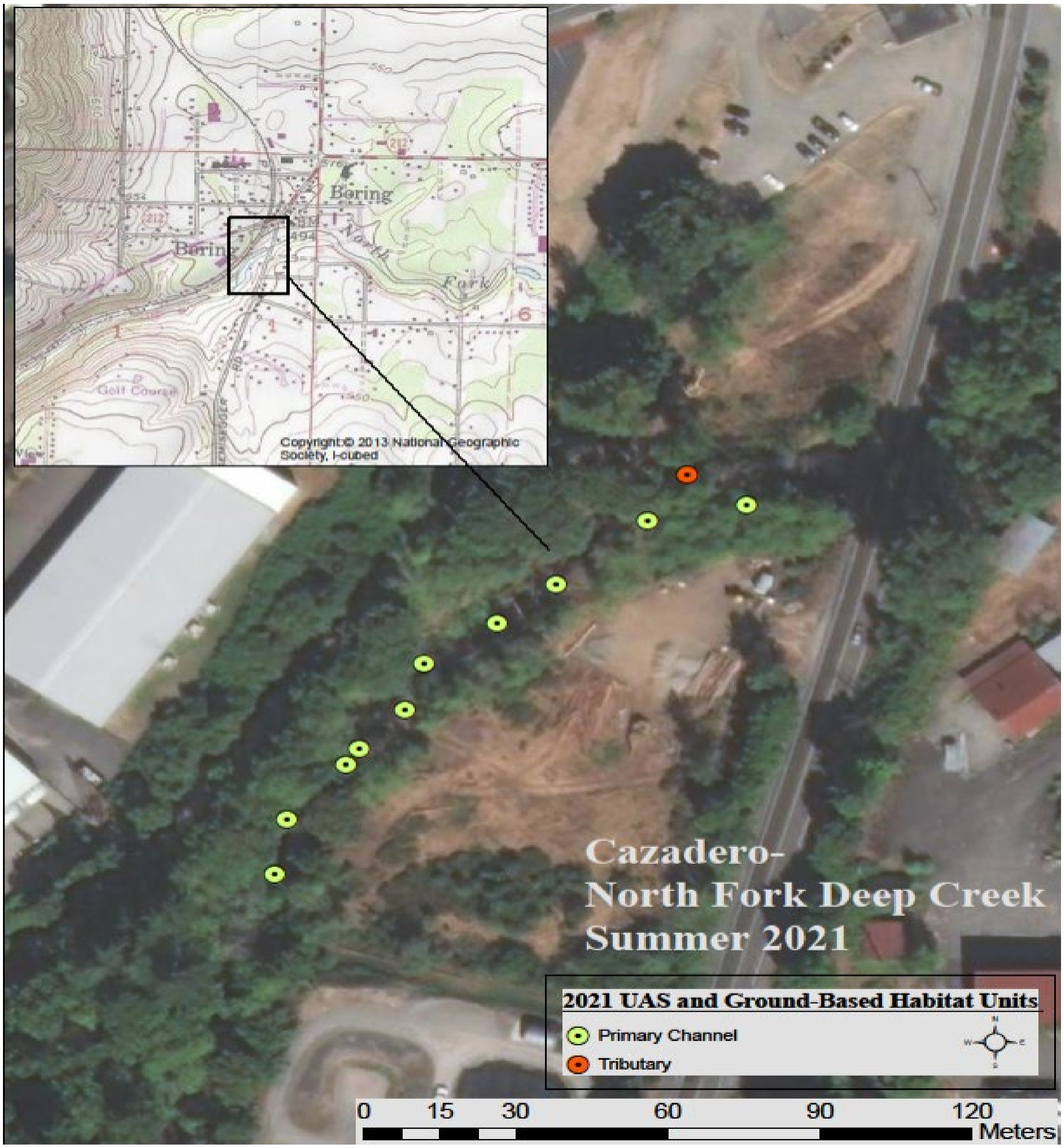


Figure 18. Cazadero (North Fork Deep Creek). Winter ground-based survey points. (ESRI World Imagery).

# RESULTS

## Ground and UAS Surveys

### Kingfisher Side-Channel

A UAS survey was conducted on October 5, 2020, to capture pre-restoration summer conditions. An on-the-ground physical habitat survey and a UAS survey were conducted on March 16, 2021, to capture pre-restoration winter flow conditions. A UAS summer post-restoration survey occurred on September 21, 2021. The Kingfisher Channel contained no secondary channel habitat (Table 1), but 82.03% of the primary channel consisted of scour pool habitat (Table 2). Overall large wood volume throughout the channel was 35.02 $m^3$ (Table 2) or 6.56 $m^3$ per 100 meters of primary channel length when standardized. One key piece (≥ 12 m in length and ≥ 60 cm in diameter) was measured. Observed substrate types throughout the Kingfisher Channel were primarily composed of fine substrates (47.87%), cobble (23.35%), gravels, and boulders, each made up over (14%) (Table 3).

The UAS images show distinct variations in habitat surface area between the summer and winter seasons (Figures 2 and 3) (Table 9). UAS imagery shows that the channel is completely inundated with water during expected winter flows (Figure 2). During summer flows, the UAS imagery shows that the presence of the tree canopy obscures much of the observable surface area (Figure 3). The ground-filtered DEM layer aided in establishing channel boundaries when canopy cover obscured areas on the orthomosaic. An on-the-ground habitat survey was conducted and did provide details on the unit boundaries and depths and provided a secondary verification.

The habitat rating of the Kingfisher Side Channel was poor-moderate before restoration activity across salmonid life history types based on the HabRate model (Burke et al. 2010). Species-specific averages across life history types ranged from 1.2 (steelhead) to 1.75 (cutthroat trout) (Tables 5, 6, 7, 8).

### Upper Control Channel

To capture winter flow conditions, an on-the-ground physical habitat survey and a UAS survey were conducted on March 15, 2021. An on-the-ground physical habitat survey and a UAS survey to capture summer flow conditions occurred on September 21, 2021 (Table 9). The Upper Control Channel contained no secondary channel habitat (Table 1), and 61.01% of the primary channel was scour pool habitat (Table 2). Overall large wood volume throughout the channel was 0.44 $m^3$ (Table 2) or 0.30 $m^3$ per 100 meters of primary channel length when standardized. No key pieces (≥ 12 m in length and ≥ 60 cm in diameter) were measured. Observed substrate types throughout the Upper Control Channel were primarily composed of cobble (43.19%), gravels and boulders, each made up over (19%), bedrock, and fine substrates made up just over (9%) each (Table 3).

The UAS images show minor variations in habitat surface area between the summer and winter seasons (Figures 4 and 5) (Table 9). The Upper Control Channel has good connectivity to the Clackamas mainstem and, as a result, has minimal habitat loss between the winter and summer seasons. UAS imagery shows that the channel is completely inundated with water during expected winter flows (Figure 4). During summer flows, the UAS imagery shows that the presence of the tree canopy obscures much of the observable surface area (Figure 5). The ground-filtered DEM layer aided in establishing channel boundaries when canopy cover obscured areas on the orthomosaic. An on-the-ground habitat survey was conducted and did provide details on the unit boundaries and depths and provided a secondary verification.

On July 15, 2021, a snorkel survey was conducted, and during the survey, 100% of the available pool habitat was snorkeled, and only dace were observed (Table 4). The habitat rating of the Upper Control Channel was poor-moderate across salmonid life history types based on the HabRate model (Burke et al. 2010). Species-specific averages across life history types ranged from 1.25 (cutthroat trout) to 2.3 (Chinook). Habitat quality decreased slightly for Chinook between 2020 and 2021 and remained the same for steelhead, coho, and cutthroat (Tables 5, 6, 7, 8). This is likely attributed to a single large pool unit with good depth and undercut banks and the presence of cold-water seeps, which provided a thermal refuge during high summer temperatures.

## Eagle Creek Complex

A UAS survey was conducted on May 8 and October 1, 2020, to capture pre-restoration summer and winter conditions. On March 15, 2021, a third UAS flight was performed to capture pre-restoration winter flow conditions. An on-the-ground physical habitat survey was conducted on March 23, 2021. More than 40% of the complex area was secondary channel habitat (Table 1), and 38.5% was pool habitat across all channel types (Table 2). Overall large wood volume throughout the complex was 576.12$m^3$ (Table 2) or, when standardized, 104.9 $m^3$ per 100 meters of primary channel length. In addition, 22 key pieces (≥ 12 m in length and ≥ 60 cm in diameter) were measured throughout the surveyed area. Observed substrate types throughout the complex were primarily composed of gravel (35.60%) and cobble (34.50%), sand made up (19.92%), and boulders accounted for (9.69%) (Table 3).

A snorkel survey was conducted on July 15, 2021, and over 45% of the available pool habitat was snorkeled (Table 4). Observations included: juvenile coho, juvenile Chinook salmon, cutthroat trout, and trout fry. Dace, shiner, northern pikeminnow, rainbow trout, and suckers were also observed. The habitat rating of the Eagle Creek Complex was moderate-good before restoration activity across salmonid life history types based on the HabRate model (Burke et al. 2010). Species-specific averages across life history types ranged from 2.25 (cutthroat trout) to 2.6 (coho). Following restoration, the HabRate model suggests habitat quality is poor-fair across species life history types. The drop in habitat quality and salmonid observations could be related to the high summer heat and warm water temperatures. As well as a rerouting of the primary and secondary channel flow characteristics resulting in dry secondary channels and a loss of summer pool habitat compared to pre-restoration. Species-specific averages across life history types ranged from 1.6 (Chinook salmon) to 2.25 (cutthroat trout). Habitat quality decreased overall following restoration for Chinook, steelhead, and coho life histories, and remained the same for cutthroat trout (Tables 5, 6, 7, 8).

A UAS, post-restoration, summer conditions survey occurred on September 21, 2021. The stream habitat surface area observed within the Eagle Creek Complex with the UAS varied dramatically between the summer and winter seasons (Figures 6 and 7) (Table 9). Some of the changes were due to the emergence of the tree canopy during the summer surveys, which resulted in a lack of visual penetration with the UAS camera (Figure 7). The use of image filters within the UAS, DEM layer did aid in the ability to see through the canopy and establish channel boundaries; however, it was challenging to acquire distinct edge boundaries and surface area of habitat units on densely treed secondary side-channel units using the UAS due to leaf canopy obstructions. An on-the-ground habitat survey was conducted and did provide details on the unit boundaries and depths and provided a secondary verification.

In the Eagle Creek Complex, it is evident from the UAS imagery that seasonal flows contribute significantly to the available stream habitat surface area. The UAS imagery shows that the primary and secondary channels are completely inundated with water during the winter flows (Figure 6). The UAS imagery shows that the primary and secondary channels are dramatically affected by the lack of flow during the summer months (Figure 7).

## Middle Control Channel

A UAS survey was conducted on March 15, 2021, to capture winter flow conditions. An on-the-ground physical habitat survey was conducted on March 23, 2021. Secondary channel habitat accounted for 15% of the Middle Control Channel (Table 1), and pools accounted for 69% of habitat across all channel types (Table 2). Overall large wood volume throughout the channel was 31.30 $m^3$ (Table 2) or, when standardized, 10.57 $m^3$ per 100 meters of primary channel length. No key pieces (≥ 12 m in length and ≥ 60 cm in diameter) were measured. Observed substrate types throughout the Middle Control Channel were primarily composed of fine sediments (33.40%), cobble (30.10%), gravels (24.91%), and boulders made up (11.57%) (Table 3).

A UAS survey occurred on September 21, 2021, to capture summer flow conditions. The UAS images show minor variations in habitat surface area between the summer and winter seasons (Figures 8 and 9) (Table 9). The Middle Control Channel has good connectivity to the Clackamas mainstem and, as a result, has minimal habitat loss between the winter and summer seasons. UAS imagery shows that the channel is inundated with water during expected winter flows (Figure 8). Three slack water sub-units provide off-channel refuge from the fast water units of the primary channel, and a tributary enters from the east. UAS imagery shows the watered channel and drying of the three sub-units during summer flows (Figure 9). The UAS imagery also shows the presence of the tree canopy obscures some of the observable surface area and the tributary. An on-the-ground habitat survey was conducted and verified the unit boundaries and the tributary location.

A snorkel survey was conducted on July 15, 2021, and 84% of the available pool habitat was snorkeled (Table 4). Observations included: dace, shiner, and northern pikeminnow. The habitat rating of the Middle Control Channel was poor-moderate for salmonid use. Species-specific averages across life history types ranged from 1.6 (coho and Chinook) to 1.8 (steelhead). Habitat quality remained the same across sampling years for nearly all species' life histories, with a slight decrease for cutthroat trout (Tables 5, 6, 7, 8). Several alcoves, a tributary, and a long pool unit with wood structures are the main attributes of this channel.

## Riverbend Side Channel

An on-the-ground physical habitat survey and a UAS survey were conducted on March 17, 2021, to capture pre-restoration winter flow conditions. An on-the-ground physical habitat survey and a UAS survey to capture summer flow conditions occurred on September 21, 2021. Secondary channel habitat accounted for 4.21% of the Riverbend Side Channel (Table 1), and pools accounted for 82.80% of habitat across all channel types (Table 2). Overall large wood volume throughout the channel was 69.08 $m^3$

(Table 2) or, when standardized, 11.14 $m^3$ per 100 meters of primary channel length. Two key pieces (≥ 12 m in length and ≥ 60 cm in diameter) were measured. Observed substrate types throughout the Riverbend Side Channel were primarily composed of fine sediments (54.46%), gravels (24.11%), cobble (19.27%), and boulders made up (2.14%) (Table 3).

Within the Riverbend Side Channel, the amount of usable stream habitat surface area observed with the UAS varies slightly between the summer and winter seasons (Figures 10 and 11) (Table 9). Some of the surface area changes can be attributed to the tree canopy during the summer surveys (Figure 11), which resulted in a lack of visual penetration with the UAS camera. The ground-filtered DEM layer aided in establishing channel boundaries when canopy cover obscured areas on the orthomosaic. An on-the-ground habitat survey was conducted and did provide details on the unit boundaries and depths and provided a secondary verification.

In the Riverbend Side Channel, it is evident from the UAS imagery that expected seasonal flow contributes only slightly to the available stream habitat surface area between the winter and summer seasons (Figures 10 and 11). The UAS images were acquired pre-restoration of the side channel and show that the upper primary and secondary channels of the Riverbend Side Channel do not have connectivity to the mainstem Clackamas during typical flows and are lightly watered to puddled during winter flows (Figure 10) and mainly dry in the summer months (Figure 11).

A snorkel survey was conducted on July 29, 2021, and 68% of the available pool habitat was snorkeled (Table 4). Observations included: dace, northern pikeminnow, bluegill, smallmouth bass, bullfrog tadpoles, and rough-skinned newts. The habitat rating of the Riverbend Side Channel was poor-moderate before restoration activity across salmonid life history types based on the HabRate model (Burke et al. 2010). Species-specific averages across life history types ranged from 1.3 (coho) to 2.0 (cutthroat trout) (Tables 5, 6, 7, 8). A lack of connectivity to the mainstem, lack of overhead shade, and warm water temperatures may compound the poor ranking associated with the available habitat.

## Lower Control Channel

An on-the-ground physical habitat survey and a UAS survey were conducted on March 17, 2021, to capture winter flow conditions. An on-the-ground physical habitat survey and a UAS survey to capture summer flow conditions occurred on September 21, 2021. Secondary channel habitat accounted for 3.7% of the Lower Control Channel (Table 1), and pool habitat accounted for 76.38% across all channel types (Table 2). Overall large wood volume throughout the channel was 50.63 $m^3$ (Table 2) or, when standardized, 21.04 $m^3$ per 100 meters of primary channel length. In addition, two key pieces (≥ 12 m in length and ≥ 60 cm diameter) were measured. The Lower Control Channel habitat was primarily composed of fine sediments (59.56%), with a mix of cobble substrate (20.45%) and gravels (16.63%) (Table 3).

The UAS images show minor variations in habitat surface area between the summer and winter seasons (Figures 12 and 13) (Table 9). The Lower Control Channel sits at a slightly higher elevation than the wetted channel of the Clackamas mainstem. In typical winter flows, the channel is inundated with water (Figure 12). During summer flows, much of the mainstem flow is directed away from the control channel, reducing habitat surface area, most notably in the large Alcove unit at the bottom end of the control channel and the secondary channel, which is nearly dry (Figure 13). During the summer UAS survey, the presence of the tree canopy made it challenging to observe distinct edge boundaries of several habitat units. The ground-filtered DEM layer aided in establishing channel boundaries when canopy cover obscured areas on the orthomosaic. An on-the-ground habitat survey was conducted and did provide details on the unit boundaries and depths and provided a secondary verification.

In the Lower Control Channel, it is evident, based on the UAS imagery, that seasonal flows contribute to the available stream habitat surface area (Figures 12 and 13) (Table 9). The UAS imagery shows that the primary and secondary channels are completely inundated with water during the winter flows (Figure 12). As shown in Figure 13, the primary and secondary channels are dramatically affected by the lack of flow during the summer months, and the available habitat surface area is significantly reduced.

On July 15, 2021, a snorkel survey was conducted, during which 100% of the available pool habitat was snorkeled (Table 4). Observations included: dace, shiner, northern pikeminnow, and pumpkinseed sunfish. The habitat rating of the Lower Control Channel was moderate-good for salmonid use across species life history types based on the HabRate model (Burke et al. 2010). Species-specific averages across life history types ranged from 2.0 (coho and Chinook) to 2.4 (steelhead). Habitat quality increased across sampling years for Chinook and coho life histories and remained the same for steelhead and cutthroat trout (Tables 5, 6, 7, 8). Good connectivity to the mainstem, overhead shade, available wood structure, and a large alcove provide opportunities for rearing and refuge.

### Johnson Creek

An on-the-ground physical habitat survey and a UAS survey were conducted on March 30, 2021. A UAS survey was completed on October 7, 2021, to capture low flow conditions. The Johnson Creek site contained no secondary channel habitat (Table 1), and the site also had no pool habitat (Table 2). Large wood volume accounted for 5.69 $m^3$ (Table 2) or, when standardized, 2.49 $m^3$ per 100 meters of primary channel length. The Johnson Creek site substrate was primarily composed of gravel (45.61%), with a mix of cobble (27.78%), boulder substrate (11.55%), and fine sediments (15.03%) (Table 3).

The UAS images show minor variations in habitat surface area between the summer and winter seasons (Figures 14 and 15) (Table 9). The UAS imagery shows that the channel is completely inundated with water during typical winter (Figure 14) and summer flows (Figure 15). The emergence of the summer foliage does obscure some of the UAS capabilities to image the unit boundaries. The ground-filtered DEM layer aided in establishing channel boundaries when canopy cover obscured areas on the orthomosaic. An on-the-ground habitat survey was conducted and did provide details on the unit boundaries and depths and provided a secondary verification.

A snorkel survey was not conducted in Johnson creek due to water quality and health concerns related to the nearby highway and streamside tent encampments. The habitat rating for Johnson Creek was moderate-good for salmonid use across species life history types based on the HabRate model (Burke et al. 2010). Species-specific averages across life history types ranged from 1.3 (coho) to 2.3 (Chinook). Habitat quality improved following restoration for Chinook and steelhead life histories, decreased slightly for coho, and remained the same for cutthroat trout (Tables 5, 6, 7, 8).

## Abernethy Creek

A physical habitat survey was conducted on April 8, 2021. Abernethy Creek contained no secondary channel habitat (Table 1), and 74.40% of the primary channel consisted of pool habitat (Table 2). Overall large wood volume throughout the channel was 95.25 $m^3$ (Table 2) or, when standardized, 18.24 $m^3$ per 100 meters of primary channel length. One key piece (≥ 12 m in length and ≥ 60 cm in diameter) was measured. Observed substrate types throughout Abernethy Creek were primarily composed of fine substrates (72.29%), gravels (16.73%), cobble (5.98%), and boulders made up (4.98%) (Table 3).

The UAS was not practical for use at this site due to the dense tree canopy and the inability to obtain a useful perspective for capturing high-quality aerial images of the creek.

A snorkel survey was conducted on July 8, 2021, and 37% of the available pool habitat was snorkeled (Table 4). Observations included: dace, shiner, and crayfish. The habitat rating of Abernethy Creek was poor-moderate for salmonid use across salmonid life history types based on the HabRate model (Burke et al. 2010). Species-specific averages across life history types ranged from 1.3 (coho) to 1.8 (steelhead) before restoration occurred (Tables 5, 6, 7, 8).

## Newell Creek North Stream

A physical habitat survey was conducted on April 8, 2021. Newell Creek contained no secondary channel habitat (Table 1), but 51.56% of the primary channel consisted of pool habitat (Table 2). Overall large wood volume throughout the channel was 186.21 $m^3$ (Table 2) or, when standardized, 12.93 $m^3$ per 100 meters of primary channel length. Six key pieces (≥ 12 m in length and ≥ 60 cm in diameter) were measured. Observed substrate types throughout Abernethy Creek were primarily composed of fine substrates (59.26%), gravels (31.90%), cobble (6.70%), and boulders made up (1.58%) (Table 3).

The UAS was not practical for use at this site due to the dense tree canopy and the inability to obtain a useful perspective for capturing high-quality aerial images of the creek.

A snorkel survey was conducted on July 8, 2021. Due to water quality and health concerns related to nearby tent encampments, only 21% of the available pool habitat was snorkeled during the survey (Table 4). Observations included: cutthroat, dace, shiner, sculpin, and crayfish. The habitat rating of Newell Creek was poor-moderate for salmonid use across species life history types based on the HabRate model (Burke et al. 2010). Species-specific averages across life history types ranged from 1.3 (coho) to 2.0 (Chinook) before restoration occurred (Tables 5, 6, 7, 8).

## Cazadero (North Fork Deep Creek)

A physical habitat survey was conducted on March 30, 2021. The Cazadero site contained no secondary channel habitat (Table 1), but over half of the primary channel consisted of pool habitat (57.40%) (Table 2). Overall large wood volume increased significantly throughout the site post-restoration effort, 54.26 $m^3$ (Table 2) or, when standardized, 32.10 $m^3$ per 100 meters of primary channel length. No key pieces (≥ 12 m in length and ≥ 60 cm in diameter) were measured. The Cazadero site channel substrate was primarily composed of cobble (51.08%), with a mix of gravels (29.39%), boulder substrate (10.75%), and fine sediments (8.76%) (Table 3).

The UAS was not practical for use at this site due to the dense tree canopy and the inability to obtain a useful perspective for capturing high-quality aerial images of the creek.

A snorkel survey was conducted on July 8, 2021. During the survey, 89% of the available pool habitat was snorkeled (Table 4). Only dace were observed throughout the surveyed area. The habitat rating of Deep Creek was moderate-good before restoration activity across species life history types based on the HabRate model (Burke et al. 2010). Species-specific averages across life history types ranged from 1.6 (coho) to 2.6 (Chinook and steelhead). Following restoration, the HabRate model suggests habitat quality is good across species life history types. Species-specific averages across life history types ranged from 2.25 (cutthroat trout) to 3 (Chinook). Habitat quality increased overall following restoration for Chinook, steelhead, coho, and cutthroat trout life histories (Tables 5, 6, 7, 8).

Table 1. Channel lengths and area across Clackamas Focused Investment Partnership survey locations during March and April of 2021 using Aquatic Inventory stream habitat survey methods described in Moore et al. (2007).

| Site Location | Primary Channel Length (m) | Secondary Channel Length (m) | Primary Channel Area ($^{m2}$) | Secondary Channel Area ($m^2$) | Off-Channel Area ($m^2$)* |
|---|---|---|---|---|---|
| Kingfisher | 533.60 | 0 | 3,283.50 | 0 | 94.82 |
| Upper Control | 145.0 | 0 | 1,688.0 | 0 | 0 |
| Eagle Creek Complex | 549.0 | 1,143.50 | 10,179.50 | 7,027.50 | 264.50 |
| Middle Control | 296.0 | 0 | 4,882.0 | 0 | 573.10 |
| Riverbend | 620.0 | 104.0 | 3,549.30 | 156.0 | 0 |
| Lower Control | 240.60 | 30.0 | 3,097.20 | 120.0 | 8,262.0 |
| Johnson Creek | 227.90 | 0 | 2,696.90 | 0 | 0 |
| Abernethy Creek | 522.0 | 0 | 3,694.70 | 0 | 0 |
| Newell Creek North | 1,439.35 | 0 | 4,234.75 | 0 | 44.54 |
| Cazadero** | 169.0 | 0 | 1,403.70 | 0 | 0 |

*Alcoves, Backwaters, and Isolated Pools; **North Fork Deep Creek

Table 2. Physical habitat summary across Clackamas Focused Investment Partnership survey locations during March and April of 2021 using Aquatic Inventory stream habitat methods described in Moore et al. (2007).

| Site Location | % Pool Habitat | Residual Pool Depth (m) | Riffle Depth (m) | Wood Volume ($m^3$) | # Of Key Wood Pieces |
|---|---|---|---|---|---|
| Kingfisher | 82.03 | 0.64 | 0.18 | 35.02 | 1 |
| Upper Control | 61.01 | 1.12 | 0 | .44 | 0 |
| Eagle Creek Complex | 38.58 | 0.75 | 0.27 | 576.12 | 22 |
| Middle Control | 69.04 | 1.12 | 0.37 | 31.30 | 0 |
| Riverbend | 82.80 | 0.42 | 0.08 | 69.08 | 2 |
| Lower Control | 76.38 | 0.40 | 0.20 | 50.63 | 2 |
| Johnson Creek | 0 | 0 | 0.46 | 5.69 | 0 |
| Abernethy Creek | 74.40 | 0.83 | 0.57 | 95.25 | 1 |
| Newell Creek North | 51.56 | 0.56 | 0.17 | 186.21 | 6 |
| Cazadero* | 57.40 | 0.85 | 0.20 | 54.26 | 0 |

*North Fork Deep Creek

Table 3. Description of streambed substrate within wetted channels across Clackamas Focused Investment Partnership survey locations during March and April of 2021 using Aquatic Inventory stream habitat survey methods described in Moore et al. (2007).

| Site Location | % Fines* | % Gravel | % Cobble | % Boulder | % Bedrock |
|---|---|---|---|---|---|
| Kingfisher | 47.87 | 14.10 | 23.35 | 14.65 | 0 |
| Upper Control | 9.15 | 19.37 | 43.19 | 19.12 | 9.15 |
| Eagle Complex | 19.92 | 35.60 | 34.50 | 9.69 | 0.26 |
| Middle Control | 33.40 | 24.91 | 30.10 | 11.57 | 0 |
| Riverbend | 54.46 | 24.11 | 19.27 | 2.14 | 0 |
| Lower Control | 59.56 | 16.63 | 20.45 | 3.33 | 0 |
| Johnson Creek | 15.03 | 45.61 | 27.78 | 11.55 | 0 |
| Abernethy Creek | 72.29 | 16.73 | 5.98 | 4.98 | 0 |
| Newell Creek North | 59.26 | 31.90 | 6.70 | 1.58 | 0.54 |
| Cazadero** | 8.76 | 29.39 | 51.08 | 10.75 | 0 |

*Combined observed values of silt and sand; **North Fork Deep Creek

Table 4. Results of snorkel surveys within pool habitats across Clackamas Focused Investment Partnership survey locations during July of 2021 using methods described in Constable et al. (2012).

| Site Location | Pool Area ($m^2$) | Snorkeled Area ($m^2$) | Sum of Coho | Sum of Cutthroat | Sum of Steelhead | Sum of Chinook | Other Fish Observed |
|---|---|---|---|---|---|---|---|
| Kingfisher | 2,771.32 | 0 | 0 | 0 | 0 | 0 | 0 |
| Upper Control | 1,030.0 | 1,030.0 | 0 | 0 | 0 | 0 | dace |
| Eagle Complex | 6,740.60 | 3,092.80 | 17 | 4 | 0 | 9 | 0+ trout*, dace, shiner, rainbow trout |
| Middle Control | 3,781.1 | 3,208.0*** | 0 | 0 | 0 | 0 | dace, shiner, NPM** |
| Riverbend | 5,186.2 | 3,560.0 | 0 | 0 | 0 | 0 | dace, NPM**, bluegill, smallmouth bass |
| Lower Control | 8,768.00 | 8,768.00 | 0 | 0 | 0 | 0 | Dace, shiner, NPM**, pumpkinseed sunfish |
| Johnson Creek | 0 | N/A | N/A | N/A | N/A | N/A | Did not snorkel due to health concerns |
| Abernethy Creek | 2,748.90 | 997.0 | 0 | 0 | 0 | 0 | dace, shiner |
| Newell Creek North Stream | 2,216.98 | 462.70 | 0 | 2 | 0 | 0 | dace, shiner |
| Cazadero**** | 902.2 | 804.2 | 0 | 0 | 0 | 0 | dace |

* Trout fry < 90 mm in fork length; ** Northern Pikeminnow; *** Snorkeled a glide habitat unit type.
**** North Fork Deep Creek.

Table 5. HabRate (Burke et al. 2010) pre-and post-restoration life history ratings for Chinook salmon habitat across Clackamas FIP sites and Control reaches.

| | | Chinook Salmon Habitat | | | |
|---|---|---|---|---|---|
| | | Spawning to | 0+ | 0+ | Chinook |
| Stream | Year | Emergence | Summer | Winter | Average |
| Kingfisher-(Pre) | 2021 | 1 | 2 | 2 | 1.6 |
| Upper Control | 2020 | 2 | 2 | 3 | 2.3 |
| Upper Control | 2021 | 2 | 2 | 2 | 2 |
| Eagle Cr Complex-(Pre) | 2020 | 1 | 3 | 3 | 2.3 |
| Eagle Cr Complex-(Post) | 2021 | 1 | 2 | 2 | 1.6 |
| Middle Control | 2020 | 1 | 2 | 2 | 1.6 |
| Middle Control | 2021 | 1 | 2 | 2 | 1.6 |
| Riverbend-(Pre) | 2021 | 1 | 2 | 2 | 1.6 |
| Lower Control | 2020 | 2 | 2 | 2 | 2 |
| Lower control | 2021 | 3 | 2 | 2 | 2.3 |
| Johnson Creek-(Pre) | 2019 | 2 | 2 | 2 | 2 |
| Johnson Creek-(Post) | 2021 | 3 | 2 | 2 | 2.3 |
| Abernethy Cr-(Pre) | 2021 | 1 | 2 | 2 | 1.6 |
| Newell North Stream-(Pre) | 2021 | 1 | 3 | 2 | 2 |
| Deep Cr, N Fk-(Pre) | 2020 | 2 | 3 | 3 | 2.6 |
| Deep Cr, N Fk-(Post) | 2021 | 3 | 3 | 3 | 3 |

Table 6. HabRate (Burke et al. 2010) pre-and post-restoration life history ratings for steelhead habitat across Clackamas FIP sites and Control reaches.

| | | Steelhead Habitat | | | | | |
|---|---|---|---|---|---|---|---|
| | | Spawning to | 0+ | 0+ | 1+ | 1+ | Steelhead |
| Stream | Year | Emergence | Summer | Winter | Summer | Winter | Average |
| Kingfisher-(Pre) | 2021 | 1 | 2 | 1 | 1 | 1 | 1.2 |
| Upper Control | 2020 | 1 | 3 | 2 | 2 | 2 | 2 |
| Upper Control | 2021 | 2 | 2 | 2 | 2 | 2 | 2 |
| Eagle Cr Complex-(Pre) | 2020 | 1 | 3 | 3 | 2 | 3 | 2.4 |
| Eagle Cr Complex-(Post) | 2021 | 1 | 2 | 2 | 2 | 2 | 1.8 |
| Middle Control | 2020 | 1 | 2 | 2 | 2 | 2 | 1.8 |
| Middle Control | 2021 | 1 | 2 | 2 | 2 | 2 | 1.8 |
| Riverbend-(Pre) | 2021 | 1 | 2 | 2 | 2 | 2 | 1.8 |
| Lower Control | 2020 | 2 | 2 | 3 | 2 | 3 | 2.4 |
| Lower Control | 2021 | 2 | 2 | 3 | 2 | 3 | 2.4 |
| Johnson Creek-(Pre) | 2019 | 2 | 2 | 2 | 2 | 2 | 2 |
| Johnson Creek-(Post) | 2021 | 3 | 2 | 2 | 2 | 2 | 2.2 |
| Abernethy Cr-(Pre) | 2021 | 1 | 2 | 2 | 2 | 2 | 1.8 |
| Newell North Stream-(Pre) | 2021 | 1 | 2 | 2 | 2 | 2 | 1.8 |
| Deep Cr, N Fk-(Pre) | 2020 | 2 | 3 | 3 | 2 | 3 | 2.6 |
| Deep Cr, N Fk-(Post) | 2021 | 3 | 3 | 3 | 2 | 3 | 2.8 |

Table 7. HabRate (Burke et al. 2010) pre-and post-restoration life history ratings for coho salmon habitat across Clackamas FIP sites and Control reaches.

| | | Coho Habitat | | | |
|---|---|---|---|---|---|
| | | Spawning to | 0+ | 0+ | Coho |
| Stream | Year | Emergence | Summer | Winter | Average |
| Kingfisher-(Pre) | 2021 | 1 | 2 | 2 | 1.6 |
| Upper Control | 2020 | 1 | 3 | 1 | 1.6 |
| Upper Control | 2021 | 3 | 1 | 1 | 1.6 |
| Eagle Cr Complex-(Pre) | 2020 | 2 | 3 | 3 | 2.6 |
| Eagle Cr Complex-(Post) | 2021 | 1 | 2 | 3 | 2 |
| Middle Control | 2020 | 1 | 2 | 2 | 1.6 |
| Middle Control | 2021 | 1 | 2 | 2 | 1.6 |
| Riverbend-(Pre) | 2021 | 1 | 2 | 1 | 1.3 |
| Lower Control | 2020 | 2 | 2 | 2 | 2 |
| Lower Control | 2021 | 2 | 2 | 3 | 2.3 |
| Johnson Creek-(Pre) | 2019 | 3 | 1 | 1 | 1.6 |
| Johnson Creek-(Post) | 2021 | 2 | 1 | 1 | 1.3 |
| Abernethy Cr-(Pre) | 2021 | 1 | 2 | 1 | 1.3 |
| Newell North Stream-(Pre) | 2021 | 1 | 2 | 1 | 1.3 |
| Deep Cr, N Fk-(Pre) | 2020 | 2 | 2 | 1 | 1.6 |
| Deep Cr, N Fk-(Post) | 2021 | 3 | 3 | 1 | 2.3 |

Table 8. Habrate (Burke et al. 2010) pre-and post-restoration life history ratings for cutthroat trout habitat across Clackamas FIP sites and Control reaches.

| | | Cutthroat Habitat | | | | |
|---|---|---|---|---|---|---|
| | | Spawning to | 0+ | 0+ | 1+ | Cutthroat |
| Stream | Year | Emergence | Summer | Winter | Summer | Average |
| Kingfisher-(Pre) | 2021 | 1 | 2 | 2 | 2 | 1.75 |
| Upper Control | 2020 | 1 | 1 | 1 | 2 | 1.25 |
| Upper Control | 2021 | 1 | 1 | 1 | 2 | 1.25 |
| Eagle Cr Complex-(Pre) | 2020 | 2 | 3 | 2 | 2 | 2.25 |
| Eagle Cr Complex-(Post) | 2021 | 2 | 3 | 2 | 2 | 2.25 |
| Middle Control | 2020 | 2 | 2 | 2 | 2 | 2 |
| Middle Control | 2021 | 1 | 2 | 2 | 2 | 1.75 |
| Riverbend-(Pre) | 2021 | 2 | 2 | 2 | 2 | 2 |
| Lower Control | 2020 | 2 | 3 | 2 | 2 | 2.25 |
| Lower Control | 2021 | 2 | 3 | 2 | 2 | 2.25 |
| Johnson Creek-(Pre) | 2019 | 2 | 2 | 2 | 2 | 2 |
| Johnson Creek-(Post) | 2021 | 2 | 2 | 2 | 2 | 2 |
| Abernethy Cr-(Pre) | 2021 | 2 | 1 | 1 | 2 | 1.5 |
| Newell North Stream-(Pre) | 2021 | 2 | 1 | 2 | 2 | 1.75 |
| Deep Cr, N Fk-(Pre) | 2020 | 2 | 2 | 2 | 2 | 2 |
| Deep Cr, N Fk-(Post) | 2021 | 3 | 2 | 2 | 2 | 2.25 |

Table 9. The surface area of ground surveys and UAS surveys between winter and summer ($m^2$).

| Site Location | Ground-Based Winter Surface area $m^2$ | UAS Winter Surface area $m^2$ | UAS Summer Surface area $m^2$ |
|---|---|---|---|
| Kingfisher | 3,378.32 | 2,959.31 | 2,959.31 |
| Upper Control | 1,688.00 | 2,184.84 | 1,861.22 |
| Eagle Creek Complex | 17,471.00 | 15,604.14 | 8,684.13 |
| Middle Control | 5,476.00 | 5,002.11 | 4,178.49 |
| Riverbend | 6,502.00 | 4,954.05 | 2,308.00 |
| Lower Control | 11,479.20 | 10,649.30 | 7,485.35 |
| Johnson Creek | 2,696.90 | 2,004.34 | 1,816.26 |

## Methods Comparison

We compared ground survey and UAS imagery results for habitat area ($m^2$) from all individual habitat units across all sampling sites where both methods occurred. Results of a simple linear regression suggest the UAS imagery can be used to describe habitat area adequately (Figure 19). The $R^2$ was 0.97 with a p-value less than 0.001 (Table 10).

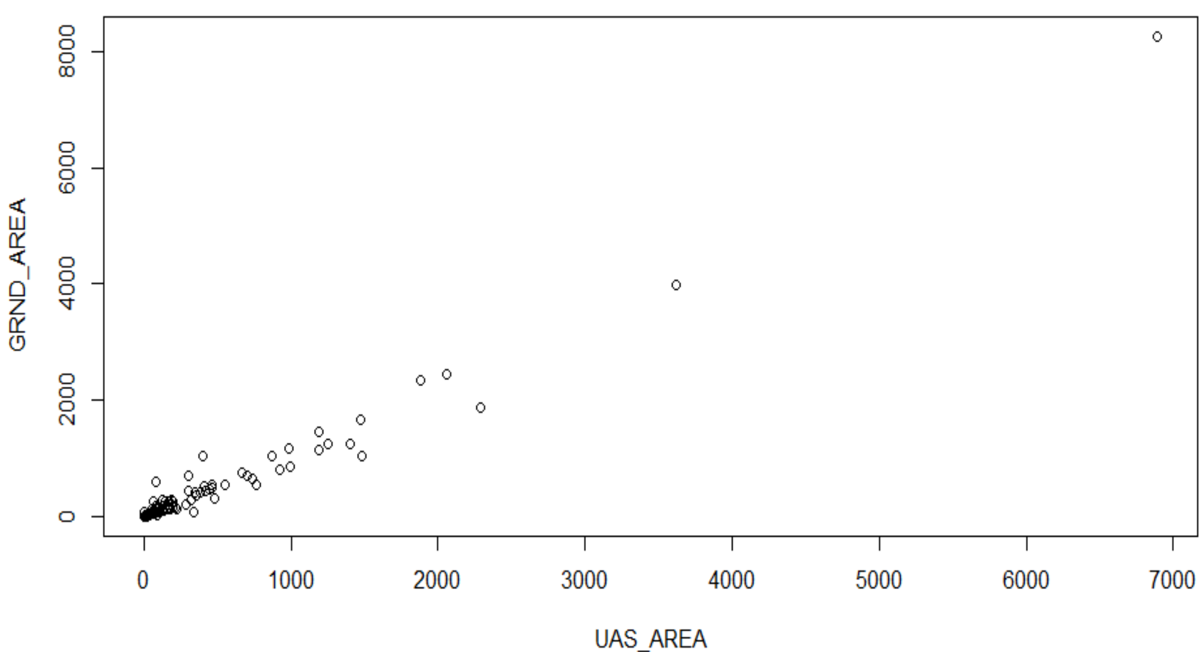


Figure 19. Results of a simple linear regression between ground survey habitats ($m^2$) and aerial imagery ($m^2$) *No UAS imagery for N Fk. Deep Creek, Abernethy Cr, or North Newell Stream.

Table 10. Results of ground surveys and UAS survey comparison results for habitat area ($m^2$).

| Residual DF | F-statistic | P-value | Adjusted $R^2$ |
|---|---|---|---|
| 110 | 3912 | < 0.0001 | 0.9724 |

*No UAS imagery for N Fk Deep Creek, Abernethy Cr, or North Newell Stream.

We used paired t-tests to describe differences in winter habitat area ($m^2$) using ground surveys and summer habitat area ($m^2$) from UAS survey imagery. Differences were not observed across seasons for most sites (Table 11). Differences were observed in the Eagle Creek Complex and Middle Control (Figure 20). Eagle Creek Complex and The Middle Control site were in the closest proximity to each other of all sites examined. The Eagle Creek Complex contained the most secondary channel area, likely influencing the results.

Table 11. Paired t-test results assessing differences in habitat area ($m^2$) between winter ground surveys and summer UAS survey imagery results.

| Site | t | df | Mean of Differences | P-value |
|---|---|---|---|---|
| Eagle Creek Complex | 3.6346 | 22 | 178.9996 | 0.001464 |
| Johnson Creek | 1.3556 | 6 | 125.8057 | 0.224 |
| Riverbend | 2.0055 | 18 | 179.8105 | 0.06018 |
| Lower Control | 1.2379 | 6 | 570.55 | 0.262 |
| Middle Control | 2.6313 | 7 | 162.1887 | 0.03385 |
| Upper Control | -2.5317 | 2 | -57.74 | 0.127 |

*No UAS imagery for N Fk Deep Creek, Abernethy Cr, or North Newell Stream.

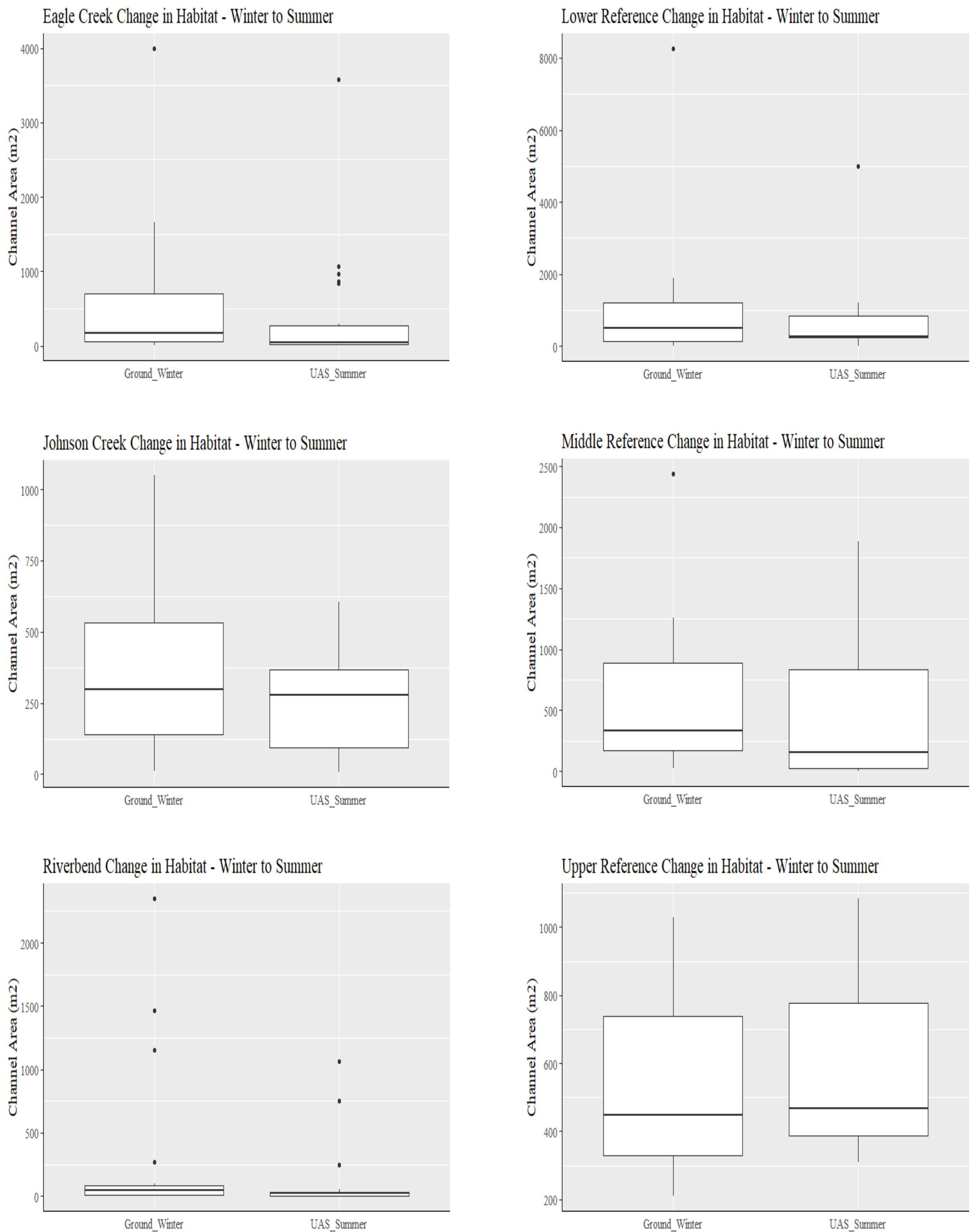


Figure 20. Box plots assessing differences in habitat area (m$^2$) between winter ground surveys and summer UAS survey imagery results.

## Restoration Assessment – All Sites

We used paired t-tests to assess all Clackamas FIP sites for pre-restoration treatment and post-treatment differences across habitat metrics described in Tables 1, 2, and 3. Across all habitat metrics, we did not observe any significant differences between pre-treatment and post-treatment winter ground surveys (Table 12). P-values ranged from 0.057 to 0.869.

Table 12. Paired t-tests assessing differences between pre-restoration treatment and post-restoration treatment across all habitat metrics.

| Habitat Metric | t | df | Mean of Differences | P-value |
|---|---|---|---|---|
| Primary Channel Area ($m^2$) | 0.17266 | 5 | 54.28917 | 0.8697 |
| Secondary Channel Area ($m^2$) | 1.0663 | 5 | 56.89667 | 0.335 |
| Off-Channel Area ($m^2$)* | 0.93265 | 5 | 800.25 | 0.3938 |
| % Pool Habitat | 0.54736 | 5 | 1.946412 | 0.6077 |
| Residual Pool Depth (m) | -0.96802 | 5 | -0.07622 | 0.3775 |
| Riffle Depth (m) | -0.89703 | 5 | -0.02535 | 0.4108 |
| Wood Volume ($m^3$) | 1.5172 | 5 | 32.98667 | 0.1897 |
| # Of Key Wood Pieces | -3.522565 | 5 | -0.83333 | 0.4618 |
| % Fines** | 1.1839 | 5 | 8.41325 | 0.2896 |
| % Gravel | 1.0161 | 5 | 3.650531 | 0.3562 |
| % Cobble | -2.4613 | 5 | -14.0893 | 0.05714 |
| % Boulder | 1.0716 | 5 | 2.575058 | 0.3329 |
| % Bedrock | -0.95111 | 5 | -0.54956 | 0.3852 |

*Alcoves, Backwaters, and Isolated Pools. **Combined observed values of silt and sand.

Channel and pool features increased post-treatment, although residual pool depth and riffle depth decreased slightly across sites (Figure 21). Wood volume increased across restoration sites as expected, but the number of key pieces of wood (≥ 12 meters in length and 60 cm in diameter) decreased slightly (Figure 22). Within stream bedload types, we observed an increase in the percent of fines (silt and sand), gravel, and boulder, and a decrease in the percent of cobble and bedrock (Figure 23).

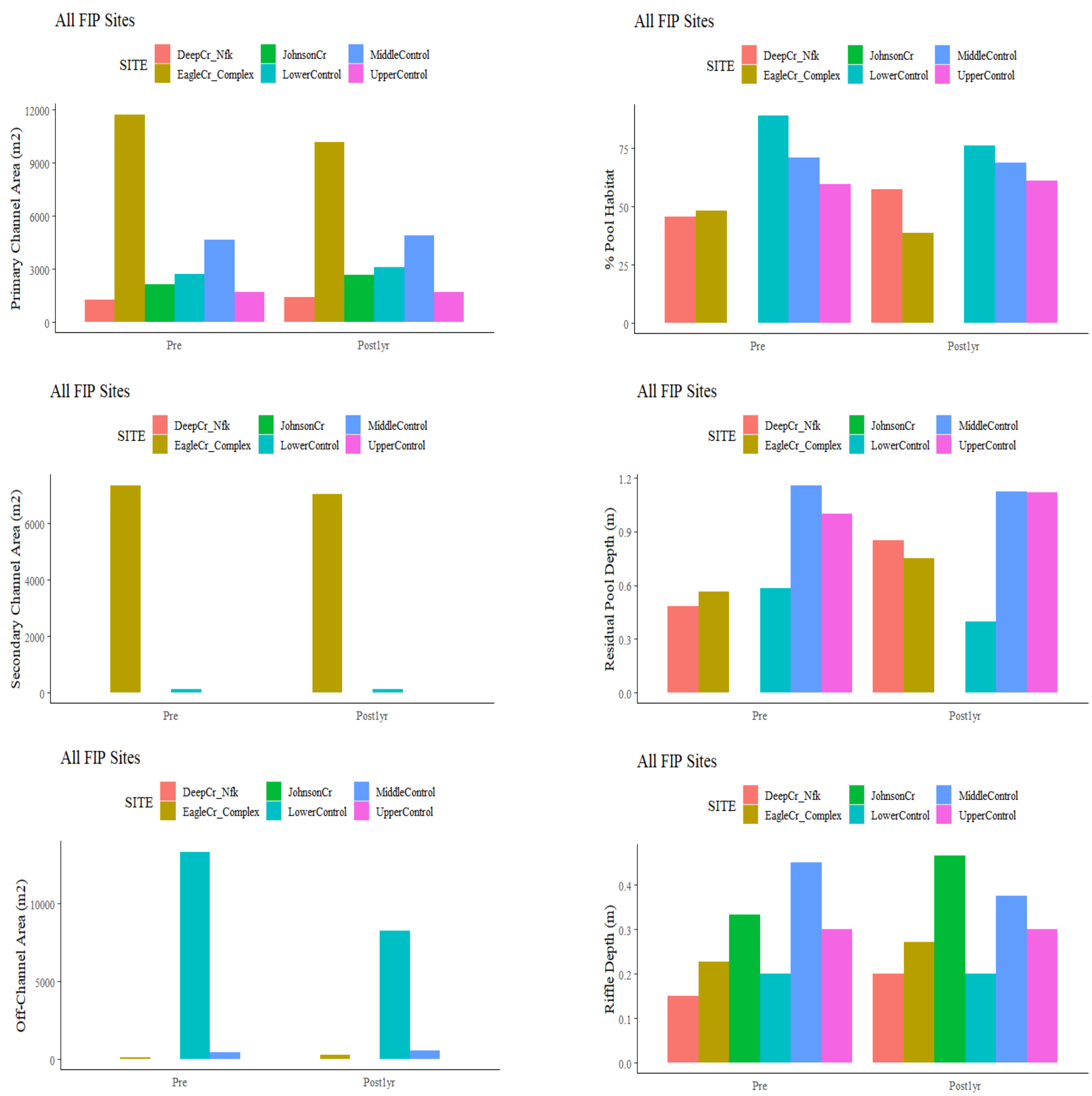


Figure 21. Bar plots describing differences between pre-restoration and post-restoration treatments across channel and pool features.

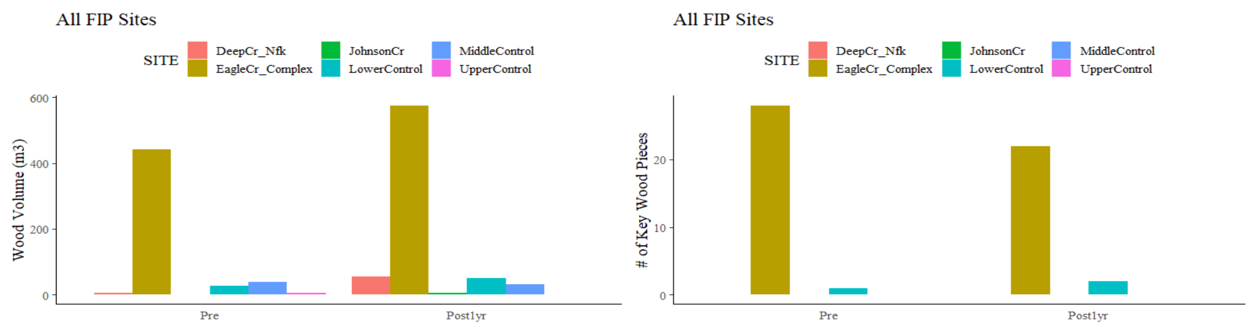


Figure 22. Bar plots describing differences between pre-restoration treatment and post-restoration treatment for wood volume ($m^3$) and the number of key pieces of wood (≥ 12 meters in length and 60 cm in diameter).

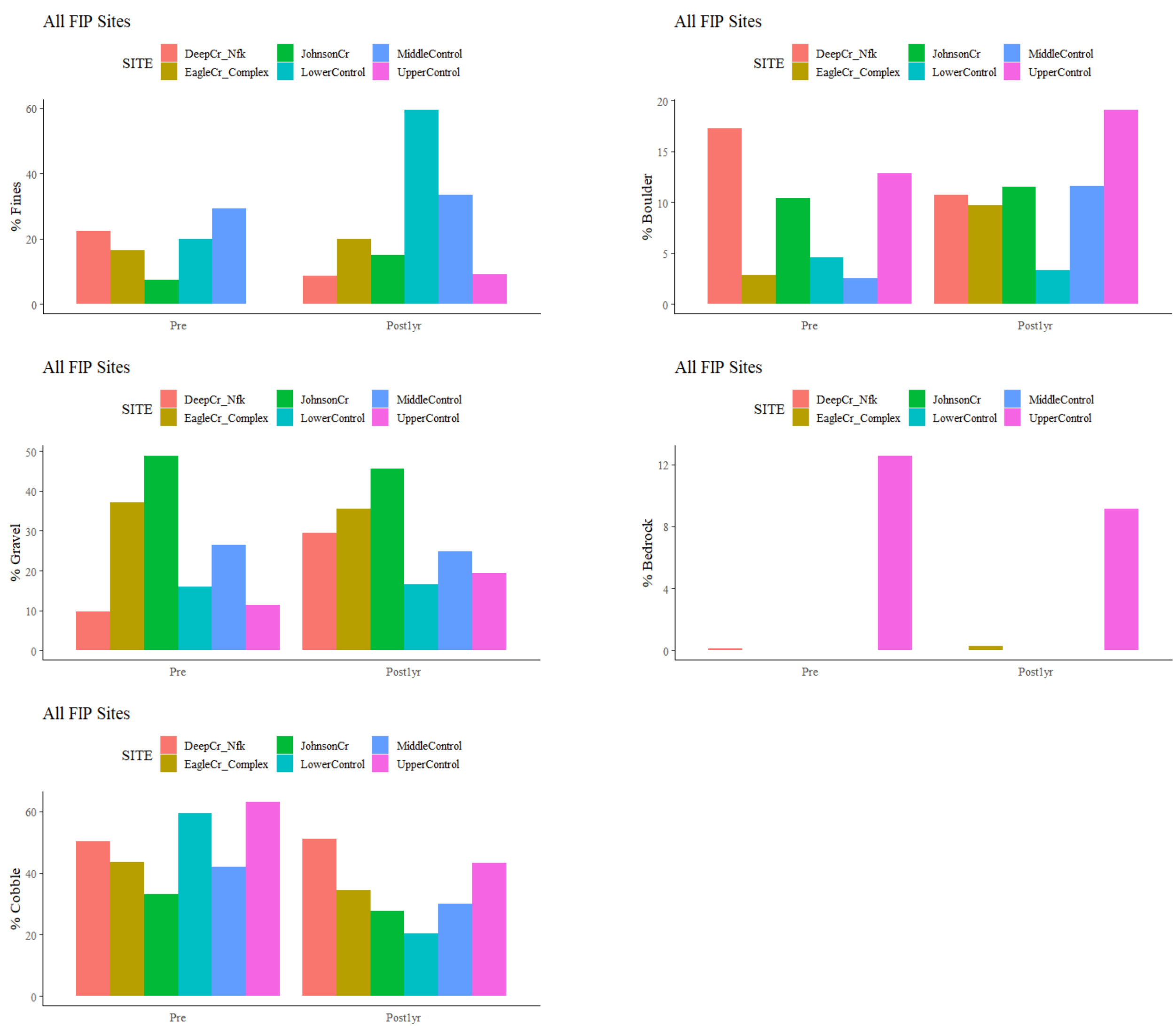


Figure 23. Bar plots describing differences between pre-restoration treatment and post-restoration treatment across bedload types.

## Restoration Assessment – Upper Control Channel

Across channel and pool features within the Upper Control Channel, there were no observable differences between year one and year two of the FIP monitoring effort (Figure 24).

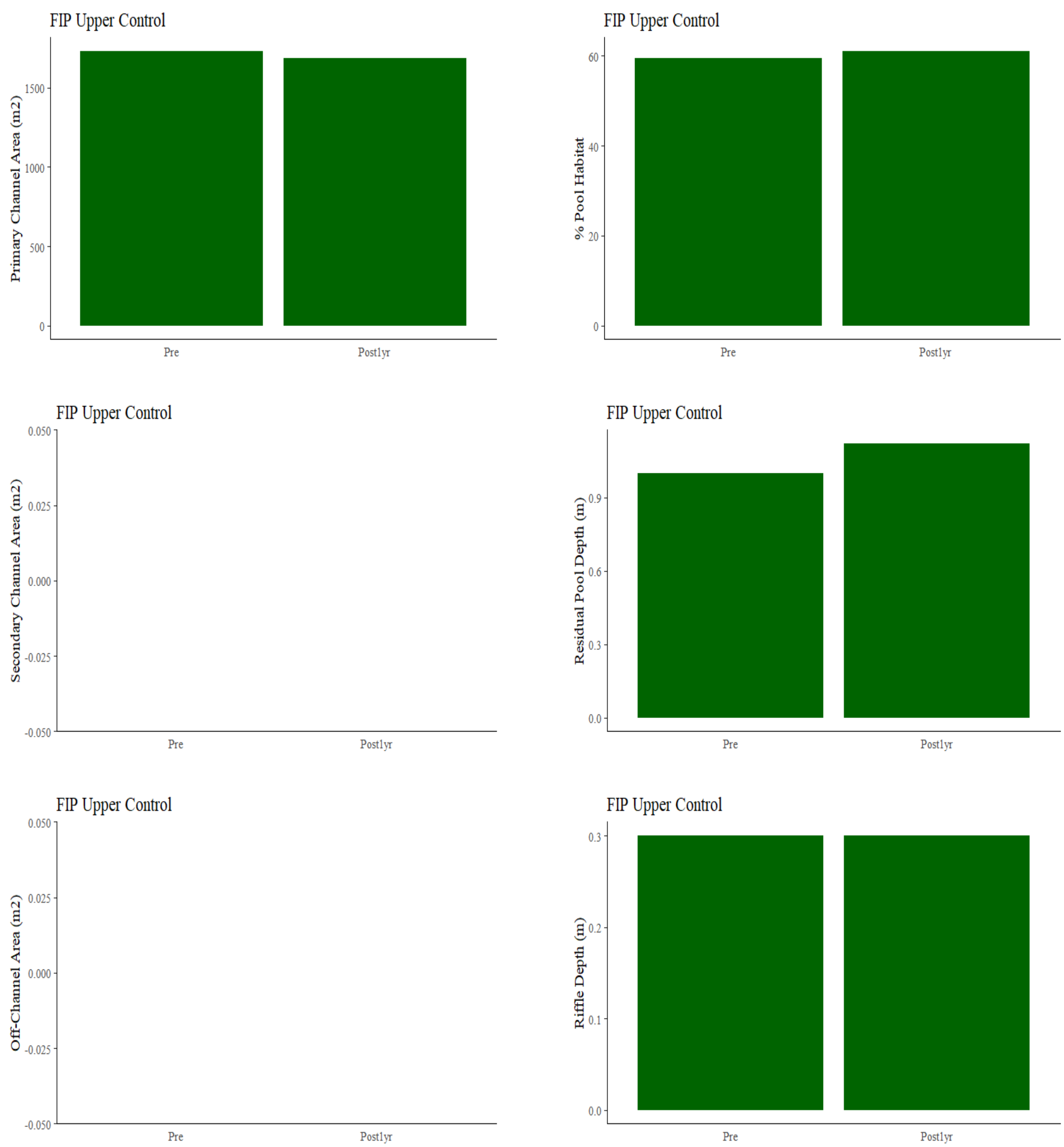


Figure 24. Bar plots describing differences between year one and year two of the FIP monitoring effort across channel and pool features within the Upper Control Channel.

Wood volume ($m^3$) noticeably decreased from year one to year two, and key pieces of wood remained absent across years in the Upper Control Channel (Figure 25).

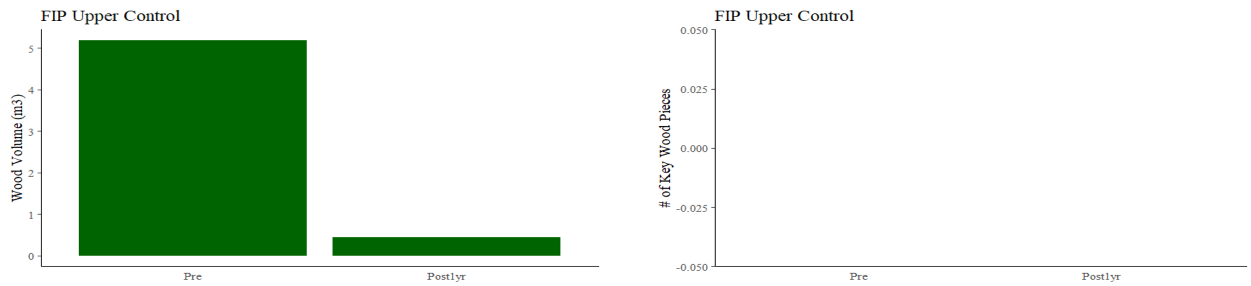


Figure 25. Bar plots for the Upper Control Channel describing differences between year one and year two of the FIP monitoring effort for wood volume ($m^3$) and the number of key pieces of wood (≥ 12 meters in length and 60 cm in diameter).

Differences were observed across bedload types within the Upper Control Channel (Figure 26). The percentage of fines (sand and silt), gravel, and boulder increased while the percentage of bedrock decreased. The percent of cobble decreased consistently with other FIP sites monitored during the sampling period.

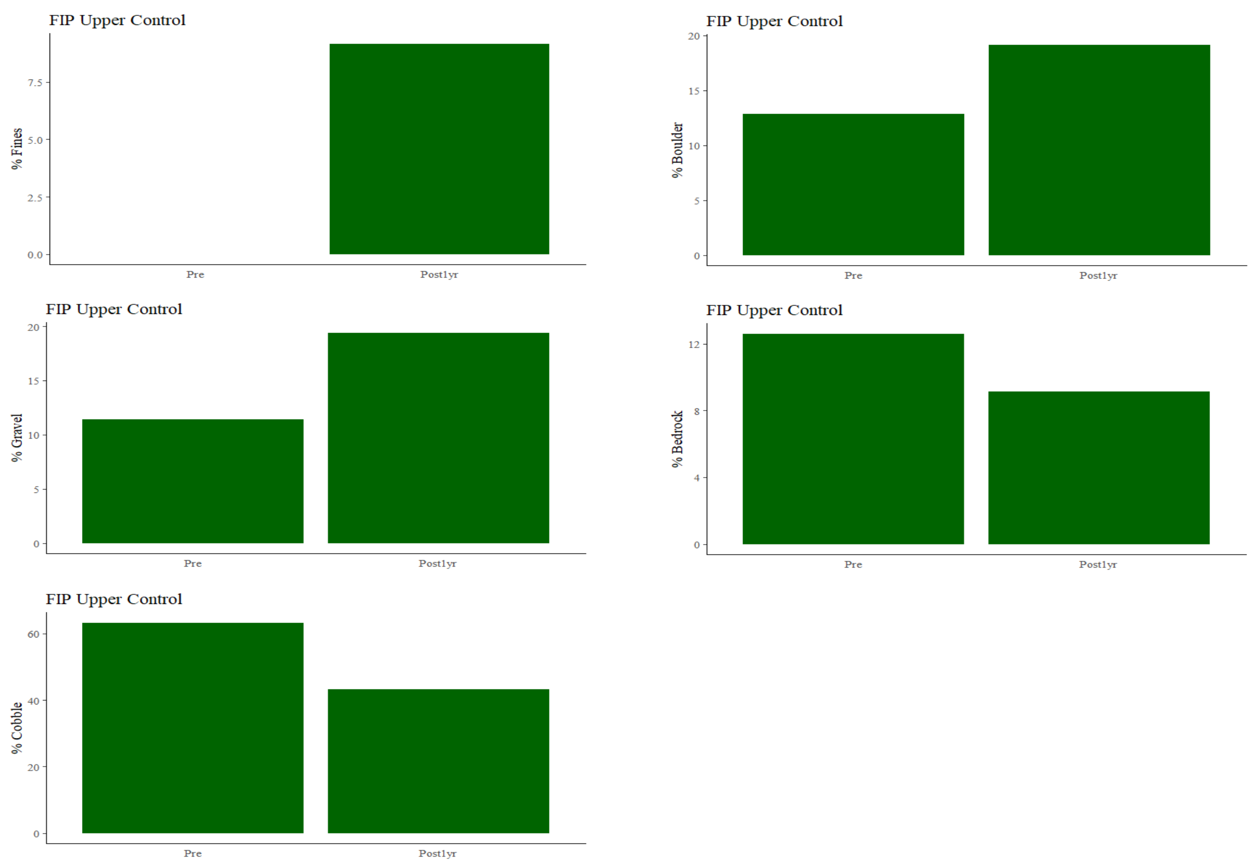


Figure 26. Bar plots for the Upper Control Channel describing differences between year one and year two of monitoring effort across bedload types.

## Restoration Assessment – Eagle Creek Complex

Across channel and pool features within the Eagle Creek Complex, differences were minimal between pre-treatment and after restoration activity (Figure 27). Off-channel habitat (alcoves, backwaters, and isolated pools) increased by over 100 $m^2$, and residual pool and riffle depth increased slightly.

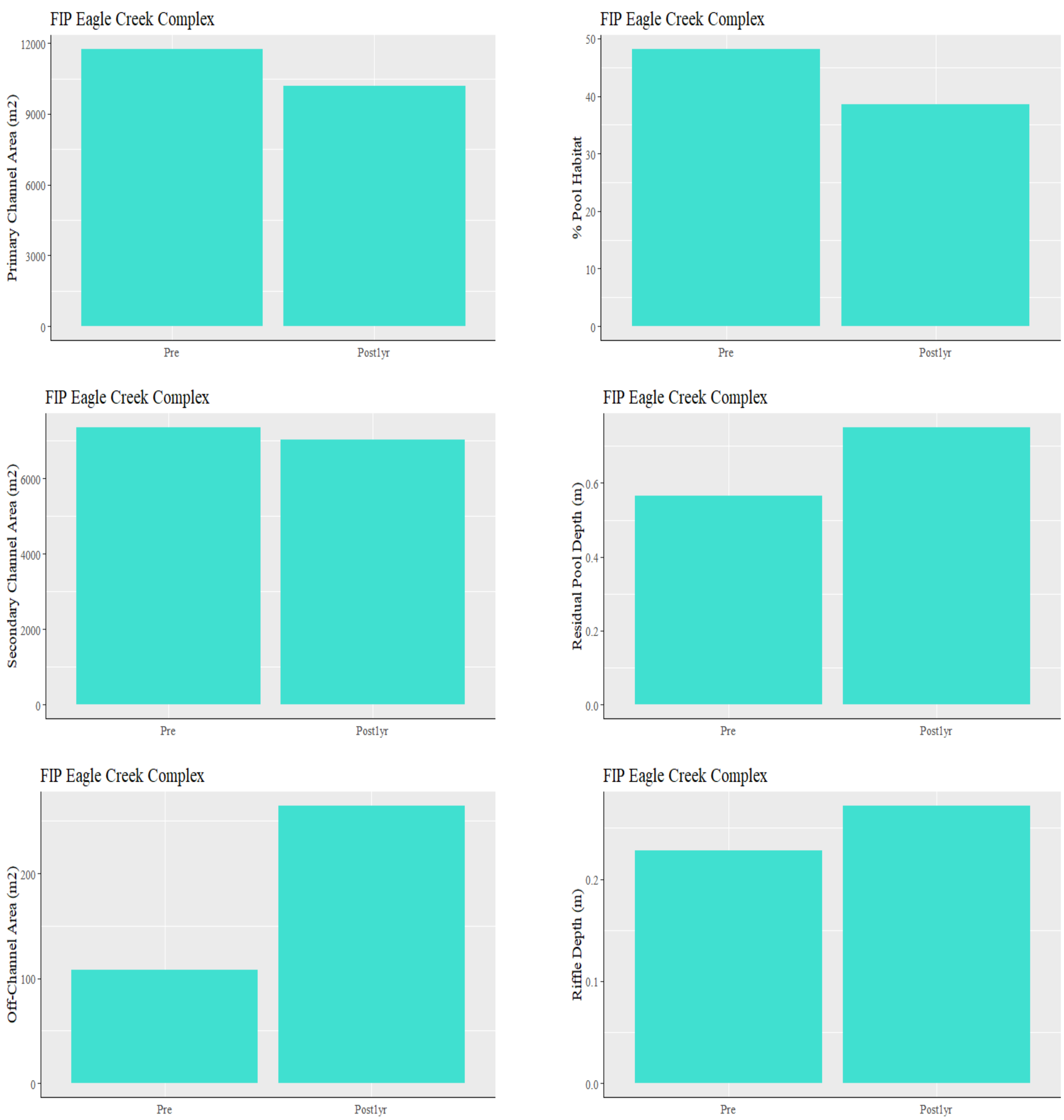


Figure 27. Bar plots describing differences between pre-restoration and post-restoration treatments across channel and pool features within the Eagle Creek Complex.

Wood volume increased within the Eagle Creek Complex as expected, but the number of key pieces of wood (≥ 12 meters in length and 60 cm in diameter) decreased slightly, consistent with other monitoring sites across the Clackamas FIP (Figure 28).

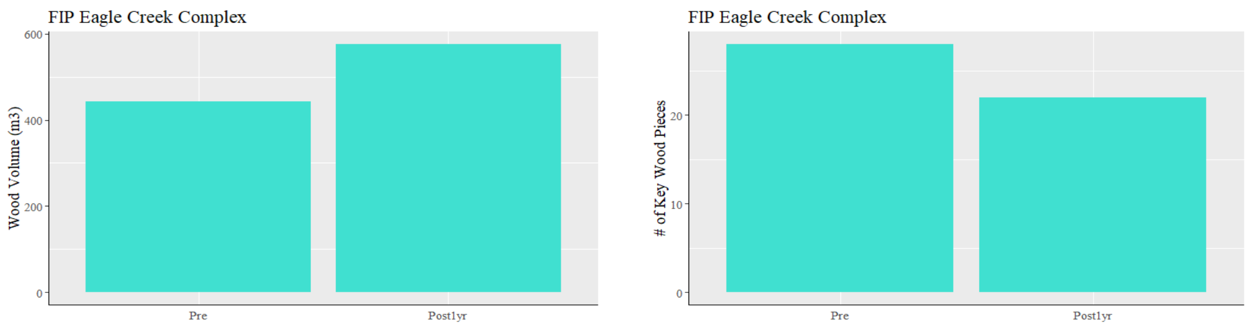


Figure 28. Bar plots for the Eagle Creek Complex describing differences between pre-restoration treatment and post-restoration treatment for wood volume ($m^3$) and the number of key pieces of wood (≥ 12 meters in length and 60 cm in diameter).

Differences across percent fines (silt and sand), gravel, cobble, and bedrock within the Eagle Creek Complex were minimal, while percent boulder increased slightly (Figure 29).

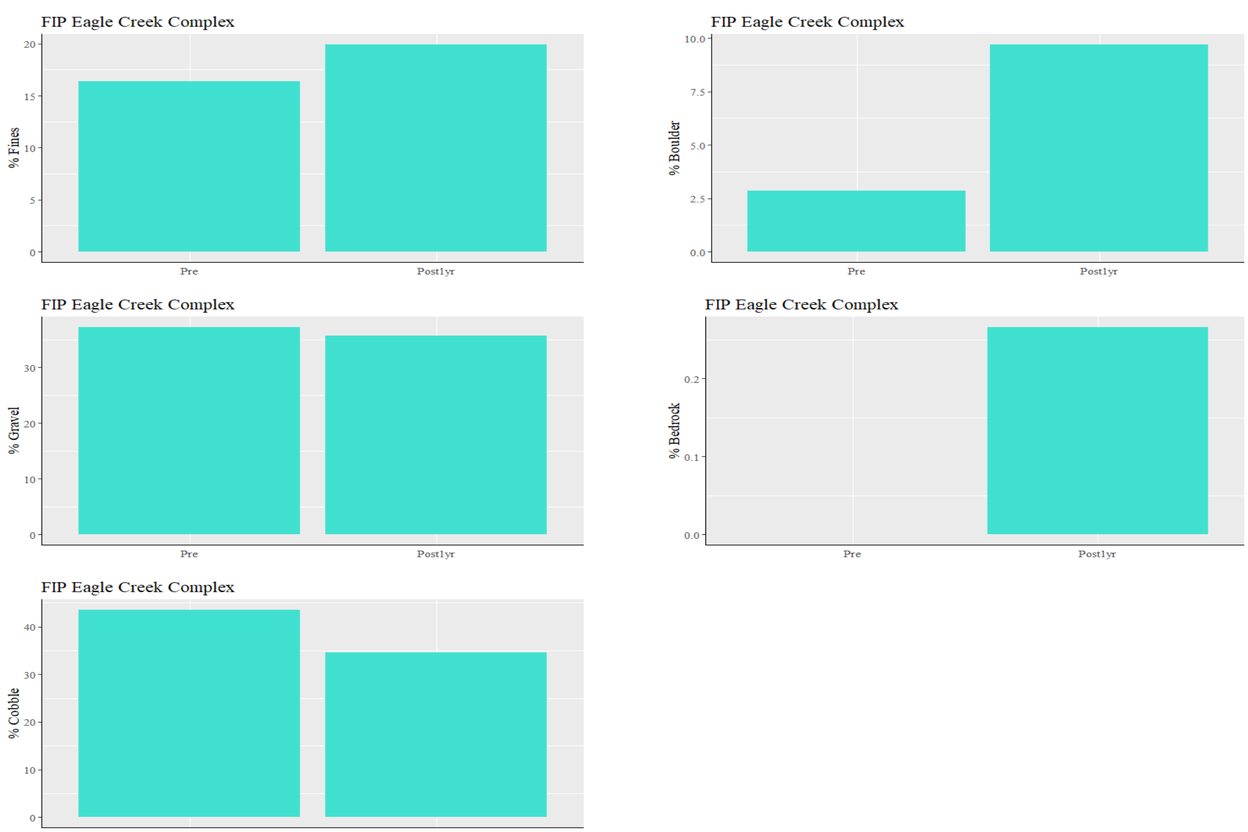


Figure 29. Bar plots for the Eagle Creek Complex describing differences between pre-restoration treatment and post-restoration treatment across bedload types.

## Restoration Assessment – Middle Control Channel

Across channel and pool features within the Middle Control Channel, differences were minimal between year one and year two of the FIP monitoring effort (Figure 30). Off-channel habitat (alcoves, backwaters, and isolated pools) increased slightly, while riffle depth decreased slightly.

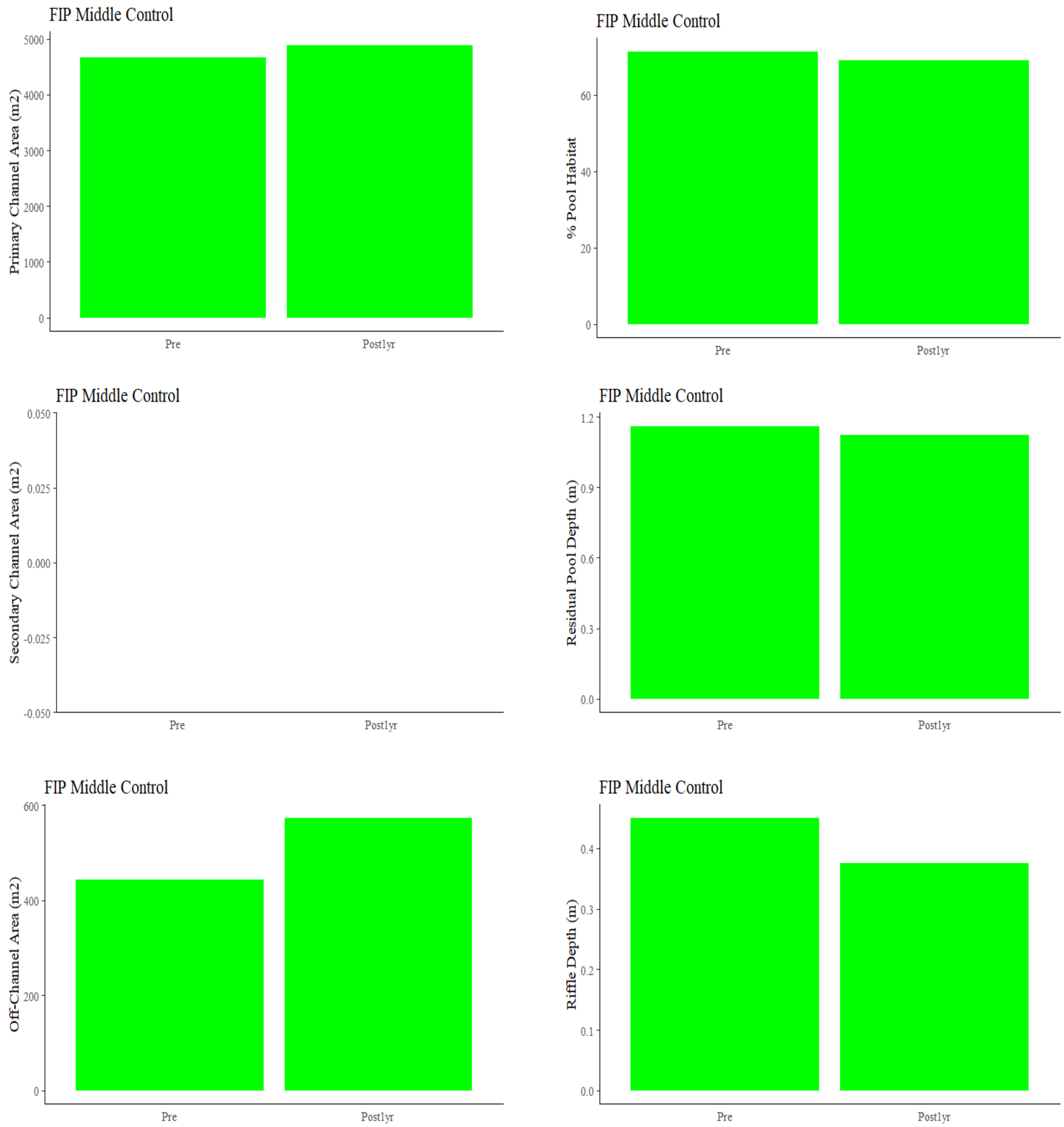


Figure 30. Bar plots describing differences between year one and year two of the FIP monitoring effort across channel and pool features within the Middle Control Channel.

Wood volume ($m^3$) decreased slightly from year one to year two, and key pieces of wood remained absent across years in the Middle Control Channel (Figure 31).

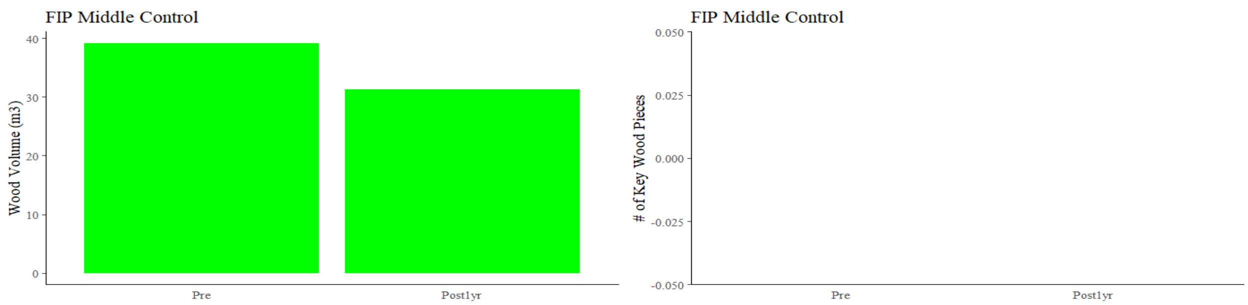


Figure 31. Bar plots for the Middle Control Channel describing differences between year one and year two of the FIP monitoring effort for wood volume ($m^3$) and the number of key pieces of wood (≥ 12 meters in length and 60 cm in diameter).

Differences were minimal across bedload types within the Middle Control Channel (Figure 32). The percentage of boulders increased slightly, while the percent of cobble decreased consistently with other FIP sites monitored during the sampling period.

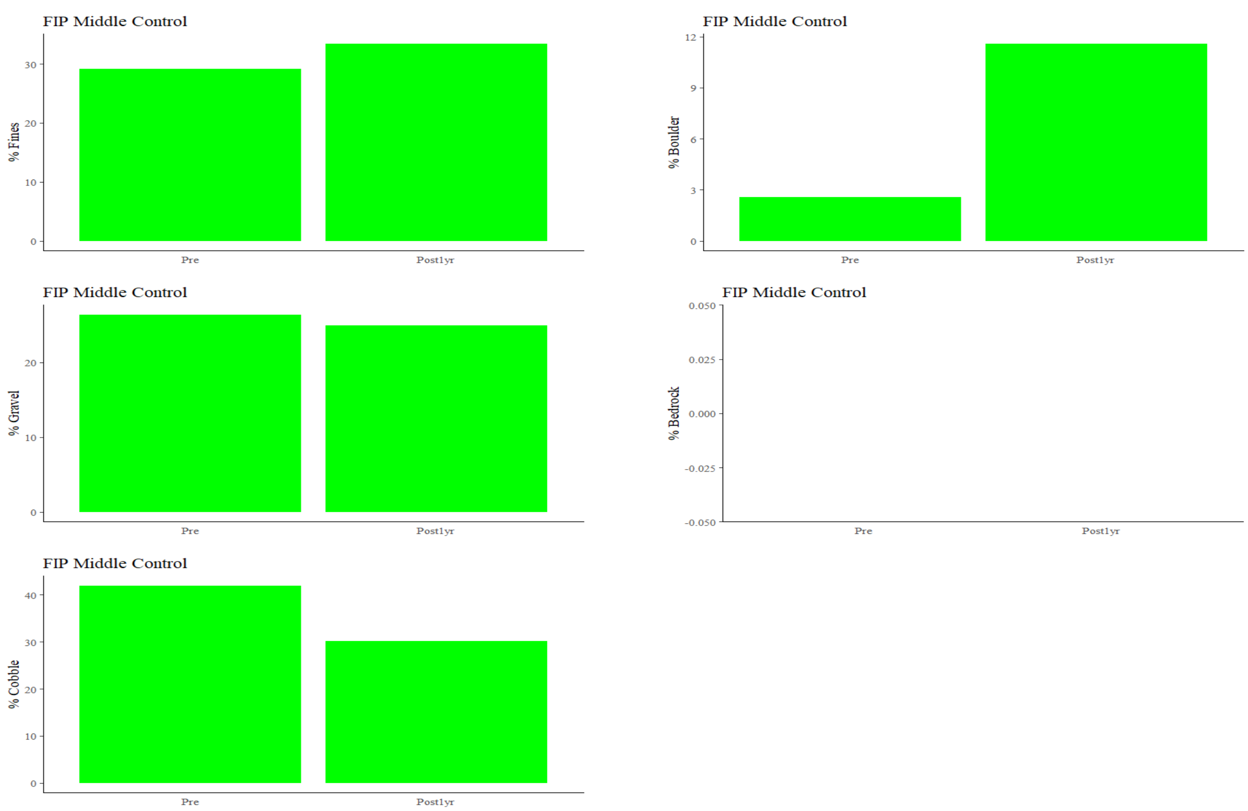


Figure 32. Bar plots for the Middle Control Channel describing differences between year one and year two of monitoring effort across bedload types.

## Restoration Assessment – Lower Control Channel

Differences were minimal across channel and pool features within the Lower Control Channel between year one and year two of the FIP monitoring effort (Figure 33). Off-channel habitat (alcoves, backwaters, and isolated pools) and residual pool depth decreased.

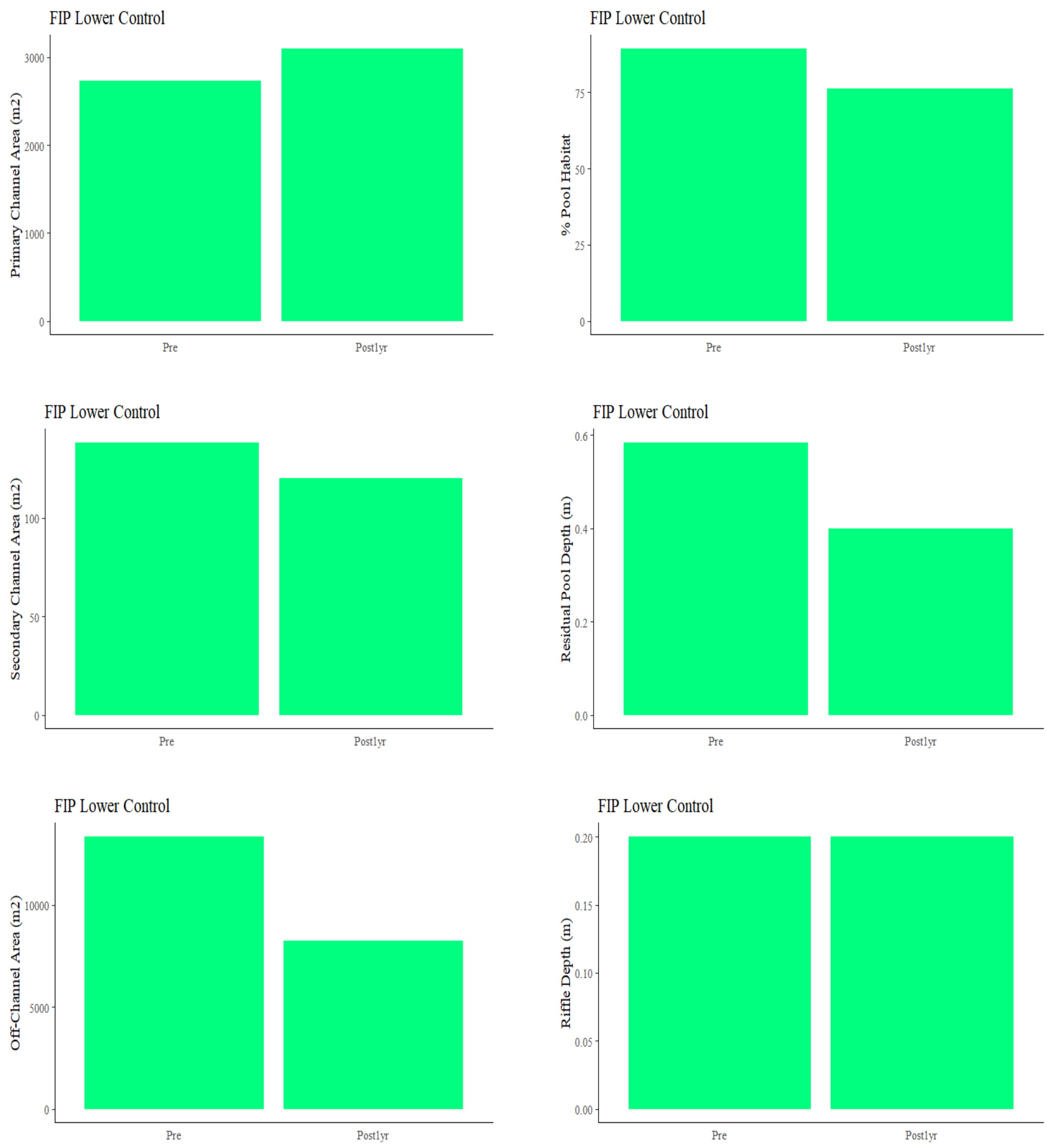


Figure 33. Bar plots describing differences between year one and year two of the FIP monitoring effort across channel and pool features within the Lower Control Channel.

Both wood volume ($m^3$) and key pieces of wood increased from year one to year two in the Lower Control Channel (Figure 34).

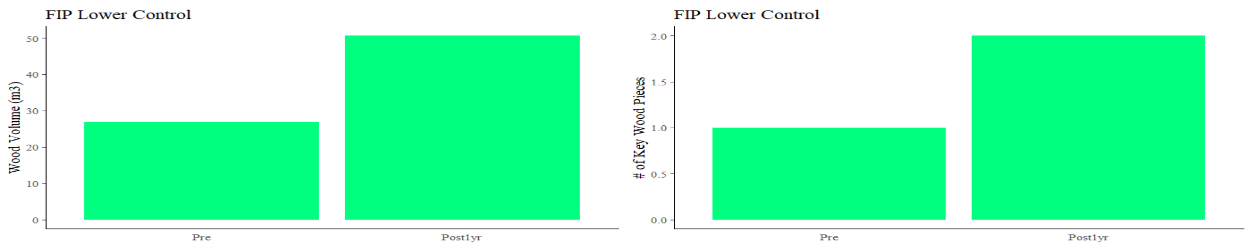


Figure 34. Bar plots for the Lower Control Channel describing differences between year one and year two of the FIP monitoring effort for wood volume ($m^3$) and the number of key pieces of wood (≥ 12 meters in length and 60 cm in diameter).

Across bedload types within the Lower Control Channel, percent gravel and boulder remained similar between year one and year two of the monitoring effort, while percent bedrock remained absent (Figure 35). The percent of fine sediment (silt and sand) increased, and the percent of cobble decreased consistently with other FIP sites monitored during the sampling period.

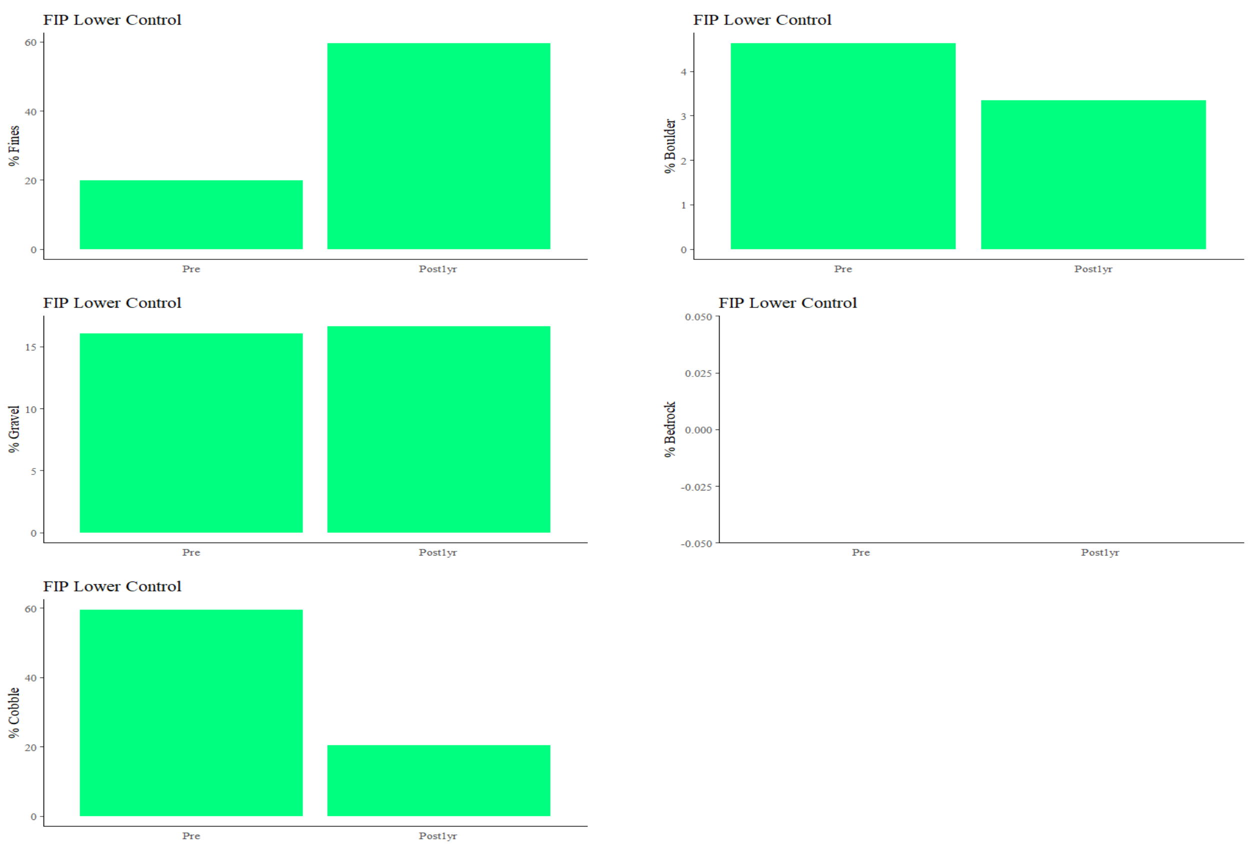


Figure 35. Bar plots for the Lower Control Channel describing differences between year one and year two of monitoring effort across bedload types.

## Restoration Assessment – Johnson Creek

Across channel and pool features within the Johnson Creek restoration site, primary channel area ($m^2$) and riffle depth (m) increased slightly between pre-treatment and post-treatment of restoration activity (Figure 36). Pools and secondary channels remained absent across the sampling period.

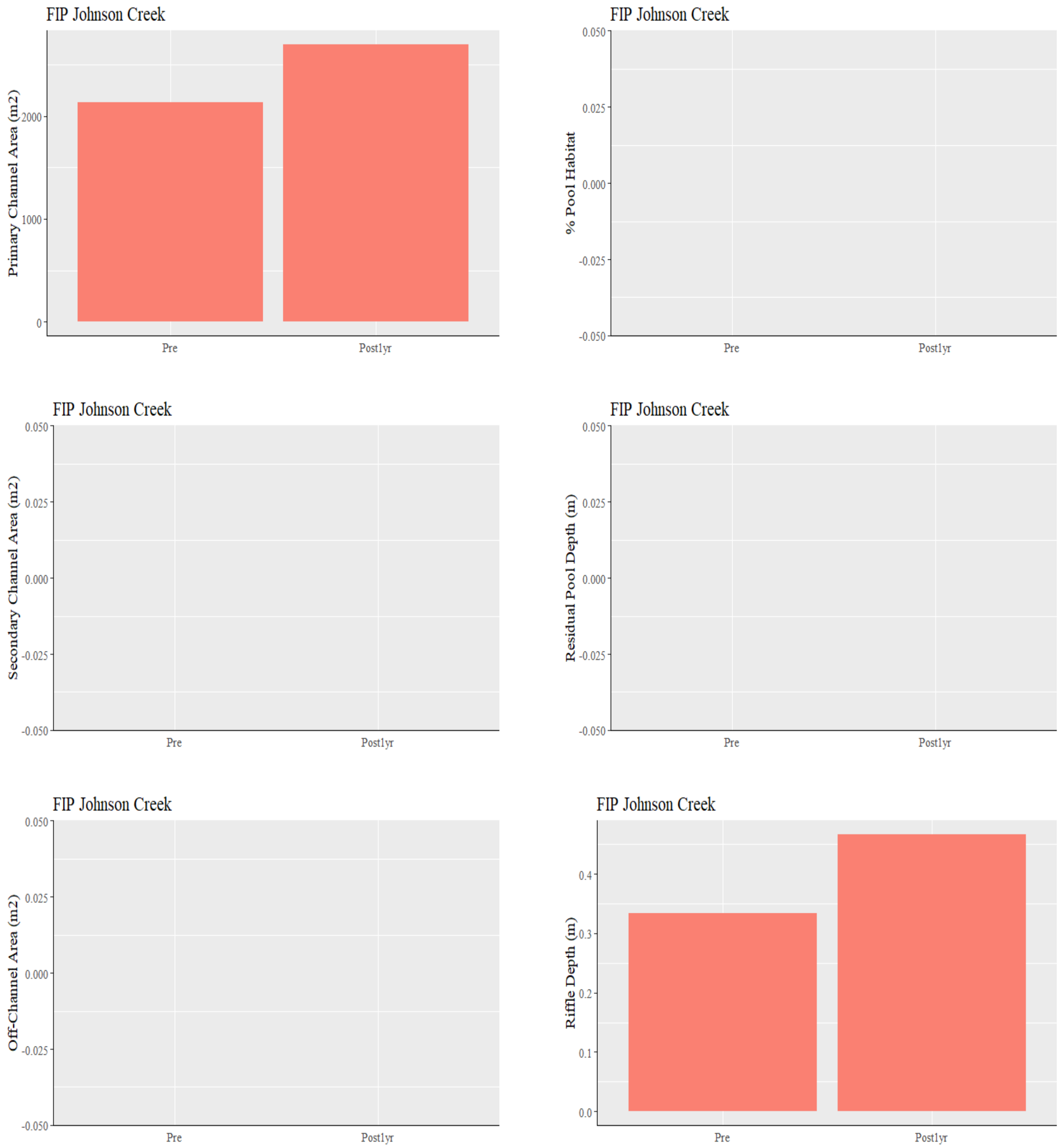


Figure 36. Bar plots describe differences between pre-restoration and post-restoration treatments across channel and pool features within Johnson Creek.

Wood volume increased within the Johnson Creek restoration site as expected, but the number of key pieces of wood (≥ 12 meters in length and 60 cm in diameter) remained absent (Figure 37).

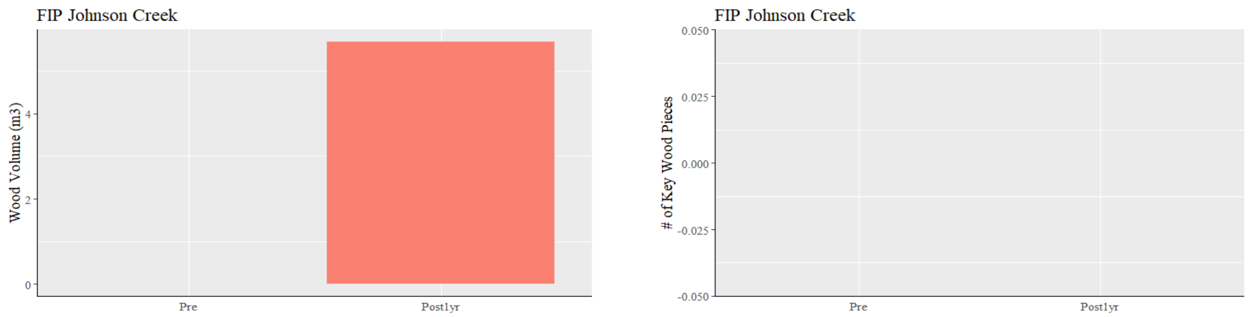


Figure 37. Bar plots for Johnson Creek describing differences between pre-restoration treatment and post-restoration treatment for wood volume ($m^3$) and the number of key pieces of wood (≥ 12 meters in length and 60 cm in diameter).

Across bedload types within Johnson Creek, percent fines (silt and sand) and boulder remained increased slightly between year one and year two of the monitoring effort, while percent gravel and cobble decreased slightly. Percent bedrock remained absent across sampling years (Figure 38).

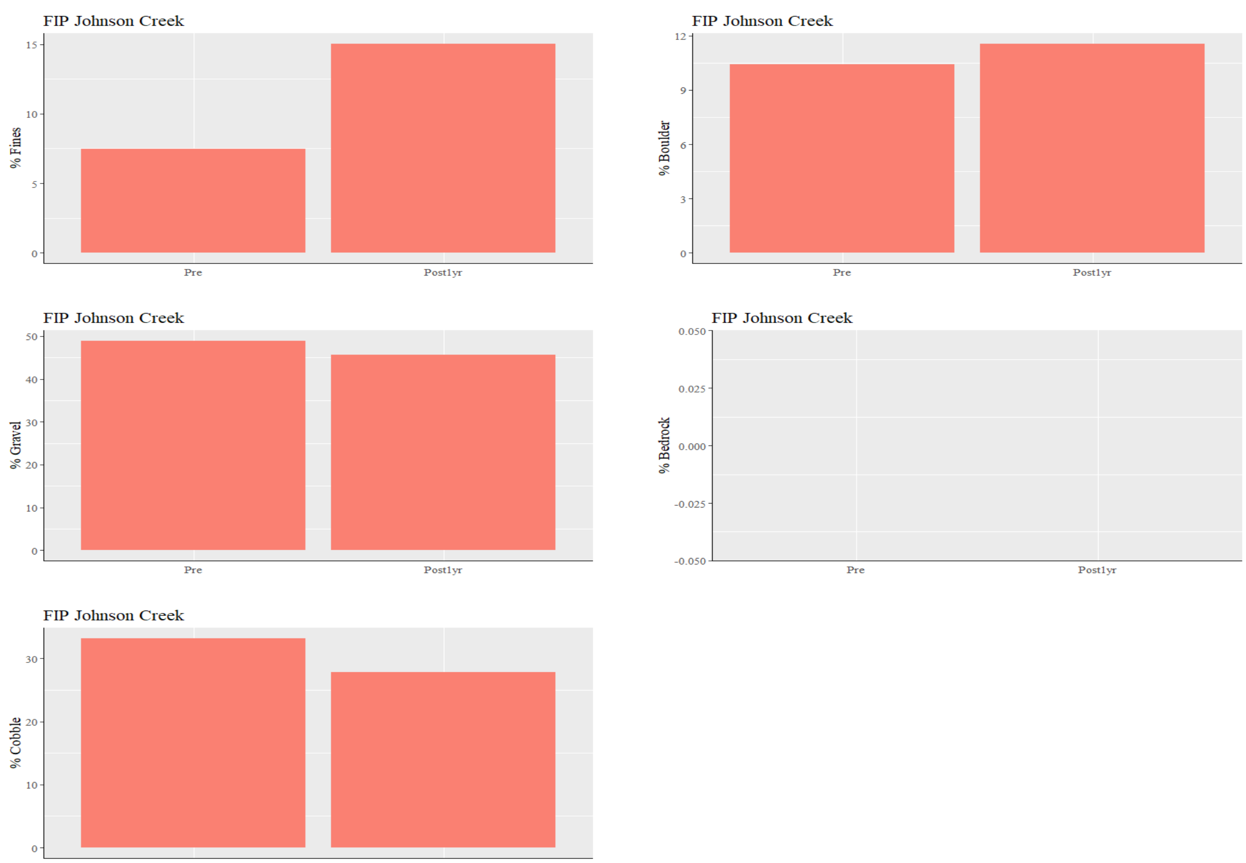


Figure 38. Bar plots for the Johnson Creek site describe differences between pre-restoration and post-restoration treatment across bedload types.

## Restoration Assessment – Cazadero (North Fork Deep Creek)

Across channel and pool features within the Cazadero (North Fork Deep Creek) restoration site, habitat metrics increased slightly between pre-treatment and post-treatment restoration activity (Figure 39). Secondary channels and off-channel habitats (alcoves, backwaters, and isolated pools) remained absent across the sampling period.

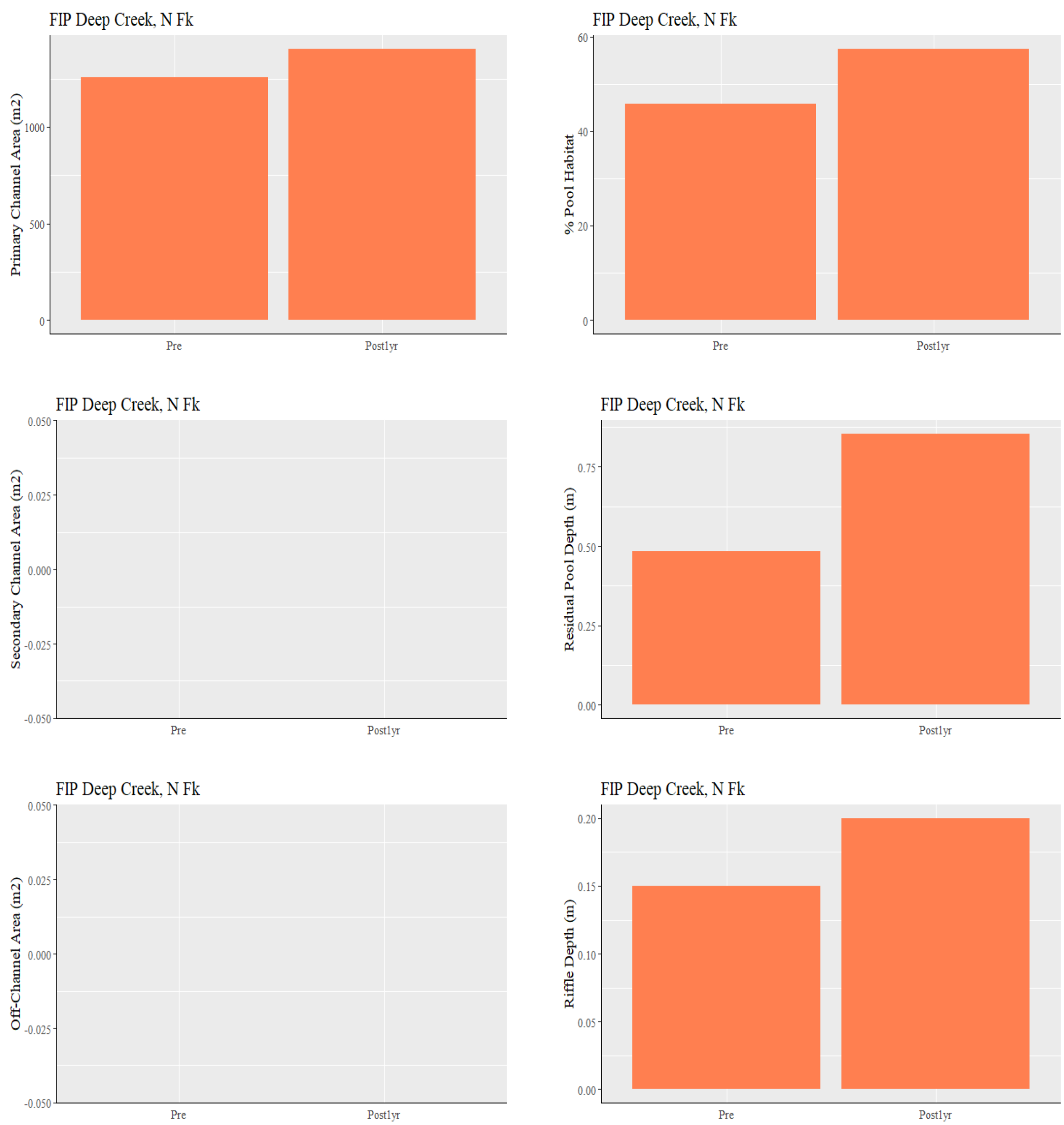


Figure 39. Bar plots describe differences between pre-restoration and post-restoration treatments across channel and pool features within the Cazadero site (North Fork Deep Creek).

Wood volume increased within the Cazadero restoration site as expected, but the number of key pieces of wood (≥ 12 meters in length and 60 cm in diameter) remained absent (Figure 40).

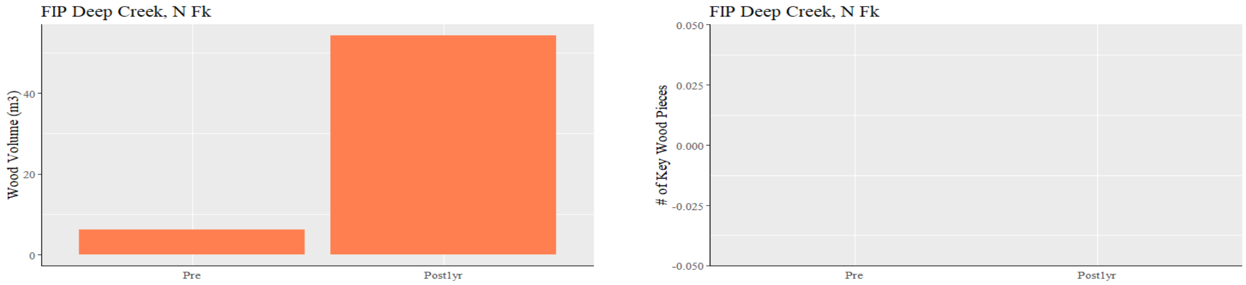


Figure 40. Bar plots for the Cazadero (North Fork Deep Creek) describing differences between pre-restoration treatment and post-restoration treatment for wood volume ($m^3$) and the number of key pieces of wood (≥ 12 meters in length and 60 cm in diameter).

Bedload types differed from pre-restoration treatment to post-restoration treatment (Figure 41). Percent fines (silt and sand) and percent boulder decreased during the sampling period, and percent gravel increased. Bedrock was approximately 16% of the bedload before restoration, and after restoration treatment, bedrock was not observed. Percentage cobble did not change after the restoration treatment.

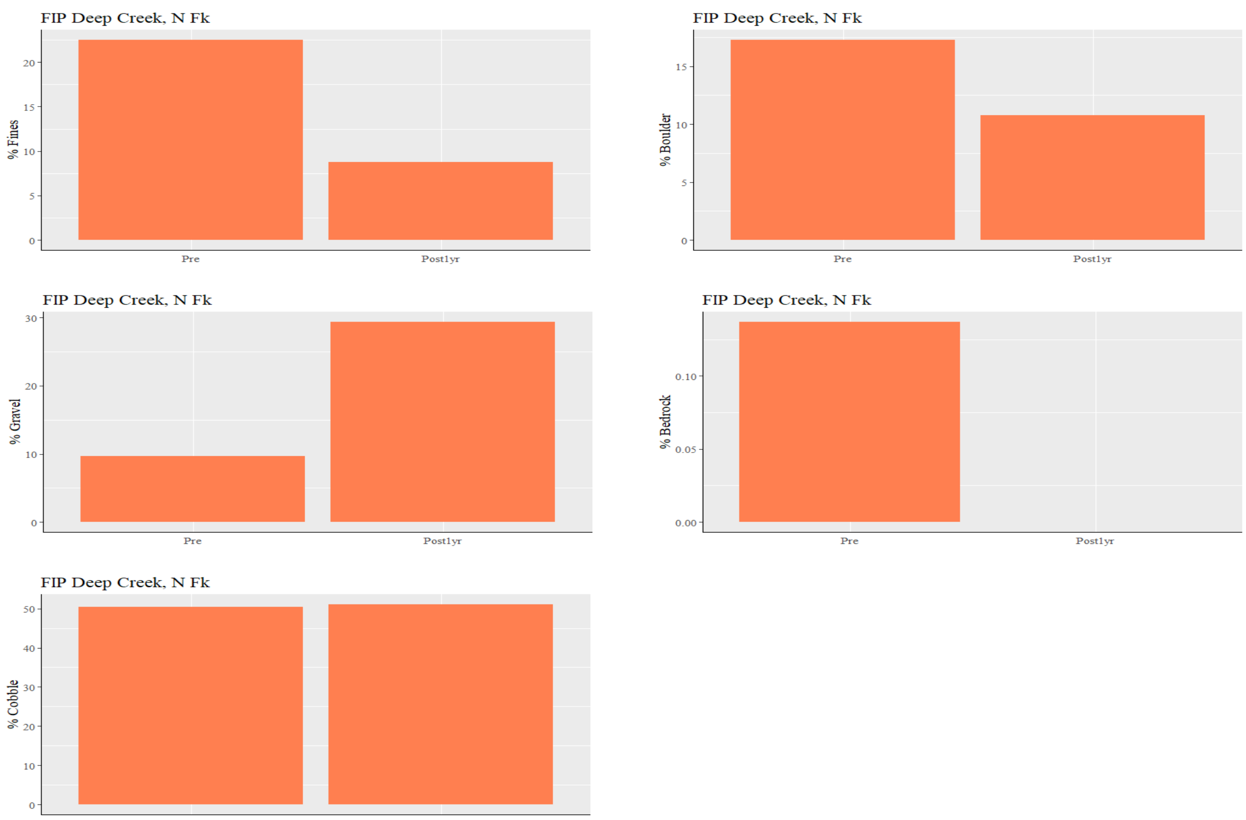


Figure 41. Bar plots for the Cazadero (North Fork Deep Creek) site describe differences between pre-restoration and post-restoration treatment across bedload types.

# DISCUSSION

Restoration efforts are underway on four sites: Kingfisher side channel, Riverbend side channel, Abernethy Creek, and Newell Creek North. Pre-restoration and post-restoration comparisons will occur once treatment efforts have been completed.

Restoration enhancements have occurred on three sites: Eagle Creek Complex, Johnson Creek, and Cazadero (North Fork Deep Creek). The Aquatic inventories Project and UAS operations will return after restoration efforts have concluded at a five-year interval. Utilizing the same protocols as referred to in this report, we will conduct comprehensive surveys of the mainstem Clackamas River and the post-restoration sites and compare and evaluate the habitat changes resulting from the restoration efforts.

When assessing one-year post-treatment results across sites, we were surprised at the lack of significant differences across habitat attributes (Jones et al. 2014). But slight desired differences were observed across sites indicating positive restoration results. We saw an overall increase in percent gravel with a decrease in percent bedrock. Additionally, we saw a slight overall increase in pool habitats, secondary channel area, and wood volume. The slight reduction of residual pool depth and riffle depth across sites could be explained by drought conditions in 2021 or the observed increase in percent secondary channel area. After restoration activity, the minimal change in wood volume is likely more reflective of existing habitat conditions across FIP sites where wood pieces were present and in sufficient volume before restoration. Structures added during restoration are more likely to remain within site areas longer. Five-year post-restoration surveys will likely reflect these efforts, and we anticipate an overall increase in wood accumulation compared to one-year post-restoration results.

## Upper Control Channel

Decreases in wood volume ($m^3$) were likely due to this site being partially inundated at high flows, and available wood pieces cannot remain in place due to active channel size and a lack of key pieces. Differences in the substrate were likely due to high winter flows and minimal structure allowing movement of bedload types during the winter season.

## Eagle Creek Complex

Wood volume increased within the Eagle Creek Complex as expected, but the decrease in the number of key pieces of wood was a surprising result. Slight channel movements and restoration actions could explain this. We will evaluate UAS survey imagery during future efforts to determine if these pieces remained within the bounds of the site but are now outside the active channel area (within the flood plain). A notable change within the Eagle Creek Complex was pre-restoration summer flow across channel types to post-restoration summer flow. We experienced a significant drought during 2021 that undoubtedly influenced this, but the Eagle Creek Complex also has the most secondary channel area of all FIP sites. These channels are more likely to show seasonal flow variation in habitat compared to single-channel type sites. Secondary channels were largely dry during the summer of 2021, except for a single isolated scour pool that was significantly cooler than the mainstem and contained all observed juvenile coho and Chinook salmon.

### Middle Control Channel
While differences were minimal between sampling years, the Middle Control Channel directly connects to the mainstem Clackamas River, and high flows are likely to displace and replace bedload types and wood pieces.

### Johnson Creek
Pool habitat and key pieces of wood remained absent in Johnson Creek following restoration, but habitat quality evaluated from HabRate modeling suggested an improvement overall. Both Chinook and steelhead habitat improved across life history types, while the quality of cutthroat trout habitat stayed the same. Coho habitat quality decreased slightly overall, but the only life history type that declined was spawning and emergence. This is likely attributed to a slight decline in percent gravel and cobble. All other coho life history types stayed the same.

### Cazadero (North Fork Deep Creek)
Secondary channels, off-channel pool habitat, and key pieces of wood remained absent following restoration activity, but all other desired habitat attributes increased. Wood placements and gravel augmentation likely aided in capturing new bedload materials. In addition, habitat quality evaluated from HabRate modeling suggested an improvement overall. Chinook, steelhead, and coho habitat improved across life history types, while cutthroat trout habitat stayed the same.

**ACKNOWLEDGMENTS**

Kara Anlauf-Dunn
Eric Brown
Dan Coffman
Peggy Kavanagh

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