Upper Deschutes Watershed Council
Community Report

Ecological Outcomes of Stream Restoration on Whychus Creek:

Stream and Floodplain Restoration at Whychus Canyon Reach 4

Upper Deschutes Watershed Council
Bend, Oregon
December 2021

This page intentionally left blank

INTRODUCTION

Whychus Creek originates as a small headwaters stream on the eastern slope of the Cascade Mountains. The creek flows 40 miles, descending through forested canyons and wide alluvial valleys before joining the Deschutes River on its journey north to the Columbia River. Abundant summer steelhead and Chinook salmon historically swam up from the Columbia to spawn in Whychus, the young fish nourished by the stream before making their own journey to the Columbia and the ocean.

With European-American settlement in the late 1800s, the stream was harnessed for irrigation, in many summers running dry. In the alluvial valleys, the stream was straightened, its meadow floodplains converted to dry pastures, its spawning gravels choked with silt. The steelhead and salmon persisted until the 1958 construction of the Pelton dam on the Deschutes blocked their migration to the Columbia, to the ocean, and back. By the end of the 20th century, Whychus Creek was a vestige of the flourishing ecosystem that had greeted those first European-American settlers.

In the late 1990s, individuals from the local community to the state level began to re-imagine Whychus Creek and other tributary streams as the dynamic ecosystems they once were. Deschutes River Conservancy (DRC), Deschutes Land Trust (DLT), and Upper Deschutes Watershed Council (UDWC) were formed to protect and restore Whychus Creek and other Deschutes River tributaries. DRC began working with irrigation districts and water rights holders to conserve and lease water, leaving more and more water in the stream during hot summer months. DLT purchased or acquired conservation easements on streamside properties, protecting ecological values on lands threatened by development. UDWC started work with water rights holders, landowners, and partner organizations to provide fish passage at diversion dams, screen diversions, and restore the stream channel to its historic meadow meanders. The restoration actions of the three partner organizations are designed to restore functioning stream channel and floodplain ecosystems, including the physical and biological conditions necessary to support self-sustaining populations of native redband as well as the steelhead trout and Chinook salmon re-introduced to the creek beginning in 2007.

What are the ecological outcomes of stream restoration on Whychus Creek? While we can count stream miles constructed and floodplain acres planted, we also need to understand the ecological response to these actions. The purpose of this report is to summarize complex information about ecological outcomes in an approachable, easily referenced format by presenting a handful of indicators that we expect to change in response to restoration actions. This report evaluates indicators for Phase I of stream channel and floodplain restoration at Deschutes Land Trust's Whychus Canyon Preserve, at Whychus Canyon Reach 4. It complements the 2018 community report titled "Ecological Outcomes of Stream Restoration on Whychus Creek", which reported on indicators for the three other restoration strategies employed by DRC and UDWC in collaboration with restoration partners: stream flow restoration; fish passage; and diversion screening.

STREAM CHANNEL AND FLOODPLAIN RESTORATION AT WHYCHUS CANYON REACH 4

PROBLEM AND NEED:

Research published over the last decade has revolutionized how scientists think of streams. Data and undisturbed reference sites from across the US and beyond show that streams in low-gradient valley reaches are naturally, and likely were historically, networks of braided and branching channels that continuously evolved to carve new flow paths across highly connected floodplains. The presence of beaver and mature riparian vegetation in these connected, complex systems accelerated ecosystem change, creating a diverse tapestry of aquatic, wetland, and riparian habitats that supported thriving vegetation and numerous and abundant fish and wildlife species, birds, and pollinators and other insects.

On Whychus Creek and other tributary streams throughout the Pacific Northwest, diversion of stream flow and modifications to stream channels and floodplains for agriculture and flood control resulted in a dramatic transformation of complex, connected valley bottom systems to efficiently drained agricultural pastures. Eighteen miles of Whychus Creek were straightened and bermed. Confined to a single channel, flood flows carried away gravels and soil and cut the channel deeper. Without old trees to fall into the stream and create pools, the channel remained simple, with relatively little structure, providing little cover or slower areas for rearing fish. The floodplain suffered. Diverse riparian vegetation was removed, replaced with pasture grasses, upland shrubs, and weed species that could tolerate dry soils.

Beginning in the mid-1990s, restoration practitioners began working to restore stream habitats in hopes of recovering the salmon and steelhead populations that have declined throughout the Columbia Basin. On Whychus Creek, a dedicated team of partners including UDWC, DLT, and USFS began designing restoration projects to re-establish stream processes that would build stream habitat. The first of these, the Camp Polk Meadow Preserve Restoration Project, broke ground in 2008 and was completed in 2012. The Whychus Floodplain Project, on National Forest land upstream of the City of Sisters, was implemented in 2014. Lessons learned through observation and monitoring of these two projects, alongside the publication of Brian Cluer and Colin Thorne's Stream Evolution Model (Cluer and Thorne 2014), informed development of a transformative new approach to designing restoration projects. Rather than designing and building channels, "Stage 0 restoration" constructs a new floodplain surface by grading high areas and filling the incised channel, then re-activates the floodplain by diverting the stream onto the constructed surface and into relict channels that remain on the landscape. Flow paths form and become channels; abundant wood placed across the floodplain surface forces scour and deposition, creating in-channel structure and aquatic habitat.

The Stage 0 restoration project implemented at Whychus Canyon Reach 4 in 2016 was expected to 1) Increase vertical hydrologic connectivity between channel and floodplain elevations and between surface water and groundwater; 2) Create abundant and high-quality fish habitat, and 3) Restore diverse wetland, wet meadow, and riparian habitat for wildlife.

BACKGROUND: Eighteen of the 40 miles of Whychus Creek were straightened and bermed from the 1940s to the 1960s, resulting in the following limiting factors identified in the Conservation and Recovery Plan for Oregon Steelhead Populations in the Middle Columbia River Steelhead Distinct Population Segment (Carmichael and Taylor 2010):

- Degraded riparian communities and large wood recruitment, damaged by past grazing, channel and floodplain modifications, and development;

- Degraded floodplain connectivity and function including loss of side- and off-channel habitat and reduced groundwater discharge, exacerbating low stream flow and high water temperatures resulting from diversion of stream flow for irrigation;

- Degraded channel structure and complexity including reduced number of channels, channel sinuosity, and channel length.

- Altered sediment routing (high fine sediment) resulting from channelization and eroding streambanks.

To the greatest extent possible, UDWC's restoration projects focus on employing a process-based approach to stream habitat restoration. This approach aims to restore the "physical, chemical, and biological processes that create and sustain river and floodplain ecosystems" (Beechie et al 2010) to set the stream channel and floodplain system on a trajectory toward self-sustaining function. These projects interrupt degradation of stream and floodplain habitat structure and function and create the necessary conditions for physical, chemical and biological processes to resume. These processes include primary responses such as floodplain inundation and groundwater storage; wood and organic material recruitment and storage; and sediment erosion, transport, and deposition. Secondary responses resulting from primary processes include physical habitat characteristics such as the number, types, and proportions of geomorphic channel units, diversity of substrate size classes, and flow velocities; and tertiary, biological responses including the plant community, macroinvertebrate community, and native fish. As such, our ecological objectives, hypotheses, and indicators for stream habitat restoration address restoration of those processes and their resulting structures.

WHAT'S BEEN ACCOMPLISHED: Stream channel and floodplain restoration projects have been implemented along 4.2 miles of Whychus Creek, at the Three Sisters Irrigation District (2010), Camp Polk Meadow Preserve (2012), Whychus Floodplain (2014), and Whychus Canyon Reach 4 (2016).

WHAT WE'RE MEASURING: UDWC is measuring indicators of primary, process responses to restoration including surface and groundwater storage, ratio of secondary to primary channel lengths, and wood and organic material storage; indicators of secondary, physical habitat responses to restoration including number of habitat units, number of pools, and stream temperature; and indicators of tertiary, biological responses including plant community, macroinvertebrate community, and native fish metrics.

WHAT WE'RE MEASURING: Primary Response: Process

Primary processes describe the interaction of water, geology (sediment), and biology (plants and sometimes animals) to create complex, heterogeneous channels and floodplain surfaces that provide habitat. Key primary processes we're measuring are runoff and flow, and supply and storage of wood and organic material.

Pre-restoration, stream flow was quickly transported through the project and downstream in a simple, straight, incised channel that was disconnected from the floodplain. The wetted area of this single channel along the mile of valley was only 3.4 acres. With the single stream channel well below the floodplain surface, flood flows rarely overflowed the channel, so the floodplain was rarely saturated and groundwater remained deep below the floodplain surface, falling further during dry, hot summer months. From mid-July to the end of August, depth to groundwater averaged 6.8 ft below the floodplain surface.

The Whychus Canyon Reach 4 restoration project was designed to put the stream back onto the floodplain, where the interaction between water and the floodplain surface would create a network of meandering channels that remained connected to the floodplain. This network of channels would keep water in the project reach for longer, creating more wetted area across the floodplain and more consistently recharging groundwater. In most places channels would be within a few feet of the floodplain surface and would support a shallow groundwater table close to the floodplain surface.

Because water was transported so quickly through the project reach and because the channel had last been moved, this time to the edge of the valley, within 60 years, there were few big trees along the stream to fall and provide structure. Pre-restoration there were four pieces of large wood per 100 meters of valley length.

The restoration design included addition of large amounts of large wood across the floodplain. As water and sediment interact with wood, the physical structure of the wood causes both deposition, sediment being dropped out of the current and deposited to create riffles and bars, and scour, sediment being picked up and moved by the current, creating pools. Juvenile fish hide under logs and macroinvertebrates live in the spaces between bark and wood.

We use four process metrics to understand the primary response to restoration in Whychus Creek:

	PROGRESS:
1. Runoff and flow: Wetted area *Objective: Increase wetted area* Wetted area is a measure of hydrologic connectivity and storage of water in the project reach.	• Wetted area in Whychus Canyon Reach 4 doubled, from 3.4 acres in 2011 to 6.8 acres in 2019.

2. Runoff and flow: Length of secondary channel per meter of primary channel *Objective: Ratio >1.5:1* The amount of secondary channel relative to the amount of primary channel is a measure of channel network complexity. A higher secondary to primary channel length ratio also indicates a higher number of confluences (two channels coming together) and diffluences (one channel diverging to create two channels). Both of these metrics have been shown to be correlated to higher fish production (Hall et al. 2018).	• The ratio of secondary channel per meter of primary channel increased from 0.1 meter of secondary channel for every meter of primary channel (0.1:1) to 2.7 meters of secondary channel per meter of primary channel (2.7:1), a 20-fold increase.
2. Runoff and flow: Groundwater depth *Objective: ≤ - 2 ft* Average depth to groundwater between July 15th and August 31st for the four monitoring wells in Whychus Canyon Reach 4 represents the lowest groundwater depth of the year at a time when demand from riparian vegetation is greatest.	• Average groundwater depth between July 15th and August 31st decreased from -6.8 feet pre-restoration to -1.6 ft in 2019.
4. Wood storage: Amount of large wood *Objective: Increase large wood* Pieces of large wood per 100 m valley length are a measure of the amount of wood interacting with active channels to provide structure for channel building and habitat for fish and macroinvertebrates	• Pieces of large wood per 100 m valley length were 11 times higher post-restoration, increasing from 4 in 2011 to 45 in 2019.

WHAT WE'RE MEASURING: Secondary Response: Physical Habitat and Water Quality

Functioning stream processes create physical habitat. Sediment deposition and erosion create habitat units including pools and riffles. More habitat units in close proximity provide all the habitat functions fish need within a smaller, more easily accessible area. More habitat units can also help cool stream temperatures. More habitat units, including deep pools, and more sinuous channel pattern (how much a channel meanders), cause more exchange of water between the stream and the shallow groundwater below and beside a stream channel, called the hyporheic zone. In the summer when flows are low and stream temperatures heat up, the cooler groundwater can help lower stream temperatures.

Stream temperature is a key factor limiting native trout populations in Whychus Creek. Just like high air temperatures affect humans, stream temperatures that are too warm make it difficult for trout to perform basic activities like foraging for food and even swimming. Living in temperatures that are chronically too warm can keep fish from growing.

We use two indicators of physical habitat and one indicator of stream temperature to understand the secondary response to restoration at Whychus Canyon Reach 4:

	PROGRESS:

2. Physical Habitat: Number of habitat units *Objective: Increase number of units* The number of habitat units is a measure of structural complexity and habitat diversity within stream channels.	• The number of habitat units in the project reach increased by 6x, from 54 in 2011 to 340 in 2019.
2. Physical Habitat: Number of pools *Objective: Increase number of pools* The number of pool units is a measure of pool habitat providing slow water, over-wintering, and summer low flow habitat to support juvenile rearing and adult holding.	• The number of pools in the project reach increased by 6x, from 23 in 2011 to 130 in 2019.
2. Water Quality: Rate of Stream Temperature Increase *Objective: ≤0.4°C 10-yr maximum* The average rate at which stream temperature increases per mile provides information about the net rate of warming in the project area compared to that observed pre-restoration.	• The rate of temperature increase in the project reach was 0.1°C per mile over three successive years (2017-2019), well below the 0.4°C 10-yr pre-project maximum

WHAT WE'RE MEASURING: Tertiary Response: Plants, Macroinvertebrates, and Fish	
Biological communities are limited or conversely supported by the physical and structural conditions of an ecosystem. Therefore, the biological communities present and the characteristics of those communities are an expression of the quantity and quality of the physical conditions and habitat. The assemblage of species that makes up a plant community is strongly influenced by access to water. Even in the high desert on the east slope of the Cascades where annual precipitation is low, the shallow groundwater in a connected floodplain can support abundant wetland, wet meadow and riparian vegetation. This proliferation of vegetation in turn supports a diversity of insect, bird, and wildlife species. Beaver use riparian tree and shrub species to build lodges and dams that provide structure in stream channels and promote channel evolution and creation of aquatic habitat. In the stream, the macroinvertebrate community is also shaped by the physical environment. A diversity of flow, temperature, and sediment conditions supports a diversity of species with different flow, temperature, and sediment preferences. The presence of sensitive EPT species that prefer cold, clear water shows that water quality is good enough for these species to thrive. Rearing native trout and salmon need slower places to rest, cover to hide under, and abundant food. In Whychus, where young steelhead trout and Chinook salmon are released every year to re-establish these populations, the number of fish in a restoration reach doesn't tell us how many fish are being produced in the project area but rather about how well the habitat is providing these essential functions. Returning adult salmon need sufficient depths to swim upstream, cold water refuges including deep pools and hyporheic groundwater upwellings, and gravels to spawn in. Adult salmon and steelhead migrating into and through the project reach provide some indication that habitat created through restoration provides the minimum conditions necessary for returning adult fish. We use five metrics to understand the biological response to the physical and habitat conditions created by restoration:	
	PROGRESS:
1. Plants: Acres of riparian vegetation *Objective: Increase acres of desired plant communities*	• Acres of vegetation classified as riparian herbaceous, shrub, or herbaceous-isolated shrub and tree increased almost three-fold from 2016 to 2017, from 4.6 acres to 12.3 acres.
2. Plants: Native wetland indicator species richness and abundance *Objective: Increase native wetland indicator species richness and abundance*	• Richness: The average number of native wetland indicator species on Whychus Canyon Reach 4 vegetation transects doubled from 6 in 2015 to 12 in 2018. • Abundance: The average percent cover of native wetland indicator species on Whychus Canyon Reach 4 vegetation transects doubled from 44% in 2015 to 87% in 2018.

3. Macroinvertebrates: Total and EPT taxa richness *Hypothesis: Increased habitat quality and diversity will support increased taxa richness*	• Total richness: The total number of macroinvertebrate taxa increased by 60%, from 29 taxa in 2015 pre-restoration to 51 taxa in 2019, three years post-restoration. • EPT richness: The number of sensitive EPT taxa in the project reach also increased by 60%, from 13 in 2015 to 21 in 2019.
4. Fish: Juvenile *O. mykiss* (redband/steelhead) density: *Hypothesis: Increased habitat quality and diversity will support higher juvenile density*	• Juvenile fish per 100 m^2: There were 3x as many *O. mykiss* per 100 m^2 in 2018 (35) post-restoration as in 2015 (11) pre-restoration. • Juvenile fish per 100 m channel length: There were 4x as many *O. mykiss* per 100 m of channel in 2018 (455) as in 2015 (108)
4. Fish: Adult migration: *Hypothesis: Habitat quality and depth will allow adult fish to use and migrate through the project reach*	• The final detection of 71% (10 out of 14) of adult salmon and steelhead that returned to Whychus Creek over three years post-restoration (2017-2019) was in or upstream of the project reach. • No returning adult salmon and steelhead were last detected in or upstream of the project reach before restoration, although one steelhead was detected in Camp Polk (upstream of Whychus Canyon Reach 4) in 2016.

NEXT STEPS

Restoration partners in the Whychus Creek watershed continue to work together to return Whychus Creek to a dynamic, evolving stream and floodplain ecosystem that supports abundant and resilient fish, wildlife, and plant communities. Irrigation districts, agencies, non-profits and concerned citizens are collaborating through the Deschutes Basin Study to develop science and solutions that ensure sufficient water for rivers, farms, and cities. The last barrier to fish passage on Whychus Creek was removed in 2021, and most diversions have been screened or decommissioned. Additional stream channel and floodplain projects are expected to restore stream, riparian and floodplain habitat and ecosystem function along 7.6 miles and on 365 floodplain acres of Whychus Creek. UDWC will continue to monitor and evaluate the ecological outcomes of restoration projects to inform development and design of future projects.

REFERENCES

Carmichael, R.W. and B.J. Taylor. 2010. Conservation and recovery plan for Oregon steelhead populations in the Middle Columbia River Steelhead Distinct Population Segment. Oregon Department of Fish and Wildlife.

Cluer, B. and C. Thorne. 2014. A Stream Evolution Model Integrating Habitat and Ecosystem Benefits. River Research and Applications. 30. 10.1002/rra.2631.

Hall, J.E., C.M. Greene, O. Stefankiv, J.H. Anderson, B. Timpane-Padgham, T.J. Beechie, G.R. Pess. 2018. Large river habitat complexity and productivity of Puget Sound Chinook salmon. PLoS ONE 13(11): e0205127.