A Review of Stage 0 Restoration Practices in California and Oregon

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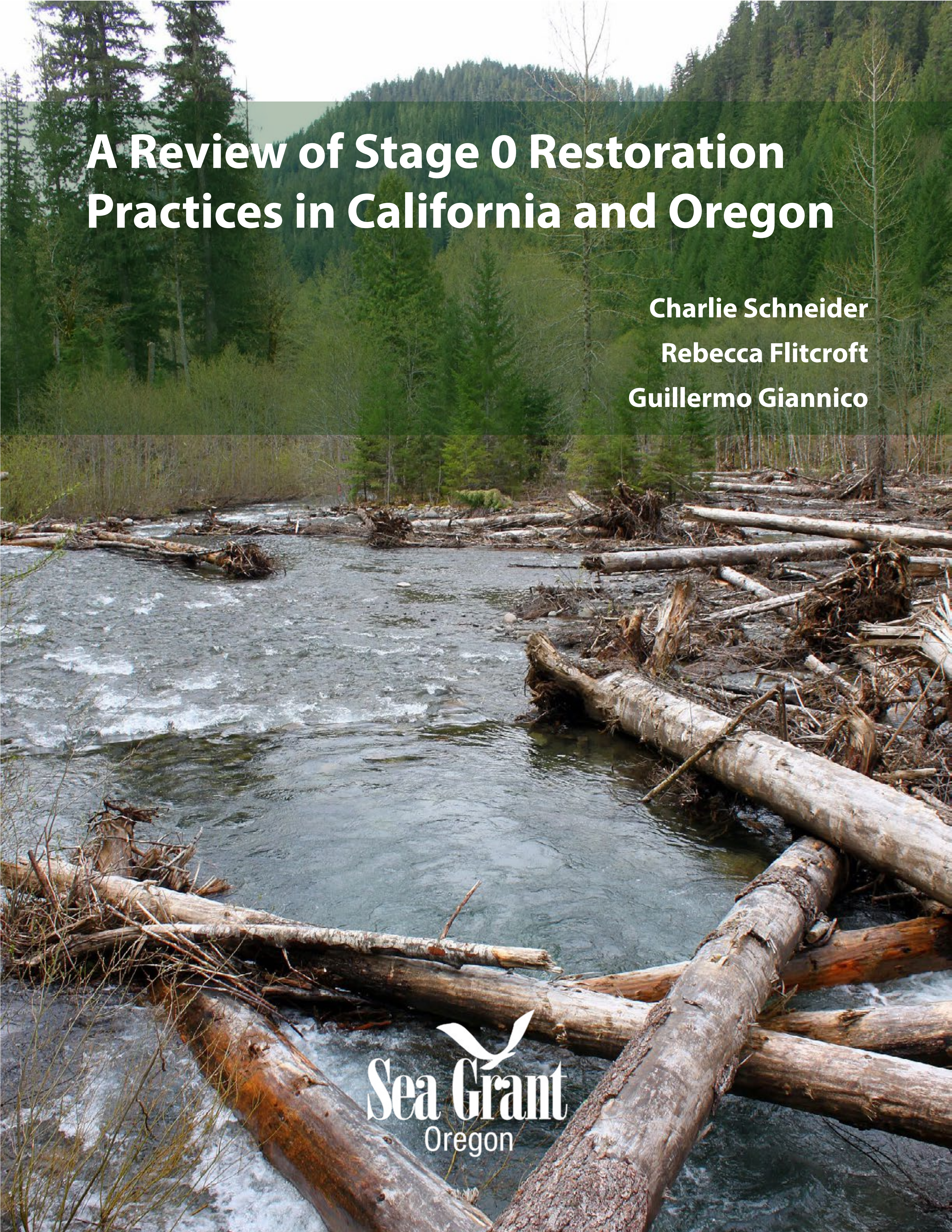

Sea Grant Oregon

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Cover image: In 2016, large wood was placed in stretches of Deer Creek, a tributary to Oregon's upper McKenzie River, as part of a stage 0 restoration project. (photo taken in 2017 by Sherri Johnson of the Forest Service)

Above: This is how the Five Mile Bell project south of Florence, Oregon, looked in May 2020 after implementation. (photo by Paul Burns of the Forest Service)

Introduction

Fragmentation, changes in land use, and simplification of river ecosystems globally have changed physical processes and habitats and decreased biodiversity (Poff et al. 2007). The last decade saw a focus on restoring natural processes in stream ecosystems rather than setting habitat objectives for individual species. The goal was to create diverse habitat conditions that native species are adapted to (Kauffman et al. 1997; Beechie et al. 2010; Kondolf et al. 2013; Wohl et al. 2015). Practitioners in the Pacific Northwest have started to focus on larger-scale floodplain restoration projects (Beechie et al. 2010; Powers et al. 2019). These efforts have been informed, in part, by evidence that suggests increased floodplain productivity may be beneficial to the growth of juvenile salmonids, which are often the targets of stream restoration and funding (Limm & Marchetti 2009; Katz et al. 2017).

In the past decade, floodplain restoration practices have coincided with theoretical developments in channel evolution models that target the importance of floodplains for ecological productivity and river dynamics. Cluer and Thorne (2013) added to existing channel evolution models by including the “stage 0” evolutionary phase, which they define as an unconfined, anastomosing, multi-threaded network of channels with high groundwater connectivity (Figure 1). This stream form is hypothesized to have been widespread throughout the Pacific Northwest prior to European settlement and provides a previously absent reference condition for restoration efforts in depositional valleys (Walter & Merritts 2008; Woelfle-Erskine et al. 2012; Cluer B. & Thorne C. 2013).

Stage 0 streams are predicted to diffuse flood pulses across the entire valley floor, raise groundwater elevations and maintain diverse habitats, resulting in high biodiversity (Cluer B. & Thorne C. 2013; Castro & Thorne 2019). These theoretical ecosystem attributes made restoration to stage 0 a popular topic at River Restoration Northwest’s symposium in 2020 and the Salmonid Restoration Federation’s conference in 2019.

In this document, we identify floodplain restoration projects in California and Oregon that aim to restore stream reaches to stage 0. We describe the restoration techniques, summarize attributes of the projects, and compare monitoring methods for evaluating outcomes. Restoration actions ranged from building human-made beaver dams to using bulldozers and backhoes to level out landscapes. We found little information, however, about

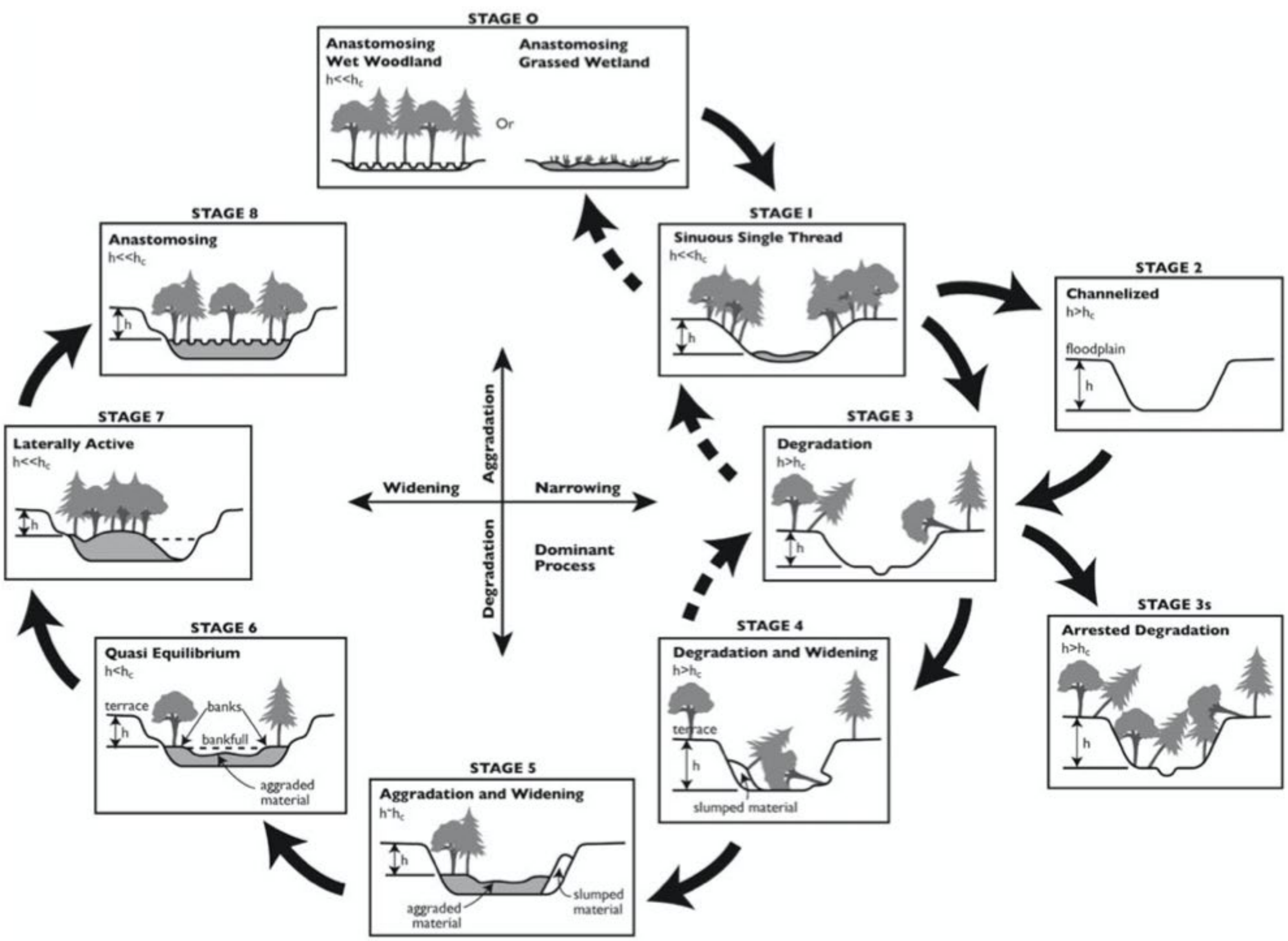
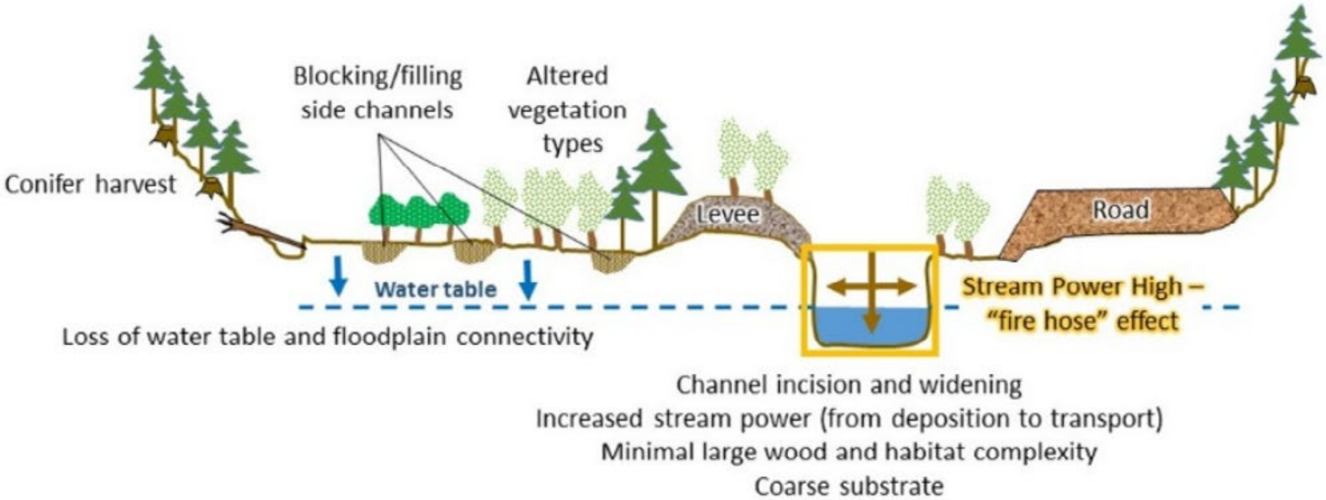


Figure 1: Cluer and Thorne’s stream evolution model, which introduced stage 0



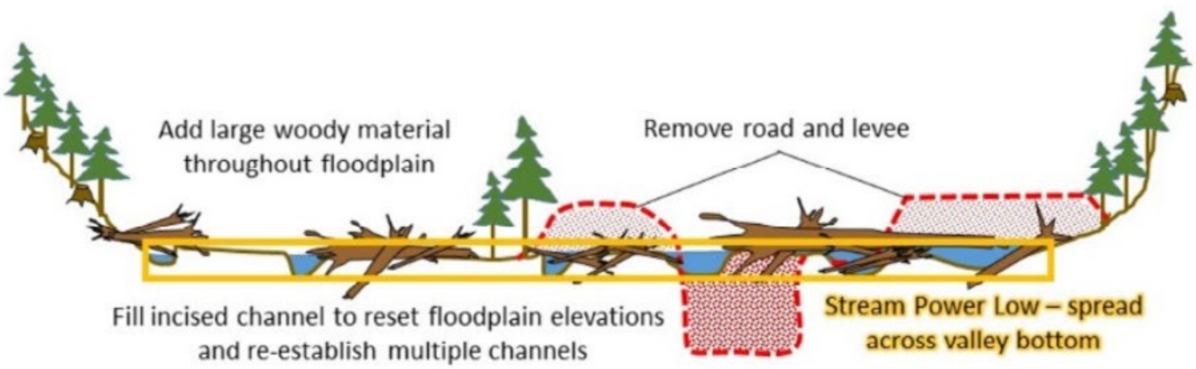


Figure 2 (top): A stream and valley before restoration (from Meyer 2018)
Figure 2 (bottom): The same floodplain after stage 0 restoration using the Geomorphic Grade Line approach (from Meyer 2018)

what level of intervention may be appropriate for the unique characteristics of each site. We also noticed a lack of completed studies to evaluate the long-term effectiveness of restoration.

Stage 0 restoration is hard to define given the lack of literature on the technique and the fact that stage 0 refers to a phase of stream evolution, and thus the intended outcome of restoration actions, rather than a restoration technique itself. For this paper, we relied on a definition developed by practitioners in Oregon during two workshops held by the Forest Service that were part of an effort to develop a monitoring plan for stage 0 restoration. Participants defined stage 0 restoration as "a valley-scale, process-based (hydrologic, geologic and biological) approach that aims to reestablish depositional environments to maximize longitudinal, lateral and vertical connectivity at base flows, and facilitate development of dynamic, self-forming and self-sustaining wetland-stream complexes" (Figure 2).

Whychus Canyon Preserve in 2021 after restoration. (photo by Jay Mather)

Identifying projects

Given the novelty of stage 0 restoration and the fact that most documentation is only available as grey literature, we identified potential projects primarily through contact with practitioners in California and Oregon. Potential projects in Oregon were identified as part of an effort currently underway that seeks to evaluate the effects of stage 0 restoration at a regional scale. Most Oregon projects occurred on federal Forest Service lands, were identified by restoration practitioners as stage 0 projects, and represented diverse sizes and outcome goals. When available, we reviewed practitioners' presentations as well as information on planning, implementation and monitoring.

To identify potential projects in California, we took a three-pronged approach. First, we reached out to participants at a workshop titled "Restoring to Stage 0" at the Salmonid Restoration Federation's 37th annual conference in 2019. Attendees identified projects that included a variety of methods, outcome goals and groups involved with them (i.e., resource agencies, nongovernmental organizations, tribes, consultants and contractors). We collected documents on design, permitting and monitoring – either online or from people implementing the projects. After that, we reached out to other practitioners whom we were told might be attempting to restore stream reaches to a stage 0 state. And finally, we searched for literature through Web of Science, Google Scholar and Google using the following terms: "Stage 0" California, "floodplain restoration" California, "anabranching" California restoration, and "channel fill" California restoration.

We assessed the documentation for the projects in Oregon and California to determine if the projects met the definition of stage 0 restoration used for this study and if sufficient empirical data were available to inform further analysis.

To see if projects met the definition, we evaluated documents on project design and planning to determine if 1) the projects attempted to restore at the scale of the entire valley; 2) the outcomes were intended to be process-based; and 3) the outcomes were intended to be self-formed and self-sustaining.

Empirical data required for a project to be considered included location, area of project, restoration techniques and annual rainfall. Additionally, information regarding one or more monitoring approaches needed to be available, but results weren't required because recent projects may have ongoing monitoring.

We considered 39 projects: 17 in Oregon and 22 in California. In the end, six in Oregon and four in California met the requirements for this review (Table 1).

Table 1: Floodplain restoration projects considered for this study

OREGON	**CALIFORNIA**
Coal Creek*	Ash Creek
Deep Creek	Big Meadows
Deer Creek*	Bogard-McKenzie
Dick Creek	Burney Gardens
Dog Creek	Butte Creek
Five Mile Bell*	Clarks Creek
Grizzly Creek	Confluence Meadow*
LeClerc Creek	Doty Ravine*
Lost Creek	Grouse Creek
McKay Creek	Harlow Meadow
Shingle Mill Creek	Horse Meadow
South Fork McKenzie*	Humbug Creek
Staley Creek*	Indian Creek*
Three Mile Creek	Kegg Meadow
Toggle Meadow	Lower Butte Creek
Whychus Creek*	McBride
Wooley Creek	Perrazo Meadows
	Red Clover/McReynolds
	Rose
	Roy's Redwood**
	Sears Point**
	Willow Creek*
* Selected for study ** In planning	

Table 2: Attributes for stage 0 restoration projects analyzed in this study

Location	State	Type of Stage 0	Restoration technique	Date completed	Ecoregion	Hydrology	Mean annual rainfall (mm)	Drainage area (km2)	Base flow (cms)	Valley type	Valley Slope (%)	Valley width (m)
Coal Creek	OR	restore floodplain connectivity	GGL	2019	Western Cascades - Lowlands and Valleys	Rain with rain on snow	1,500-2,000	56	UR	Alluvial fan	< 2	160
Deer Creek	OR	restore floodplain connectivity	GGL	2016	Western Cascades - Montane Highlands	Rain with rain on snow	2800	60	UR	Unconfined	1.8	140
Five Mile Bell	OR	restore floodplain connectivity	Multiple phases, GGL in later phases	2013-2020	Oregon Coast Range - Coastal Lowlands	Rain dominated	1,500-2,000	20.6	0.5	Lacustrine	0.02	200
South Fork McKenzie	OR	restore floodplain connectivity	GGL	2017-2020	Western Cascades - Lowlands and Valleys	Reservoir controlled	2,000-2,500	9.3	0.8	Alluvial fan	0.75	500
Staley Creek	OR	restore floodplain connectivity	GGL	2017-2018	Western Cascades - Lowlands and Valleys	Rain with rain on snow	1,500-2,000	105.2	0.8	Unconfined	2	240
Whychus Creek	OR	restore floodplain connectivity	GGL	2012 and 2016	Ponderosa Pine/ Bitterbrush - woodland	Glacial with rain on snow	500-750	652.7	0.7	Unconfined	0.9	120
Confluence Meadow*	CA	restore floodplain connectivity	Called Pond and plug but full channel fill and valley grading w/ long profile	Yet to be implemented	Cascades - California Cascades Eastside Conifer Forest	Snow dominated	760	400	Intermittent	Unconfined	0.1	446
Doty Ravine	CA	restore floodplain connectivity	BDAs, repopulated with beaver naturally, levee removal, incremental approach	2016	Central California Valley - Northern terraces	Rain dominated	550- 900	62	Unreported	Unconfined	Unreported	160
Indian Creek*	CA	restore floodplain connectivity	GGL	Yet to be implemented	Klamath Mountains/ California High North Coast Range - Eastern Klamath low elevation forests	Rain with rain on snow	960-1300	88	Unreported/ Intermittent	Unconfined	0.2	200
Willow Creek	CA	Passive, Barrier removal	Land use change, reestablished longitudinal connectivity	2011	Coast Range - Coastal Franciscan Redwood Forest	Rain dominated	1370	22	Unreported/ Intermittent	Unconfined	0.5	115

Key Attributes

We summarized key characteristics of the 10 projects in Table 2, which we adapted from Powers et al. (2019). Attributes include restoration technique, ecoregion, hydrology, mean annual rainfall, drainage area, base flow, the type of valley and its slope and width.

Projects were completed (sometimes in phases) between 2011 and 2020. The oldest was Willow Creek in California. Although this project was completed before the coining of the term "stage 0," we included it because it meets the definition of stage 0 restoration used in this study and is an example of a stage 0 stream reach (Cluer et al. 2019).

Two projects in California – Indian Creek and Confluence Meadow – have yet to be implemented but are included in this publication based on their design documents. The projects have been funded, and permitting has been completed. They illustrate a shift in restoration techniques in California.

Of the 10 projects, seven used – or plan to use – the Geomorphic Grade Line (GGL) restoration method. This approach uses a geographic information system to develop a cut-and-fill plan to restore depositional valleys to a common grade that is then allowed to self-adjust to natural geomorphic processes over time (Powers et al. 2019). This technique uses heavy equipment to "reset" the entire valley floor. All of the projects in Oregon were designed – at least in part – using GGL, but in California, only Indian Creek plans to use this approach.

Other less intensive actions included the use of human-made beaver dam analogs (BDAs) (Wheaton et al. 2019) and a barrier removal project coupled with land use change (California State Parks 2010). The Confluence Meadow project in California plans to use a similarly intensive channel fill resembling GGL, although with borrow sites from higher elevation areas rather than a complete valley regrade calculation (Sloat 2017).

Valley widths ranged from 115-500 meters and drainage basins ranged from 9.3-652.7 square kilometers. Valley width and basin size were distributed relatively evenly between the two states. All valley slopes were less than 2%, although Powers et al. (2019) listed a GGL project – Three Mile Creek in Oregon – with a valley slope of 7% that is not included in our study.

Precipitation varied among projects, with ones in California tending to receive less rain than those in Oregon, although baseflow wasn't reported in some projects. California projects were more likely to be focused on streams that are intermittent in some years or seasonally.

Monitoring efforts

We compiled monitoring efforts in Table 3. We adapted this table from efforts led by the Forest Service that grouped data into the following categories:

Biological monitoring – fish or other wildlife; may include macroinvertebrate sampling, environmental DNA (eDNA), spawning surveys, movement tracking with Passive Integrated Transponder (PIT) tags, smolt trapping, snorkel surveys or mussel or bird surveys

Water quality monitoring – temperature, dissolved oxygen, isotopes, conductivity or nitrogen

Depth to groundwater and input monitoring – using wells or piezometers

Surface water monitoring – depth or discharge

Physical characteristics – distribution or volume of large woody debris; quantity or quality of substrate; or bankfull measurements

Riparian vegetation – measurements of vegetative change

Elevation monitoring – transects or randomly selected elevation points

Light Detection and Ranging (lidar) – a sensing method that

Table 3: Monitoring efforts at stage 0 restoration projects in California and Oregon

Location	Monitoring Plan	Biological monitoring	Water quality monitoring	Ground water	Physical characteristics	Surface water	Riparian Vegetation	Elevations	Lidar	Pictures
		May include: macroinvertebrates; eDNA; spawning surveys; snorkel surveys for fish; mussel surveys	May include: temperature; isotopes; conductivity; nitrogen	May include: wells	May include: physical habitat metrics such as LWD or substrate; bankfull measurement	May include: depth; flow		May include: geomorphic transects; randomly selected elevation points		May include: photo points; general project photos
Oregon										
Coal Creek	X	X	X		X	X	X		X	X
Deer Creek	X	X	X		X	X	X		X	X
Five Mile Bell				X		X	X	X	X	X
South Fork McKenzie	X	X	X	X	X	X	X	X	X	X
Staley Creek	X	X	X		X	X	X	X	X	X
Whychus Creek	X	X	X	X	X	X	X	X	X	X
California										
Confluence Meadow*		TBD	TBD	TBD	X	TBD	TBD	X		X
Doty Ravine		X	X		X	X	X			X
Indian Creek*		TBD	TBD	X	TBD	X	TBD	X	X	X
Willow Creek		X	X			X				X
Proportion of projects using technique		88%	88%	38%	75%	100%	88%	50%	75%	100%

* Pre-project data only. Not included in proportion

sends pulses of laser light to determine the presence, shape and distance of objects; it can generate three-dimensional representations of the topography of terrain, including the bottom of streams

Photos – used as references to see changes over time in channels, riparian vegetation and other features

Of the eight completed projects analyzed for monitoring information in Table 3, each included discharge or water depth data. Water quality information (typically temperature) was collected at seven of the sites. Isotope and conductivity data were collected at the Staley and Coal Creek projects (U.S. Forest Service 2018).

Three projects – South Fork McKenzie, Five Mile Bell and Whychus Creek – measured depth to groundwater using wells. Shallow groundwater and high hyporheic exchange are a hallmark of stage 0 channels, with vertical connectivity at base flows being a key objective. The depth to groundwater at Whychus Creek and Five Mile Bell decreased after restoration (Figure 3).

Photos were available for each project analyzed. They consisted of opportunistic captures, time-lapse series from trail cameras, shots from fixed photo points (Image 1), and images from camera-equipped drones (Figure 4). Drone photography was used to document a 20% increase in riparian vegetation cover classes at Whychus Creek one year after implementation (Perle 2019).

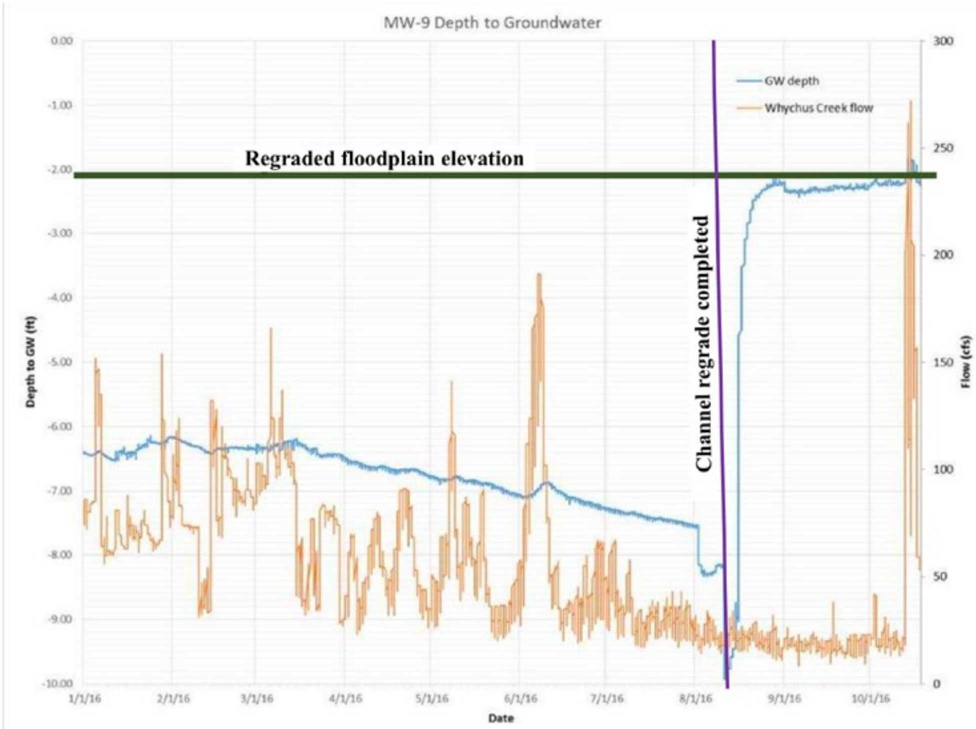


Figure 3 (left): Groundwater and stream flow response to channel regrading in Whychus Creek in Oregon (adapted from Burns 2019)

Figure 3 (below): Groundwater response to channel regrading in Five Mile Bell, measured as groundwater elevation (from "Five Mile Bell Floodplain Connectivity, 2018 Monitoring Report")

Figure 4: Number of projects with different types of photo monitoring

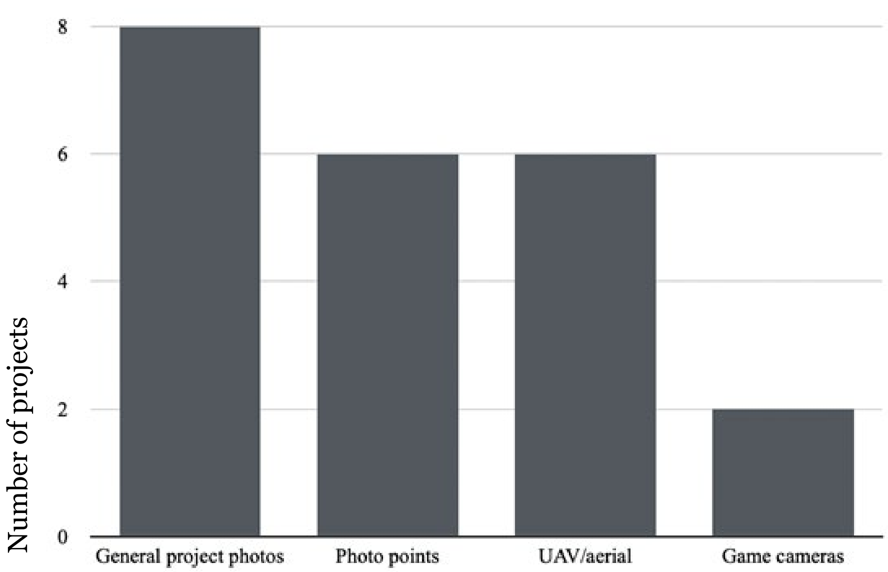


Image 1: Over three years, Jay Mather, a volunteer photographer for the Deschutes Land Trust, photographed the same spot at the Whychus Canyon Preserve to document change.

Image 2: Dan Scott, a river scientist at the University of Washington, used a drone to photograph Deer Creek in 2016 before restoration (top) and in 2021 after restoration (bottom).

Table 4: Information collected during patch or transect sampling

Location	Sample Design	Vegetation	Elevation	Surface water (Flow, temp, or depth)	Subtrate	Geomorphic Features	LWD	Macroinvertebrates	Photos
Oregon									
Coal Creek	Patch	X	X	X	X		X	X	X
Deer Creek	Transect	X		X	X	X	X	X	X
Five Mile Bell	Transect	X							
South Fork McKenzie	Transect	X	X	X	X	X	X	X	X
Staley Creek	Patch	X		X	X		X	X	X

Scott and Collins (2019) coupled aerial photos with field surveys in an attempt to document Deer Creek before and after the project (Image 2). Although they noted that management actions increased wood loading and habitat heterogeneity, Deer Creek had not been subject to a large enough flow event to naturally adjust the project site at their time of reporting.

Physical characteristic monitoring was used at six completed projects. Four completed projects surveyed surface elevations; they were all in Oregon and relied on transects or patches to document morphological change over time. Researchers looked at substrate size, large woody debris distribution, elevation, macroinvertebrates and vegetation (Table 4).

Geomorphic Grade Line projects used lidar for planning purposes (Powers et al. 2019). A Digital Elevation Model (DEM), which can be derived from lidar data, was used to define a desirable elevation that was then projected across the valley floor to create a target surface for cut and fill. Although lidar and a resulting DEM can be used in post-implementation comparison, practitioners have yet to use post-project lidar to quantify change within project boundaries.

Biological and vegetation monitoring were used in seven of the completed projects. Biological monitoring techniques varied widely across projects and between California and Oregon, with more intensive monitoring occurring in Oregon. Five of six projects in Oregon sampled macroinvertebrates, but none of the projects in California did (Table 5). Macroinvertebrate sampling

Table 5: Biological monitoring data for the eight completed projects

Location	Macroinvertebrates	eDNA	Fish sampling, Spawner, Snorkel Surveys	Mussel Surveys
Oregon				
Coal Creek	X		X	
Deer Creek	X		X	
Five Mile Bell				
South Fork McKenzie	X	X	X	X
Staley Creek	X		X	
Whychus Creek	X		X	
California				
Doty Ravine		X		
Willow Creek			X	

techniques were included in transect or patch monitoring with macroinvertebrates collected in wetted channels (Table 4).

Projects used multiple methods to assess fish abundance and habitat use, including snorkel surveys, redd/spawner surveys, PIT tagging, electrofishing and minnow trapping. PIT tagging from Willow Creek and spawner surveys from Deer Creek documented successful post-project recolonization of habitats where target species were previously thought to be extirpated (Prunuske Chatham, Inc. & UC Cooperative Extension/CA Sea Grant 2014; Meyer 2018). Juvenile fish surveys in Whychus Creek found a greater abundance of salmonids in treated versus untreated stream reaches, although nearly all individuals in this study were from reintroduction stocking efforts (Perle 2019). Two projects used eDNA to assess fish and amphibian presence; however, neither reported results.

Of the eight completed projects, seven looked at change in riparian vegetation. While some only looked at post-management change, others looked at before and after conditions. Patch surveys, transects and aerial photos were used.

Discussion

Projects

Many valley-scale floodplain restoration projects have been completed in California and Oregon in the last decade, but there's a contrast in the techniques and terminology used. Projects meeting the applied definition of stage 0 in California have used less intensive management actions, like beaver dam analogs, although this seems to be changing as two projects there using a valley-grading approach are being implemented.

Image 3: Pond-and-plug floodplain restoration on McReynolds Creek in the Sierra Nevada mountains in California (from Wilcox 2010)

Concurrent with the development of Cluer and Thorne's stream evolution model, Forest Service practitioners in Oregon were working to restore incised depositional valleys at the valley scale using process-based restoration but without the stage 0 restoration moniker. Powers et al. (2019) noted that nearly 20 completed projects in the Pacific Northwest used the GGL approach. This suggests a situation where practitioners and theory were coevolving as a result of the growing focus on process-based restoration. These practitioners have embraced the stage 0 terminology (Powers et al. 2019).

In California, other types of intensive floodplain restoration techniques that are not designed to achieve a stage 0 stream condition have been used, the foremost being the pond-and-plug technique (Image 3) used in montane meadow restoration efforts (Rosgen 1997).

California is home to almost 100 pond-and-plug projects (Center for Watershed Sciences 2022). A census of pond-and-plug projects, however, was not the purview of this report because the technique does not meet the process-based definition that we used to select projects. The goals of this technique are somewhat similar to stage 0, with management activities seeking to reconnect floodplains and restore hydrologic function (Lindquist & Wilcox 2000; Hammersmark et al. 2008; Tague et al. 2008). This technique involves creating earthen plugs in incised stream reaches to distribute flow out of incised channels and onto the historic floodplain (Lindquist & Wilcox 2000). Fill material is sourced from the incised channel or occasionally the floodplain and results in a string of small, open-water ponds between the plugs. Projects are typically implemented at the valley scale and are generally intensive, using heavy equipment and creating significant disturbance during implementation (Pope et al. 2015).

Studies of pond-and-plug projects reveal higher groundwater levels, increased water storage, and more frequent floodplain inundation after the projects (Hammersmark et al. 2008; Tague et al. 2008; Hunt et al. 2018). Concerns, however, remain about the use of restoration features novel to local processes and their long-term viability (Natali & Kondolf 2018). Questions have also been raised about the ecological function of meadows after pond-and-plug treatments. Pope et al. (2015) found greater plant biomass in pond-and-plug meadows, but they also found that soil carbon, wetland habitat and herbaceous cover did not differ between treated and untreated meadows. Their study did not do a before and after comparison of project sites. These findings suggest that there is still much to learn about intensive floodplain restoration, such as stage 0, and indicate the need for investments in long-term intensive monitoring.

Monitoring

Stage 0 stream reaches exhibit different spatial extents and breadths of habitat types versus single-thread channels. As a result, many stream monitoring techniques – especially in the Pacific Northwest – that have been developed in wadable streams with a focus on salmonid habitat may not adequately capture the habitat diversity of stage 0 reaches (Powers et al. 2019; Roni et al. 2019). Additionally, with process-based restoration, there is a potentially unknowable temporal aspect specific to each site that will play an important role in site evolution. Furthermore, understanding how management actions are affecting ecosystem benefits may not be possible for some time because biological elements take time to establish.

Monitoring results have shown that many of the physical objectives of stage 0 have developed post-project. These include: elevated water tables (Figure 3); an increase in habitat diversity (Ciotti et al. 2021.; Perle 2019; Scott & Collins 2019); and retention of large woody debris (Perle 2019; Scott & Collins 2019). This suggests that implementation has been successful, at least in the short term. Doty Ravine, the only project in our analysis using beaver dam analogs, reported significant aggradation of the incised channel, meeting a key objective (Ciotti et al. 2021). Initial monitoring results show promise, but long-term datasets are needed.

One of the promises of stage 0 restoration is the reestablishment of habitats with maximum complexity and a variety of habitats that support large numbers of different species while being highly resilient to natural disturbance. As such, biological monitoring that improves our understanding of biotic responses to stage 0 restoration is critical in assessing ecological function and the effectiveness of this approach. Projects with more intensive monitoring like Whychus Creek, South Fork McKenzie, Coal Creek, Deer Creek and Staley Creek may help fill information gaps as results become available.

A study on primary productivity in Whychus Creek has shown increases in cold water diatoms and a higher autotrophic index in post-project reaches compared to a reference reach (Edwards et al. 2020). Additionally, macroinvertebrate richness increased as did the number of sensitive Trichoptera, Ephemeroptera and Plecoptera taxa (Perle 2019). These results suggest restoration is meeting goals, at least in the short term.

Many of the projects surveyed listed improvements to fish habitat as an important objective. It is generally accepted that fish growth rates increase with access to floodplains

(Limm & Marchetti 2009; Witmore 2014; Katz et al. 2017), although studies looking at fish growth in stage 0 reaches have not been completed. A key concern with stage 0 restoration is a potential negative impact to endangered or threatened salmonids, specifically regarding fish passage and stranding risks (Bianco 2018). These concerns can be reduced by assessing population abundance and diversity or documenting migration success via telemetry data, as has been done on multiple projects. Initial results from Whychus Creek, for example, suggest that juvenile fish are using a restored stage 0 reach more than an unrestored reference reach (Perle 2019). Salmonids have been documented spawning in restored reaches of multiple projects, and telemetry data have demonstrated successful passage through restored reaches (Prunuske Chatham, Inc. & UC Cooperative Extension/CA Sea Grant 2014; Meyer 2018).

Strengths and limitations of this study

Identification of projects in Oregon was limited to existing data compiled by the Forest Service's Pacific Northwest Research Station. Other stage 0 projects may have been completed in Oregon, particularly ones using beaver dam analogs, which may or may not meet the definition of stage 0 used for this study. The identification of projects in California could have been improved through additional outreach to practitioners in montane meadow ecosystems. There may be other projects that fit the applied definition of stage 0 restoration but do not use that term.

Collection of monitoring data was based on available information. It's possible that additional uncoordinated monitoring efforts are taking place. For example, fisheries monitoring, such as spawner or snorkel surveys conducted by state or tribal fisheries agencies, may be taking place within the same stream systems as part of wider monitoring efforts.

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