AN ABSTRACT OF THE THESIS OF

Rebecca R. Miller for the degree of Master of Science in Fisheries Science presented on September 23, 2010.
Title: Is the Past Present? Historical Splash-dam Mapping and Stream Disturbance Detection in the Oregon Coastal Province.

Abstract approved:

Kelly M. Burnett   Joseph L. Ebersole

Severe scouring from splash damming was one of the earliest reported forms of widespread anthropogenic disturbance in streams of the Pacific Northwest, USA. Splash damming was a common method of log transport in western Oregon from the 1880s through the 1950s. Before being released in large freshets to downstream lumber mills, water and logs were stored in reservoirs behind splash dams. Further protocol called for dynamiting downstream obstacles such as large boulders and natural logjams. In recent literature, the legacy effect of historical splash damming is proposed as contributing to currently poor habitat conditions for lotic species, such as Pacific salmon (*Oncorhynchus* spp.), but this has never been formally evaluated at a regional scale. In this study, all known splash-dam sites and log drives in western Oregon were recorded in a geo-database and mapped in ArcGIS 9.3 at the 1:24,000 scale. Splash-dam sites were located through intense archival, historical aerial photograph and field searches. The final splash-dam map was overlaid with regionally available continuous and probabilistic stream surveys. After accounting for basin area and channel slope, in-channel variables were compared between reaches upstream and downstream of splash dams (within-basin analysis) and between reaches in splashed and not-splashed basins (among-basin analysis). Only data from sites located in a forested land cover and sedimentary rock type in the Oregon Coastal Province were analyzed. A significant difference $(\alpha = 0.1)$ was seen in either within- or among-basin analyses for each evaluated category of in-channel variable (geomorphology, substrates, pools, and channel complexity). Both analyses demonstrated significantly more bedrock and fewer deep pools in splashed reaches. In the among-basin analysis, three times fewer pieces of key large wood were found in splashed reaches $(p = 0.07)$. Many of the in-channel variables that demonstrated significant differences are regarded as indicators of salmon habitat quality. This is the first regional study to document that splash-dam legacy effects still persist on evaluated stream reaches 50-130 years after the practice ceased. Further, I detected a splash-damming signal in widely used regional monitoring datasets, which suggests that legacy effects should be considered in future applications of these datasets. Splash-damming impacts are pervasive and persistent throughout the Oregon Coastal Province; consequently, extensive and intensive restoration measures may be necessary to accelerate recovery of certain stream habitat characteristics in streams where splash damming and log drives occurred. This study demonstrates the importance of including archival information in modern-day studies, and that history can account for significant variation in the stream environment.

Is the Past Present? Historical Splash-dam Mapping and Stream Disturbance Detection in the Oregon Coastal Province

by
Rebecca R. Miller

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented September 23, 2010
Commencement June 2011

Master of Science thesis of Rebecca R. Miller presented on September 23, 2010.

APPROVED:

Co-Major Professor, representing Fisheries Science

Co-Major Professor, representing Fisheries Science

Head of the Department of Fisheries and Wildlife Department

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Rebecca R. Miller, Author

ACKNOWLEDGEMENTS

This work benefited from the contributions of many talented and wise individuals, to whom I am deeply indebted. Dr. Kelly Burnett helped me every step of the way, from securing project funding, guiding me through the scientific method process, thesis writing, and both professional and personal support. Dr. Joe Ebersole provided thoughtful comments and insight throughout the entire project. Mark Meyers brought a geography perspective to the project. The project would have never gotten off the ground without funding from the Oregon Watershed Enhancement Board (OWEB) and the US Forest Service.

To create my splash-dam dataset, I recruited help from numerous historical society librarians and volunteers. Colin Kelly patiently helped me wade through many historical photographs at the University of Oregon map library. Paul Burns of the Siuslaw National Forest and Chris Sheridan from the Coos Bay Bureau of Land Management helped organize meetings with current and retired fisheries biologists, archeologists, and local landowners. Participants included Paul Burns, Chris Sheridan, Stephen Samuals, John Colby, Glenn Harkelroad, Bill Hudson, Dan Vanslyke, Frank Price, and many others. The Coos Bay Watershed Association helped search for splash-dam sites, and provided hydrological data and historical documentation leads that were quite valuable. Bob Danehy, Weyerhaeuser fish biologist, provided a historical fisheries perspective, and helped coordinate and participate in splash-dam site searches. The kind folks at the Flying M Ranch gave me the grand tour of the Petch Splash Dam. Loretta Ellenburg’s knowledge of the Oregon Coast Range back roads made splash dam searching easy. It was wonderful swapping splash-dam stories and ideas with Jessica Phelps!

Thanks to Robin Leferink and Shannon Hubler at the Oregon Department of Environmental Quality Lab; Kim Jones, Julie Firman and others at ODFW Corvallis Research office; and Phil Kaufmann at the Environmental Protection Agency who all provided stream survey datasets and answered my subsequent questions. A special thanks to Phil, who showed me the ropes of the EMAP stream survey protocols, along with Jochen Steindl, who makes an excellent stream survey partner!

I couldn’t make the project happen without the day-to-day support from the many folks at the USFS Pacific Northwest Forest Research Station. My officemate and fellow graduate-student, Brian Neilson, became a good friend and soundboard. Kelly Christiansen and Ken Vance-Borland always provided GIS help and map design comments with a smile! Nicholas Som, Becky Flitcroft, Manuela Huso and Pat Cunningham all provided statistical consultation throughout the project. Kathryn Ronnenberg provided editorial proofing and helped with final figures. Kathryn also encouraged me to dust off the old viola and join the Willamette Valley Symphony.

The world works in mysterious ways. Unbeknownst to me I ran into Patricia Benner, a river historian and ecologist, at the Benton County Historical Museum. During her research she stumbled upon an amazing 1920s riverine photograph collection of the Mid-Fork Coquille River. She generously shared the photographs with me and many were included in presentations and the following thesis. I had the privilege to meet Jim Sedell, one of the masterminds who recognized splash-dam legacy impacts in the early 1980s. It still amazes me that no one really picked up the trail, until now. Another serendipitous moment occurred when I met Jake Flitcroft, who operated the South Fork Coos River splash dams. Spending the day conversing and hunting for old splash-dam sites with Jake brought the project out of the history books and into life. It was truly a fine day—complete with ice cream!

Finally, I'd like to thank my friends and family. Especially, Tom and Janet Miller —a daughter couldn't ask for more amazing parents. And of course Sarah, my twin sister and best friend, what would I do without you!

CONTRIBUTION OF AUTHORS

Dr. Kelly Burnett, Dr. Joe Ebersole and S. Mark Meyers helped with study design, data analysis and editing of thesis manuscripts. Kathryn Ronnenberg provided editorial proofing and figures.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS *(Continued)*

Page

TABLE OF CONTENTS *(Continued)*

Page

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

GENERAL INTRODUCTION

Environmental legacies are past events that can be detected in modern-day environments and have been documented in terrestrial, freshwater and marine ecosystems (Foster 1988, Harding et al. 1998, McClenachan 2009). Specifically, historical ecologists use clues from the past to piece together what the landscape might have looked like, what management practices took place, and to what degree those practices influence the present-day landscape (Swetnam et al. 1999). Freshwater ecosystems in the Pacific Northwest have been altered by numerous land-use changes in the past 150 years, for example the conversion of wetlands and floodplains for agricultural purposes (Sedell and Froggartt 1984). Unlike many other historical land-use management practices that continue to this day, such as forestry or agriculture, splash damming was favored for many years and then prohibited in the 1950s. Thus, I can evaluate whether actions from 50-130 years ago left an enduring legacy on the streamscape. Using historical archives it is possible to identify splash dammed and not-splash dammed streams, and so I can compare these areas to one another to detect whether a quantifiable legacy from splash damming practices still exists.

Splash dams were constructed in forested mountain streams to transport timber to downstream mills (Beckham 1990). Dam gates would open and a large freshet of water and logs would rush downstream, repeatedly scouring the stream, ultimately to bedrock (Wendler and Deschamps 1955). Recent literature attributes splash damming as one of the key historical culprits in Pacific Northwest stream simplification and the decline of salmonid species (Lichatowich 1999, Taylor 1999) and further suggests that physical conditions in splash-dammed streams have yet to recover (Sedell and

Luchessa 1981, Dolloff 1993). Although the ability to detect a disturbance event (via response variables) typically diminishes with time, because splash-damming impacts were reportedly so severe (State of Oregon 1924, James 1956), ecological effects may still persist.

This project is the first regional study that addresses whether a legacy from splash damming can be quantified. Specific objectives are 1) map and create a geodatabase of historical splash-dam and log-drive sites in Western Oregon; and 2) to compare physical stream habitat characteristics in the Oregon Coastal Province between reaches upstream and downstream of splash dams (within-basin analysis) and between reaches in splashed and not-splashed basins (among-basin analysis).

CHAPTER 2

IS THE PAST PRESENT? HISTORICAL SPLASH-DAM MAPPING AND STREAM DISTURBANCE DETECTION IN THE OREGON COASTAL PROVINCE

Introduction

Studies of environmental legacy are recognized as important for identifying whether history continues to shape and influence current ecological conditions, processes and landscape patterns (Allen et al. 2004, Christensen 1989, Foster et al. 2003, Swetnam et al. 1999). Two key components for any environmental legacy study are the disruption, either from natural or anthropogenic sources, of an ecosystem (at dynamic equilibrium), and the passage of time (Rhemtulla and Mladenoff 2007). In terrestrial ecosystems, historical perturbations decades to millennia ago have been detected in modern-day vegetation diversity and forest soils (Dupouey et al. 2002, Foster et al. 1988, Hermy and Verheyen 2007, Itoa and Buckley 2004, Koerner et al. 1997). Legacies can be inconspicuous on the landscape, but once revealed the historical pattern becomes obvious and can help explain modern-day observations. For example, at abandoned farms in southern New England only when the type of crop historically grown was identified could researchers explain the composition of late-successional tree species; with birch preferring abandoned row crops and red cedar establishing in old pastures (Russell 1978).

Though relatively few studies of environmental legacy have been conducted on stream ecosystems, legacies are expected to have an importance similar to terrestrial landscapes because streams are strongly tied to the catchments they drain (Hynes 1975). Explanatory variables that describe historical conditions can improve statistical models that explain and predict physical stream conditions and aquatic biota assemblages, occurrence and genetics (Maloney et al. 2008, Poissant et al. 2005, Wenger et al. 2008). For example, streams with similar riparian areas and landcover contained significantly different diversities of fish and macro-invertebrates, and these differences were best explained by land use practices 40 years prior (Harding et al. 1998). Considering environmental legacies can shed new light on basic ecological conditions and disturbance processes in streams. To illustrate, scientists are re-thinking what constitutes 'natural' stream channel form in United States mid-Atlantic streams, as innovative fluvial studies in the 1950s were conducted in streams already highly altered by sediment aggradation and degradation from watermill dams during the late 17^{th} - 20^{th} centuries (Montgomery 2008, Walter and Merrits 2008).

Prior to the construction of extensive road networks, log drives and splash dams in streams were commonly used to transport logs and may have left an enduring legacy on aquatic ecosystems. In forested mountainous regions of North America and Europe many streams served as log transport networks during the 19^{th} and mid 20^{th} century (Coy et al. 1992, Sedell and Duval 1985, Tornlund and Ostlund 2002). Log drives employed seasonal floods to float timber to downstream lumber mills. Splash dams assisted log drives by controlling water flow (Beckham 1990, Farnell 1979, Sedell and Duval 1985). Splash dams spanned the width of the stream and created an upstream reservoir in which water and logs were stored (Figure 2.1). Opening the splash-dam spillway released a freshet—a large pulse of water and logs. While effective at moving logs, these freshets were observed to highly alter stream conditions (Bell and Jackson 1941, Gharrett and Hodges 1950, Wendler and Deschamps 1955). Historical photographs of splashed waterways show long reaches scoured to bedrock and little channel complexity (Figure 2.2). In effect, a splash-dammed stream became a giant chute for log transport.

Figure 2.1. A 1950 aerial photograph of the Tioga Splash dam (indicated by white arrow) located approximately 33 kilometers east of Coos Bay, Oregon. At time of photograph the reservoir extended approximately 2.5 kilometers upstream of the dam. Photograph source: COQ16_8_May_1950 University of Oregon.

Figure 2.2. The Middle Fork Coquille River, Oregon, was splash dammed from 1923-1941 and scoured to bedrock. Photograph source Port of Coquille 1929**.**

Splash-dam impacts could be manifested miles from the source and freshets were commonly unannounced (Flitcroft, pers. comm). To illustrate, on the North Fork Yamhill River in Oregon, the Trullinger grist mill was located 19-22.5 kilometers downstream of a series of splash dams. At the grist mill site, splash freshets would suddenly raise the water 0.6 m, leaving behind dirt, debris and logs in the mill raceway (Moser and Farnell 1981). Besides altering stream conditions, Mrs. Olive Moore testified to the Public Utilities Commission (PUC) that splash-dam freshets directly harmed fish.

> "Millions of salmon were below the dam. When they would let the splash loose that would throw the fish all out on the banks….I went among the logs and there were nice salmon mashed up between the logs." (State of Oregon 1924)

Fisheries biologists grimly reported that splash-dam operations on Camp Creek, Oregon 'resulted in almost complete annihilation of salmon and steelhead runs' (James 1956).

In the Pacific Northwest of North America, much literature has surmised that splash dams were a key historical culprit in stream simplification and thus salmon declines (Lichatowich 1999, Northcote and Hartman 2004, Sedell et al. 1981, Sedell and Duval 1985, Taylor 1999). Yet, few formal studies have quantified the potential of splash dams to leave an environmental legacy (International Pacific Salmon Fisheries Commission 1966, Napolitano 1998) and none considered a broad spatial extent. The research presented here builds upon previous efforts to map splash dams in Western Oregon and Washington by Sedell and Duval (1985), who created a 1:3,000,000 display map primarily to illustrate the prevalence of splash damming in the region until the practice was prohibited in the mid 20th century. The two objectives of this project are to: 1) map and create a geodatabase of historical splash-dam and log-drive sites in Western Oregon; and 2) to compare in-channel habitat variables in the Oregon Coastal Province between reaches upstream and downstream of splash dams (within-basin analysis) and between reaches in splashed and not-splashed basins (among-basin analysis). Specifically, I identified locations of splash dams and log drives from historical records and local knowledge, mapped splash dams and log drives on 1:24,000 scale hydrography, developed and populated the geodatabase with attributes including name of splash dam, date of splash dam use, height of splash dam, and citation source. I then evaluated the utility of historical aerial photographs and field searches for identifying locations of splash dams. For the second objective, I relied on available data from previous field surveys to examine the potential that an environmental legacy of splash damming may be detected in the modern-day stream environment.

Disturbance and Legacies

Since the mid-1980s, disturbance has been an important topic in stream ecology (e.g., Reice et al. 1990, Resh et al. 1988) but debate persists about how best to describe and classify disturbance in fluvial systems (Stanley et al. 2010, Rykiel 1985). Here, I follow an approach, adapted for streams, that relies on the concept of perturbation, wherein disturbance is defined as the cause of a perturbation and response as the effect (Bender et al. 1984, Glasby and Underwood 1996, Lake 2000).

Both the disturbance and the response components can be distinguished temporally, and then independently classified as either a press or pulse (Bender et al. 1984; Glasby and Underwood 1996). A pulse disturbance is a relatively discrete, short-term event, as illustrated by a single accidental toxicant spill into a stream (Figure 2.3a). A press disturbance is a sustained event, occurring over the period evaluated (Figure 2.3b), for example chronically elevated pollutant loads in a stream associated with urbanization. The press/pulse dichotomy was thought insufficient to describe drought as a disturbance, and so Lake (2003) defined a ramp disturbance as having an increasing magnitude over time (Figure 2.3c). The three existing classes of disturbance may not be wholly adequate to describe a historical disturbance, such as splash damming, that continued over a long period and then ceased. Such disturbance has been described elsewhere (Foster et al. 1988) but not formally classified. Consequently, I introduce the temporal class of a sustained pulse disturbance as relevant to the study of environmental legacies in streams (Figure 2.3d).

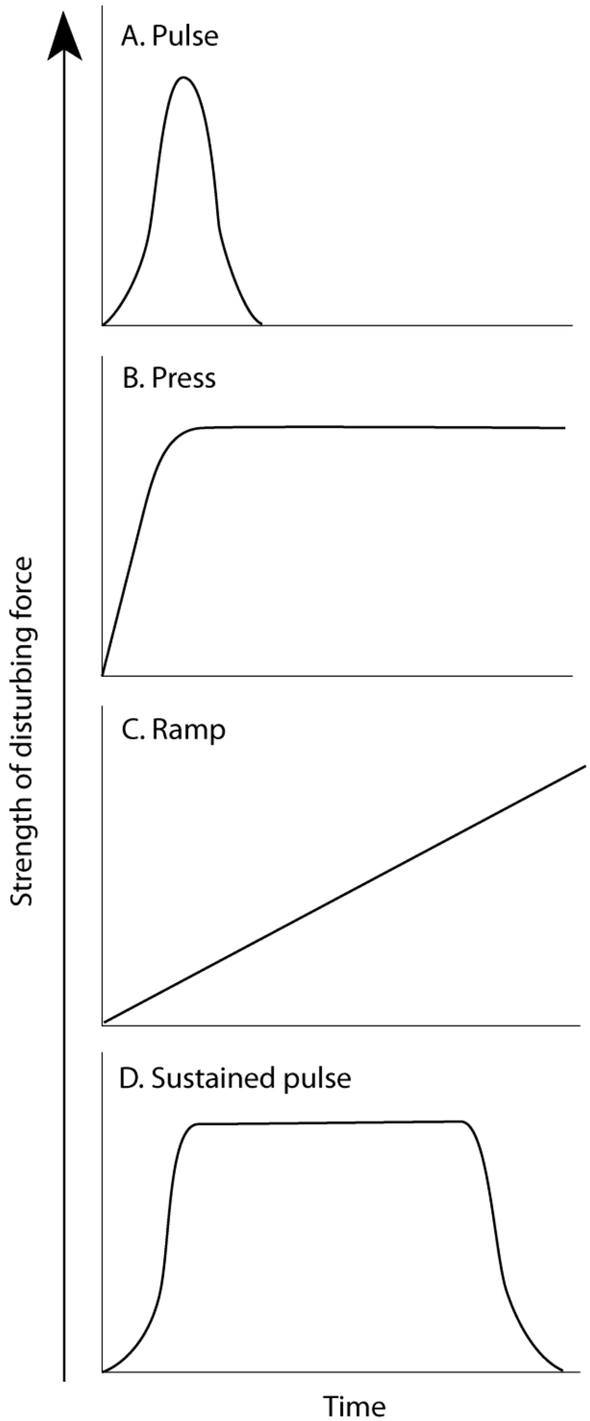

Figure 2.3. Four different disturbance classifications based on temporal duration and magnitude, with time on x-axis and increasing disturbance strength on y-axis. Pulse (a) occurs over a brief time period, at a high magnitude; Press (b) occurs over the entire time period evaluated, at a high magnitude; Ramp (c) occurs over the entire time period evaluated, with increasing magnitude incrementally; Sustained Pulse (d) occurs over a long-term period at a high magnitude, and then ceases.

Although disturbances may be of human or non-human origin, my intent is to characterize splash damming as a sustained pulse disturbance within the context of a natural flood regime. Floods are an essential process shaping the stream environment (Junk et al. 1989, Resh et al. 1988, Stanley et al. 2010). The frequency, magnitude, duration, and seasonal timing of flood flows define the flood regime (Lake 2000, Poff et al. 1997, Rykiel 1985) and components of the flood regime express a natural range of variability to which organisms have adapted and evolved (Gauer 1997, Lytle and Poff 2004, Pearsons et al. 1992, Reice et al. 1990). Overlaying splash damming as a sustained pulse disturbance (1880-1956) would have altered every component of the natural flood regime in the Oregon Coastal Province, but changes to flood magnitude and frequency were likely the most important for stream habitats. Because huge volumes of water were stored behind splash dams, the magnitude of flood flows was likely much greater than under the natural flood regime. Based on anecdotal documentation, splash damming generally increased the frequency of flood flows (Bell and Jackson 1941, Farnell 1979, Gharrett and Hodges 1950, International Pacific Salmon Fisheries Commission 1966, Wendler and Deschamps 1955). For instance, a freshet occurred every day with the 5 o'clock whistle on Steel Creek in the Coquille River basin, Oregon (Farnell 1979).

Splash damming would have routinely increased stream power over the natural flood regime and thus could have had numerous effects on physical habitat characteristics. Stream power determines the amount and size of material that flowing water can transport and is, in its most simple form, a multiplicative function.

$$\Omega = \rho g Q S$$

Where ρ is the density of water, *g* is the acceleration due to gravity, *Q* is the hydraulic discharge and *S* is the channel slope (Bangold 1973, Rhoads 1987).

Because splash dams increased the magnitude and frequency of hydraulic discharge, splash-dam freshets likely transported more and heavier objects than most natural flood flows. Thus, I expect that sediment erosion and log transport would have been greater in splash dammed than in not-splash dammed areas with substantial and varied consequences for stream habitats, including increased amounts of exposed bedrock, decreased amounts of spawning gravel for salmon, and reduced abundances of large wood. The flow-related effects of splash dams were undoubtedly exacerbated by the fact that logs entrained in splash-dam freshets increased streambed scour, off-channel habitats were blocked to prevent trapping of logs, and downstream obstacles, such as large boulders and natural log jams, were “cleaned”, often by dynamite (Brown 1936, Bryant 1914). Given this context and the three previously defined temporal classes of disturbance response (Lake 2000), a press response seems most useful for describing the effects of splash damming on stream habitat. In a press response, the system establishes a new state or dynamic equilibrium (Figure 2.4), which is often at a lower level of function or productivity than before the disturbance (van Andel and Aronson 2006). However, I propose that a useful alternative may be to describe the effects of splash damming on streams as a sustained pulse response, in which the effects of the disturbance diminish over a relatively long period and the system eventually recovers partially or fully to a condition similar to that before disturbance, reflecting resilience (Figure 2.4).

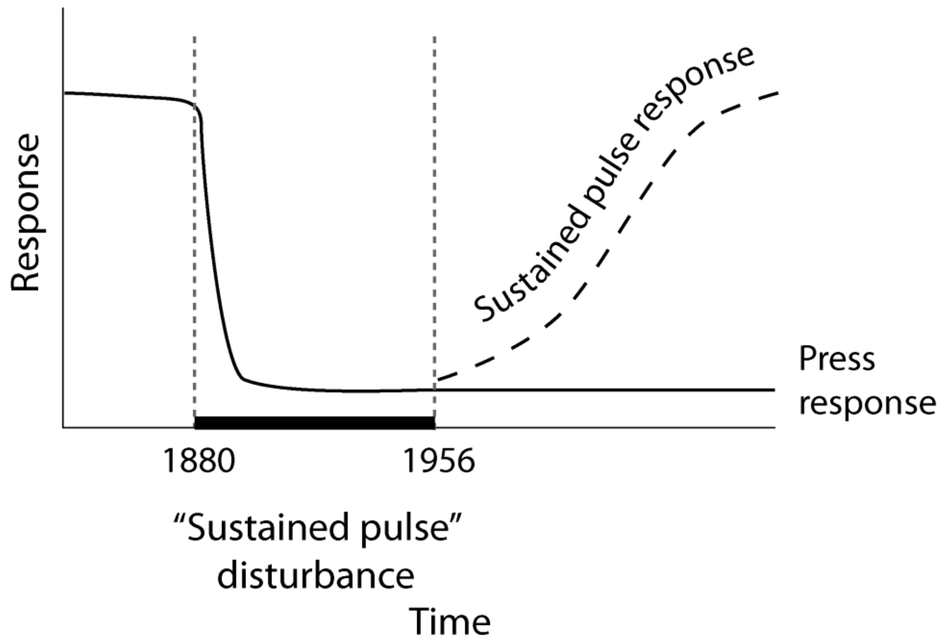

Figure 2.4. A sustained pulse disturbance, in which the flood regime was altered by splash damming between 1880s-1956. Over the past 50+ years, the most likely response of stream habitat conditions is either a Press Response (solid line) or a Sustained Pulse Response (thick broken line).

The focus of my thesis is to examine whether the environmental legacy of splash damming persists in the modern-day stream environment. I hypothesize that the legacy of this 'sustained pulse' disturbance can be seen in modern-day in-channel variables, when compared to areas that have not experienced splash damming but would have experienced the natural flood regime. Differences for in-channel variables between areas that have and have not been splash dammed would support the hypothesis that a splash-damming legacy persists in the stream environment but do not distinguish whether splash-damming effects are best classified as a press or a sustained pulse response. However, if differences between splashed and not-splashed areas are not observed, then stream habitats may have recovered and a sustained pulse response may be more apt.

Study Area

Splash dams and log drives were mapped in western Oregon over approximately 6.5 million ha (Figure 2.5). Elevation ranges from sea level to 3429 m. The region experiences a mild, maritime climate with annual precipitation that ranges from 150 cm to 300 cm (Franklin and Dyrness 1973). Precipitation falls primarily from October through March, as rain at low elevations (< 350 m) and as snow at high elevations (> 1100 m) (Harr 1981). The region contains numerous stream networks with drainage densities up to 8.0 km/km^2 (FEMAT 1993). The Oregon Coastal Province lithology is composed of mudstone, sandstone, and siltstone with outcroppings of basalts, while the Cascade Range consists predominantly of volcanic basalts (Ludington et al. 2006). Natural vegetation in the mountainous areas where splash dams were used is dominated by forests consisting primarily of Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla)*, mountain hemlock (*Tsuga mertensiana),* western redcedar (*Thuja plicata*), and several fir species *(Abies* sp.*),* as well as big leaf maple *(Acer macrophyllum),* vine maple (*Acer circinatum),* and red alder *(Alnus rubra).*

For several reasons, I restricted analysis of the potential environmental legacy of splash dams to the Oregon Coastal Province (~2.5 million ha) (Figure 2.5). The province has been relatively unaffected by construction and operation of dams for purposes other than log transport. Additionally, streams of the Oregon Coastal Province are inhabited by all five species of anadromous salmonids that occur in western Oregon: Chinook salmon (*Oncorhynchus tschawytscha*), coho salmon (*O. kisutch*), steelhead (*O. mykiss*), cutthroat trout (*O. clarki clarki*) and chum salmon (*O. keta*). Juveniles of some of these species may rear for more than a year in freshwater and estuaries before migrating to the ocean, and adults generally return to their natal stream to spawn (Healey 1991, Sandercock 1991). Given the listing of coho salmon as Threatened under the U.S. Endangered Species Act (1973), state and federal agencies have extensive monitoring data for streams in the province.

Except for interior river valleys and a prominent coastal plain in some places, mountains dominate the Oregon Coastal Province (maximum elevation - 1250 m). Land-use is predominantly forestry, interspersed with limited agriculture in wide valleys and the coastal plain (Anderson et al. 1976, 2000); very little of the province is in more developed uses of urban and rural residential (Kline et al. 2003). Forest ownership is primarily industrial timberland (41%), while the remaining ownership holdings are in federal (25%), state (12%), and private non-industrial timber land (22%) (Ohmann et al. 2007). Forests in much of the Oregon Coastal Province have been harvested at least once since European settlement, with less than 5% of the forested area currently estimated in old growth (>200 yrs) (Wimberly et al. 2000). By the late 1800s, channels, floodplains, and forests had been extensively altered along most major coastal rivers (Burnett et al. 2007, Sedell and Duval 1985).

Figure 2.5. Splash-dam mapping extent (black outline) and Oregon Coastal Province (orange). Statistical analysis was limited to the Oregon Coastal Province. Named rivers may be referenced throughout the text.

Methods

SPASH-DAM MAPPING

Archive Searches

Splash-dam sites in western Oregon were located by searching 3 libraries, 17 museums and 2 courthouses for literature documentation, historical maps, and photographs (Table 2.1). Incidental information on streams affected by log drives was also identified while searching for information on splash dams. I prioritized inquiries by first searching larger statewide museums and then small local museums located within the Oregon Coastal Province. For each museum or library I requested information via email or phone. If splash damming or logging records existed, I would travel on-site to view records. Museum searches were in accordance with local museum protocols. At some museums I searched the card catalog myself under the terms ‘splash dam, log drives, logging and lumbering’ and retrieved items, while at other locations employees or volunteers retrieved requested documents. I recorded, photocopied, or digitally scanned materials containing splash-dam locations, anecdotal evidence, or historical photographs.

Table 2.1. Western Oregon archives searched for splash-dam documentation.

Archive Searched	Location	Request	Splash Dam Items
Benton County Historical Museum	Philomath	On-site	Documents, historical photographs
Clatsop County Historical Society	Astoria	Email	No information
Coos Bay Historical and Maritime Museum	Coos Bay	Email	Documents, historical photographs
Coos County Logging Museum	Myrtle Point	On-site	Historical photographs, local contacts
Douglas County Historical Museum	Roseburg	Email	Did not search, photographs available
Historical Society of Columbia County	St. Helens	Phone	Did not search, but may have information
Lane County Historical Society	Eugene	On-site	Documents, historical photographs, interview transcripts
Lincoln County Historical Society	Newport	Email	No information
Museum of the Oregon Territory	Oregon City	On-site	Documents, newspaper clippings
North Lincoln County Historical Society	Taft	Email	No information
Oregon Historical Society Museum	Portland	On-site	Documents, historical photographs, video
Oregon State Supreme Courthouse	Salem	On-site	Kamm vs. Normand
Oregon State University Library - Gerald Williams Collection	Corvallis	On-site	Historical photographs
Oregon World Forestry Center	Portland	Phone	No information
Polk County Museum	Rickreall	On-site	Documents, historical photographs
Siuslaw Pioneer Museum	Florence	On-site	Documents, historical photographs, map
State of Oregon Archives –(Public Utility Commission Files)	Salem	On-site	Documents, historical photographs, historical maps, engineering designs, legal proceedings and testimony
State of Oregon Division of State Lands Library	Salem	On-site	Farnell, James; Stephen Moser; and Frost Division of State Lands Navigability Reports, 27 vol. Salem, 1976-1981.
Tillamook County Courthouse	Tillamook	On-site	Holden vs. Coates Lumber Company (Records now located at Salem Archives Building)
Tillamook Forest Center	Tillamook	Phone	No information
USFS PNW Research Lab Library	Corvallis	On-site	Farnell, James; Stephen Moser; and Frost Division of State Lands Navigability Reports, 27 vol. Salem, 1976-1981.
Vernonia Pioneer Museum	Vernonia	Phone	Did not search, but may have information
Washington County Historical Society	Hillsboro	On-site	Historical photographs
Yamhill Historical Society	Lafayette	On-site	Documents, historical photographs, local contacts

Geodatabase Development and Analysis

From archived documentation, I created two vector data layers, splash-dam points and log-drive lines, by using ArcGIS 9.3 (ESRI 2008). Splash-dam points and log-drive lines were edited to correspond with the overlaid watercourses layer from the Pacific Northwest Hydrogaphy Framework 1:24,000 scale (Oregon Hydrological Framework 2005). The splash-dam points and log-drive lines data layers are housed in a geodatabase, a container of multiple spatial data layers, and mapped in the Oregon Lambert Projection. A data dictionary is provided, containing a complete list of splash-dam (Table 2.2) and log-drive attributes (Table 2.3).

Table 2.2. Data dictionary of splash-dam attributes stored as a point data file in the geodatabase**.**

Data Field	Data Definition	Notes
Stream Name	Name of stream where dam was located	
Name	Name of splash dam	
Dam Owner	Company or person who owned dam	May have more than one owner over dam lifespan.
Date of Use	Known date of splash-dam operation	Hyphen represents exact date of use; 1894-1920. Question mark represents unknown date; for example ?-1935 indicates an unknown start date, last date of operation was 1935.
Last date of use	Last known date of splash-dam operation	'Date of use' text attribute was standardized by creating a numeric 'last date of use' attribute that was recorded as: 1) the known end date; 2) 1 yr after the most recent 'date of use' when the end date was not known with certainty; 3) the midpoint (i.e., 1910s = 1915) when a range of estimated operation dates was known; or 4) a blank when the 'date of use' was unknown.
Dam Height	Reported dam height (m)	
Dam Construction	Information on building specifications	
Notes	Ancillary Information	
Location Confidence	Confidence that the mapped point represents the true location of the splash dam (H, M, L)	Based on interpretations of anecdotal documentation H = location of the splash dam was determined by historical map or river mile, and so the location was mapped at the indicated site. M = location of the splash dam could be narrowed to a particular stream segment based on historical anecdotal evidence, thus the location was mapped at the midpoint of the stream segment; L = anecdotal information suggests that the dam existed somewhere along a stream, and so the location was mapped at the stream midpoint.
Final Location Confidence	Final Location Confidence after any aerial photo or field search	
Source Citation	Primary citation for the location of the	

Data Field	Data Definition	Notes
	dam	
Secondary Citation	Supporting evidence for the location of the dam (in no particular order)	
Historic Photo	Citation of historic splash-dam photograph	
Historical Photo 2	Additional ancillary and photograph citation information	An extension of photo column (since each column has a max. of 255 characters, sometimes information would exceed character limit).
Historical Photo 3	Additional ancillary and photograph citation information	
Point on 1985 Map	Splash-dam point on map by Sedell and Duval (1985) (Y/N)	The same splash dam on the 1985 map may be at a different location than on the 2010 map because Sedell and Duval followed a different protocol.
Aerial photo	Citation of Historical aerial photograph	Aerial photos are housed in University of Oregon Library.
Aerial photo date	Date of historical aerial photographs	
Aerial Selected	Was site searched for on aerial photographs (Y/N)	Y= site randomly selected for aerial photo search; N = site not randomly selected for aerial photo search.
Aerial Confirm	Was site found on aerial photographs (Conclusive/Not Seen/Inconclusive)	Conclusive= site found in aerial photo search; Not Conclusive = site not found in aerial photo search; Inconclusive = inconclusive.
Distance Aerial	Distance between the mapped GIS point and the actual splash-dam location as found in historical aerial photographs (m)	
Aerial Evidence	Description of splash dam found in aerial photograph	Description of what was viewed in aerial photo, what hindered viewing efforts.
Field Selected	Was site searched in the field (Y/N)	Y= site selected for field search; N= site was not selected for field search.
Field confirm	Was splash dam found in field (Y/N/Null)	Y= site searched, remnant found, N=site searched, no remnant found, <Null>= site not searched.
Time search	Time searched for splash dam (minutes)	

Data Field	Data Definition	Notes
Distance search	Linear distance searched for splash dam (m)	
Field Evidence	Description of splash dam remnant found in the field	
Distance from map	Distance between found remnant and GPS coordinates of mapped location (m)	
Point Placement	Specific description of mapped location	

Table 2.3. Data dictionary of log drive attributes stored as a line layer in the geodatabase.

Data Field	Data Definition	Notes
Stream Name	Name of stream with log drive	
Date of Use	Date of log drive operations on stream	Hyphen represents exact date of use 1894-1920. Question mark represents unknown date; for example ?-1907-? means stream was driven in 1907, unknown if drives occurred before or after that period.
Proprietor	Group who drove logs down river	
Lessor	Authority who granted permission for log driving	Permission from state or county was not needed for all drives, particularly those by smaller operators.
Notes	General information on log drives	
Notes2	Additional notes	An extension of notes (since each column has a max. of 255 characters, sometimes information would exceed character limit).
Log Drive Certainty	A confidence if stream driven (Yes or Unknown)	Yes=demonstrated evidence that log drive took place. Unknown= it is thought that the stream was driven based on historical information, but unclear if drives took place. For example, the PUC leased a stream to a proprietor, but no demonstrated evidence that log drives actually took place.
Log Drive Intensity	An attempt to categorize intensity (H,M,L, null)	Based on interpretations of anecdotal information. Where H=evidence that stream was used consistently over many years for driving. M=evidence that stream was used occasionally for driving. L=evidence that stream was only used sporadically. Null=Not enough anecdotal evidence to make determination.
Board Feet	Amount of board feet driven on stream	Volume tallied from Farnell, James; Stephen Moser; and Frost. Division of State Lands Navigability Reports, 27 vol. Salem, 1976-1981. -Not a total of all board feet driven for all years, but gives general idea of minimum amounts.
Source Citation	Primary citation for the location of the log drive	
Secondary Citation	Supporting evidence for location of the log drive (in no particular order)	

Data Field	Data Definition	Notes
Photo Reference	Citation of log drive photographs	
Shape Length	Length of stream that facilitated log drives (m)	

I mapped the splash dam at the most precise location based on available information. I devised a location confidence classification to reflect potential variability in the specificity and reliability of historical information on splash-dam locations (see data dictionary-Table 2.2 for classification definitions). I did not attempt a location confidence classification with the log drive information because anecdotal information was typically much more general in describing locations of log drives. When anecdotal information described a stream as ‘log driven,’ then the entire stream length was designated as a log drive. If found documentation, such as a Public Utilities Commission Map, that showed more restrictive bounds, then only that stream section was mapped. I created a classification of log-drive intensity to give users a relative sense of how much log driving activity took place along the stream.

To confirm draft splash-dam sites and identify any missed splash dams, I met with current and retired fisheries biologists, archeologists, local landowners, and one splash-dam operator. Participants were prompted with a 1 x 1.5 m draft splash-dam map at the 1:75,000 scale. Splash dams that did not exist on the draft map but for which there was local knowledge were added, and the name of the participant was cited as a reference. Two meetings were held; one at the USFS Mapleton office and the other at the Bureau of Land Management (BLM) office in Coos Bay. Meeting notes with Jake Flitcroft, who operated the Tioga splash dam on the South Fork Coos River, are provided in Appendix A.

To evaluate whether a relationship existed between the specificity of historical data and the age of the splash-dam structure, I compared the mean (t-test) and variance

(Levene's test of homogeneity of variance) of 'last date of use' for high and low location-confidence splash dams. Sites with an unknown date of last use were omitted from these analyses.

Historical Aerial Photograph Searches

I evaluated the utility of historical aerial photographs as a potential source for mapping splash-dam sites. I randomly selected 47 splash-dam sites (21 H, 9 M, 17 L), and viewed historical aerial photos housed at the University of Oregon Map Library in Eugene, Oregon. For each mapped splash dam I requested the historical aerial photos with the highest resolution flown the earliest after dam construction. The number of Public Land Survey System (PLSS) sections requested as historical aerial photographs varied by location confidence. For dams with high location confidence, only the PLSS section containing the dam was examined. For dams with medium and low location confidence, 2-3 or 3-6 PLSS sections from the mapped splash-dam location were viewed.

For each splash-dam site, I determined whether a splash dam could be identified in the historical aerial photos. First, I scanned each photo as a JPEG and viewed it on a computer screen. I looked at the stream network within the historical aerial photograph for splash-dam evidence. Each splash-dam site in the sample was labeled as found (Y), inconclusive (I), or not seen (N) in the historical aerial photograph. I described the rationale for each site classification, in an 'aerial notes' attribute in the geodatabase. For all confirmed and inconclusive sites, I digitally scanned the historical aerial photograph thought to contain the dam. The digitally-scanned photos are located at the United States Forest Service, Pacific Northwest Research Station (USFS PNW) Corvallis Forestry Sciences lab in Corvallis, Oregon, archived with the Land and Watershed Management Research team. I conducted a Chi-square test on the ability to view a splash dam remotely (using the classifications confirmed, inconclusive, and not seen) by location confidence type.

Field Searches

To estimate the percentage of sites where splash-dam evidence might persist in the field, I selected a sample of 16 GIS-mapped splash-dam sites for field searches based on accessibility, high location confidence, and/or dam remnants believed to still exist. In the field, I found the presumed location of each selected splash dam from the map, by using the splash-dam map and GPS coordinates. I walked the stream up to 1000 m (500 m upstream and downstream of the mapped location) or until a splash-dam remnant was found. Streams were searched during the summer low-flow period, allowing access to the stream channel. Streambed, banks, and floodplain/terraces were examined for splash-dam remains. Splash-dam artifacts or evidence could include log cribbing or anchor pilings. At any splash-dam remnant found, the site was described and a GPS coordinate and photo were taken. Photo points of remnants are archived at the USFS PNW Corvallis Forestry Sciences Laboratory with the Land and Watershed Management Research team, in Corvallis, Oregon.

Comparing Mapped and Confirmed Locations

For each splash-dam site confirmed, from either an historical aerial photo or field search, I compared the location of the originally mapped GIS point to the actual location of the dam. In the lab, I measured the stream-length distance (m) on a 1:24,000-scale Oregon Framework hydrographic layer between the mapped GIS point and the confirmed splash-dam location, which was indicated by the GPS waypoint taken in the field or identified from historical aerial photos. I calculated the range and average distance between locations of confirmed GPS sites and originally-mapped GIS points. A new field, ‘Final Location Confidence,’ was created in the geodatabase. Each confirmed site was updated to a ‘high’ location confidence status in the ‘Final Location Confidence’ field and the GIS point was moved to the confirmed site.

EVALUATING THE LEGACY OF SPLASH DAMMING

Using existing stream survey datasets collected by state and federal agencies for regional monitoring, I compared in-channel variables in stream reaches upstream and downstream of splash dams (within-basin analysis) and in splashed and not-splashed basins (among-basin analysis). Statistical comparisons were confined to streams in the dominant land cover and rock type of the Oregon Coastal Province, and considered the covariates basin area and channel slope.

Initial Screening of Splash Dams

To limit environmental variation in in-channel variables due to factors other than splash damming, I confined the analysis to data collected in sedimentary rock types and forestland cover in the Oregon Coastal Province. Underlying basin lithology and land cover can influence in-channel characteristics (Allan et al. 1997, Richards et al. 1996, Sable and Wohl 2006, Wing and Skaugset 2002). In Oregon Coastal Province streams, for example, substrate sizes are smaller, channel slopes are lower, and juvenile coho salmon densities are greater in sedimentary basins than basaltic basins (Hicks and Hall 2003). Splash dams mapped in siltstone, shale, sandstone, mudstone, and greywacke on the 1:5,000,000 scale Quaternary geological map of Oregon (Ludington et al. 2006, Walker and McLeod 1991) were identified as "sedimentary." Splash dams mapped in evergreen, deciduous, or mixed forest classes on the 30-m National Land Cover Database (Anderson et al. 1976), last updated in 2000, were identified as "forestland."

Developing Covariates: Basin Area and Channel Slope

I used basin area and channel slope as potential covariates in statistical analyses. Basin area and channel slope are components of stream power (Bangold 1973), which determines the capability, in both quantity and size, of a stream to transport material. Both basin area and channel slope tend to change gradually and predictably from the headwaters downstream, with basin area increasing and channel slope decreasing (Frissell et al. 1986, Vannote et al. 1980). For many in-channel variables, statistical relationships have been identified with basin area and channel slope. For example, large wood is generally more abundant in streams with steep channels and small basin areas, and deep pools are typically found in larger basins (Bilby and Ward 1989, Gurnell et al. 2002, Stack 1988). In addition, basin area and channel slope are associated with salmonid species habitat partitioning (Montgomery et al. 1999, Sharma and Hilborn 2001). Basin area and channel slope have been previously modeled along with hydrography from 10-m Digital Elevation Models (DEMs) for the Oregon Coastal Province (Clarke et al. 2008).

Within-basin Analysis

Site selection. I restricted the within-basin comparisons to a subset of mapped splash-dam sites that met three criteria: 1) were mapped with high location confidence; 2) the basin upstream of the splash dam contained >75% sedimentary rock types and > 75% forestland cover; and 3) a stream habitat survey had been conducted within the splash-dam reach, as described below. When multiple splash dams occurred on the same stream, only the furthest upstream site was selected for analysis.

Delineation of Splash-dam Reservoirs. Where selected splash-dam sites and habitat surveys co-occurred, I delineated the potential upstream extent of the splash-dam reservoir. I considered the stream section inundated by the splash-dam reservoir as part of the splash-dam site. The reservoir section was excluded from the analysis because the stream section within the reservoir experienced multiple scouring events from draining. I created a reservoir polygon by delineating topographical contour lines using ArcGIS 9.3 3-D Analyst and available 10-m DEMs. All dams were assumed to be 10 m in height (the smallest resolution of the DEM), unless historical evidence indicated the dam was taller, then 20 m was used. I then approximated the reservoir length, area, and volume for each selected splash dam.

I defined stream length from 0 to approximately 2 km above of the splash-dam reservoir as 'upstream' and from 0 to approximately 2 km below of the splash dam as 'downstream.' Given the width of surveyed streams, a 2-km reach was considered appropriate (Reynolds et al. 2003) given the spatial scale examined.

Habitat Surveys. For within-basin comparisons, continuous stream surveys, dynamically segmented in GIS, were obtained from the Oregon Department of Fish and Wildlife (ODFW) Aquatic Inventories Program and the Siuslaw National Forest (SNF). Agencies chose streams for survey based on an opportunistic, non-random design. Field crews began each survey at a tributary junction and continued upstream (typically 10^0 – 10^1 km) to the headwaters, classifying each habitat unit (e.g., pool, glide, riffle) and collecting data at the habitat-unit scale for numerous in-channel variables according to standard methods (Moore et al. 2008).

I limited within-basin comparisons to a subset of the in-channel variables to reduce the likelihood of incorrectly attributing differences to legacy effects of splash dams. Thus, I selected in-channel variables that were relatively uncorrelated with one another (Pearson rank correlation $\rho < 0.60$), most closely approximated a normal distribution, had a relatively high signal-to-noise ratio as evaluated by Flitcroft et al.

(2002), were ecologically important to salmonids, and were anecdotally reported as having been affected by splash damming.

Data on the selected subset of in-channel variables were collected by the agencies in the following manner. Terrace heights were recorded every 10^{th} habitat unit to the nearest 0.1 m using a meter stick. For each habitat unit, percent area of channel substrates in bedrock and three diameter classes—silt and organics (SO), gravel (2-64 mm), and cobble (64-256 mm)—was visually estimated. The deepest location in each pool was measured to the nearest 0.05 m with a meter stick. The number of key wood pieces (>0.6 m diameter, >12 m length) was counted in each habitat unit. For side-channel habitat units, ODFW recorded the length and width in the field and later multiplied these to calculate side channel area (m^2). The Siuslaw National Forest dataset did not collect terrace heights, silt and organics, or calculate side-channel area.

I summarized habitat unit-scale data on in-channel variables for the 2-km reach upstream and downstream of each selected splash-dam site. For percent substrates, I weighted each habitat unit length by total reach length, multiplied the weighted length by percent substrate in the unit, and finally summed the total weighted percent substrate across all units in the reach. I summed the total key wood pieces and averaged the number of key wood pieces per 100 m. Similarly, I summed unit estimates of side-channel area for each reach and calculated the proportion of total reach area. Terrace heights and scour pool depths were averaged for the entire reach. I counted pools greater than 1 m deep within the reach.

Each stream was surveyed once during summer low flows between 1993 and 2005. A 100-year storm event occurred in western Oregon during both February and November of 1996. Approximately half of the surveys were before the 1996 storms. Based on least squares means difference tests using an ANOVA block design with the factorial treatments 'before or after the 1996 storm' and paired reaches by watershed, values were similar ($p > 0.1$) before and after 1996 for each evaluated in-channel variable (SAS version 9.1, 2003). Thus, all subsequent within-basin analyses excluded year of survey.

Comparing Covariates for Reaches Upstream and Downstream of Splash Dams. From available digital hydrography (Clarke et al. 2008) for each 2-km surveyed reach upstream and downstream of a splash dam, basin area was assigned at the furthest downstream point and channel slope was averaged over the entire 2-km reach. I compared covariates to establish that paired upstream and downstream reaches were similar to each other physically and well matched for comparing in-channel variables. Differences between upstream and downstream a splash dam for mean basin area and mean channel slope were tested using mixed effects ANOVA. The factor upstream or downstream of a splash dam was the fixed effect, with a random effect of paired reaches. As expected, means for basin area differed significantly ($p = 0.007$) between reaches upstream ($\bar{x} = 42$ km^2, SE = 9.70) and downstream ($\bar{x} = 51$ km^2, SE = 9.70) of splash dams. In contrast mean channel slope was not significantly different ($p = 0.195$) between reaches upstream ($\bar{x} = 0.014$, SE = 0.003) and downstream ($\bar{x} = 0.0086$, SE = 0.003) of splash dams.

Among-basin Analysis

Site Selection. All splash dams in sedimentary rock types and forestland cover were considered for analysis without regard to location confidence. Reaches with existing probabilistic stream habitat surveys were overlaid with the mapped splash-dam shapefile in ArcGIS. In ArcGIS, I identified probabilistic surveys located along the stream within 2 km either upstream or downstream of mapped splash dams. The location confidence and position of survey relative to a splash dam were considered less critical for the among-basin analyses, because the entire basin is assumed to have been somewhat influenced by splash damming and related activities. I restricted the reach selection to within 2 km of the mapped splash-dam location for consistency between the within- and among-basin analyses. I paired each splashed reach to the nearest surveyed reach in sedimentary rock types and forestland cover that had a similar basin area and channel slope but no known history of splash damming or log driving (not-splashed reaches). The selected sites did not have any recent restoration improvements, according to searches conducted on the online Oregon Watershed Restoration Inventory (OWRI) database.

Habitat Surveys. For among-basin analyses, I obtained probabilistic Environmental Monitoring and Assessment Program (EMAP) stream survey data sets from the US Environmental Protection Agency (EPA), the Oregon Department of Environmental Quality (ODEQ), and the ODFW. All agencies follow the same random, systematic design for site selection, and the collection of field data on in-channel variables is standardized (Kaufmann et al. 1999). Thus, the surveys were combined to yield a large comprehensive dataset with numerous in-channel variables. Survey reaches were defined as 40 times the low-flow wetted width (m) and data on numerous in-channel variables were collected in the field at the habitat-unit scale. Each stream reach was surveyed between 1996 and 2007. For stream reaches surveyed more than once during this period (two EPA sites), the survey that occurred the closest to year 2010 was selected. Again, I retained for analyses a subset of in-channel variables that were relatively uncorrelated with one another (Pearson rank correlation $\rho < 0.60$), most closely approximated a normal distribution, had a relatively high signal-to-noise ratio as evaluated by Flitcroft et al. (2002), were ecologically important to salmonids, and were anecdotally reported as having been affected by splash damming.

Data on the subset of evaluated in-channel variables were collected and summarized by the agencies in the following manner. Active channel heights and active channel widths were measured with a meter tape at 11 transect cross-sections and were averaged by reach. Percentages of substrate in bedrock and in gravel (diameter class 2-64 mm) were determined for each reach from either EPA pebble counts or ODFW visual estimates. The EPA pebble counts were conducted at 11 cross-sections (5 particles at each cross section) and pebble size frequencies were converted to areal cover percentages and averaged for the entire reach. The ODFW visually estimated the percentage of substrate by category. Large boulders (>0.5 m) were counted and key wood pieces (0.6 m in diameter and > 12 m in length) were counted and measured in each habitat unit and averaged per 100 m. The total number of pools per reach was counted, percent area in scour pools was averaged for the entire reach, and the number of pools >1 m deep were counted and averaged per 1 km. The percent of reach area in side channels was calculated only by the ODFW.

Comparing Covariates for Reaches in Splashed and Not-splashed Basins. Based on available digital hydrography (Clarke et al. 2008) for each surveyed reach, basin area was assigned at the furthest downstream point and channel slope was averaged over the entire reach. I compared covariates to establish that paired splashed and not-splashed reaches were similar to each other physically and well matched for comparing in-channel variables. Differences between splashed and not-splashed for mean basin area and mean channel slope were tested using mixed effects ANOVA. The factor splashed or not-splashed was the fixed effect, with a random effect of paired reaches. The mean basin area was not significantly different ($p = 0.9925$) between splashed reaches ($\bar{x} = 56.37$ km^2, SE = 7.92) and not-splashed reaches ($\bar{x} = 56.40$ km^2, SE = 7.92). Similarly, the mean channel slope was not significantly different ($p = 0.832$) between splashed reaches ($\bar{x} = 0.0052$, SE = 0.001) and not-splashed reaches ($\bar{x} = 0.0055$, SE = 0.001).

Statistical Analysis

I first built candidate multiple linear regression models for each in-channel response variable to identify which combinations of potential explanatory variables to account for in least squares mean difference tests assessing whether a splash-damming legacy may be detected. Explanatory variables evaluated in the models were legacy (reaches upstream or downstream of splash dam for the within-basin analysis and reaches splashed or not splashed for the among-basin analysis), the covariates basin area and channel slope, and two-way interactions among these. Each candidate model was fitted as a mixed effects model using Proc Mixed (SAS version 9.1, 2003), with paired reaches as random effect and legacy as a fixed effect. Maximum likelihood estimation was used because it incorporates both fixed effects and random effects.

Competing regression models for each in-channel variable were evaluated via the Akaike's Information Criterion (Akaike 1974) with a correction for small sample sizes (AICc). For each in-channel variable, all models ≤ 2 AICc from the 'best model' were considered competing models and equally plausible candidates. I chose to consider only models ≤ Δ 2 AICc, because model plausibility decreases as AICc increases. To select the 'best model' from these candidates for testing least squares mean differences in each in-channel variable, a set of rules was developed: 1) all model candidates with more than 3 explanatory variables were excluded, due to concerns about model over-fitting; 2) if legacy was not a significant explanatory variable in any candidate model, then the in-channel variable was not evaluated further; and 3) the simplest 'best model' containing legacy was selected (given that evaluation of potential splash-damming effects is the primary research objective), however when a 2-way interaction with legacy had a significant ($\alpha = 0.1$) Type 3 Fixed Effect, the more complex model was selected.

Based on the 'best model' identified by the AICc rule set, I applied a least squares mean difference test for each in-channel response variable. To evaluate differences for each in-channel variable, I used a Proc Mixed (SAS 9.2) blocked by paired reaches (random effect) and legacy (fixed effect). A LSMEANS statement was applied to calculate the difference estimates. Statistical assumptions of normality and homogeneity of absolute residuals were examined with Shapiro-Wilks and Levene's tests, respectively. Mean differences were considered significant at the $\alpha = 0.1$ level.

Results

SPLASH-DAM MAPPING

Final Splash-dam Map

After an exhaustive search of available historical sources of information, I located and mapped 232 splash-dam sites and 213 log-drives (Figure 2.6). Locations for eleven of the mapped splash-dam sites were based on local knowledge. Of the 232 splash-dam sites, 79 were not included on the map by Sedell and Duval (1985). There were 17 points on 1985 splash-dam map for which I could find no evidence of splash damming, however I did find evidence of log driving.

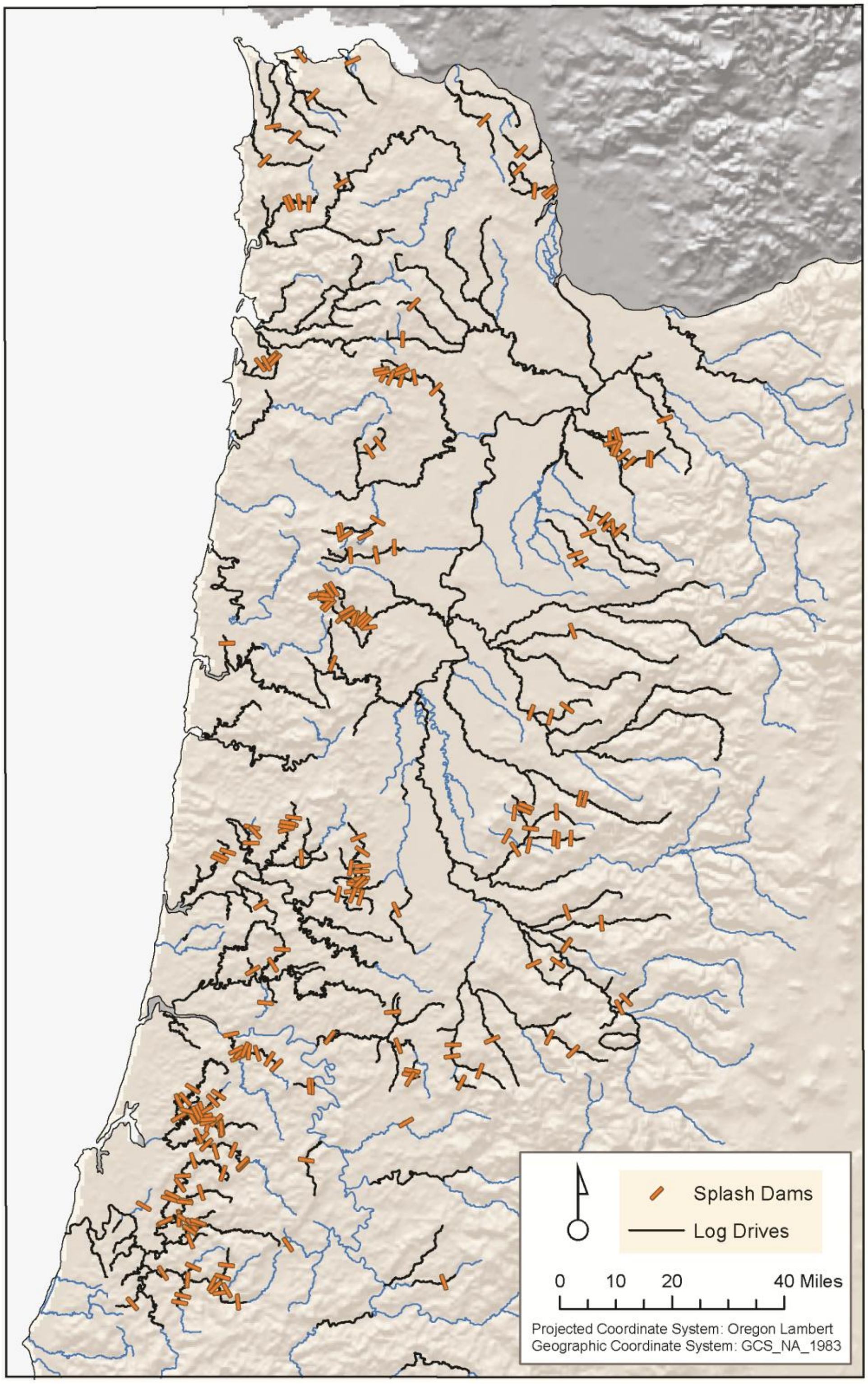

Figure 2.6. Splash dams and log drives located within western Oregon identified through archive searches and local meetings.

The confidence at which dams could be mapped varied. Location confidence was high at 144 sites, medium at 26 sites, and low at 62 sites. For the subset of splash dams with information on 'last date of use,' dams with high and low location confidence differed significantly for the variance (Levene's Test p-value = 0.0018) and mean (Satterthwaite approximate t-value = 7.76; p-value <0.0001; df = 140) 'last date of use' (Table 2.4).

Table 2.4. Mean, standard error, and range of 'last date of use' of splash dams by location confidence class.

Location Confidence	N	Mean 'last date of use'	Standard Error	Range
H	133	1922	1.33	1876-1956
M	24	1916	3.13	1901-1935
L	53	1906	2.10	1875-1947

Historical Aerial Photograph Searches

The majority (70%) of examined sites exhibited no evidence of a splash dam in the historical aerial photographs (Table 2.5), with low photo resolution, vegetation, and shadows hindering viewing efforts. Only 7 (15%) of 47 randomly selected splash-dam sites could be positively identified from historical aerial photos (Figure 2.7). Inconclusive evidence for another 7 splash-dam sites was seen in historical aerial photos. Examples of inconclusive evidence included human activity or streamside clearings, structures that could either be a bridge or splash dam (Figure 2.8), and multiple logs within the stream channel, but the dam itself was not observed. Although location confidence and the ability to view dams in the historical aerial photographs were statistically unrelated (Chi-square value 3.5, df = 5, p-value = 0.47), twice as many dams with a high location confidence were confirmed than with a low location confidence (Table 2.6).

Table 2.5. Number of splash dams randomly selected by location confidence class that were identified as confirmed, inconclusive and not seen in historical aerial photos.

Splash-Dam Location Confidence	Confirmed	Inconclusive	Not Seen	Total
H	4	5	12	21
M	1	1	7	9
L	2	1	14	17
Total	7	7	33	47

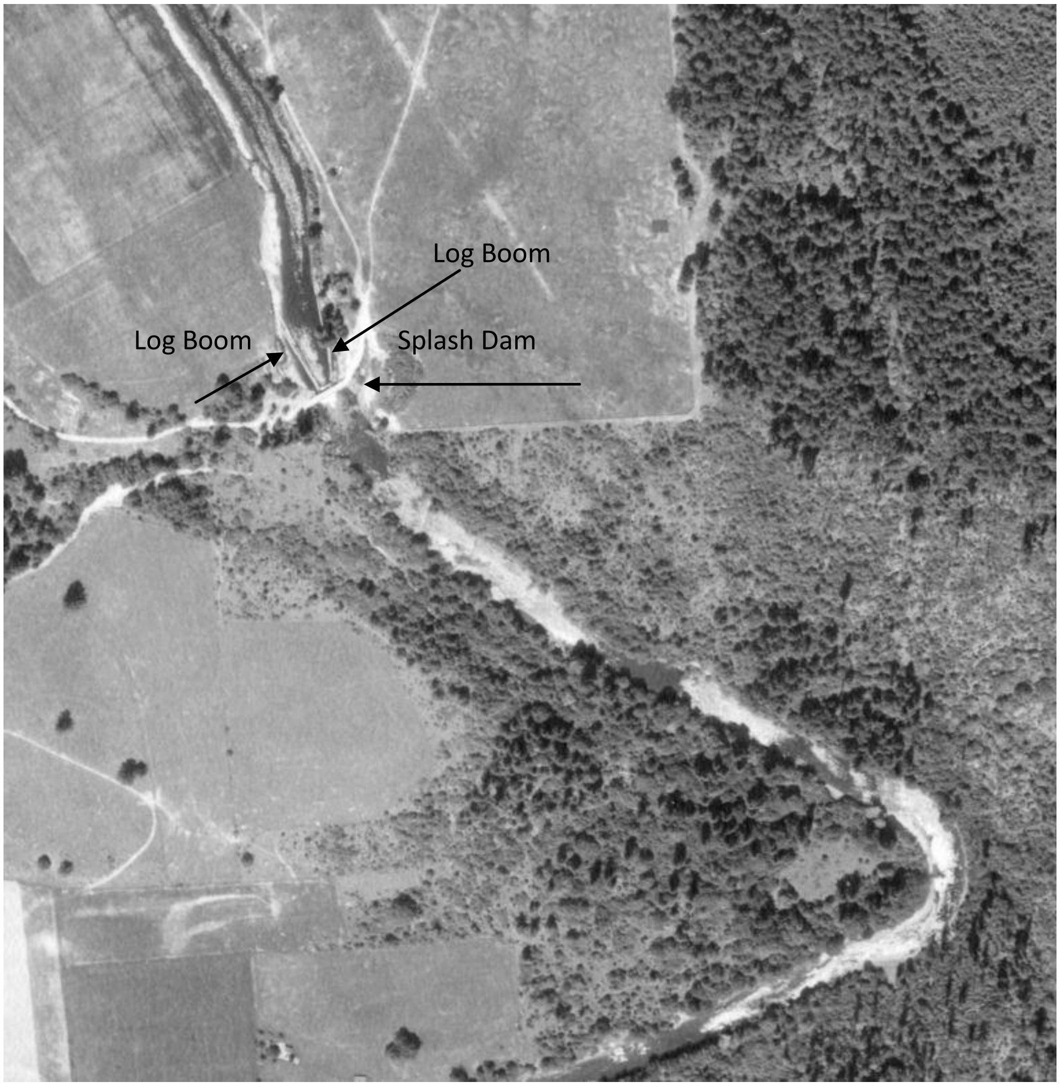

Figure 2.7. Example of a splash-dam location that was confirmed from a1950 historical aerial photo. The splash dam on the East Fork Coquille River is evident from two log-booms that guide logs through the spillway. Photo Source: COQ9_29_5_1950 University of Oregon Map Archives.

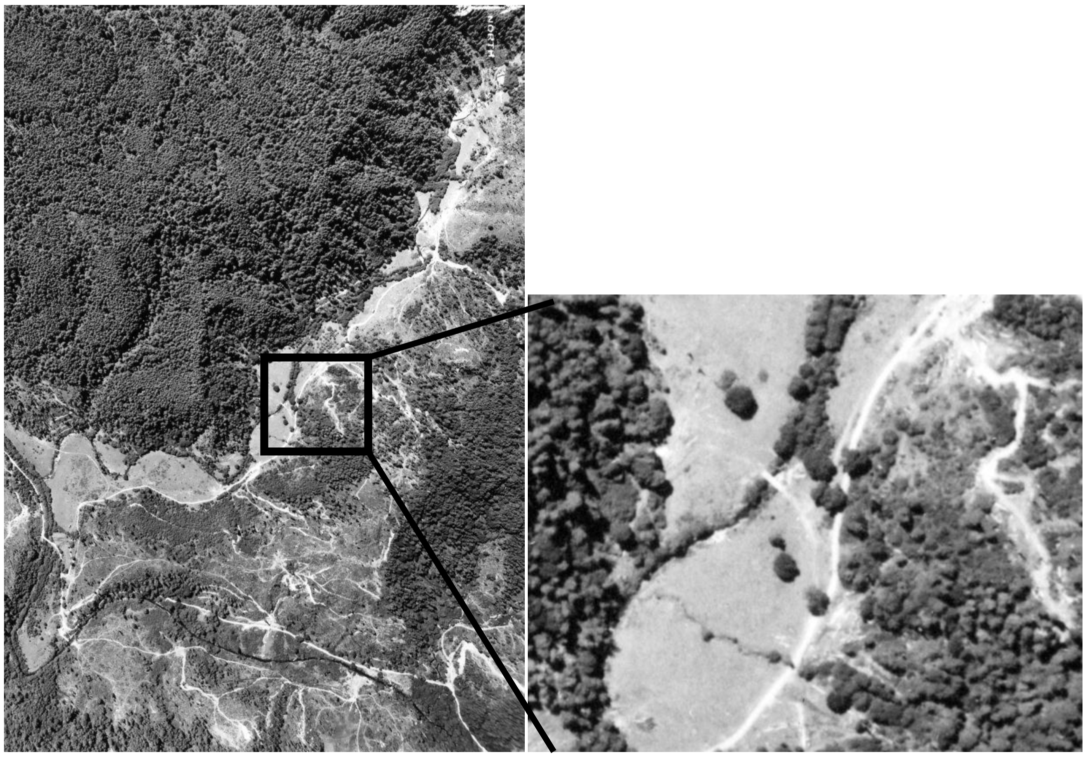

Figure 2.8. Example of inconclusive evidence of a splash dam on historical aerial photos. A structure across Wilhelm Creek is evident but inconclusive as to whether this was a splash dam or bridge. Photo Source: LC2-20W-17 University of Oregon Map Archives.

Field Searches

Probable splash-dam remnants were found at 63% of the sites field searched. I found two splash-dam sites beyond the 500-m nominal search length. In the first instance, a long, deep pool that started about 400 m upstream from the mapped splash-dam site required that I leave the stream and scout along the bank. During this process, I came across a splash dam located 655 m upstream from the mapped location. In the second instance, local knowledge directed me to the exact remnant location, 541 m downstream of the mapped point. Found probable remnants included the actual structure itself (Figure 2.9), but much more commonly consisted of eyehooks and rebar drilled into bedrock, wire cables, notched or blasted bedrock, concrete, anchor pilings with square metal spikes (Figure 2.10), a winch (Figure 2.11), and Lincoln-log style cribbing. Potential environmental cues matching historical descriptive evidence at some locations were terrace heights corresponding to the described splash-dam height, and adjacent riparian forests with a visually estimated age similar to the ‘last date of use’ for the splash dam and interspersed with large decaying stumps.

Figure 2.9. The Little Fall Creek splash dam was the most intact structure found during searches. Splash-dam cribbing and boards are still present. Remnant is approximately 12 m across, 1.5 m high, and structural cribbing extends 20 m downstream; note notched spillway (center) allows for fish passage. Photograph taken in 2009 by R. Danehy.

Figure 2.10. Fallen splash-dam piling hidden in grass, East Fork Millicoma, Oregon. Photograph taken in 2009 by author.

Figure 2.11. Winch embedded in stream sediment several meters downstream of splash-dam remnants, Camp Creek, Oregon. Photograph taken in 2009 by author.

Comparing Mapped and Confirmed Locations

The range of distances between the GIS mapped and actual splash-dam sites was narrower for sites confirmed by historical aerial photos (51 -300 m) than by ground searches (6-665 m). For all high location confidence confirmed sites combined, the average distance between the actual location and the original mapped point was 234 m. I combined both the historical aerial and ground search methods to calculate location variability because the exact splash-dam location was known. I moved 18 splash-dam points to the confirmed location and updated the location confidence to 'high' for the one medium and two low location-confidence points that were found.

WITHIN-BASIN ANALYSIS

Selected Habitat Reaches

Ten splash dams in the Oregon Coastal Province met the selection criteria of high location confidence, sedimentary rock types, forestland cover, and 2 km of continuous habitat survey available both upstream and downstream of the dam (Table 2.6). Lengths of modeled splash-dam reservoirs ranged between 81 m and 1,559 m. The last date of splash dam use ranged from 1915 to 1956. Basin areas downstream of the splash dam ranged from 11.5 km^2 to 103 km^2.

Table 2.6. Available data summarized for reaches upstream and downstream of splash dams.

Watershed	Stream Location (Legacy)	Date of Survey	Data Source	Basin Area Km^2	Avg. Channel Slope (m/km)	Reach Length (m)	Last Date of Use	GIS Splash-Dam Pool Length (m)	Splash-Dam Height (m)	Terrace Height (m)	Avg. % SO	Avg. % Gravel	Avg. % Cobble	Avg. % Bedrock	Pools >1m	Avg. Scour Pool Depth (m)	Key Wood Pieces	Side Channel Area (m^2)
	Upstream	1995	ODFW	23.9	0.0074	1995	1909	1559	20	1.2	4.7	29.4	33.5	20.2	8	0.84	11	28
Luckiamute River	Downstream	1995	ODFW	60.3	0.0120	2017				1.5	1.4	9.3	23.9	26.7	15	1.26	3	1946
	Upstream	1999	ODFW	48.1	0.0068	1995	1918	674	10	4.3	4.3	22.4	6.8	30.7	9	0.91	2	0
Middle Creek	Downstream	1999	ODFW	55.7	0.0065	2007				4.2	4.9	24.5	8.4	33.7	7	1.00	8	0
	Upstream	2005	ODFW	69.9	0.0510	2022	1925	81	10	1.4	0.3	16.0	37.1	0.0	28	1.27	9	2869
Rock Creek	Downstream	2005	ODFW	74.7	0.0150	1996				2.4	0.0	15.1	23.3	26.1	24	1.17	2	584
	Upstream	1999	ODFW	11.7	0.0220	2005	1915	651	10	0.7	0.6	42.9	19.9	32.8	0	0.49	19	557
WF Smith River	Downstream	1999	ODFW	18.6	0.0083	2012				1.0	4.2	37.5	8.3	42.9	2	0.63	12	262
	Upstream	1994	ODFW	9.3	0.0181	2011	1935	120	10	1.5	10.9	28.2	20.5	23.6	1	0.39	10	26
Waggoneer Creek	Downstream	1994	ODFW	15.6	0.0110	2015				1.6	9.2	28.9	17.6	29.2	1	0.48	1	176
	Upstream	1995	ODFW	66.4	0.0034	1958	1956	702	10	2.2	0.4	22.5	15.5	16.6	11	0.91	21	0
Camp Creek	Downstream	1995	ODFW	78.7	0.0036	2007				1.8	6.1	26.9	5.7	19.8	11	1.08	20	1016
	Upstream	1995	ODFW	6.8	0.0044	1998	1915	497	10	1.4	34.7	29.3	11.9	8.7	9	0.74	35	172
Bewley Creek	Downstream	1995	ODFW	11.5	0.0085	1992				2.1	25.1	27.8	10.3	20.8	10	1.00	7	17
	Upstream	2002	ODFW	50.3	0.0040	2009	Unkn	1016	10	2.9	4.6	49.2	10.5	11.4	11	0.78	0	233
Big Creek	Downstream	2002	ODFW	62.4	0.0045	1986		1172*		4.5	4.5	40.1	14.4	17.6	9	0.75	3	264
	Upstream	1993	SNF	22.8	0.0082	1991	Unkn	478	10	-	-	43.6	41.7	8.2	10	0.88	16	-
NF Siuslaw River	Downstream	1993	SNF	29.2	0.0082	2022				-	-	26.6	29.8	25.3	8	0.91	37	-
	Upstream	1997	ODFW	96.0	0.0145	2003	1924	204	10	1.6	4.5	9.8	16.3	57.7	4	0.88	27	662
WF Millicoma River	Downstream	1997	ODFW	103.4	0.0086	2010				2.1	2.8	16.9	17.9	36.4	5	1.08	9	0

* For the 2 km downstream section, from the splash-dam site to 1172 m downstream was not surveyed, and so I relaxed the criteria for survey proximity to include this dam.

Model Selection and Mean Differences

Based on the model selection criteria (Δ AICc ≤ 2), legacy (whether stream reach was located upstream or downstream of a splash dam) was included as an explanatory variable in the subset of competing 'best models' for six of nine in-channel variables (Table 2.7). Estimated least squares mean differences in reaches upstream and downstream of splash dams were significant for three of these in-channel variables: terrace height (m), percent cobble, and pools > 1 m depth. In contrast, percent gravel, percent silt and organics, and side channel area (m^2) were best explained by basin area and/or channel slope, and means were not considered to differ significantly ($p > 0.1$) upstream and downstream of splash dams.

Table 2.7. Candidate within-basin regression models and estimated least squares mean differences for in-channel variables. Modeling considered legacy (upstream or downstream of a splash dam), basin area, and channel slope as potential explanatory variables. All candidate models within 2 AICc for each in-channel variable are presented. Where 0 is the first ranked model and k is the number of estimated parameters. The final selected ‘best model’ and mean differences are shown in bold face.

In-channel variable	Explanatory variables	Type III Fixed Effects p-values	ΔAICc	k	Mean Difference Estimate	Down stream Splash Dam	Up stream Splash Dam	df	t-value	P value
Channel Geomorphology										
Terrace Height (m)	**legacy**	**0.05**	**0**	**4**	**0.43**	**+**	**-**	**8**	**2.22**	**0.06**
	channel slope	0.11	1.41	4						
	basin area	0.15	1.92	4						
Substrate										
% Bedrock	**legacy**	**0.09**	**0**	**4**	**6.88**	**+**	**-**	**9**	**1.79**	**0.11**
	channel slope	0.13	0.72	4						
	basin area	0.30	1.87	4						
% Cobble	channel slope	0.02	0	4						
	legacy, channel slope	0.09, 0.06	0.53	5						
	legacy	**0.02**	**1.15**	**4**	**5.40**	**-**	**+**	**9**	**-2.57**	**0.03**
	channel slope, basin area	0.02, 0.17	1.77	5						
% Gravel	**basin area**	**0.01**	**0**	**4**						
% Silt Organics	**basin area**	**0.10**	**0**	**4**						
Pools										
Avg. Scour Pool Depth (m)	channel slope	0.002	0	4						
	legacy, channel slope	**0.14, 0.01**	**1.07**	**5**	**0.17**	**+**	**-**	**8**	**3.86**	**0.005**

In-channel variable	Explanatory variables	Type III Fixed Effects p-values	ΔAICc	k	Mean Difference Estimate	Down stream Splash Dam	Up stream Splash Dam	df	t-value	P value
Pools > 1 m depth	basin area	0.043	0	4						
	legacy, basin area	**0.07, 0.009**	**0.46**	**5**	**1.70**	**-**	**+**	**8**	**-1.93**	**0.09**
Channel Complexity										
Key wood pieces /100m	**legacy**	**0.25**	**0**	**4**	**0.25**	**-**	**+**	**9**	**-1.17**	**0.27**
	basin area	0.58	1.09	4						
	channel slope	0.85	1.38	4						
Side Channel Area (m^2)	basin area, channel slope	0.07, 0.001	0	5						
	channel slope	0.001	0.75	4						

AMONG-BASIN ANALYSIS

Selected Stream Reaches

Thirteen splash dams in the Oregon Coastal Province met the selection criteria of sedimentary rock types, forestland cover, a habitat survey within 2 km of the dam, and pairing with a not-splashed surveyed reach (Table 2.8). Most of the selected probabilistic surveys were conducted by ODFW (n = 21). Of the selected splash dams, 8 of 13 were classified as high location confidence. The last date of splash dam use ranged from 1896 to 1956. Basin area ranged from 8 km^2 to 104 km^2.

Table 2.8. Summarized data for GIS queried splashed and not splashed stream reaches. Data are not available for each in-channel variable for each pairing due to differences among EPA, ODEQ and ODFW in data collection methods. *Pairing considered an outlier and so not used in analysis.

Watershed	Legacy	Splash Dam Loc. Con.	Last Date of Use	Data of Habitat Survey	Basin Area (km^2)	Avg. Channel Slope (m/km)	Active Channel Height (m)	Avg. % Gravel	Avg. % Bedrock	Number of Pools /Reach	% Scour Pool in Reach	Pools >1 m/ km	Key Wood Pieces/ 100 m	% Reach in Side Channel	Large Boulders /100 m
Steel Creek	splashed	H	1935	ODFW	11	0.0013	0.6	14	48	18	21	1.9	0.3	1.6	4
Weekly Creek	not splashed			ODFW	11	0.0084	0.7	50	10	35	43	4.9	0.2	2.6	1
Sandy Creek	splashed	L	1925	ODFW	42	0.0044	0.2	26	30	18	83	2.1	0.0	0.4	4
Camas Creek	not splashed			ODFW	41	0.012	0.6	14	15	19	39	7.9	0.9	5.9	141
Elk Creek	splashed	L	1946	ODFW	31	0.004	0.4	37	38	-	-	-	0.0	-	-
Arrow Creek	not splashed			EPA	26	0.007	0.6	47	4	-	-	-	1.3	-	-
Elk Creek	splashed	L	1919	ODFW	8	0.014	0.4	40	1	27	38	1.0	0.4	0.2	22
Rogers Creek	not splashed			ODFW	9	0.0089	0.4	59	0	37	76	0.7	2.0	5.8	2
Camp Creek	splashed	H	1956	ODFW	85	0.0053	1.0	5	68	13	54	4.9	0.8	0.8	101
Wassen Creek	not splashed			ODFW	69	0.0028	0.5	46	22	17	75	3.2	0.0	1.2	13
Middle Creek	splashed	H	1918	ODFW	49	0.005	0.6	24	27	20	62	2.4	0.0	6.7	42
Big Tom Folley Cr	not splashed			ODFW	55	0.005	0.7	57	1	20	43	9.3	0.1	1.5	9
NF Nehalem River	splashed	H	1928	ODFW	88	0.0047	1.3	29	41	6	48	0.9	0.2	0.5	1
EF Nehalem River	not splashed			ODFW	77	0.0008	0.6	18	5	17	85	12.9	0.0	0.03	1
Humbug Creek	splashed	M	1923	ODFW	65	0.0043	0.8	23	4	23	55	4.6	0.1	20.3*	1
Fishhawk Creek	not splashed			ODFW	62	0.0032	0.7	17	19	13	47	4.9	0.3	2.4*	5
NF Coquille River	splashed	H	1925	ODFW	102	0.0026	1.0	25	43	11	17	6.1	0.2	0.0	2
SF Alsea River	not splashed			ODFW	104	0.01	0.8	9	36	13	40	7.4	0.7	1.8	14
EF Millicoma R	splashed	H	1898	ODFW	57	0.015	0.8	18	22	13	26	2.7	0.1	1.1	61
SF Coquille River	not splashed			ODFW	64	0.0074	0.6	37	14	15	67	1.0	0.6	1.3	10
Myrtle Creek	splashed	L	1925	ODFW	67	0.001	0.7	22	26	21	73	4.9	0.0	0.5	75
Salmon River	not splashed			ODFW	60	0.001	0.7	10	32	13	18	6.2	0.2	2.5	40

Watershed	Legacy	Splash Dam Loc. Con.	Last Date of Use	Data of Habitat Survey	Basin Area (km^2)	Avg. Channel Slope (m/km)	Active Channel Height (m)	Avg. % Gravel	Avg. % Bedrock	Number of Pools /Reach	% Scour Pool in Reach	Pools >1 m/km	Key Wood Pieces/100 m	% Reach in Side Channel	Large Boulders /100 m
Marys River	splashed	H	1916	ODEQ	61	0.002	0.4	7	3	-	-	0.0	-	-	-
Yaquina River	not splashed			ODEQ	96	0.0032	0.8	11	29	-	-	1.0	-	-	-
Long Tom River	splashed	H	1896	EPA	67	0.005	0.8	-	65	-	-	-		-	-
Five Rivers	not splashed			ODEQ	60	0.0027	0.8	-	32	-	-	-		-	-

Model Selection and Mean Differences

Based on the model selection criteria (Δ AICc $\leq$ 2), legacy (whether reach was located in a splashed or not-splashed basin) was included as an explanatory variable in the subset of competing 'best models' for eight of nine in-channel response variables (Table 2.9). Estimated least squares mean differences between splashed and not-splashed reaches were significantly different for three of these eight in-channel response variables. In contrast, number of boulders/100 m was best explained by channel slope, and means were not considered to differ significantly ($p > 0.1$) in splashed and not-splashed reaches.

Table 2.9. Candidate among-basin regression models and estimated least squares mean differences for in-channel variables. Modeling considered legacy (reaches in splashed or not-splashed basins), basin area and channel slope as potential explanatory variables. All candidate models within 2 AICc for each in-channel variable are presented. Where 0 is the first ranked model and k is the number of estimated parameters. The final selected 'best model' and mean differences are shown in bold font.

In-channel variable	Explanatory Variables	Type III Fixed Effects p - value	ΔAICc	k	Mean Difference Estimate	Splashed	Not Splashed	df	t-value	p-value
Channel Geomorphology										
Active Channel Height	**legacy, basin area, legacy*basin area**	**0.06, 0.0004, 0.024**	**0**	**5**	**0.04**	**+**	**-**	**10**	**0.57**	**0.58**
	basin area	0.0008	0.64	3						
Substrate										
% Bedrock	**legacy, basin area**	**0.02, 0.03**	**0**	**4**	**15.12**	**+**	**-**	**11**	**2.67**	**0.02**
	basin area	0.04	0.18	3						
% Gravel	**legacy, basin area, legacy*basin area**	**0.03, 0.01, 0.09**	**0**	**5**	**9.01**	**-**	**+**	**10**	**-1.69**	**0.12**
	basin area	0.01	0.03	3						
	legacy, basin area	0.11, 0.01	0.12	4						
Pools										
# of Pools/reach	basin area	0.0004	0	3						
	legacy, basin area	0.24, 0.0005	1.62	4						
	legacy, basin area, legacy*basin area	**0.05, 0.0004, 0.09**	**1.70**	**5**	**2.54**	**-**	**+**	**7**	**-1.23**	**0.26**

In-channel variable	Explanatory Variable	Type III Fixed Effects p - value	ΔAICc	k	Mean Difference Estimate	Splashed	Not Splashed	df	t- value	p- value
Pools										
% Scour Pools in reach	channel slope	0.37	0	3						
	legacy	**0.55**	**0.49**	**3**	**5.74**	**-**	**+**	**9**	**-0.59**	**0.57**
	basin area	0.99	0.87	3						
Pools > 1 m depth/km	**legacy, basin area**	**0.07, 0.19**	**0**	**4**	**2.50**	**-**	**+**	**9**	**-1.95**	**0.08**
	basin area	0.21	1.00	3						
	legacy, channel slope	0.07, 0.43	1.26	4						
	legacy	0.06	1.87	4						
Channel Complexity										
Key wood pieces /100 m	**legacy, channel slope, legacy*channel slope**	**0.54, 0.02, 0.05**	**0**	**5**	**0.36**	**-**	**+**	**8**	**-2.07**	**0.07**
	legacy, channel slope	0.07, 0.07	1.44	4						
Large Boulders /100 m	**channel slope**	**0.04**	**0**	**3**						
% of reach in side channel	basin area	0.11	0	3						
	legacy	0.22	1.39	3						
	legacy, basin area	**0.21, 0.10**	**1.57**	**4**	**1.15**	**-**	**+**	**7**	**-1.25**	**0.25**
	channel slope	0.31	1.90	3						

Discussion

This study created a geodatabase of splash dams and log drives throughout Western Oregon, and demonstrated that a legacy of splash damming on modern-day streams can still be detected 50 to 130 years after the practice ceased. Available historical sources of information enabled mapping of 232 splash dams and 213 log drives, with varying degrees of confidence. I attempted to quantify the variability between the archival mapped location and the actual on-the-ground location of the splash dam by confirming splash dams using either historical aerial photographs or field searches. Although evidence of splash dams was found in historical aerial photographs and in the field, searching archived records was the only practical means for regional mapping of splash dams and log drives. Considering both the within- and among-basin analyses, I detected a significant legacy effect of splash damming for all categories evaluated (geomorphology, substrates, pools, and channel complexity). I found statistical differences in splashed and not-splashed reaches for in-channel variables, many of which are regarded as important indicators salmon habitat quality (percent bedrock, number of pools >1 m depth/km, and key wood pieces). This study demonstrates the importance of considering archival information in modern-day studies and that history can account for significant variation in stream environments.

SPLASH-DAM MAPPING

Although local knowledge and field searches were valuable resources in mapping splash dams and brought splash damming ‘out of the history books and into life,’ archival (both museum and library) searches identified the vast majority of splash-dam sites. Using historical aerial photographs alone will not result in a comprehensive splash-dam map; nearly 70% of the splash dams randomly selected from the dataset were not visible on aerial photos. The historical photo searches were constrained by temporal availability and spatial resolution of existing historical photographs. In some instances, the splash dam’s ‘last date of use’ was well before the 1903 invention of the airplane (Anderson 2007), and larger splash dams were easier to spot than smaller splash dams, which is consistent with other remote-sensing archeological mapping applications (Campana 2002). In addition, the protocol for historical aerial photograph searches may have increased the likelihood that a splash dam was confirmed in the low and medium location confidence classifications because the number of PLSS sections viewed increased with decreasing location confidence. Field searches can be efficiently conducted only with targeted archival or aerial photo evidence. Most found remnants were subtle and would likely be missed during traditional stream surveys. However, when an aerial photo or field search revealed a splash dam, this provided strong evidence about the exact location and allowed assessment of variability between the mapped point generated by archive searches and the actual location.

Archived information, such as that regarding the precise location of splash dams or number of splash dams on a stream, though essential, varied in quality and quantity, and thus some splash dams and log drives may be incorrectly located on the map or were omitted. Variability in available evidence is attributable in part to the probability that precise information about a splash-dam location was documented and retained for 50 to 130 years. This was supported by the location confidence analysis, which indicated splash dams abandoned more recently were more likely to be assigned a high location confidence. Caution may be warranted for some applications of the map given the observed variability (6 - 655 m) between mapped and actual location of splash dams. The map should be sufficiently accurate for most broad-scale applications, such as regional landuse planning and monitoring, (FEMAT 1993, Oregon Plan 1997) but additional ground-truthing may be necessary for site-specific applications (e.g., research design and watershed assessment).

The splash-dam location confidence classification is a unique approach that offers users guidance for assessing accuracy of mapped splash dams. My classification differs from other archeological approaches which use predictive modeling based on multiple available datasets to determine the probability that a location will support a feature of interest (Duncan and Beckman 2000, Kvamme 2006). A statistical modeling approach could be applied to evaluate whether known splash-dam sites are associated with certain human or environmental attributes. Any such relationships could be used to predict possible locations of splash dams that were missed during the current mapping, given that some splash dams were likely never documented. Despite accuracy limitations, the attributed geodatabase of splash dams and log drives is the first of its kind for any region and offers a foundation for planning and interpreting future research, monitoring, and management in the Oregon Coastal Province.

As can be seen from the map, splash dams and log drives were pervasive throughout the study area. Visual observation from mapped locations shows that splash dams could have been constructed at any point along a stream (mouth, mid-stream and headwaters), and remnants were found in both constrained and unconstrained valleys. Although I did not attempt to quantify relationships between locations of splash dams and landscape characteristics, some patterns were suggested. For example, a stream appeared more likely to have been splash dammed or log driven with increasing basin area. Supporting this is the fact that I was unable to find habitat surveys in not-splashed streams with basin areas larger than 110 km^2 to pair with splashed sites. This indicates that reference streams, those streams little-influenced by human activities, are unlikely to exist for larger sedimentary lithology streams in the Oregon Coastal Province.

Remnants of splash dams were found during ground searches, emphasizing that these structures were built to last, and suggesting that their legacy may be evident in stream habitats. I found evidence of splash dams at 10 of 16 searched sites with high-location confidence; the longevity of these structures in a dynamic stream environment is a testament to how well-constructed some splash dams were. Splash dams are often portrayed as simple, poorly built, temporary structures that were dynamited to release freshets. While structures of this type likely existed, most qualitative archival information described splash dams much differently. In many instances, a splash-dam structure was used repeatedly over multiple years—some operated for up to 40 years. Historical photos show dams of robust construction, and instructional books describe sophisticated engineering components, economic costs, and site considerations for multiple designs of splash dams (Bryant 1914, Brown 1936). The 'last date of use' for found dam remnants ranged from 1905-1956, indicating that structures more than 100 years old can still be detected in the field. Evidence that some splash-dam structures still exist in the stream environment suggests the plausibility of detecting a splash-damming legacy in stream habitats.

SPLASH-DAM LEGACY DETECTION

Results from both within- and among-basin comparisons provide support for the hypothesis that an environmental legacy of splash damming can be detected in stream habitats of the Oregon Coastal Province. This is the first study to demonstrate a regional relationship between historical splash damming and modern-day stream habitat characteristics. Although splash damming in the Oregon Coastal Province ceased during the 1950s, the variable representing its effect (legacy) was included in the subset of competing 'best models' for 14 of the 18 in-channel variables examined. Solid statistical evidence of a splash-damming legacy was found in either within- or among-basin comparisons for at least one in-channel variable in each evaluated category (geomorphology, substrates, pools, and channel complexity).

The potential effects of splash damming on stream habitats were somewhat more evident in among-basin analyses than within-basin analysis, but both approaches were useful for analyzing existing monitoring data. The subset of competing 'best models' included the variable 'legacy' for 89% of the in-channel variables examined in among-basin analysis, but only 67% of the in-channel variables examined in within-basin analysis. For the five habitat variables examined in both analyses (percent bedrock, percent gravel, number of pools > 1 m depth per km, number of key wood pieces per 100 m, and percent area of side channel habitat), estimated least squares mean differences were largest for among-basin analyses of splash-damming effects. The among-basin analysis approach may appear more sensitive to identifying the effects of splash damming in the Oregon Coastal Province for two reasons. First, activities related to log transport may have affected areas upstream of splash dams for within-basin analysis. This may have occurred because log drives on reaches upstream of splash dams were undocumented and/or because I underestimated the area of splash-dam reservoirs in my spatial analysis. Either could have minimized observed differences in habitat characteristics between reaches upstream and downstream of splash dams for the within-basin analysis. The second is that forest-management activities may have been more intense throughout basins containing a splash dam than in those that did not. Thus, the presence of a splash dam may reflect a greater overall potential for forestry-related effects on streams identified in among-basin analyses that are not specific to splash damming.

Including the covariates basin area and channel slope improved the ability to detect a legacy effect by allowing me to account for environmental factors that can highly influence stream conditions. It was more important to account for covariates in the among-basin analysis than the within-basin analysis. In the within-basin analysis, 33% of the candidate models containing legacy included a covariate (Table 2.7), whereas in the among-basin analysis, 87% of the candidate models containing legacy included a covariate (Table 2.9). This is due to inherent differences between basins, and is consistent with observed variances for in-channel variables that were larger in the among-basin analysis than in the within-basin analysis. Additionally in the among-basin analysis, it was important to include an interaction between legacy and a covariate for several in-channel variables. In the among-basin analysis, percent gravel and number of pools per reach interacted with basin area and legacy, with less gravel and fewer pools per reach in smaller splash-dammed basins. Splashed reaches were devoid of key wood pieces regardless of basin area or channel slope. The relationship of key wood pieces in splashed reaches to covariates contradicts many empirical and conceptual studies (Bilby and Ward 1989, Fetherston et al. 1995, Wing and Skaugset 2002) which show that the number of key wood pieces is related positively to channel slope and negatively to basin area. However, relationships of the number of key wood pieces to channel slope and basin area in not-splashed reaches were consistent with empirical studies.

Despite some in-channel variables demonstrating little or no association with splash damming, results for other in-channel variables in this regional study of the

Oregon Coastal Province were generally consistent with results from site-specific studies done elsewhere (International Pacific Salmon Fisheries Commission 1966, Napolitano 1998). Those studies, conducted in the Stellako River, B.C., and in the North Fork of Caspar Creek, CA, immediately and 150 years after splash damming ceased, demonstrated channel incision, less wood kg/m^2 and severe gravel scouring downstream of the dam. These results were attributed to high magnitude and frequent flood flows from splash damming that increased sediment erosion and wood transport. Accordingly, I found that reaches downstream of splash dams or in splashed basins contained higher percentages of exposed bedrock substrates and fewer deep pools than areas in the Oregon Coastal Province thought to be less directly affected by splash damming. These findings may partially relate to the fact that splashed areas had fewer key wood pieces than not-splashed areas, with three times fewer key wood pieces in among-basin comparisons. Large wood, generally considered an integral structural element in Pacific Northwest streams (Gurnell et al. 2002, Swanson et al. 1976), can trap and sort gravel, which can reduce areas of bedrock and create deep pools (Bilby and Ward 1989, Grette 1985).

More bedrock associated with splash damming may have negative consequences for biota and water quality. Higher percentages of stream substrates in bedrock suggest lower percentages in gravel and cobble. This was substantiated by among-basin analysis, showing a one-third lower percentage of gravels in splashed reaches, and by the within-basin analysis showing a lower percentage of cobbles in reaches downstream of splash dams. More bedrock substrate in splashed reaches suggests gravels and cobbles are less stable and that higher stream velocities may persist in splashed reaches, due in part to the lack of key wood pieces to slow stream velocity. Mobile sediments and high-velocity flows can disrupt the abundance and diversity of macro-invertebrates, important food sources for aquatic species (Brooks et al. 2005, Reice 1980). Likewise, fewer gravels and cobbles may reduce available areas suitable for salmon and lamprey (*Lampetra tridentata*) spawning. In splashed reaches for the among analysis, the mean value observed for percentages of bedrock is nearly three times higher, and percentages of gravels are below ODFW reference site values and do not meet spawning habitat benchmarks (Anlauf and Jones 2007, Anlauf et al. 2009). Though not measured in this study, I hypothesize that water temperatures may be higher in historically splash-dammed streams. Streams dominated by bedrock are generally warmer and are associated with greater temperature variation when compared to alluvial (gravel-dominated) streams, due to a decreased opportunity for hyporheic exchange (Johnson 2004, May and Lee 2004, Poole and Berman 2001, Torgersen et al. 1999). In the study region, warm water temperatures in bedrock channels have been negatively associated with survival and growth of juvenile salmonids (Ebersole et al. 2006, Reeves et al. 1989, Richter and Kolmes 2005).

The finding of fewer deep pools in splashed areas likely has negative implications for salmon. Deep pools are important for rearing and migrating salmon, providing cold water and over-winter refugia (Beschta and Platts 1986, Fausch and Northcote 1992, Matthews et al. 1994, Tschaplinski and Hartman 1983). The demonstrated relationship of fewer deep pools in streams with a splash-dam legacy is consistent with other studies examining effects of historical land uses on streams (Collins et al. 2002, McIntosh et al. 2000). My finding of more deep pools (> 1 m depth/km) upstream than downstream of splash dams contrasts with many empirical studies, including my findings for scour pools in the within-basin analysis, that demonstrate deeper pools are a function of increasing basin area (Bilby and Ward 1989, Gurnell et al. 2002, Stack 1988). This is likely because bedrock-dominated pools are shallower than alluvium-dominated pools in the Oregon Coastal Province (May 2004). Further, the lack of key wood pieces reduces availability of structural elements needed to create and maintain deep pools (Fausch and Northcote 1992, Grette et al. 1985, Lisle and Kelsey 1982).

The legacy of splash damming did not manifest in some evaluated in-channel variables, suggesting either that splash-dam freshets never affected these variables or that the in-channel variables are no longer statistically sensitive to legacy effects (via resilience). In the among-basin analysis, for example, large boulders were best explained by only channel slope, implying insufficient competence of splash-dam freshets to transport heavy boulders a great distance. In the within-basin analysis, again, basin area alone best explained the percent silt and organics. A splash-damming legacy for silt and organics was not included the ‘best model’, possibly because distributions of highly mobile silt had recovered by the time habitat surveys were conducted 50 to 130 years after splash damming stopped. Silt particles typically have an immediate response to perturbations (Beschta 1978, Rice et al. 1979) but recover quickly once the perturbation ends (Cline et al. 1982, Madej 2001). Finally, it is important to mention that although the means of some in-channel variables were not statistically different between splashed and not-splashed reaches, the differences may be biologically significant. In the among-basin analysis, for example, the percent area in side channels for splashed reaches was half of that for not-splashed reaches (1.3% in splashed and 2.5% in not-splashed). While the overall side-channel percentages may be small, given the importance of side channels for salmon growth and overwinter survival (Solazzi et al. 2000, Swales et al. 1986, Tschaplinski and Hartman 1983), the reduced availability of side channels in splashed reaches may be biologically relevant.

Two disturbance-response types, either a press response or a sustained-pulse response (Figure 2.4), best describe the potential recovery trajectory of in-channel variables during the 50-130 years following splash damming. Those in-channel variables with large statistical differences between splashed and not-splashed reaches, (e.g., key pieces of wood and percent bedrock in the among-basin analysis) may reflect either a slow sustained-pulse or press response trajectory. Those in-channel variables with moderate differences that were not statistically significant but matched historical evidence following a splash-dam flood regime, (e.g., percent gravels in among analysis and cobbles in the within-basin analysis) may indicate a sustained-pulse response with the in-channel variable somewhere along the recovery trajectory. Natural stream processes following splash damming that could potentially diminish legacy effects are inputs from adjacent tributaries, subsequent flood events, or debris flows (May and Gresswell 2003, Minshall et al. 1985).

Many in-channel habitat variables have apparently not recovered from splash-dam impacts, and a region-wide, whole-watershed restoration approach may be needed to accelerate recovery. Legacy impacts likely persist because splash damming altered fundamental stream features. Mechanisms for natural recovery are limited because splashed areas are devoid of meaningful stream complexity that could potentially capture and store sediments and large wood. Additionally, subsequent stream management, such as stream cleaning (to remove slash and other wood from streams following timber harvest) may have occurred in splashed areas, further hindering natural recovery processes. Streams may be experiencing a very slow recovery (sustained-pulse response) or functioning at a new, lower dynamic equilibrium (press response); in either case restoration efforts can accelerate stream recovery. Splash damming was pervasive throughout the Oregon Coastal Province and many of the affected areas are in salmon habitat, including that for ESA listed coho (threatened) and steelhead (species of concern). Site-specific stream habitat restoration can be effective in the Oregon Coastal Province at increasing the amount of large wood, pool area, and salmonid abundance (Roni et al. 2006). However, given the spatial extent of splash damming and because historical splash-dam freshets occurred along the entire stream below a dam, large-scale longitudinal restoration projects and whole-watershed restoration (Bell et al. 1997, Nehlsen 1997) are likely needed to return splashed areas to complex, high-quality salmon habitat.

Because a splash-damming signal was still detectable in current regional datasets, legacy effects may be important to consider in planning future stream research and monitoring in areas where streams have been used to transport logs. Even though the regional datasets were not specifically targeting splash-dam effects on streams, statistical differences between splashed and not-splashed areas were apparent for some in-channel variables. The EMAP regional stream habitat datasets are used by many federal, state, and local entities. In some situations, failing to account for splash-damming legacy effects may confound or mask responses. As an example, legacy effects may help clarify why landscape characteristics such as topography, land cover, and geology explain substantial in-channel variation in some studies (e.g., Burnett et al. 2006, Hughes 2006) but not in others (Burnett et al., in review) in coastal Oregon. To reduce the potential for misinterpreting monitoring and research results, design for future aquatic studies in forested and sedimentary regions of the Oregon Coastal Province should either exclude splashed areas or account for legacy effects.

CHAPTER 3

GENERAL CONCLUSION

This study provides both quantitative and statistical evidence that the influence of splash-dam freshets occurring 50-130 years ago can be detected for some in-channel variables. However, a legacy effect was evident only when historical splash-dam locations were reconstructed, and demonstrates the importance of including archived information in modern-day studies. Archival documentation at museums and libraries provided the most abundant splash-damming records. Historical aerial photographs rarely captured splash-dam structures, and field searches found splash-dam remnants still existing in the stream environment. The newly-constructed map illustrates that splash dams were prevalent throughout western Oregon, including the Oregon Coastal Province.

Streams affected by splash damming experienced a profound flood disturbance regime shift. Splash-dam flood regimes occurred for nearly 40 years on some systems, creating more frequent and greater magnitude floods. The higher magnitude splash-dam freshets had a greater capacity to transport bedload, and reportedly left behind little in-channel substrate and stream complexity (Bell and Jackson 1941, Gharrett and Hodges 1950, Wendler and Deschamps 1955). This splash-dam freshet regime, in which the disturbance regime occurred over many years and then ceased, falls under a special classification of disturbance—the sustained pulse. A sustained pulse disturbance has not been previously described in disturbance literature (Bender et al. 1984, Glasby and Underwood 1996, Lake 2000) but may be a useful tool for those studying the environmental legacies of past land use.

This analysis is the first to quantify splash-damming legacy effects on the regional scale. I found statistical evidence for all categories evaluated (geomorphology, substrates, pools, and channel complexity) in either the among- or within-basin analyses. Across both analyses, I found significantly more bedrock and fewer deep pools in splashed reaches. Both of these in-channel variables are important for salmonid spawning, rearing, and migration (Beschta and Platts 1986, Fausch and Northcote 1992, Matthews et al. 1994, Tschaplinski and Hartman 1983). The covariates channel slope and basin area were consistently important to include for analyses.

Results of this study show that historical splash damming occurred throughout western Oregon, and that evaluated stream reaches in the Oregon Coastal Province still bear splash-dam impacts 50-130 years later. Results from this study show that a splash-damming signal was still detectable in current regional datasets, therefore legacy effects may be important to consider in planning future stream research and monitoring in areas where streams have been used to transport logs. Finally, if restoring habitat for salmonids is a priority in these areas, whole-watershed active and passive restoration measures will be needed to recover legacy effects of splash damming. Just as prior generations purposefully engineered the entire stream for log transport, modern-day generations can manage and restore streams to desired conditions.

BIBLIOGRAPHY

Akaike, H. (1974) A new look at the statistical model identification. *IEEE Trans. Autom. Contr.*, **19,** 716-723.

Allan, J.D., D.L. Erickson, and J. Fay (1997) The influence of catchment land use on stream integrity across multiple spatial scales. *Freshwater Biology* **37,** 149–161.

Allen, J.D. (2004) Landscapes and riverscapes: The influence of land use on stream ecosystems. *Annual Review of Ecology, Evolution and Systematics,* **35,** 257-284.

Anderson, J.D.J. (2007) *Introduction to Flight.* McGraw-Hill, New York.

Anderson, J.R., E.E. Hardy, J.T. Roach, R.E. Witmer (1976) A land use and land cover classification system for use with remote sensor data. United States Geological Survey Professional Paper 964, United States Government Printing Office, Washington, DC.

Anlauf, K.J. and K.K. Jones (2007) Stream habitat conditions in Western Oregon, 2005. Oregon Department of Fisheries and Wildlife, Salem, OR.

Anlauf, K.J., K.K. Jones, and C.H. Stein (2009) The status and trend of physical habitat and rearing potential in coho bearing streams in the Oregon Coastal Coho Evolutionary Significant Unit. Oregon Department of Fisheries and Wildlife, Salem, OR.

Bangold, R.A. (1973) The nature of saltation and of 'bed-load' transport in water source. *Series A, Mathematical and Physical Sciences,* pp. 473-504. The Royal Society.

Beckham, D. (1990) *Swift flows the river: Log driving in Oregon.* Arago Books, Coos Bay, OR.

Bell, M.C., and R.I. Jackson (1941) Adams River dam. pp. 19. International Pacific Salmon Fisheries Commission.

Bell, S.S., M.S. Fonseca, and L.B. Motten (1997) Linking restoration and landscape ecology. *Restoration Ecology,* **5,** 318–323.

Benda, L.N., L.N. Poff, D. Miller, T. Dunne, G. Reeves, G. Pess, and M. Pollock (2004) The network dynamics hypothesis: how channel networks structure riverine habitats. *BioScience,* **54,** 413-427.

Bender, E.A., T.J. Case, and M.E. Gilpin (1984) Perturbation experiments in community ecology: Theory and practice. *Ecology,* **65,** 1-13.

Beschta, R. 1978. Long-term patterns of sediment production following road construction and logging in the Oregon Coast Range. *Water Resources Research,* **14,** 1011-1016.

Beschta, R.L., and W.S. Platts (1986) Morphological features of small streams: Significance and function. *Journal of the American Water Resources Association,* **22,** 369–379.

Bilby, R.E., and J.W. Ward (1989) Changes in characteristics and function of woody debris with increasing size of streams in western Washington. *Transactions of the American Fisheries Society*, **18,** 368-378.

Brooks, A.J., T. Haeusler, I. Reinfelds, and S. Williams (2005) Hydraulic microhabitats and the distribution of macroinvertebrate assemblages in riffles. *Freshwater Biology*, **50,** 331–344.

Brown, N.C. (1936) *Logging-Transportation.* John Wiley and Sons, Inc., New York.

Bryant, R.C. (1914) *Logging: The principles and general methods of operation in the United States.* J. Wiley and Sons, Inc, New York.

Burnett, K.M., G.H. Reeves, S. Clarke, and K.R. Christiansen (2006) Comparing riparian and catchment influences of stream habitat in a forested montane landscape. *American Fisheries Society Symposium 48* . American Fisheries Society, Bethesda, MD.

Burnett, K.M., G.H. Reeves, D.J. Miller, S. Clarke, K. Vance-Borland, and K. Christiansen (2007) Distribution of salmon-habitat potential relative to landscape characteristics and implications for conservation. *Ecological Applications*, **17,** 66-80.

Burnett, K.M., K.Vance-Borland, R.L. Flitcroft, and L.M. Ganio. In review. Aquatic and Riparian Effectiveness Monitoring Program: Modeling in-channel variables from landscape conditions. PNW Research Station GTR.

Campana, S. (2002) Ikonos-2 multispectral satellite imagery to the study of archaeological landscapes: An integrated multi-sensor approach in combination with “traditional” methods. Pages 219-225 in: M. Doerr and A. Sarris, eds. *The Digital Heritage of Archaeology, Computer Applications and Quantitative Methods in Archeology.* Hellenistic Ministry of Culture, Athens.

Christensen, N.L. 1989. Landscape history and ecological change. *Journal of Forest History*, **33,** 116-125.

Clarke, S.E., K.M. Burnett, and D.J. Miller (2008) Modeling streams and hydrogeomorphic attributes in Oregon from digital and field data. *Journal of the American Water Resources Association*, **44,** 459-477.

Cline, L.D., R.A. Short, and J.V. Ward (1982) The influence of highway construction on the macroinvertebrates and epilithic algae of a high mountain stream. *Hydrobiologia*, **96,** 149-159.

Collins, B.D., D.R. Montgomery, and A.D. Haas (2002) Historical changes in the distribution and functions of large wood in Puget Lowland rivers. *Canadian Journal of Fisheries and Aquatic Sciences*, **59,** 66–76 .

Coy, F.E.J., T. Fuller, L. G. Meadows, and D. Fig (1992) Splash dam construction in eastern Kentucky's Red River drainage area. *Forest Conservation and History*, **36(4),** 179-184.

Dolloff, C.A. 1993. Large woody debris, fish habitat, and historical land use. *Biodiversity and Coarse Woody Debris in Southern Forests: Effects on biodiversity* USDA Forest Service General Technical Report SE 94, pp. 130-138.

Duncan, R.B., and K.A. Beckman (2000) The application of GIS predictive site location models within Pennsylvania and West Virginia. Pages 33-53 in: K. Wescott and R.J. Brandon, eds., *Practical applications of GIS for archaeologists: a predictive modeling toolkit*. CRC Press, Philadelphia.

Dupouey, J.L., E. Dambrine, J.D. Laffite, and C. Moares (2002) Irreversible impact of past land use on forest soils and biodiversity. *Ecology,* **83,** 2978-2984.

Ebersole, J.L., P.J. Wigington Jr., J.P. Baker, M.A. Cairns, M.R. Church, B.P. Hansen, B.A. Miller, H.R. LaVigne, J.E. Compton, and S.G. Leibowitz (2006) Juvenile Coho salmon growth and survival across stream network seasonal habitats. *Transactions of the American Fisheries Society,* **135,** 1681-1697.

ESRI (2008) ArcGIS 9.3. Environmental Systems Research Institute, Redlands, CA.

Farnell, J.E. (1979) Coos and Coquille Rivers navigability studies. Oregon Division of State Lands, Salem, OR.

Fausch, K.D. and T.G. Northcote (1992) Large woody debris and salmonid habitats in a small coastal British Columbia stream. *Canadian Journal of Fisheries and Aquatic Sciences* **49,** pp. 682-693.

FEMAT [Forest Ecosystem Management Assessment Team] (1993) Forest ecosystem management: an ecological, economic, and social assessment. Report of the Forest Ecosystem Management Team. Washington, DC.

Fetherston, K.L., R.J. Naiman, and R.E. Bilby (1995) Large woody debris, physical process, and riparian forest development in montane river networks of the Pacific Northwest. *Geomorphology,* **13,** 133-144.

Flitcroft, R., K. Jones, K. Reis, and B. Thom (2002) Year 2000 stream habitat conditions in western Oregon. Oregon Department of Fish and Wildlife, Portland.

Foster, D.R., G. Motzkin, and B. Slater (1988) Land-use history as long-term broad-scale disturbance: Regional forest dynamics in Central New England. *Ecosystems* **1,** 96–119.

Foster, D., F. Swanson, J. Aber, I. Burke, N. Brokaw, D. Tilman, and A. Knapp (2003) The importance of land-use legacies to ecology and conservation. *BioScience,* **53,** 77-88.

Franklin, J.F., and C.T. Dyrness (1973) Natural vegetation of Oregon and Washington. USDA Forest Service General Technical Report PNW-GTR-008, pp. 427. Portland.

Frissell, C.A., W.J. Liss, C.E. Warren, and M.D. Hurley (1986) A hierarchical framework for stream habitat classification: viewing streams in a watershed context. *Environmental Management,* **10,** 199-214.

Gauer, U. (1997) Collembola in Central Amazon inundation forests –strategies for surviving floods. *Pedobiologia,* **41,** 69–73.

Gharrett, J.T., and J.I. Hodges (1950) Salmon fisheries of the coastal rivers of Oregon south of the Columbia. Oregon Fish Commission, Portland, OR.

Glasby, T.M., and Underwood, A.J. (1996) Sampling to differentiate between pulse and press perturbations *Environmental Monitoring and Assessment,* **42,** 241-252.

Grette, G.B. (1985) *The role of large organic debris in juvenile salmonid rearing habitat in small streams*. Thesis, University of Washington, Seattle.

Gurnell, A.M., H. Pie'Gay, F.J. Swanson, and S.V. Gregory (2002) Large wood and fluvial processes. *Freshwater Biology* **47,** 601–619.

Harding, J.S., E.F. Benfield, P.V. Bolstad, G.S. Helfman, and E.B.J. Jones III (1998) Stream biodiversity: The ghost of land use past. *Proceedings of the National Academy of Sciences*, **95,** 14843–14847.

Harr, R.D. (1981) Some characteristics and consequences of snowmelt during rainfall in western Oregon. *Journal of Hydrology,* **53,** 277-304.

Healey, M.C. (1991) Life history of chinook salmon. Pages 311-394 in: C. Groot and L. Margolis (eds.) *Pacific salmon life histories*. University of British Columbia Press, Vancouver, BC.

Hermy, M., and K. Verheyen (2007) Legacies of the past in the present-day forest biodiversity: A review of past land-use effects on forest plant species composition and diversity. *Ecological Research* **22,** 361-371.

Hicks, B.J., and J.D. Hall (2003) Rock type and channel gradient structure salmonid populations in the Oregon Coast Range. *Transactions of the American Fisheries Society* **132,** 468-482.

Hughes, R.M. (2006) Landscape influences on stream habitats and biological assemblages. *American Fisheries Society Symposium 48*. American Fisheries Society, Bethesda, MD.

Hynes, H.B.N. (1975) The stream and its valley. *Proceedings of the International Association of Theoretical and Applied Limnology* **19,** 1-15.

International Pacific Salmon Fisheries Commission [IPSF] (1966) Effects of log driving on the salmon and trout populations in the Stellako River. International Pacific Salmon Fisheries Commission, Vancouver, BC. 88 p.

Itoa, S., R. Nakayamaa, and G.P. Buckley (2004) Effects of previous land-use on plant species diversity in semi-natural and plantation forests in a warm-temperate region in southeastern Kyushu, Japan. *Forest Ecology and Management* **196,** 213–225.

James, N.C. (1956) Letter to Public Utilities Commissioner Holtzel. Oregon Fish Commission. Salem Archives Building, Public Utilities Commission Files, 5/9/2/4 Box 2, L-F-8 (Camp Creek), Salem, Oregon.

Johnson, S.L. (2004) Factors influencing stream temperatures in small streams: substrate effects and a shading experiment. *Canadian Journal of Fisheries and Aquatic Sciences*, **61,** 913-923.

Junk, W., J.P.B. Bayley, and R.E. Sparks (1989) The flood pulse concept in river-floodplain systems. In: *The International Large River Symposium, Canadian Special Publications in Fisheries and Aquatic Sciences* **Vol 106,** 110-127.

Kaufmann, P.R., P. Levine, E.G. Robison, C. Seeliger, and D.V. Peck (1999) Quantifying physical habitat in wadeable streams. U.S. Environmental Protection Agency, Washington, DC.

Kline, J.D., D.L. Azuma, and A. Moses (2003) Modeling the spatially dynamic distribution of humans in the Oregon (USA) Coast Range. *Landscape Ecology,* **18,** 347-361.

Koerner, W., J.L. Dupouey, E. Dambrine, and M. Benoit (1997) Influence of past land use on the vegetation and soils of present day forest in the Vosges Mountains, France. *Journal of Ecology,* **85,** 351-358.

Kvamme, K.L. (2006) There and back again: Revisiting archeological location modeling. Pages 4-34 in: M. Mehrer and K. Wescott (eds.) *GIS and archaeological site location modeling*. CRC Press, Boca Raton.

Lake, P.S. (2000) Disturbance, patchiness, and diversity in streams. *Journal of North American Benthological Society,* **19,** 573–592.

Lake, P.S. (2003) Ecological effects of perturbation by drought in flowing waters. *Freshwater Biology,* **48,** 1161-1172.

Lichatowich, J. (1999) *Salmon without rivers : a history of the Pacific salmon crisis.* Island Press, Washington, DC.

Lisle, T.E., and H.M. Kelsey (1982) Effects of large roughness elements on the thalweg course and pool spacing. L.B. Leopold (ed.) *American geomorphological field group field trip guidebook.* Berkeley.

Ludington, S., B.C. Moring, R.J. Miller, K.S. Flynn, J.G. Evans, and P.A. Stone (2006) Preliminary integrated geologic map databases for the United States. United States Geological Survey, Reston, VA.

Lytle, D.A., and N.L. Poff (2004) Adaptation to natural flow regimes. *Trends in Ecology and Evolution,* **19,** 94-100.

Madej, M.A. (2001) Erosion and sediment delivery following removal of forest roads. *Earth Surface Processes and Landforms,* **26,** 175–190

Maloney, K.O., J.W. Feminella, R.M. Mitchell, and S.A. Miller (2008) Landuse legacies and small streams: Identifying relationships between historical land use and contemporary stream conditions. *Journal of the North American Benthological Society,* **27,** 280-294.

Matthews, K.R., N.H. Berg, and D.L. Azuma (1994) Cool water formation and trout habitat use in a deep pool in the Sierra Nevada, California. *Transactions of the American Fisheries Society,* **123,** 549-564.

May, C.L., and R.L. Gresswell (2003) Processes and rates of sediment and wood accumulation in headwater streams of the Oregon Coast Range, USA. *Earth Surface Processes and Landforms,* **28,** 409-424.

May, C.L., and D.C. Lee (2004) The relationships among in-channel sediment storage, pool depth, and summer survival of juvenile salmonids in Oregon Coast Range streams. *North American Journal of Fisheries Management,* **24,** 761-774.

McClenachan, L. (2009) Documenting loss of large trophy fish from the Florida Keys with historical photographs. *Conservation Biology,* **23,** 636-643.

McIntosh, B.A., J.R. Sedell, R.F. Thurow, S.E. Clarke, and G.L. Chandler (2000) Historical changes in pool habitats in the Columbia River basin. *Ecological Applications,* **10,** 1478-1496.

Minshall, G.W., K.W. Cummins, R.C. Petersen, C.E. Cushing, D.A. Bruns, J.R. Sedell, and R.L. Vannote (1985) Developments in stream ecosystem theory. *Canadian Journal of Fisheries and Aquatic Sciences,* **42,** 1045-1055.

Montgomery, D.R. (2008) Geology: Dreams of natural streams. *Science,* **319,** 291-292.

Montgomery, D.R., E.M. Beamer, G.R. Pess, and T.P. Quinn (1999) Channel type and salmonid spawning distribution and abundance. *Canadian Journal of Fisheries and Aquatic Sciences,* **56,** 377-387.

Moore, K., K. Jones, J. Dambacher, C. Stein, et al. (2008) Methods for stream habitat surveys Aquatic Inventories Project. Oregon Department of Fish and Wildlife, Aquatic Inventories Project, Conservation and Recovery Program, Corvallis, OR.

Moser, S.A., and J.E. Farnell (1981) Yamhill River navigability study. Oregon Division of State Lands, Salem, OR.

Napolitano, M.B. (1998) Persistence of historical logging impacts on channel form in mainstem North Fork Caspar Creek. Pages 97-101 in R.R Ziemer (ed.) *Proceedings of the conference on coastal watersheds: The Caspar Creek story, 6 May 1998; Ukiah, California. General Technical Report PSW-GTR-168*. U.S. Forest Service, Pacific Southwest Research Station, Albany, CA.

Nehlsen, W. (1997) Prioritizing watersheds in Oregon for salmon restoration. *Restoration Ecology,* **5,** 25-33.

Northcote, T.G., and G.F. Hartman (2004) *Fishes and Forestry.* Blackwell Science, Ames, IA.

Ohmann, J.L., M.J. Gregory, and T.A. Spies (2007) Influence of environment, disturbance and ownership on forest vegetation of coastal Oregon. *Ecological Applications,* **17,** 18-33.

Oregon Hydrological Framework (2005) Oregon Water Courses. R. Harmon (ed.). Oregon Water Resources Department, Salem, OR.

Oregon Plan (1997) The Oregon Plan for Salmon and Watersheds. Governor's Natural Resources Office, State of Oregon, Salem, OR.

Pearsons, T.N., H.W. Li, and G.A. Lamberti (1992) Influence of habitat complexity on resistance to flooding and resilience of stream fish assemblages. *Transactions of the American Fisheries Society*, **121,** 427-436

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg (1997) The natural flow regime. *BioScience,* **47,** 769-784.

Poissant, J., T.W. Knight, and M.M. Ferguson (2005) Nonequilibrium conditions following landscape rearrangement: The relative contribution of past and current hydrological landscapes on the genetic structure of a stream-dwelling fish. *Molecular Ecology,* **14,** 1321-1331.

Poole, G.C., and C.H. Berman (2001) An ecological perspective on instream temperature: natural heat dynamics and mechanisms of human-caused thermal degradation. *Environmental Management*, **27**: 787–802.

Reeves, G.H., F.H. Everest, and T.E. Nickelson (1989) Identification of physical habitats limiting the production of coho salmon in western Oregon and Washington. USDA, United States Forest Service General Technical Report PNW-GTR-245, Pacific Northwest Research StationCorvallis, OR.

Reice, S.R. (1980) The role of substratum in benthic macroinvertebrate microdistribution and litter decomposition in a woodland stream. *Ecology,* **61,** 580-590.

Reice, S.R., R.C. Wissmar, and R.J. Naiman (1990) Disturbance regimes, resilience, and recovery of animal communities and habitats in lotic ecosystems. *Environmental Management,* **14,** 647-659.

Resh, V.H., A.V. Brown, A.P. Covich, M.E. Gurtz, H.W. Li, G.W. Minshall, S.R. Reice, A.L. Sheldon, B.J. Wallace, and R.C. Wissmar (1988) The role of disturbance in stream ecology. *Journal of the North American Benthological Society,* **4,** 433-455.

Reynolds, L., A.T. Herlihy, P.R. Kaufmann, S.V. Gregory, and R.M. Hughes (2003) Electrofishing effort requirements for assessing species richness and biotic integrity in western Oregon streams. *North American Journal of Fisheries Management,* **23,** 450–461.

Rhemtulla, J., and D.J. Mladenoff (2007) Why history matters in landscape ecology. *Landscape Ecology,* **22,** 1-3.

Rhoads, B.L. (1987) Stream power terminology. *Professional Geographer,* **39,** 89-195.

Rice, R., F.B. Tilley, and P.A. Datzman (1979) A watershed's response to logging and roads: South Fork of Caspar Creek, California, 1967-1976. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Berkeley, CA.

Richards, C., L.B. Johnson, and G.E. Host (1996) Landscape-scale influences on stream habitats and biota. *Canadian Journal of Fisheries and Aquatic Sciences,* **53,** 295-311.

Richter, A., and S.A. Kolmes (2005) Maximum temperature limits for Chinook, coho, and chum salmon, and steelhead trout in the Pacific Northwest. *Reviews in Fisheries Science,* **13,** 23 -49.

Roni, P., T. Bennett, S. Morley, G.R. Pess, K. Hanson, D. Van Slyke, and P. Olmstead (2006) Rehabilitation of bedrock stream channels: the effects of boulder weir placement on aquatic habitat and biota. Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA.

Russell, E.W.B. (1978) *Vegetational change in northern New Jersey since 1500 A.D.: A palynological, vegetational and historical synthesis*. PhD Thesis, Rutgers University, New Brunswick, NJ.

Rykiel, E.J. (1985) Towards a definition of ecological disturbance. *Austral Ecology,* **10,** 361-365.

Sable, K.A., and E. Wohl (2006) The relationship of lithology and watershed characteristics to fine sediment deposition in streams of the Oregon Coast Range. *Environmental Management,* **37,** 659-670.

Sandercock, F.K. (1991) Life history of coho salmon. Pages 395-445 in: C. Groot and L. Margolis (eds.) *Pacific salmon life histories.* University of British Columbia Press, Vancouver, BC.

SAS (2003) Statistical Analysis Software Institute, Cary NC.

Sedell, J.R., and S. Duval (1985) Influence of forest and rangeland management on anadromous fish habitat in western North America: Water transportation and storage of logs. USDA United States Forest Service General Technical Report GTR-PNW-186, Pacific Northwest Research Station, Portland, OR. 68 p.

Sedell, J.R., and J.L. Froggatt (1984) Importance of streamside forests to large rivers: the isolation of the Willamette River, Oregon, USA, from its floodplain by snagging and streamside forest removal. *Proceedings of the International Association of Theoretical and Applied Limnology,* **22,**1824-34

Sedell, J.R., and K.J. Luchessa (1981) Using the historical record as an aid to salmonid habitat enhancement. Pages 210-223 in: N.B. Armantrout (ed.) *Acquisition and utilization of aquatic habitat inventory information : Proceedings of a symposium*. Western Division, American Fisheries Society, Bethesda, MD.

Sedell, J.R., F.H. Everest, and F.J. Swanson (1981) Fish habitat and streamside management: Past and present. Pages 244-255 in: *Proceedings of the Society of American Foresters Convention*. Annual Meeting, Bethesda, MD.

Sharma, R., and R. Hilborn (2001) Empirical relationships between watershed characteristics and coho salmon (*Oncorhynchus kisutch*) smolt abundance in 14 western Washington streams. *Canadian Journal of Fisheries and Aquatic Sciences,* **58,** 1453-1463.

Solazzi, M., T.E. Nickelson, S.L. Johnson, and J.D. Rodgers (2000) Effects of increasing winter rearing habitat on abundance of salmonids in two coastal Oregon streams. *Canadian Journal of Fisheries and Aquatic Sciences,* **57,** 906–914

Stack, W.R. (1988) *Factors influencing pool morphology in Oregon coastal streams*. Thesis, Oregon State University, Corvallis, OR.

Stanley, E.H., S.M. Powers, and N.R. Lotti (2010) The evolving legacy of disturbance in stream ecology: Concepts, contributions, and coming challenges. *Journal of the North American Benthological Society,* **29,** 67–83.

State of Oregon (1924) Testimony Nehalem Driving and Boom Company. *Public Utilities Commission*. State of Oregon, Salem Archives Building PUC 5/9/2/5 Box 3 LF-25, Salem, OR.

Swales, S., R.B. Lauzier, and C.D. Levings (1986) Winter habitat preferences of juvenile salmonids in two interior rivers in British Columbia. *Canadian Journal of Zoology,* **64,** 1506–1514.

Swanson, F.J., G.W. Lienkaemper, and J.R. Sedell (1976) History, physical effects, and management implications of large organic debris in western Oregon streams. (USDA United States Forest Service General Technical Report PNW-GTR-56, Pacific Northwest Forest and Range Experiment Station Portland, OR.

Swetnam, T.W., C.D. Allen, and J.L. Betancourt (1999) Applied historical ecology: Using the past to manage for the future. *Ecological Applications,* **9,** 1189-1206.

Taylor, J.E.I. (1999) Burning the candle at both ends: Historicizing overfishing in Oregon's nineteenth-century salmon fisheries. *Environmental History,* **4(1),** 54-79.

Torgersen, C.E., D.M. Price, H.W. Li, and B.A. McIntosh (1999) Multiscale thermal refugia and stream habitat associations of chinook salmon in northeastern Oregon. *Ecological Applications,* **9,** 301–319.

Tornlund, E., and L.Ostlund (2002) Floating timber in northern Sweden: The construction of floatways and transformation of rivers *Environment and History,* **8,** 85-106.

Tschaplinski, P.J., and G.F. Hartman (1983) Winter distribution of juvenile coho salmon (*Oncorhynchus kisutch*) before and after logging in Carnation Creek, British Columbia, and some implications for overwinter survival. *Canadian Journal of Fisheries and Aquatic Sciences,* **40,** 452–461.

van Andel, J., and J. Aronson (2006) *Restoration ecology: the new frontier.* Blackwell, Oxford, UK.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing (1980) The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences*, **37**.

Walker, G.W., and N.S. McLeod (1991) Geological map of Oregon. United States Geological Survey, Washington D.C.

Walter, R.C., and D. Merrits (2008) Natural streams and the legacy of water-powered mills. *Science,* **319,** 299-304.

Wendler, H.O., and G. Deschamps (1955) Logging dams on coastal Washington streams. Washington State Department of Forestry, Olympia, WA.

Wenger, S.J., J.T. Peterson, M.C. Freeman, B.J. Freeman, and D.D. Homans (2008) Stream fish occurrence in response to impervious cover, historic land use, and hydrogeomorphic factors. *Canadian Journal of Fisheries and Aquatic Sciences,* **65,** 1250-1264.

Wimberly, M.C., T.A. Spies, C.J. Long, and C. Whitlock (2000) Simulating historical variability in the amount of old forests in the Oregon Coast Range. *Conservation Biology,* **14,** 167-180.

Wing, M.G., and A. Skaugset (2002) Relationships of channel characteristics, land ownership, and land use patterns to large woody debris in western Oregon streams. *Canadian Journal of Fisheries and Aquatic Sciences,* **59,** 796-807.

APPENDIX A

Transcript of Splash Dam Meeting with Jake Flitcroft
June 30th 2009

RM: Today is June 30th 2009, my name is Becky and I am here with Jake Flitcroft…
JF: Right.
RM: So Jake explained that he grew up in the Glenn Creek Area.
JF: Right Glenn Creek, there. (*Looking at a map of the Glenn Creek, Millicoma and S. Fork Coos River Basin)*…There was one dam on the East Fork Millicoma above Glenn Creek that I don't know too much about *(This would have been King Dam or Grove Dam)*. There was a small dam right on Glenn Creek just above the forks *(of the Glenn & E.F. Millicoma).* The lower dam here *(Lockheart Dam)* was a regular splash dam. The little dam in Glenn Creek area, it was just a water retainer, it didn't run any logs. It had a raised gate, that they could raise up and down, but they didn't run any logs through that.

RM: So how did they know when to release the water? Did they coordinate with other dams?
JF: Actually, they would coordinate but when they turned it loose, but before the water hit, they'd start getting this one ready to dump. If it got too full, it would overtop the dam and you couldn't open it. The water had to drop down. To get any logs in the dam or above the dam to get through. You had drop the water down so that it would go under without tearing up the upper dam apart. This dam, the one below *(Lockheart #43),* it was an ordinary that you tripped. The boards were 6'x8', stacked up and you would trip them on the top of the dam. Like the picture on the cover of Dow Beckham's book. You would lift up the board and it would fly and it would have a piece of cable attached to it so it wouldn't go on down the river. And when you closed it, you would shove it and drop it down a slot.

RM: So was that easy to lift it?
JF: Nooo! *(laughing*) When you had a full head of water, sometimes if you tripped one, it'd make a run, and maybe half the dam would open. And then you would go get the other boards, and sometimes you wouldn't, it would take a lot of pressure.

RM: Kind of like the picture on the front of Dow Beckham's book.
JF: Right. Yeah you see here, these boards are 6'x8's, and you've got a big pry bar here. You see him standing back here. You can see a sput end that goes into a notch. He's got a piece. Then you can come down and raise it up. Sometimes it'd take two of you. You can see there's two of them. And that would twist like this, and it would

raise you right off your feet. But this was a full head of water, you can tell that by the cross. But you had to have that water down, otherwise you couldn't get out on the dam. If you look at the upper dam *(Tioga Dam on S.F. Coos)* …. When you tripped those dams, when it had a full head of water, that whole dam just shaked!

RM: Yeah?
JF: That would make you a little bit nervous! And the upper dam *(Tioga)* he's *(Dow Beckham)* got a picture of it in here somewhere. When they built that upper dam, there were no roads up the river. There was a logging camp near Hatcher Creek and that's where they stayed.

JF:(*Cold decking photos*) they would just put the logs on the ground alongside the river. If they put it in the river, it would just plug it up. They spread the logs out so when they did splash, they'd come down and take 'em. The splash would only take them so far and it would just string logs out from the dam, clear to the tidewater. The biggest tool you had with the splash dam was the dynamite. Because when they first started doing *(splashing)* all of the rivers, to make them so they would all splash, you would have huge boulders and what-not riding down and you'd have to blow those all out. And then the logs would jam up and you'd have to blow those up. So you'd take a case of dynamite dump it down and blow it up so it would go.

In the winter when you got a real good freshet, you would splash every day, because there was so much water coming down. OK, but you had to get the water down low enough so that you could close it *(the dam)*. Because you are underneath, you've got to shove that board up.

RM: So how long did it take for the dam to empty out all the water?
JF: aw…anywhere from a real hard freshet and other water coming down, it would take maybe a half a day, to get it down low enough so that you could close it again. When you closed it, you only had until over night until you could open it again. When it *(river water)* got down and you had a real running river, you'd get down below it, you'd have logs piled up mile, two miles down to the tidewater.

(Looking through Dow Beckham's book) Here's the upper dam…

RM: what page is that on? 103.

JF: You can see the water is clear full and it is going over top. You could open this dam without getting out here. See it had these two big doors. The doors would open this way.

RM: Kind of slide out.
JF: Two on each side, and a little opening so you could let some of the water out. In order to slow it down, because once you've started…when that *(the dam)* is really up and full, you couldn't hardly… you got a yarder, well, I call it a yarder, but it is a winch sitting over here, and you could open these doors, with the donkey. And they'd slide, but there was a huge amount of pressure, you didn't have rollers, or wheels, they just slid!

RM: Ok, So the donkey slid open the gates and the little side door would release the pressure.

JF: That's how you'd open it. And then we had logs on the upper end there, and the yarder had a small drum on it. That's what we call a 'strong liner.' Haywire and a boom. There was a boom up here that channeled the logs into the opening. Water wasn't really flowing until it started through the dam, it didn't have that much power. You'd get up there, and put a loop around some of the logs, and force them, pull them out, and you'd run up and get some more as it was coming down. Until you got to a point where you didn't have any logs hanging up on the spillway itself, otherwise you couldn't close the dam.
RM: Yeah…
JF: So you could stop it. The same on the other dams. Once you got it loose, you could pull the logs through.

RM: And how far down did the power of the water move the logs downstream?
JF: It would take more than one splash. See your logs don't travel as fast as the water, not all the time. And it would just leave logs hanging up as the water spread out. …..then it had enough water to keep it going.

RM: Ok, so not every time you opened, released the dam, it didn't always have logs in it? Some splashes just had water.
JF: Water, right. You'd have logs strung out from here to clear to tidewater. There would be logs up on banks, and sitting on rocks. And then when the water came up again, they'd go down. And you'd keep filling behind with logs and send them down. I can say at tidewater, sometimes you would have as high as two miles of backed up

logs, and then you'd have to take a donkey or a yarder up the side of the river, and pull out those logs. And break those up because sometimes they'd be 3 or 4 deep, stacked.

RM: How big were the logs that typically went down?
JF: Well, this was all good timber, as you can see here. 2 ft in diameter as far up as 8 ft in diameter. This is all old growth timber. It wasn't third growth! The third growth/small timber, we didn't even bother with. We just liked the hemlock. They'd log the hemlock, but leave the butts in the woods, because they would sink.

But the funny thing is that you would have a good roar when you were standing on the dam, but if you went down river, you wouldn't even know it was coming.

RM: Really? Wow!

JF: Like I said, she (daughter Becky) said something about letting people know about/notify that splashes took place? They didn't let anyone know. They didn't pay any attention to that. The only fish ladder that I know of, was in the lower dam, wasn't any on this one *(Tioga)*.

RM: Is that the one you operated, the Lower dam?
JF: When I was working it I operated this one *(Tioga)* and the lower dam. The upper dam, the Tioga dam.

RM: OK. The ones on the S. F. Coos.
JF: We called them the 'upper dam' and the 'lower dam.' You can see the distance. So when the water got about in here, you would let the lower dam go.

RM: So did you just time it so that you knew when the logs would be about at this point?
JF: Yeah, you had to get this thing open before the logs got there, because then you couldn't open the dam. That's the one where you had to get out on top! *(Tioga)*

RM: Becky said that you were on this picture *(the cover of Dow Beckhams book)*?
JF: No…no. This is Sammy Hightower, Dow Beckham, Bob Arnold, and the guy with the funny hat back there that's George… There isn't a picture of me in this one. Beckham went to a lot of trouble to put together this book.

RM: Yeah, it's a great book! So how many board feet to you estimate went down with each splash?
JF: Each one?
RM: How many logs?
JF: Well….it would depend on if it were in a freshet stage or the other. Anywhere from 200,000 to 2 million. It varied.

RM: Did they have contracts, so it would just depend on what was cut at the time?
JF: No. They did have brands, but we never did sort any logs. They were all one outfit's logs. Erwin and Lyons and then Menasha. Weyerhaeuser never had anything to do with them. Weyerhaeuser 's got a lot of the land up there. They're the ones that really cleaned it out. When I was there, that was still all old growth timber.

RM: When did the old growth timber get cut out?
JF: I don't know, Weyerhaeuser finished it up, but it hasn't been that many years ago. Some left, but not all that much.

RM: Did you ever think about salmon migration, did you ever not splash because of salmon running up the creek?
JF: We didn't pay any attention to that then. No. Not a bit. But, what's amazing, above Glenn Creek when we were up there you could see the salmon there. The bottom would just be solid, full of them. Once the dam was down, why then the salmon could go on up.
RM: That was just the little flush dam on Glenn Creek.
JF: Yes, but you would go up on in here *(pointed on map)* and it was just solid fish.

RM: I was reading up on the N. Fork Nehalem River, they had some splash dams up there, and some people described the splash dam freshets, and they described how the water went up onto the farm land and the logs and fish got stranded up on the farm fields. Did you ever come across anything like this?
JF: We would have water that would go up on the farmer's field near Bessie Creek, but above there, was no farm fields, but we would have logs everywhere. But there *(Nehalem)*, they probably didn't have catch booms, and we had catch booms. One of the catch booms was at Allegany and the other was at Dellwood. Dellwood was the furthest you could go up the tidewater. Allegany to the west fork was a part of the tide water. From the tidewater down, you rafted your logs and took them down by boat.

RM: Was the water really muddy when you opened the dams?

JF: Yeah… oh yeah. If you look in those rivers now, you don't see much gravel, it's all gone. It's all just bedrock.

RM: So do you think a lot of the gravel was sluiced out from the splash dams?
JF: Yeah, it's all been sluiced out.

RM: So the sites at the lower and upper dams, they didn't have roads?
JF: When they built the dam, they didn't have roads, no. The roads go up there now. And the roads were up there later when we splashed the dams.

RM: So did they cut the trees and truck them to this point *(splash dam)* and then dump them into the river, or how did the logs get to the splash dams?
JF: They just used what was handy, yarder. They didn't have any logging trucks up there. There was a little log camp here, across from Hatcher creek. I (?) stayed there and worked at Tioga. XX would come over the hill from Middle Creek and Cherry Creek. I believe it was Cherry Creek, went over the mountain and down to the Tioga basin.

RM: Are there any other interesting things that we haven't talked about?
JF: Well…let's see here… some questions here. 'How high was the surge of water?' Well I don't know, it had to be, well in the middle about 6 or 7 feet. You know, you had logs that were 8 ft-10 ft through.
It *(the water)* would graduate, you know, as it went down. It would sploosh out, and then it would level out the further down you went.

RM: How did they determine where to build these dams?
JF: Well a lot of times, they had a good solid piece of bedrock, because you had to drill down in that bedrock to put in steel bars, cable to tie your logs to. Just where would be a natural kind of spot to put it.

RM: OK, so maybe where the hillslopes came together.
JF: Yeah, right. Yeah if you notice here *(photograph)* there's a bank on the side. (*Laughter*) built all around it.

RM: So when you worked on the splash dams were there any technologies that changed over time? Did it change, or did it stay pretty much the same as far as operation?

JF: No once this is set up, well you'd lose that or change that. But actually those dams didn't last too many years, you know they had a tendency to wash out. They weren't the safest thing.

RM:Yeah!
JF: (*Laughter*)
RM: Pretty treacherous to walk on them? You'd have to know what you are doing to go out on them.
JF: Well one time this dam here *(Tioga)* these are 4x12 planks were standing on, and the water would go over them and wash them out every once in a while. There was one time I had an old portable generator that we would take out there. So I was pulling that generator out there one time, and the dam was pretty well dammed, but anyway, I step through one them board and I went down! Next thing I knew I was looking straight up at the sky!

RM: Wow! That's scary!
JF: Yeah, it was interesting….

RM: So how did you…did it appeal to you to do that type of work? Did you just learn on the job?
JF: It was this guy right here, old Dow, he was, actually he was a school teacher. He was running the dams, and when I got out of high school, I started working the river crew. Most of the work was down in Tidewater. We run these dams, then rebuild them.

RM: So splashing was only part of your job?
JF: Yeah, we'd open those dams then we'd come down. In the summer time you'd seldom open them, there wasn't enough water. … the logs that were stacked in the dam.

RM: So it wasn't something that you went up there every day to check.
JF: No. (*laughter*) A good freshet, that's what you wanted so you could move the logs. And you'd move millions of logs.

RM: So do you know if any of these dams still exist? Like remnants of the dams? I know they were washed away and burned, but are any of the pilings still…
JF: I doubt if there is anything much left of them. There could be some parts of it, like metal or something on the edge. They had to blow them up at a certain time, because

the state mandated no more dams. Blew em' up, burned them up. And that was better than 50 years ago. But I haven't been up the S. Coos River in years. I went and talked to a guy at Weyerhaeuser, and they changed the road, so you can't get up there without their permission. They said if you wanted to we could go up there. We could go up there and see if you can see those *(Tioga and Lower dam).*

RM: OK, let's go! Let's see, anything else?

JF: Some of the logs were trucked and some were cold decked to the river. We didn't coordinate/communicate, with other dams, we just ran down to the next *(lower)* dam. And there weren't any more dams above the Tioga.