United States Department of Agriculture
Forest Service

PNW
Pacific Northwest
Research Station

Science FINDINGS

INSIDE

issue one hundred ninety eight / july 2017

"Science affects the way we think together."
Lewis Thomas

Adaptation To Wildfire: A Fish Story

John Marshall

A logjam on Mission Creek in the Wenatchee National Forest. Trees killed by wildfire that are delivered to streams through debris flows or by simply falling into the river become cornerstones of complex instream habitat.

"Eventually, all things merge into one, and a river runs through it."
—Norman Maclean

Fire is a powerful force in America's forests. The Forest Service and other federal, tribal, state, and local government agencies work together to respond to tens of thousands of wildfires annually. During the 2016 fire season, 67,743 wildfires burned roughly 5,509,900 acres, according to the National Interagency Coordination Center's 2016 wildland fire summary report.

Destructive megafires (those larger than 100,000 acres) tend to grab the headlines, but fire can be a potent regenerative force as well. Recent studies by scientists with the Pacific Northwest Research Station find that fire, in some cases, may actually improve habitat for some species of native salmonids. Fire is an important source of instream wood, for example. As trees killed or weakened by fire fall into streams, they help create pools of deeper water and hiding places for fish. Landslides and debris torrents following wildfire deliver sediment to streams. Ranging from soil to boulders, these additions to streams become key habitat components. By altering upslope conditions, fire increases the complexity of instream fish habitat.

The question now posed by many natural resource managers is how to manage fire in

IN SUMMARY

In the Pacific Northwest, native salmon and trout are some of the toughest survivors on the block. Over time, these fish have evolved behavioral adaptations to natural disturbances, and they rely on these disturbances to deliver coarse sediment and wood that become complex stream habitat. Powerful disturbances such as wildfire, postfire landslides, and debris flows may be detrimental to fish populations in the short term, but over time, they enrich instream habitats, enhancing long-term fish survival and productivity.

Over the past century, dams, roads, and timber harvest practices have contributed to the decline in the amount and complexity of salmon and trout habitat in the Pacific Northwest. New research indicates that wildfire suppression adjacent to streams also may have inadvertently reduced the quality of aquatic habitat. The accumulation of forest fuels also has set the stage for higher-than-normal fire intensity, and perhaps larger fires that may cause extensive damage to local fish populations. This poses a significant problem for isolated and vulnerable fish populations such as bull trout.

Scientists with the U.S. Forest Service's Pacific Northwest Research Station and partners modeled the potential effects wildfire on spring Chinook salmon and bull trout habitat in Washington's Wenatchee River subbasin. Their findings indicate that, in some situations, wildfires or managed wildfires may be a useful management strategy for aquatic habitat restoration.

a way that reaps beneficial effects, including improvement to stream habitat for salmon and trout, while avoiding large and overly severe fire.

Rebecca Flitcroft, Gordon Reeves, and Paul Hessburg, all with the Pacific Northwest Research Station, and their colleagues set out to examine the likely response of native fish to fire in the Wenatchee River subbasin in central Washington. By drawing on the study team's expertise in fish biology, statistics, landscape and fire ecology, geography, hydrology, soil science, and silviculture, they modeled potential outcomes of predicted fire on local populations of spring Chinook salmon and bull trout. The result was a better understanding of the complex effect of wildfire on aquatic habitat.

Adaptable Survivors

Salmon are amazingly adaptable creatures, and they're programmed to work hard for their survival. One need only look at their life cycle to appreciate their determination: they hatch in inland fresh water, spend their young lives making their way to the ocean, where they feed and compete for several years before their biological clock tells them to return to their birthplace to spawn—often hundreds of miles upstream. They fight the current and each other to overcome dams, waterfalls, bears, and humans with fishing rods to reach the small section of stream where they started, and begin the life cycle anew.

Purpose of PNW Science Findings

To provide scientific information to people who make and influence decisions about managing land.

PNW Science Findings is published monthly by:

Pacific Northwest Research Station
USDA Forest Service
P.O. Box 3890
Portland, Oregon 97208

Send new subscriptions and change of address information to:

pnw_pnwpubs@fs.fed.us

Rhonda Mazza, editor; rmazza@fs.fed.us

Cheryl Jennings, layout; cjennings@fs.fed.us

Science Findings is online at: http://www.fs.fed.us/pnw/publications/scifi.shtml

To receive this publication electronically, change your delivery preference here:

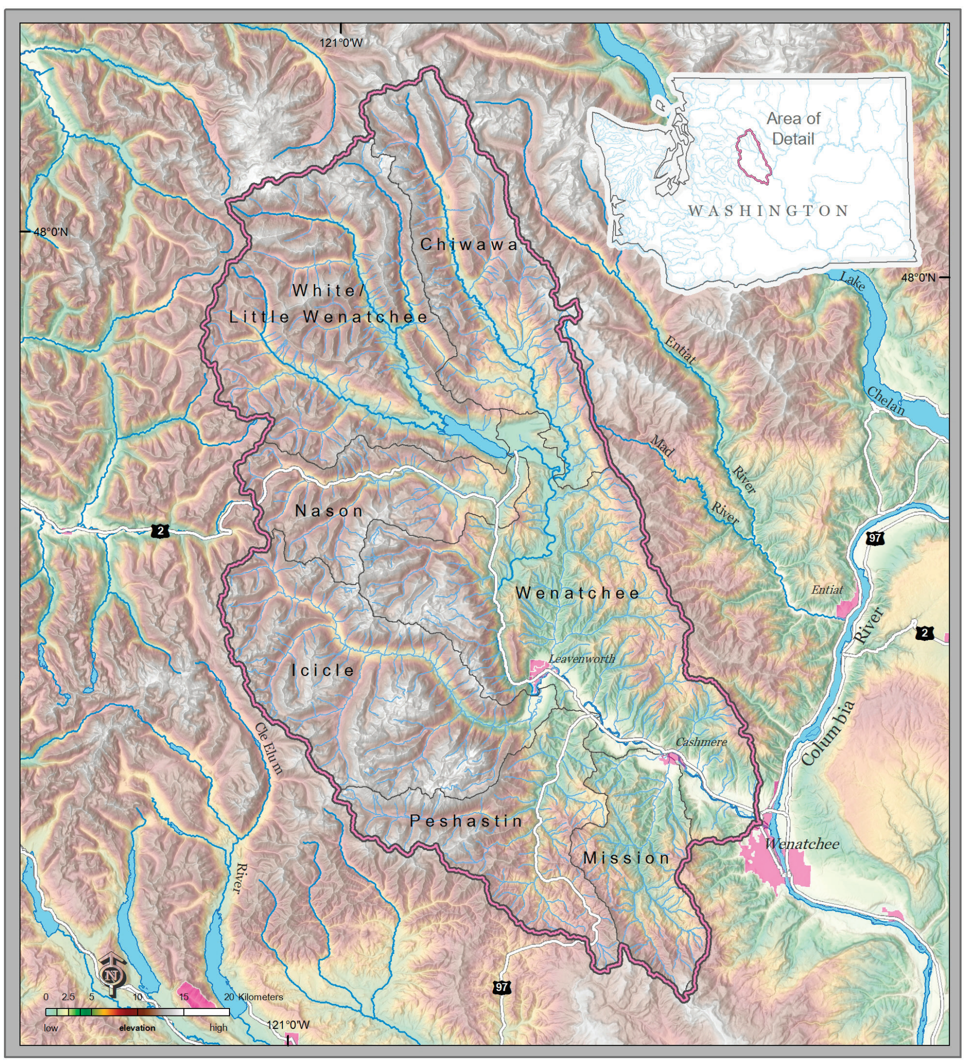
http://www.fs.fed.us/pnw/publications/subscription.shtml

United States Department of Agriculture

Forest Service

KEY FINDINGS

- Wildfire effects on aquatic ecosystems are complex and varied. Models project that wildfire can improve habitat quality for adult and overwintering juvenile spring Chinook salmon by increasing instream wood. Fire may lead to temporary increases in fine sediment in the stream, which can degrade egg and fry habitat in the short term.
- Spring Chinook salmon historically occupied areas in the Wenatchee River subbasin that would have experienced both positive and negative effects from wildfire. As the population of spring Chinook salmon has declined, so has their distribution into areas predicted to experience positive effects from fire.
- Owing to their dependence on cold-water refugia, bull trout in the Wenatchee River subbasin are already isolated in headwater streams. Wildfire that causes further habitat fragmentation through debris flows or landslides may temporarily increase that isolation.
- Climate change will reduce the availability of cold water in some locations, affecting bull trout habitat patch sizes and locations, and increasing their vulnerability to large and severe wildfires into the future.
- Disturbances such as wildfire contribute soil, sediment, wood, and coarse material to stream channels as pulses, with periods of recovery between inputs. This characteristic of the natural disturbance regime allows for the development and maintenance of complex habitats needed for salmonids.



Map of the study area in central Washington.

The current distribution of Pacific salmon (*Oncorhynchus spp.*) in the Pacific Northwest can be traced to the end of the last ice age, about 10,000 years ago. They spread themselves broadly throughout the Columbia River basin, and they flourished—until about 150 years ago when human changes to the environment made life harder than in the previous millennia. Now spring Chinook salmon (*Oncorhynchus tshawytscha*), among other salmon, are listed as endangered species in Columbia River and California tributaries, and are threatened in a range of rivers and streams throughout Oregon, Idaho, and Washington.

"The threats and distresses have been death by a thousand cuts," Flitcroft says. "Dams have been a significant impediment. Warm-water fish such as bass and walleyed pike, which were introduced for sport fishing, eat juvenile salmon and compete for habitat. We've altered and filled floodplains by building communities and farms, and we have dammed many rivers, which has slowed and warmed the water, essentially turning portions of many rivers into reservoirs."

And we've suppressed wildfire.

Flitcroft explains that wildfire has a way of shaking up an ecosystem in a way that adds complexity—something that helps with the survival not only of salmon, but other creatures as well. Given the opportunity, salmonids and other species that are adapted to disturbance will gravitate toward a more complex environment rather than a simpler one.

Roger Tabor, U.S. Fish and Wildlife Serivce

Chinook salmon (Oncorhynchus tshawytscha) *are an anadromous salmon iconic of the Pacific Northwest. Juvenile chinook (above) spend up to a year in freshwater before migrating to the ocean to grow to maturity.*

Roger Tabor, U.S. Fish and Wildlife Serivce

Bull trout (Salvelinus confluentus) *are a cold-water salmonid native to the Pacific Northwest. This species is in decline in much of its range and is often found in high elevation areas where instream habitat is still intact.*

"Pick any creature and it's going to need some level of habitat complexity," Flitcroft says.

Not only does greater complexity contribute to the food possibilities in streams, it stimulates the innate ability of salmon to thrive under new circumstances. This adaptive capacity has been a key to their survival throughout time. The human imprint on the environment today has simultaneously created more barriers than salmon have ever had to face, and has simplified that environment.

"Many of the things we've done to simplify habitats have reduced opportunities for individuals to express their natural adaptation to disturbance in complex systems," she says.

Bull trout (*Salvelinus confluentus*) are even more vulnerable to habitat degradation, according to Gordon Reeves. Whereas salmon, in their long travels, experience and can live through a range of temperatures, bull trout need consistently colder waters. They're listed as a threatened species throughout the western United States mostly because of rising water temperatures and habitat fragmentation. Timber harvests, cattle grazing—both of which expose the water to more sunlight—and the warming climate are causing bull trout to seek refuge in higher elevation streams where they can find pockets of colder water.

Their remaining strongholds occur in headwater tributaries. These colder bull trout streams are poorly connected with other cold-water streams because of the presence of roads, dams, and other barriers, so their habitat is isolated, and they have fewer places to go to find cold water.

Fire can be beneficial for bull trout, just as it can be beneficial to salmon, Reeves says, because it changes the landscape—something he calls a "disturbance event." The computer modeling work he and Flitcroft did for the Wenatchee basin looked at possible ways fish habitat could be improved with different approaches to management. They found that approaches that allowed for the possibility of disturbance events could potentially enhance habitat.

Reeves notes that disturbance events have commonly happened throughout history in all forest types. Why wouldn't native fish have become highly adapted to them?

"Look at Yellowstone," he says, referring to the forest fires in 1988 that burned more than a third of the national park. "Many postfire areas are thriving. It's like a big reset."

Wood for Salmon

The scientists chose to study the Wenatchee River basin for several reasons, including its history of supporting fish, its relative aridity compared with the forests west of the Cascades, and its susceptibility to wildfire. The area has warm, dry summers, with dry grasslands below the mixed-conifer forests, which are dominated by ponderosa pine, Douglas-fir, and grand fir. Fire suppression, timber harvest, overgrazing, and climate change during the past century have led to large accumulations of dead wood, dense forests, insect outbreaks, and disease epidemics. These conditions, combined with drought, set the stage for bigger, more severe fires than ever before.

To study the area and show possible outcomes for fish under different conditions and management scenarios, the scientists worked with Jeff Falke, Kristina McNyset, and other collaborators from Oregon State University, the Okanogan-Wenatchee National Forest, the U.S. Geological Survey, and TerrainWorks, an environmental analysis company.

For the salmon study, they set out to answer three questions: What are the potential effects of wildfire on the quality of spring Chinook habitat? Are the effects different for the different life stages of the fish? And are the wildfire effects different on streams currently used by spring Chinook, as opposed to streams they used in the past?

On that last question, Flitcroft and her colleagues point out that, historically, wild spring Chinook salmon were distributed more broadly in the Wenatchee River and its major tributaries, and returning adults had relatively clear routes for colonizing new habitats. In modern times, owing to fish passage barriers and declining habitat quality, the fish are restricted to portions of the Chiwawa, White, and Little Wenatchee Rivers, and to the Nason and Icicle Creek watersheds.

Paul Hessburg, a landscape ecologist, looked at the possible effects of wildfire in the Wenatchee subbasin by simulating them on computerized maps. He randomly dropped pixel "ignitions" on locations throughout the area, and tracked the results using a fire growth model, FLAMMAP, under different wind and weather conditions. After setting 650,000 simulated fires, he was able to predict where the fires were likely to be the most destructive, and also where they might actually help fish.

"We were particularly interested in how wood and stream temperature would affect habitats necessary for adult spring Chinook salmon to maintain themselves and spawn successfully," Flitcroft explains.

So the team developed a model to account for dead trees toppling into the stream following one of the more probable fires.

The addition of wood to the stream helps create beneficial fish habitats, Flitcroft explains. When a fire-killed tree falls into a stream, it slows the water, allowing gravel and heavier sediments to build up behind the tree. Often, water spilling over the trees at high flows will excavate deep pools that later have the potential to store cold water, even at low flows. These are important habitats for fish needing cold water. Where heavier sediments and gravels build up behind trees, this kind of habitat is excellent for rearing juvenile fish. It provides a refuge that keeps them from being washed downstream, and the fallen trees provide cover that protects them from birds, raccoons, and other predators.

The pools that are created are not so good for spawning habitat because egg survival partially depends on steady water flow, which clears sediment from spawning gravels. In fact, the model that projected the delivery of fine sediment to streams after fires showed that the quality of egg and fry habitat in the Wenatchee subbasin would initially decline as a result of fire. The scientists interpret that as more of a short-term problem, whereas the longer-term prospect for salmon habitat is improved by moderate fire severity.

Another model looked at predicted changes in water temperature which, understandably, can rise during a fire, but can also subsequently rise in response to the decline in shade-giving, streamside vegetation.

In analyzing all the modeled scenarios, the scientists found that wildfire may have a net positive effect on spring Chinook salmon habitat by increasing habitat diversity. Moreover, they found that wildfire had an overall positive effect on spring Chinook in their current distribution area, while the effect of fire on salmon in the historical distribution was mixed.

The habitat changes created by fire can also allow the salmon to express more of their inherent adaptation to dynamic conditions, Flitcroft explains, and that will be important as the Earth's climate continues to warm.


John Marshall


John Marshall

Tarpiscan Creek in eastern Washington, shortly after a fire (top) and 2 years later. Riparian vegetation can recover quickly after fire.

Seeking Cold Water

Average annual air temperatures in the Pacific Northwest have risen about 2 °F over the past 100 years, and are likely to go up another 3.5 °F over the next six decades. This will lead to changes in the region's water cycle as more precipitation falls as rain rather than snow; increase the length of fire seasons by more than 80 days; and increase the frequency, severity, and size of wildfires. Together, these changes will all contribute to increasing stream temperatures.

That's bad news for bull trout, especially because lower stream flows resulting from those factors will likely reduce the number of connected streams, leaving the fish with fewer options to seek and find colder water.

But the scientists found that wildfire and different management techniques could potentially mitigate some elements of the problem, and that could include allowing more moderate-severity wildfires.

Allowing more wildfires doesn't mean just letting nature take its course, however. In fact, the isolated places where bull trout have found cold-water refugia are also areas where wildfire intensity is predicted to be dangerously high. By comparison, spring Chinook occupy lower, larger river habitats that tend to be highly connected and have lower predicted wildfire intensity. The scientists' wildfire modeling showed that the best option for bull trout is to prevent big, severe fires that drastically reduce suitable habitat and could lead to their extinction. This points to the role that fuel management and managed wildfires can play in bull trout conservation planning. Other local actions such as barrier removal would also help reduce the bull trout's vulnerability to climate change.

Taken together, the two studies offer support for setting holistic goals for fire management, perhaps leading to less fire suppression and more active intentional burning under moderately benign weather conditions.

Hessburg and several colleagues are beginning work on an aquatic landscape evaluation tool for the Wenatchee and other watersheds of the eastern Cascade Range. It is meant to facilitate the analysis of map-based information on locations of cold-water refugia, fish passage barriers, road-constrained flood plains, key sediment sources, existing fish strongholds, and reaches with high intrinsic habitat potential. This would help planners find ways through fire management and other aquatic restoration efforts to make fish habitats better connected and more resilient to the effects of future fires and climate warming.

"We're really trying hard to move the needle on how we view fire," Hessburg says. "Since 1935, the focus has been putting out fires. Now we're in a period of transition. My sense is that people are still trying to get their heads around this new way of thinking."

Reeves agrees. "These landscapes and environments are very dynamic, but regulatory and management agencies often take a more static view, thinking these systems are very homogeneous. Disturbance events such as landslides actually enhance fish habitat; this is a shocker to many people."

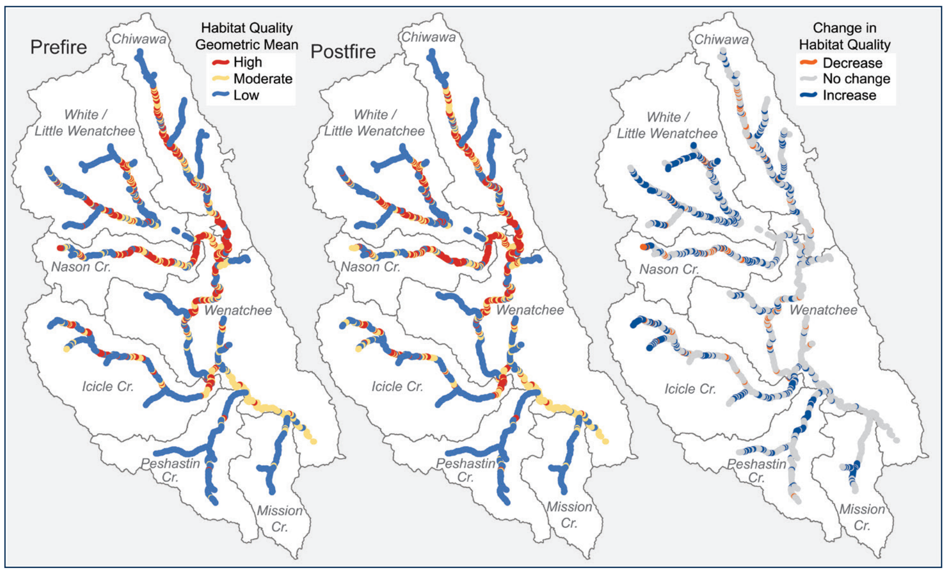
Reeves says it's important to acknowledge that disturbances such as wildfires are critical to maintaining natural systems. "We should recognize there are ecological consequences to different management techniques, including fire prevention. When we make a decision to stop a fire, that's a social decision, but it often has significant ecological consequences," he says.

The scientists' work, published in 2015 and 2016, has caught the eye of a variety of researchers and managers looking at how to adjust their management techniques. The Chinook salmon study was featured in the Wenatchee World newspaper, which led local land and aquatic managers to contact the scientists for more information. Other national forests have asked for similar modeling work on their watersheds to better inform their fire management and habitat restoration work.

The findings bolster an emerging body of research about the adaptations fish have made to fire, including data showing that steelhead populations demonstrate surprising physical changes after intense wildfire, including accelerated growth and spawning in young fish. "We're getting responses from folks who suspected that fire was important, but who didn't have enough background or information to implement management changes until our studies came out," Flitcroft says.

LAND MANAGEMENT IMPLICATIONS

- Forest management activities, such as enhancing river network connectivity through fish passage barrier removal and reducing predicted fire intensity and sizes, may increase the resilience of bull trout in the face of disturbances such as climate change and wildfire.
- Natural disturbances, along with sound riparian management and road management practices that allow natural flood plain functioning, are important in maintaining healthy change in aquatic habitats. Connected, complex aquatic habitats benefit from ecosystem management practices that are analogous to the spatial extent of wildfires and bridge human-imposed divides such as land ownership boundaries.
- Fire planning that includes aquatic issues such as habitat quality, stream network connectivity, and fish population resilience offers resource managers the opportunity to broaden fire management goals and activities to include potential positive effects on aquatic habitats.



Flitcroft et al. 2016

Overall habitat quality modeled for spring Chinook salmon throughout the Wenatchee River watershed under pre- and postfire conditions. The map on the far right shows how habitat quality will change overall, indicating that much of the area stays the same, while some areas will have increases or decreases in habitat quality.

Writer's Profile

John Kirkland has been writing about science, higher education, and business for more than 20 years. He lives in Portland, Oregon.

"I salute the gallantry and uncompromising standards of wild trout, and their tastes in landscapes."

—John Madson

For Further Reading

Falke, J.; Flitcroft, R.; Dunham, J., et al. 2015. Climate change and vulnerability of bull trout (*Salvelinus confluentus*) in a fire-prone landscape. Canadian Journal of Fisheries and Wildlife. 72(2): 304–318. https://www.treesearch.fs.fed.us/pubs/49619.

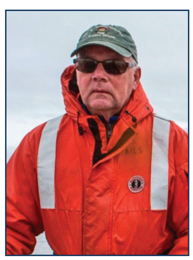
Flitcroft, R.L.; Falke, J.A.; Reeves, G.H., et al. E. 2016. Wildfire may increase habitat quality for spring Chinook salmon in the Wenatchee River subbasin, WA, USA. Forest Ecology and Management. 359: 126–140. https://www.treesearch.fs.fed.us/pubs/49900.

Science
FINDINGS

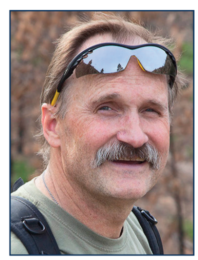
U.S. Department of Agriculture
Pacific Northwest Research Station
1220 SW Third Avenue
P.O. Box 3890
Portland, OR 97208-3890

Scientist Profiles

REBECCA FLITCROFT is a research fish biologist with the Pacific Northwest Research Station. She earned her Ph.D. in fisheries science from Oregon State University. She is particularly interested in statistical and physical representations of stream networks in analysis and monitoring to more realistically represent stream complexity and connectivity for aquatic species.



GORDIE REEVES is a research fish ecologist with the Pacific Northwest Research Station. His research focuses on the freshwater ecology of anadromous salmon and trout, conservation biology of those fish, potential impacts of climate change on aquatic ecosystems and associated biota, and aquatic aspects of landscape ecology. Reeves has a Ph.D. in fisheries sciences from Oregon State University.



PAUL HESSBURG is a research landscape ecologist with the Pacific Northwest Research Station. His research focuses on the landscape and disturbance ecology of historical, current, and future western forests; resilience mechanisms of large landscapes; decision support for environmental analysis and planning; and landscape restoration. Hessburg received his Ph.D. in botany and plant pathology from Oregon State University.

Flitcroft and Reeves can be reached at:

USDA Forest Service
Pacific Northwest Research Station
3200 SW Jefferson Way
Corvallis, OR 97331

Flitcroft: phone: (541) 750-7346
E-mail: rflitcroft@fs.fed.us

Reeves: phone: (541) 750-7314
E-mail: greeves@fs.fed.us

Hessburg can be reached at:

USDA Forest Service
Pacific Northwest Research Station
1133 N Western Ave.
Wenatchee, WA 98801

Phone: (509) 664-1722
E-mail: phessburg@fs.fed.us

Collaborators

Jeff Falke, Kristina McNyset, and Ken Vance-Borland, Oregon State University, Corvallis, OR

Lee Benda and Dan Miller, TerrainWorks, www.terrainworks.com

Jason Dunham, U.S. Geological Survey, Corvallis, OR