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PRACTICAL TOOLS

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# A simple, reliable method for long-term, in-stream data logger installation using rock-climbing hardware

S. Kathleen Fogg[1,2] | Scott J. O'Daniel[3] | Geoffrey C. Poole[1,2] | Ann Marie Reinhold[1,2] | Amanda A. Hyman[4]

[1]Department of Land Resources and Environmental Sciences, Montana State University, Bozeman, MT, USA

[2]Montana Institute on Ecosystems, Bozeman, MT, USA

[3]Confederated Tribes of the Umatilla Indian Reservation, Pendleton, OR, USA

[4]Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, TN, USA

**Correspondence**
S. Kathleen Fogg
Email: sarah.fogg@msu.montana.edu

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## Abstract

1. Long-term deployment of in-stream data loggers provides valuable information about stream conditions, particularly at times when streams are difficult to sample manually. However, in streams with high water velocities and substantial shear stress, the detachment of loggers from their installation points is a common problem. Thus, successful logger retrieval requires a durable installation method.
2. We present a method for data logger installation using rock-climbing hardware that is simple to assemble, economical and minimally invasive. The method is applicable in streams with exposed bedrock or boulders, which serve as attachment points for loggers.
3. Installed loggers are capable of withstanding extreme environmental conditions. After deploying 18 loggers for approximately 15 months in six different streams with snowmelt-dominated hydrographs, we retrieved 16 of the 18 loggers originally deployed. Where loggers were not recovered, hardware failure at installation sites was not likely the cause.
4. In addition to application in streams, the use of rock-climbing hardware may be well-suited to securing long-term data logger installations on rock substrates in any extreme environment.

KEYWORDS

climbing hardware, data logger, extreme flows, installation, long-term, river, stream, temperature logger

## 1 | INTRODUCTION

Collection of continuous, long-term environmental data has become a fundamental tool for ecologists. The ability to deploy data logging equipment under diverse and often harsh environmental conditions is critical, especially given the need to understand long-term climate trends (Hobbie, Carpenter, Grimm, Gosz, & Seastedt, 2003; Lindenmayer et al., 2012). Data logger installations that can withstand extreme flow events in rivers and streams represent an important and especially challenging case (Isaak, Horan, & Wollrab, 2013).

Common methods for in-stream data logger installation include attachment via tethers anchored to shoreline structures (Mauger, Shaftel, Trammell, Geist, & Bogan, 2015) or to the upstream streambed (Stonestrom & Constantz, 2003) and deployments attached to rods (e.g. rebar, fence posts) driven into the stream bank or streambed (Constantz, Stonestrom, Stewart, Niswonger, & Smith, 2001). Long-term rod installations can be successful in hydrogeomorphic contexts where water velocity and shear stress are consistently low (e.g. the SRTMN monitoring network in Scotland; Jackson, Malcolm, & Hannah, 2016), but these and similar methods can fail under the shear stress associated with high water velocity.

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Springtime snowmelt causes high-energy flooding in montane streams. High water velocities associated with annual peak discharge can impart extreme shear stress (Begin, 1981) and possible impacts to the logger from logs, cobbles and other large mobile sediments, which can result in detachment of the logger from its installation point. As a result, a preponderance of stream data in snowmelt-dominated hydrosystems is collected in the summer months when baseflow conditions facilitate data collection (Isaak, 2011). This leaves a gap in stream data over the remainder of the year that long-term deployments of in-stream data loggers can help to overcome.

Isaak et al. (2013) present a logger installation method using water-resistant epoxy to adhere polyvinyl chloride (PVC) housing to immobile structures in streams. The epoxy method is suitable for streams with snowmelt-dominated hydrology in the Northern Rocky Mountain Region of the United States. This method has high logger retrieval rates in long-term studies and is tamper resistant, but can be cumbersome to install and can leave permanently installed PVC housing in the stream.

In this paper, we provide a method for long-term in-stream data logger installation using rock-climbing hardware. This method is minimally invasive, expeditious, tamper resistant, and has high logger retrieval rates after long-term in-stream deployments. Similar to the epoxy method, our method utilizes logger housing made from PVC, but uses climbing hangers to affix loggers in the stream instead of epoxy. Thus, upon retrieval, no permanent hardware is left in the stream. Because our method affixes data loggers to rock, it is most applicable to streams with boulders or exposed bedrock, conditions common in montane streams with snowmelt-dominated hydrology.

## 2 | DESCRIPTION AND IMPLEMENTATION

We describe in detail the construction of PVC housing and subsequent installation of HOBO© U20 freshwater temperature and water-level loggers. We encased the data loggers in PVC housing to protect the loggers from harsh in-stream environments (e.g. scouring by sediment during high flow) and provide a surface for camouflage paint. We expect this installation technique to be easily adapted for data loggers of different sizes by adjusting the dimensions of the PVC housing.

We purchased all tools and hardware in the United States, where imperial units of measure prevail. Therefore, we describe all tool and hardware sizes using imperial units and provide metric conversions in parentheses.

### 2.1 | Logger housing construction

We used 1-1/4 inch (31.8 mm) inside diameter PVC pipe (Figure 1f) cut to 20 cm in length, which allowed the housing to extend approximately 2 cm past each end of the logger. We perforated the housing

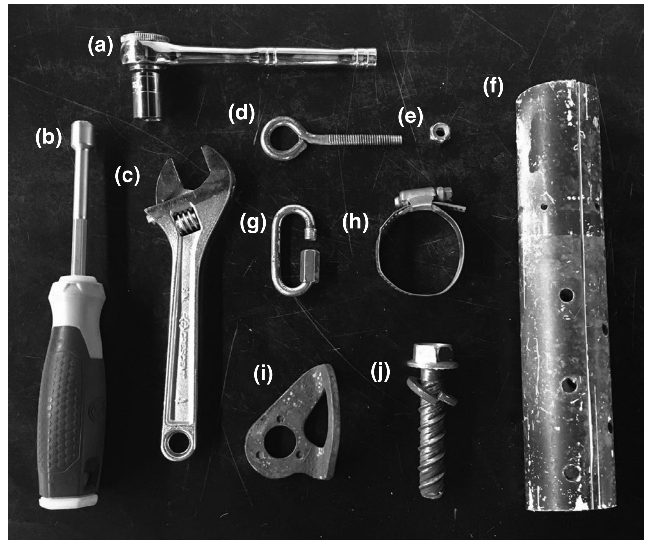


**FIGURE 1** Tools and hardware for assembling logger housing: (a) ratcheting socket driver with 7/16-inch (11.1 mm) socket, (b) 5/16-inch (7.9 mm) nut driver, (c) crescent wrench, (d) 3/16-inch × 3-inch long (4.8 mm × 76.2 mm) eye bolt, (e) 7/16-inch (11.1 mm) nylon lock nut, (f) polyvinyl chloride housing, (g) 3/16-inch (4.8 mm) stainless screw-locking quick link, (h) 2-inch (50.8 mm) diameter stainless steel hose clamp, (i) climbing hanger, (j) 1/2-inch × 3-inch (12.7 mm × 76.2 mm) concrete bolt with split lock washer

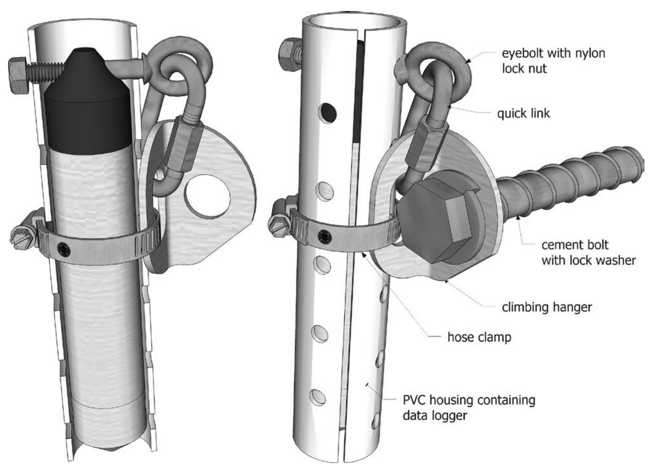


**FIGURE 2** Diagram of assembled logger housing (right) and cutaway of the polyvinyl chloride housing to show eye bolt threaded through the hole in the logger cap (left)

using a 1/4 inch (6.35 mm) diameter bit installed in a drill press. We used the same bit to drill a hole though both walls of the housing approximately 1.5 cm from one end of the housing to accept an eye bolt (Figure 1d) to secure the logger (Figure 2).

We chose 1-1/4 inch (31.8 mm) PVC so that the housing would be close-fitting to the logger, which has a diameter of 24.6 mm. Because of the tight tolerance between the logger and housing, course sand and organic material will often lodge between the logger and housing during long-term deployment, hampering removal of the logger from the housing. To address this problem, we cut an approximately 3-mm wide slit in along the length of one side of the

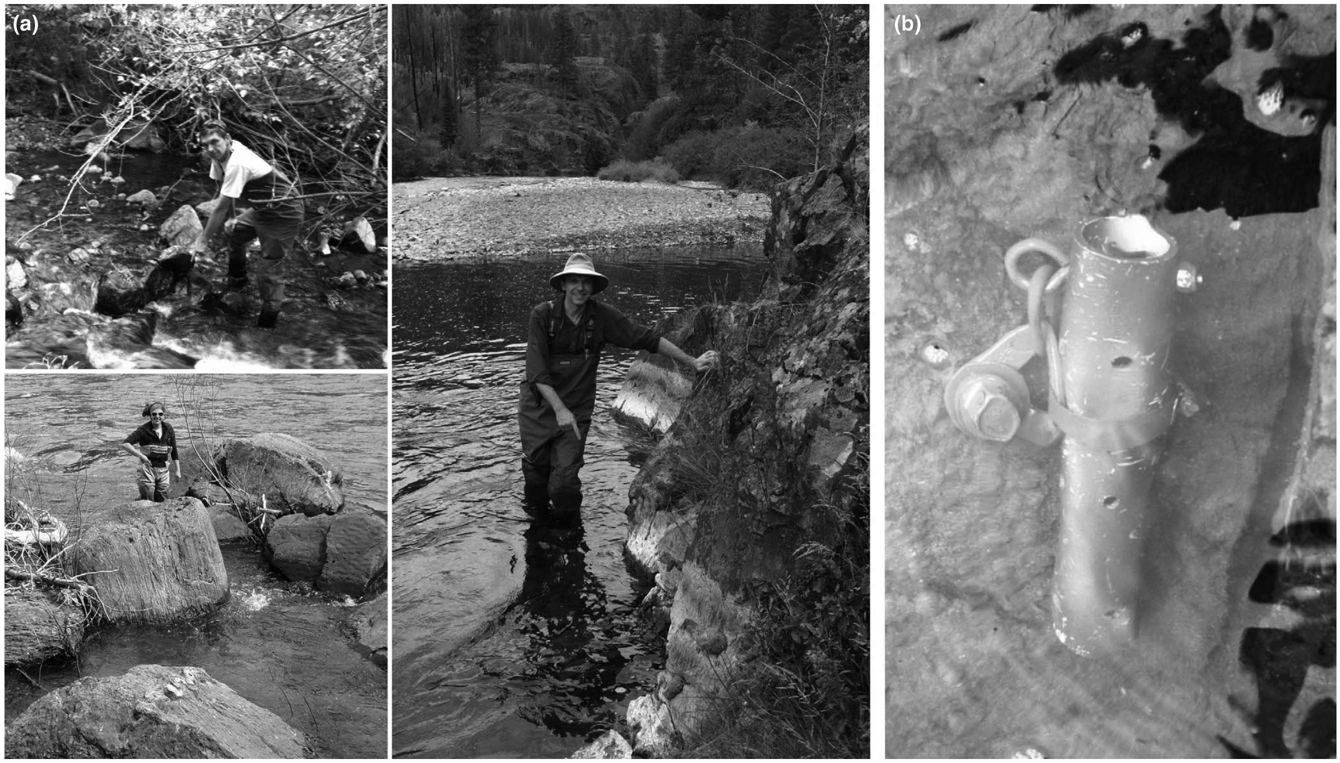

**FIGURE 3** Examples of installation sites: (a) Clockwise from top left: East Pine Creek, OR; Imnaha River, OR; Middle Fork of the Flathead River, MT. (b) Installed logger assembly in the Imnaha River, OR

housing using a table saw. The slit causes a slight decrease in the diameter of the PVC housing when compressed by the hose clamp used to secure the housing to a climbing hanger (Figure 2). Upon retrieval of the logger, the hose clamp is released and the housing expands slightly. This change in housing diameter is enough to free debris trapped between the logger and housing, allowing easy removal of the logger.

White PVC in a stream is often conspicuous and therefore increases the risk of logger vandalism or tampering. To camouflage the housing, we spray-painted the PVC housing a brown–green colour, a colour similar to streambed material (Figure 3b). We used Krylon© Fusion spray paint, which is formulated to bond to plastics including PVC.

Climbing hangers (Figure 1i) were used to anchor loggers in the stream. The hangers have two holes; a 3/8 inch (9.53 mm) round hole intended for the anchor bolt and a larger oval hole intended for a climber's carabiner. In the US market, long (39 in; 99.1 cm) rock drill bits were only available in 1/2 inch (12.7 mm) diameter, requiring use of 1/2 inch (12.7 mm) diameter anchor bolts (Figure 1j). Therefore, we expanded each hanger's bolt hole using a drill press and a 5/8 inch (15.88 mm) diameter drill bit.

## 2.2 | Assembly

The completed housing and climbing hanger assembly is shown in Figure 2. To assemble, we suspended the logger within the PVC housing using an eye bolt. The eye bolt was threaded through one side of the PVC, through the logger attachment hole and through the other side of the PVC (Figure 2). The eye bolt was secured with a nylon locking nut (Figure 1e) using a crescent wrench (Figure 1c) to hold the eye of the bolt and a socket driver (Figure 1a) to tighten the nylon lock nut.

We used a screw-locking quick link (Figure 1g) to attach the climbing hanger to the eye bolt (Figure 2), tightening the quick link with a crescent wrench. The quick link served as a fail-safe against logger loss, in the event of hose clamp (described next) failure. We laid the hanger flat along the PVC housing and threaded a hose clamp (Figure 1h) through the carabiner hole in the climbing hanger and around the PVC housing (Figure 2). We tightened the hose clamp using a nut driver (Figure 1b), which compressed the housing and closed the length-wise slit.

## 2.3 | Logger deployment

We installed 18 data loggers in six different streams in northeastern Oregon and northwestern Montana, USA. The streams were the Imnaha River (Joseph, OR), East Eagle Creek (Halfway, OR), East Pine Creek (Halfway, OR), Umatilla River (Pendleton, OR), Grande Ronde River (La Grande, OR) and Middle Fork Flathead River (Nyack, MT). The loggers were deployed for approximately 15 months, from summer 2012 to autumn 2013. Loggers were installed during baseflow, which allowed for the safest and easiest access into the stream while helping to ensure that the installations were submerged throughout the year.

### 2.3.1 | Site selection

Data loggers were installed on large boulders that were unlikely to move during high flows or installed on exposed bedrock (Figure 3a). When selecting a boulder or bedrock location, we chose locations in (or with strong hydrologic connection to) the main flow of the stream. Unless the goal of logger deployment is to record conditions of habitats out of the main flow, any installation site should be in a location where water is rapidly exchanging with the well-mixed main flow of the channel.

### 2.3.2 | Installation

We used a cordless hammer drill and a 1/2 inch (12.7 mm) diameter concrete drill bit, 39 inches (99.1 cm) in length (Figure 4d,a), to drill a hole underwater at the attachment site (note: Figure 4a shows an 18 inch (45.7 cm) long bit for display purposes only). Because our drill could not be submerged in water, the position of the logger underwater was limited by the length of the drill bit and the angle at which the hole was drilled. Generally, in deeper streams (where the drill bit length limited the depth of installation to <50% of stream depth) we installed the loggers as far under the water surface as we could. In shallow streams, we targeted 50%–60% of the stream depth for logger installations.

After deploying our loggers, we became aware of waterproof submersible hammer drills. We have not tested these tools, but an effective submersible hammer drill could provide more flexible drilling angles, simplify installation in some circumstances, and would allow use of shorter and less-expensive drill bits for installation at any depth below the stream surface. Drilled holes were approximately 8 cm deep, slightly deeper than the concrete bolt length. A piece of brightly coloured tape wrapped around the drill bit at the desired hole depth allowed us to gauge the depth of the hole as we drilled. We maintained a constant drill bit angle while drilling and, to the extent possible, we drilled perpendicular to the rock surface. To secure the logger assembly to the rock (Figure 3b), we inserted the concrete bolt with lock washer (Figure 4e) through the bolt hole in the climbing hanger. We then placed the assembly against the rock and screwed the concrete bolt into the drilled hole with a 1/2 inch (12.7 mm) socket and driver (Figure 4c).

Maintaining a constant drill angle is paramount. When a constant angle is not maintained while drilling, the diameter of the installation hole becomes too large. After installation, firm (but not excessive) torque should be applied to the concrete bolt to ensure that the bolt is secure. If the bolt continues to turn under firm torque, the diameter of the hole may be too large or the rock may be too soft to secure the logger. In such cases, the assembly should be removed and another hole drilled.

In rare cases, when drilling another hole was impractical or the rock was too soft to anchor the concrete bolt, we used a wedge expansion anchor rather than a concrete bolt. To install a wedge expansion anchor, we inserted the wedge anchor through the climbing hanger and lock washer. We then threaded a nut onto the tip of the wedge expansion anchor, leaving the nut slightly proud of the end of the anchor to protect the threads. We placed the wedge anchor into the hole in the rock and struck the nut with a hammer until the expansion wedge opened. We tightened the nut snug against the lock washer and climbing hanger using a crescent wrench. Removing the nut from the wedge expansion anchor allows the logger to be removed from the anchor, but the anchor itself is permanent and therefore should be used only when no other installation alternative is feasible. Upon decommissioning a wedge expansion anchor installation, we recommend cutting down the wedge expansion anchor as close to the rock surface as possible with a hack saw and blunting any remaining sharp edges with a hammer.

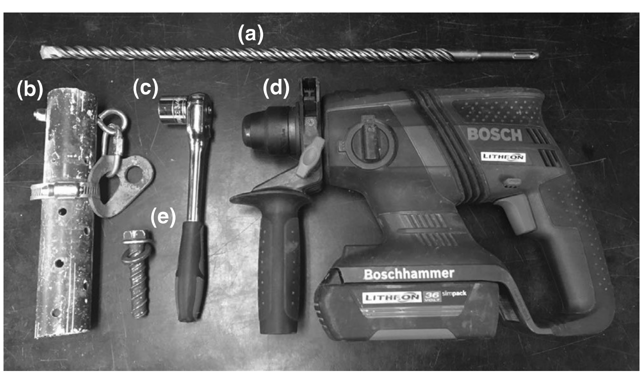


**FIGURE 4** Tools and hardware for in-stream installation: (a) 1/2-inch (12.7 mm) × 18-inch (45.7 cm) long-rotary hammer drill bit for concrete, (b) assembled logger housing, (c) ratcheting socket driver with 3/4-inch (19.1 mm) socket attached, (d) cordless rotary hammer drill, (e) 1/2-inch (12.7 mm) concrete bolt with split lock washer

## 3 | RESULTS AND DISCUSSION

Eastern Oregon and western Montana hydrology is characterized by spring snowmelt events resulting in rapid increases in stream discharge. During the approximately 15-month deployment, the loggers were subject to extreme flows events (e.g. Figure 5). Despite the extreme flows, we were able to retrieve 89% (16 out of 18) of the data loggers. One of the lost loggers (Grand Ronde River, OR) was installed at a popular fishing location. There was no indication of damage to the hole drilled in the rock; we believe the logger was stolen by removing the concrete bolt with a wrench. The other lost logger was attached to bedrock on the Umatilla River bottom, but was buried beneath sediment aggraded during annual peak flow. We assume the logger is still attached to the bedrock beneath the sediment, but have no way to verify whether the installation hardware failed. Loss of these two loggers illustrates that, regardless of the installation method used, the retrieval success is also dependent upon the choice of the in-stream attachment location. The level of human use and potential for aggradation of sediment at the installation site are two important considerations to avoid logger loss.

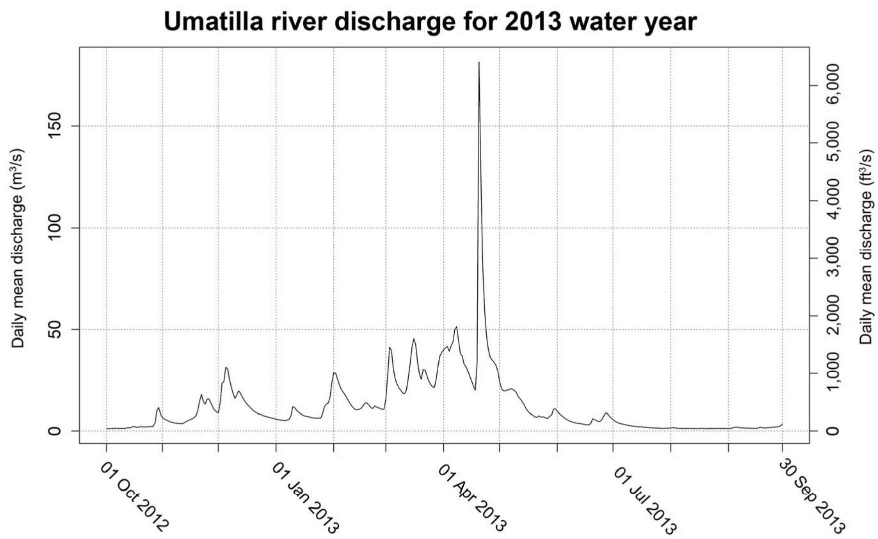


**FIGURE 5** Daily mean discharge for the Umatilla River during the 2013 water year at United States Geological Survey site 14020850 on the Umatilla River near Pendleton, OR, USA. The loggers were deployed during the summer of 2012 and retrieved the summer of 2013. The loggers withstood extreme flow events in the winter of 2013

We present the climbing hanger method as a novel way to install in-stream data loggers. The epoxy method, introduced by Isaak et al. (2013), uses marine-grade underwater epoxy to attach PVC housing to immovable in-stream structures such as large boulders, bedrock or bridge supports. Success of the epoxy method depends upon the water temperature, cleanliness of the installation surface and applying pressure to the epoxy long enough for proper adhesion. In contrast, climbing hanger installation success is not influenced by environmental variables. The need to account for water temperature, scrubbing the installation surface and application of constant pressure until the epoxy has set may make logger installation with epoxy more time-consuming than using a climbing hanger.

The climbing hanger method allows for easy removal of the logger and housing, which is both an advantage and disadvantage. Decommissioning a data collection site is quick and straightforward, and once the bolt and housing is removed, the only thing left behind is a hole in the rock. However, vandals can use a wrench to unscrew the logger from the rock. Fortunately, most people recreating on rivers do not carry large wrenches; thus, we believe the installations are, for the most part, tamper-resistant. Regardless, we reiterate that proper camouflage and, when possible, installation in a location with low recreation pressure are likely to improve logger recovery rates.

The climbing hanger method is limited to streams that have immobile boulders or exposed bedrock for attachment points. In-streams that lack appropriate installation sites for climbing hangers, such as sand- or mud-bottomed streams, attaching loggers to rebar or fence posts in the streambed may be the most suitable alternative method. In-streams with highly mobile beds, a logger can be tethered to an immobile attachment point on the stream bank (Mauger et al., 2015; Ward, 2011). Some stream reaches without boulders or bedrock attachment points may have bridge supports or abutments, which serve as appropriate attachment points using the epoxy method (Isaak et al., 2013). We *do not* recommend installing climbing hangers on infrastructure. Drilling a hole in a bridge support, for instance, could affect its structural integrity over time.

## 4 | CONCLUSION

We presented a simple, fast, cost-effective and low-impact method for installing long-term data loggers in rocky rivers and streams using PVC housing and rock-climbing hardware. This method is extensible for use with any appropriate self-contained data logger in locations where bedrock or boulder substrates are available. Our method addresses many challenges associated with installing loggers in extreme flow environments, where shear stress or current-borne debris may cause loss of loggers and associated data.


### ACKNOWLEDGEMENTS

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### AUTHORS' CONTRIBUTIONS

G.C.P., S.J.O., A.A.H., A.M.R. and S.K.F. conceived the ideas and designed methodology; G.C.P., A.A.H., S.J.O. and S.K.F. collected the data; S.K.F., S.J.O. and A.M.R. led the writing of the manuscript; S.K.F. compiled photographic figures and created the plot; G.C.P. developed the technical drawing. All authors edited manuscript drafts and gave final approval for publication.

### DATA AVAILABILITY STATEMENT

Discharge data shown in Figure 5 are available from the United States Geological Survey National Water Information System (water data.usgs.gov/nwis) for site 'USGS 14020850 UMATILLA R AT W RESERVATION BNDY NR PENDLETON, OR'.

## ORCID

*S. Kathleen Fogg* https://orcid.org/0000-0002-9164-1369
*Geoffrey C. Poole* https://orcid.org/0000-0002-8458-0203
*Ann Marie Reinhold* https://orcid.org/0000-0003-0411-3486

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