River Channel Response to the Removal of The Pilchuck River Diversion Dam, Washington State

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Research Note

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Abstract

In August 2020, the 3-m tall Pilchuck River Diversion Dam was removed from the Pilchuck River, allowing free fish passage to the upper third of the watershed for the first time in over a century. The narrow, 300-m long impoundment behind the dam was estimated to hold 4,000–7,500 m^3 of sand and gravel, representing less than one year's typical bedload flux. Repeat cross section surveys, stage sensors, and time-lapse cameras were used to document the physical channel response over the first year following dam removal. A total of 7,400 m^3 (effectively 100%) of impoundment sediment was eroded in the first year, with 25% accomplished by manual regrading during dam removal. Most river-caused erosion occurred during a sequence of modest flows in October 2020. Downstream deposition totaled 4,300 m^3, predominately filling in the first 100 m downstream of the dam site. Deposition tapered below detectable levels within 350 m, and most downstream channel adjustments occurred before November 2020. Multiple high flows after December 2020 caused little upstream or downstream change. The physical river response to this dam removal then appears to have been largely accomplished within several months by modest flows, consistent with pre-removal modeling and observations from other regional dam removals. Efficient sediment evacuation was likely aided by the narrow and steep-walled impoundment geometry. Our observations support existing guidance that the physical river response to small dam removals is typically rapid and modest; the benefits of removal may then often be gained with minimal negative downstream geomorphic impacts.

Keywords: channel change, dam removal, fish passage, sediment transport

Introduction

Over the past decades, the pace of dam removal in the United States has accelerated dramatically and continues to climb (American Rivers 2022). Dam removals influence physical and ecological processes in river reaches both upstream and downstream of the dam (Bellmore et al. 2017, Foley et al. 2017, Major et al. 2017). While dam removals are generally pursued with the expectation of providing long-term ecological, economic, and societal hazard benefits (Tonitto and Riha 2016, Foley et al. 2017, Vahedifard et al. 2021), the release of impoundment sediment has the potential to impact downstream channel migration and flood conveyance, alter habitat conditions, and, in some cases, spread contaminated sediments (Tonitto and Riha 2016, Tullos et al. 2016). Understanding the potential for such impacts is central to decisions about if or how a given dam removal proceeds (Cui et al. 2014, Randle and Bountry 2017, East et al. 2023). Those decision-making and planning efforts are supported by knowledge gained from direct observations of physical responses to recent dam removals. However, only a small fraction of

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documented dam removals have associated published pre/post monitoring (Bellmore et al. 2017), and while large dam removals (e.g., Warrick et al. 2015) understandably receive significant attention, most dam removal projects are small and receive relatively less scientific attention (Bellmore et al. 2017).

The Pilchuck River Diversion Dam (hereafter, the Pilchuck Dam) is located along the Pilchuck River in western Washington (Figure 1). The 3 m diversion dam was constructed in 1932 as part of a diversion system to supply water to the city of Snohomish. Although the dam nominally included a fish ladder, design and sedimentation issues made it ineffective, and the structure represented a significant barrier to fish passage (Haring 2002). Below the dam, limited habitat and high water temperatures were identified as primary limitations for fish (Leonetti and Rustay 2012). Given that the watershed upstream of the dam contained quality spawning habitat and relatively cooler stream temperatures, removal of the dam was identified as a priority for restoration of fish populations in the Pilchuck River, including Endangered Species Act-listed Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss irideus*), and bull trout (*Salvelinus confluentus*) (Tulalip Tribes 2022). After a decade of discussion and a decision by the city of Snohomish to end water withdrawals in 2018, local partners agreed to pursue removal of the dam with the Tulalip Tribes of Washington acting as the project lead.

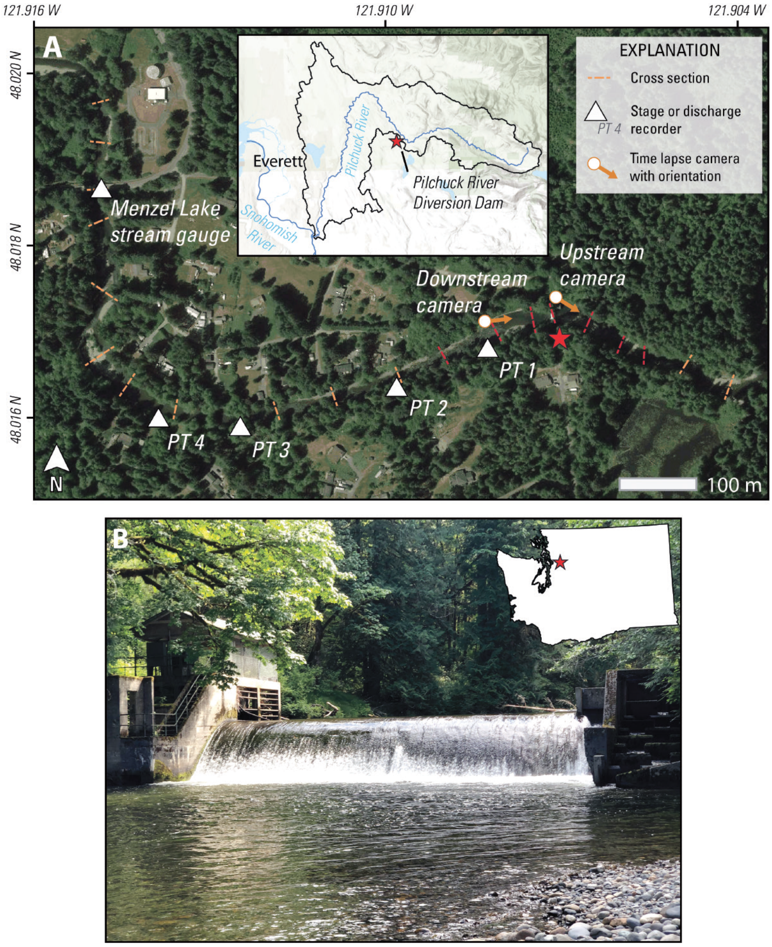

Figure 1. Site map of study area. A) Details of monitoring elements in reach near the Pilchuck Dam. Inset shows Pilchuck River watershed. Subset of cross sections resurveyed in September 2020 shown in red. Base map from Esri and its licensors, copyright 2020. B) Image of the Pilchuck Dam at low flow, taken in 2020 by S. Anderson. The dam is 3 m high and 18 m wide. Red star indicates location of dam in all panels and insets.

Pre-removal analyses indicated that the sediment delivery associated with the removal of the Pilchuck Dam was likely to be small relative to typical sediment loads in the river, and negative downstream impacts were considered unlikely (Shattuck and Shea 2019). This expectation was supported by prior dam removal studies, in which downstream impacts of dam removals have generally been modest and short-lived (Foley et al. 2017, Major et al. 2017). That body of work includes numerous removals in the Pacific Northwest (Major et al. 2012, Wilcox et al. 2014, East et al. 2015), where high background rates of sediment transport (Pfeiffer et al. 2017) likely facilitate efficient mobilization of impoundment sediments. However, the Pilchuck River immediately downstream of the diversion dam is lined by riverfront properties, such that any changes in downstream flood conveyance capacity would be a cause for concern. Funding sources for the removal also required monitoring to ensure that fish passage was re-established following removal. For these reasons, and for the general purpose of expanding monitoring studies of small dam removals, the US Geological Survey (USGS) partnered with the Tulalip Tribes to conduct geomorphic monitoring over the first year following dam removal. Monitoring included repeat cross section surveys, continuous stage-monitoring to assess bed elevation change, and time-lapse cameras. This note summarizes results from those efforts, demonstrating that geomorphic adjustments following dam removal were, if anything, more rapid and less significant than anticipated.

Methods

Study Area

The Pilchuck River drains a 352 km^2 watershed in western Washington and is a major tributary of the Snohomish River (Figure 1). The watershed is underlain by a mix of Mesozoic metamorphic and Tertiary volcanic and metavolcanic material (Washington Division of Geology and Earth Resources 2016). Most of the major river valleys and much of the lower watershed is covered by continental glacial material. Downstream of the dam, the river is a meandering gravel-bedded system with extensive gravel bars. Upstream of the dam, the river becomes more confined within glacial terraces and mountainous terrain, though remains meandering with flanking gravel bars.

The 113 km^2 contributing area above the Pilchuck Dam consists primarily of forested mountainous terrain with essentially no infrastructure or flow modification. The watershed was extensively logged in the mid-20th century, with associated road building, but has not seen intensive harvest in recent decades. High flows in the Pilchuck River are driven by fall and winter rainstorms, with the 0.5 annual exceedance probability flow (0.5 AEP; the ‘two-year flood’) at the dam site estimated to be about 105 m^3·s^{-1} (Mastin et al. 2016).

Pilchuck Dam—The Pilchuck Dam started as a small log-crib structure built in 1912. That structure was replaced by a 3 m concrete structure built in 1932 about 50 m downstream from the log-crib structure. That concrete structure remained until removal in 2020 (Tulalip Tribes 2022). The Pilchuck Dam was a run-of-the-river structure and did not regulate flow.

Upstream of the dam site, the river is confined within a narrow (approximately 30 m), steep reach bounded by near-vertical bedrock walls. An in-channel bedrock exposure located about 300 m upstream of the dam was presumed to mark the upstream limit of substantial reservoir sedimentation. At the time of removal, the impoundment reach was filled with sediment to the level of the dam crest. Given high estimated rates of sand and gravel transport, it is likely that the impoundment filled within a few years after initial construction. As a result, the dam is unlikely to have modified long-term sediment transport for most of its existence. Prior to removal, total reservoir sediment volume was estimated to be between 4,000 and 7,500 m^3 (Shattuck and Shea 2019). Surficial sediments in the impoundment reach were predominately gravels between 10 and 256 mm with median particle diameters (D50) around 70 mm, similar to downstream reaches (Snohomish County Surface Water Management 2012, Shattuck and Shea 2019). Impoundment material at depth was not sampled but was presumed to be a mixture of sand and gravel.

The first 500 m of channel downstream of the dam is predominantly plane-bedded, lacking distinct pools or riffles beyond the dam’s immediate plunge pool (Figure 1). The river then passes through a short (approximately 200 m) reach with a mix of mid-channel and channel-flanking gravel bars and deep pools. The river then again straightens and returns to a more plane-bed configuration to the end of the study domain. The mean annual bedload flux in the reach was estimated at around 30,000 tonnes (t) per year, using the empirical gravel transport relation of Yang (1984) supported by local surficial grain size data and hydraulics from the US Army Corps of Engineers' one-dimensional Hydrologic Engineering Center River Analysis System (HEC-RAS) modeling (Shattuck and Shea 2019). Assuming reservoir sediments had a bulk density around 2 tons·m^{-3} (Randle and Bountry 2017), the pre-removal estimates of impoundment sediment volumes represented 8,000 to 15,000 t of material, or roughly 25–50% of the typical annual bedload flux. This ratio places the removal within the 'small' category based on Bureau of Reclamation guidance (Randle and Bountry 2017). One-dimensional HEC-RAS modeling of bed elevation changes following dam removal suggested that about 60% of impounded sediment was likely to be evacuated within the first year, with limited downstream deposition (Shattuck and Shea 2019).

The Pilchuck Dam was removed during low flow conditions in July and August of 2020. Impoundment sediment immediately upstream of the dam was regraded to form a broad gravel bar, extending roughly 50 m below the former dam site, and largely filling the deep plunge pool that had existed at the downstream edge of the dam. Manual regrading was a by-product of in-river access pathways for machinery and the subsequent re-shaping of a quasi-natural channel form during cleanup of the work site, and was not intended to mitigate or facilitate impoundment erosion (Tulalip Tribes 2022).

Multiple monitoring efforts, beyond the geomorphic monitoring described here, were conducted in association with the dam removal. These included turbidity and pH monitoring for compliance with water quality standards during construction and salmon spawner/redd surveys both before and after dam removal. The results of those additional monitoring efforts are summarized in the Tulalip Tribe's (2022) final report on the dam removal.

Topographic Surveys

Repeat cross sections were used to monitor channel change through the dam impoundment and the downstream river channel (Figure 1). A total of 20 sections were established, sited at roughly equal intervals from 300 m upstream of the dam to 900 m downstream of the dam. Cross sections were surveyed using an automatic optical level ("autolevel"), with fixed monuments established at both ends of each section. Monuments were placed at or near bank crests, such that cross sections just covered the approximate bankfull channel and did not extend across overbank areas. Absolute coordinates of these monuments were obtained using a combination of global navigation satellite system (GNSS) and total station surveys and were used to convert relative distance/height data from the autolevel surveys into absolute coordinates.

An initial survey was completed on 6 July 2020, prior to any dam deconstruction efforts. A partial re-survey, encompassing seven sections between 120 m upstream of the dam and 150 m downstream of the dam, was completed on 21 September 2020, after dam removal but prior to any high flows (Figure 1). All sections were resurveyed again on 19 July 2021. A longitudinal profile of the channel thalweg (the deepest point of a given cross section) was also surveyed with a total station during each of the three survey efforts. The longitudinal surveys extended over the full study area in the July 2020 and July 2021 surveys, while only covering a limited extent around the dam for the September 2020 survey. Details of the surveys and data are provided in Anderson et al. (2022).

The mean elevation of each cross section was calculated by dividing the integrated cross section area above survey datum by cross section width and was used to estimate mean elevation and area change between surveys. Volumetric change was estimated using average end-area methods, in which the average area change at sequential sections was averaged and multiplied by the along-channel distance between the two sections to obtain a volume. We estimated volumetric change between the cross section at the dam crest and the first downstream cross section using just the area change of the downstream cross section multiplied by the distance to the dam, since the substantial lowering at the dam crest itself was not representative of the deposition that occurred just downstream.

Stage Monitoring

Changes in relations between water surface elevation (stage) and discharge can be used to infer approximate changes in local channel bed elevation (Gilbert 1917, James 1997, Anderson and Konrad 2019), since channel aggradation tends to result in higher stages for a given discharge. The potential to monitor such changes at sub-daily timescales makes this approach well-suited to document the rapid changes that often follow dam removals (Wilcox et al. 2014, East et al. 2015, Cashman et al. 2021). To that end, four non-vented pressure transducer water level sensors were installed downstream of the Pilchuck Dam, recording stage at one-hour intervals from July 2020 through July 2021. Sensors were located 110, 210, 415, and 525 m downstream of the dam; we refer to these pressure transducers (PT) by number in downstream order (PT 1, PT 2, etc.; Figure 1). An additional sensor was installed along the bank to provide atmospheric pressure corrections to all four submerged sensors. Fixed reference points were established near each sensor in locations where the distance to water surface could be manually measured. These manual measurements were used to assess stability of the sensor datums over time. Details of the installations and record post-processing are available from Anderson et al. (2022).

Geomorphic assessment of continuous stage records requires some method of identifying and removing the stage variations caused by changing discharge. This can be accomplished using any time series that is strongly and consistently correlated with discharge in the study reach of interest. This typically is a discharge record, or a stage record in a location with a stable bed, at a hydrologically similar site (upstream, downstream, or in an adjacent basin). Here, we used stage records from a gauge operated by Snohomish County on the Pilchuck River about 800 m downstream of the dam (Pilchuck River at Menzel Lake Road; real-time data is available at Snohomish County Surface Water Management 2021, and data used in this study are available from Anderson et al. 2022). Repeat cross sections, visual inspection, and streamflow measurements made over the study period all support the assumption that the channel bed and stage-discharge relation at the Menzel Lake Road gauge site were stable over the study period.

For each pressure transducer, we defined a baseline relation between recorded stage and the concurrent stage at the Menzel Lake Road gauge using locally weighted regression (LOESS; Cleveland and Devlin 1988). These baseline relations were fit to records between 1 July 2020 and 10 October 2020, bracketing a period of stable channel conditions at all sites. We then calculated the difference between observed stage at a given pressure transducer sensor and the LOESS-predicted stage based on the Menzel Lake Road stage (the 'stage offset') for the entire period of record. Positive stage offsets indicate that the stage at a given pressure transducer was higher than expected given stage conditions at the Menzel Lake Road gauge. This is typically interpreted as indicating an increase in channel bed elevation at the hydraulic control for the sensor location. Stage sensors were all located in a plane-bedded reach, such that these hydraulic controls were generally the adjacent channel bed, as opposed to a downstream riffle. The time window over which baseline relations were defined only includes Menzel Lake Road stages up to about 3.68 m (equivalent to discharge around 40 $m^3 \cdot s^{-1}$), so stage offsets could not be calculated when flows went above that level. Flows below 40 $m^3 \cdot s^{-1}$ represent about 97% of the total study period.

PT 1 was buried by coarse sediment and appeared to have become partially disconnected from the main channel at low flows after 10 January 2021. However, the sensor continued to show good responsiveness to flows when discharge at Menzel Lake Road was above 16 $m^3 \cdot s^{-1}$. After 10 January 2021, we retained stage offsets from PT 1 when discharge at Menzel Lake Road was between 16 and 40 $m^3 \cdot s^{-1}$. Records for PT 2 became erratic after 3 December 2020, likely due to fouling of intakes with fine sediment, and all records from PT 2 after that date were discarded.

Time-Lapse Cameras

Two time-lapse cameras were installed and used to qualitatively assess channel change near the dam site. Both installations used a 24.1 megapixel Canon EOS Rebel T7 camera shooting at one-hour intervals. One installation was located on river-right about 100 m downstream of the dam, looking back upstream toward the dam (Figure 1); we refer to this as the downstream camera. The second installation was located on river-right directly adjacent to the dam site, looking upstream through the impoundment reach; we refer to this as the upstream camera. Both cameras were installed July 2020 and took photos through to 19 July 2021.

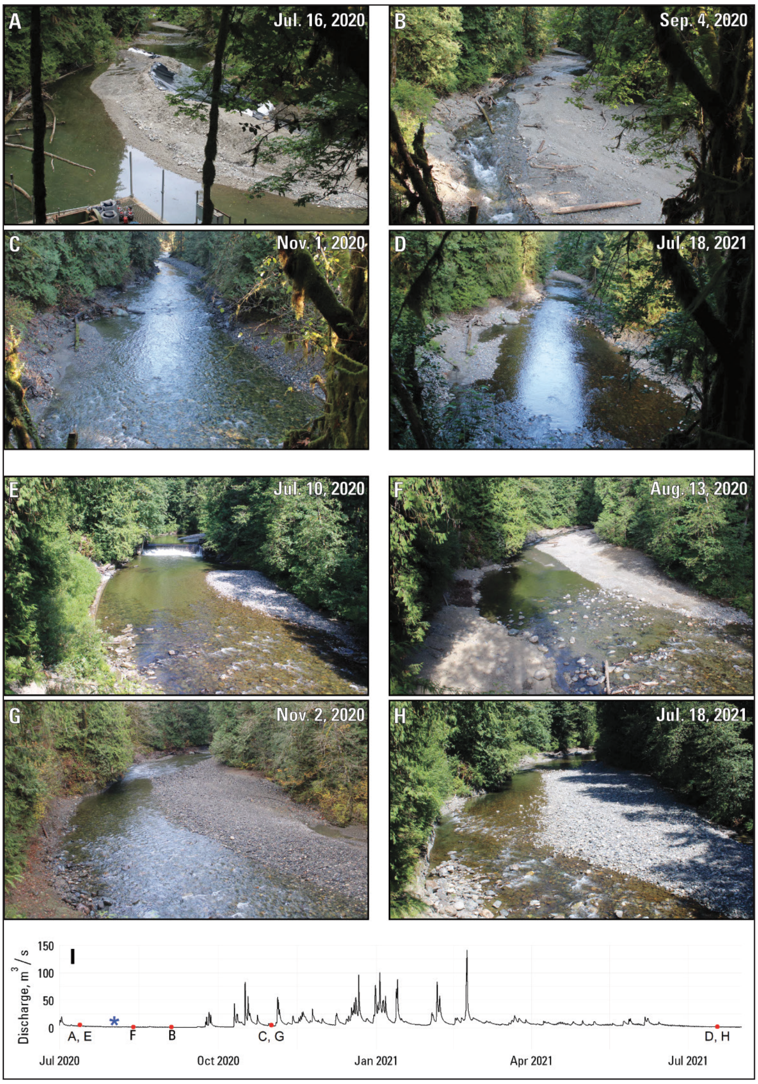

Figure 2. Selected images from the upstream (A–D) and downstream (E–H) time-lapse cameras. A) Upstream camera, looking upstream through impoundment reach during early dam deconstruction. Impoundment sediment has already been shifted to create a bypass channel for water. B) Impoundment conditions immediately after dam removal. C) After first high flows; majority of impoundment sediment has been removed at this point. D) At end of study period. E) Downstream camera, looking upstream toward dam prior to removal. F) Conditions immediately after dam removal; gravel bar on river left was formed through manual grading of impoundment sediment. G) After first high flows. H) At end of study period. Timing of photos (red dots) relative to discharge from the Snohomish County stream gauge at Menzel Lake Road shown in (I), with asterisk indicating completion of the dam removal.

Results

During dam deconstruction, sediment in the lower impoundment was graded to form a broad river-left gravel bar that extended downstream of the (now-removed) dam crest and fill in the dam's plunge pool (Figure 2). Repeat cross sections show this regrading accomplished a net transfer of about

1,900 m^3 of sediment from the first 100 m of impoundment reach down to the first 100 m of the reach immediately downstream (Figure 3).

Once flows began to rise in the fall of 2020 (Figure 2I), erosion of the remaining impoundment sediment was rapid and largely accomplished within several months of the dam's removal. Time-lapse imagery shows that substantial river-driven erosion of impoundment sediments started during a series of minor flows in mid-September 2020, with peaks up to 28 m^3·s^{-1}. Most of the remaining impoundment erosion occurred over a series of moderate peaks between 50 and 80 m^3·s^{-1} through late October 2020. By early November 2020, the impoundment reach was largely devoid of exposed gravel surfaces, and, despite multiple high flows up to 140 m^3·s^{-1}, there were no visually obvious changes to impoundment-reach geometry over the rest of the monitoring period (Figure 2).

A steep riffle, flowing over a mixed bedrock/cobble bed,

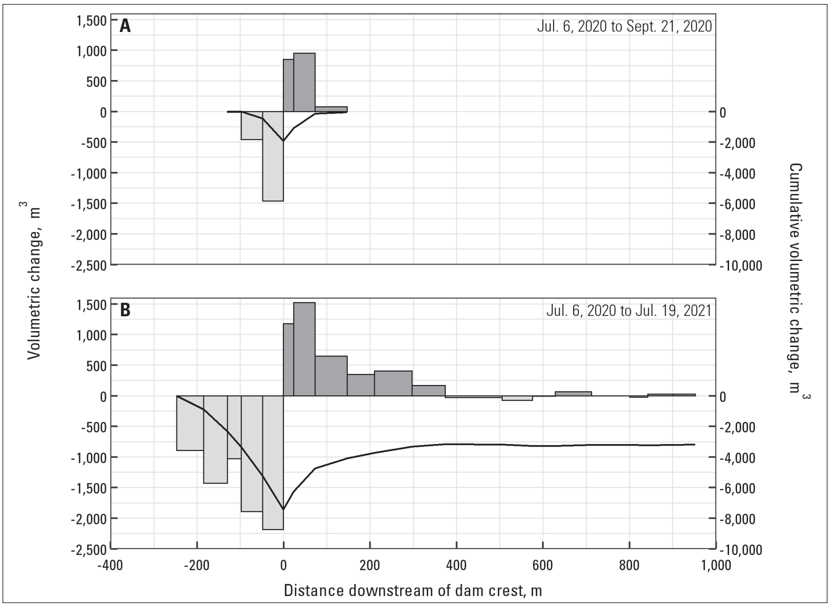

Figure 3. Volumetric channel change near the Pilchuck Dam site from A) 6 July 2020 to 21 September 2020, showing impacts of sediment regrading during dam deconstruction, and B) 6 July 2020 to 19 July 2021, showing integrated change one year after initial pre-removal survey. Volumes are based on repeat cross sections, using average end-area methods. Bars show volumetric change between sequential cross sections; black line shows longitudinal cumulative volumetric change starting from upstream-most cross section.

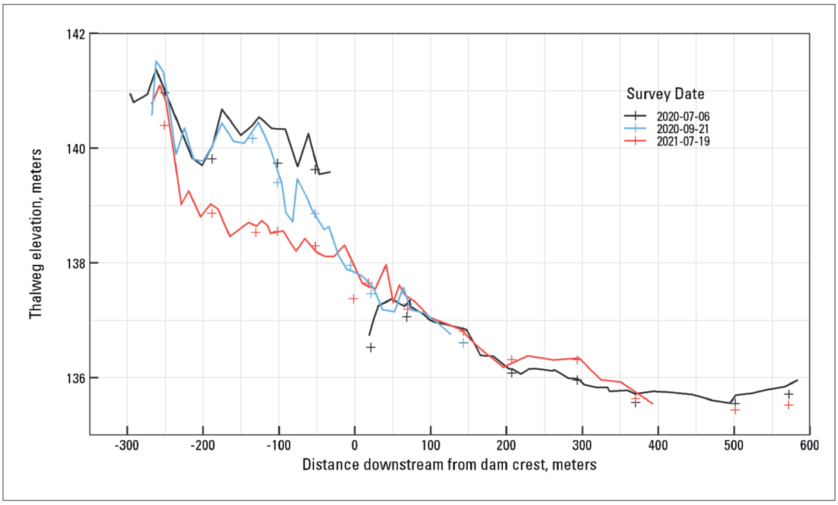

Figure 4. Approximate channel thalweg of the Pilchuck River before (black) and after (blue and red) removal of the Pilchuck Dam. Lines represent total station longitudinal profile surveys; crosses are minimum elevations extracted from cross section surveys.

formed at the upstream edge of the impoundment reach (Figure 4). This bedrock-controlled step marked the limit of substantial erosion upstream of the dam, consistent with pre-removal expectations. A total of 7,400 m^3 was removed from the impoundment over the one-year monitoring period, lowering much of the reach 1–2 m (Figures 3, 4).

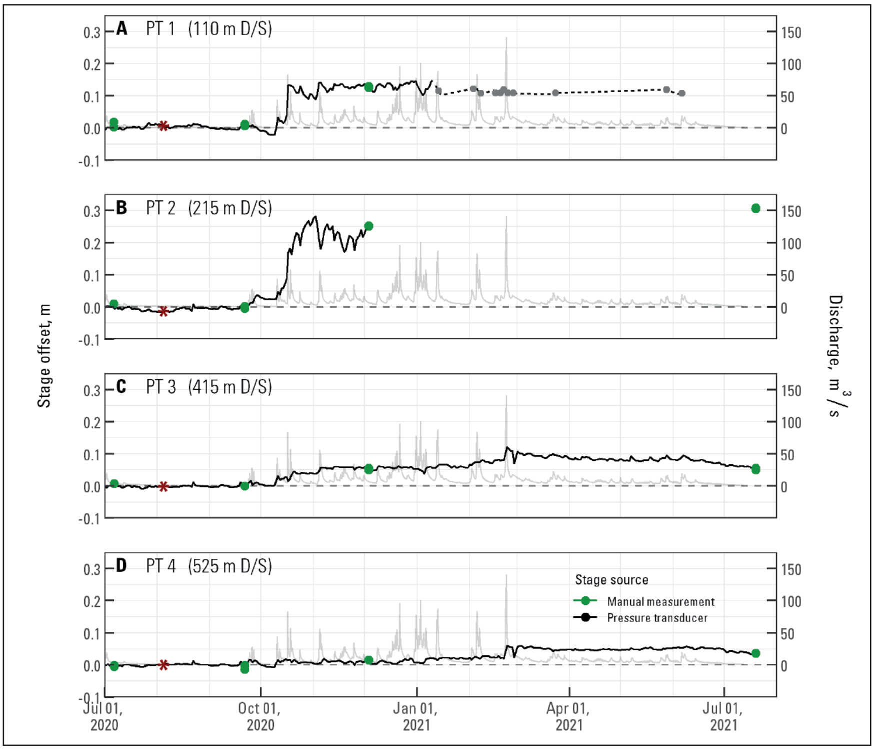

Figure 5. Stage offsets based on stage monitoring downstream (D/S) of the Pilchuck Dam; panels A–D show data from pressure transducers (PT) 1–4, respectively. Stage offsets provide an approximate measure of changes in mean channel bed elevation near the site of a given pressure transducer. Asterisks indicate timing of dam removal. Dashed line and points in A reflect analysis of PT 1 records after partial burial by sediment (see methods). Stage offsets based on manual stage measurements are shown (green points) to validate datum consistency at all sites and, for PT 2, to provide a point estimate of relative channel elevations at the end of the study.

Downstream channel adjustments after dam removal were modest, spatially limited, and largely complete by mid-January of 2021 (Figures 2–5). At the end of study period, deposition was most pronounced immediately downstream of the dam, where both manual regrading and fluvial transport filled in the dam's plunge pool and placed sediment in a large river-left gravel bar (Figures 2–4). Sediment deposition farther downstream accumulated across the width of the plane-bedded channel. Mean elevation change tapered downstream, dropping below detectable levels within 350 m of the dam crest location (Figure 3). No significant elevation change was observed at any cross section downstream of that point, though stage monitoring suggests minor aggradation (approximately 0.05 m) may have occurred in the low gradient reach 400–500 m downstream of the dam (Figure 5C, D).

Continuous estimates of bed elevation change based on stage monitoring provided a more detailed look at the timing of these downstream changes (Figure 5). At PT 1 and 2, most vertical channel adjustments were accomplished by moderate events in October 2020. After October 2020, elevation at the two sites varied only modestly, with no substantial net change through July 2021. Modest deposition at PT 3 (approximately 0.1 m) occurred in two steps during October 2020 and late February 2021 high flows, while deposition at PT 4 (approximately 0.05 m) occurred only during the late February peak.

Volumetric deposition downstream of the dam totaled 4,300 m^3, or about 60% of the volume eroded from the impoundment (Figure 3).

Given measured impoundment erosion of 7,400 m^3, approximately 3,100 m^3 of impoundment sediment was mobilized beyond the 1 km reach monitored here. This is equivalent to about 10% of the estimated mean annual bedload flux (Shattuck and Shea 2019).

Discussion

The physical river response to the Pilchuck Dam removal was both modest and rapid. Essentially 100% of impoundment sediment was evacuated within months after dam removal, with modest flows doing much of the work (Figures 2, 3). Significant downstream channel adjustments were spatially limited to the first 350 m below the dam, and the downstream channel was sufficiently stable by January 2021, six months after removal, that multiple subsequent high flows near or above the 0.5 AEP flow caused little observable channel change (Figure 5). Substantial channel adjustments, both upstream and downstream of the dam, thus appear to have been largely accomplished within several months. The net sediment delivery to reaches beyond our study limits was around 3,100 m^3 (Figure 3), representing a small fraction of typical annual bedload flux (Shattuck and Shea 2019).

The observed evacuation of reservoir sediments was both more rapid and more complete than predicted by pre-removal modeling (Shattuck and Shea 2019), with most work accomplished by relatively moderate (50–75% of 0.5 AEP) high flow events early in the flood season. The efficient removal of impoundment sediments by modest flows has been widely observed in other dam removal studies (Major et al. 2017) and is typically attributed to elevated shear stresses within an upstream propagating knickpoint or knickzone that forms in response to the drop in local base level (e.g., Major et al. 2012). Rapid erosion during this initial 'process-driven' period may then be followed by relatively slower 'event-driven' erosion, as high flows and lateral channel migration are increasingly required to access impoundment sediments stored away from the initially incised channel (Pizzuto 2002, Pearson et al. 2011, Collins et al. 2017). For the Pilchuck Dam removal, this second stage of event-driven erosion was largely precluded by the narrow and steep-walled geometry of the impoundment reach. High flows typically span from bedrock wall to bedrock wall, allowing knickzone erosion to remove sediment from the full width of the impoundment. The narrow and confined nature of the impoundment reach then likely increased the overall efficiency of sediment evacuation. The presence of a steep bedrock step several hundred meters upstream of the dam (Figure 5) also reduced the longitudinal extent of backwatering from the dam, which presumably helped limit the volume of sediment stored behind the dam, and so released upon removal.

Initial downstream channel adjustments following dam removals are typically discussed as transient responses to large pulses of impoundment sediment. This implies that downstream channels are likely to experience some degree of recovery as impoundment erosion rates wane (e.g., Wilcox et al. 2014, Ritchie et al. 2018). In contrast, stage monitoring downstream of the Pilchuck Dam showed elevations increased quickly and then remained at those new levels through the end of our study period, with no obvious 'recovery' phase (Figure 5). This stability occurred despite the occurrence of multiple high flows after most of the impoundment sediment had already been evacuated.

A similar wedge of persistent deposition was observed after the 2007 removal of the 14 m Marmot Dam on the Sandy River, Oregon (Cui et al. 2014). The wedge appeared in pre-removal modeling studies, where it was predicted to persist through the end of the 10-year modeling period, and direct observations over four years after removal closely matched model predictions of this feature (Cui et al. 2014). The wedge below the removed Marmot Dam, about 2 m at its highest point and tapering over 1.2 km, was substantially larger than the deposition observed below the Pilchuck Dam. However, the deposition wedge dimensions scale with dam height, with maximum deposition about 10–20% of dam height and tapering over a distance roughly 100 times the dam height in both cases. Whether these wedge features persist beyond the relatively short monitoring periods remains to be seen, and neither feature represented a geomorphic or ecological hazard. However, the persistence of these proximal downstream wedge deposits is a notable contrast to the otherwise rapid redistribution of sediment associated with most dam removals.

Taken all together, the rapid and modest changes we observed following the removal of the Pilchuck Dam agree with Bureau of Reclamation guidance (Randle and Bountry 2017) that small dam removals, with stored sediment volumes equivalent to less than one year's typical sediment flux, are unlikely to have significant geomorphic impacts on downstream reaches. Our observations also validate the decision to simply remove the dam with no efforts to mediate erosion of impoundment sediments, which would have likely increased costs while providing little benefit. We found the combination of repeat cross sections and stage monitoring provided a complementary mix of spatial and temporal resolutions and recommend them as relatively low-cost monitoring methods for small dam removals in seasonally-wadable rivers.

The removal of the Pilchuck Dam eliminated on-going maintenance costs and removed the risk of unplanned failure. Preliminary fish count data (Tulalip Tribes 2022) showed an immediate uptick in both Chinook and pink salmon (*Oncorhynchus gorbuscha*) immediately upstream of the dam in the two years after removal. The geomorphic monitoring presented here indicated that these benefits were accrued with minimal downstream geomorphic impacts, even when using a rapid dam removal strategy with no attempt to mitigate reservoir erosion.

Conclusion

The physical response of the Pilchuck River following the 2020 removal of the Pilchuck Dam was both rapid and relatively uneventful, with no negative downstream geomorphic consequences. Both erosion of impoundment sediment and downstream geomorphic adjustments were largely accomplished within several months of the removal, with low to moderate flows doing most of the work. Our findings are consistent with both existing guidance on likely geomorphic impacts of small dam removals and prior research on dam removals in the region. Our work builds on published literature showing small dam removals may often achieve project goals with little risk of negative downstream impacts on physical habitat, flood conveyance, or channel mobility.

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Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the US Government.

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