TECHNICAL MEMORANDUM

To: Kinni Corridor Collaborative

From: Sean Morrison and Marty Melchior, Inter-Fluve

Date: December 29, 2020

Re: Drone based Drawdown Analysis

A drone-based drawdown analysis was conducted on the Powell Falls dam impoundment (Lake Louise) during and after a drawdown of Lake Louise. The drawdown occurred between October 2nd, 2020 and October 16th, 2020. This analysis shows an initial downcutting of the channel and the beginning of lateral migration following a rainfall event of October 12th.

The last day of the analysis was December 11th, 2020. On this day, the channel was narrow relative to pre-dam conditions (Inter-Fluve 2015), with a low sinuosity. It is expected that the channel will continue to erode through the processes of channel widening and lateral migration under normal flow conditions until the channel has adjusted so that it can convey bankfull flows. Once the channel has adjusted to convey bankfull conditions, significant erosion is only expected to occur following large flood events.

See Appendix A for images showing the channel movement during and after the drawdown, and the projected restored channel position (Inter-fluve 2015).

Channel Evolution During Drawdowns

The uncontrolled release of impounded sediments often occurs in two phases: a 'process-driven' and 'event-driven' phase (Figure 1). In the 'process-driven' phase, dam removal results in base level lowering, an increase in the energy gradient and incision through the former impoundment (Doyle et al. 2002, Pearson et al. 2011). Following this phase, during the 'event-driven' phase "larger flood events are necessary to erode impounded sediments more distant from the new channel" (Collins et al. 2017). Typically, 'event-driven' sediment movement requires floods at or larger than the 5-year event. The change from 'process- driven' to 'event-driven' occurs when a stable channel slope is generally reached and the channel is large enough to convey bankfull flows (Collins et al. 2017). In dam removals where downstream sedimentation is a concern, excavation of a pilot channel often sufficiently replicates the 'process-driven' erosion allowing the majority post-construction erosion follow an 'event-driven' trajectory.

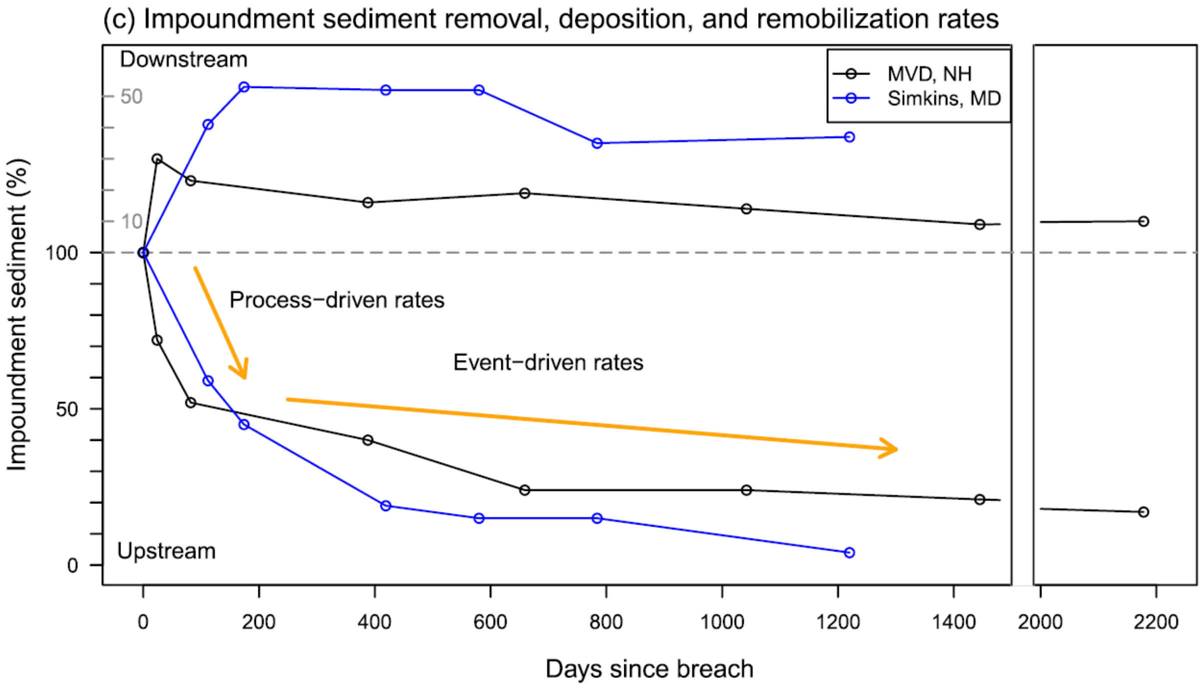

Figure 1: Impoundment sediment erosion and deposition rates for two dam removals (from Collins et al. 2017)

Project Background

The Powell Falls and Junction Falls Dams impound the Kinnickinnic River within the City of River Falls, Wisconsin, approximately 10 river miles upstream of the river's confluence with the St. Croix River. Currently, the City is planning to remove the Powell Falls Dam and complete stream restoration by 2026 (City of River Falls 2018).

The river reach immediately downstream of the Powell Falls Dam flows through a confined bedrock valley. The average channel bankfull width is 60 ft with the bankfull depth 4 ft at pools. Cobbles and exposed bedrock are the typical substrate in most riffles with sand located in pools. Riparian tree cover is typically composed of silver maple, box elder, and cottonwood. (Inter-fluve 2017a, 2020a)

The river reach immediately upstream of the Powell Falls Dam consists of Lake Louise, the impoundment located between the Powell Falls and Junction Falls Dams. The impoundment can be roughly divided into a lake-like downstream portion and a more river-like portion immediately downstream of the Junction Falls Dam. The impoundment contributes to increased downstream water temperatures (Kiap-TU-Wish 2014) and is dominated by shallow waters (~3 ft deep) and aquatic invasive species (Inter-fluve 2020b). Approximately 200,000 cubic yards (a cubic yard is about enough material to half fill the bed of a pickup truck) of sediment are currently stored within the impoundment (Ayers 2020. The sediment is predominately composed of silt and sand (Inter-fluve 2015).

An analysis of channel bed slopes through River Falls and coring of the impoundment sediments (Inter-Fluve 2017) suggest the pre-dam channel in Lake Louise was likely 60-65 feet wide, 3-4 feet in mean depth with a gravel riffle-pool morphology and a moderate gradient (0.2-0.6%). The banks were likely forested with common riparian forest trees such as black willow, cottonwood, silver maple, swamp white oak and elm, and a native shrub understory. A small tributary channel from a spring pond to the north also enters the Kinnickinnic River at the upper end of Lake Louise but is not a significant source of water or sediment, though the tributary may serve as a spawning and rearing area for native trout populations following dam removal and restoration.

Drawdown events

On June 28-29, 2020, a large rain event (6.75 inches in River Falls) caused flooding within the Kinnickinnic River Watershed and the surrounding areas. At USGS gage 05342000, located at the County Road F crossing in Pierce County, discharge peaked at 6,450 cfs at 2:45 pm. For comparison, the 10-year recurrence interval flood at the Powell Falls Dam is 6,800 cfs (FEMA 2011). The June 28-29th flood event damaged the right wingwall of the Powell Falls Dam. This damage prompted the River Falls Municipal Utilities (RFMU) to lower the Powell Falls Dam impoundment (Lake Louise) to inspect the dam structure (Ayres 2020). The drawdown of the impoundment began October 2nd by opening the dam sluice gate. The drawdown was completed on October 15th, 2020.

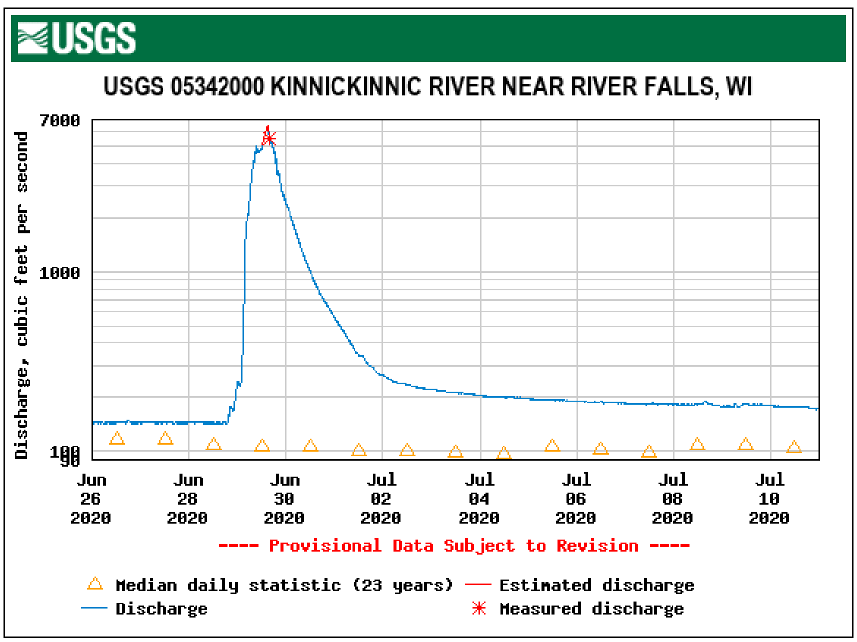

Figure 2: USGS gage data from the flood occurring on June 28-29, 2020.

Methods

The Kinnickinnic Corridor Collaborative and River Sky Drones have flown repeat drone surveys over the newly exposed lakebed before, during and after the drawdown (publicly available at https://kinnicc.org/lake-monitoring). Drone imagery was processed with Pix4D and Adobe Photoshop to create a single-image orthomosaic for each set of drone photographs. Orthomosaics were georeferenced by Inter-Fluve. Banklines were digitized in GIS software between an abandoned sewer crossing near the waste water treatment plant and the Powell Falls dam. Banklines were digitized along the wetted perimeter, which represents the incised low-flow channel which developed during and after the drawdown. The incised low-flow channel was sampled since it was an easily discerned in the photos and due to the incised nature of the channel, and relatively constant discharge over the time period sampled, provided a consistent metric for sampling. Cross-section width was determined at three locations spaced along the reach and located where minimum lateral channel movement was observed. In addition to drone imagery data, rainfall measurement, total suspended solids (TSS) (collected by the City of River Falls), and discharge (at USGS gage 05342000 located at County Road F) were also used in this analysis for comparison purposes.

Results

Orthoimage results are provided in Appendix A of this memo. The drawdown of the Lake Louise impoundment began on October 2nd. Imagery collected on October 4th shows the initiation of channel formation with a riffle forming between cross-sections 1 and 2. TSS measurements downstream of the dam show and increase from 4 mg/L on October 2nd to 104 mg/L on October 4th. Measured channel width was between 75 and 128 ft (Table 1).

By October 10th, continuing incision of the channel caused TSS to increase downstream of the dam peaking at 1370 mg/L on October 7th before falling 283 mg/L on October 10th. On October 10th, the channel was relatively straight, though possible indications of the beginning of meander development were present downstream of cross-section 2. Measured channel width had narrowed to between 36 and 48 ft (Table 1). The abandoned sewer pipe at the upstream end of the study was also clearly exposed.

A 1.83-inch rainfall event occurred on October 12th which temporarily refilled the impoundment. Mean daily discharge rose from 134 cfs on October 11th, to 192 cfs on October 12th. TSS spiked on October 13th to 3081 mg/L in response to this event. Drone imagery collected on October 15th showed channel change in response to this event. Most apparent was the development of two meanders between cross-sections 2 and 3, the realignment of the channel to the right at cross-section 2, and the development of a riffle at cross-section 3. On October 15th, TSS was 768 mg/L and measured channel width varied between 33 and 37 ft (Table 1).

Imagery collected on 10/18, 10/24, 11/02, 11/16, and 12/11 showed the continuation of channel development. TSS continued to fall and was at 49 mg/L on 11/4. Channel width remained between 30 and 50 feet at the sampled cross-sections (Table 1). A scallop bank downstream of cross-section 3 on 10/24 developed into a meander by 11/16. Together the imagery collected between 10/18 and 12/11 showed the continued development of the two meanders between cross-sections 1 and 2 (though the inside bank remained relatively stationary), the continued widening of the channel, and the development of the meander near cross-section 1.

Table 1: Channel width estimated from drone imagery at sample cross-sections

Date	Cross-Section 1 Channel Width	Cross-Section 2 Channel Width	Cross-Section 3 Channel Width
10/04	99	75	128
10/10	48	38	36
10/15	33	33	37
10/18	45	33	30
10/24	40	41	34
11/02	40	31	30
11/16	40	35	35
12/11	46	36	36

Discussion

On the ground photos collected on 11/25 showed near vertical banks which were approximately 12 ft high near the dam and gravels on the channel bottom (Figure 3). Assuming a wedge shape of sediment along the length of the channel between the dam and abandoned sewer crossing with an average width of 39 ft, 10,790 cubic yards of sediment may have been release due to the drawdown. Ayres (2020) estimates that 8,000 cubic yards of sediment may have been released due to the drawdown. Since no bathymetric survey was done before the drawdown occurred, the exact amount of sediment released during the drawdown cannot be accurately quantified. The range provided by the Inter-fluve and Ayres reports provides a reasonable range of the sediment volume released during the drawdown. The most recent sediment volume estimates by Ayres (2020) suggest that 200,000 cubic yards of sediment are currently stored in the impoundment, and that 80,000 cubic yards total is likely to be mobilized if the drawdown continues.

To put these volumes into context and help visualize the potential downstream impact, volumes are converted into idealized sediment depths within the river channel (Table 2). These calculations follow the same procedures as previously presented (Inter-fluve 2017) by assuming that 80% of the excavated sediment volume is sand sized and is uniformly deposit entirely within the river channel immediately downstream of the dam. These calculations show that enough sediment has already been released from the impoundment to cover the mile of stream channel downstream of the Powell Falls Dam with 0.5-0.7 ft of sediment. The total volume of sediment likely to be mobilized is enough to cover 5 miles of stream channel with over 1 foot of sediment. These numbers are meant purely for visualization purposes. In reality, sediment deposition thickness will vary widely and occur outside the river channel on the floodplain as well as within the channel.

Table 2: Idealized in-channel sediment deposits assuming sediment is uniformly deposited within the channel.

Total Sediment Volume Released (cyd)	200000	80000	10790	8000
Sand Fraction (assume 80%; cyd)	160000	64000	8632	6400
Depth of sediment deposition over 5 miles (ft)	2.9	1.2	0.2	0.1
Depth of sediment deposition over 2 miles (ft)	6.9	2.7	0.4	0.3
Depth of sediment deposition over 1 mile (ft)	13.7	5.5	0.7	0.5

Gravels on the channel bottom may indicate that the channel has reached its pre-dam elevation and initial incision of the channel is nearing completion (Figure 3). However, the gravels may also be unassociated with the pre-dam channel and represent a coarse layer deposited in the impoundment or a coarsening layer caused by the winnowing (removal) of fine-grained sediment. The near vertical banks are unstable and will continue to erode and calve into the channel even under relatively low flow conditions. Immediately downstream of the Powell Falls Dam, several mid-channel bars have developed following the drawdown (Figure 4). These bars are composed primarily of the sand sized sediment eroded during the drawdown as the new channel was excavated. Finer grained sediment was transported further downstream as suggested by the increased turbidity during the drawdown. The deposition immediately downstream of the dam is temporary and larger floods are expected to transport the sediment further downstream and may lead to the burial of gravel riffle substrates, which are the most abundant and beneficial aquatic habitats located downstream of the Powell Falls dam (Inter-Fluve 2020a).

Unstable banks and a narrow channel compared to reference and pre-dam conditions indicate that the channel is still undergoing ‘process-driven’ sediment removal. The ‘process-driven’ sediment removal is expected to continue until the channel has widened to the point where it can convey bankfull flows (60-65 ft bottom width, 3-4 ft mean depth, and 3:1 side slopes; Inter-fluve 2017). Once the channel has achieved these dimensions, sediment removal will likely follow an ’event-driven’ trajectory with major sediment release typically occurring only following flood events. For reference, Collins et al. (2017) suggest that major sediment release will typically occurring following a 5-year flood event. In the Kinnickinnick River watershed a

5-year 24 hour rainfall event is 3.79 inches (USGS Streamstats) and the 5-year recurrence interval bankfull discharge is 2314 cfs (Inter-fluve 2017). However, these values are only rough estimations of when sediment release will occur during the 'event-driven' phase since numerous other factors such as vegetation establishment, impounded sediment cohesiveness, and channel armoring will influence sediment release timing.

Figure 3: Photo of the channel collected on 11/25.

Figure 4: Drone image collected on 12/11 above the Powell Falls dam showing bar development immediately downstream.

Conclusions

While the dam remains in-place, outflow is limited by the dimensions of the sluice gate and the impoundment is expected to temporarily refill during large rain events (Ayres 2020). The refilling of the impoundment will help minimize the erosion of impounded sediment during flood events by decreasing shear stress along the channel banks. However, since erosion is minimized during large flood events, the amount of time it will take to transition fully to an 'event-driven' phase is expected to be longer compared to similar size dams. Excavation of a pilot channel would limit the amount of sediment eroded from the impoundment during normal flows, however it would have only a minor influence during high flows, since the dam already the dominate control.

In the planned removal of the Powell Falls Dam, excavation of all or a significant portion of the potentially mobile sediment would mitigate effects on downstream habitats and ecosystems. At minimum, excavation of a pilot channel should be completed. This will sufficiently replicate the 'process-driven' erosion so that the majority of erosion will follow an episodic 'event-driven' trajectory. With the pilot channel excavated, the river within the former impoundment would function similarly to downstream reaches and, overtime, naturally create floodplain riparian area, pools and riffle, and other habitat features.

If desired by local stakeholder groups and necessary funds secured a full restoration could be designed and constructed. This would include the installation of habitat features (a detailed list of potential habitat features is provided by Inter-fluve (2017)) within the former impoundment. Habitat features would provide an immediate and ecological benefit to aquatic and riparian species and, with planting, would provide an immediate aesthetic benefit to the community. Additional elements such as riverside trails and access points could also be incorporated into the restoration plan.

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