Downstream Channel Impacts of Reservoir Sediment Management

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Kansas City District
River Engineering and Restoration Section

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Outline

- Natural rivers
- Effects of drawdown flushing
- Effects of sediment bypass
Impacts from Lack of Turbidity: Colorado River

- Humpback Chub numbers have decreased substantially and they are now federally protected.
- One primary reason is that the Colorado River used to be usually over 1000 FNU, but after construction of Glen Canyon Dam now is usually below 50 FNU. The small chub become easy prey for trout species in clear water.

David Ward and Rylan Morton Starner, USGS, Grand Canyon Monitoring and Research Station

Brown trout
mean TL = 261 mm

Humpback chub
mean TL = 56 mm
Unregulated Rivers Experience High Sediment Loads During Floods

Missouri River at Sioux City, IA. Data is approximate for demonstration purposes only.
Downstream Impacts Depend On Two Major Factors

1-How closely does the management option match the natural timing, concentration, and gradation of incoming sediment load?

2-What the downstream channel is “used to”
   - Historically-turbid Midwest stream vs. Historically-clear mountain stream
   - When was the downstream channel infrastructure built (and for what conditions?)
Effects of Drawdown Flushing

US Examples
- Willwood
- Spencer Dam
- Fall Creek

Minimizing Downstream Channel Impacts
The Willwood Diversion Dam was built in 1924 and still contains some original equipment that could only be replaced by drawing the water behind the dam down.

Piles of sediment have built up behind the Willwood Diversion Dam, which was built in 1924.
This view looks downstream from the dam.
Spencer Dam Flushing
Spencer Dam Fish Kills- 1977-1979

Hess and Newcomb (1982) document fish kills

DO dropped to 3.1 mg/L

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Spencer Dam: Operational Changes since 1989

The pool is drained slowly before the flushing begins.

“The operational modifications of raising the gates slowly and dropping the hydro pond at a reduced rate has been successful in avoiding fish kills since 1989.”

--Gutzmer, King, and Overhue 1996

“It appears that with environmentally friendly ways to pass sediment, fish below Spencer Dam survive and express resilience to conditions created by sluicing.”

--Gutzmer, King, Overhue, and Chrisp 2002
Suspended Sediment Loads
Fall Creek Outflow – 2012/13

- Pre-drawdown: 4,300 tons (34 days)
- Drawdown: 51,600 tons (6 days)
- Post-drawdown: 4,030 tons (53 days)

Schenk and Bragg (2014)
“During the drawdown, DO data at Fall Creek Outflow decreased rapidly at the onset of the large sediment release from approximately 13 mg/L to a minimum value of 6.50 mg/L.”
Dissolved Oxygen and Turbidity, November 2015

Fall Creek below Winberry Creek, near Fall Creek, OR (14151000)

Dissolved Oxygen (mg/L)

Turbidity (FNU)

“DO at Jasper decreased slightly during the drawdown to a minimum value of 11.63 mg/L, suggesting that although a small effect is possible, the sediment release from Fall Creek Lake did not cause a rapid decrease in DO approximately 10 river miles downstream of the dam.” --Schenk and Bragg (2014)
Fall Creek Sediment Flushing

- Ten-fold increase in the adult salmon that later return to Fall Creek
- No observed fish kills
- In-reservoir: Removal of invasive species, significant increase in natural populations
Effects of Drawdown Flushing

US Examples

- Spencer Dam
- Fall Creek
- Willwood

Minimizing Downstream Channel Impacts
Minimizing Downstream Impacts

- Mimic natural conditions
  - Max SSC = flood SSC
  - Time of year = natural flooding time of year

- Minimize fish impacts
  - Assess with Severity Index
  - Dilute sediment discharges
  - Alternate clear water and sediment laden discharges
Newcomb and Jenson (1996) Meta Analysis

- 80 studies
- Six simple, empirical equations relating severity of ill effects on fish to
  - SSC in mg/l
  - Duration in hours

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<td>&gt;80–100% mortality</td>
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### Juvenile and Adult Salmonids

**Duration of exposure to SS (log\_e hours)**

![Duration of exposure to SS (log\_e hours)](image)

**Average severity-of-ill-effect scores (empirical)**

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Adult Freshwater Nonsalmonids

Duration of exposure to SS (log$_e$ hours)

(A)

Average severity-of-ill-effect scores (empirical)

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## Adult Freshwater Nonsalmonoids

### Duration of exposure to SS (logₑ hours)

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### Average severity-of-ill-effect scores (calculated)

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**Note:** The table shows the average severity-of-ill-effect scores for different concentrations and durations of exposure to SS.
For more information:

Newcombe, C. and Jensen, J. 1996.

“Channel Suspended Sediment and Fisheries: A Synthesis for Quantitative Assessment of Risk and Impact”

Lake Como (Italy)

Lake Como (Italy)

- Non-consecutive days
  - 2009: 16 days from 23 May to 10 July
  - 2010: 6 days from 8 July to 20 July
  - 2011: No flush

- SSC Thresholds:
  - 1,500 mg/L daily average
  - 3,000 mg/L alert value to adjust ongoing activity

Lake Como (Italy)

- Total sediment removed:
  - 2009: 75,000 tons in 16 days
  - 2010: 24,000 tons in 6 days
  - 2011: No flush

- 44% fines
- 54% sand
Results

- Macroinvertebrates
  - Seasonal changes, no change during flush years vs. non flush year
- Bullhead (EU protected)
  - Increase in density
- Brown trout
  - No impact
Outline

- Natural rivers
- Effects of drawdown flushing
- Effects of sediment bypass
Two types of bypass (as far as the downstream channel is concerned)

1-Options that raise the base-level SSC

2-Options that raise the flood-related SSC

If “raise” = “restore” the effect is generally positive from an ecological perspective, though there could still be infrastructure concerns.
Solis Reservoir, Switzerland

Map of Solis Reservoir showing sampling points along the Albula River and the Prodavosbach stream. The map includes a scale indicating distances of 0, 0.5, and 1 km. Key features include:

- Sampling points marked with circles.
- SBT and SBT outlet marked with special symbols.
- Flow direction indicated with an arrow.

Source: Martin, Doering, and Robinson, 2017
Solis Reservoir, Switzerland

Oertli and Auel, 2015
Downstream Discharge

Oertli and Auel, 2015
Solis Reservoir, Switzerland

Measured
- Chemical properties
- Sediment respiration
- Benthic organic matter
- Sediment size distribution
- Periphyton and macroinvertebrates

5x/year for two years
Solis Reservoir, Switzerland: Conclusions

- Sediment Bypass Tunnel (SBT) discharges induced effects in the downstream channel typical of natural flooding.

  “In the short term, SBT operations can increase the flow/sediment variability that is often lost in flow-regulated rivers.”

- “A permanent positive change in the system would take several years of adaptive management operations, similar to experimental floods.”

- “In conclusion, we found that SBTs, if ecologically implemented (i.e. having the operational characteristics similar to the natural flood features of a system), can improve the longitudinal connectivity of sediments of rivers impounded by dams. Indeed, SBT events can be used as environmental flows to simulate more natural flow/sediment regimes of receiving waters.”

Martin, Doering, and Robinson, 2017
Conclusion

✓ ▪ Natural rivers
  ► How closely does the sediment discharge match the natural, no-dam conditions?

✓ ▪ Effects of drawdown flushing
  ► How can the sediment concentrations be limited to acceptable severity levels?

✓ ▪ Effects of sediment bypass