Reservoir Sediment Management Options For Long-term Sustainability

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Sediment Management Options

Minimize sediment inflow

React to sediment accumulation

Sustainable Management
Reservoir Sediment Sustainability

“What comes in, must go out!”

“Available Storage

Sediment-rich water

Sediment-rich water
Lake Dredging Costs

- John Redmond: $6.5/cu yd
- Mission Lake: $6.5/ cu yd
- Lake Seminole: $27/ cu yd
- Kanopolis: $229 / cu yd
Dredging in Perspective

- Cost for dredging all 8 federal reservoirs in the Kansas River Basin:
  - At $6.5/yd³
  - $105+++ million/year
  - $151/person each year

<table>
<thead>
<tr>
<th>Department</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health and Environment- Environment</td>
<td>$4,440,934</td>
</tr>
<tr>
<td>Department of Agriculture</td>
<td>$9,894,366</td>
</tr>
<tr>
<td>Kansas Water Office</td>
<td>$1,154,576</td>
</tr>
<tr>
<td>Department of Wildlife, Parks, and Tourism</td>
<td>$5,151,993</td>
</tr>
<tr>
<td>Department of Wildlife, Parks, and Tourism</td>
<td>$20,641,869</td>
</tr>
</tbody>
</table>
Sediment Bypass

Sediment bypass at Nagle Dam, South Africa (Figure from Annandale 2013)

Sediment bypass tunnel at Miwa Dam, Japan (Figure from Annandale 2011)
Sediment Bypass

- **PRO**
  - Passes sediment during high flows (more natural)

- **CON**
  - Very expensive retrofit for existing facilities
  - Doesn’t pass 100% of sediment
Solis Reservoir, Switzerland

Oertli and Auel, 2015
Downstream Discharge

Oertli and Auel, 2015
### Effectiveness

<table>
<thead>
<tr>
<th>1987 Flood (No SBT)</th>
<th>2014 Flood (with SBT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>252 m³/s</td>
<td>288 m³/s</td>
</tr>
<tr>
<td>248,000 m³ deposition</td>
<td>102,000 m³ deposition</td>
</tr>
</tbody>
</table>
Sediment Pass-through (aka routing, aka sluicing)

Flood Flow
Full of Sediment
High velocity

Backwater from reservoir
Low velocity
Depositional

Clear water discharge
Sediment Pass-through (aka routing, aka sluicing)

- Flood Flow: Full of Sediment, High velocity
- Backwater from reservoir: Low velocity, Depositional
- Slightly more turbid release
Sediment Pass-through (aka routing, aka sluicing)

- Rising limb of hydrograph
- High sediment concentration
- Falling limb of hydrograph
- Low sediment concentration

Discharge (cfs)

Time (hours or days)
Sediment Pass-through (aka routing, aka sluicing)
Reservoir Drawdown Flushing

Draw down the reservoir
Reservoir Drawdown Flushing

Draw down the reservoir
Reservoir Drawdown Flushing

Draw down the reservoir
Reservoir Drawdown Flushing

Very high sediment load
Reservoir Drawdown Flushing

Very high sediment load

Headcuts and “bank” erosion move upstream

Very high sediment load
Reservoir Drawdown Flushing

Very high sediment load

Headcuts and “bank” erosion move upstream

Very high sediment load
Reservoir Drawdown Flushing

Very high sediment load

Headcuts and “bank” erosion move upstream

Very high sediment load
Reservoir Flushing: Fall Creek
Reservoir Flushing: Spencer Dam
Reservoir Flushing: Spencer Dam
Gebidim Dam Flushing
Reservoir Flushing: Problem!

Most reservoirs don’t have flushing gates.

Inlet above the bed.
Reservoir Flushing

**PROS**
- No external power
- No land needed
- Significant sediment removal

**CONS**
- Uses ALL the water
- Sediment-laded effluent – high concentration short duration
- Potential downstream impacts
- Will not usually flush out the “floodplain” i.e. maintained reservoir storage may be less than the original
Hydrosuction
Hydrosuction

Siphon up the sediment

Bucket Demo:
https://www.youtube.com/watch?v=A8Wksyl4Nnw&feature=youtu.be
Hydrosuction

Siphon up the sediment

Height constraint
Dredging with Downstream Discharge of Sediments

Siphon up the sediment

Dredge
Hydrosuction

Go through the dam, abutment, or spillway
Hydrosuction in the United States

- Experimental installation on Grove Lake, NE
  - 3,000 ft 6-inch PVC pipe
  - Sand balance restored for more than 5 years
Hydrosuction Internationally

Sedicon
Santa Maria HPP, Guatemala
Santa Maria HPP, Guatemala
Santa Maria HPP, Guatemala
El Canada Reservoir
El Canada Hydrosuction
El Canada Hydrosuction-Connecting to Existing Conduit

Fig. 2.

Bypass connection to existing drainage pipe (a) side view (b) downstream view
El Canada Hydrosuction-Floating Barge
El Canada Hydrosuction-Discharge
Results

- ≈ 157,000 cy in first 6 months

<table>
<thead>
<tr>
<th>Year</th>
<th>Concentration</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>12%</td>
<td>86%</td>
</tr>
<tr>
<td>2013</td>
<td>9%</td>
<td>98%</td>
</tr>
<tr>
<td>2014</td>
<td>8%</td>
<td>98%</td>
</tr>
</tbody>
</table>
Inlet Extension Analysis at Tuttle Creek Lake
Inlet Extension Analysis at Tuttle Creek Lake

Dam safety concerns
### Table 2: Summary of results for the three (3) design options.

<table>
<thead>
<tr>
<th>Option</th>
<th>Cavitation</th>
<th>Design Flow Velocity [ft/s]</th>
<th>Design Flow Rate (ft³/s)</th>
<th>Estimated Production Rate [10⁶ yd³/yr] (6% solids)</th>
<th>Maximum Pipe Elevation Above Reservoir without Cavitation [ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>28 – 29</td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>28 – 29</td>
</tr>
<tr>
<td>3 (1 Pipe)</td>
<td>No</td>
<td>8.9 – 19.1</td>
<td>28 – 60</td>
<td>2.0– 4.2</td>
<td>N/A</td>
</tr>
<tr>
<td>3 (2 Pipes)</td>
<td>No</td>
<td>8.9 – 19.1</td>
<td>56 – 120</td>
<td>4.0 – 8.4</td>
<td>N/A</td>
</tr>
</tbody>
</table>

1 pipe: 26 to 54% of annual sediment load
2 pipes: 52 to 109 % of annual sediment load

Important: Would require drilling a hole into the side of the current inlet works.
An Option for Tall Dams: Notch
The Spillway
An Option for Tall Dams: Notch The Spillway
An Option for Tall Dams: Notch The Spillway
Capture Zone (Aprx. 6500 ft)

2-2 ft diam. Flexible HDPE Pipes, 3000 ft each.

2-2 ft diam. Ductile Iron Pipes, 3500 ft each.

2400 linear ft
2-2 ft diam. Ductile Iron Pipes
10 ft diam. tunnel

0 0.125 0.25 0.5 Miles
Summary

- Dredging with land disposal
- Dredging with downstream discharge
- Bypass
- Pass-through (routing, sluicing)
- Drawdown flushing
- Hydrosuction (up-and-over or through)
- Density current venting