Why and How to flush a reservoir without environmental impacts

FRUCHART Francis

Regional Workshop on Discharge and Sediment Monitoring and Geomorphological Tools for the Lower-Mekong Basin
Vientiane, Lao PDR, 21-22 October 2008
Why allow sediment to pass dams?

Effect of sedimentation
- upstream of the dam (reservoir) - downstream of the dam

Is it better to let sediment stay in the reservoir?

‘Hard Flushing’ or ‘Environmentally Friendly’ flushing?

How to flush the sediment while minimizing environmental impacts?

Is there an incentive for hydropower plant owners to flush?
Material transportation in rivers

Suspension
fine materials

Bed load
coarse materials

threshold $\tau > \tau_c$
Sedimentation in a reservoir

- Fine materials (suspension)
- Coarse material (bed load)

Storage capacity

Dead volume

≈ zero except some wash load
Bottom gate flushing

Maintain bottom gate use
Necessary for security
Uncontrolled concentration downstream
Best practice: operation during a flood
Hard flushing:
High and uncontrolled concentration downstream
Destruction of the biodiversity downstream
Best practice: no flushing?
No Flushing:

- No more storage capacity
- Fine sediment reaches the turbine
- Pipes and turbine damages by erosion
Flush the coarse materials = bed load
Flush the fine materials First
Flood is needed
Appropriate bottom gate
Miwa dam  Japan

- Construction completed in 1959  Reservoir 37 million $m^3$
- In 1972 Sedimentation reached 10 million $m^3$  in 1982:  + 4 million $m^3$
- objective: preserve the volume of the reservoir - no regard to environment
Miwa dam Japan – bypass tunnel

- Diversion tunnel 4.3 km
- MIWA dam
- MIWA dam
- Sediment dam
- Diversion weir

685,000 m³
500,000 m³
400,000 m³
73%
Environmentally Friendly Flushing ©

to send downstream only the concentration of sediment that the environment can withstand

Hard flushing: to send as much sediment as possible downstream

© WWF Marc Goichot
CNR developments along the Rhone river, France
- 1 dam
- 17 run of the river developments
Run of the river development scheme

± transparent to present solid transportation
Upper Rhone river France - Switzerland

Geneva lake

Chancy Pougny dam

Verbois dam

Seujet barrage

Mont Blanc

Verbois

Sedimentation 500 000 m³/year

Genissiat dam
Geneva lake Switzerland

Seujet barrage

Verbois dam Switzerland
Chancy Pougny dam
Switzerland – France border

Genissiat dam France
Flushing Verbois-Chancy-Genissiat dams organized every 3 years since 1970. Duration 1 week.

Upper Rhone river France - Switzerland
Rhone river - Genissiat dam

Head 67 m
6 turbines  66 MW 125 m³/s
Total volume 52 millions m³
Used volume 12 millions m³

1 bottom gate
1 mid depth gate
1 spillway
Longitudinal narrow reservoir
Steep cliffs
General purpose
Prolong the life time of the Genissiat reservoir
Transit of the sediments sent by Swiss dams

3 main issues of the flush
1. Guarantee acceptable concentrations downstream
2. Guarantee the biodiversity of the old Rhone river Chautagne, Belley, Bregnier-Cordon run of the river developments downstream
3. Guarantee 125 m³/s for cooling the Bugey nuclear power station downstream
reservoir

downstream
Downstream concentration limits to be respected:

- 5 g / l average
- 10 g /l 6 hours max
- 15 g /l 30 minutes max

Monitoring in real time

- Water levels
- Suspension concentration
- Water quality, oxygen, Water Temperature, Bacteriology (bath areas), Toxicology (sediments)
- Clogging of spawning area

+ Before and after the flush: Electrical fishing
gradient of concentration in the reservoir

- no suspension
- suspension with gradient of concentration
- uniform suspension

concentration gradient

in the reservoir
C = 1g/l
C = 20 g/l
Concentration 20 g/l peaks up to 80 g/l
Weak concentration
C = 1g/l

600m³/s

Half depth gate
C1 Q1
Bottom gate
C2 Q2

gate discharge regulation
Concentration 5g/l

REAL TIME Concentration measurement
Suspension concentration measurement - $\gamma$ ray device

Continuous measurement:
- Gamma ray densimetry
- Bottom gate
- Mid depth gate
- 6 km downstream
by authorized specialists

+ Punctual measurements:
  - Picnometer (density measurement)
  - Pancake (quick drying)
Run of the river development management downstream

- Ecological discharge cancelled
- Discharge with suspension through the power station
- Monitoring Temperature...
2003 Genissiat reservoir flushing assessment

- **no damage to the environment**
- **Heavy organization**
  - 2 country close cooperation
  - 80 people involved during 1 week
  - lot of monitoring over 150 km
  - 30 year experience
- **Efficient**
  - output ≈1 600 000 tons > input
  - Cost 1.5 M€ -loss for energy- staff
  - Dredging cost effectiveness very good ≈1 € /ton
Flushing a cascade of dams

Need of appropriate structures for each dam

Appropriate bottom gate and at least mid depth gate for the downstream dam
Impact of dams downstream
Downstream effect of dams on river morphology

Material transportation
Siltation in the reservoir

Bed aggradation (sedimentation) downstream of the dam despite embankments

Hydraulics
Decrease of the floods downstream (morphogenic discharge)

Hoa Binh dam - capacity 5 Billion m³

CNR study for CPO MARD Vietnam

Thao River
Red River
Da River
Dams should be transparent:

• to sediment transport
  (suspension and bed load)

• to morphogenic floods (average floods)
Material transport capacity of the river downstream?

Material transport from the tributaries?

Sea shore stability problems?
Conclusion

• **Flushing a reservoir is complicated**
  Appropriate structures to be included in the design
  Take into account:
  – effect of the reservoir on flood mitigation
  – existing morphology and environment downstream
  Comprehensive morphological view needed - upstream - downstream

• **‘Environmentally friendly flushing’**
  Important organization with real time monitoring
  Advantages:
  Maintain the storage capacity of the reservoir
  Cost effective alternative to dredging
  Respects environment and morphological equilibrium of the river
For the Mekong river
Thanks
Xiexie nimen
Xin cam on
Kop Khun kha
Khob jai
Tjé zu bé
Or kun
Merci