KTH ROYAL INSTITUTE OF TECHNOLOGY

Safe operation of bottom outlets

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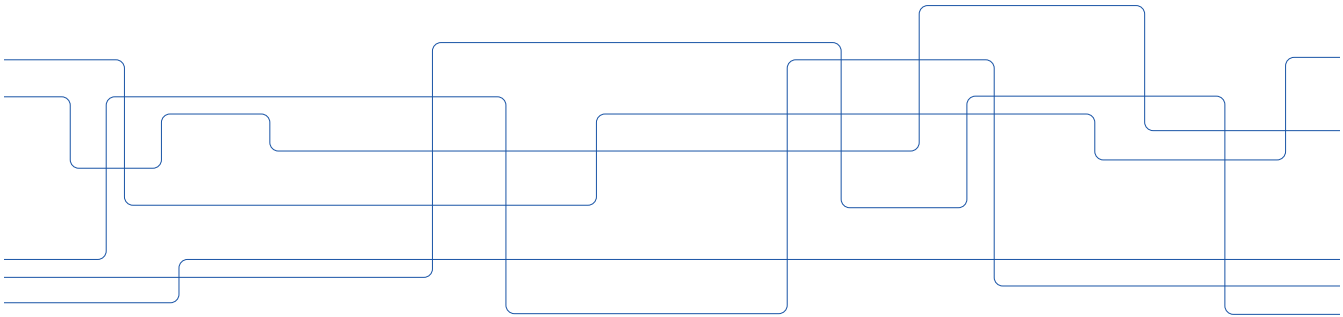


Bottom outlets

- Discharge floods
- Empty reservoirs
- Removing sediment

Air entrainment in bottom outlets

- 8/24 bottom outlets with airflow related issues*
- Vibration
- Blowouts
- Lower discharge capacity
- Structural damages

	Typ 1	Typ 2	Typ 3	Typ 4	Typ 5	Okänd typ	**Summa**
Rapporterade problem	1	4	1	1	2	0	**9**
Rapporterade problem direkt relaterade till luft	1	4	1	0	2	0	**8**

Typ 1: Bergtunnelutskov, Typ 2: Schaktutskov med delvis trycksatt vattenväg, Typ 3: Kulvertutskov, Typ 4: Utskov med ingen eller mycket kort vattenväg, Typ 5: Kombinerat yt- och bottenutskov.

*Dath, J.; Mathiesen, M., Förstudie hydraulisk design: Inventering och översiktlig utvärdering av bottenutskov i svenska dammanläggningar.

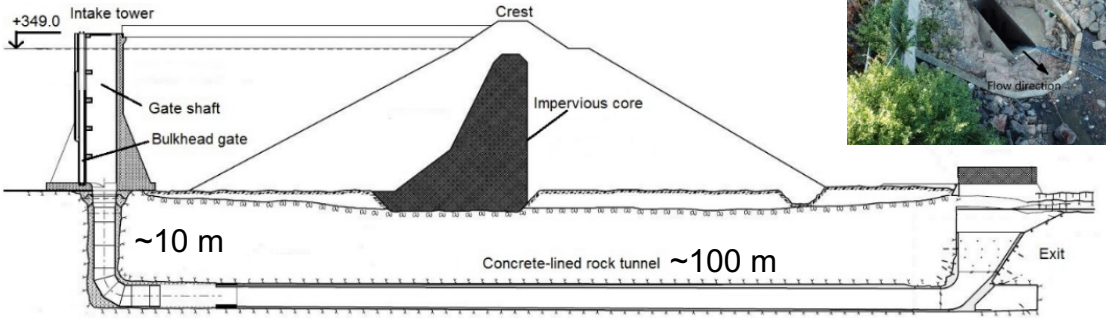
Air entrainment in bottom outlets

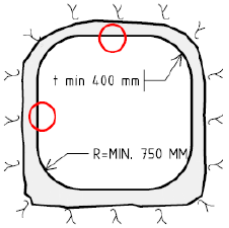
- Common problems
- Air-water interactions
- Mitigation measures for safe operation

Letafors

Grundsjön

Project layout



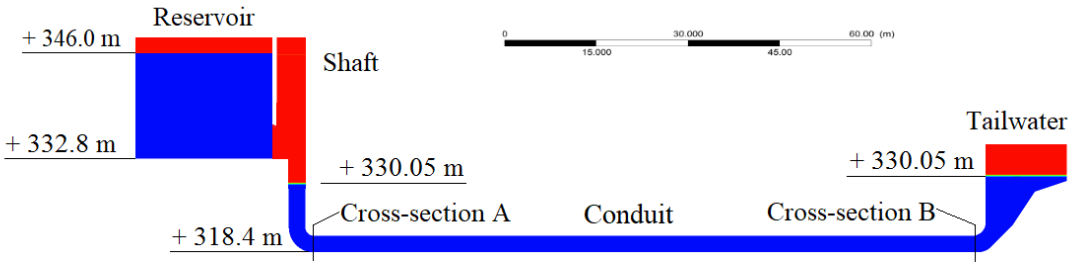


Field tests

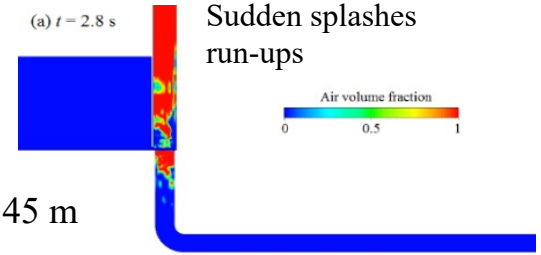
- Z_{us} = 346 m (3 m below FRWL), Z_{ds} = 330 m.
- H = 0.3 m, Q = 10 m^3/s
  Blowouts, F = 30-35 s, T = 8-10 s, h = 4-5 m
- H = 0.4 m, Q = 14 m^3/s
  More air entrainment, intensive upsurges and blowouts
- H = 0.5 m, Q = 16 m^3/s
  Continuous blowouts, longer duration, vibration, noise

CFD simulations

- Z_{us} = 346 m (3 m below FRWL), Z_{ds} = 330 m
- H = 0.45 m, H = 0.8 m

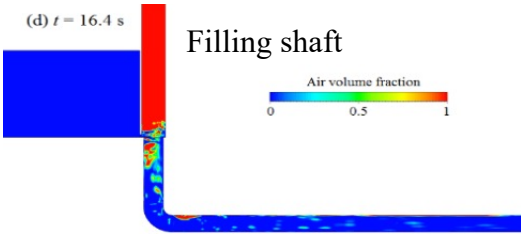


Air entrainment

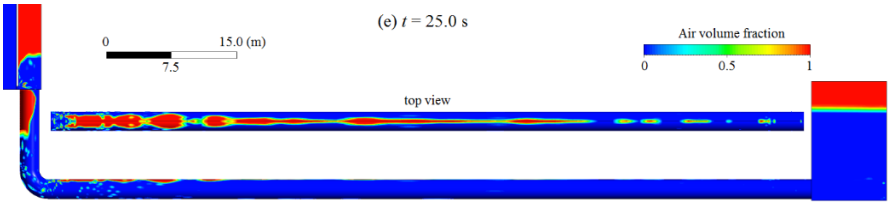


Sudden splashes
run-ups

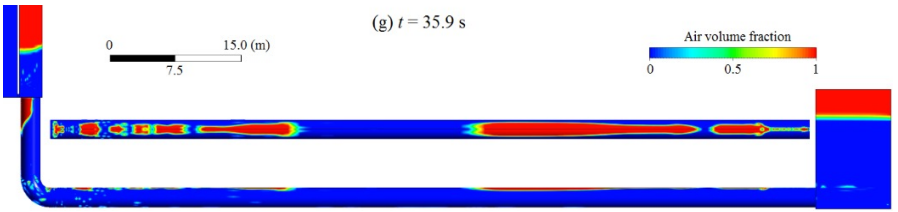
H = 0.45 m



Filling shaft

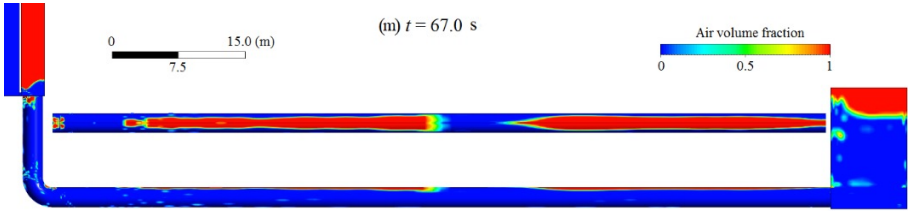


Fluctuation
Large air pocket

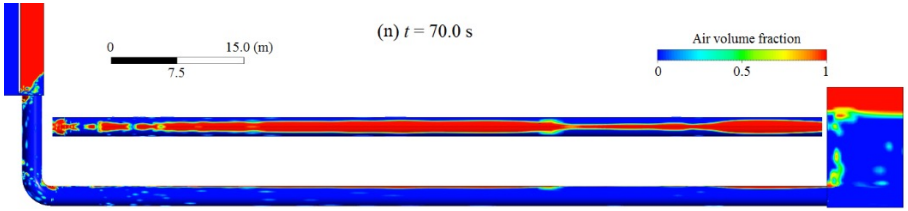


Accumulation
Breakup

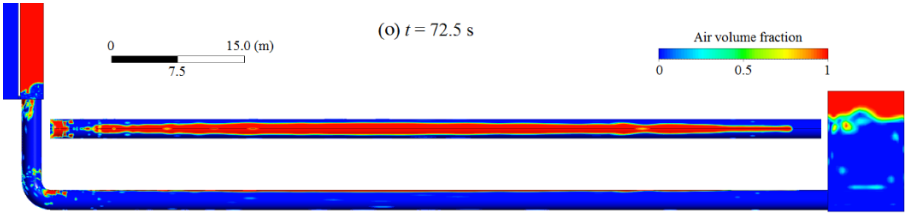
Air entrainment



Blowout
h = 4.2 - 4.8 m

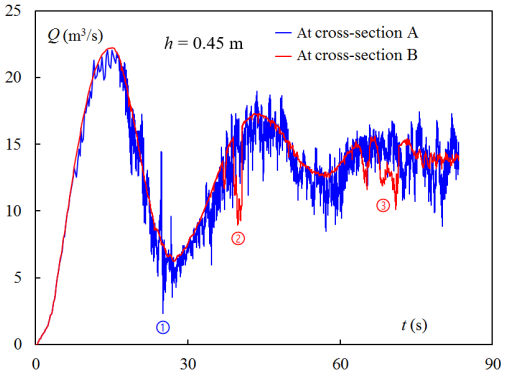


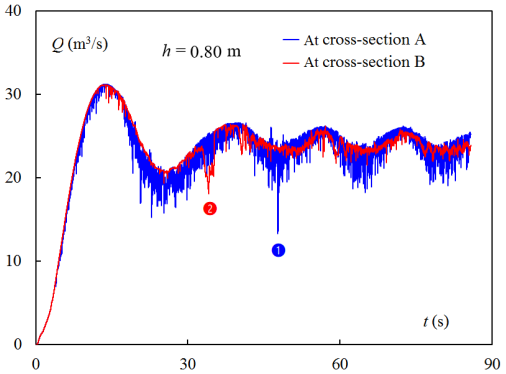
Negative bore



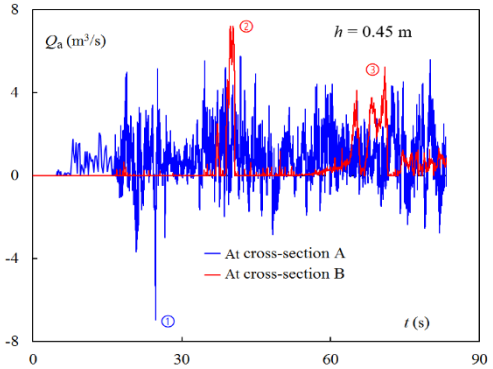
Air-water flows

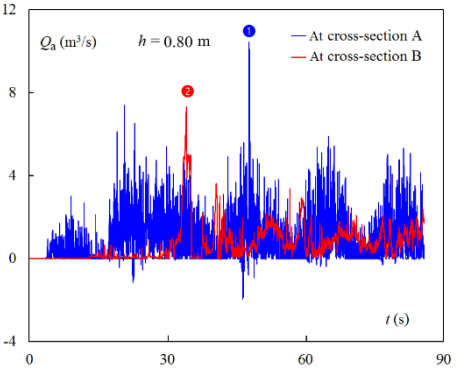
Q water



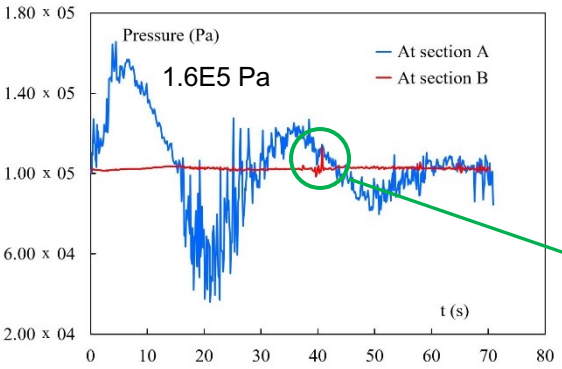


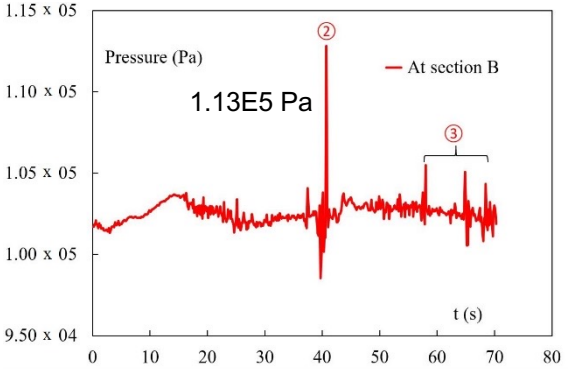
Q air

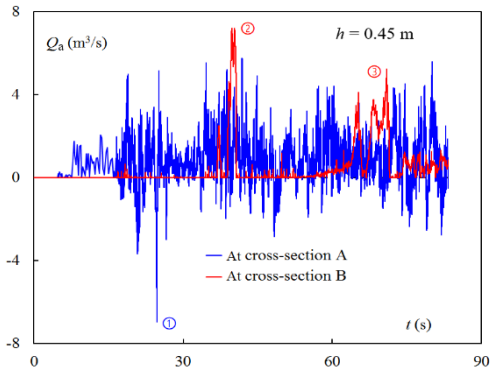




Pressure fluctuations

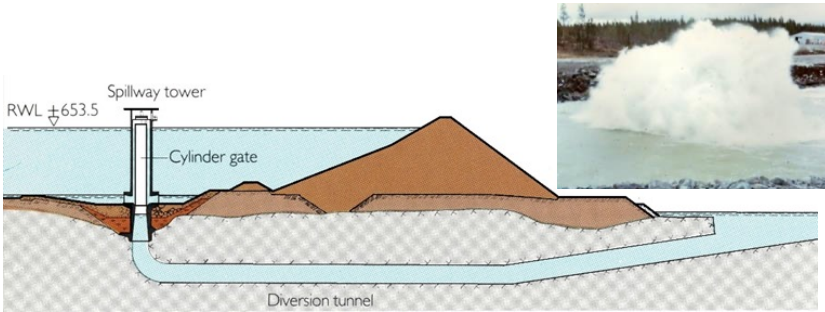


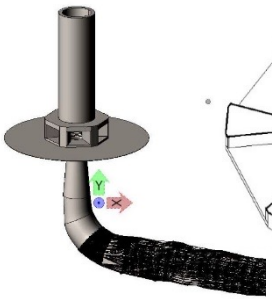


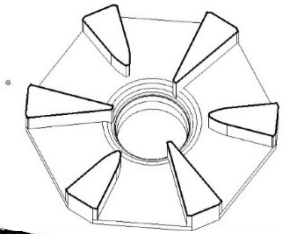


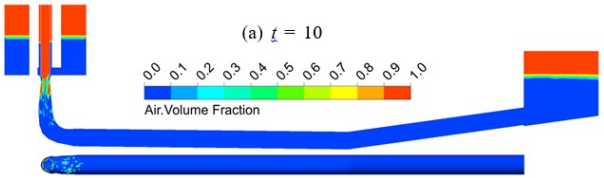
Another bottom outlet

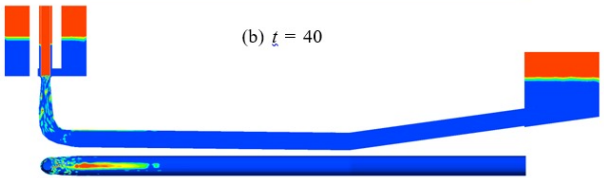
- Accumulation, breakup, blowout

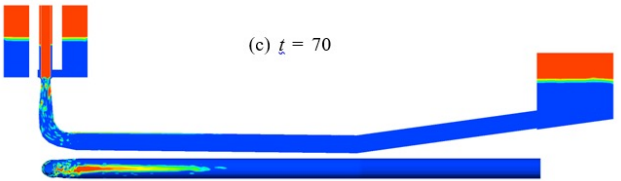


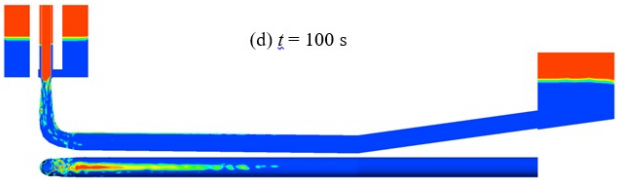






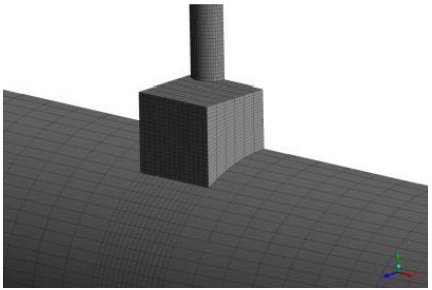


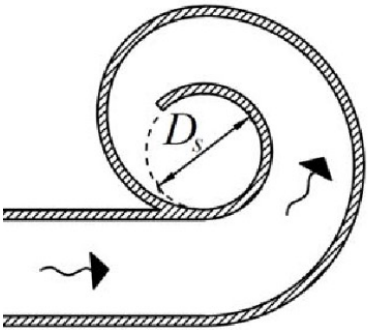


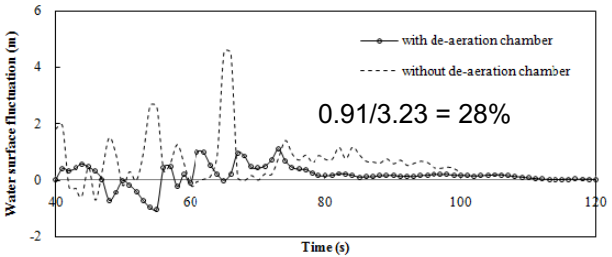


Mitigation measures

- Deaeration
- Intake optimization







Summary

- Air flows cause serious problems (vibration, blowouts, etc.)
- Air entrainment and detrainment
- Mitigation measures

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