Piping and erosion in the buffer; Results from downscaled tests

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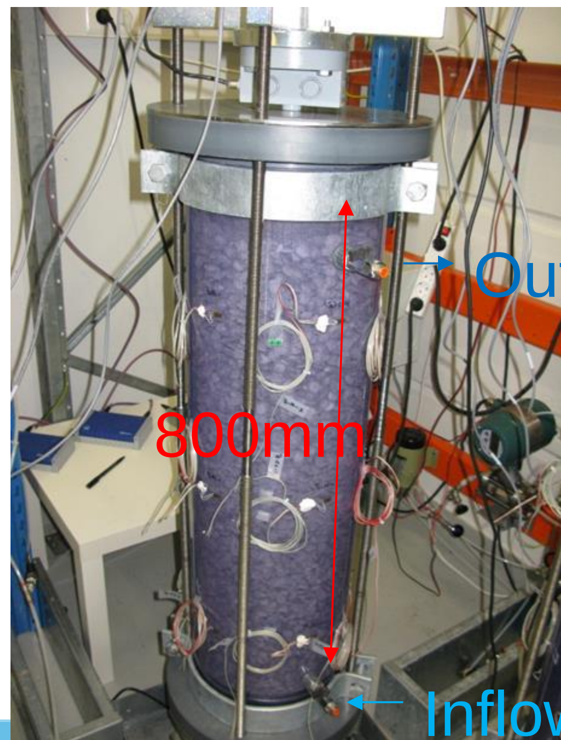
Outline

- Overview of downscaled buffer erosion tests
  - ”scale 1:6” (or ~ 1m)
  - time ~4 months
  - maximal inflow (Olkiluoto) case: 0.1 l/min
- Statistical analysis of erosion measured from outflow
  - 7 tests
  - ~2.5 years of total test time
  - ~128 m^3 of water through buffer bentonite
- Results
  - Erosion is constant in time
  - Erosion is remarkably unsensitive to setup details

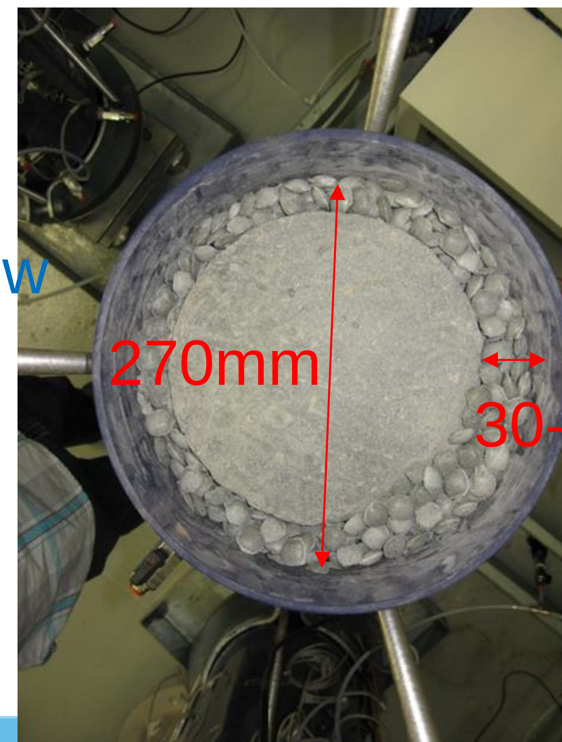
The transparent, downscaled buffer test ”Transu & X-Boy”
(X. Pintado et al., Posiva WR 2012-100)

- MX-80 blocks and pellets
- Point-like inflow, 0.1 l/min
- Erosion rate: outflow clay content measured by drying

X-Boy



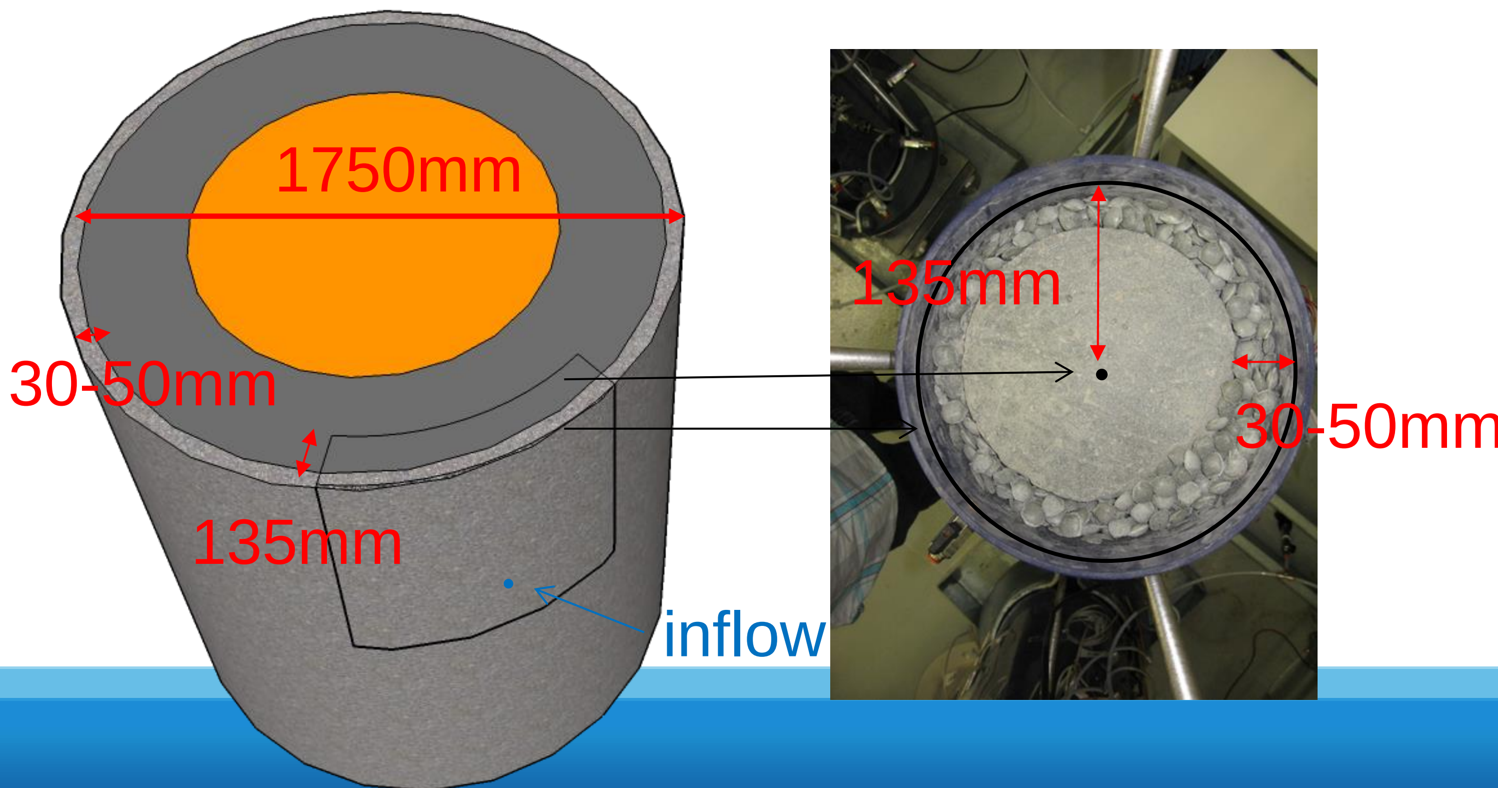
Transu



The transparent, downscaled buffer test ”Transu & X-Boy”

(X. Pintado et al., Posiva WR 2012-100)

- Represents outer edge of buffer - *curvatures different*
- Inflow, wetting, erosion, (swelling) in early phase



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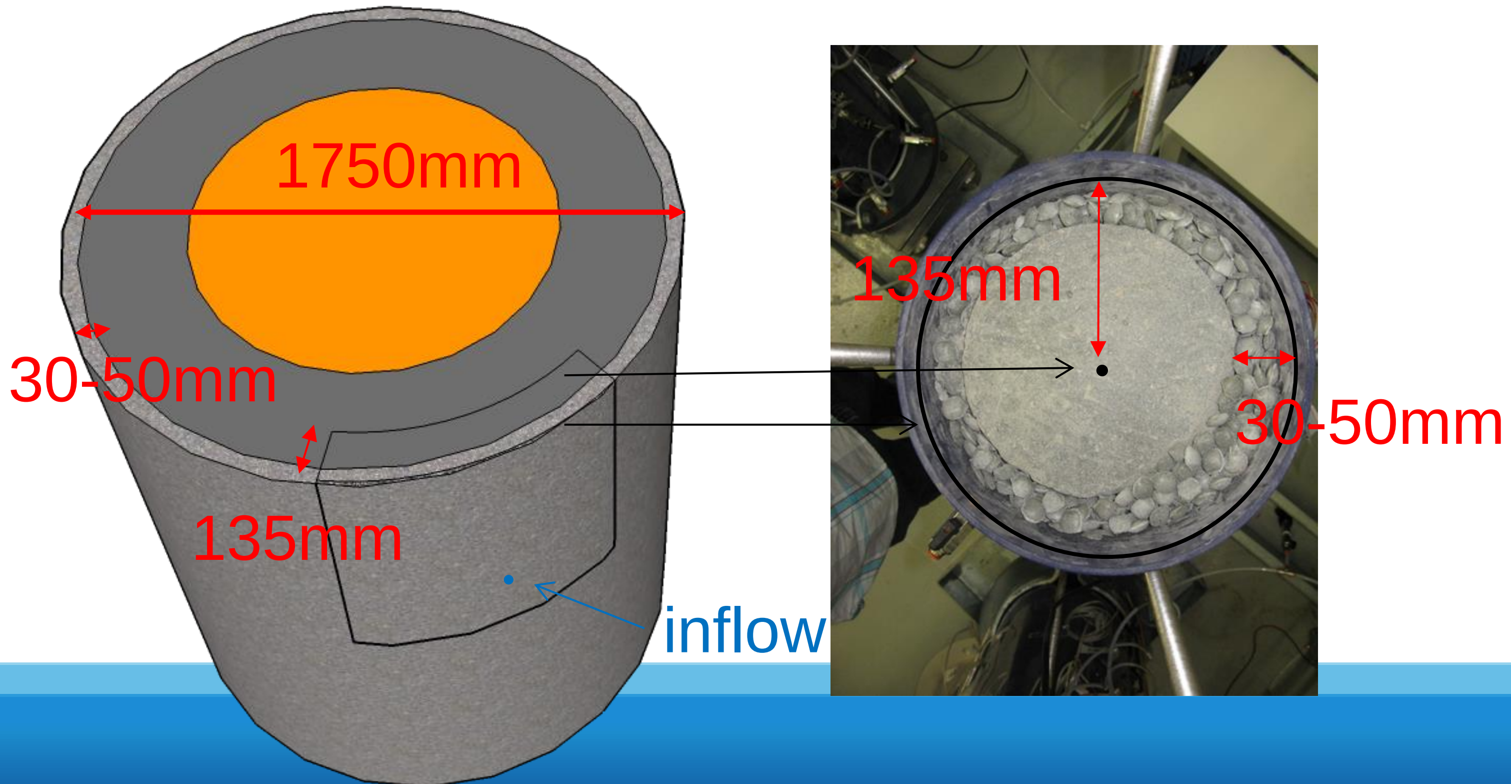
- Inflow, wetting, erosion, (swelling) in **<u>early phase?</u>**



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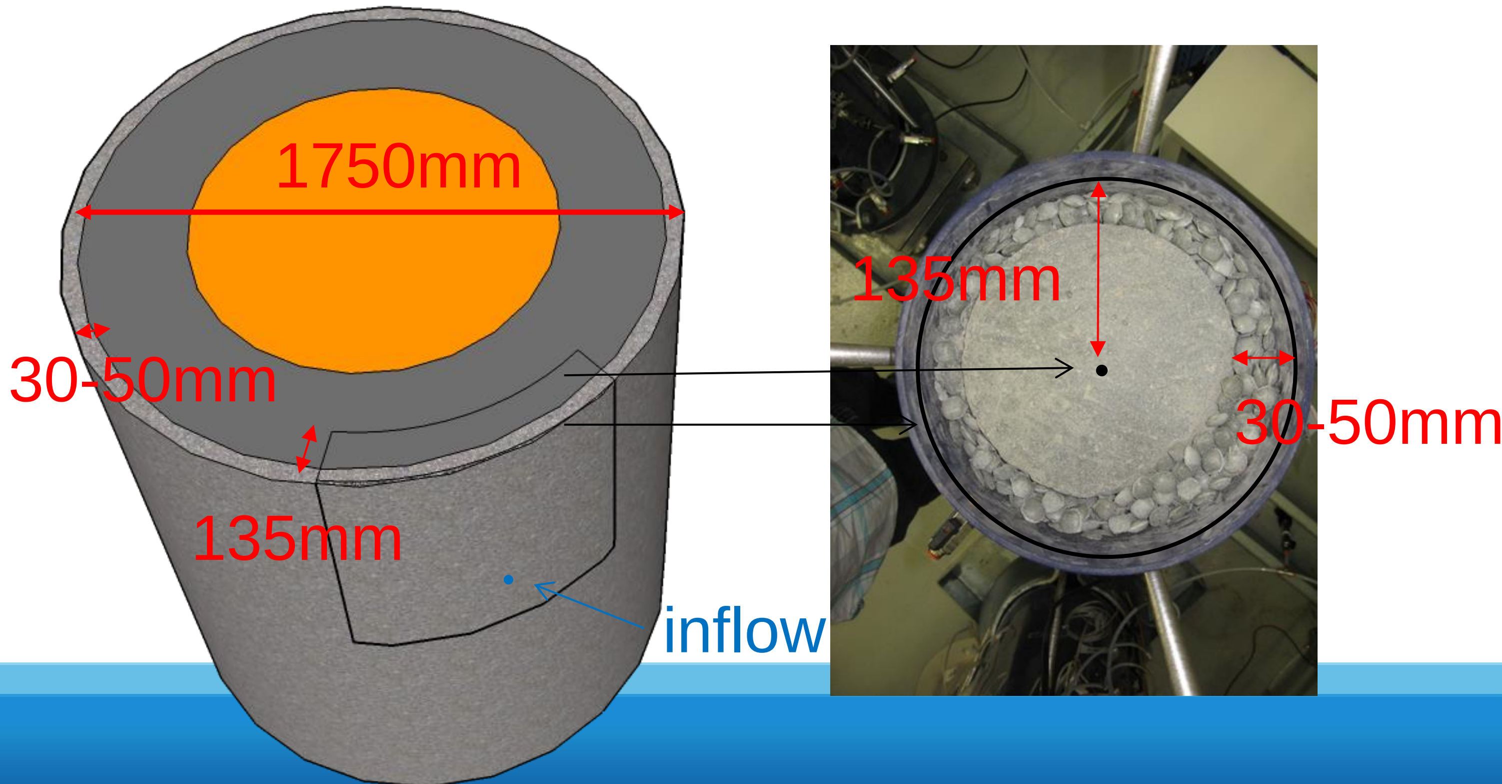
(X. Pintado et al., Posiva WR 2012-100)

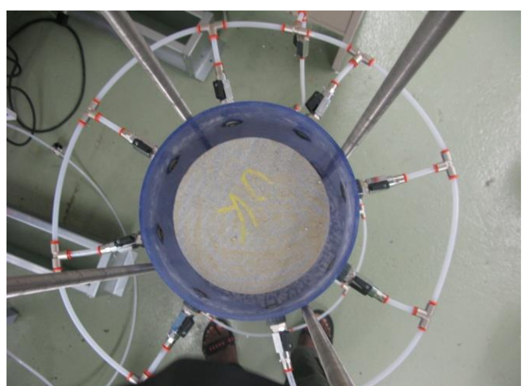
- Represents outer edge of buffer - *curvatures different*
- Inflow, wetting, erosion, (swelling) in early phase
- Downscaled bentonite mass saturates in ~4 months



Transu, visual observations

- Transparent cell is transparent 
- With several inlets/outlets, tendency to ”choose” a single channel from one inlet to one outlet.

= Flow focusing dynamics (common pressure source)



Transu, visual observations

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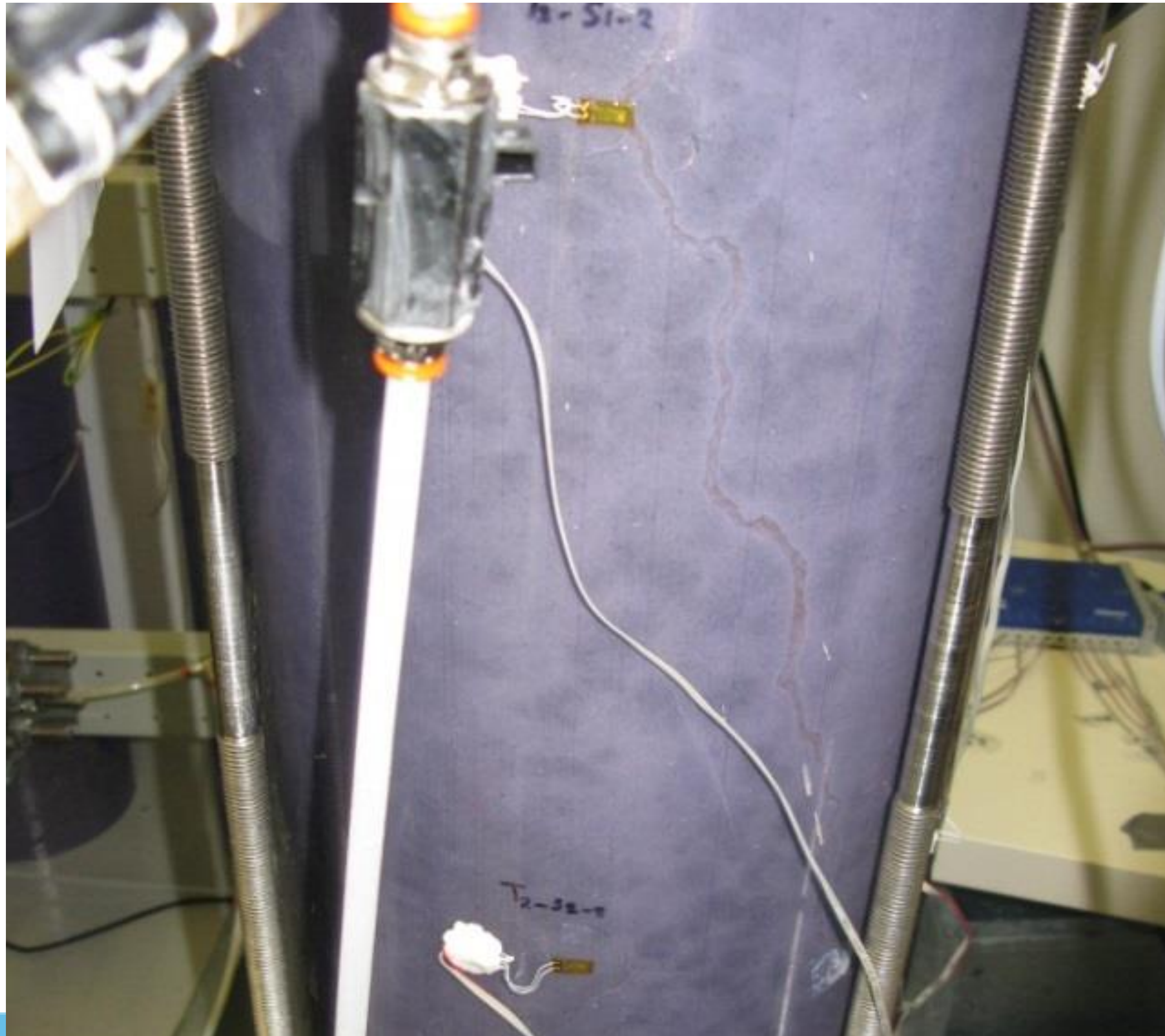
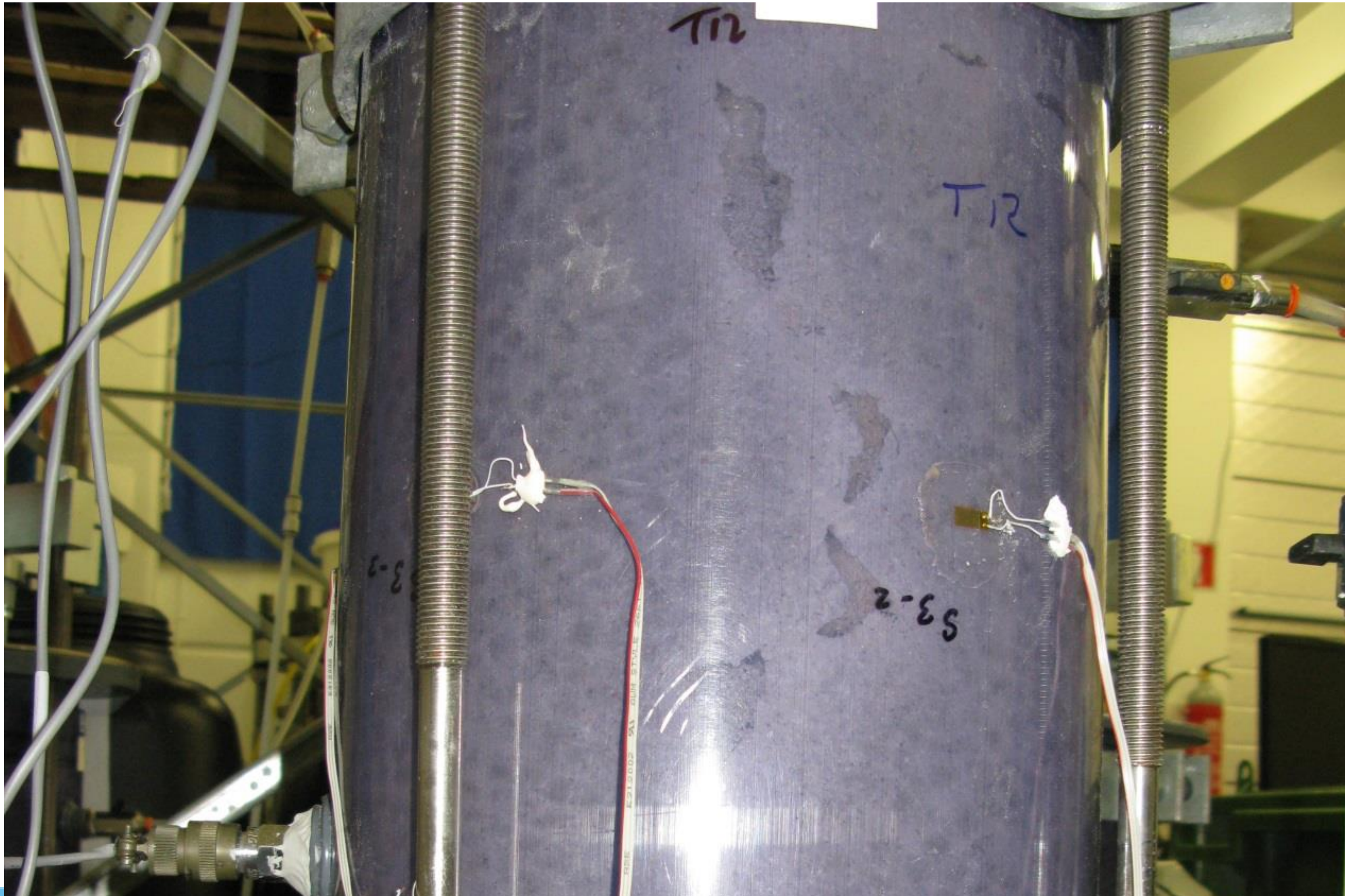


Channel is stable and steady, generally

Transu, visual observations



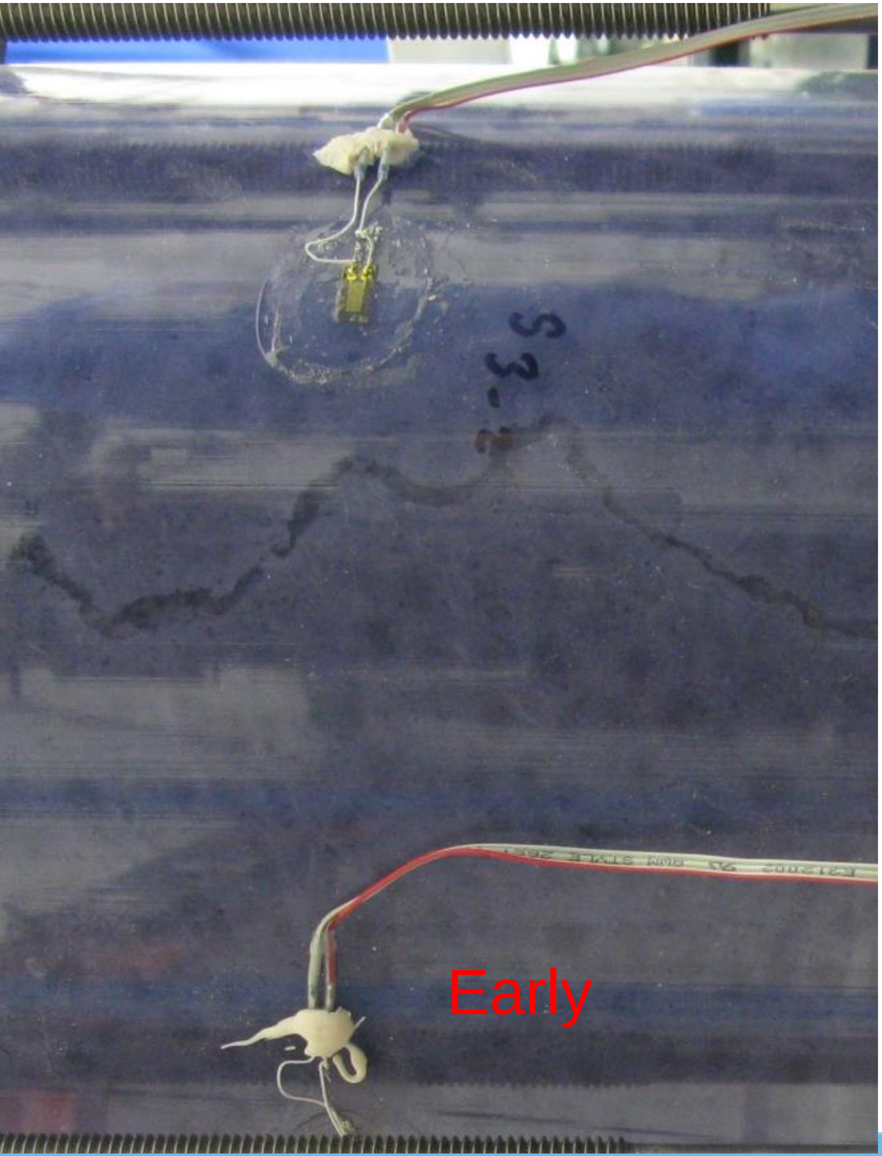
Stream pools with bentonite detritus

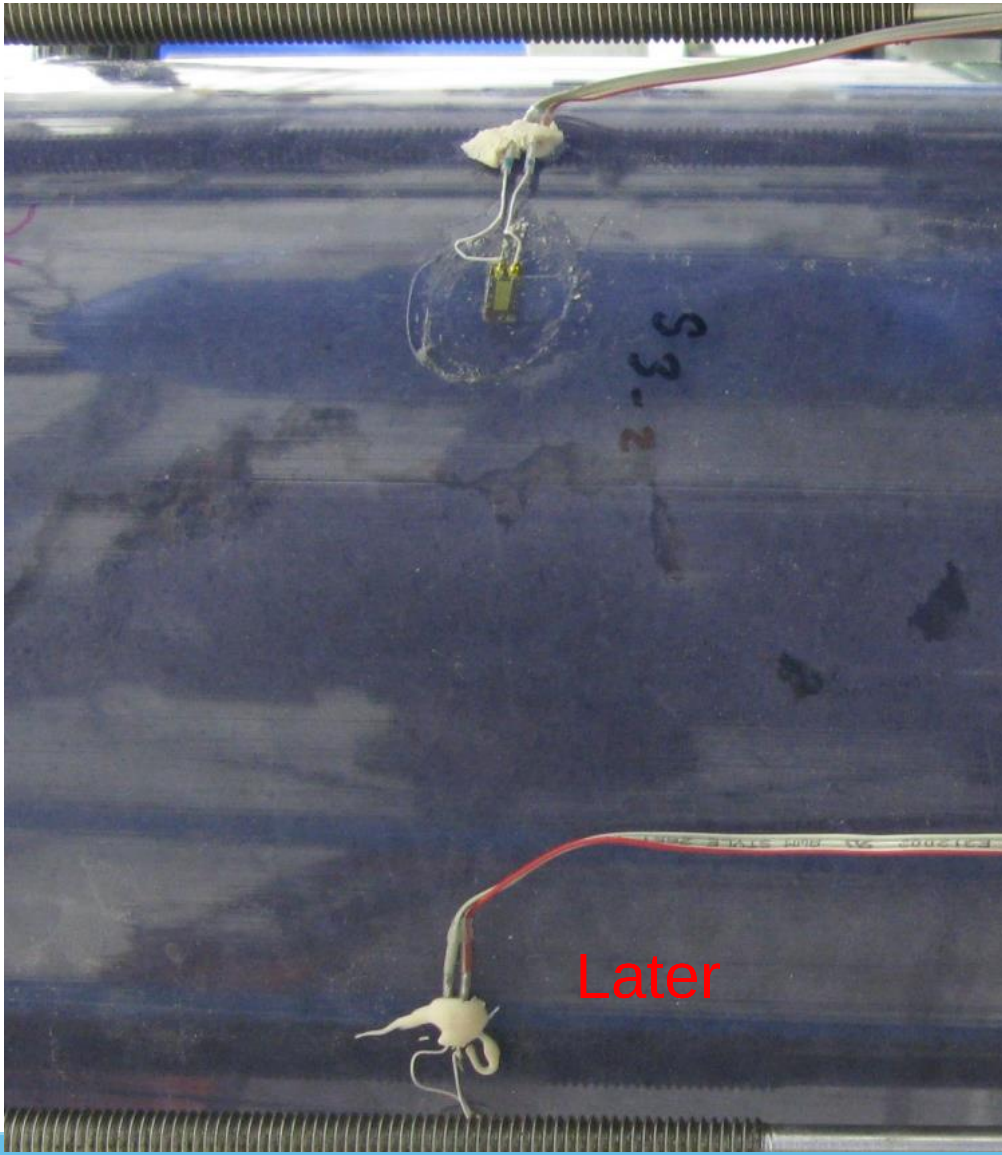
Transu, visual observations

Gap without pellets

1 g/l salt

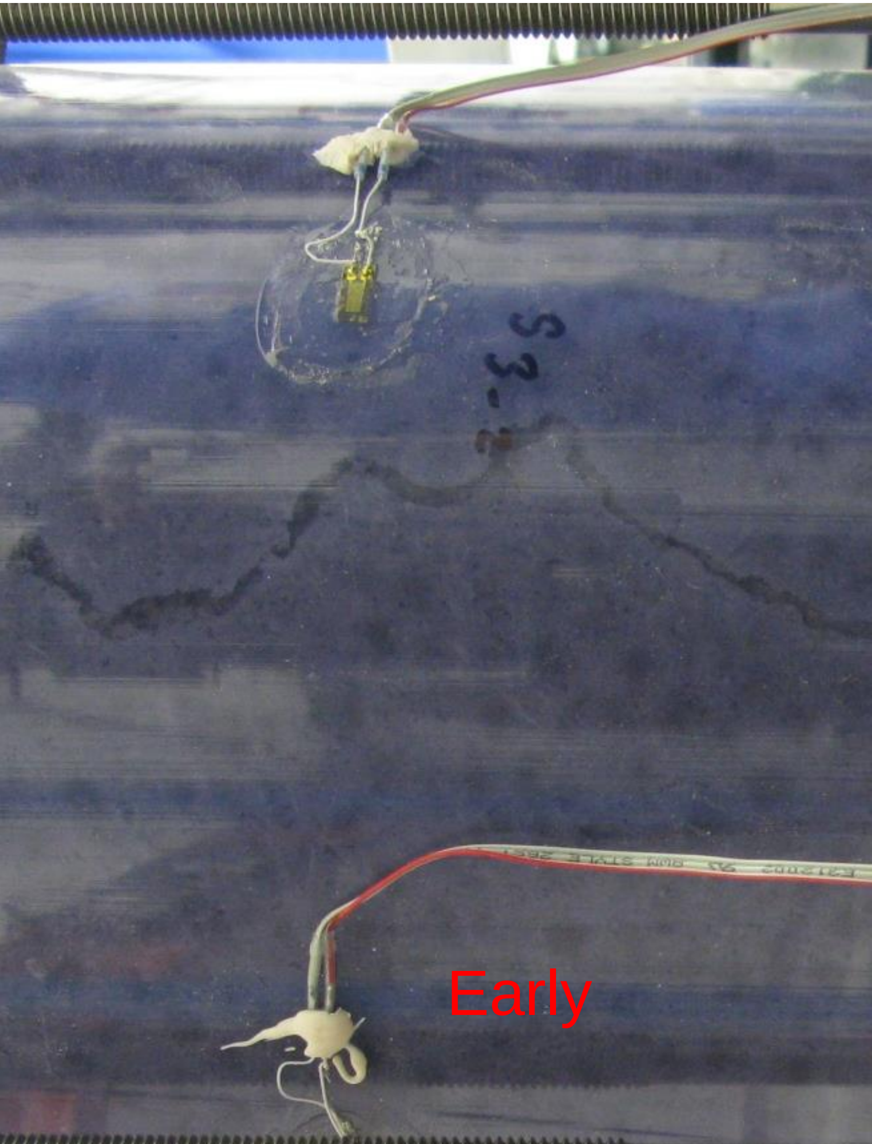
Transu, visual observations

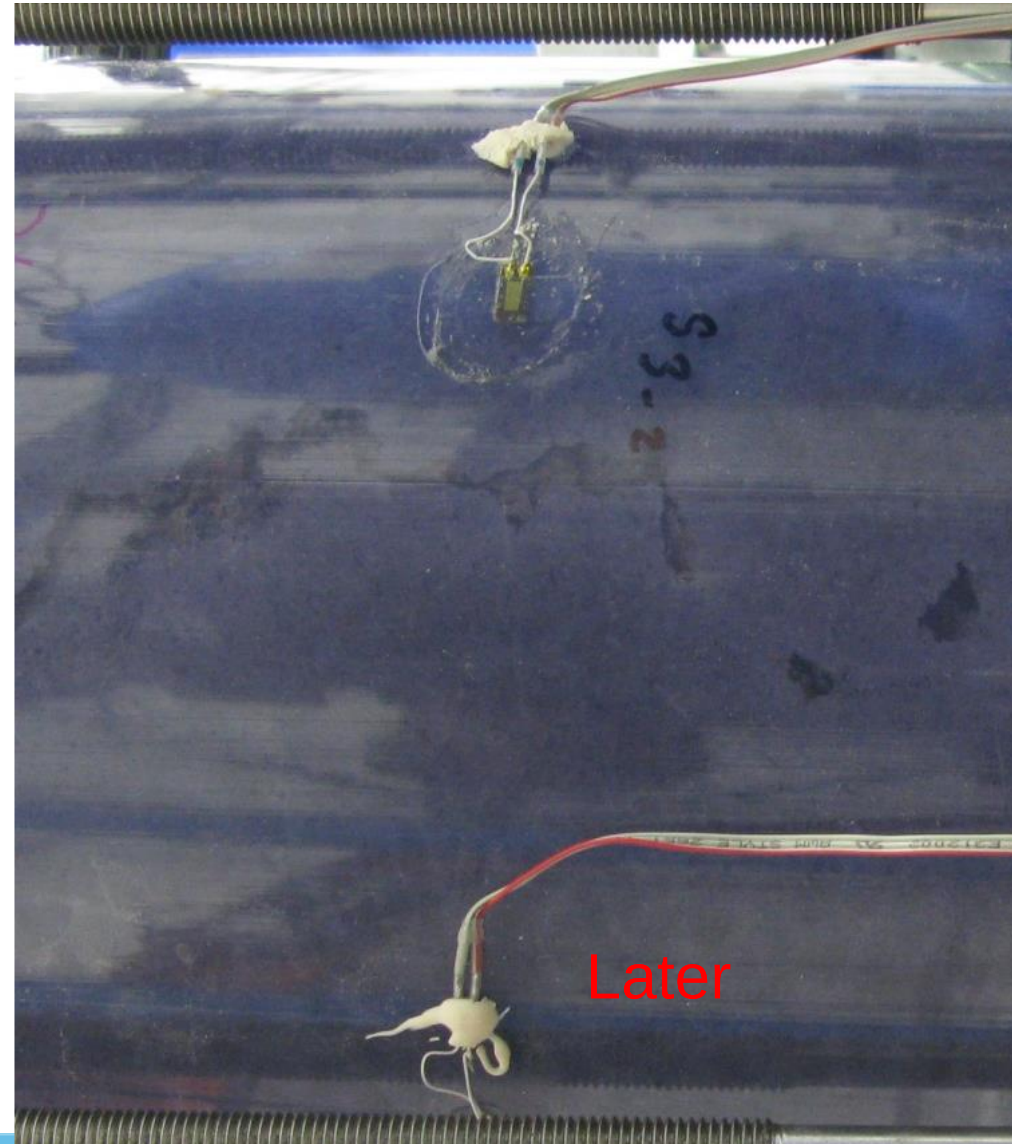




Channel size and detritus material increases in time

Transu, visual observations





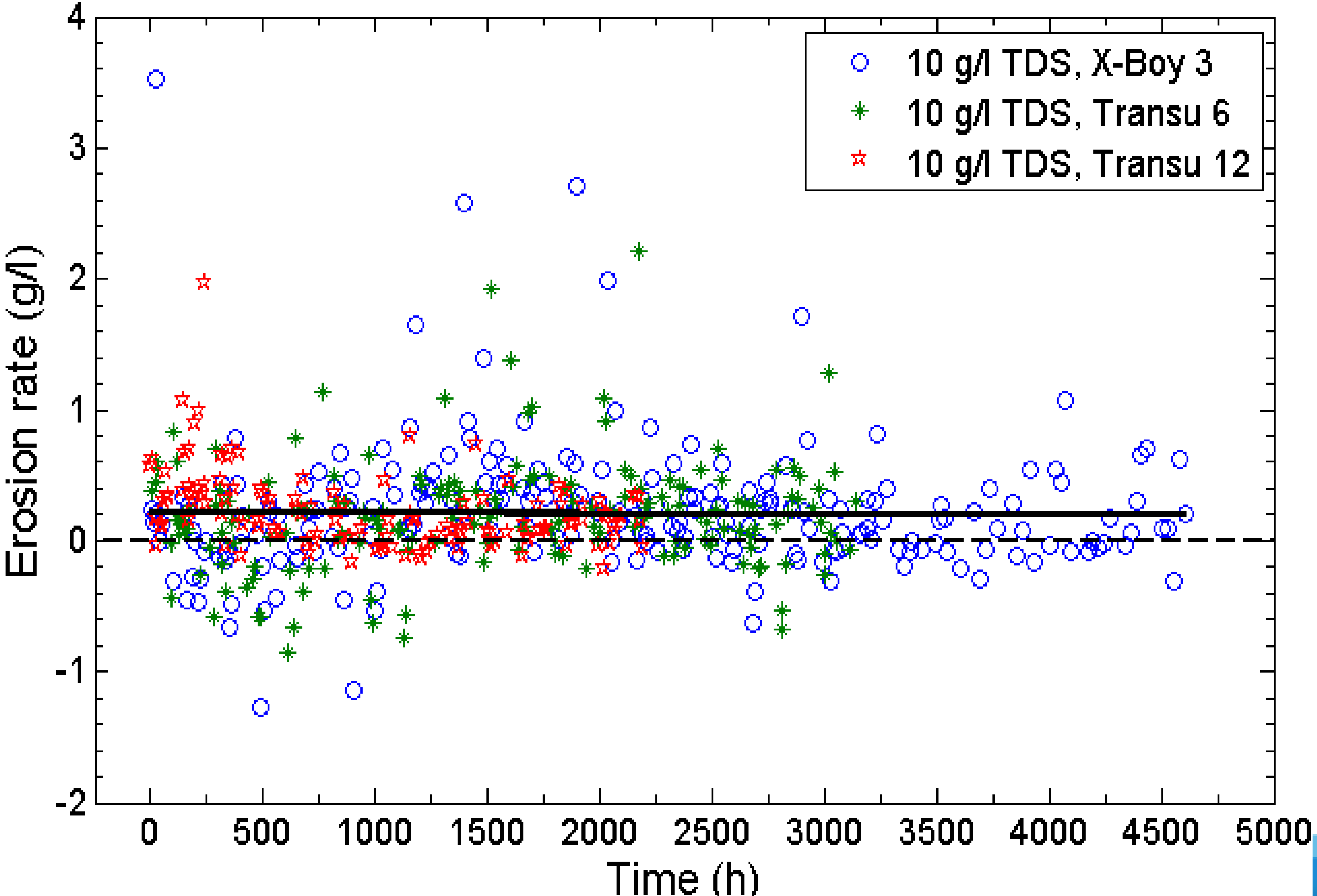
Channel path evolves (slightly) in time

Erosion test matrix

test type	duration (h)	pellet slot (mm)	pellets	inflow salinity (g/l)	average erosion (g/l)
transparent	678	29,5	SKB pillow	1	0.18±0.03
transparent	3143	29,5	SKB pillow	10	0.16±0.05
transparent	2726	29,5	None	1	0.14±0.02
transparent	2664	49,5	Posiva pillow	1	0.23±0.02
transparent	2736	49,5	Posiva pillow	10	0.19±0.04
steel cell	4690	30	SKB pillow	10	0.17±0.05
steel cell	4690	30	SKB pillow	1	0.18±0.09

- Vary: pellet slot, salinity, steel/transparent

Erosion as a function of time



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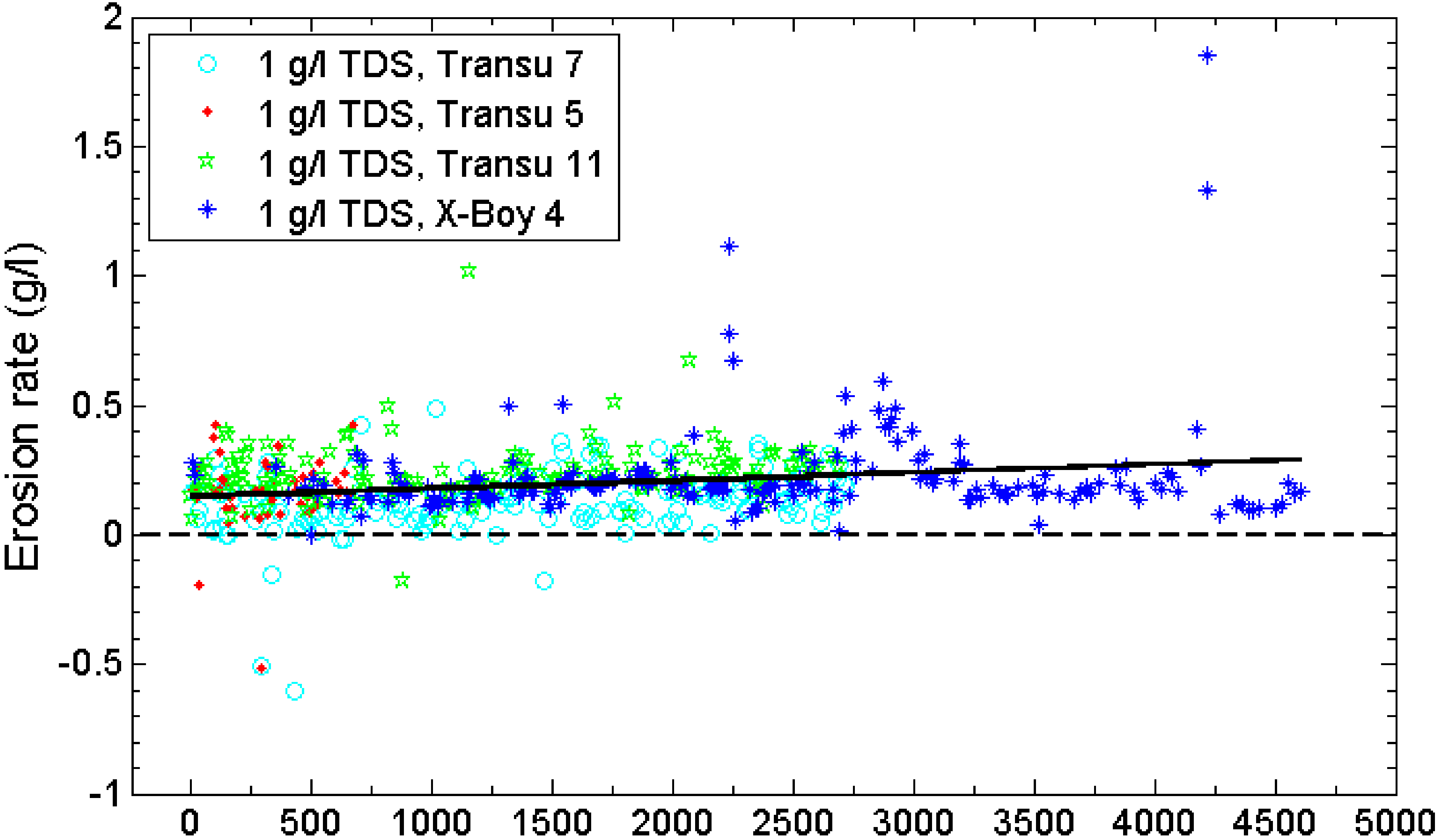
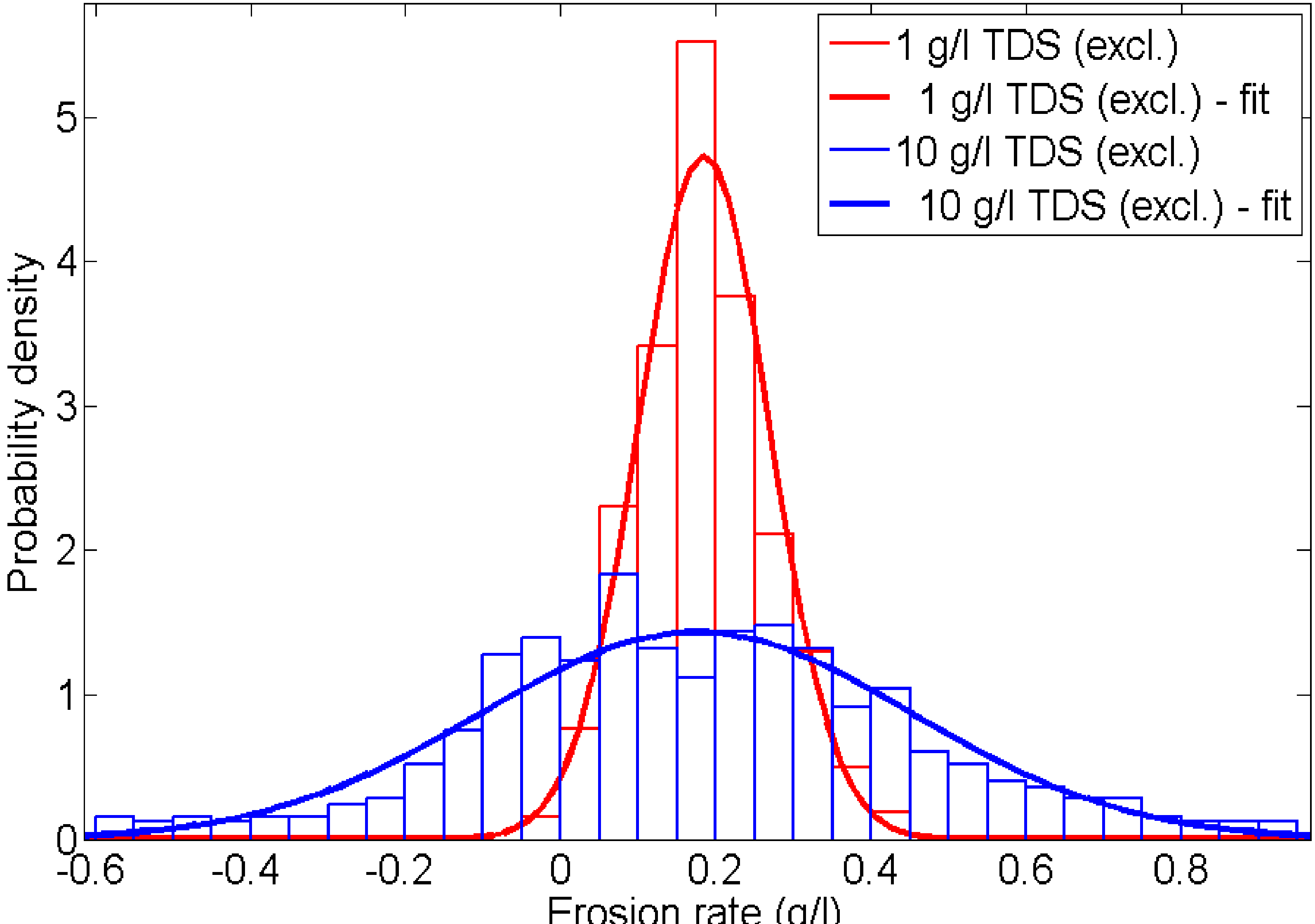
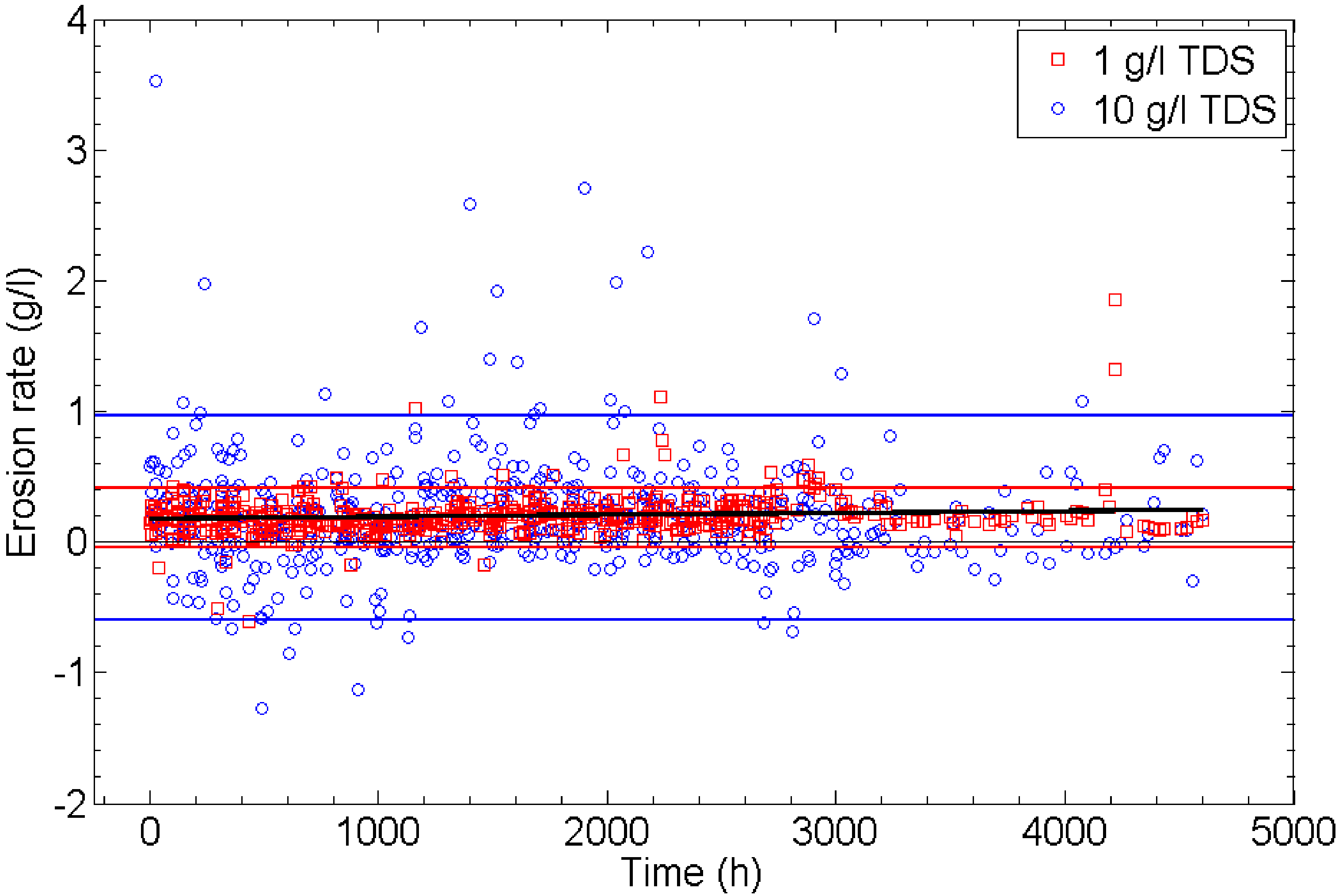


Erosion rate distribution



Erosion outliers; long tail



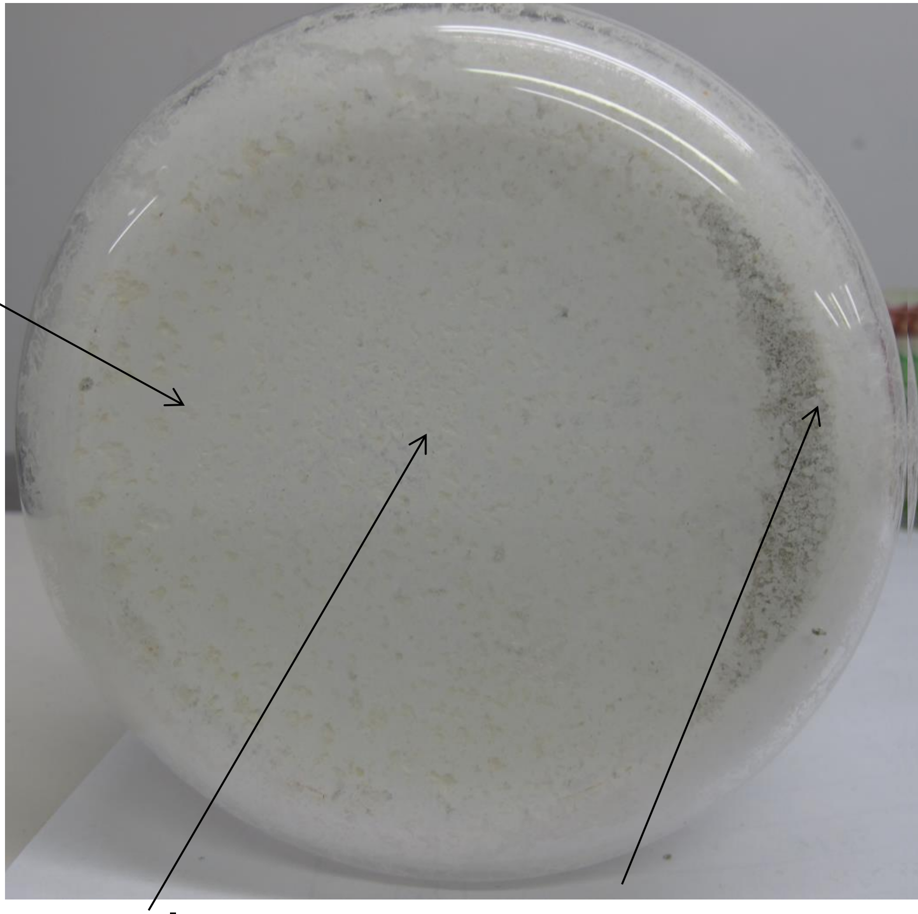
Scatter (negative erosion !?!)

Dried outflow sample:

10 g/l salt

0.2 g/l bentonite

Measurement error
signal / background



Questions

- Piping channels visually
  - Different between salinity and gap conditions
  - Evolve in time
- Yet erosion keeps constant?

- Erosion rate in pellets observed to decrease in inflow(=time) (Sanden 2010):

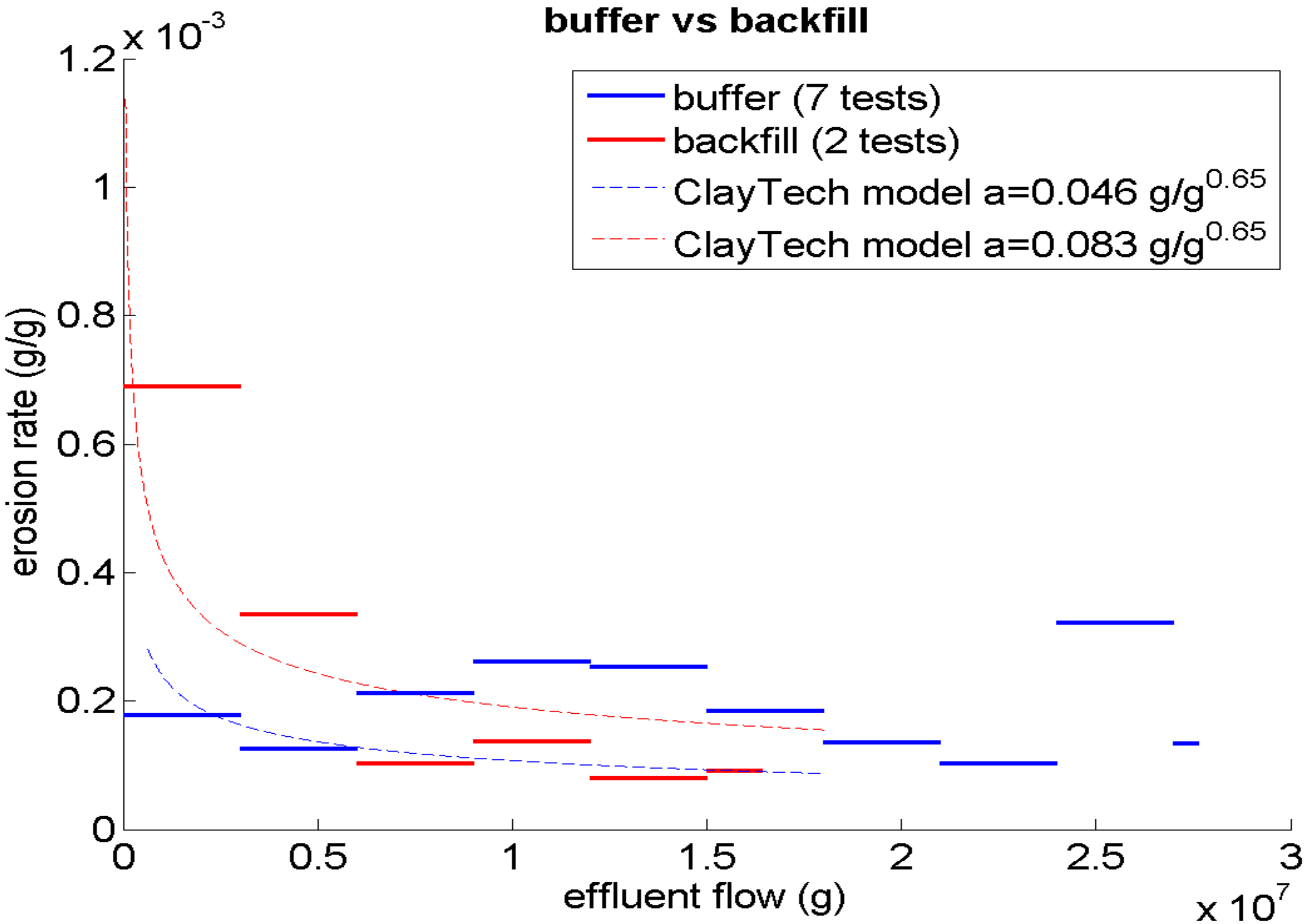
$$m_{eroded} = a \cdot (V_{inflow})^{0.65}$$

$$\Rightarrow \quad c[g/l] = \alpha \cdot t^{-0.35}$$

-  Swelling (of blocks to channel) controls erosion?

Swelling vs erosion?

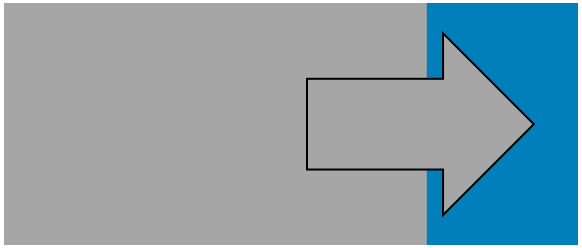
- Friedland Clay blocks swell less than MX-80

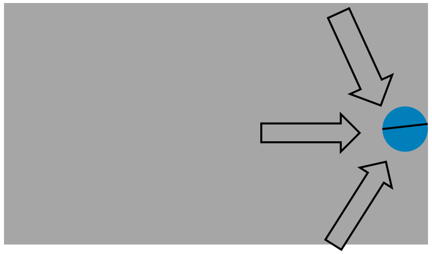


Swelling vs erosion?

- Swelling controls erosion?
- Prediction: Erosion increases linearly with test length
  - Does not seem to hold so simply, but results still pending…
- Radial inward swelling into the channel:
  high curvature, low density bentonite

Radial inward swelling





- Swelling rates from axial are at least an order of magnitude too high to explain erosion

Summary

- Piping erosion in 1:6 buffer tests at 0.1 l/min inflow is **0.2 ± 0.1 g/l**
- Erosion is constant in time and not sensitive to pellet gap properties and inflow salinity

- Hypothesis: swelling control erosion
- Outlook:
  - Dependence on channel (test) length
  - Comparing test methods between B+Tech/Posiva and SKB/Clay Tech
  - Constitutive models, <u>radial inward swelling</u>:
    - Narrow enough channel, swelling almost stops?

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Erosion as a function of time

- Average the data in time slots
- Apparently constant erosion in time and between tests