Improved CFD Simulation Approaches for Manhole Mixing Investigations

Paul Bennett*, Virginia Stovin*
& Ian Guymer#,

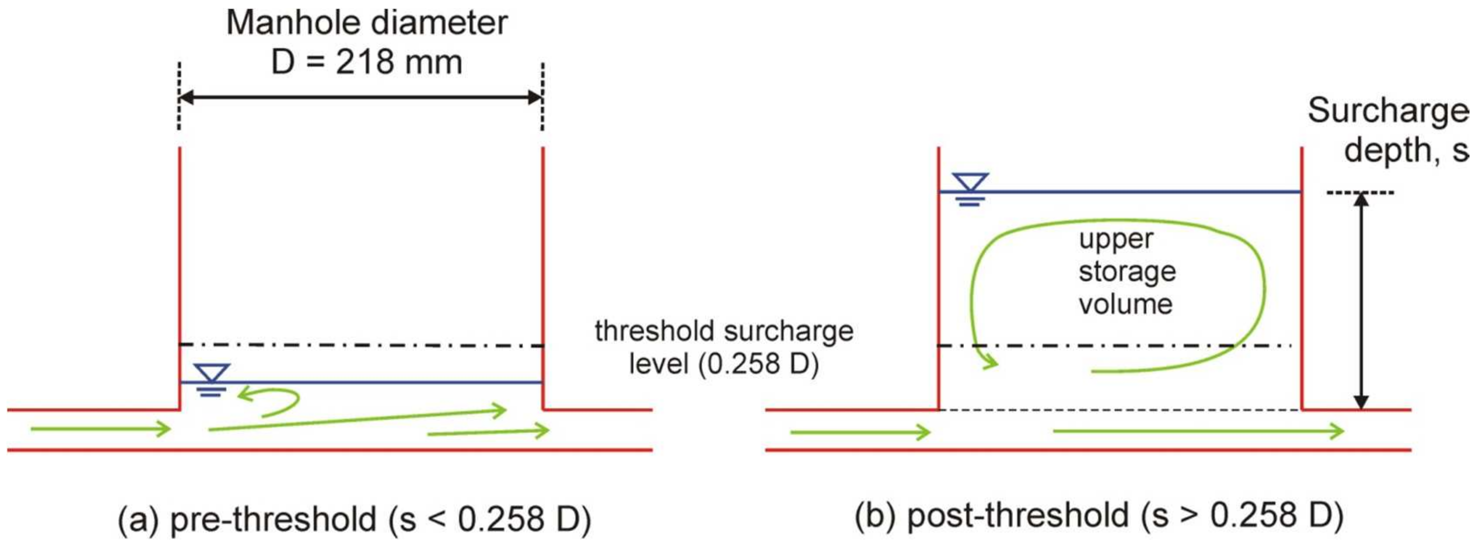
*The University of Sheffield, UK
#The University of Warwick, UK

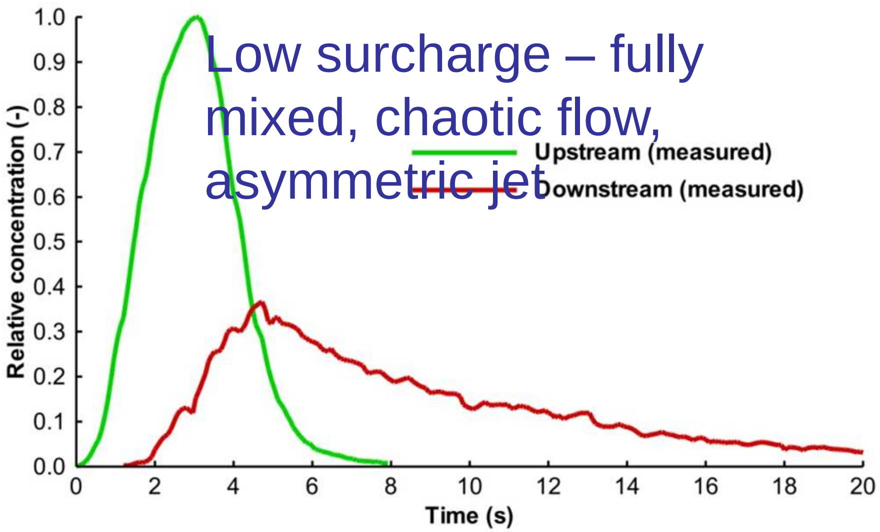
Surcharged Manhole

Dry-weather flow

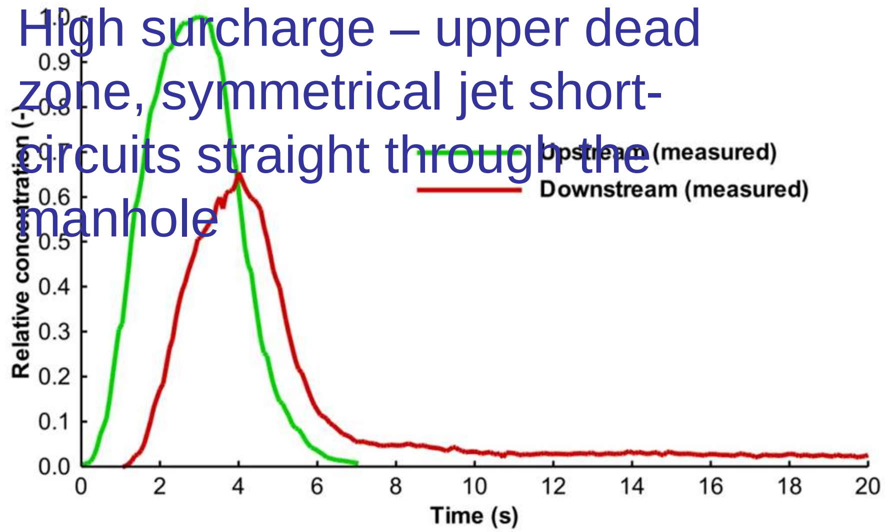
Surcharged flow under storm conditions

Surcharged Manhole – flow regime and solute transport





Low surcharge – fully mixed, chaotic flow, asymmetric jet



High surcharge – upper dead zone, symmetrical jet short-circuits straight through the manhole

Laboratory Dye Visualisation
Low Surcharge

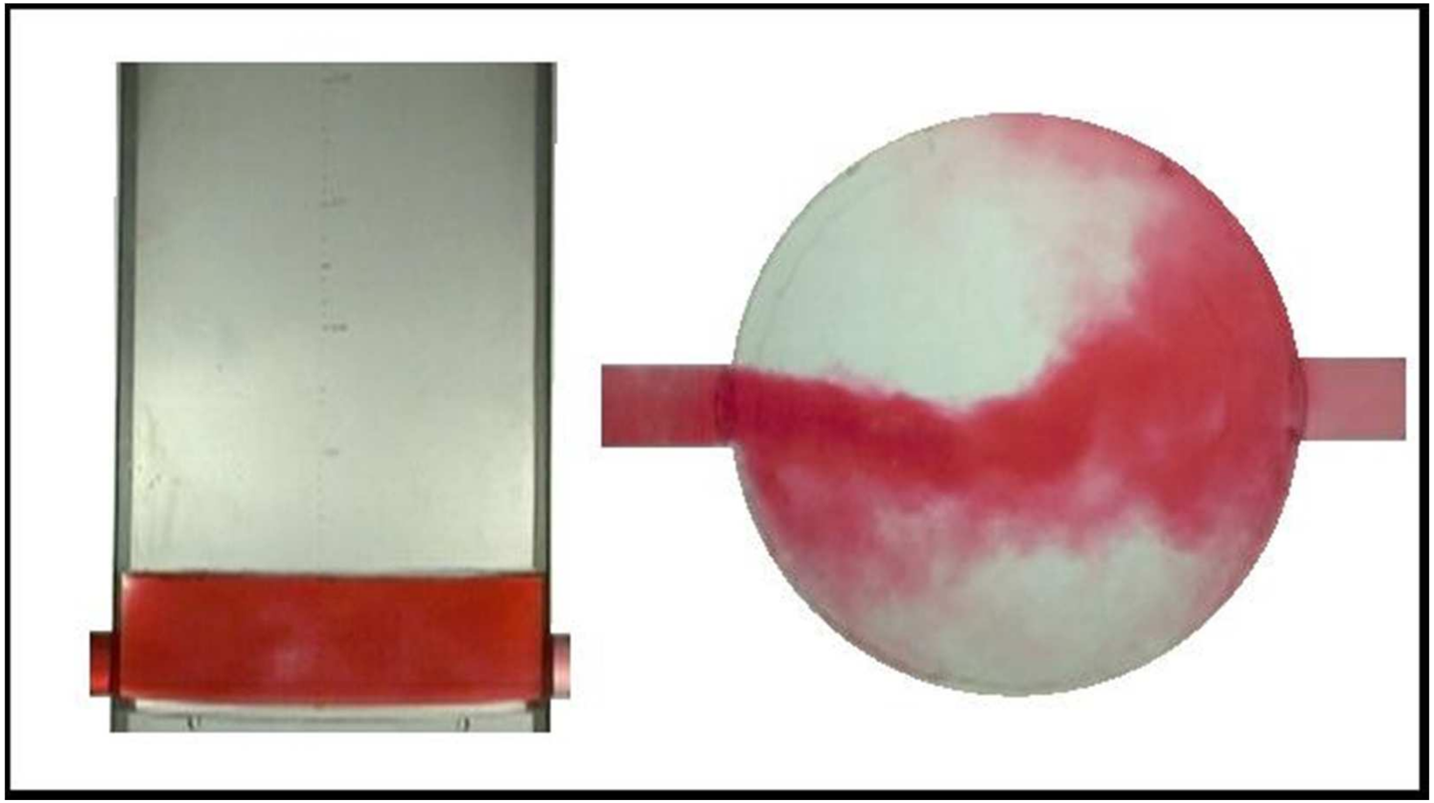


Image courtesy of Amy Jones

Laboratory Dye Visualisation
High Surcharge

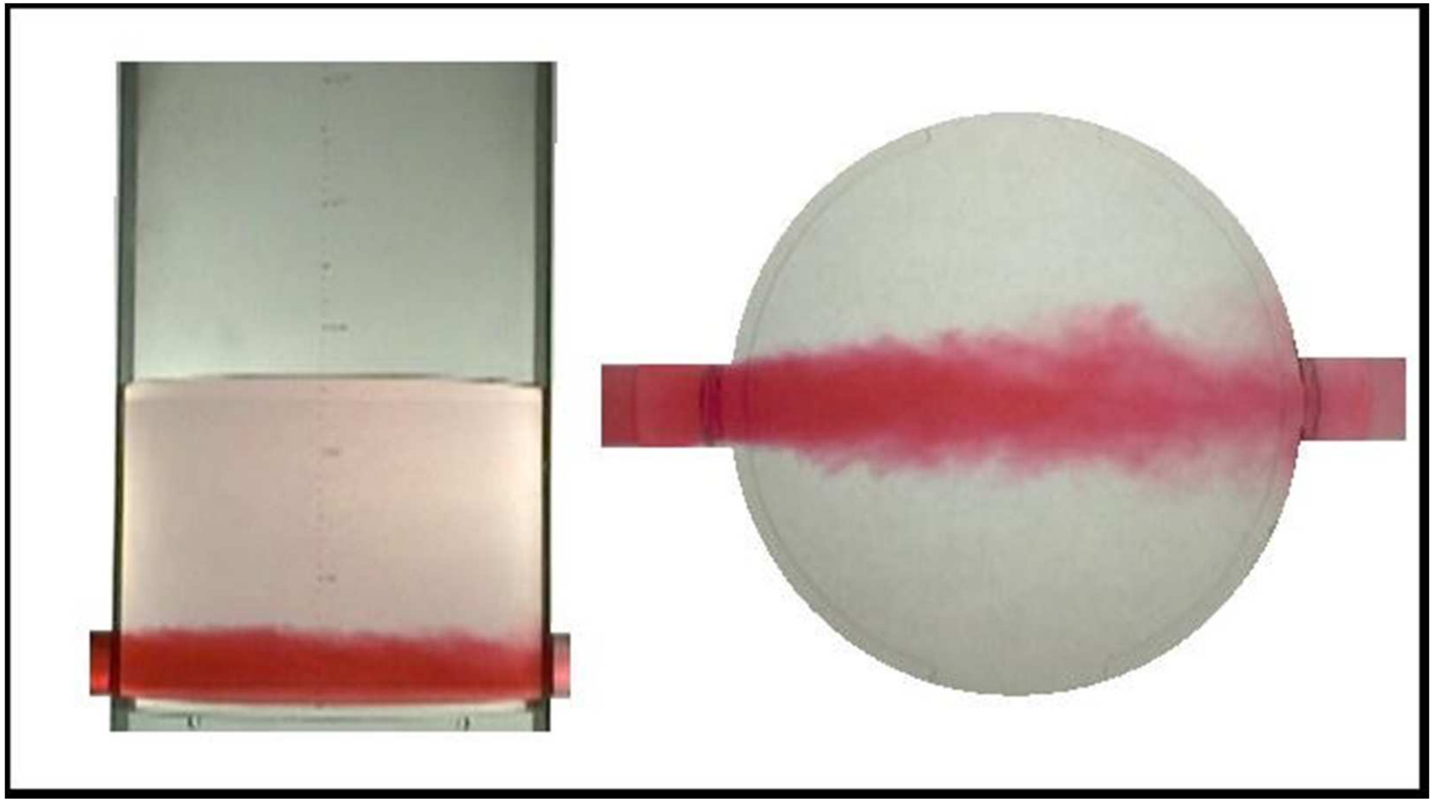
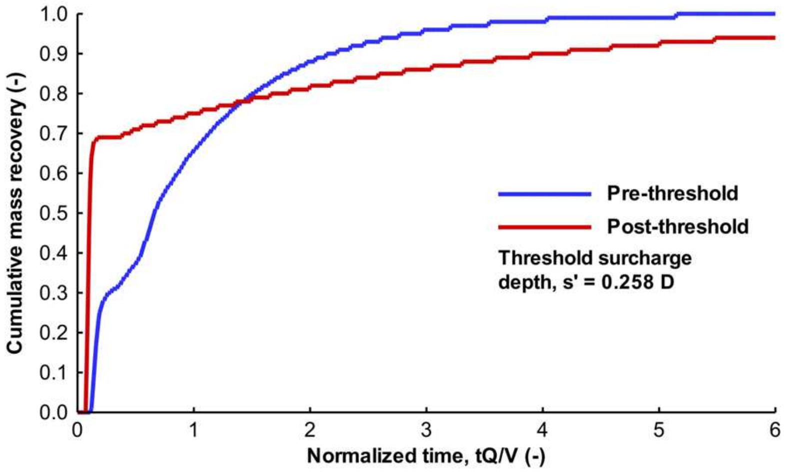
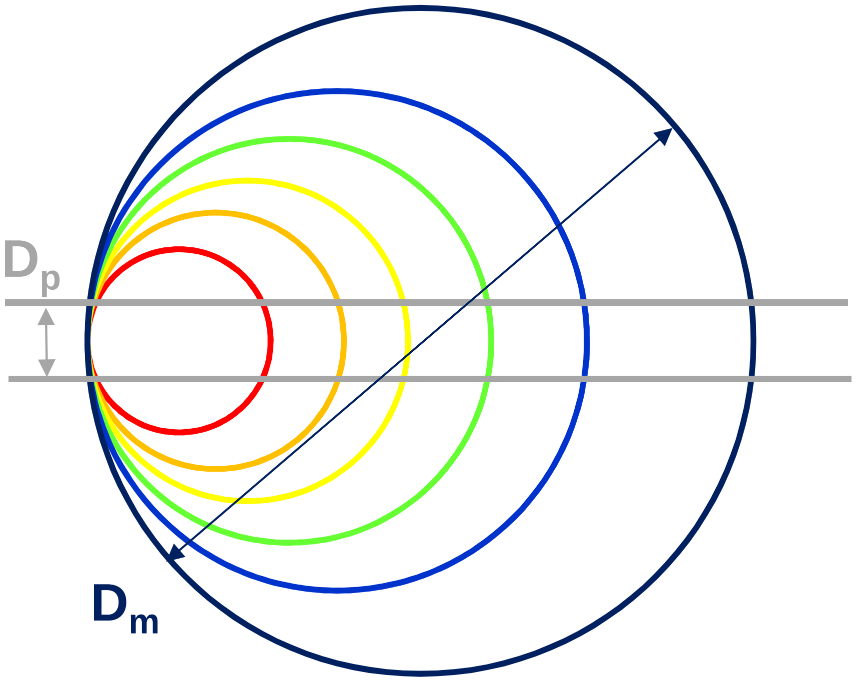


Image courtesy of Amy Jones

Aims

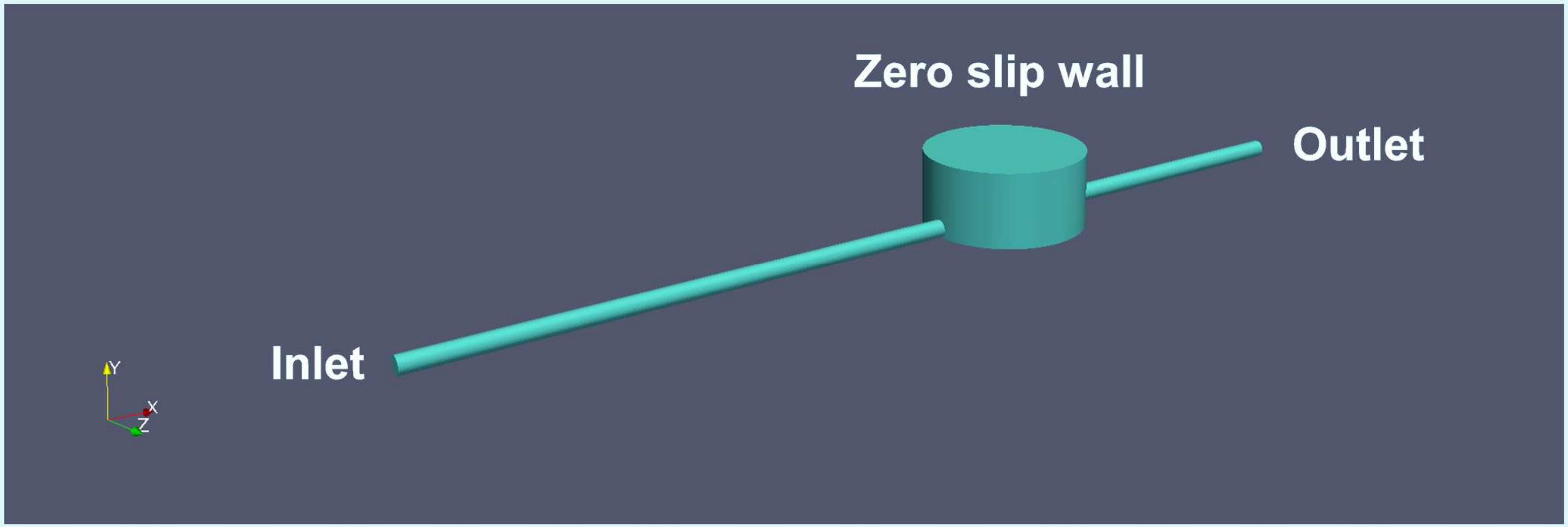




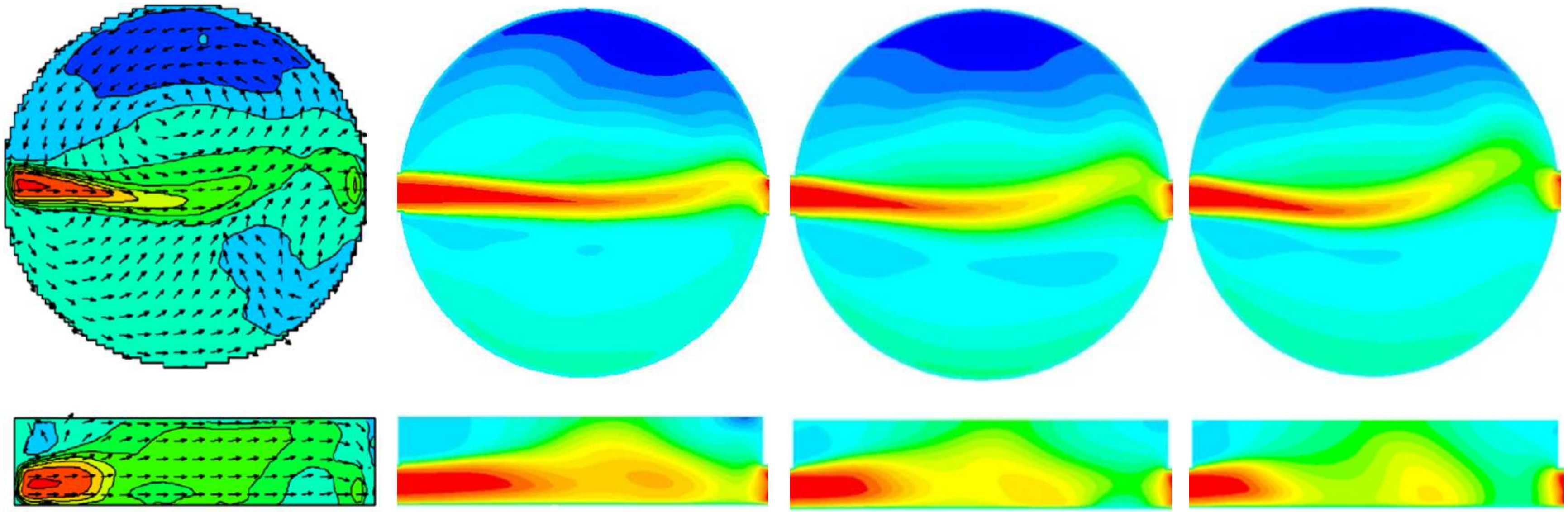
- Previous work
  - Steady flows
  - Simple manhole configurations
- Expand the study into unsteady conditions
  - requiring the free surface to be modelled in CFD
  - in parallel with laboratory study (Amy Jones, Univ. Warwick)
- Increase the scope of manholes investigated (smaller D_m/D_p ratios)
- Validated CFD model

CFD Model Boundary Conditions
Steady Flow

- Inlet : Velocity Inlet – Profile derived from periodic pipe model
- Outlet: Pressure Outlet
- 'Free Surface': Wall – Zero slip conditions
- Monitors set corresponding to laboratory Fluorometer positions



Primary Validation



PIV
(Lau, 2008)

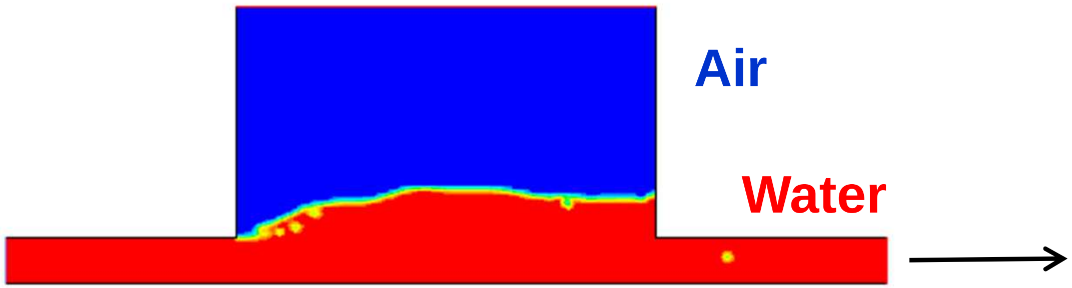
k-ε RNG

RSM

k-ε Realizable

‘An immediate benefit of the realizable model is that it more accurately predicts the spreading rate of both planar and round jets. It is also likely to provide superior performance for flows involving rotation, boundary layers under strong adverse pressure gradients, separation, and recirculation.’ FLUENT User Manual

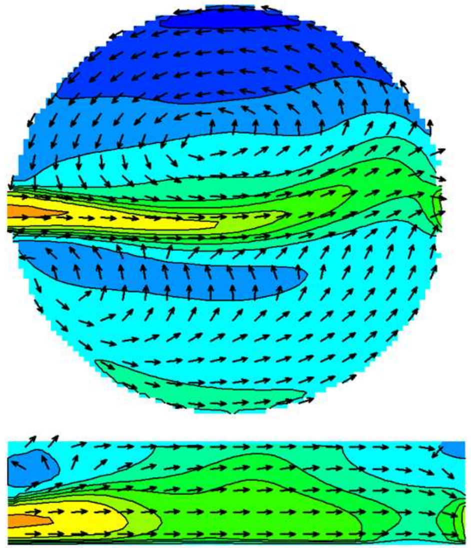
VOF Free Surface Modelling



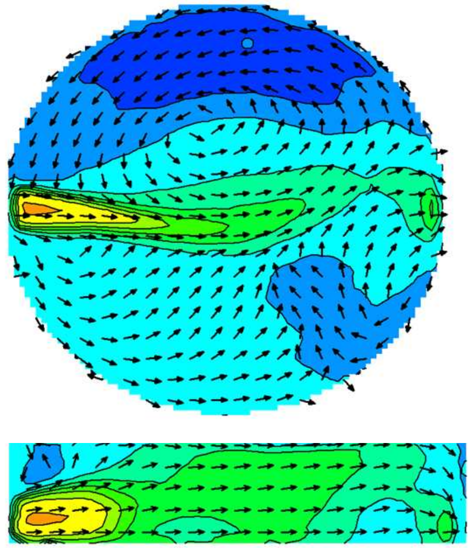
- Time-dependent inflow - unsteady conditions
- Volume Of Fluid (VOF) model with Geo-reconstruct scheme
- Inlet: Velocity Inlet – Profile derived from periodic pipe model
- Outlet: Pressure Outlet – Pressure to retain required head
- Model Top: Pressure Outlet – 0 Pa

Primary validation with free surface modelling

Low surcharge
Below threshold

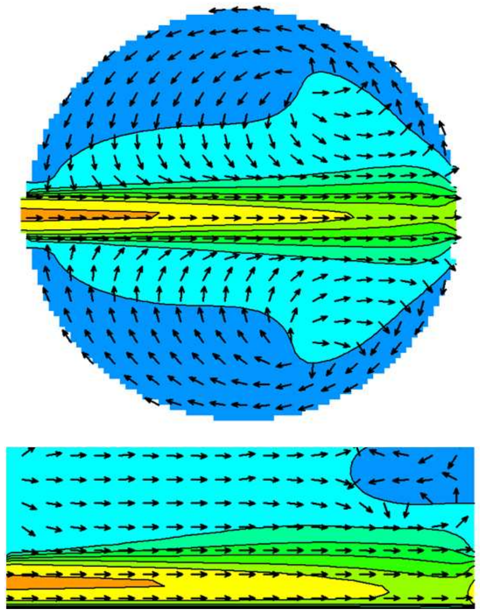


VOF (Realizable)

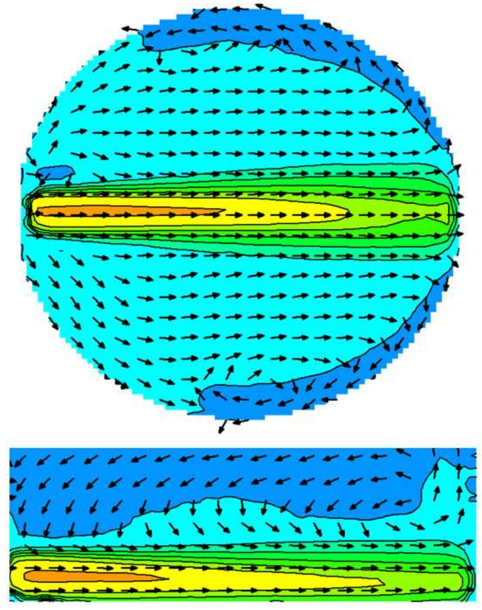


PIV

High surcharge
Above threshold

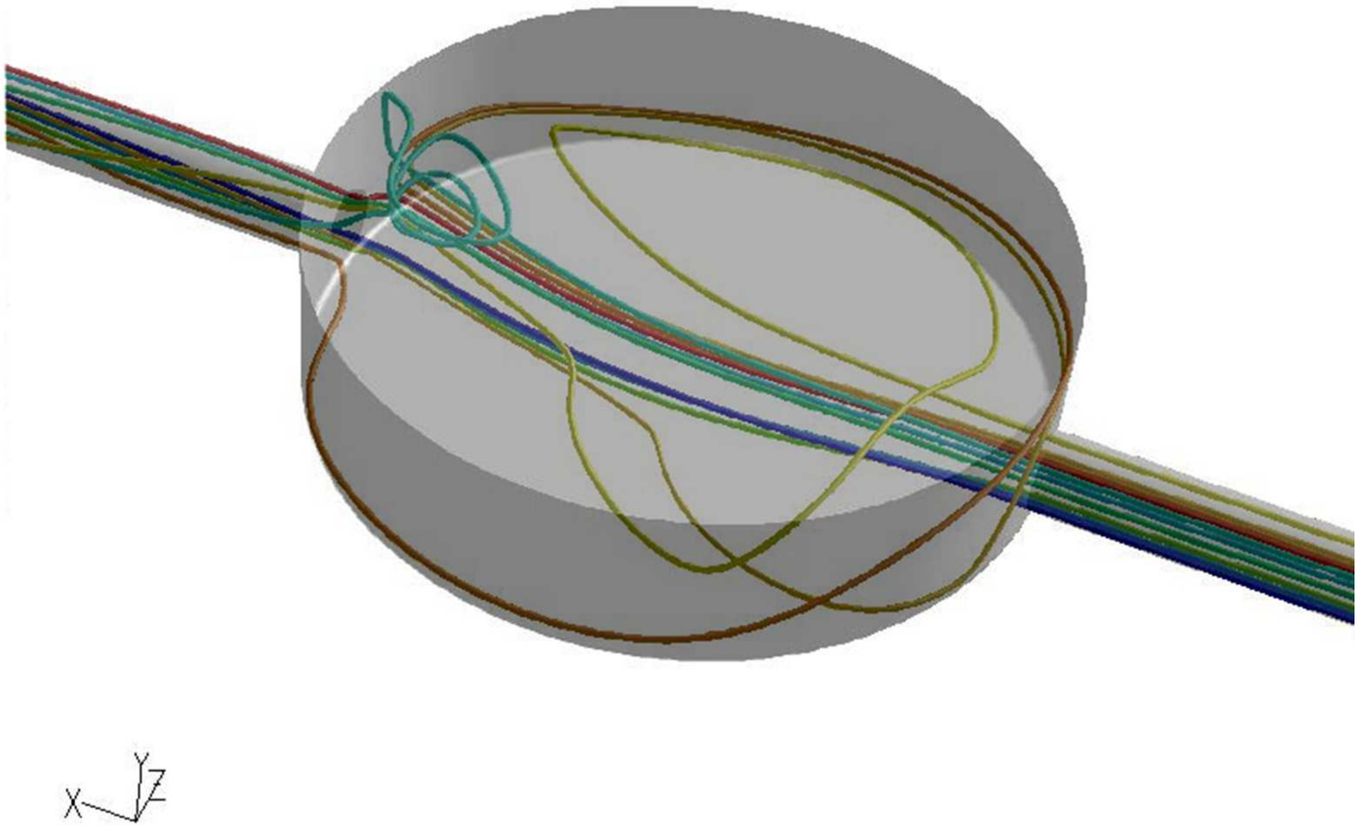


VOF (Realizable)



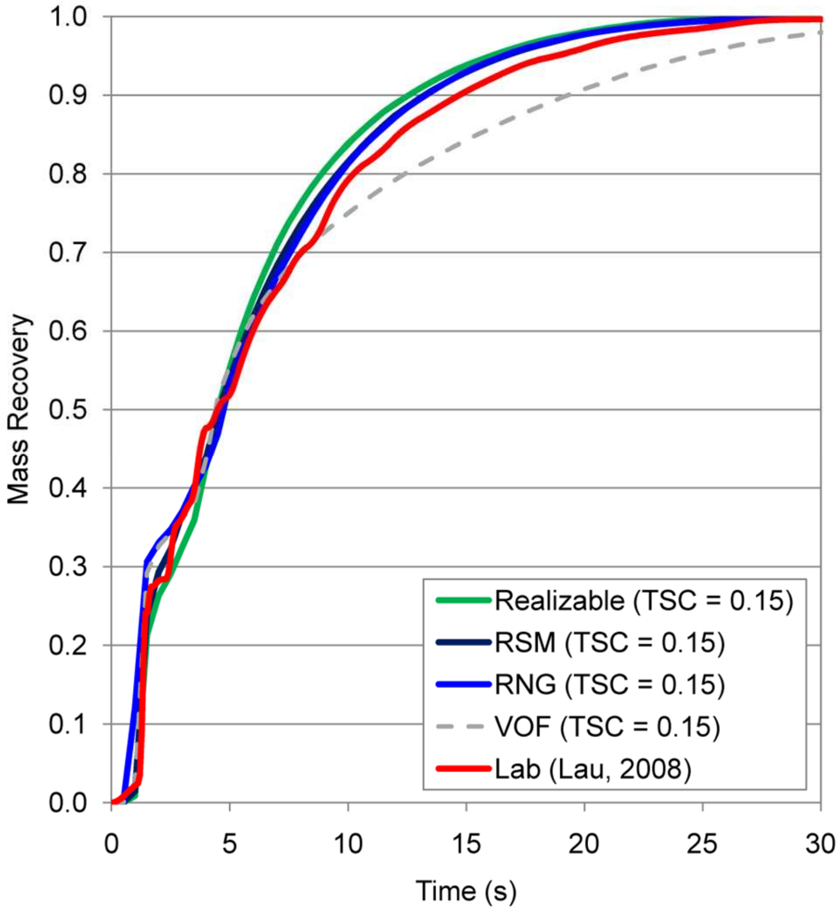
PIV

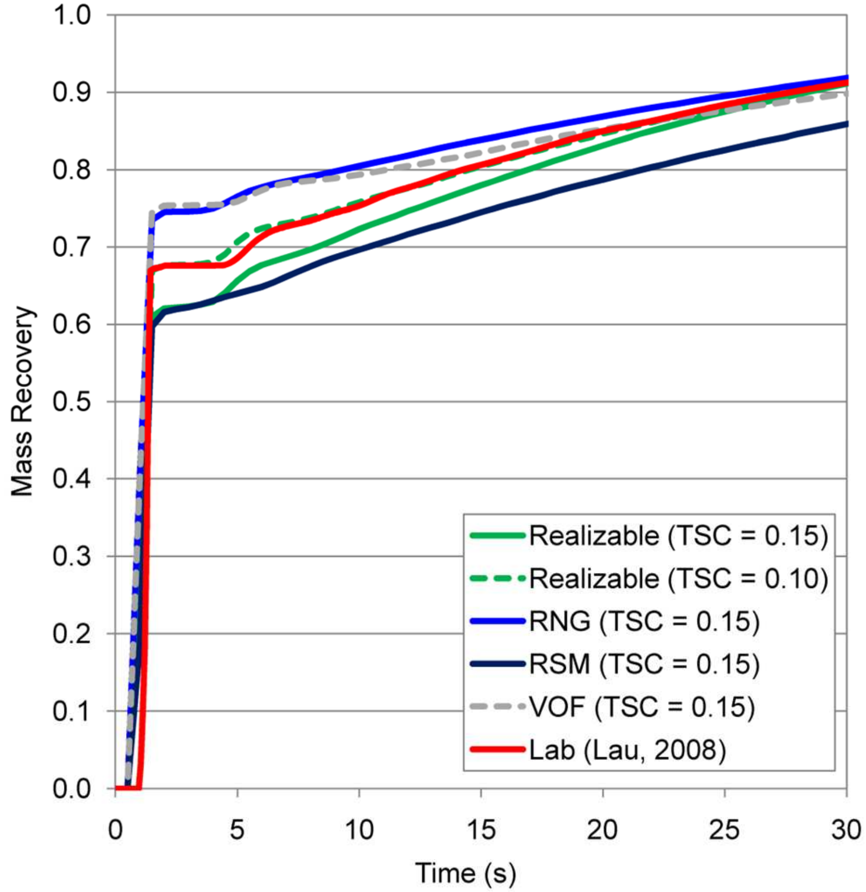
Secondary Validation
Discrete Phase Modelling (Particle Tracking)



- Stochastic tracking of 60,000+ neutrally-buoyant particles
- Residence Time Distribution (RTD) & Cumulative RTD (CRTD)

Secondary Validation



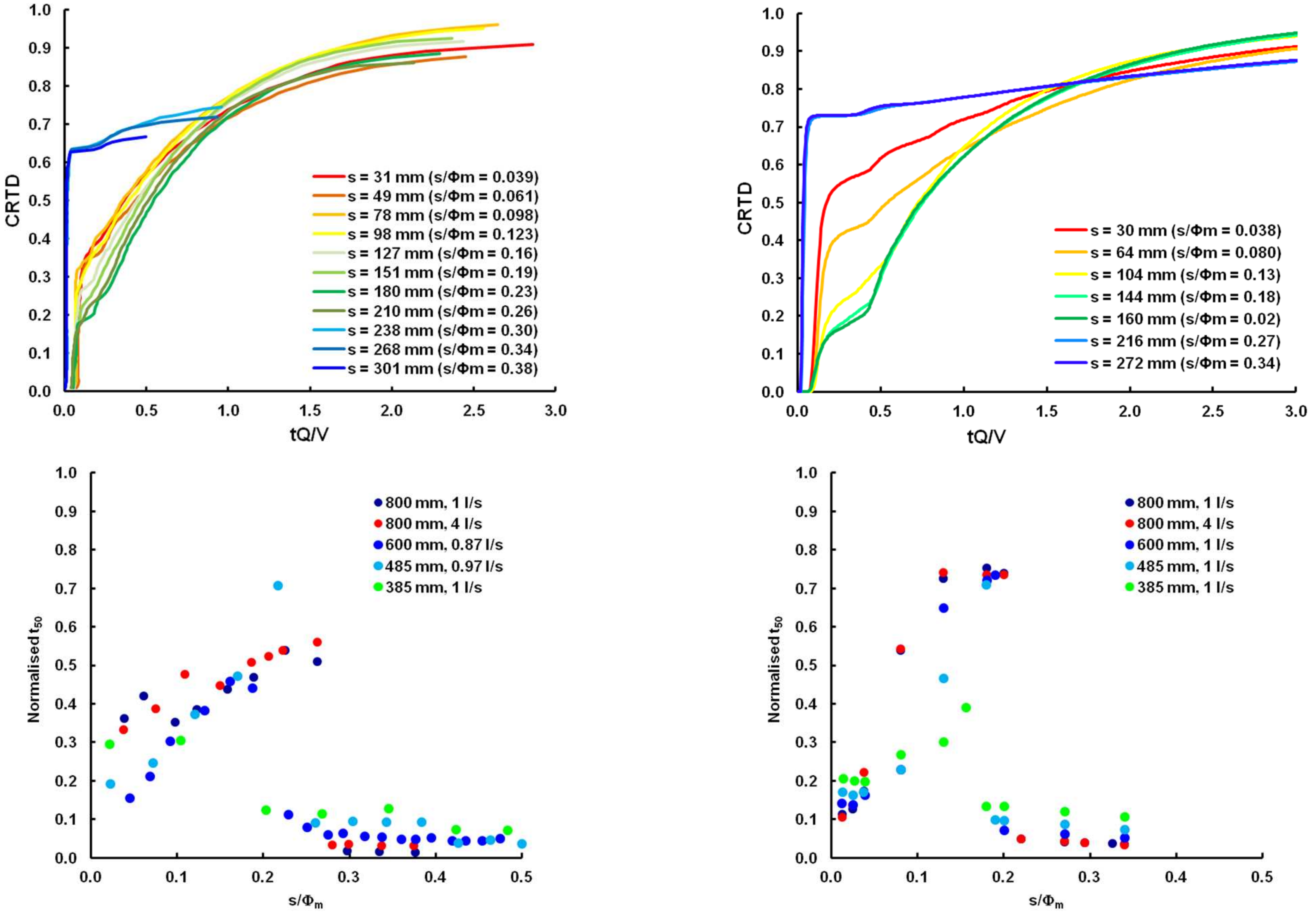


Low surcharge
Below threshold

High surcharge
Above threshold

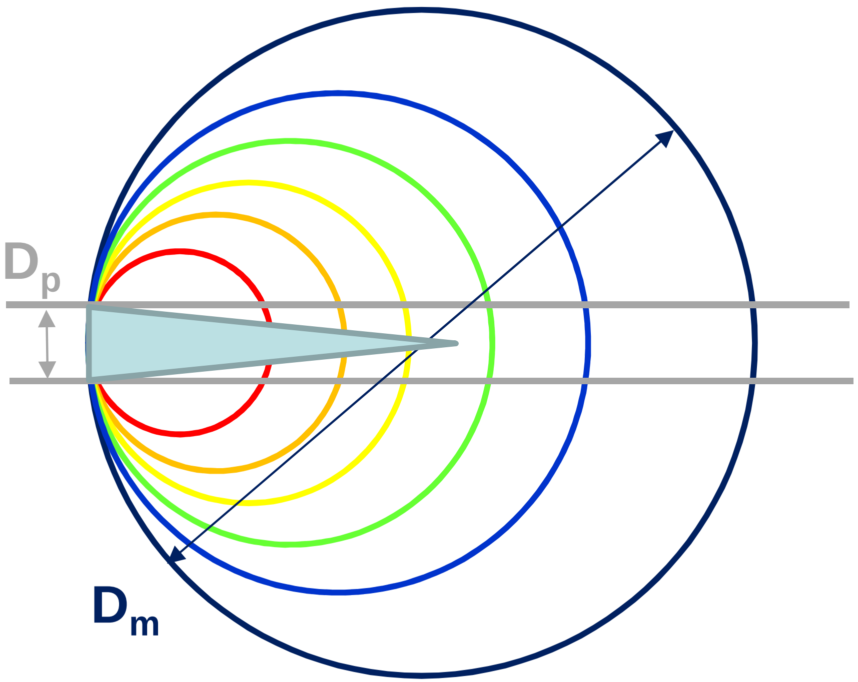
TSC – Time Scale Constant, controls how long a particle remains in an eddy

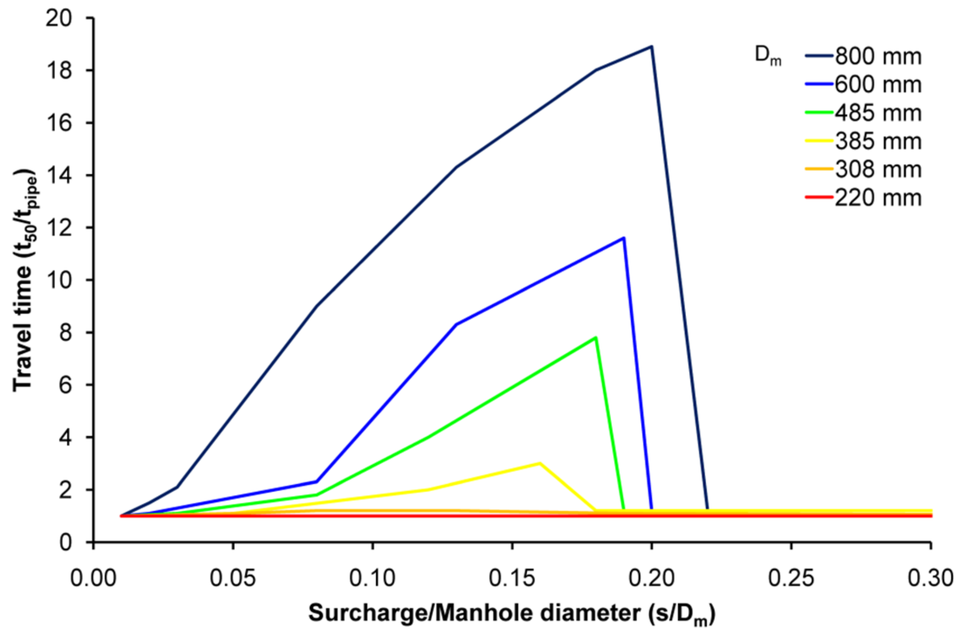
Tertiary Validation



Laboratory data **CFD data**

Effect of D_m/D_p on Residence Times





- As manhole diameter (D_m) decreases, the solute transport characteristics tend towards pipe flow (i.e. the low surcharge enhanced mixing effect disappears)
- This can be explained with reference to jet theory – the jet will bypass the mixing volume if $D_m/D_p < \sim 5$

Conclusions

- Both the RSM and k-ε Realizable turbulence models offer a good fit with laboratory flow field PIV data.
- The k-ε Realizable model by nature requires much less computational expense than the RSM and is therefore desirable for applications such as this.
- Volume of fluid free surface models can be shown to replicate similar flow fields to that of the fixed lid assumption. This allows for the possibility of extending validated work into more realistic unsteady conditions.
- At D_m/D_p ratios $< \sim 5$ solute passes through the manhole as though it remained confined within a pipe.

THANK YOU

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