Influence of Vegetation on Pond Residence Times

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Mixing Processes in Pipes, Sewers & the Natural Environment – from Theory to Practice

18th & 19th April 2023, University of Sheffield, UK.

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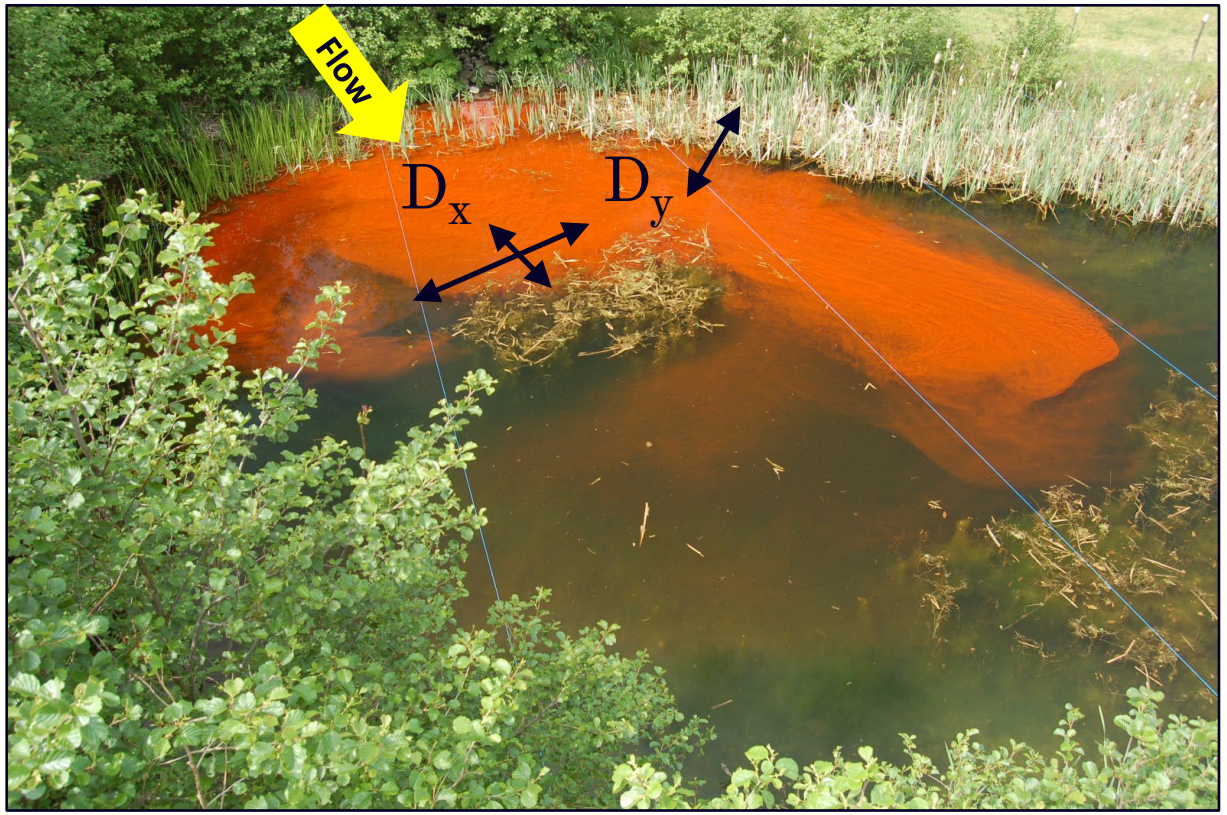
UKRI Engineering and Physical Sciences Research Council

IAHR AIRH International Association for Hydro-Environment Engineering and Research

Supported by Spain Water and IWHR, China

Mixing in Ponds

- Vegetation is often present in stormwater ponds
- Vegetation promotes the settlement of sediments and the biological degradation of pollutants
- However, vegetation could promote short-circuiting, reduce residence time and reduce the efficiency of treatment processes



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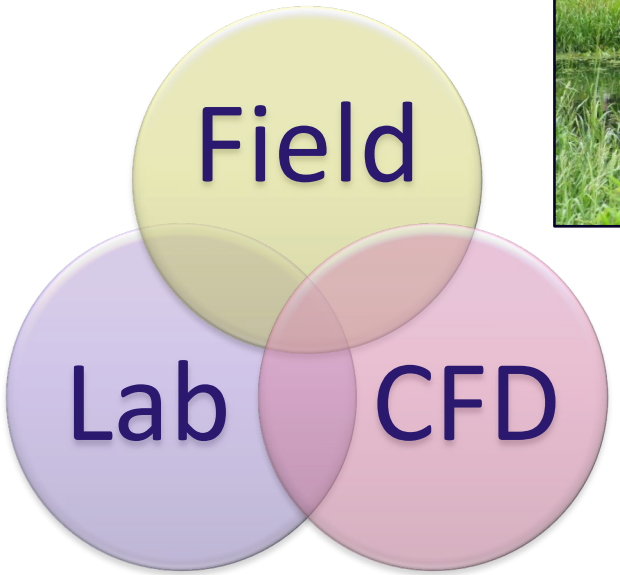
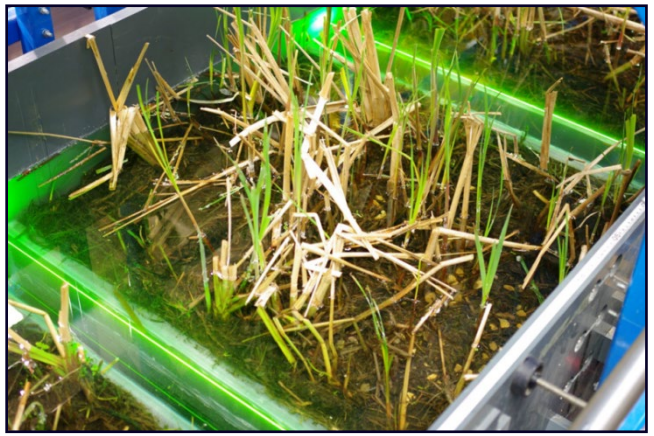
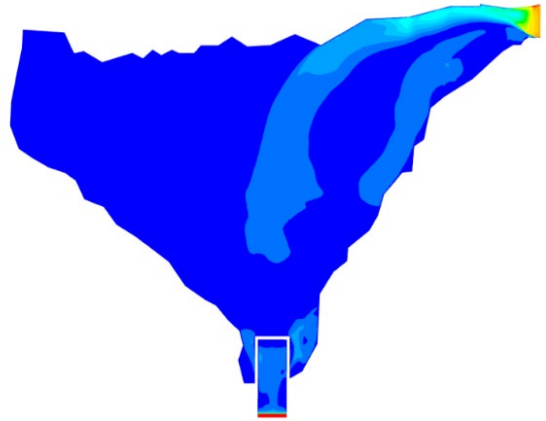
Mixing due to vegetation

EPSRC
Pioneering research and skills

- Effect of spatial distribution and type of vegetation on hydraulic residence time distribution (RTD) within ponds
- Develop and validate appropriate modelling tools to describe hydraulic performance







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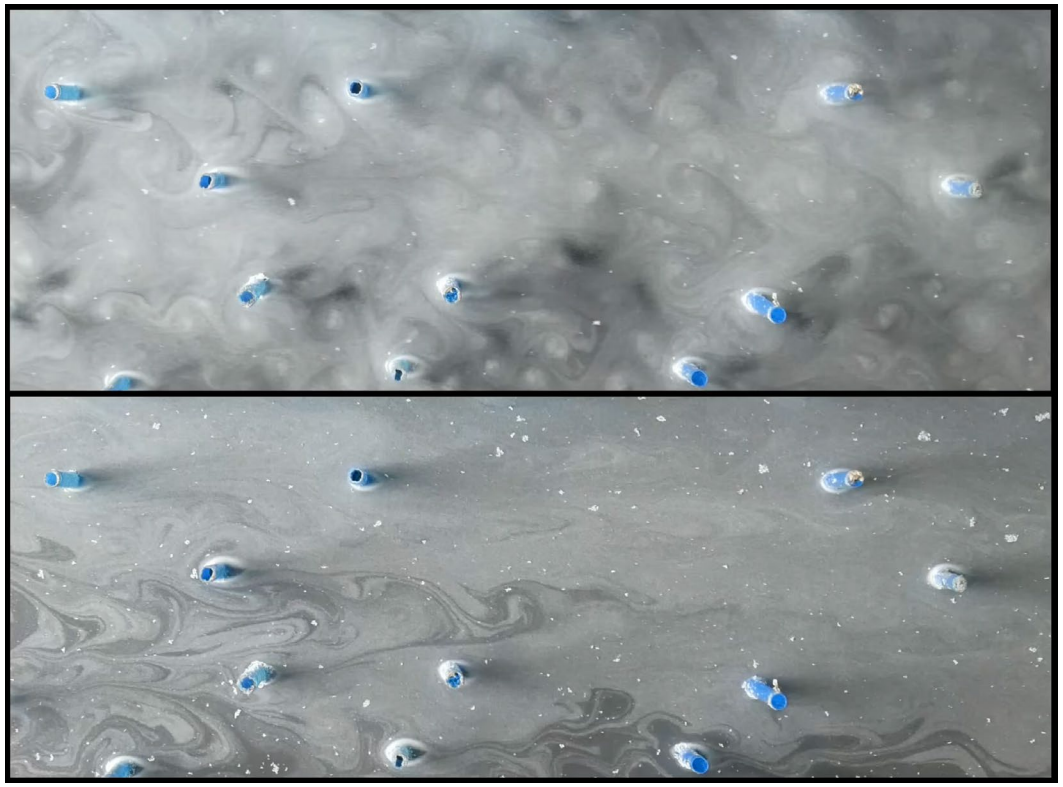
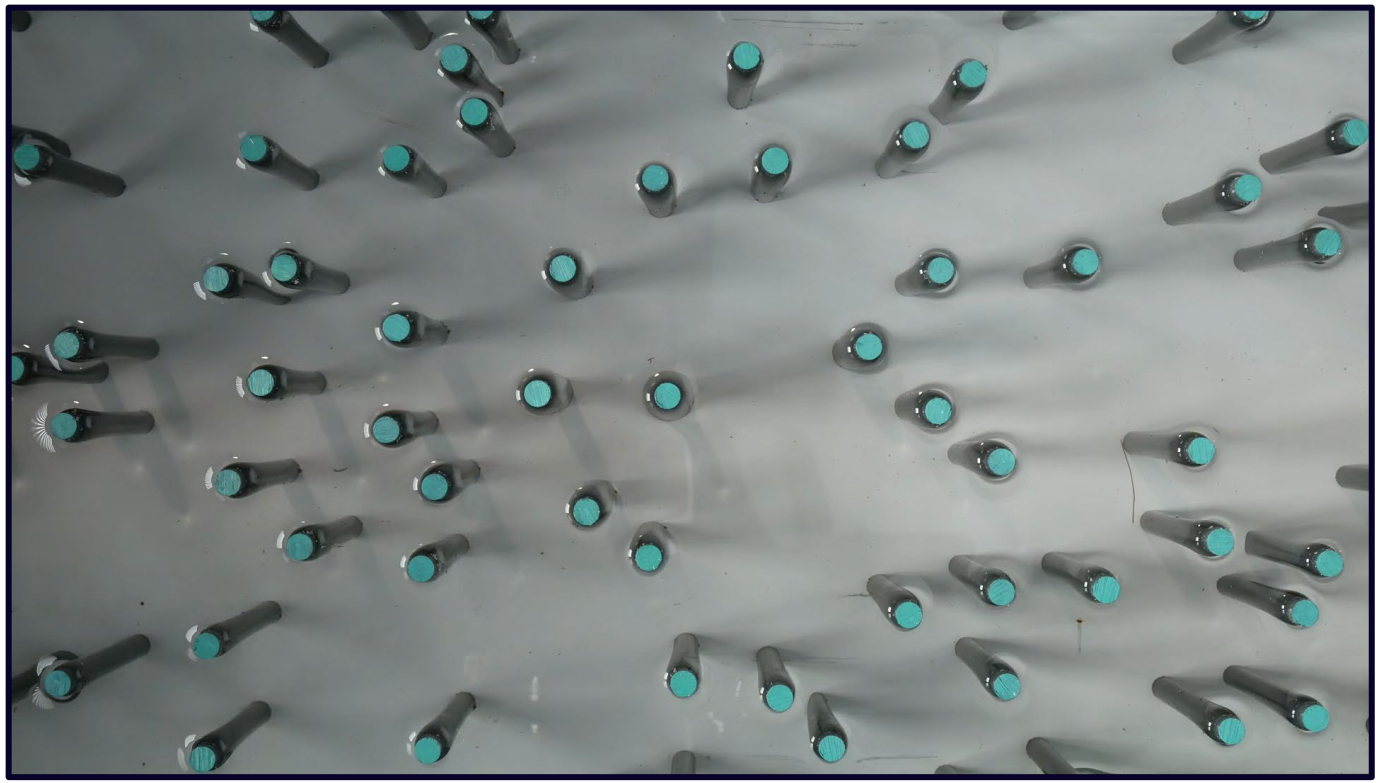
Preliminary studies

Lab

Surface velocity



Solute mixing



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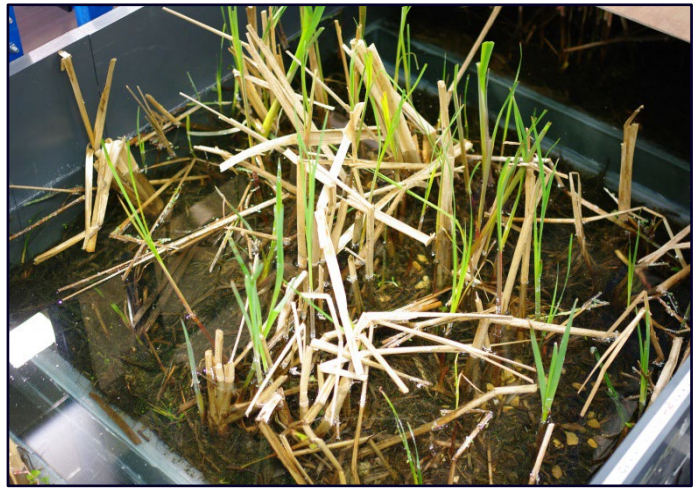
Species tested

Lab

Typha - Winter



Carex - Summer

Typha - Summer

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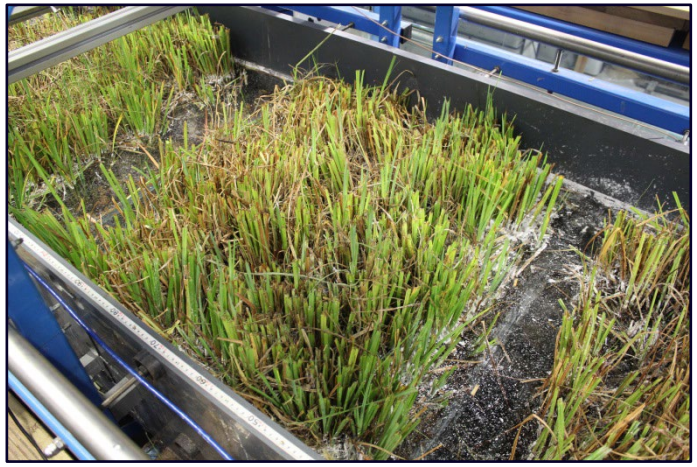

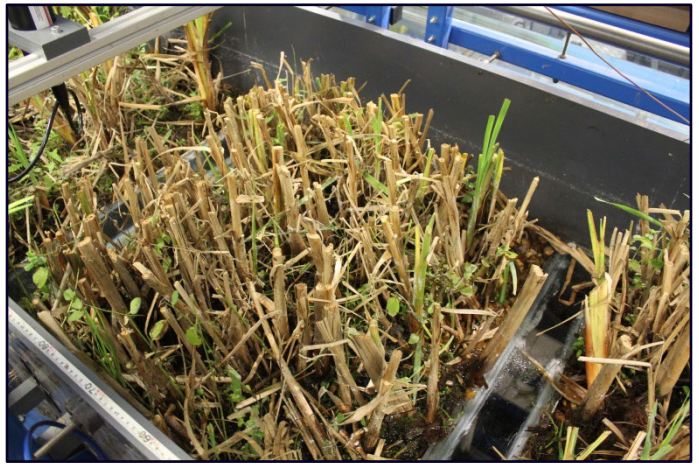

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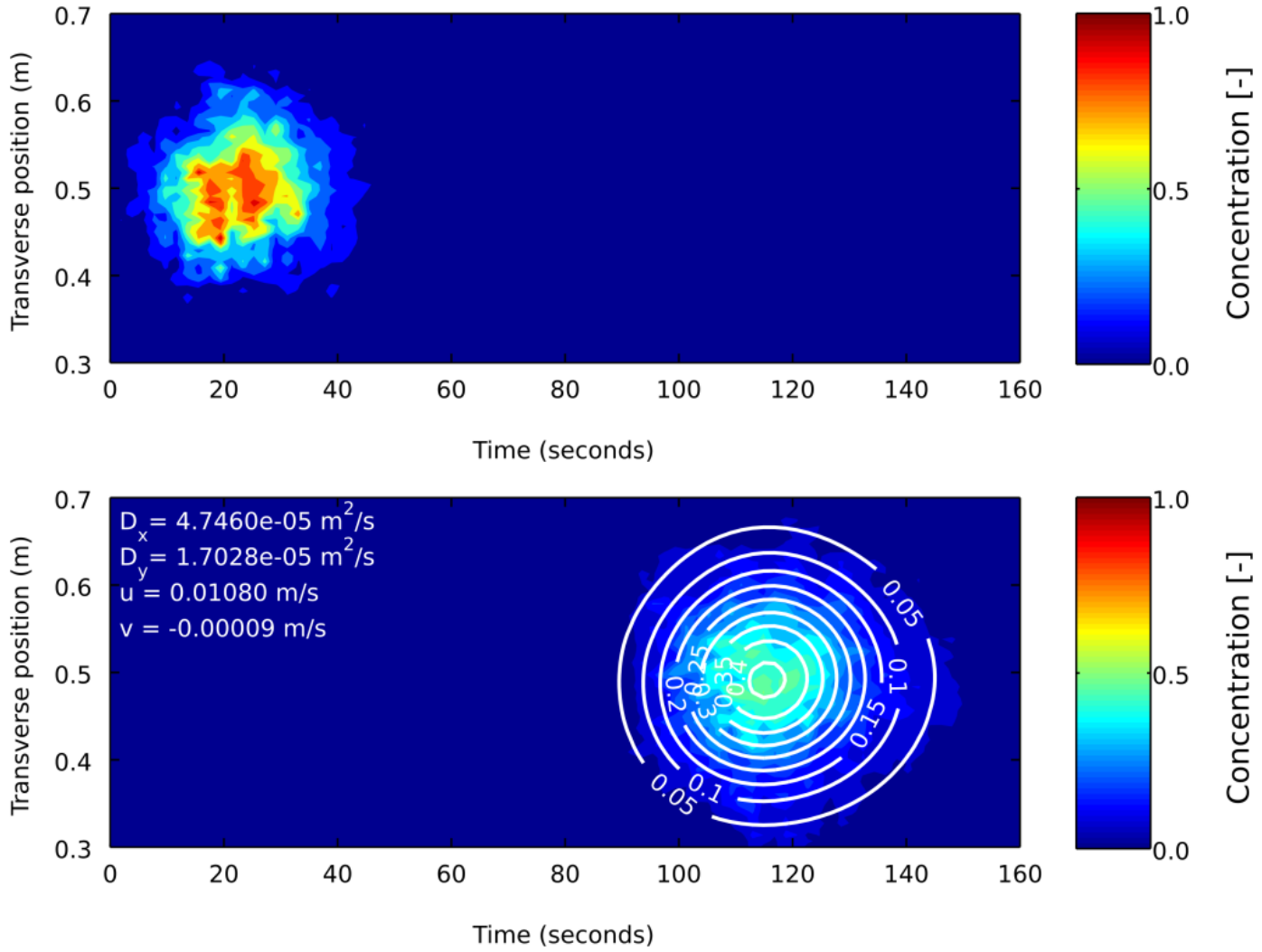
Real Vegetation

Lab



Simultaneous determination of longitudinal and transverse mixing

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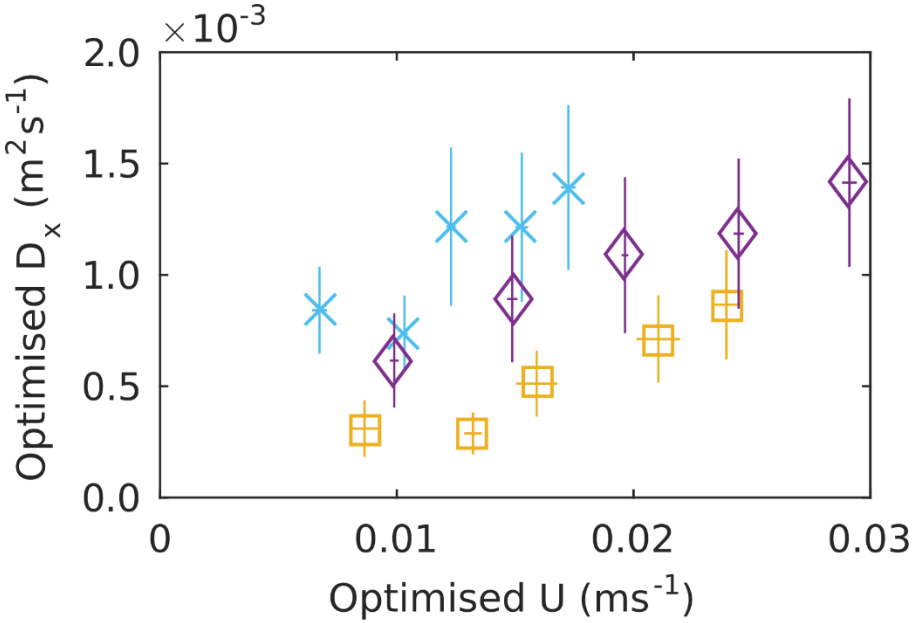
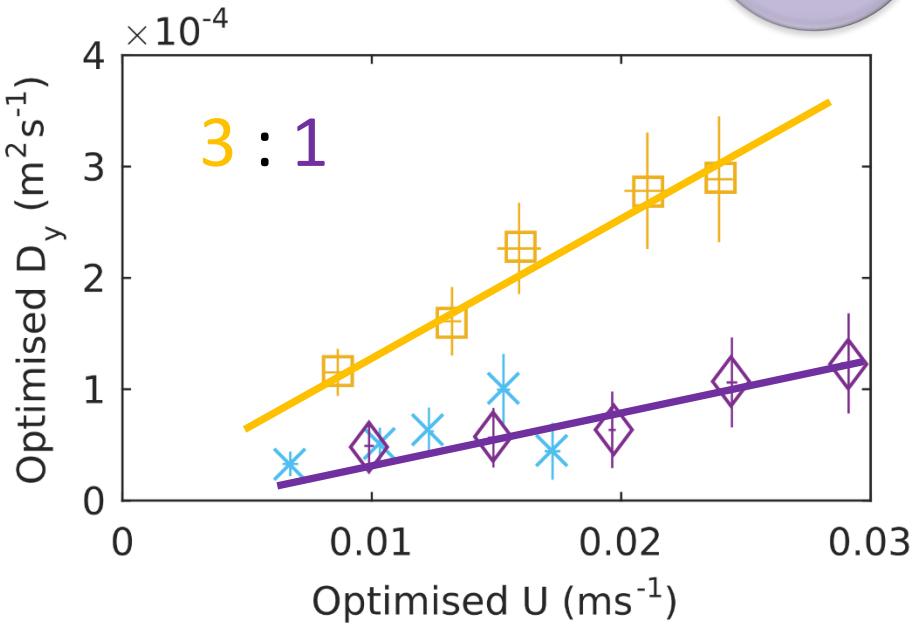
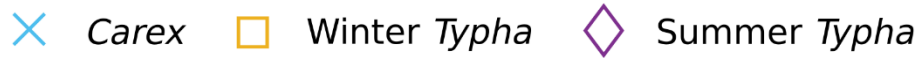
Sonnenwald, F., Hart, J.R., West, P., Stovin, V.R. and Guymer, I. (2017) "Transverse and longitudinal mixing in real emergent vegetation at low velocities" Water Resources Research

Real Vegetation - Dispersion

Lab







- D_x similar trends, slightly different magnitudes
- Winter Typha exhibits greater transverse mixing

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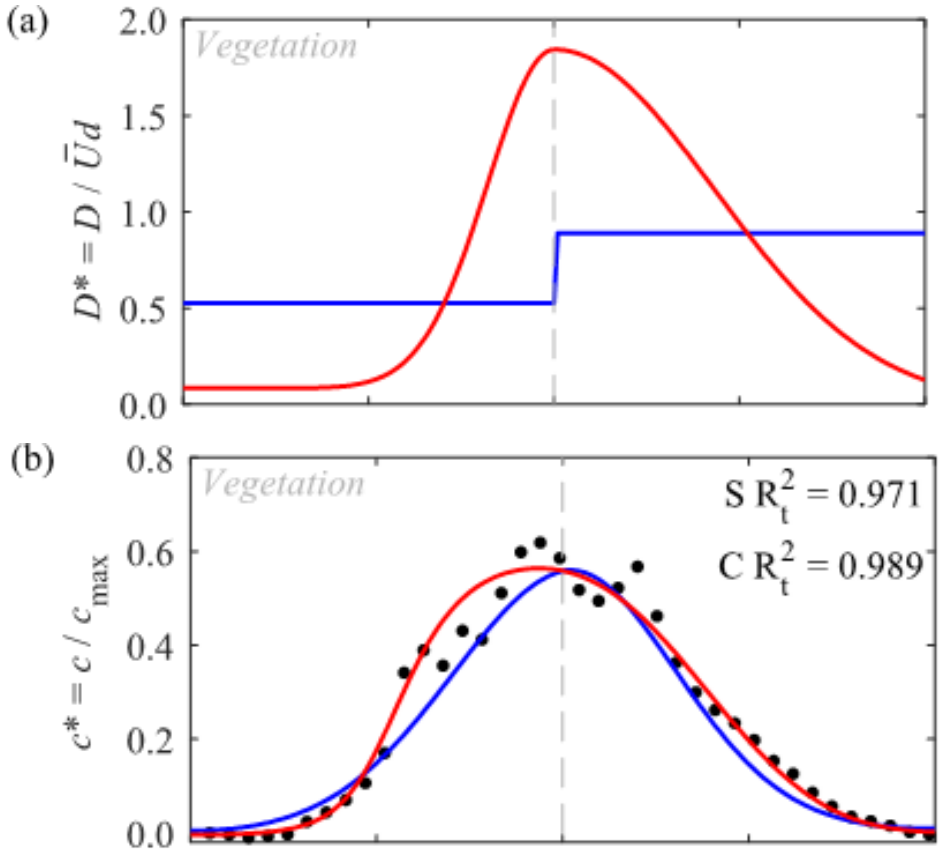
Sonnenwald, F., Hart, J.R., West, P., Stovin, V.R. and Guymer, I. (2017) "Transverse and longitudinal mixing in real emergent vegetation at low velocities" Water Resources Research

Partial vegetation – transverse shear effects

Lab



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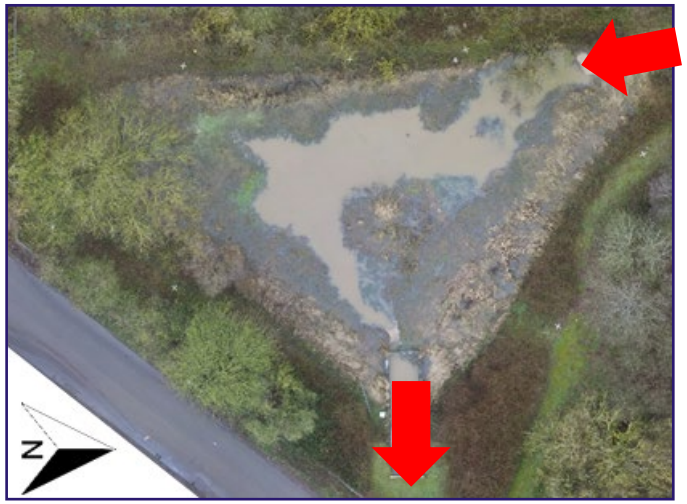
West, P.O., Wallis, S.G., Sonnenwald, F.C., Hart, J.R., Stovin, V.R., & Guymer, I. (2020). Modelling transverse solute mixing across a vegetation generated shear layer. Journal of Hydraulic Research

Field studies – highway run-off pond

Field

- > 25 years old
- Established vegetation
- Mean depth ≈ 0.543 m
- Volume ≈ 513 m^3
- Low flow residence time ~8 hours
- Discharge 20 l/s to 100 l/s



Field tracer study

Field

Dye injection

In-pond monitoring

Outlet monitoring

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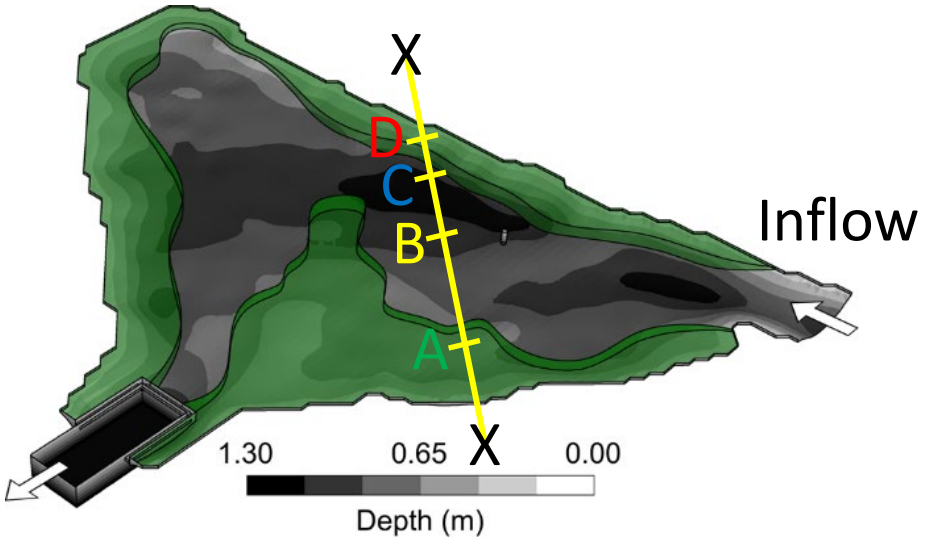
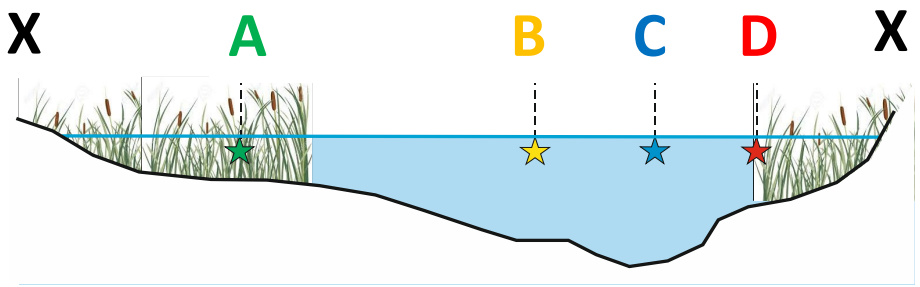
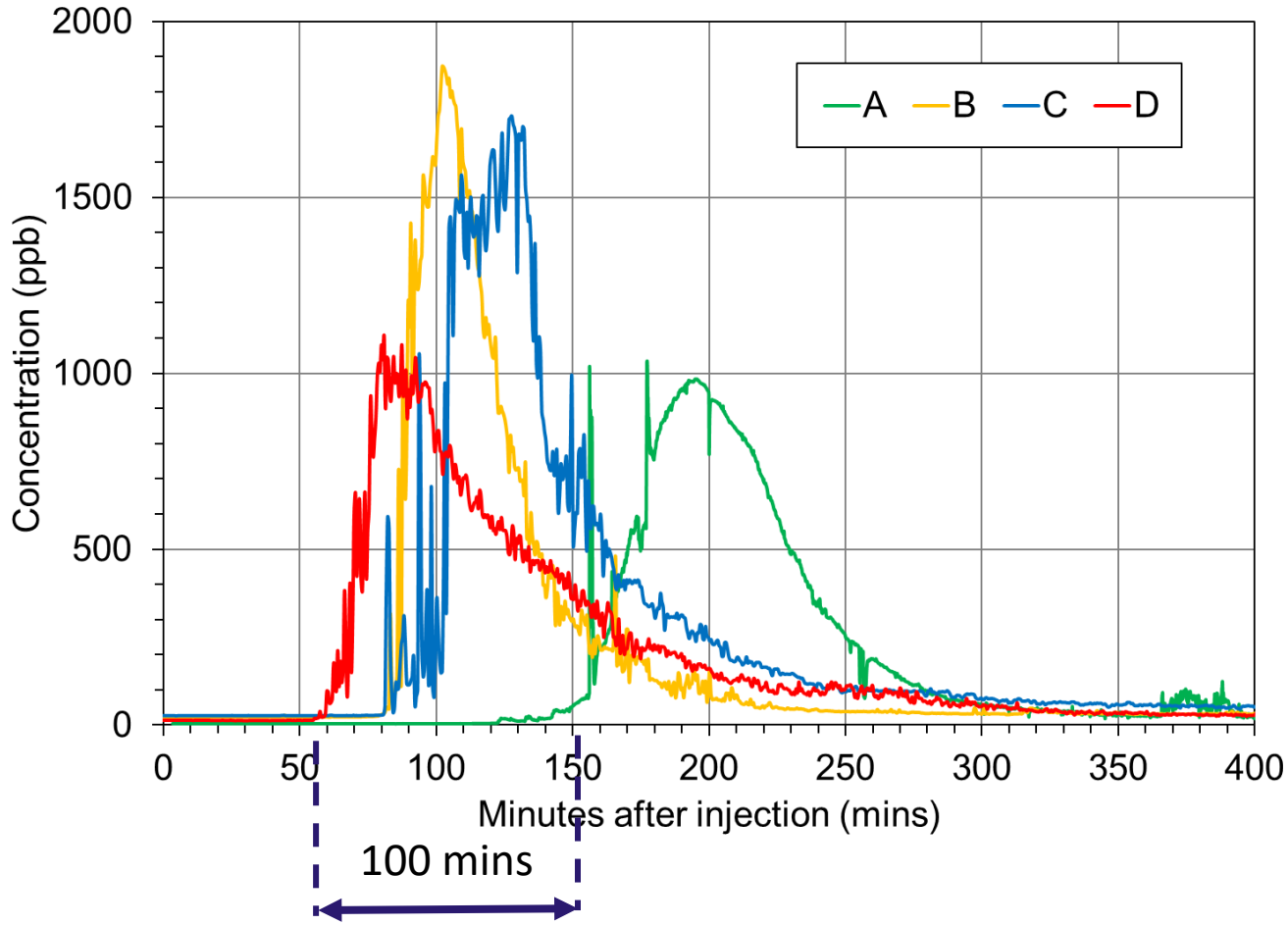
Summer monitoring at section X-X

Field







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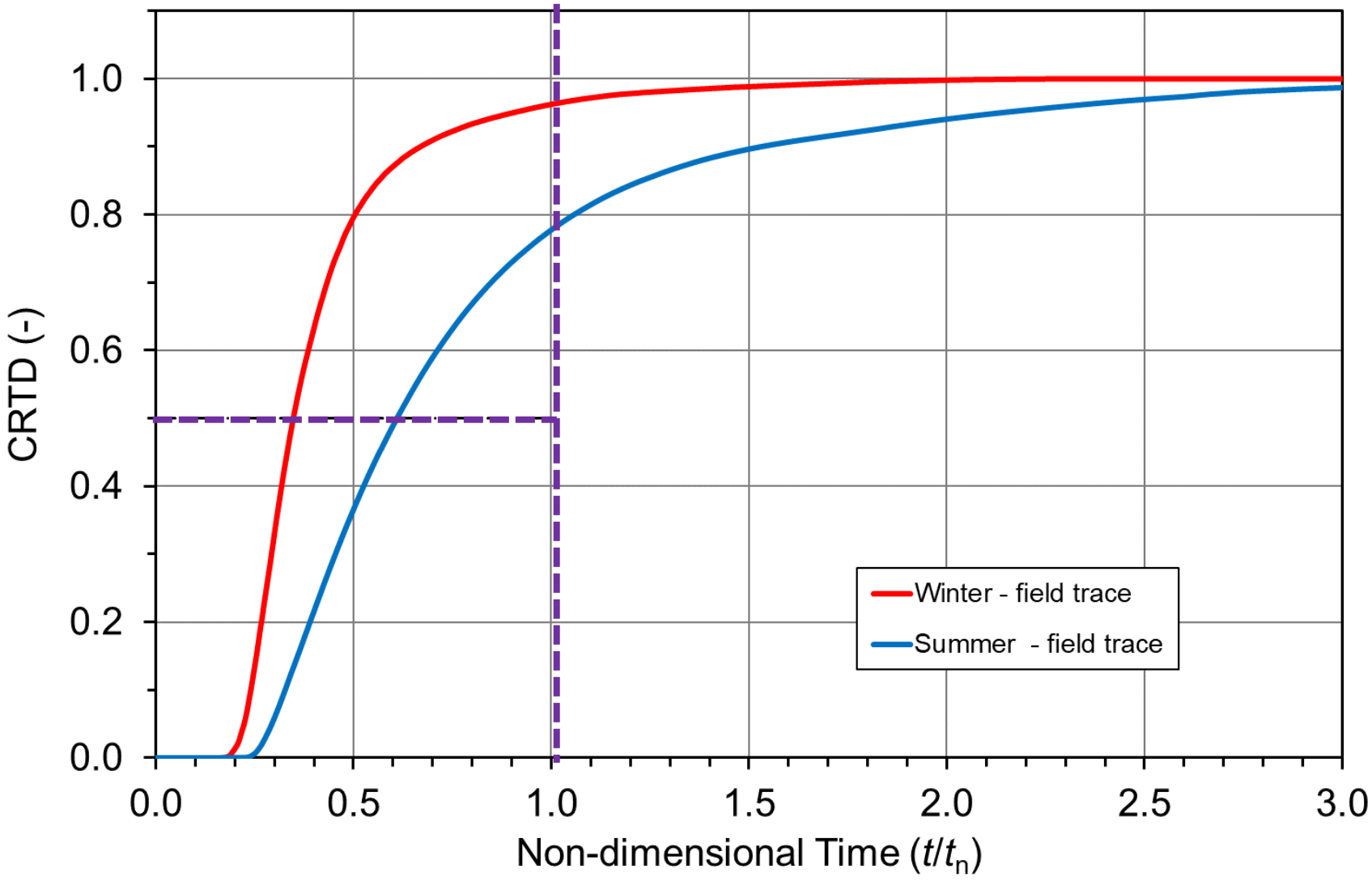
CRTDs at Outlet

Field

- Multiple summer traces
- $t_n = \frac{\text{volume}}{Q_{mean}}$
- Winter short-circuiting



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Fieldwork Outcomes

Field

- Total vegetation surface coverage varied from ~60 % in summer to ~40 % in winter
- Change in vegetation distribution and characteristics impacted the system hydraulics
- From recorded residence time distributions:
  - first arrival and peak concentration times were similar for both summer and winter vegetation
  - winter vegetation generated less spread in the tracer and had a lower mean residence time
- Data suggests that the summer flow experienced more mixing, probably as a result of the increased vegetation cover

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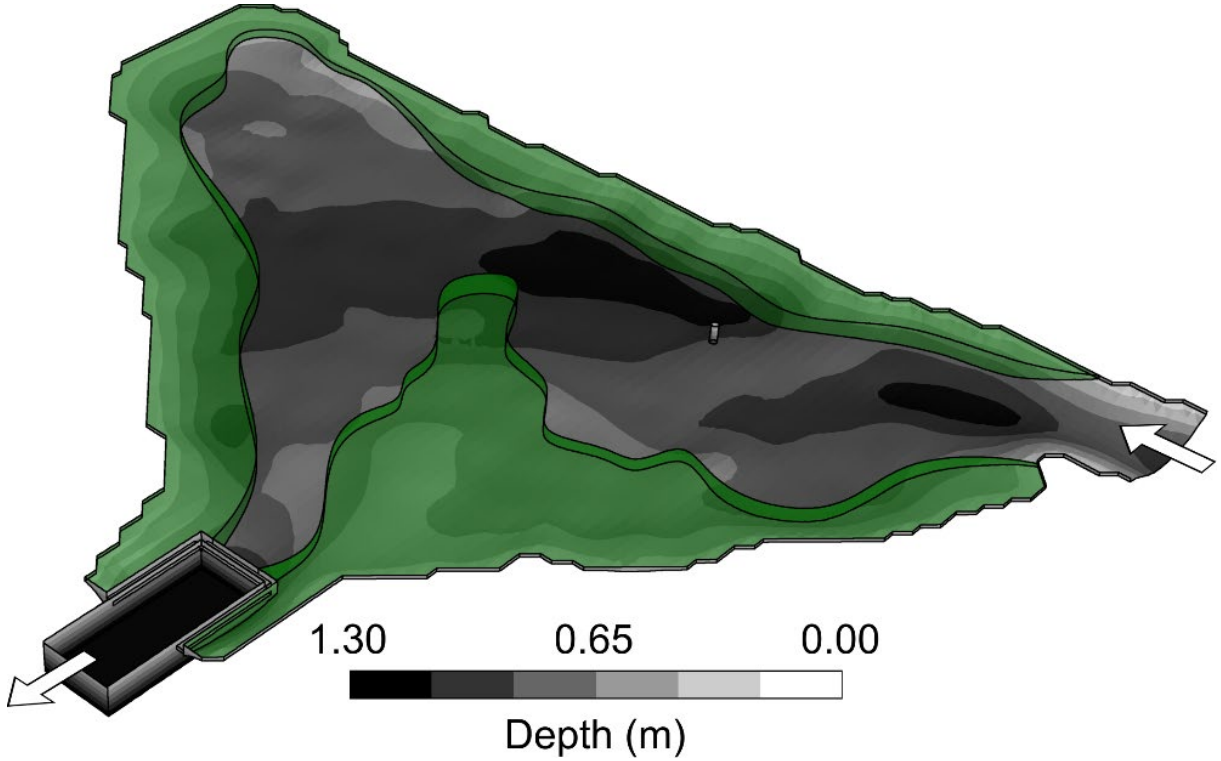
CFD Modelling Approach

CFD

- Stem-scale modelling not feasible
- Bulk-scale approach using a porous zone to represent vegetation
- Drag and mixing coefficients estimated based on vegetation characteristics and local flow conditions
- Developed user-defined functions



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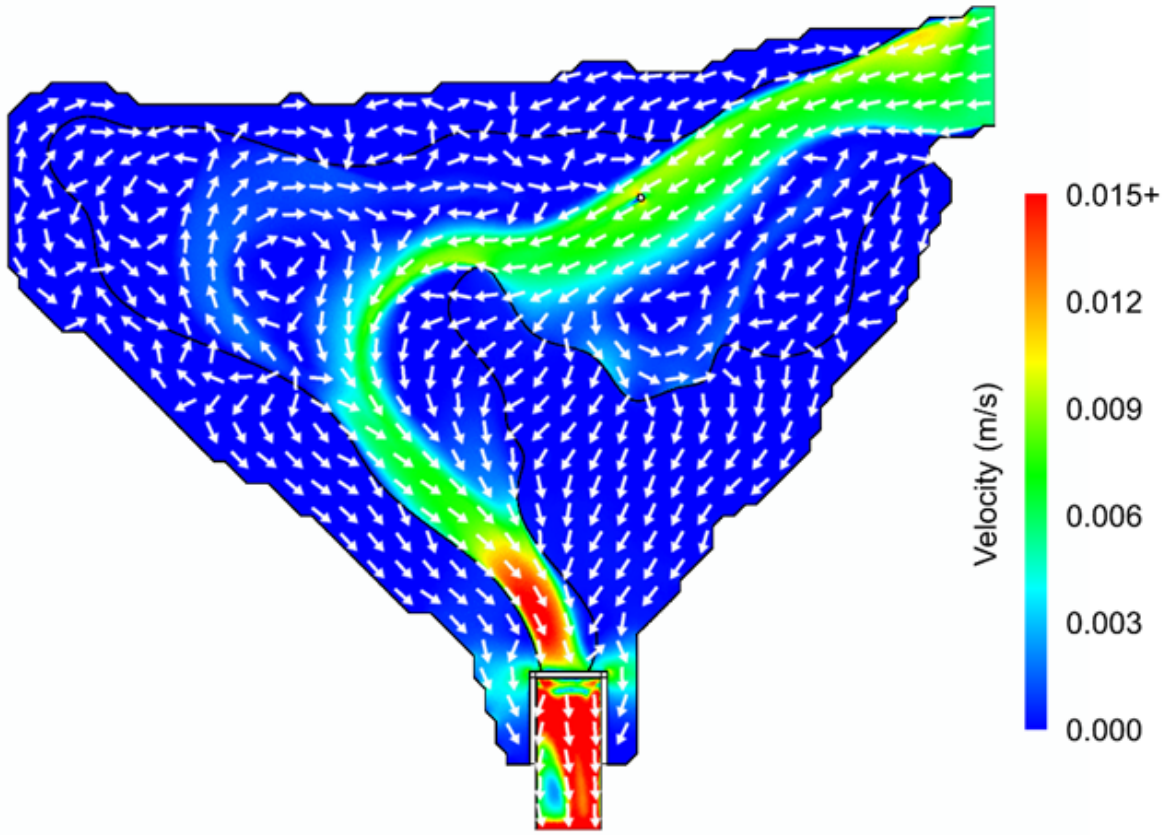
Sonnenwald, F., Guymer, I.,& Stovin, V. (2019) A CFD-based mixing model for vegetated flows. Water Resources Research

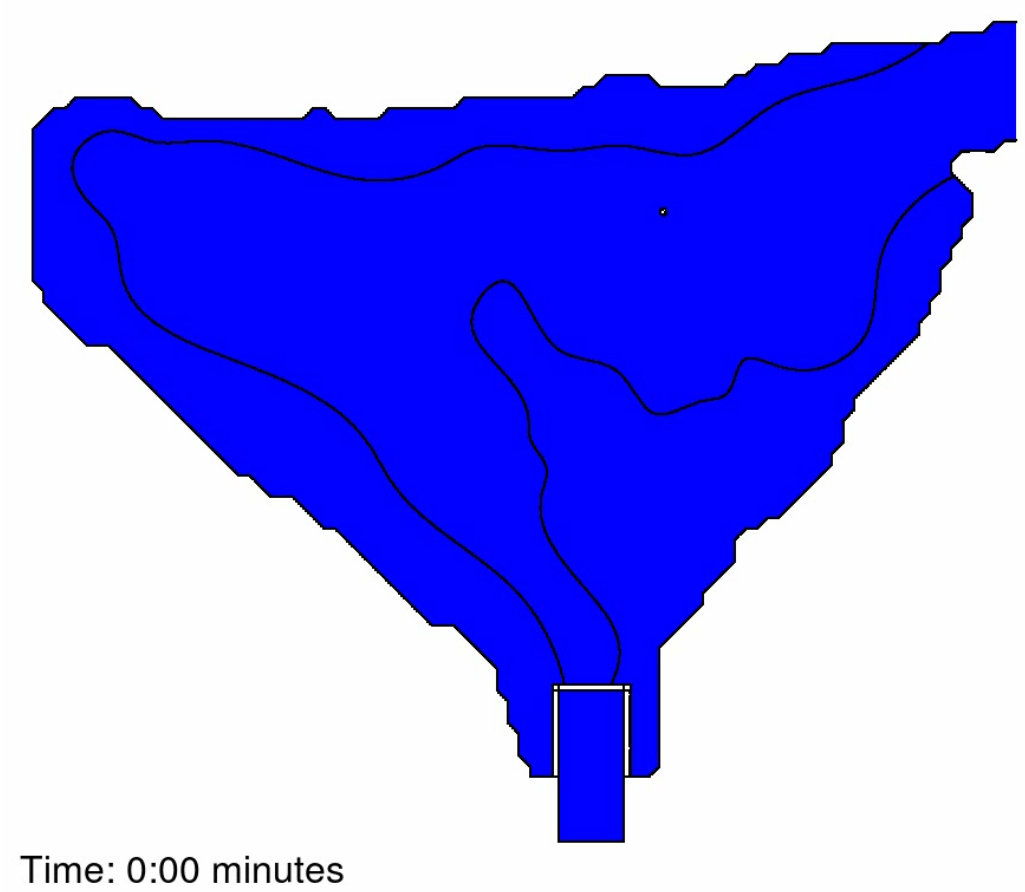
CFD Results

CFD

Flow field



Solute mixing



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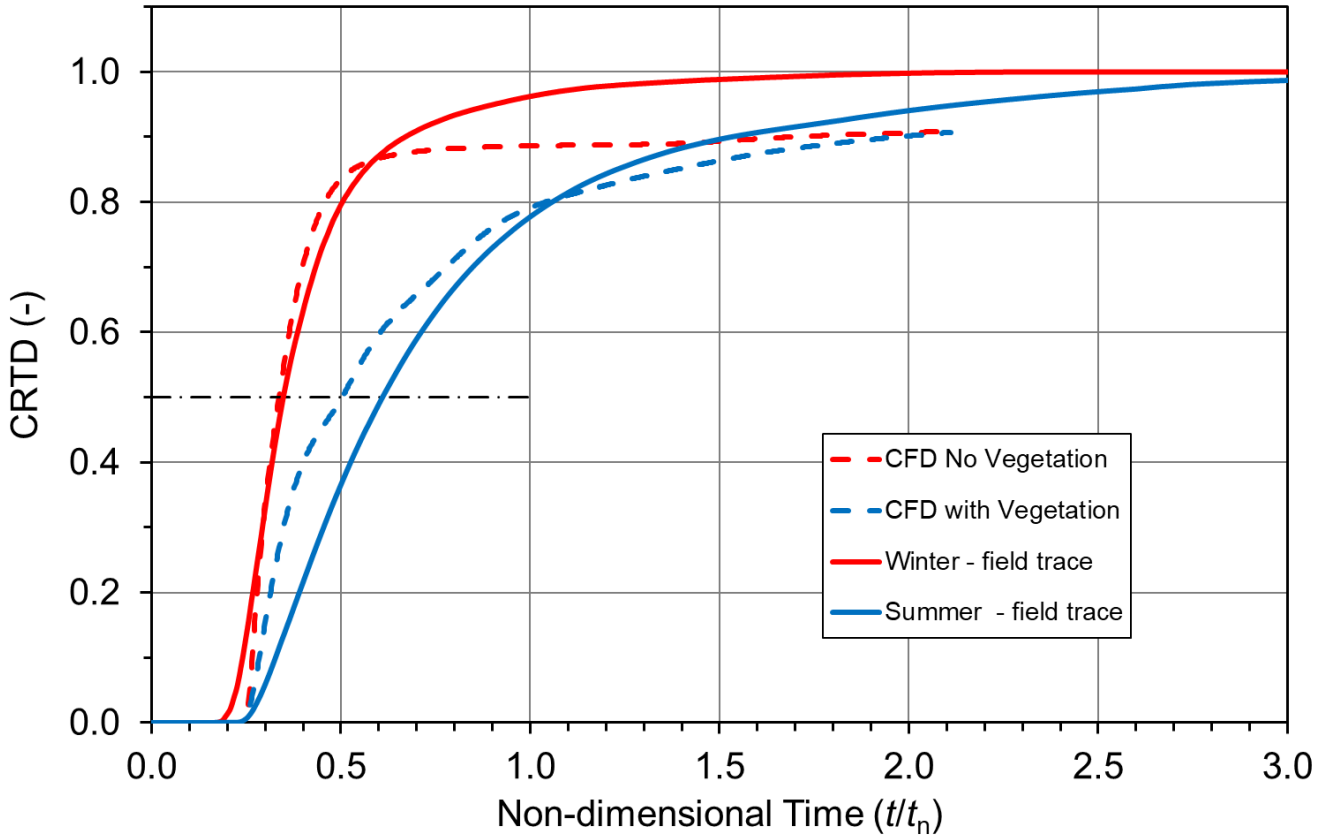
Summary

- It is feasible to capture the effects of vegetation on pond flow field and mixing processes via commercial CFD modelling tools combined with the user-defined functions
- A comparison of modelled and measured solute traces suggests that the residence time distributions are reproduced well in the model



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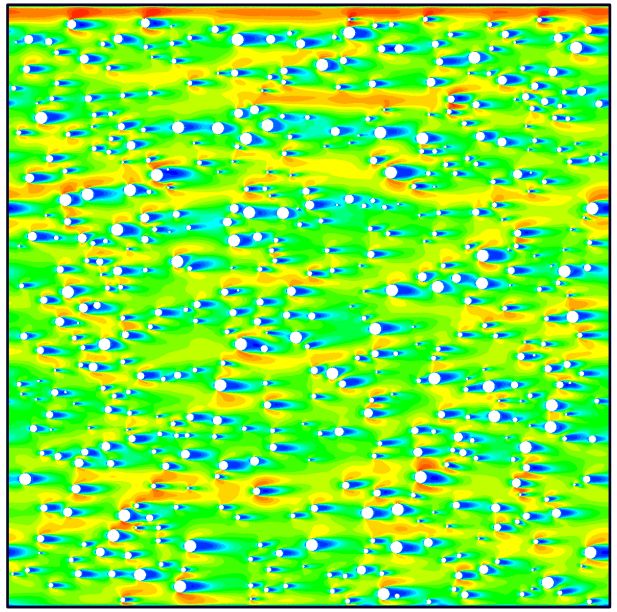
- Failure to incorporate vegetation effects could lead to poor estimation of mixing processes, residence times & treatment efficiency

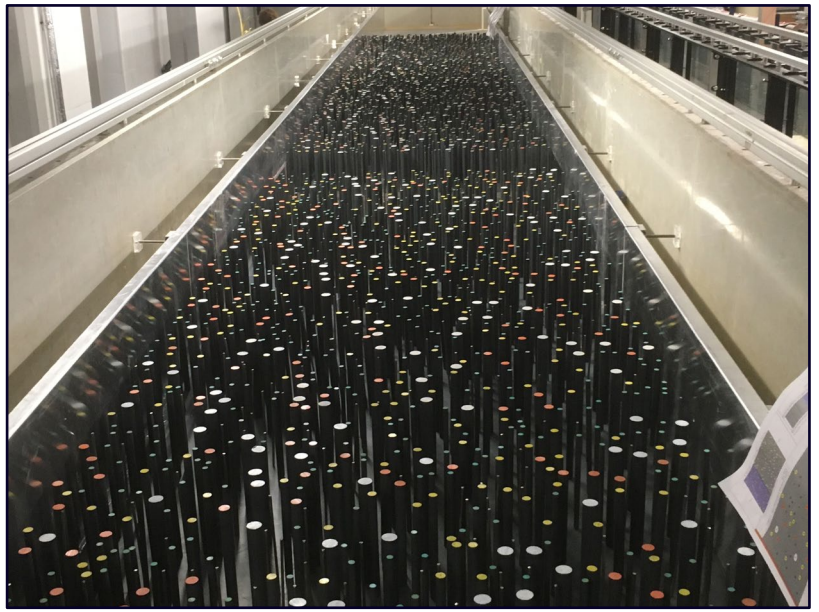
Next steps

Is it possible to determine D_x & D_y values from vegetation characteristics?

CFD Modelling



Laboratory Studies



Over to Virginia & then onto Leo …..

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