Longitudinal Dispersion from Cylinders to Realistic Plant forms

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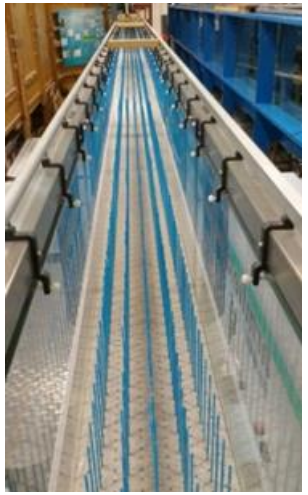
WATER INFRASTRUCTURE AND RESILIENCE WIRe

EPSRC Centre for Doctoral Training

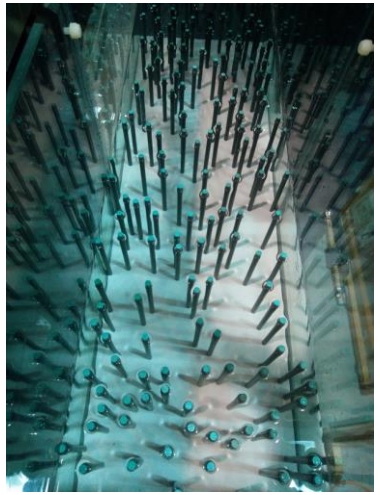
SEVERN TRENT WATER

Background

Artificial plant models from previous studies



Straws

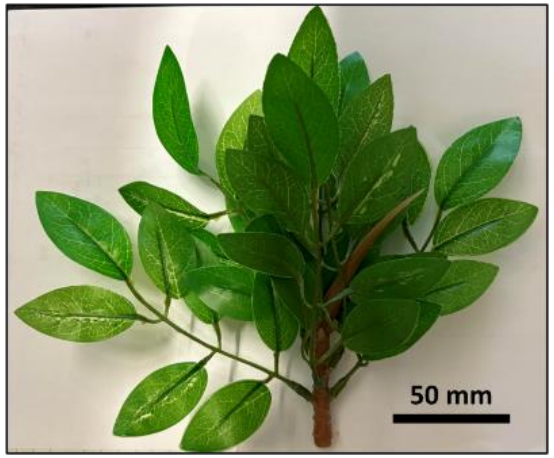


Dowel pins

Cable ties

Plant Structure

This study



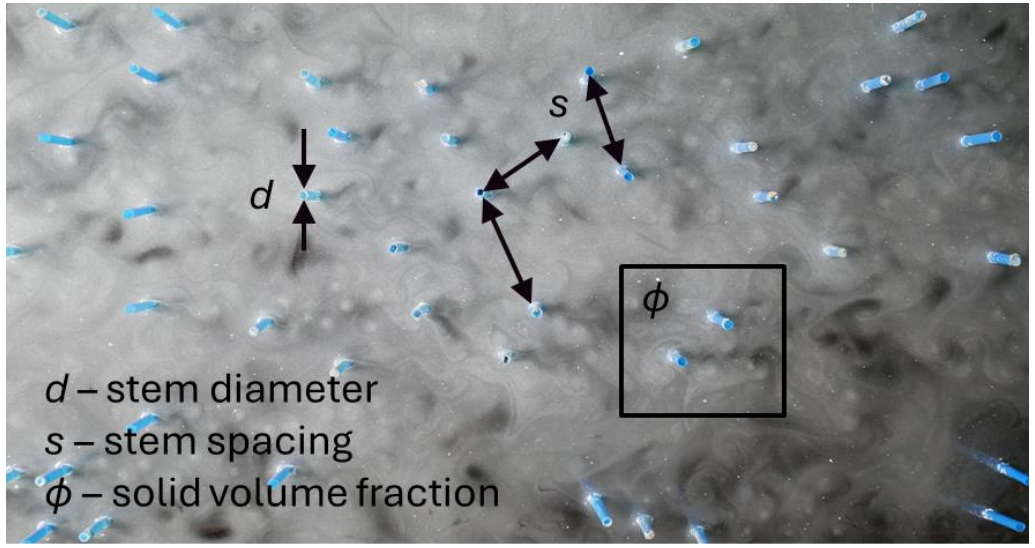
Limitations of using artificial plants:

- Oversimplification of plant structure
- Plant aging/growth and seasonal changes
- Inadequate generation of turbulence

Natural vegetation

Background

- Previous studies on artificial vegetation in a 300 mm wide flume.



Vegetation type	Configuration	d (m)	SVF, Φ	S (m)	S_{50} (m)	Reference
Drinking straws	Periodic	0.004	0.0050	0.0519	0.0519	Sonnenwald et al. (2019)
Drinking straws	Pseudo-random	0.004	0.0050	0.0249	0.0239	Sonnenwald et al. (2019)
Plastic dowels	Random	0.008	0.0270	0.0227	0.0223	Sonnenwald et al. (2019)
The Randosticks	Random	0.010	0.0522	0.0184	0.0173	Corredor-Garcia et al. (2022)
Cable ties	Random	0.004	0.0070	0.0244	0.0233	Sonnenwald et al. (2022)

Methodology

- Dye tracing experiments were conducted in a 12.5 m long, 300 mm wide flume set to uniform flow conditions at a depth of 105 mm.
- Longitudinal dispersion coefficients (Dx) were determined over a range of discharges up to 12 l/s for the two cases in the table below.
- Solid volume fraction is the volume of plants within a 1 m stretch of the flume to the volume of water in that stretch.

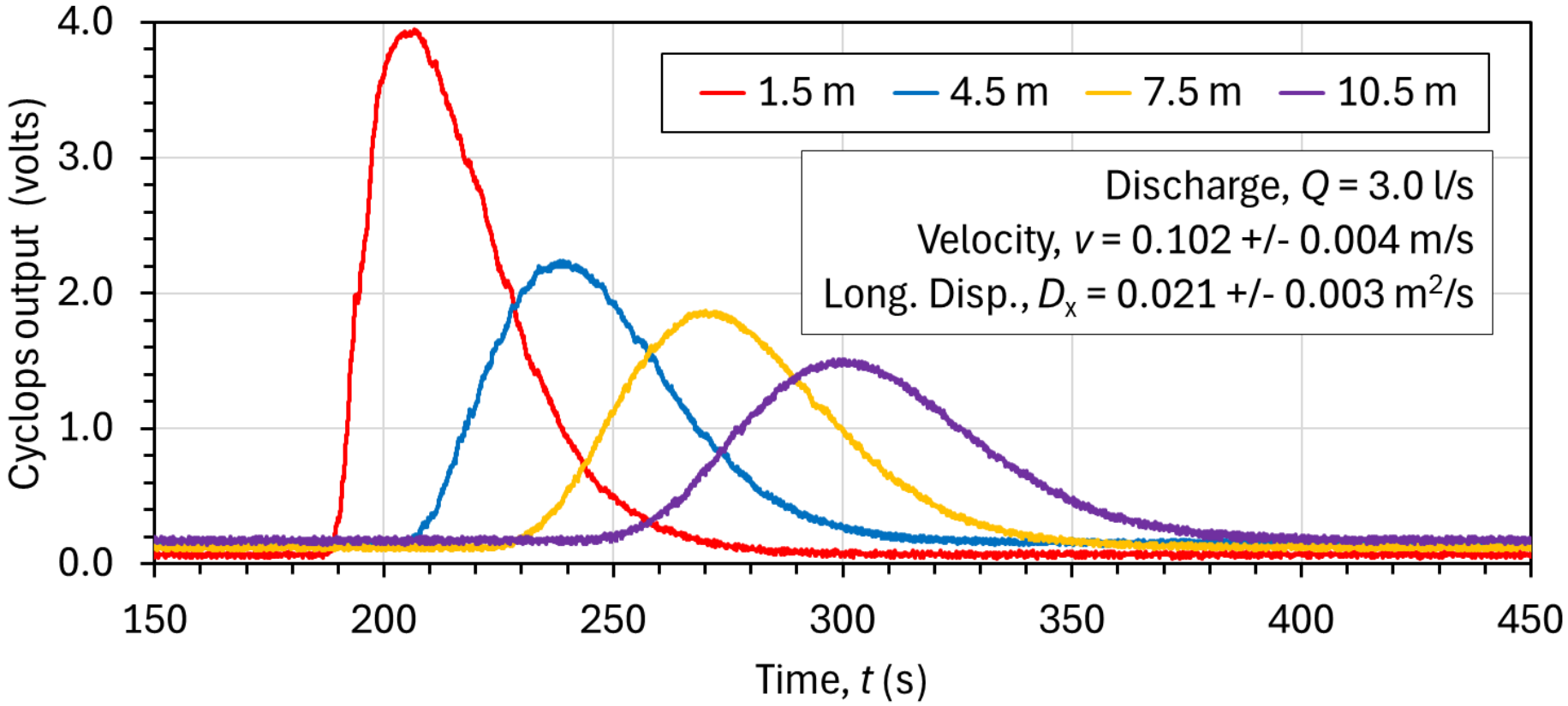
Φ = 0.008

Φ = 0.005

Configuration	Density	Number of Plants per metre	Solid volume fraction (Φ)
Regular	High	25	0.008
Preferential flow	Low	15	0.005

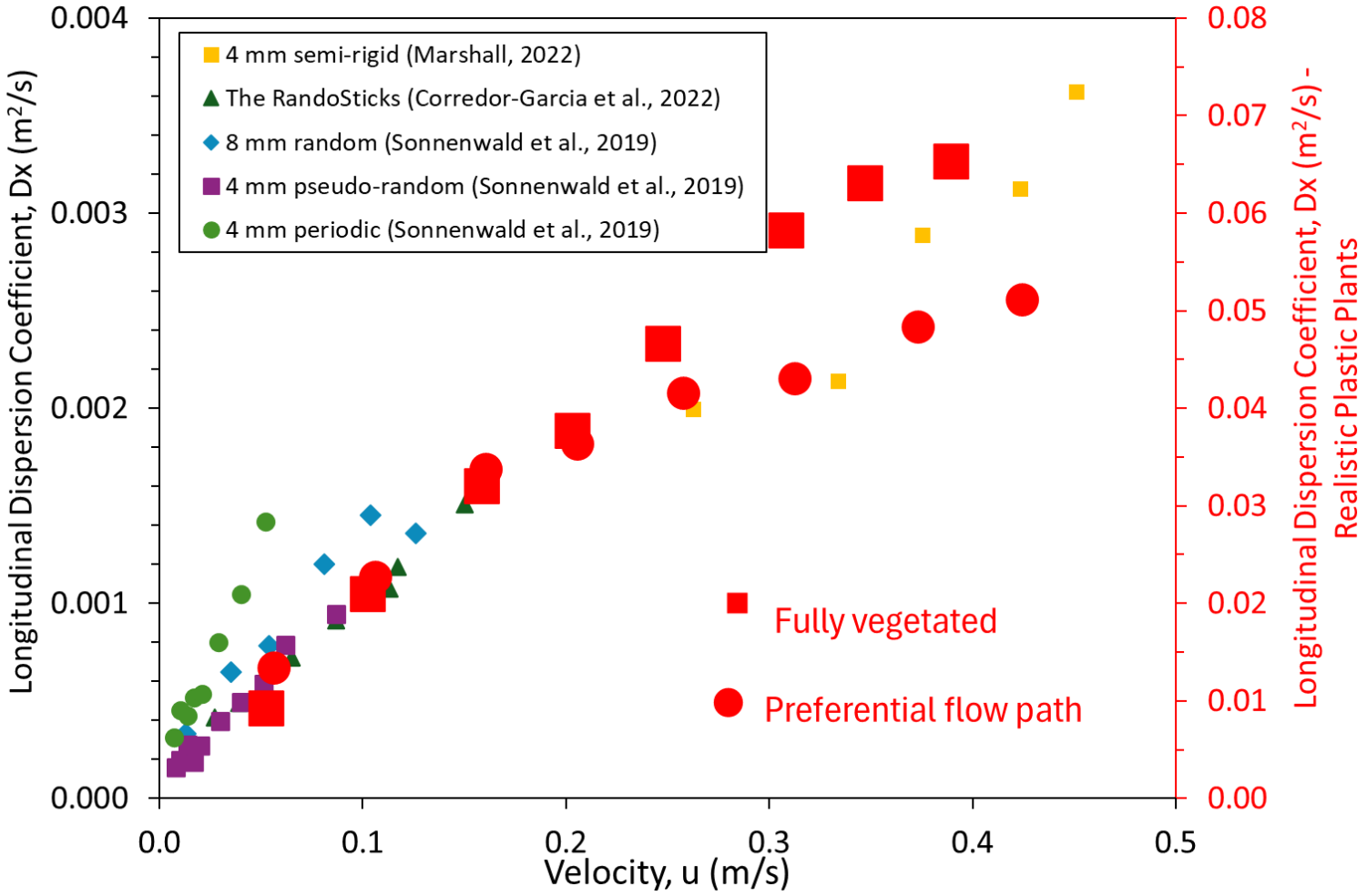
Methodology

- 4x Turner C7F Cyclops at 3 m intervals, recorded fluorescence at mid-width and mid-depth point.
- 5x repeat pulse injections of Rhodamine WT
- 15x values of the mean flow velocity, u (m/s) and the longitudinal dispersion coefficient, Dx (m^2/s) were obtained for each flow condition.



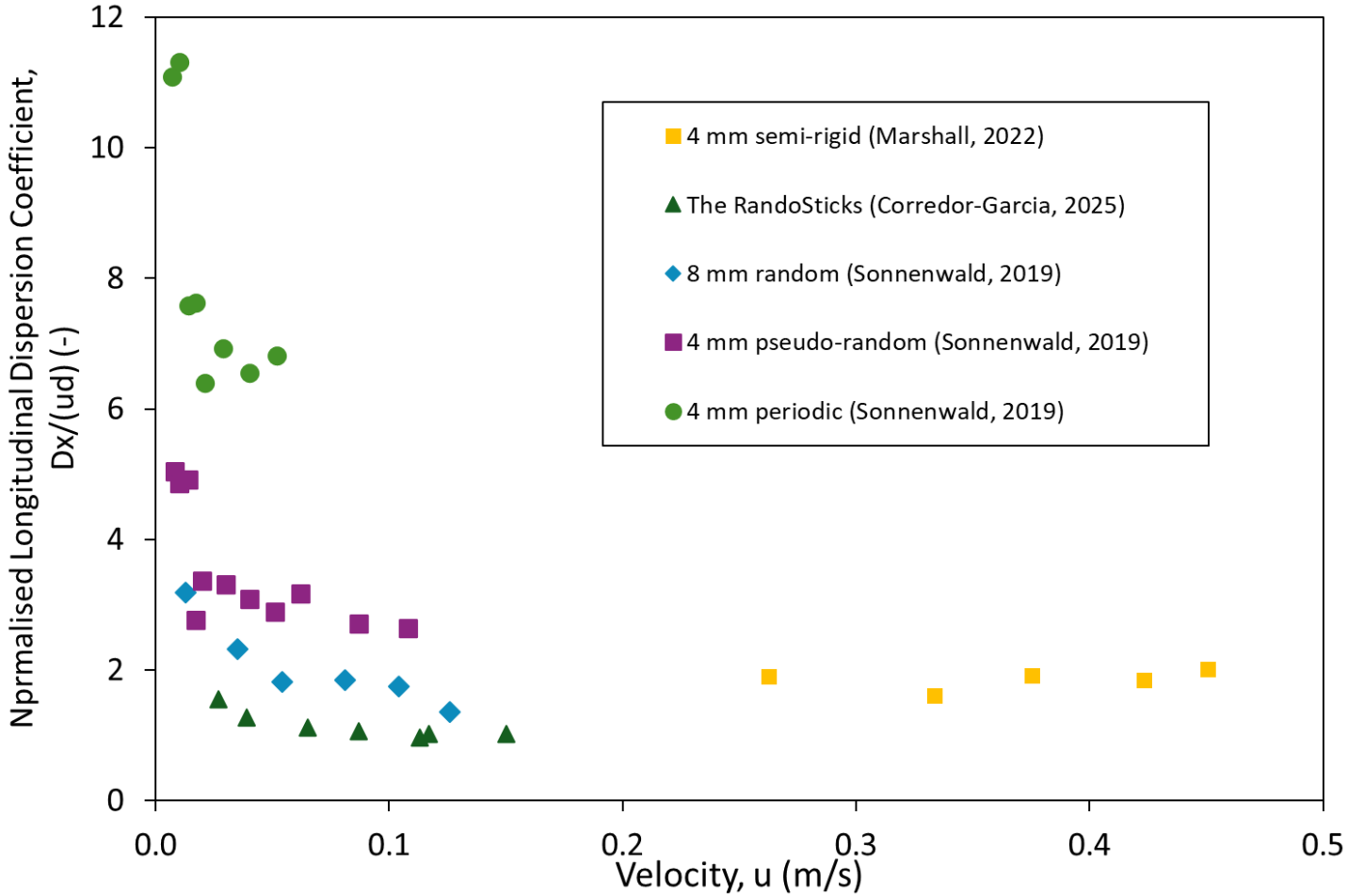
Results and Discussion

- The values of Dx for single diameter cylinders are an order of magnitude lower than those of artificial plants
- For regular patterns, Dx and u have a linear relationship unlike for preferential flow path.



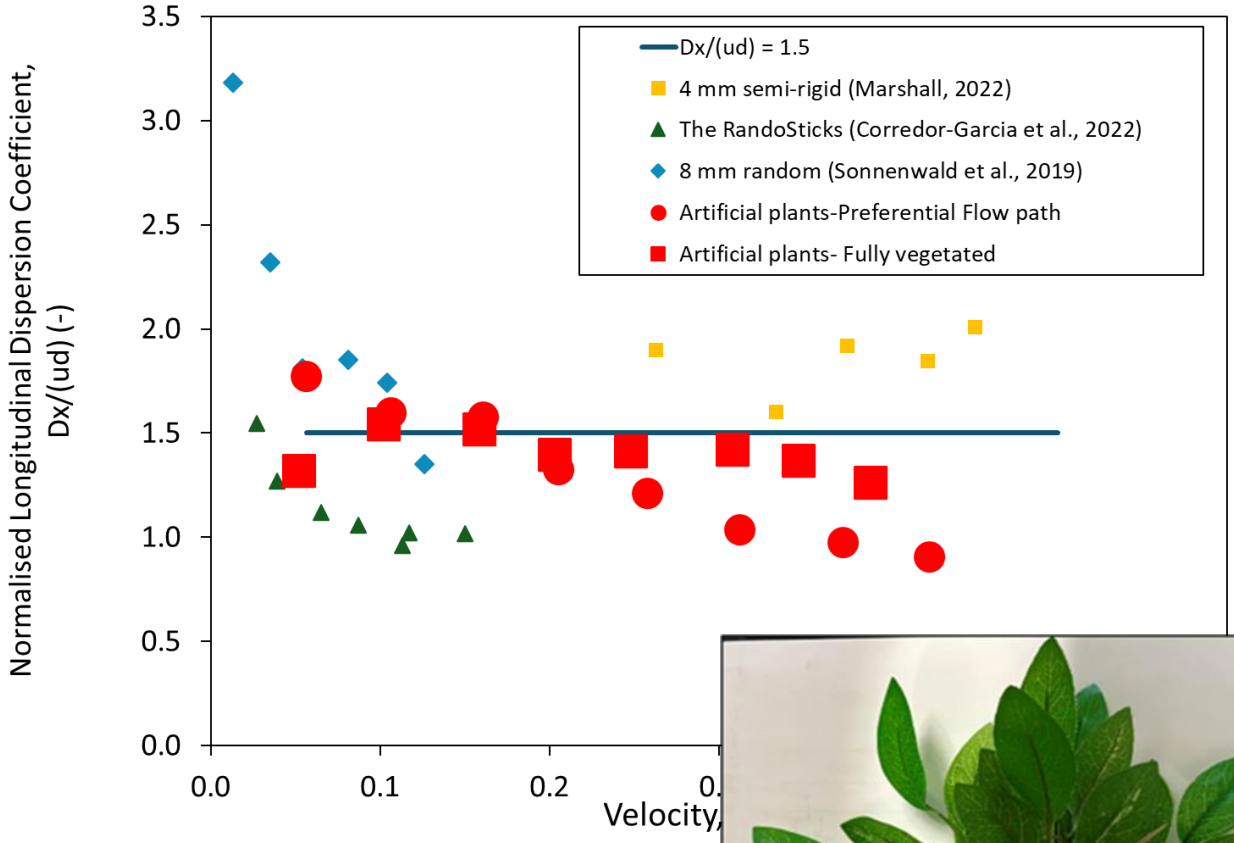
Results and Discussion

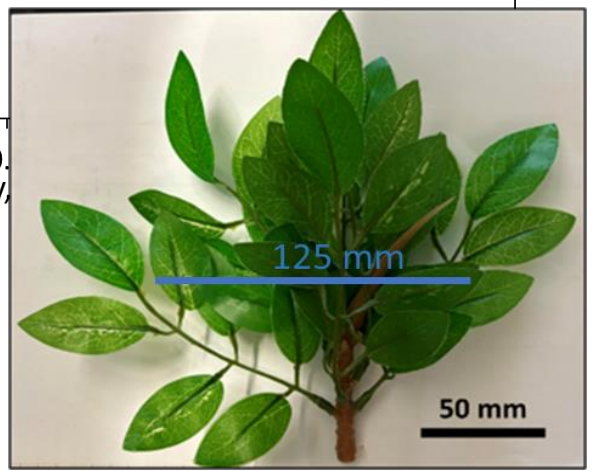
- Dx is usually normalized using velocity and a length scale such as stem diameter.
- Dx/(ud) = constant.



Results and Discussion

- Dx was normalized using plant diameter.
- Plant has variable diameter. Therefore, a reverse method used.
- What value of d will the synthetic vegetation data points collapse to fit Dx = 1.5ud?
- d = 125 mm, a representative plant diameter incorporating the leaves (not just the stem)



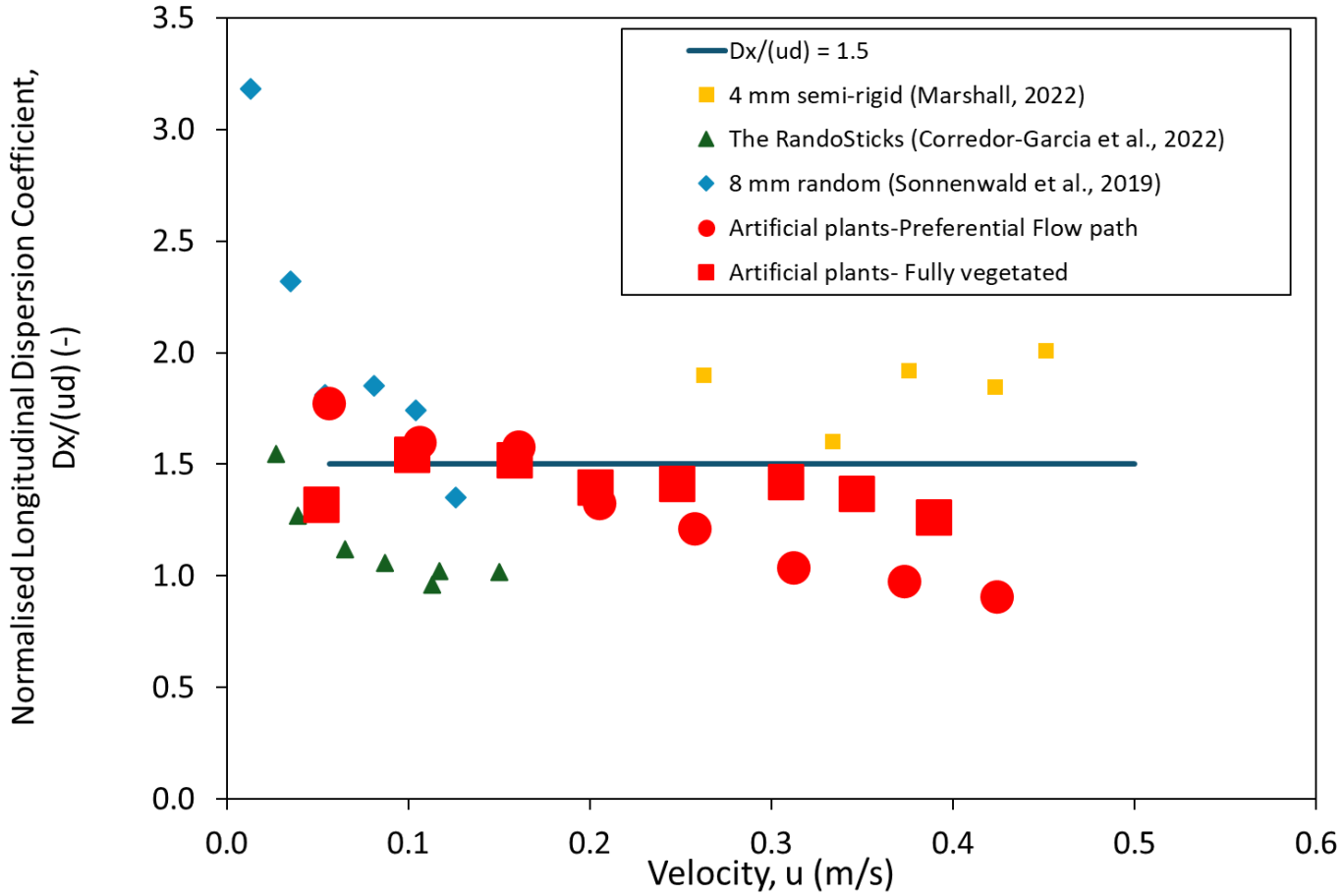


Limitation:

How to identify the representative diameter?

Results and Discussion

- Should normalisation of Dx be constant?



Conclusions and Recommendations

- This study confirms that earlier simplified physical models using cylinder arrays do not accurately reflect the complex mixing processes seen in realistic vegetated flows.
- Irregular patterns, like the preferential flow paths, are more realistic in rivers. This showed a non-linear relationship between velocity and Dx.

Recommendations

- Better model plants should be used in further mixing studies
- Further studies on more realistic and irregular patterns should be done to study the reliability of constant value normalization.