Testing hydraulic efficiency of pressure difference samplers while varying mesh size and type

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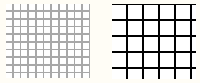
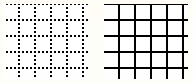
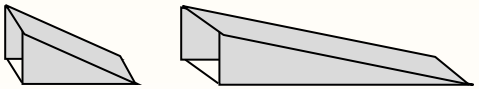
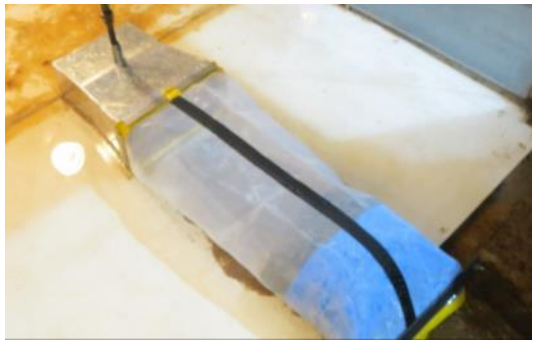
Problem

Different mesh bags are attached to pressure difference samplers to collect bedload depending on the user's particle size range of interest. Bags may vary in:

- mesh width 
- mesh % open area (density of the weave) 
- bag length 
- bag shape 
- Level of gravel fill (incl. bag end clogging)

- Degree of mesh clogging by extensive seams



Some effects of bag properties on hydraulic or sampling efficiency are qualitatively known:

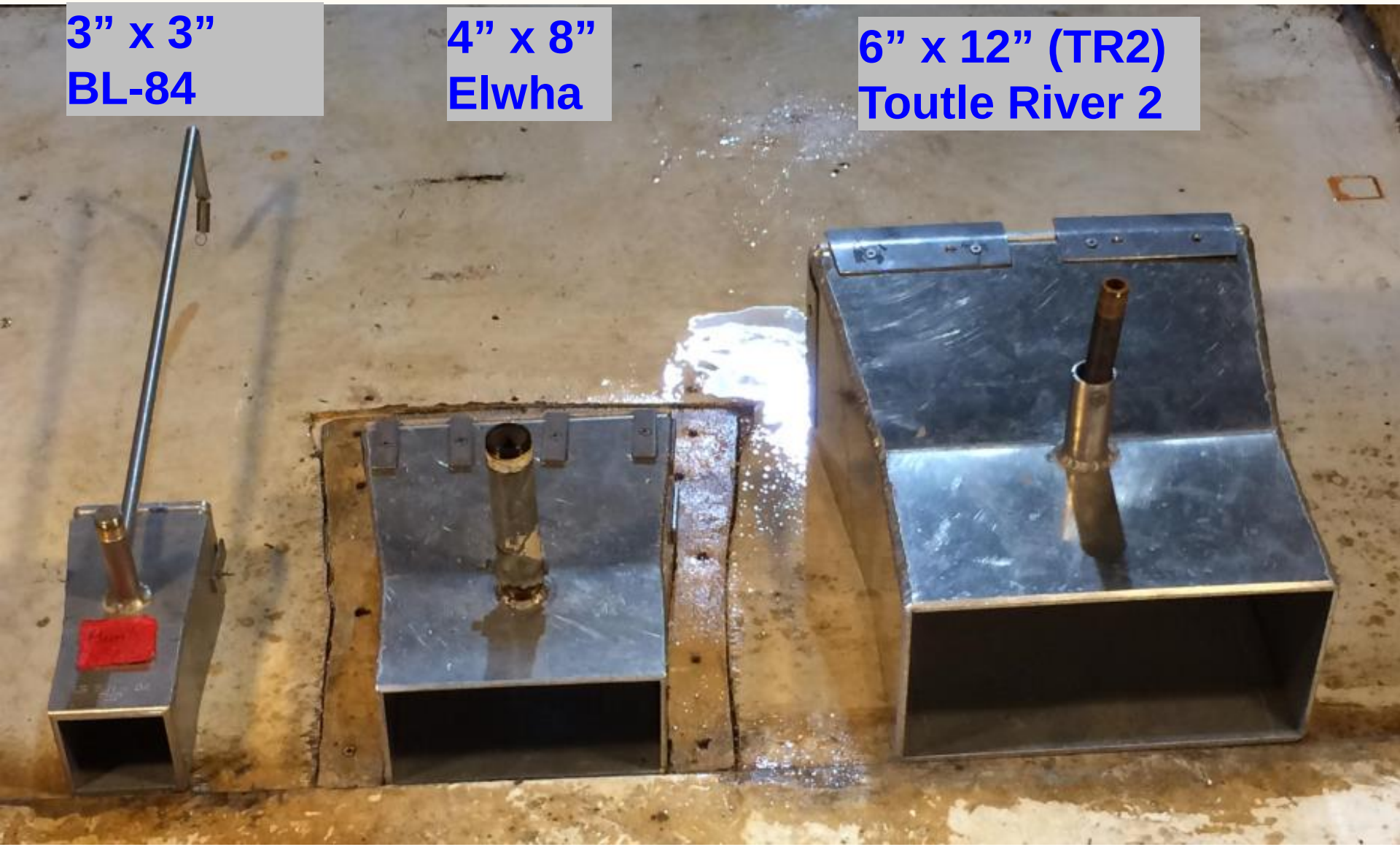
- Higher sampling efficiency for longer bags on 3” Helley-Smith sampler (O’Leary and Beschta, 1981)
- Less hydraulic efficiency (i.e., more backwater) for more tightly woven nets (Bunte and Swingle 2009)
- Higher hydraulic and sampling efficiency for flexible nets (Bunte and Swingle 2009) in the presence of organic debris

But systematic study is lacking that investigates how various bag properties affect hydraulic efficiency of pressure difference samplers

Study aims

- Define a combined parameter that integrates various factors determining flow through a sampler mesh bag
- Evaluate how flow velocity in front of a sampler (v_x) and hydraulic efficiency (HE) are affected by various netting and bag properties
- Assess the relative magnitude of target flow velocity, bedload sampler size, and netting/bag properties on v_x and HE
- Suggestions for optimizing hydraulic efficiency

3 pressure-difference bedload samplers tested



Nets with various mesh width (mm) tested for TR2 sampler

- 4 nets for TR2 (0.5, **1**, 2, **3.6** mm)
- 3 nets for Elwha (0.5, **1**, and **3.6** mm)
- 2 nets for BL-84 (**0.25** and **0.5** mm)

Two levels of gravel fill for two of the nets tested for each sampler

Complex test matrix:

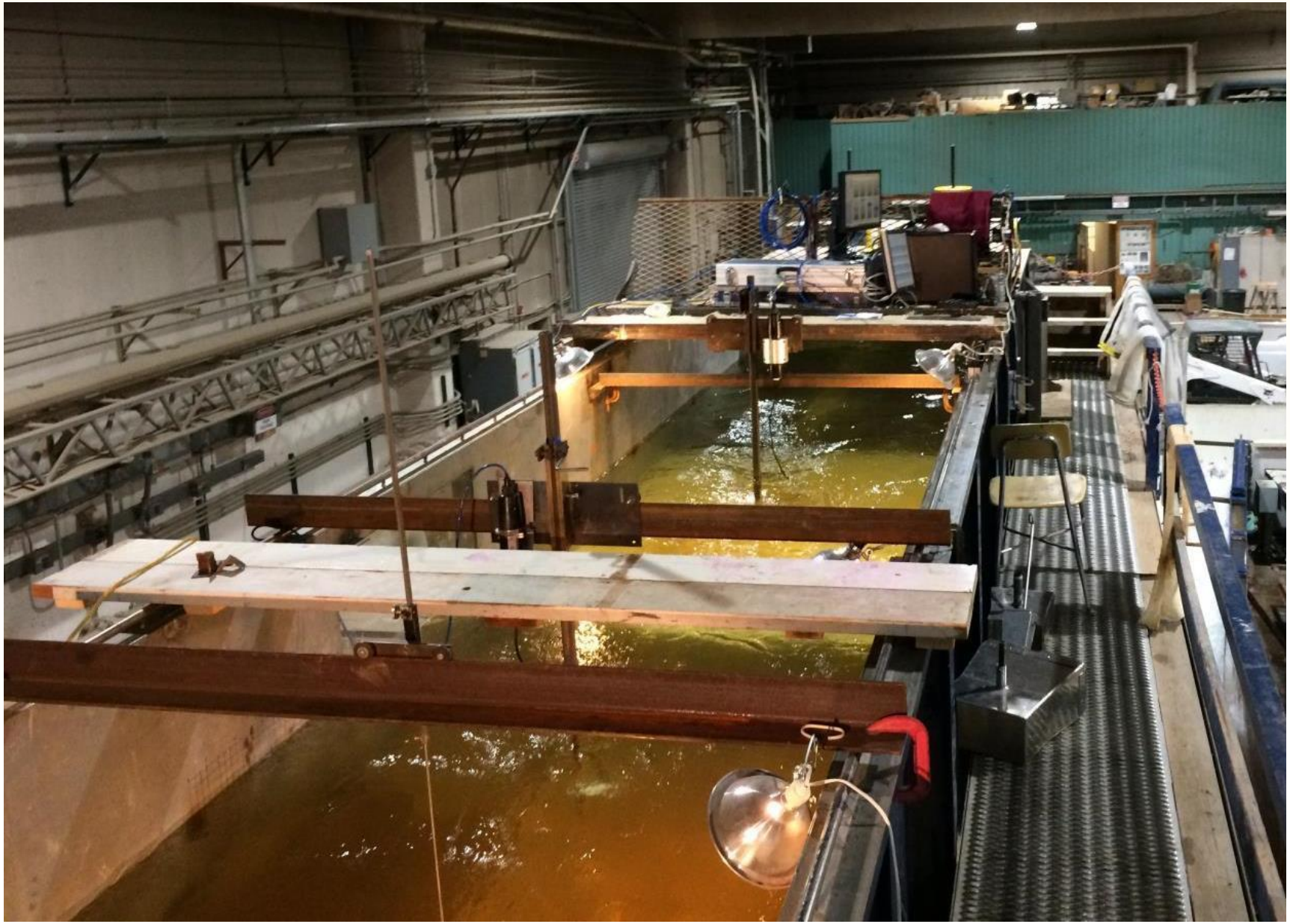
- 3 bedload samplers
  - 6” x 12” Toutle River 2
  - 4” x 8” Elwha
  - 3” x 3” BL-84

- 3 target flow velocities (ft/s) determined at 6” above ground
  - 1
  - 2.5
  - 3.5

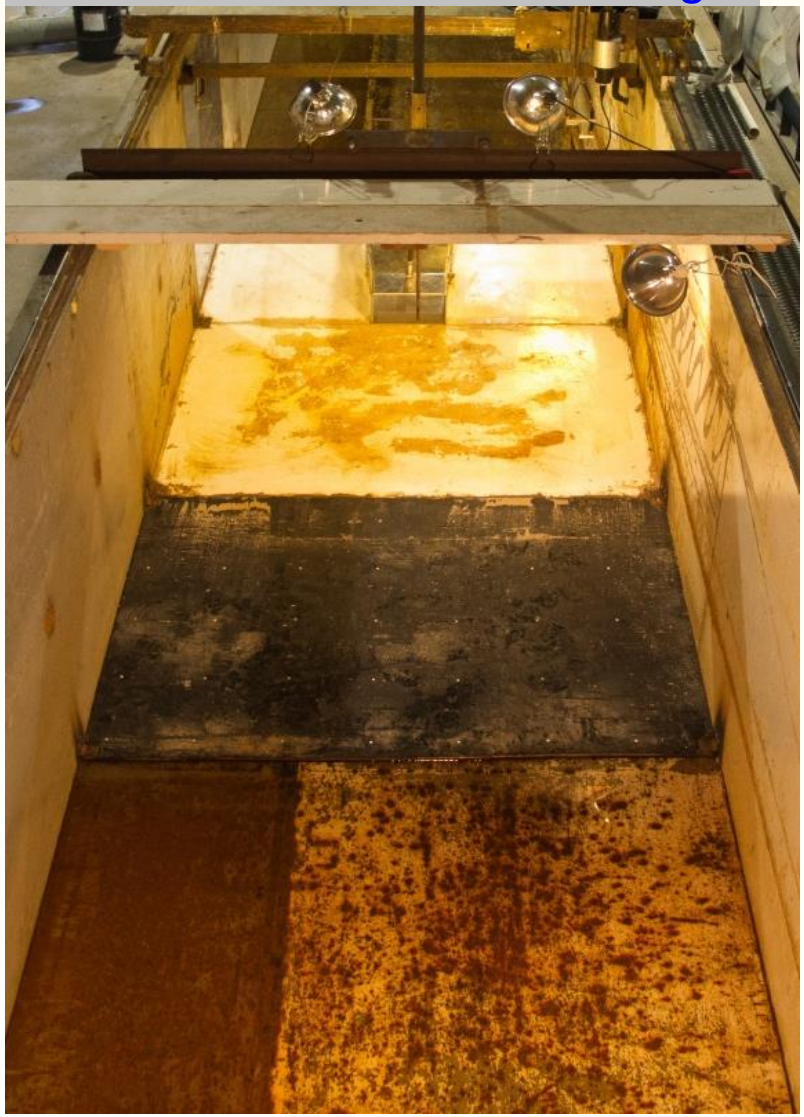
- 8-10 sampler/bag/net configurations:
  - No sampler in flume
  - Sampler with no bag attached
  - 2 nets for BL-84 (**0.25** and **0.5** mm)
  - 3 nets for Elwha (0.5, **1**, and **3.6** mm)
  - 4 nets for TR2 (0.5, **1**, 2, **3.6** mm)
  - 2 nets for each sampler with two gravel fills (30 and 50%)

↳ ≅ 70 runs/series
2 series
(re-runs)

Flume 6 ft wide and 40 ft long at Engineering Research Center



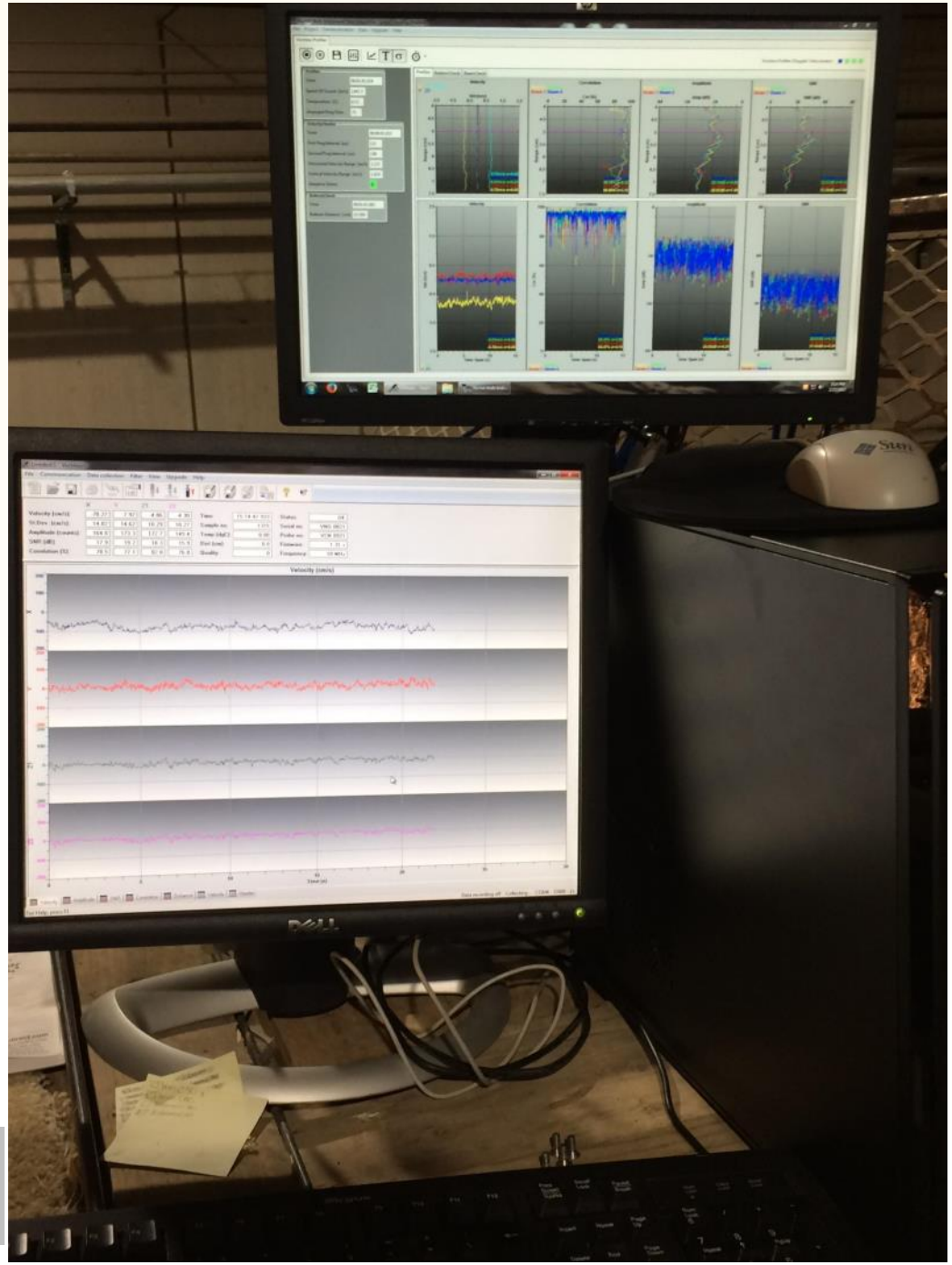
installed false floor, 12 ft long



with cut-out for each sampler body

…for smooth transition between flume and sampler

ADV Vetrino and ADV Profiler

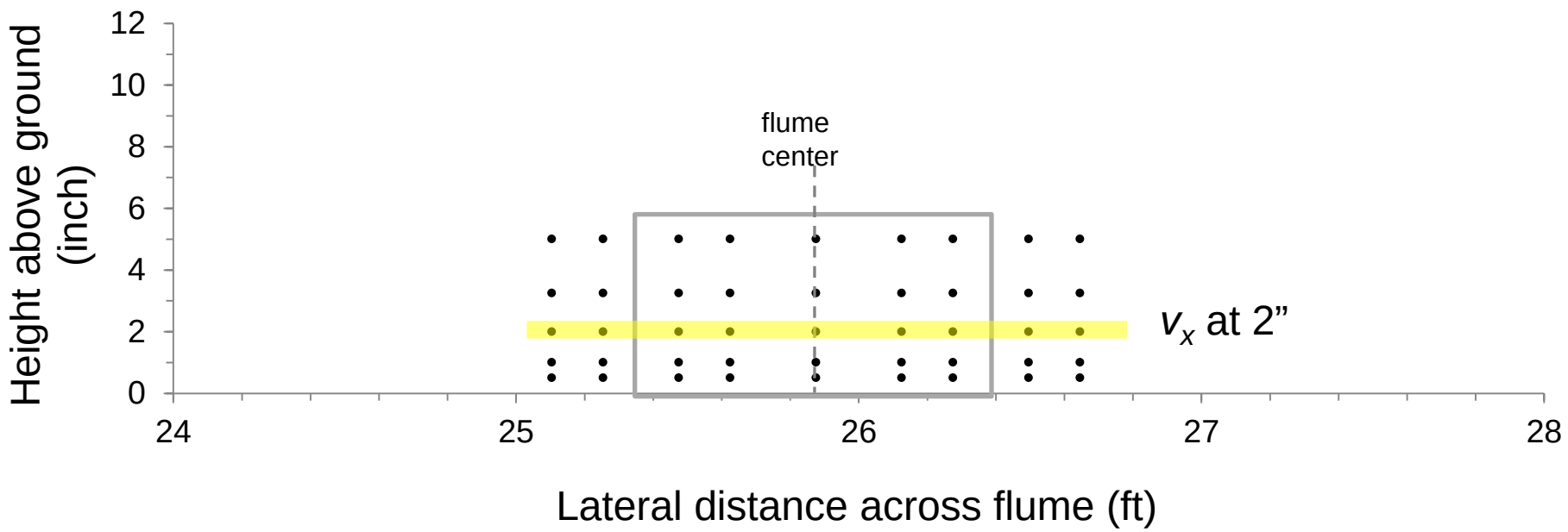


Output from ADVProfiler

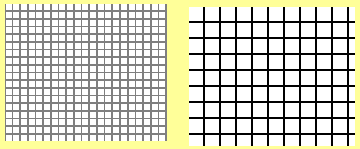
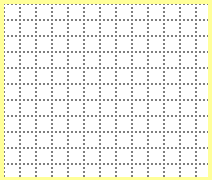
Sampled point matrix of flow velocity

- Scaled laterally with sampler opening width
- was vertically constant at 2” above ground

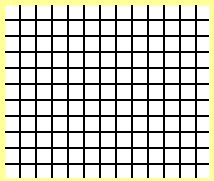
- Scaled laterally and vertically with sampler opening size for another series of runs

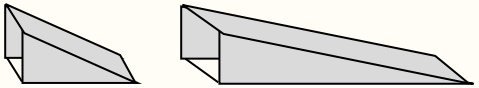
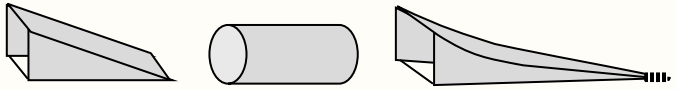


Bedload sampler mesh bags may vary in:

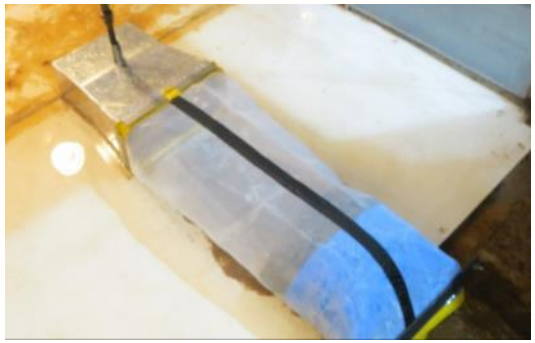
- mesh width 
- mesh % open area (density of the weave) 

gauze? sturdy grid?



- bag length 
- bag shape 

- Level of gravel fill (incl. bag end clogging)

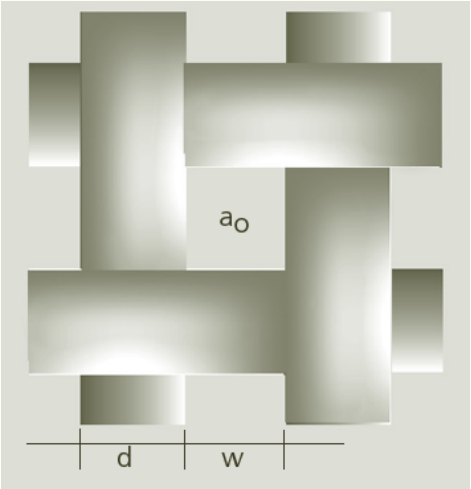


- Degree of net clogging by extensive seams

↳ **Needed to define a combined parameter that integrates various netting properties**

Relation between mesh width and % sampler bag open area

% mesh open area (industry parameter)



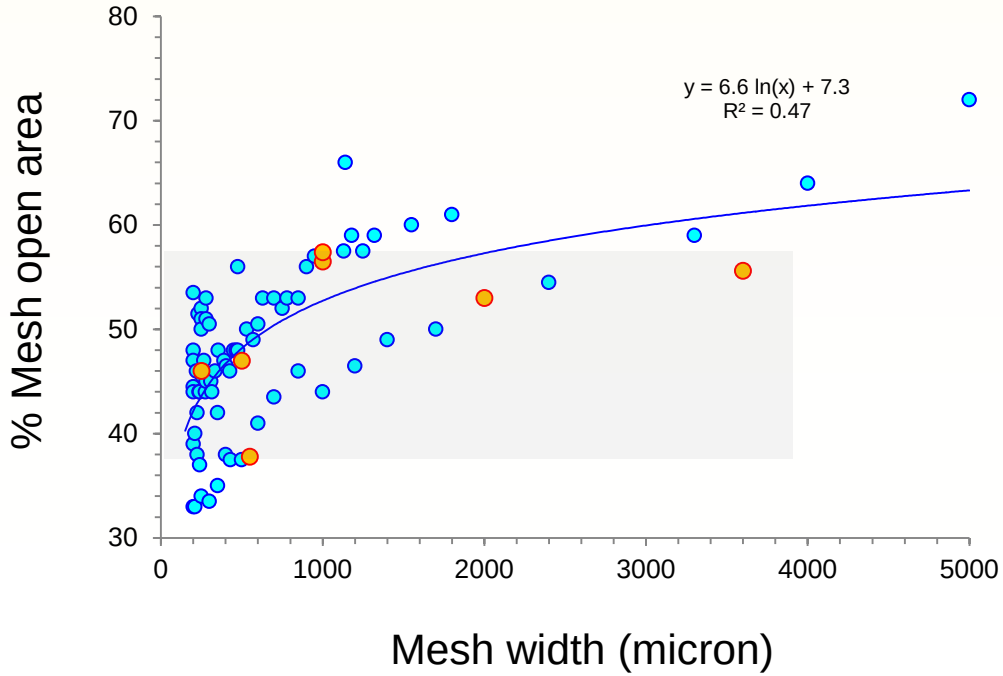
a_o = open area
$= w^2 \cdot 100/(w+d)^2$

d = thread diameter
w = mesh width

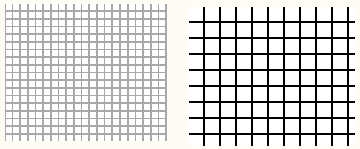
Nets with various mesh width (mm)

...loose relation only between mesh width and % mesh open area

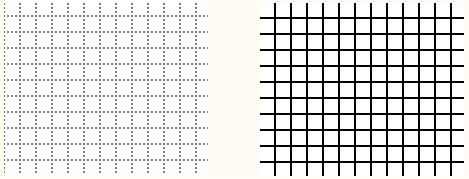
%*Ao* ranges from 38 to 58

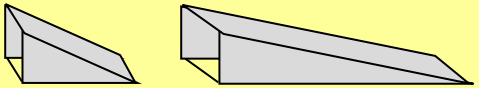
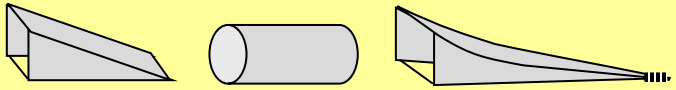


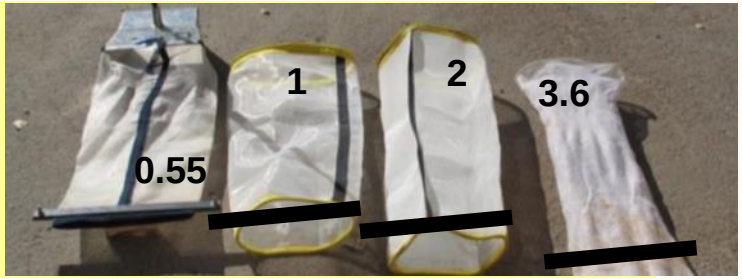
Bedload sampler mesh bags may vary in:

- mesh width 
- mesh % open area (density of the weave)

gauze? sturdy grid?

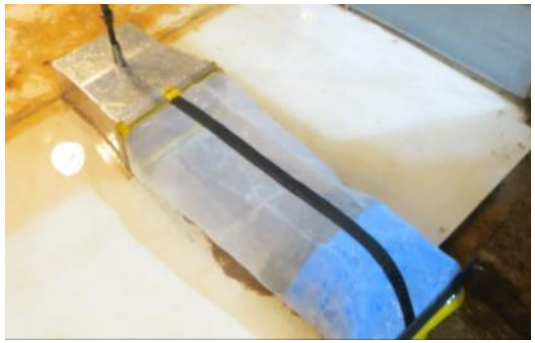


- bag length 
- bag shape 



- Level of gravel fill (incl. bag end clogging)

- Degree of net clogging by extensive seams



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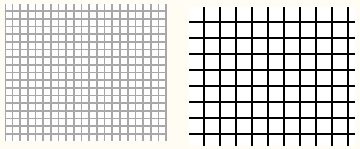
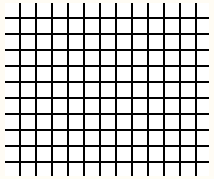
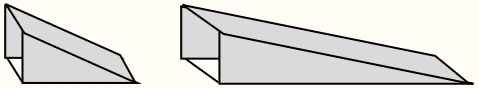
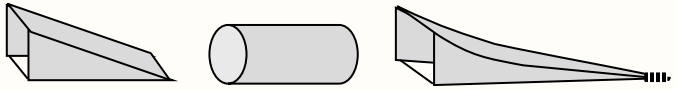
- mesh width 
- mesh % open area (density of the weave)

gauze? 

sturdy grid? 

- bag length 
- bag shape 

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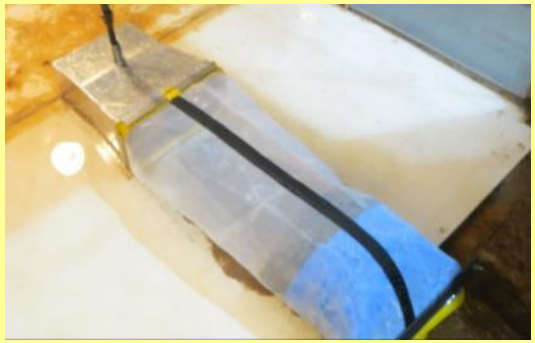
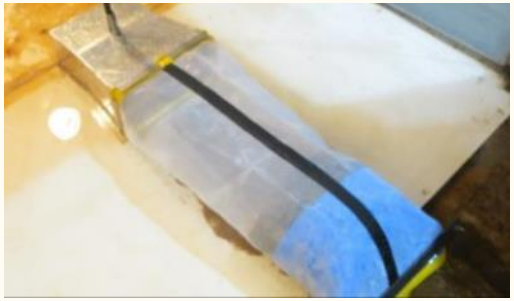


↳ **Needed to define a combined parameter that integrates various netting properties**

+



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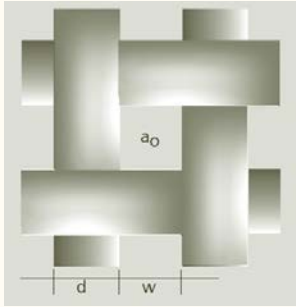
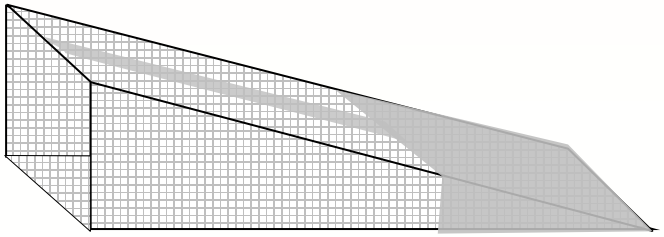


$\%A_{clogged}$ $\%A_{seam}$ $\%Ao$

- Needed to combine net blockage ($\%Ao_{clogged}$ and $\%Ao_{seam}$) with $\%Ao$ into one parameter $\boldsymbol{\%Ao_{final}}$ to relate to v_x and hydraulic efficiency

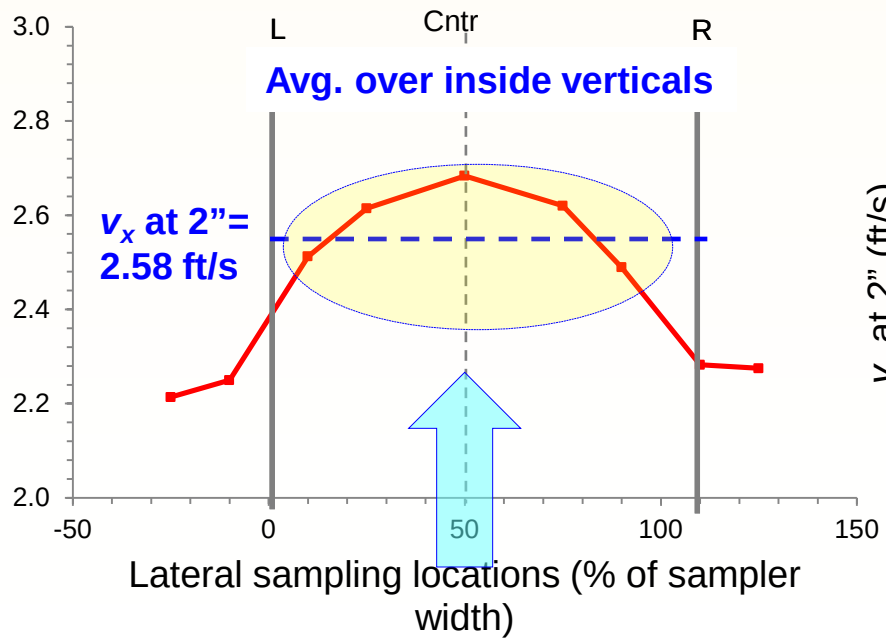
$$\boldsymbol{\%Ao_{final}} = (\%A_{tot} - \%A_{clogged} - \%A_{seam}) \cdot (\%Ao_{net})$$

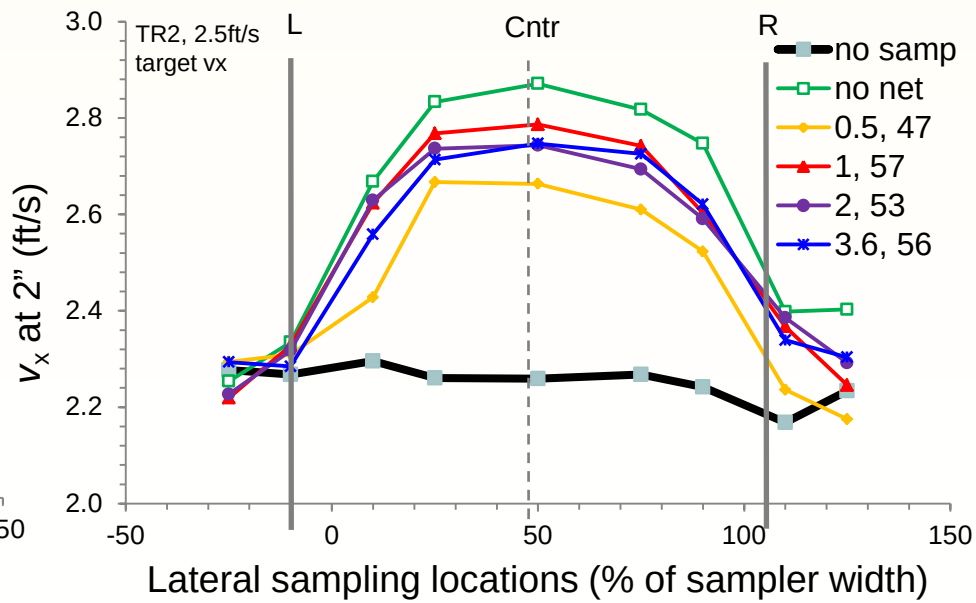


$\%Ao_{final}$ for tested nets ranged from 20 to 55%

Define a velocity parameter

- Averaged laterally over all inside verticals → ***v_x* at 2"**
- Hydraulic efficiency **HE** = v_x *at 2"* · *100/*v_x *at 2"*$_{no\ sampler}$
- Computed v_x at 2" and HE for all samplers, all target velocities and all bag configurations

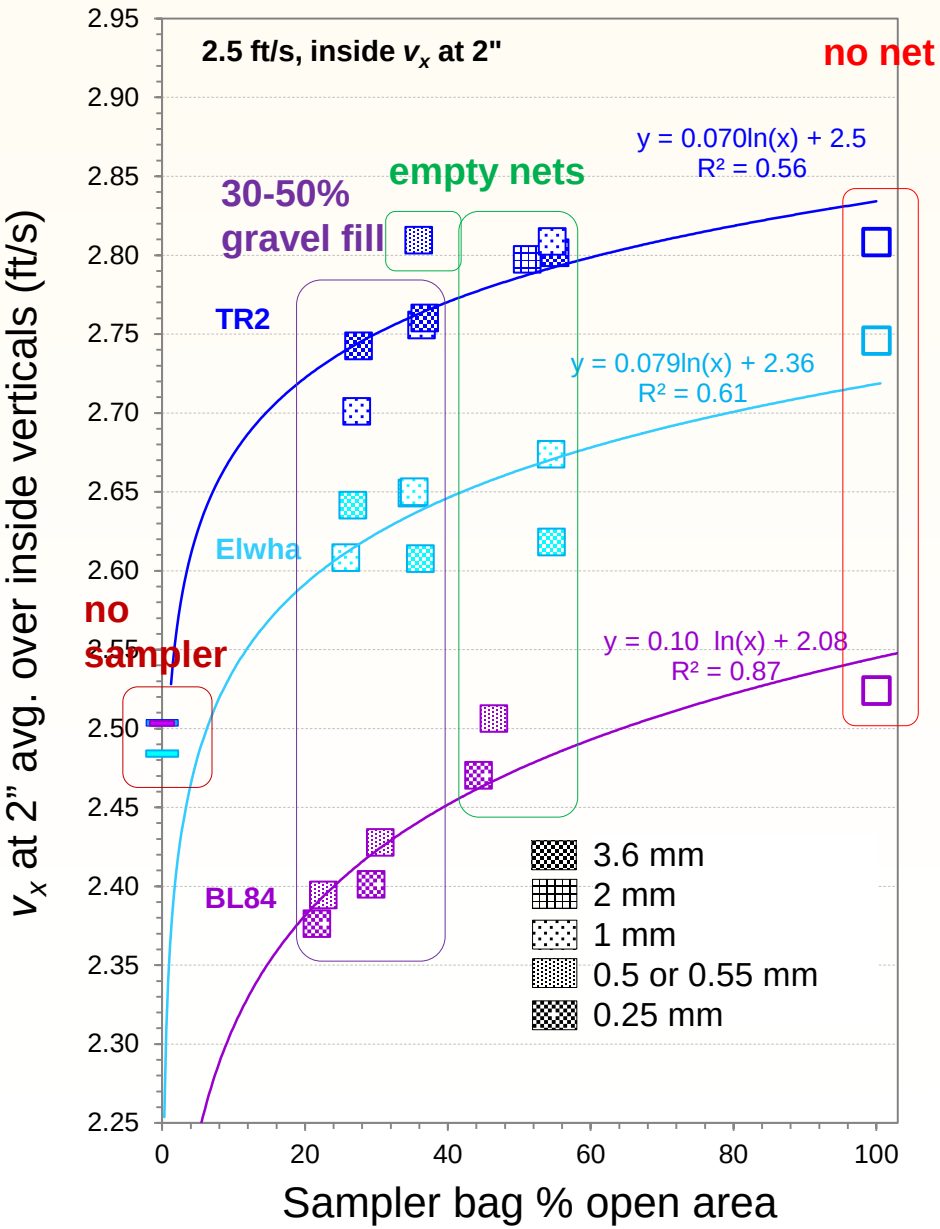




Results

Combined plots of v_x at 2”:

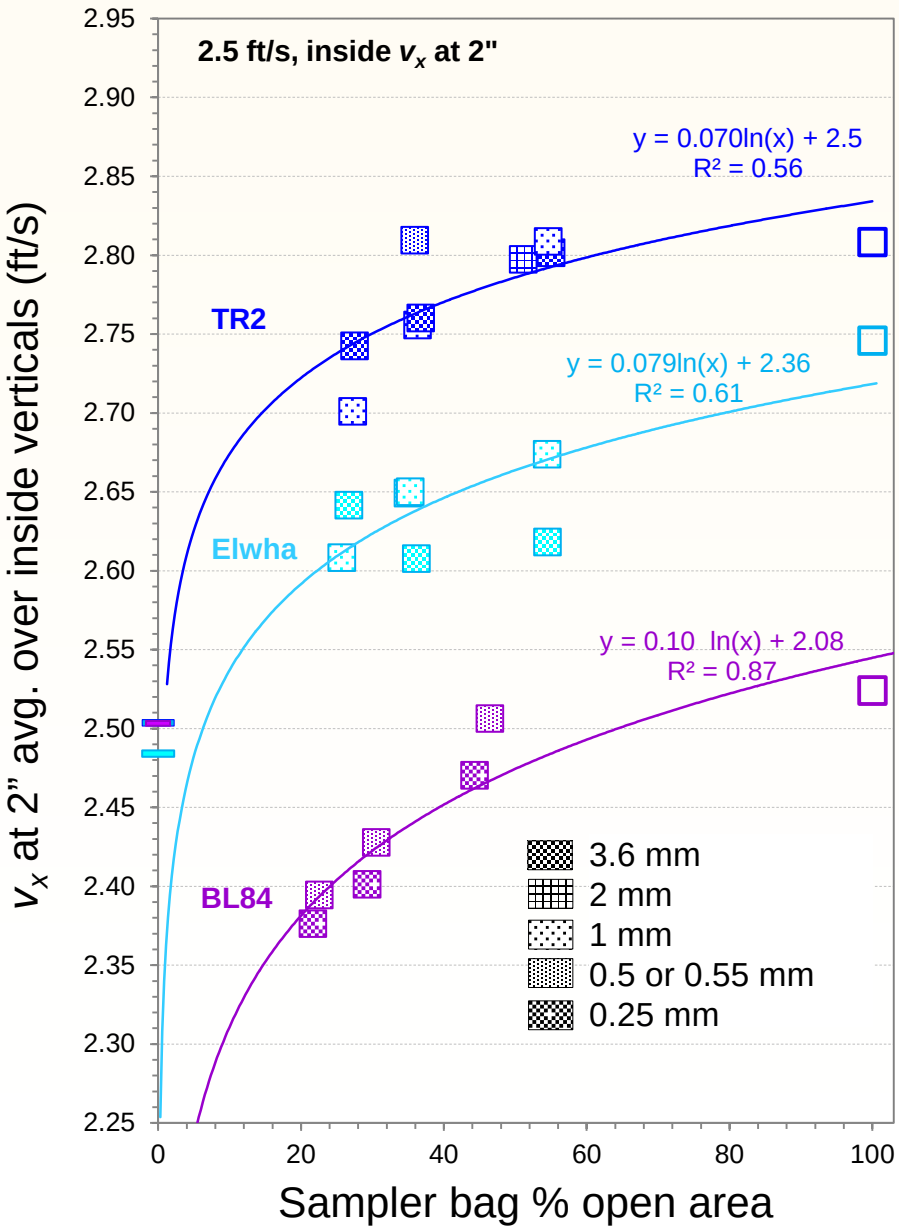
- 3 samplers
- 7-9 bag configurations
- one target velocity



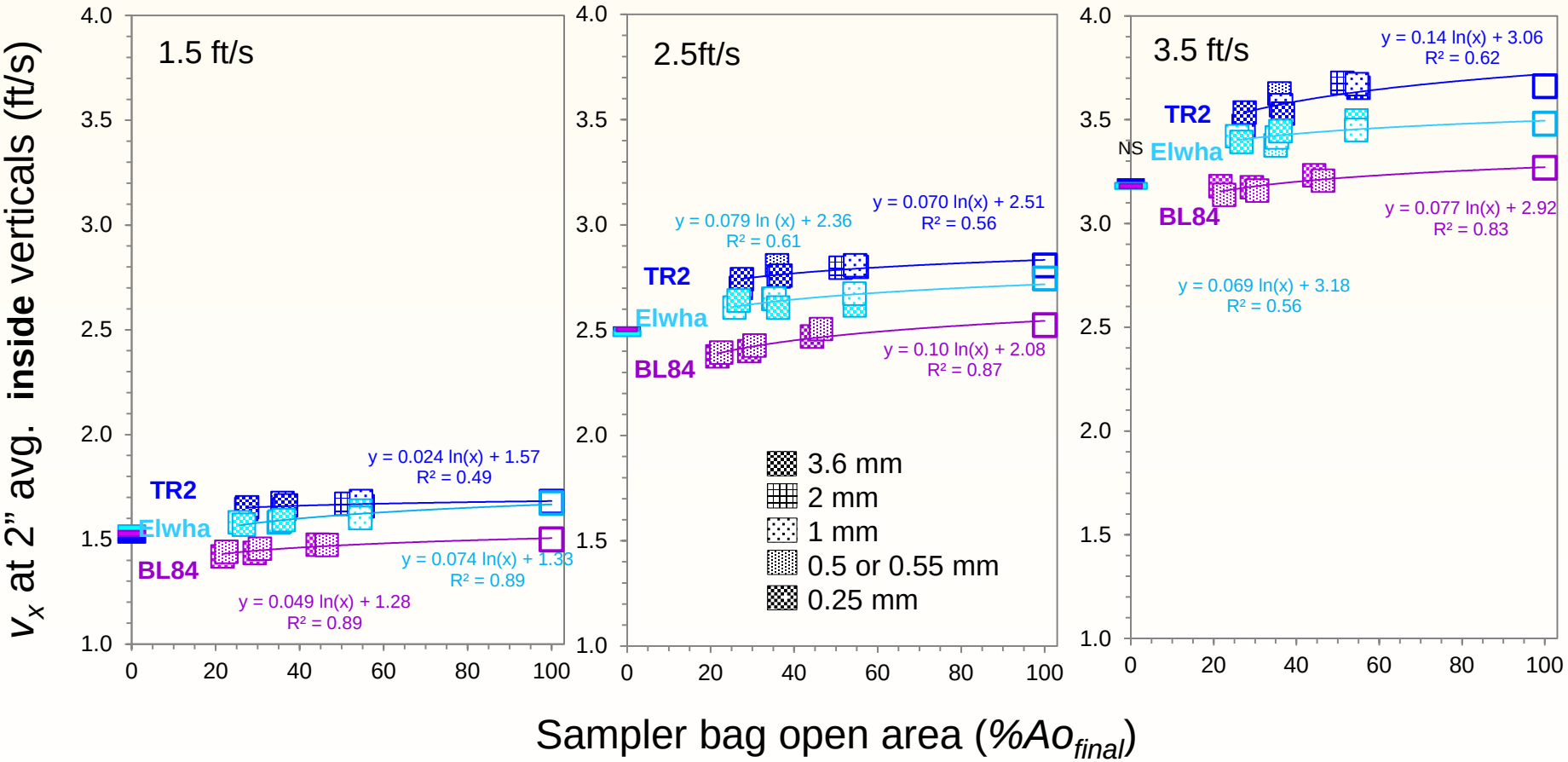
- Fairly well defined positive functions v_x at 2" = $f(\%Ao_{final})$

- Log functions
  v_x at 2" = $a \ln(\%Ao_{final}) + b$
  best described the trend
  (steep rise then flattening)

  ↳ **$\%Ao_{final}$ is an appropriate parameter to characterize mesh bag properties**



v_x at 2: 3 samplers, 3 target velocities and 7-9 bag configurations



v_x at 2" increases with:

- target velocity
- sampler size
- % bag open area

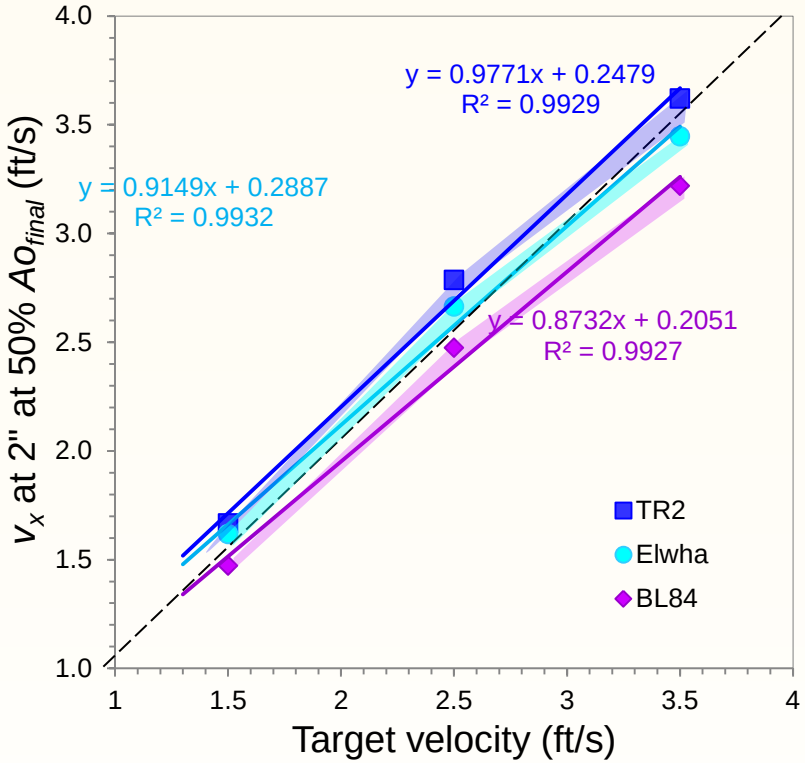
What is the relative contribution of each factor?

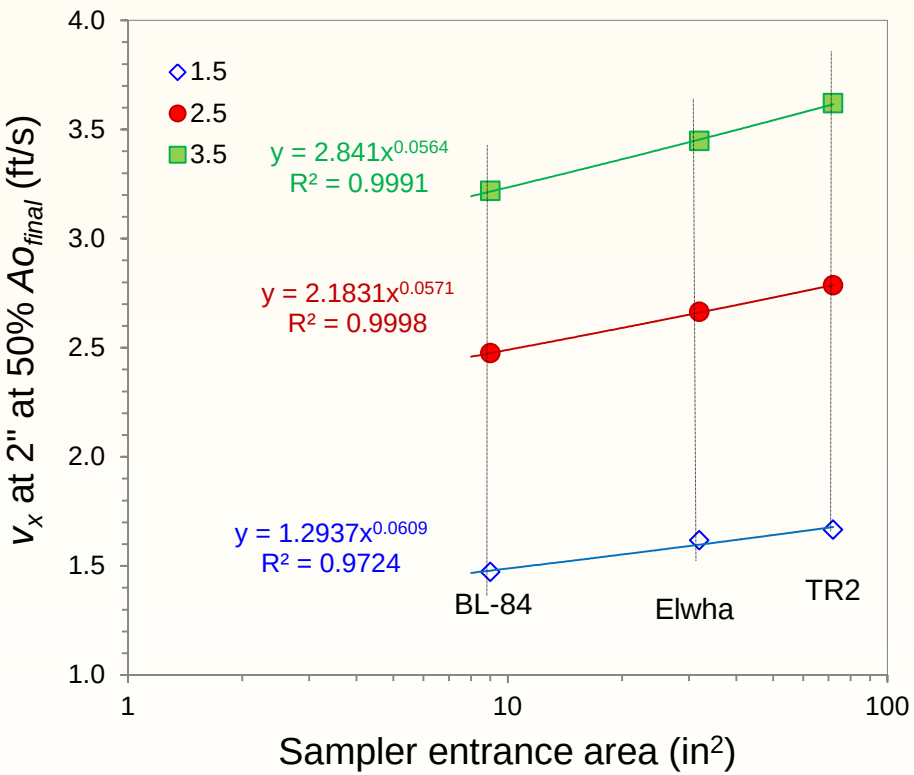
- target velocity (v_x)
- sampler entrance area (A_{smpl})
- % bag open area ($\%Ao_{final}$)

to

- v_x at 2”
- HE for v_x at 2”

at one selected value (=50%) of Ao_{final}

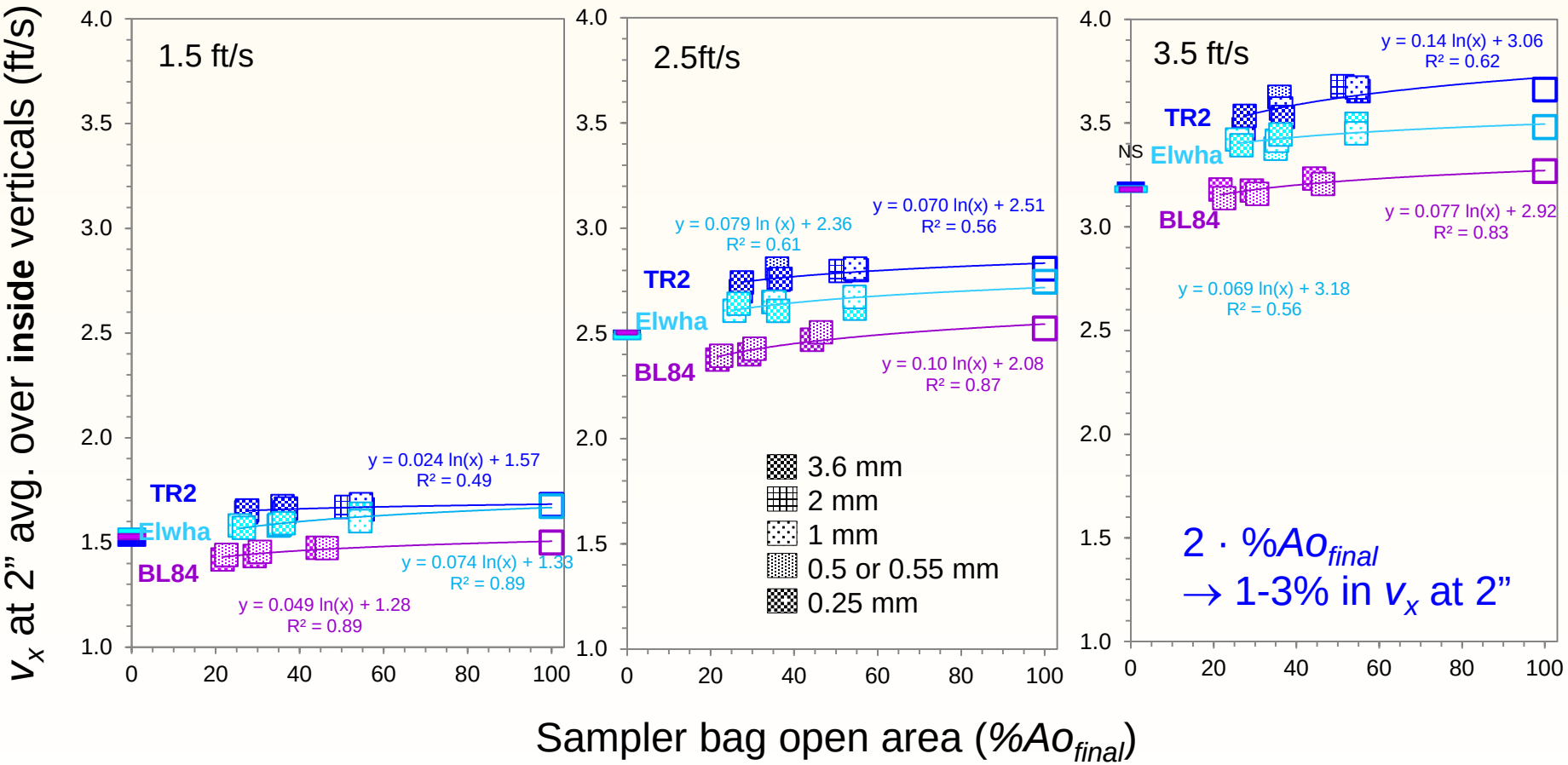




2 · target v_x
→ 87% in v_x at 2”

2 · A_{smpl}
→ 5% in v_x at 2”

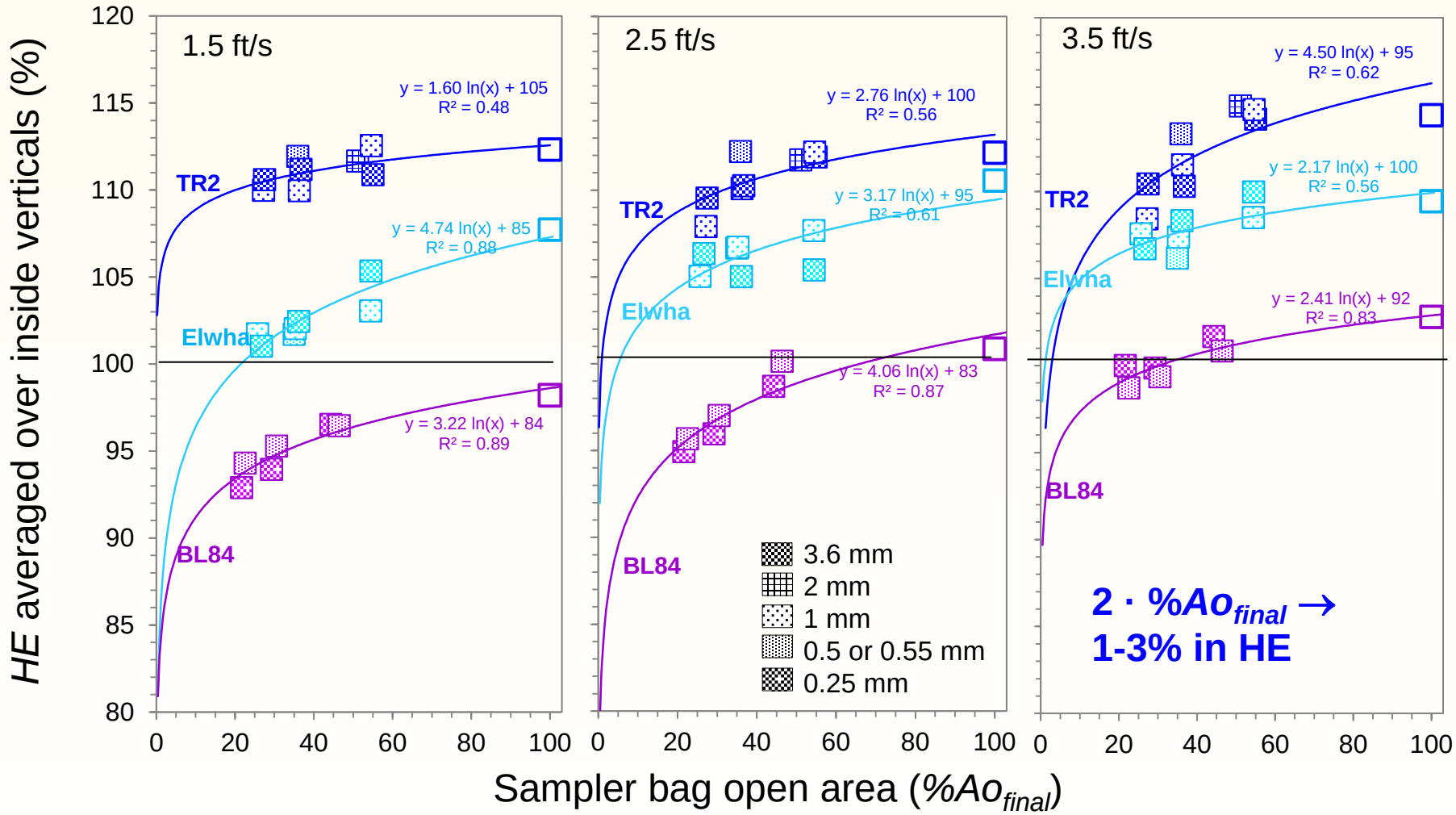
v_x at 2: 3 samplers, 3 target velocities and 9-7 bag configurations



v_x at 2" is primarily determined by

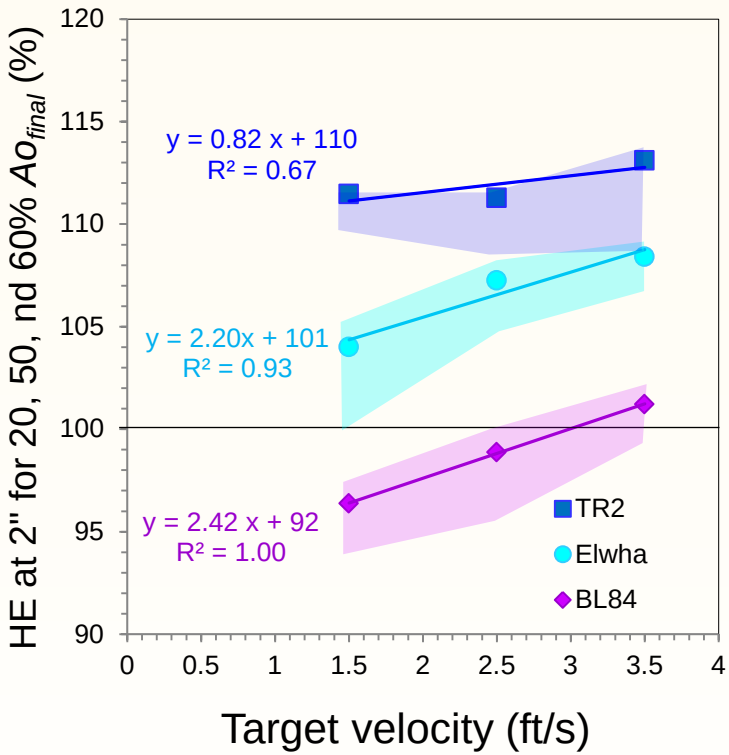
- target v_x (87%)
- sampler entrance area (5%)
- mesh density & bag fill level (1-3%)

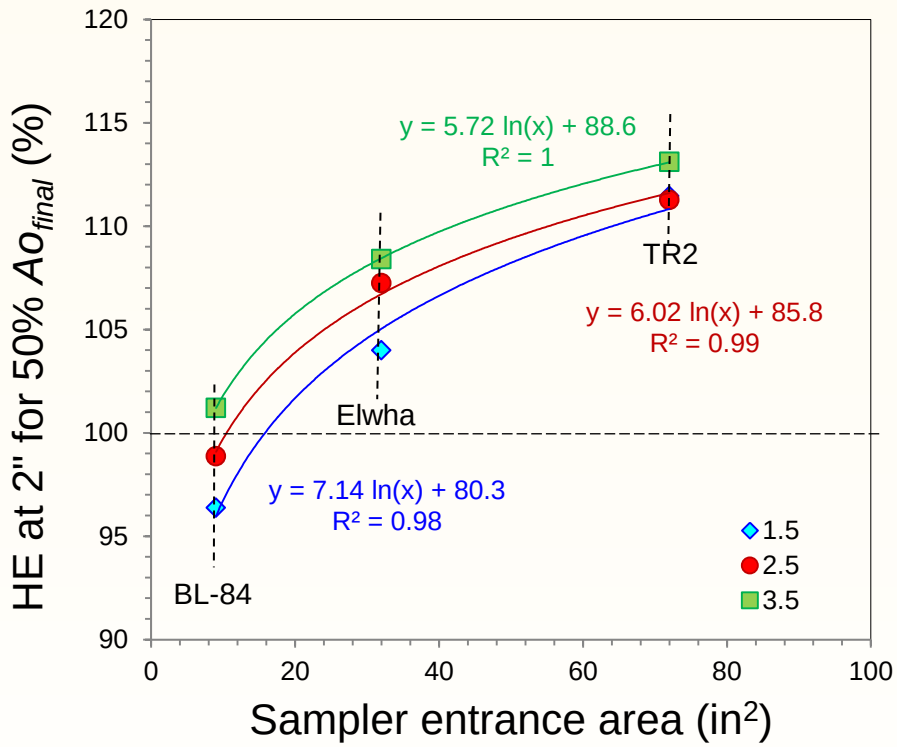
HE: 3 samplers, 3 target velocities and 7-8 bag configurations



v_x at 2" increases with

- target velocity
- sampler size
- % bag open area

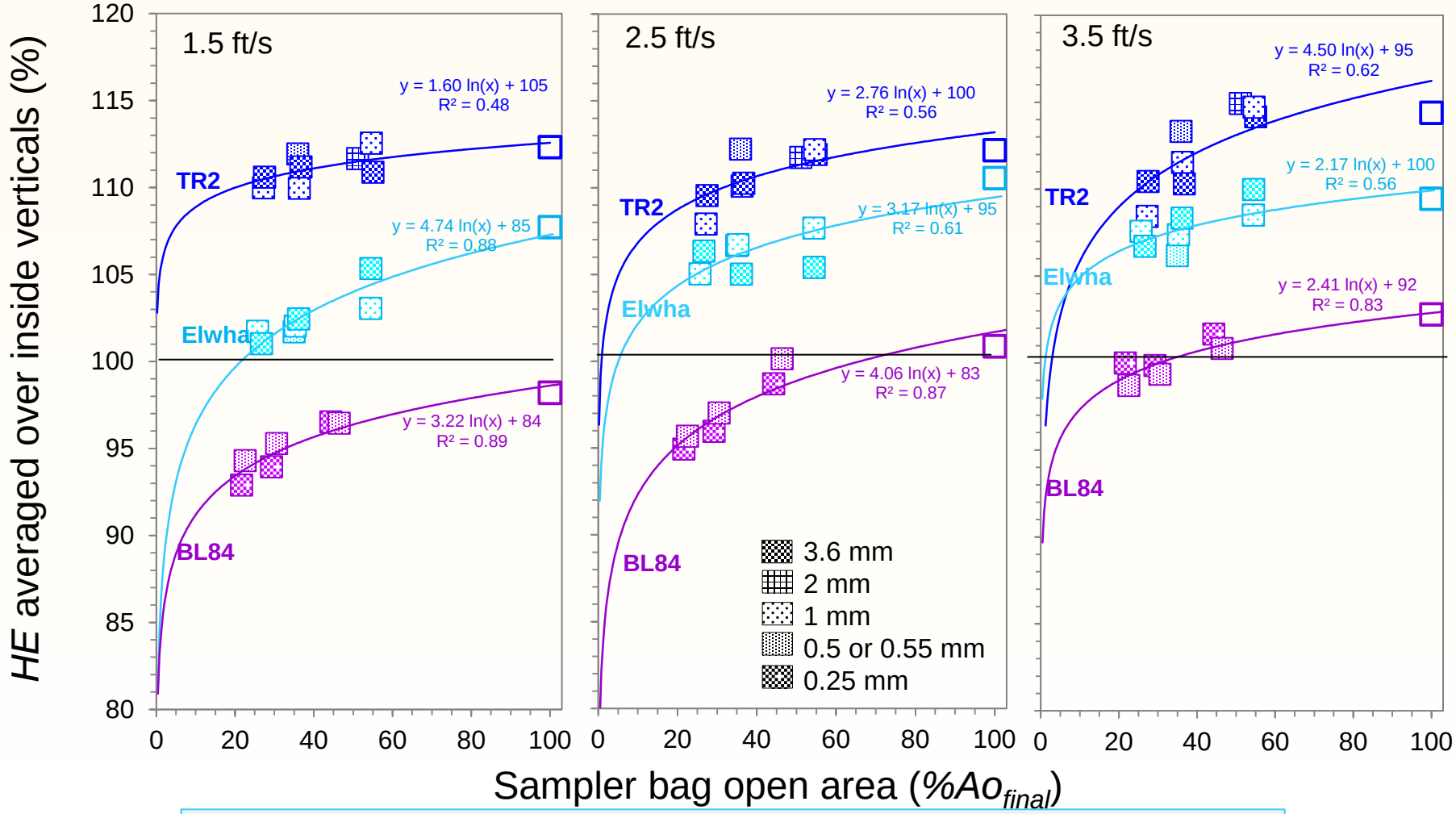




$2 \cdot$ target $v_x \rightarrow$
5% in v_x at 2”

$2 \cdot A_{smpl} \rightarrow$
4% in v_x at 2”

HE: 3 samplers, 3 target velocities and 7-8 bag configurations



HE for v_x at 2" relatively evenly determined by

- target v_x (5%)
- sampler entrance area (4%)
- mesh density & clogging (%Ao_{final})(1-3%)

Increase (%) in v_x and HE due to doubling (=100% increase) in affecting parameters

	Affecting parameter		
Affected flow parameter	**Target v_x**	**Sampler entrance area**	**Net density & clogging (%Ao_{final})**
v_x at 2”	87	5	1-3
Hydraul. Efficiency	5	4	1-3

Summary and Conclusions

- $\%Ao_{final}$ appropriately characterizes mesh bag properties
- Log functions $v_x = f(\%Ao_{final})$ best described the "steep-flat" trend
- v_x mostly affected by v_{tar}, a few % by sampler size and $\%Ao_{final}$
- HE more evenly affected by v_{tar}, sampler size and $\%Ao_{final}$
  - Don't change samplers within a project
- Elwha and TR2 have HE >100%, while BL-84 has HE ≅ 100%
  - Opening ratio of 1.4 too large for big samplers (1.1 or 1.2?)
  - Opening ratio of BL-84 should be slightly larger;
  - Perhaps new design: downscaled 3"by 6" Elwha
- Sampler bag/net properties affect v_x and HE
  - Unclogged nets with **tight weave** have a low $\%Ao_{final}$
  - Gravel fill notably reduced $\%Ao_{final}$, and hence HE
  - Net clogging difficult to circumvent:
    - shorter sampling time → unrepresentative sample.
    - Multiple short term samples → more scooped particles

Thank you!
Questions?