An Overview of Flow Regimes Describing Slurry Transport

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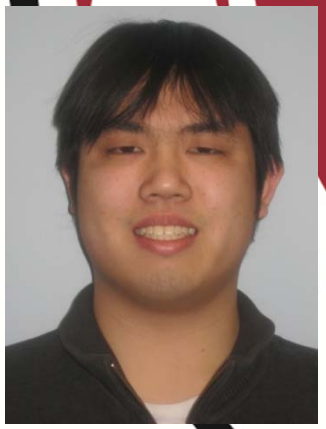
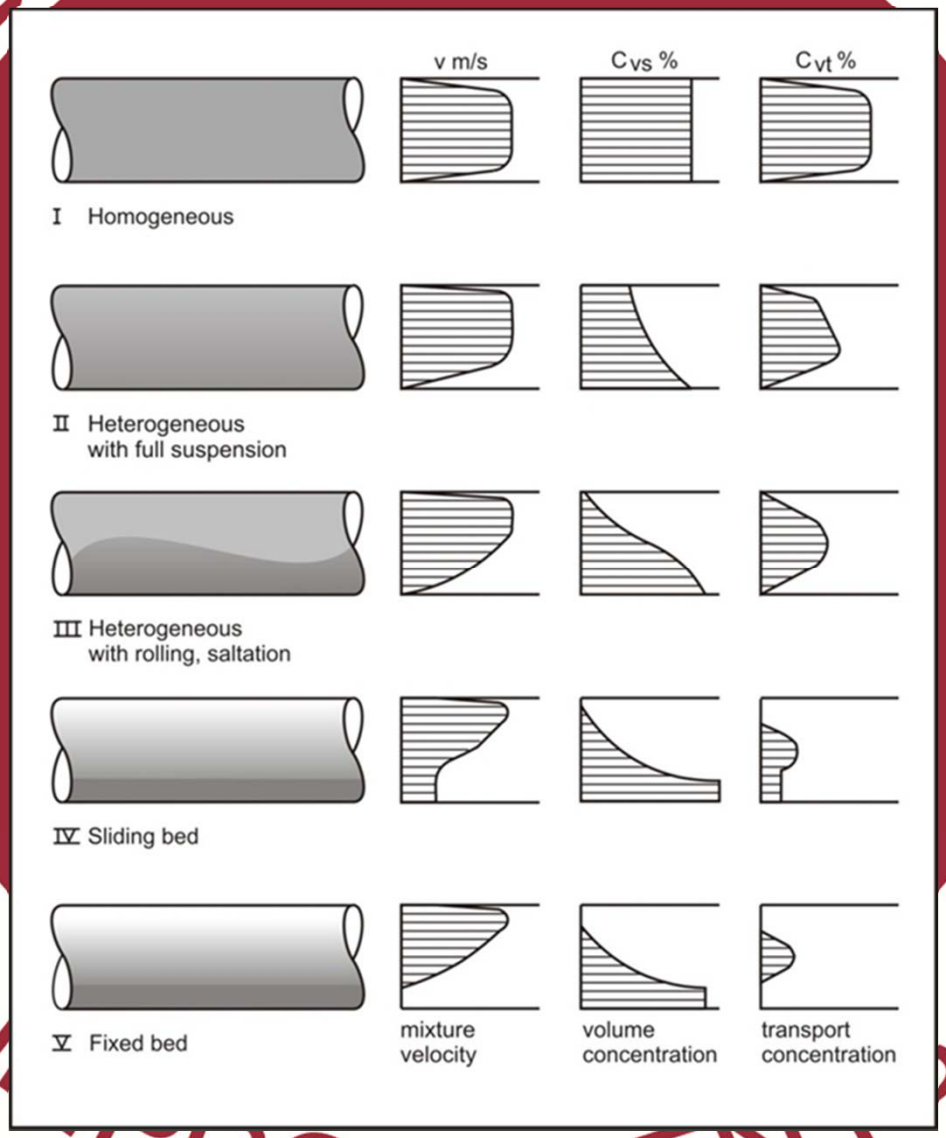
Safety Moment



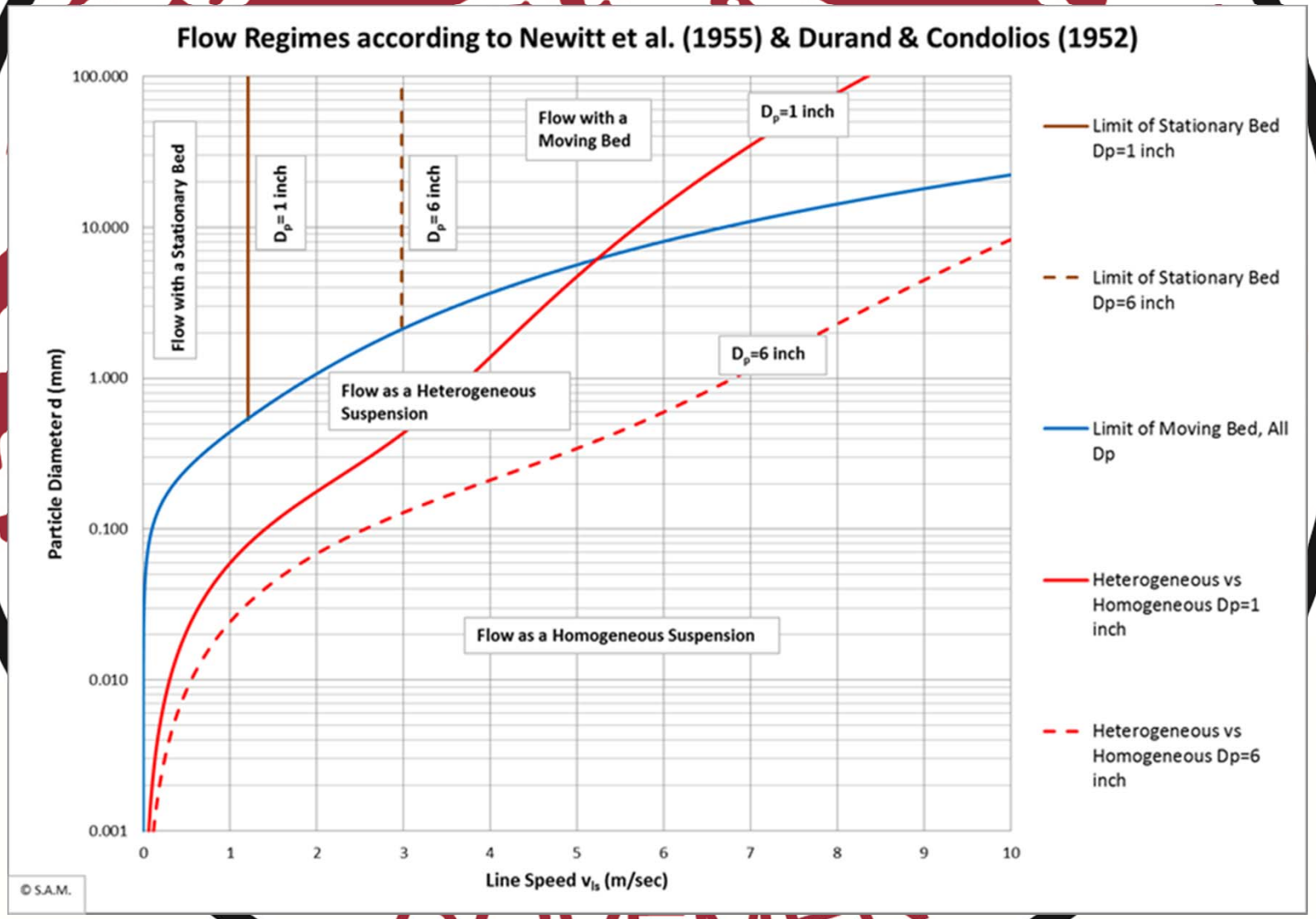
Problem Definition

- There are many models, empirical and fundamental for the various phases of flow
- The models are often based on lab tests, and often in small pipe relative to current dredging practice
- There is still no generic fundamental model for slurry transport, particularly in large diameter pipelines, connecting the different flow regimes

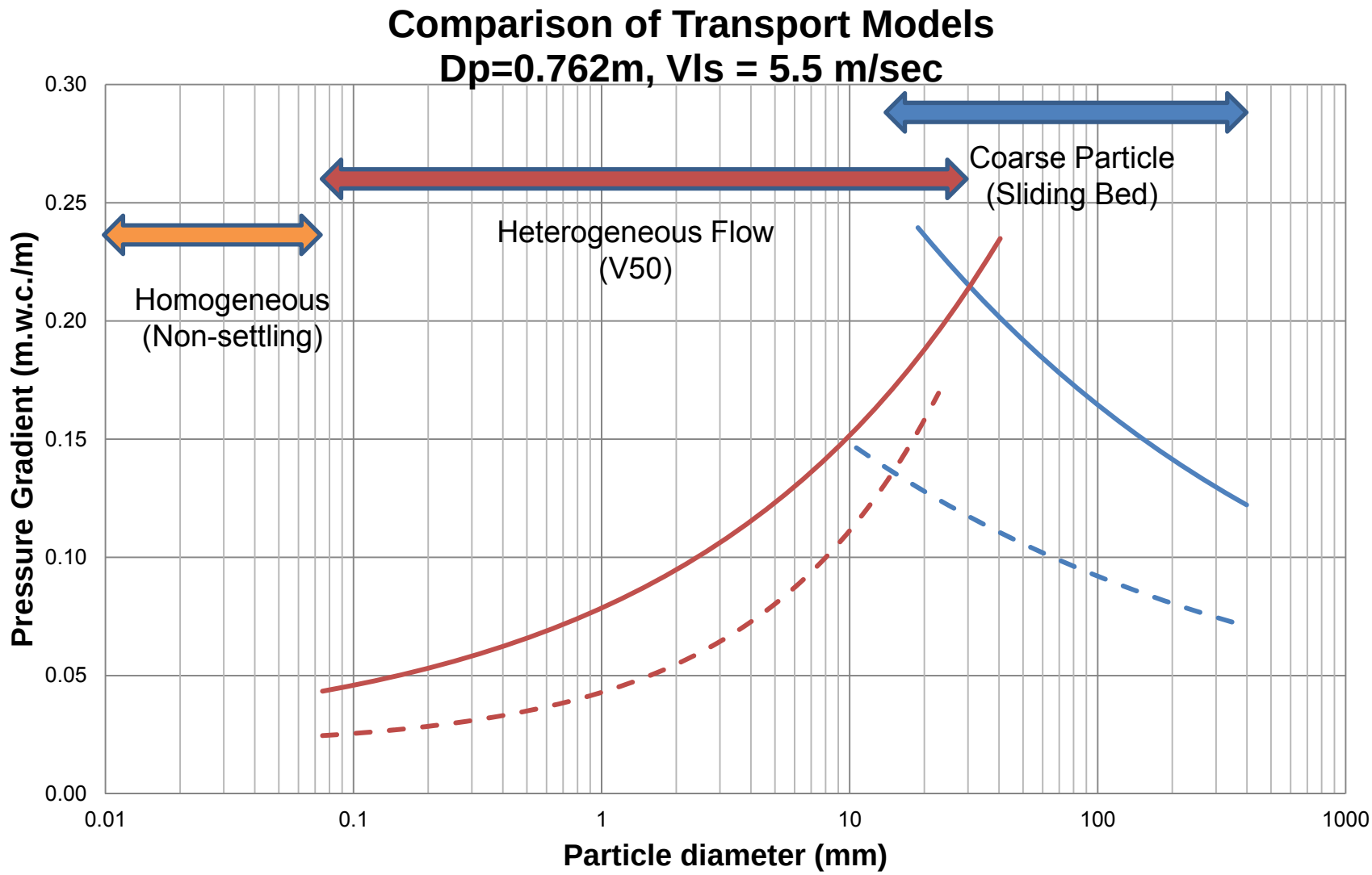
Regimes History



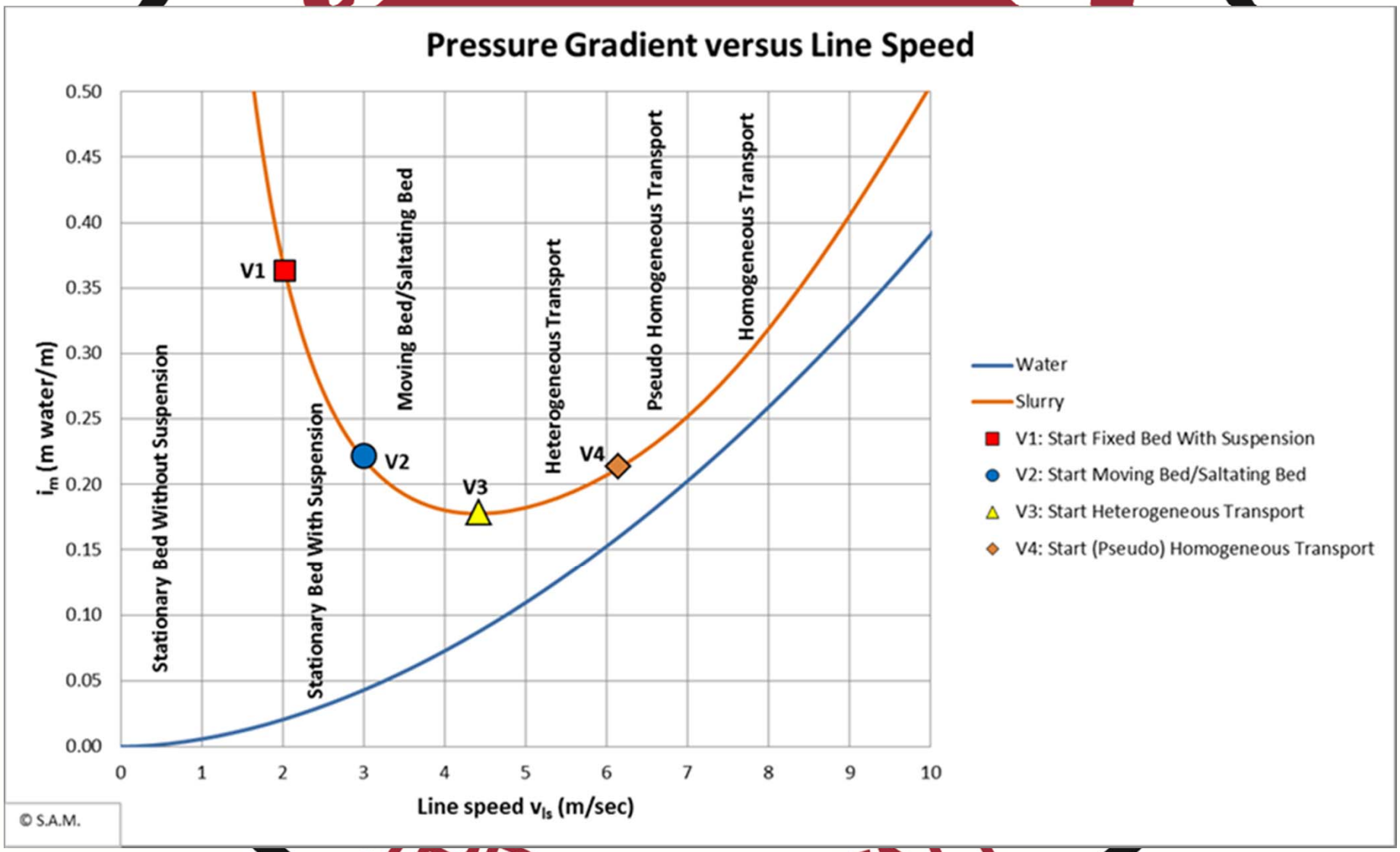
Newitt et al. (1955)
D, C & G (1952, 1960)



Wilson, Addie, Sellgren & Clift (1992)



Abulnaga (2002)

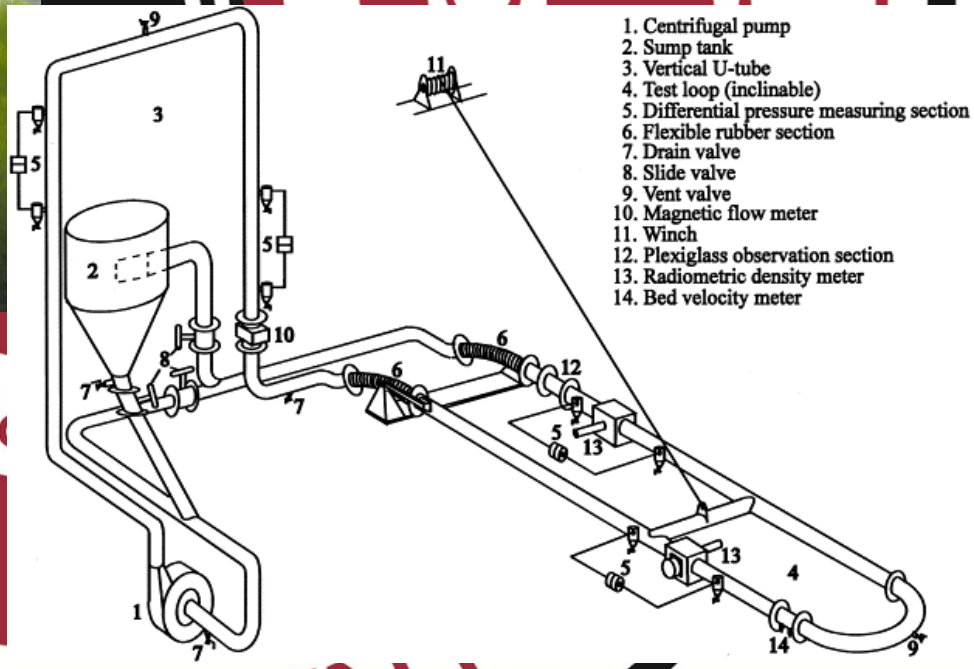


9 Flow Regimes

Volume Concentrations

$C_v = \frac{\rho_m - \rho_{fl}}{\rho_s - \rho_{fl}}$: Volume concentration from density readings

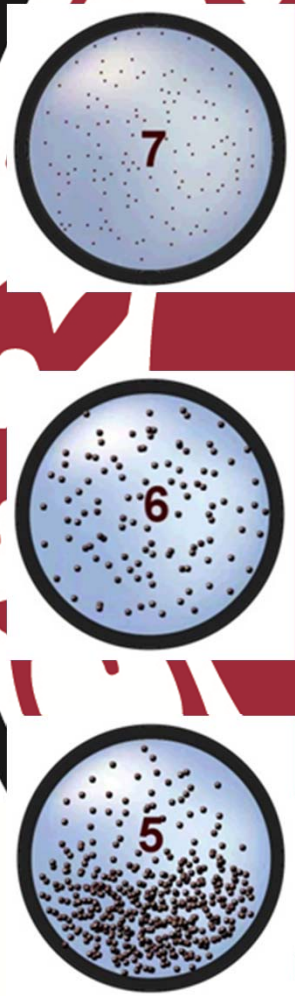
$C_{vt} = \frac{\dot{v}_s}{\dot{v}_m}$: Transport (delivered) volume concentration.



$C_{vs} = \frac{Q_s}{Q_m}$: Spatial volume concentration. Generally fixed in a lab environment.

Regimes with No Bed

$C_{vs} \approx C_{vt}$



7. Homogeneous Transport

6. Pseudo-Homogeneous Transport

5. Heterogeneous Transport

Regimes with a Sliding Bed

8. Sheet Flow

$C_{vs} \approx C_{vt}$

Constant C_{vs}

Constant C_{vt}

3. Sliding Bed with Suspension

$C_{vs} > C_{vt}$

4. Sliding bed with Suspension

$C_{vs} > C_{vt}$

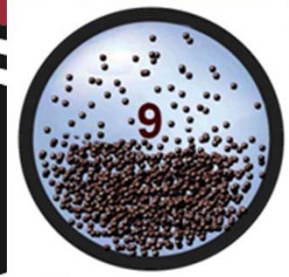
Regimes with a Fixed Bed

Constant C_{vs}

2. Fixed Bed with Suspension
$C_{vs} >> C_{vt}$

1. Fixed Bed without Suspension
Note $C_{vt} = 0$!

Constant C_{vt}



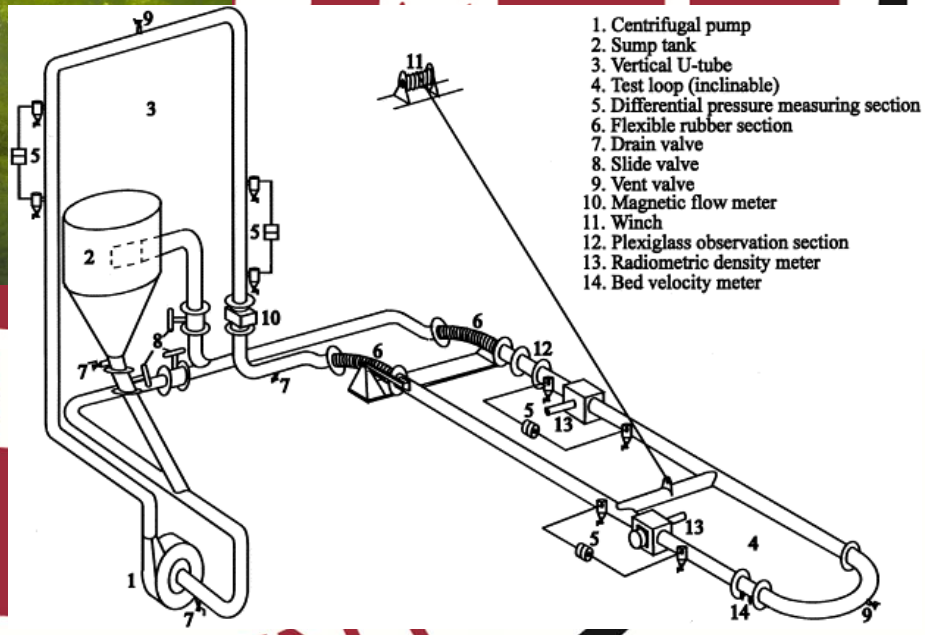
9. Fixed bed with Suspension
$C_{vs} >> C_{vt}$


C_{vs} = 1.0
C_{vt} = 0.0


03/04/2006

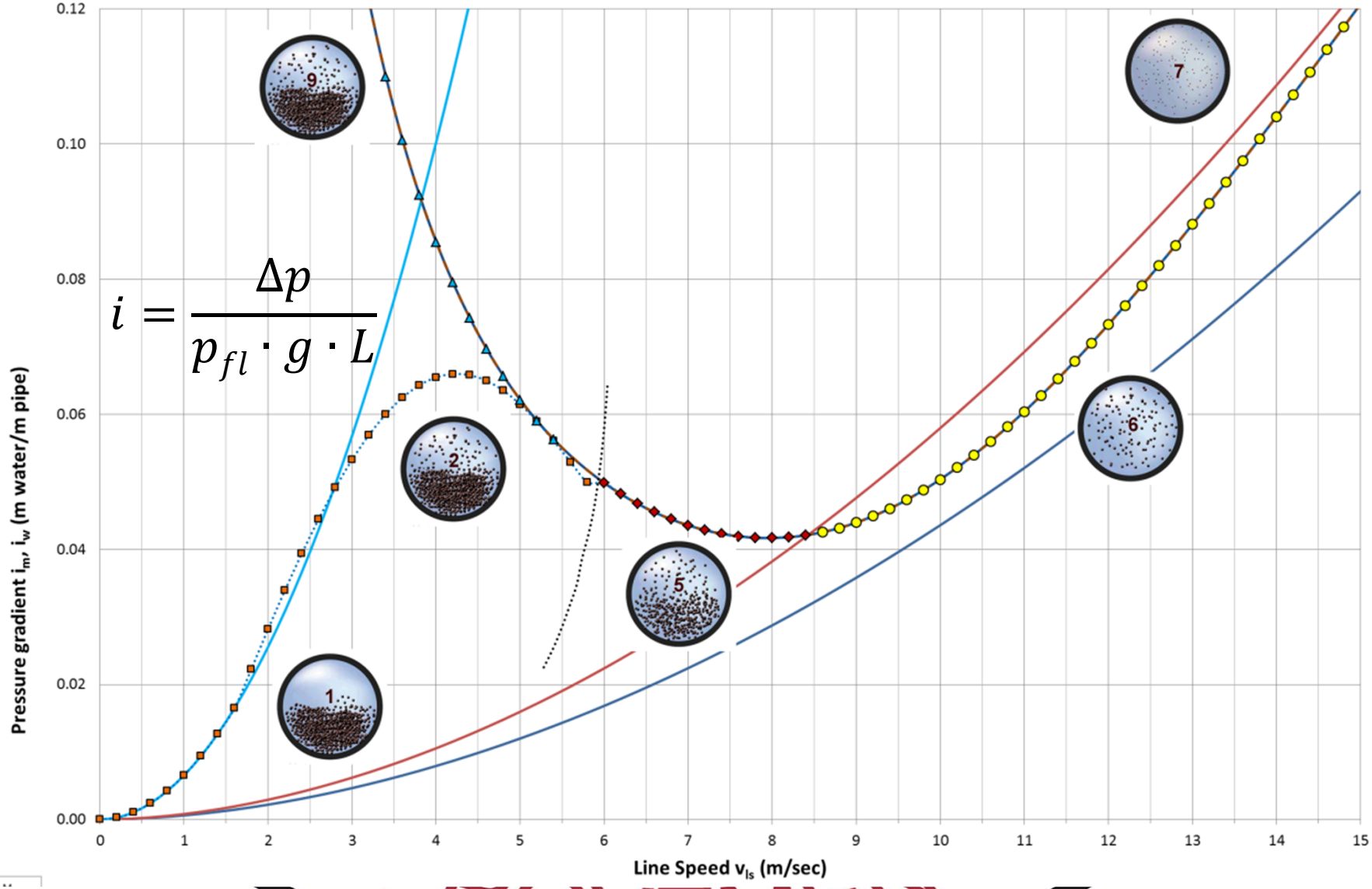
Scenarios

R1 – R3: Real Life, constant C_{vt} (we hope)

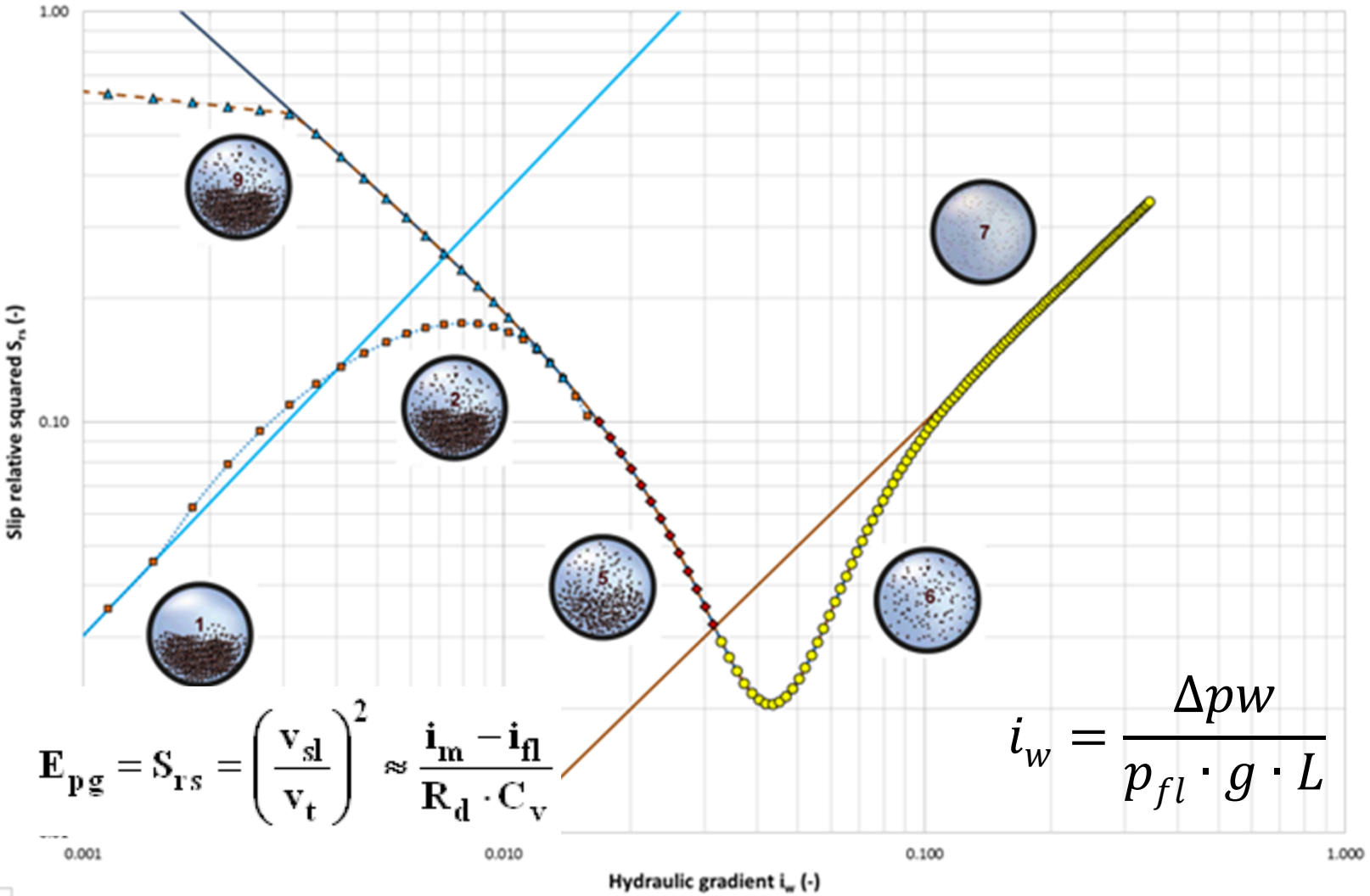


L1 – L3: Laboratory Setting, constant C_{vs}

Scenario L1 & R1



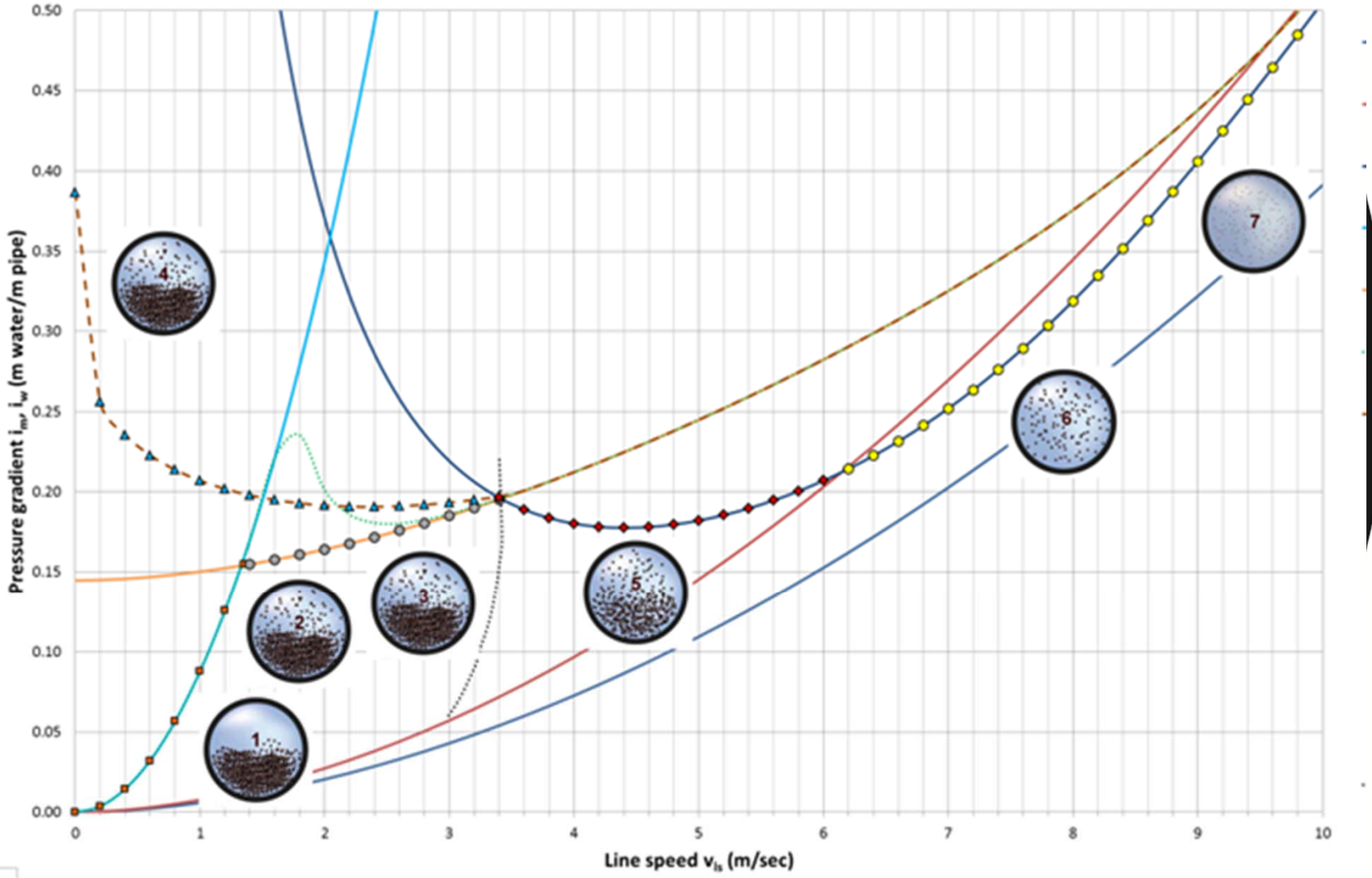
Scenario L1 & R1 (S_{rs} vs i_m)



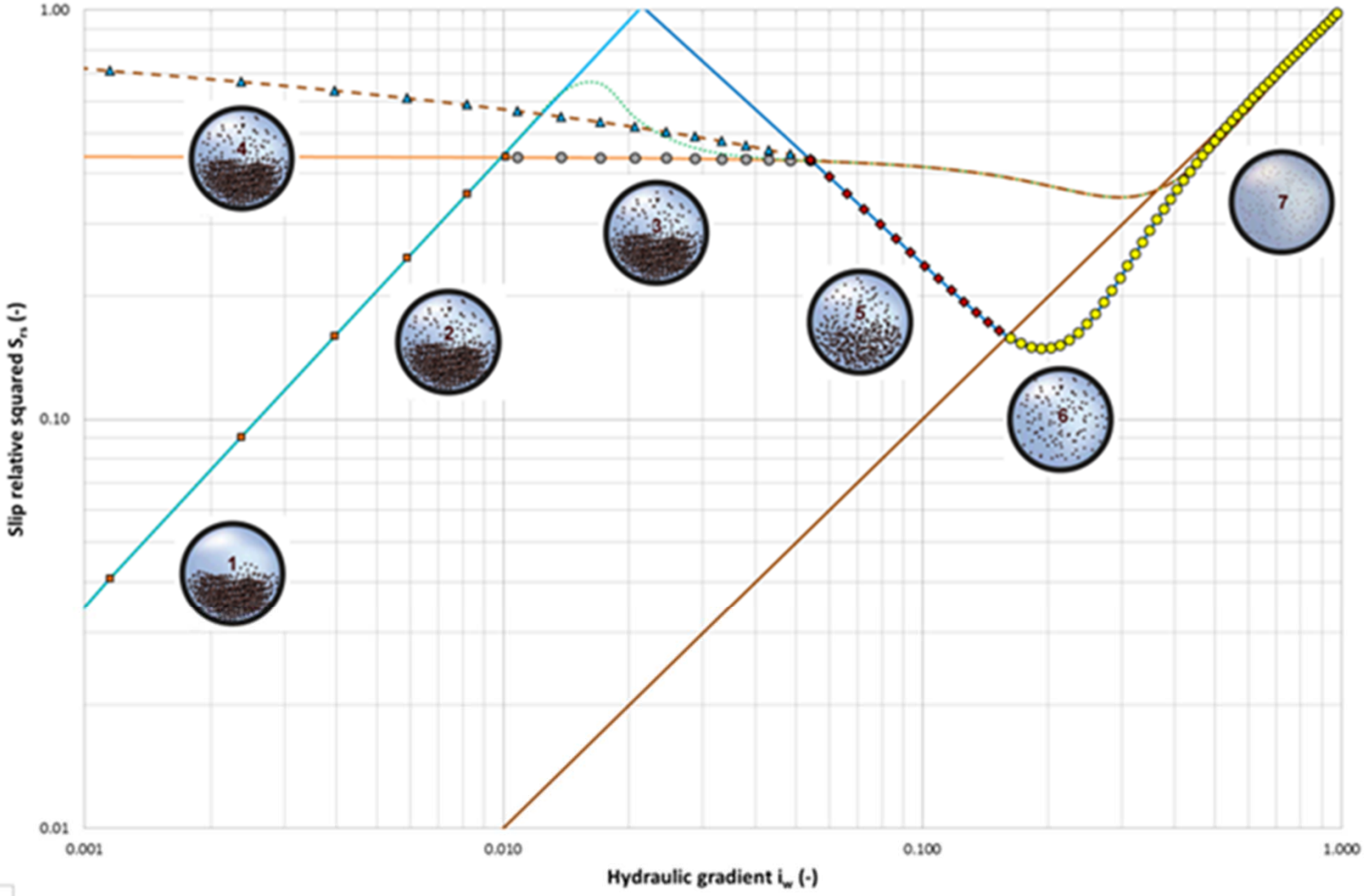
$$E_{pg} = S_{rs} = \left(\frac{v_{sl}}{v_t}\right)^2 \approx \frac{i_m - i_{fl}}{R_d \cdot C_v}$$

$$i_w = \frac{\Delta pw}{p_{fl} \cdot g \cdot L}$$

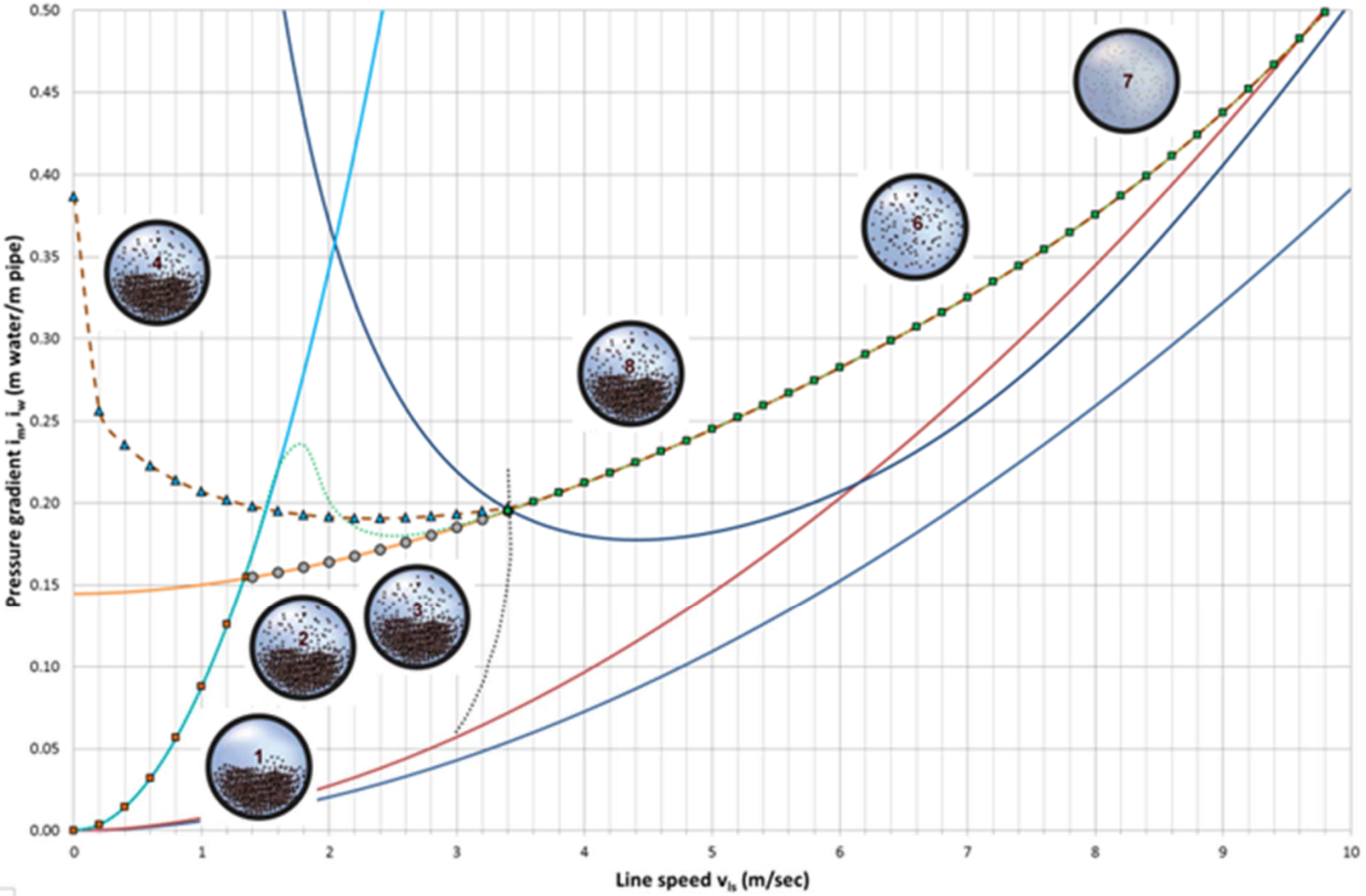
Scenario L2 & R2



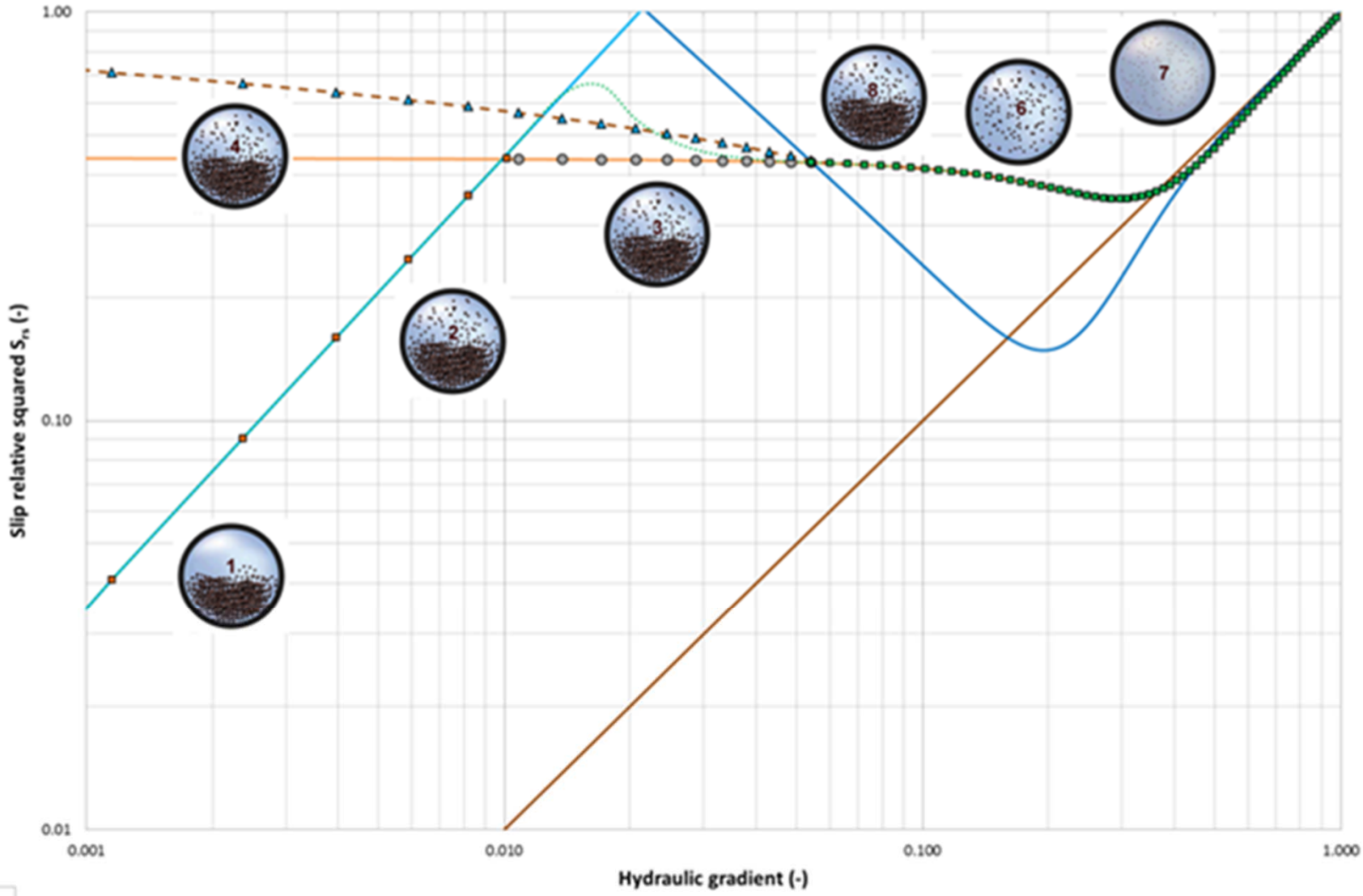
Scenario L2 & R2 (S_{rs} vs i_m)



Scenario L3 & R3



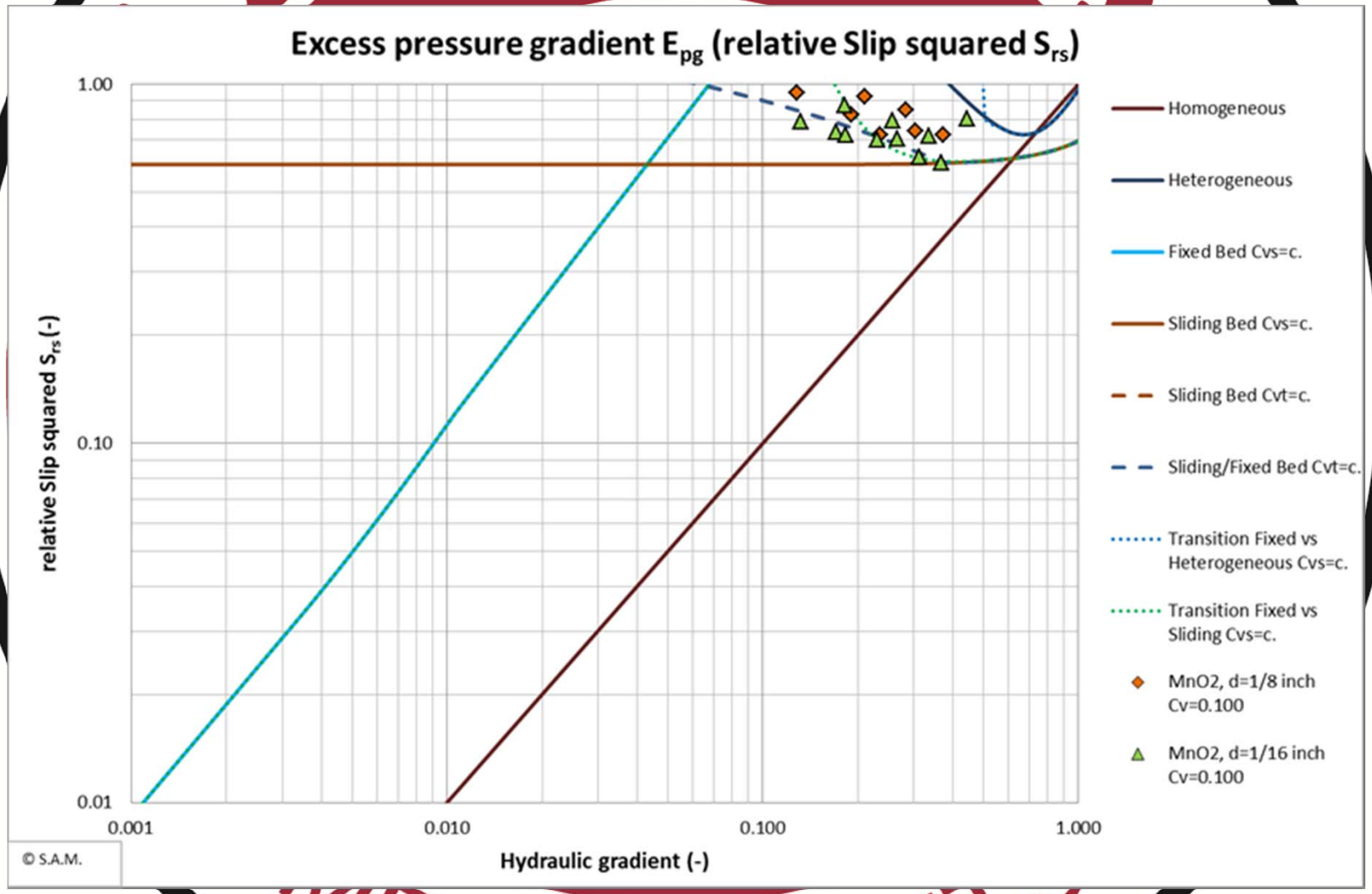
Scenario L3 & R3 (S_{rs} vs i_m)



Verification/Validation

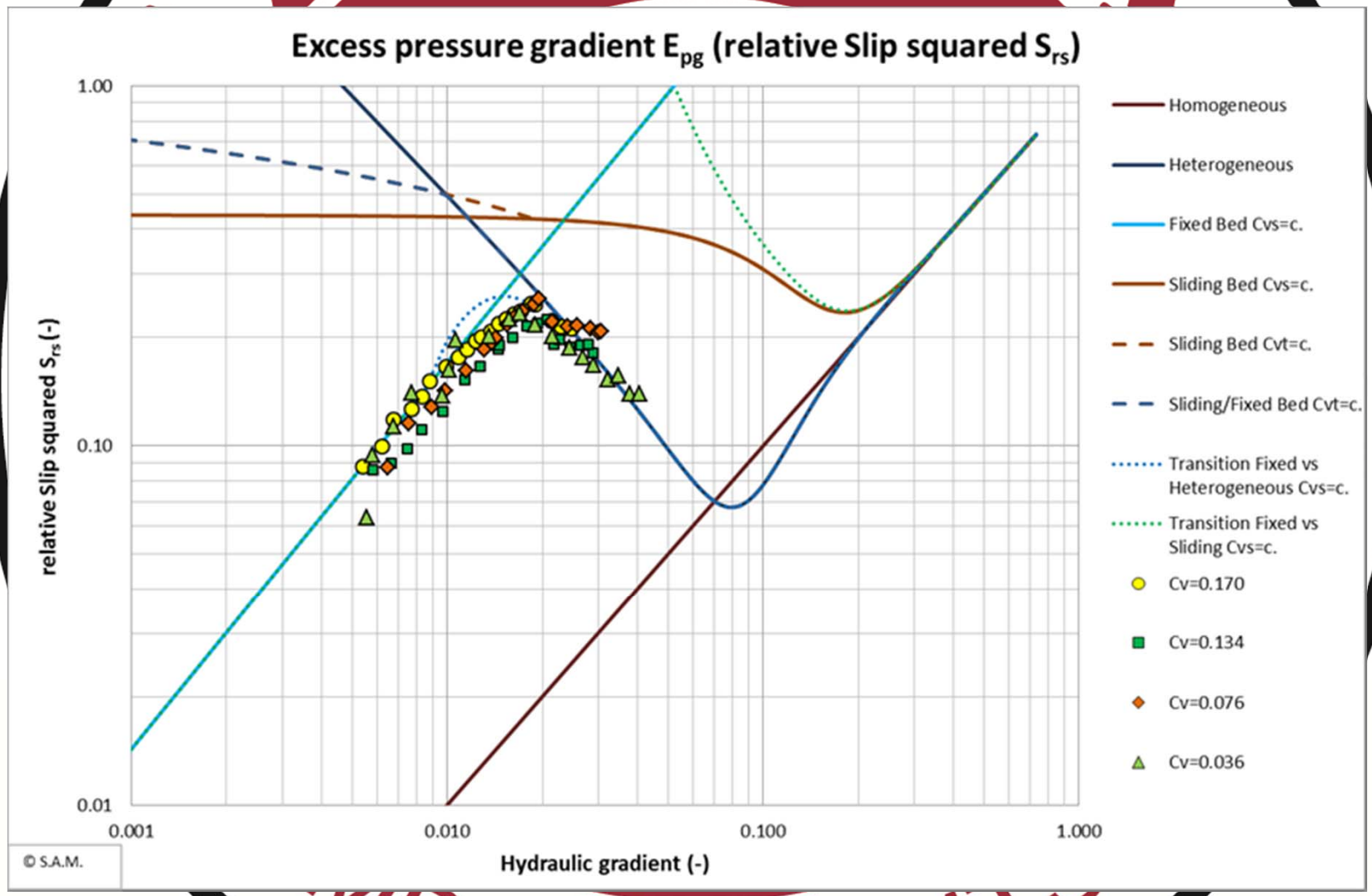
Experimental Data

Sliding Bed, Cvt=c.



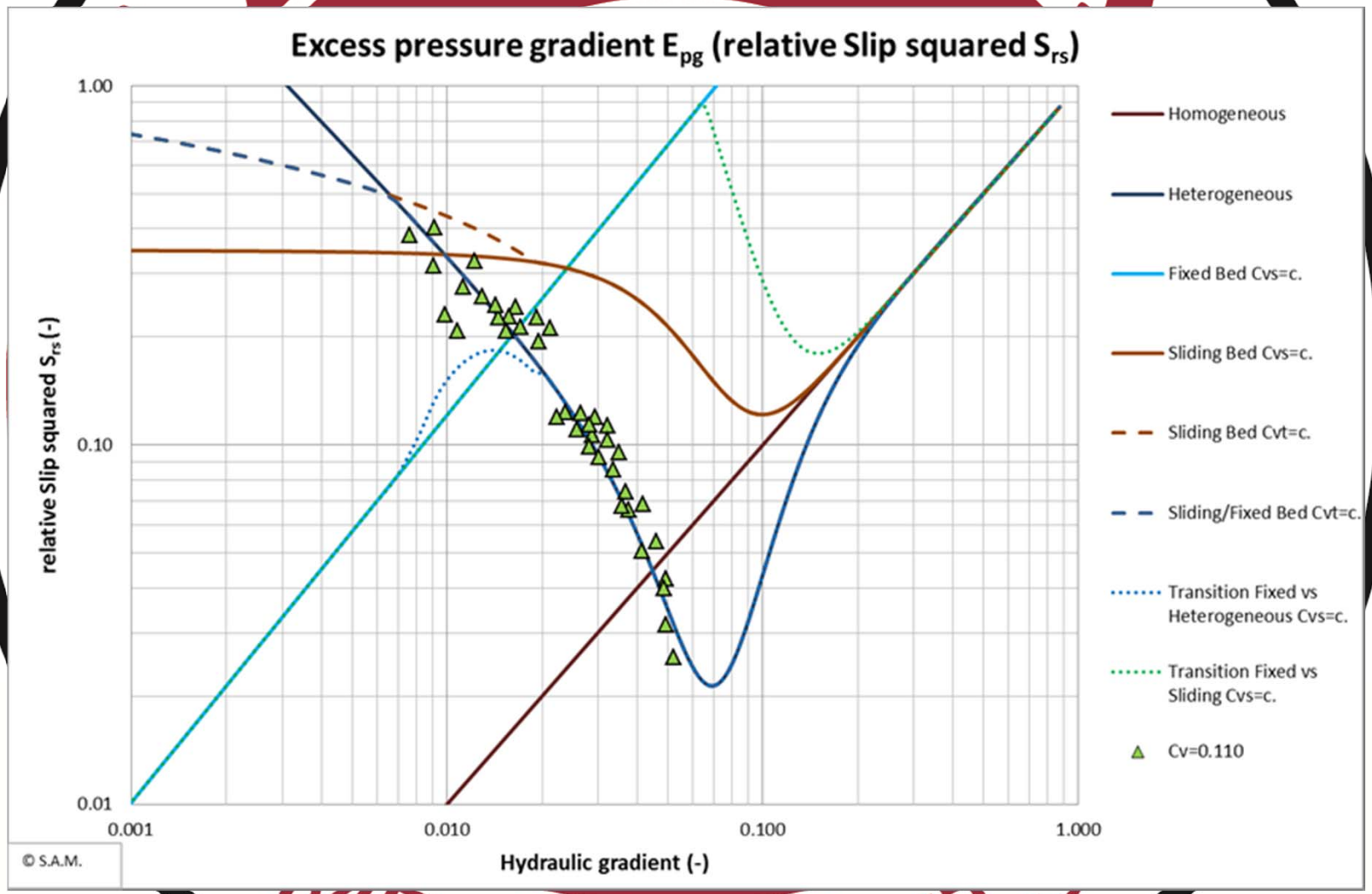
Newitt et al. (1955) D_p=.025m, d=1.6-3.2mm

Fixed Bed - Heterogeneous



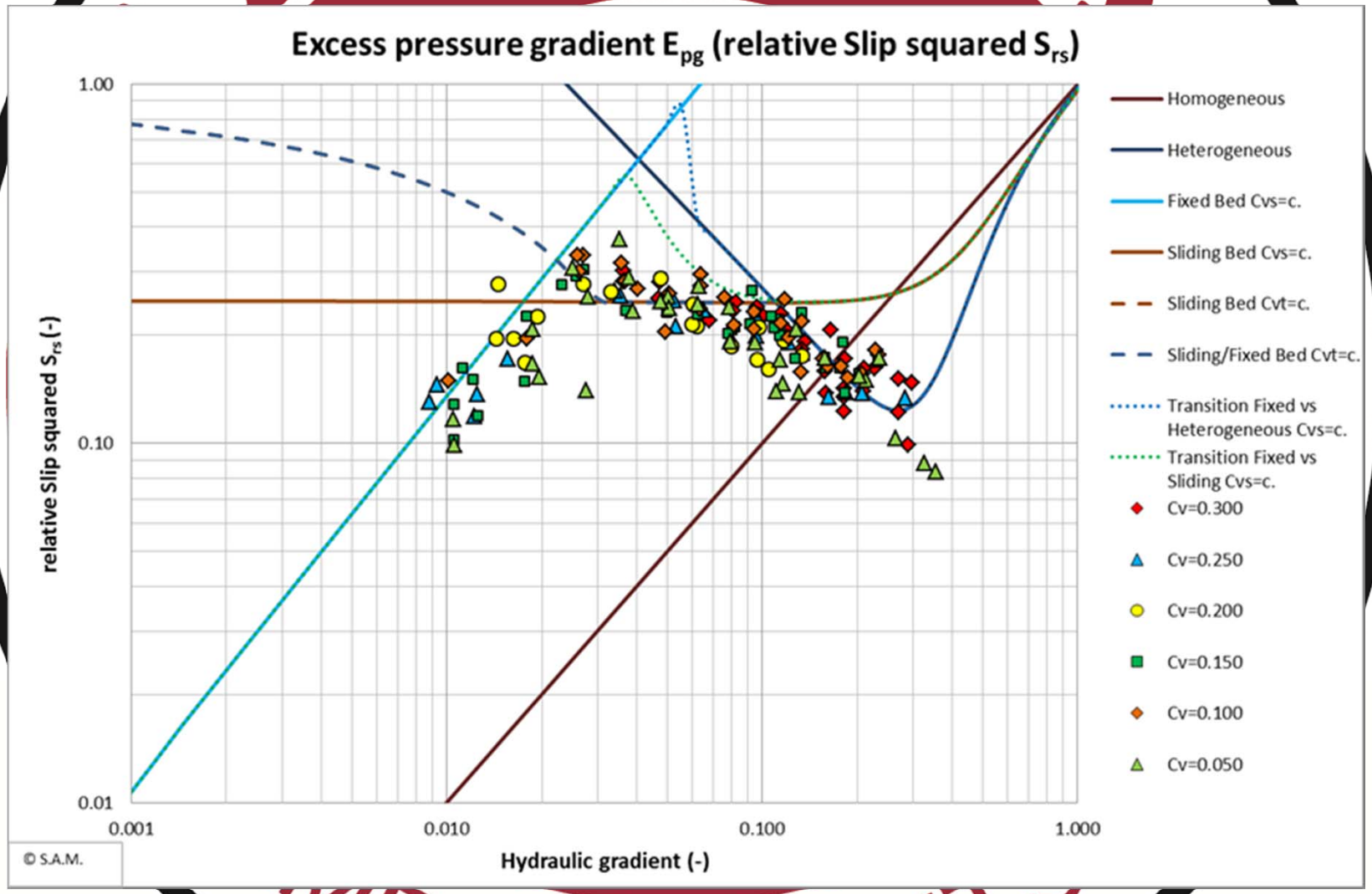
Kazanskij (1980) D_p=0.5m, d=1.5mm, C_{vs}

Heterogeneous



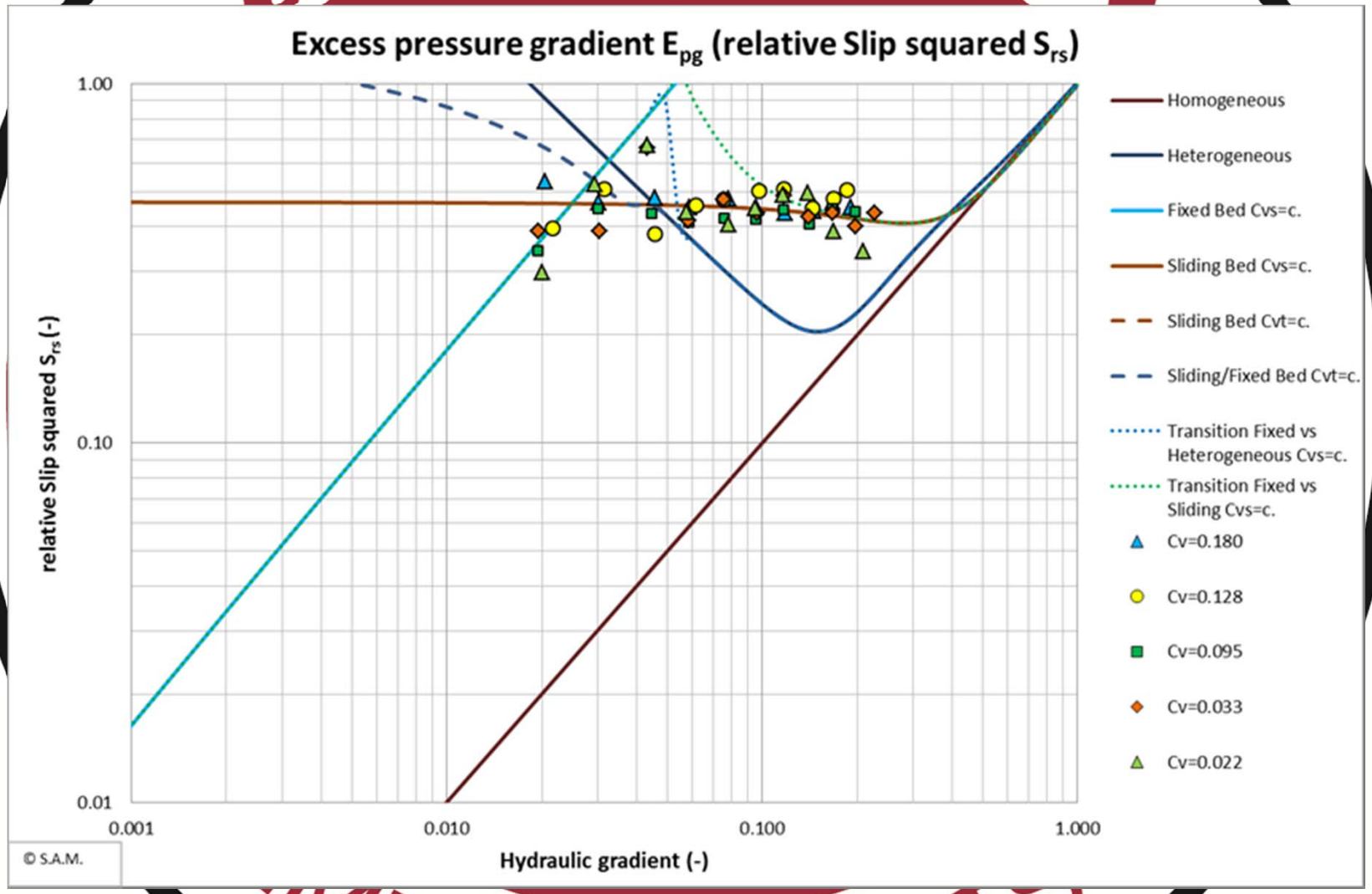
Clift et al. (1982) D_p=0.44m, d=0.68mm, C_{vt}

Fixed Bed – Sliding Bed - Heterogeneous



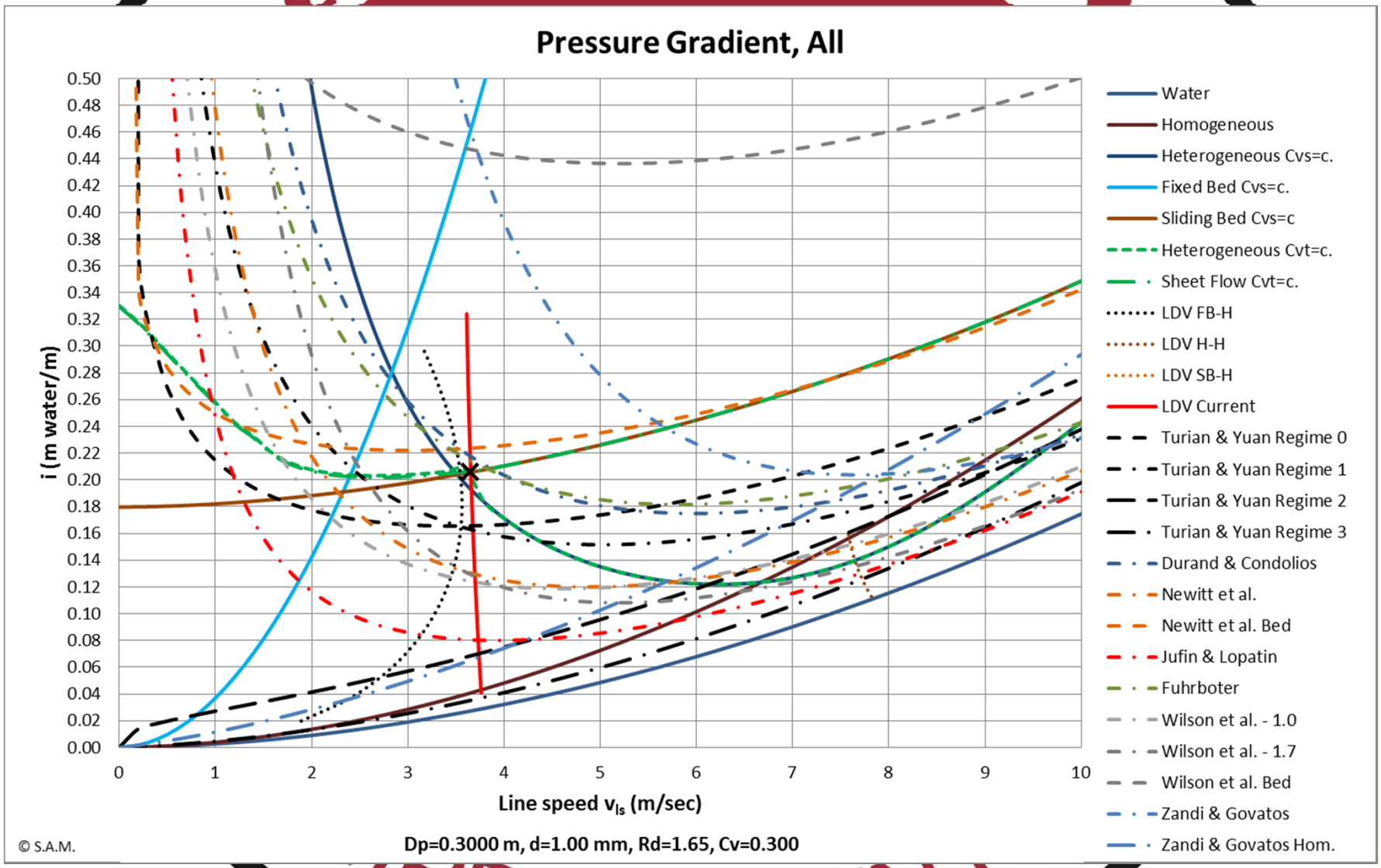
Wiedenroth (1967) D_p=0.125m, d=2.2mm, C_{vs}

Fixed Bed – Sliding Bed - Sheet Flow

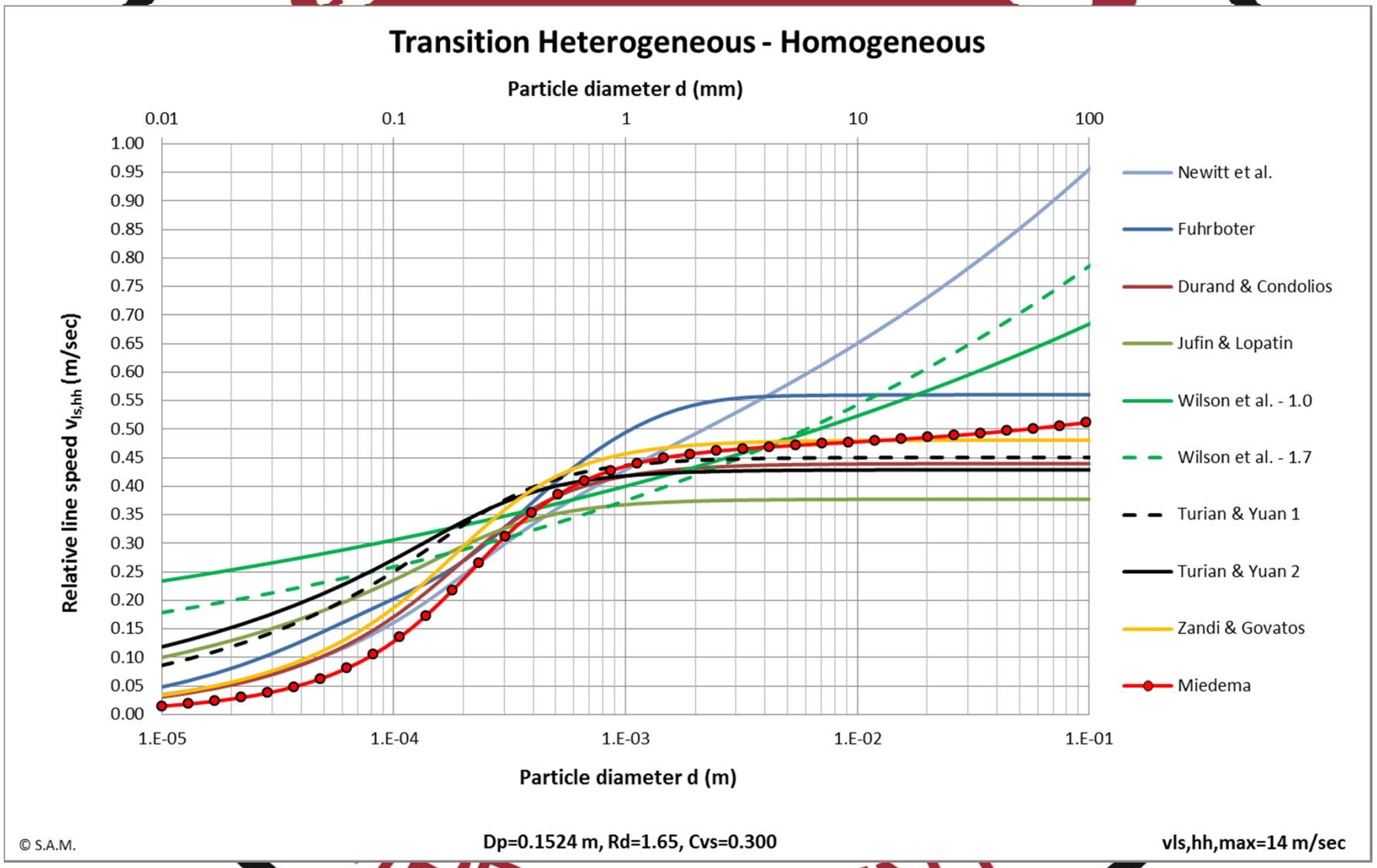


Boothroyde (1979) D_p=0.2m, d=4.3mm

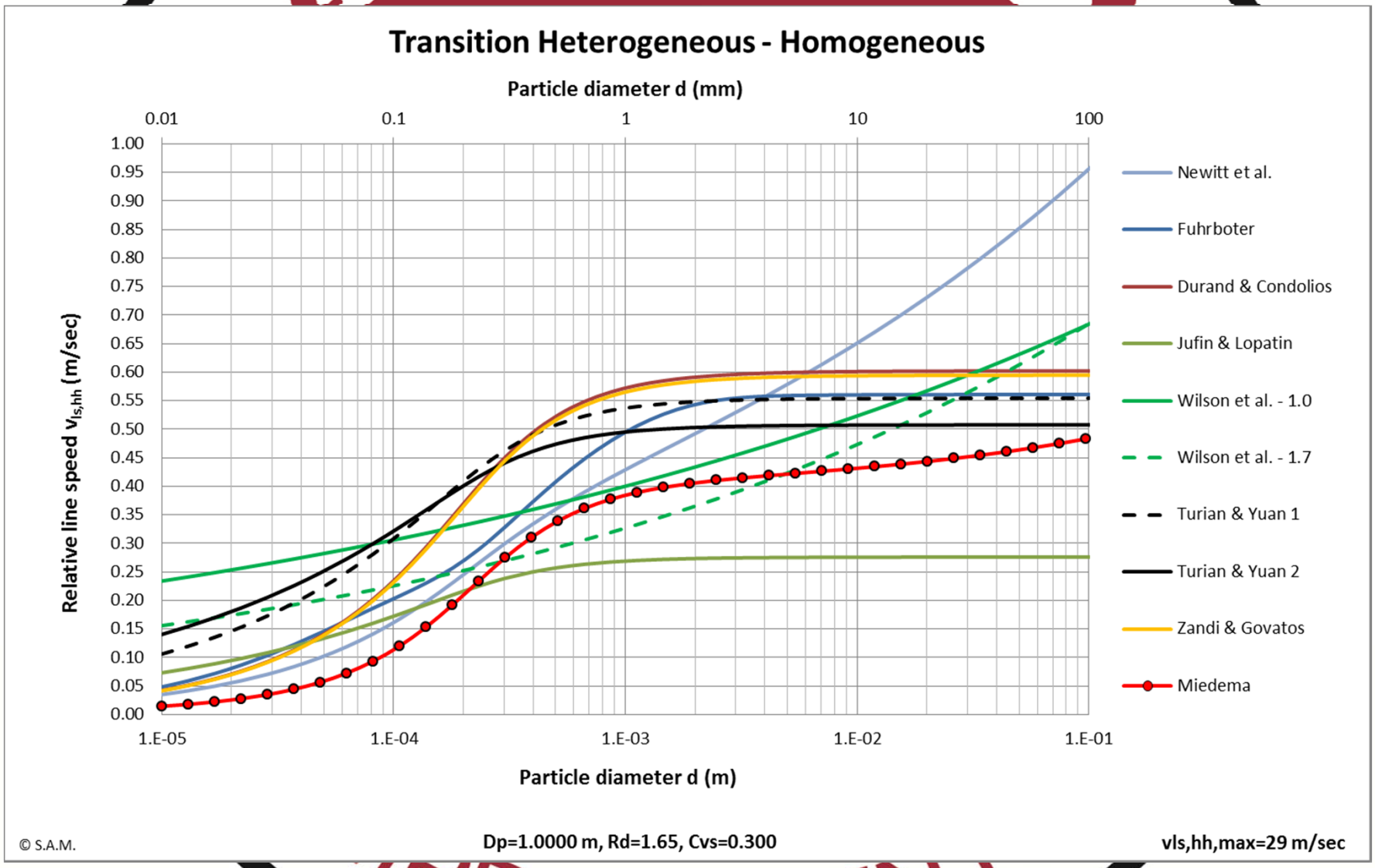
21 Different Models



Different Models for Dp=0.15 m, Cv=0.30



Different Models for Dp=1.00 m, Cv=0.30



Energy Considerations

Energy Dissipation by:

- Viscous Friction & Turbulence (Darcy Weisbach)
- Potential Energy Losses (Hindered Settling Velocity)
- Kinetic Energy Losses (Collisions)
- Sliding & Rolling Friction
- Magnus Lift Work (Viscous Sub-Layer, Low Speed)
- Turbulent Lift Work & Eddy Work (High Line Speed)

Heterogeneous Transport

- Energy Dissipation by:
- Viscous Friction & Turbulence (Darcy Weisbach)
- Potential Energy Losses (Hindered Settling Velocity)
- Kinetic Energy Losses (Collisions)

$$\Delta p_m = \Delta p_{fl,visc} + \Delta p_{s,pot} + \Delta p_{s,kin} = \Delta p_{fl,visc} \cdot \left(1 + \frac{\Delta p_{s,pot}}{\Delta p_{fl,visc}} + \frac{\Delta p_{s,kin}}{\Delta p_{fl,visc}}\right)$$

Details:
Sape A. Miedema, Robert C. Ramsdell (2013):
A HEAD LOSS MODEL FOR SLURRY TRANSPORT BASED ON ENERGY CONSIDERATIONS
WODCON XX. Brussels, Belgium.: WODA

Conclusions – Regimes and Results

- 9 Flow regimes can be distinguished. Not every flow regime is present for every combination of particles, pipe and concentration.
- It is crucial to distinguish between constant volumetric spatial and transport concentration in interpreting experimental results.
- With a good model for each flow regime, the scenarios can be constructed and the correct flow regime can be predicted.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Questions?