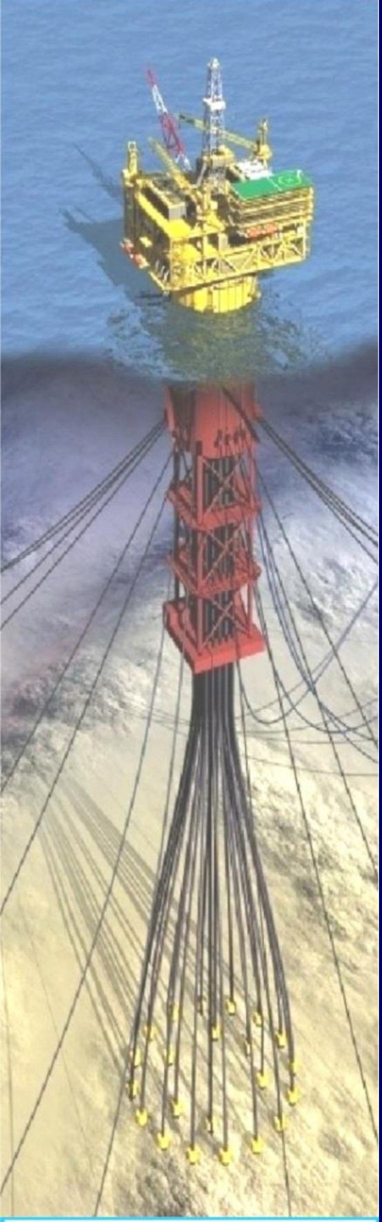
CEDA DREDGING TECHNOLOGY WEBINARS #6

WELCOME

Flow regime diagrams in slurry transport models

Dr. ir. Sape Miedema

Delft University of Technology



DHLLDV Framework Flow Regimes & Scenarios

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Dredging A Way Of Life

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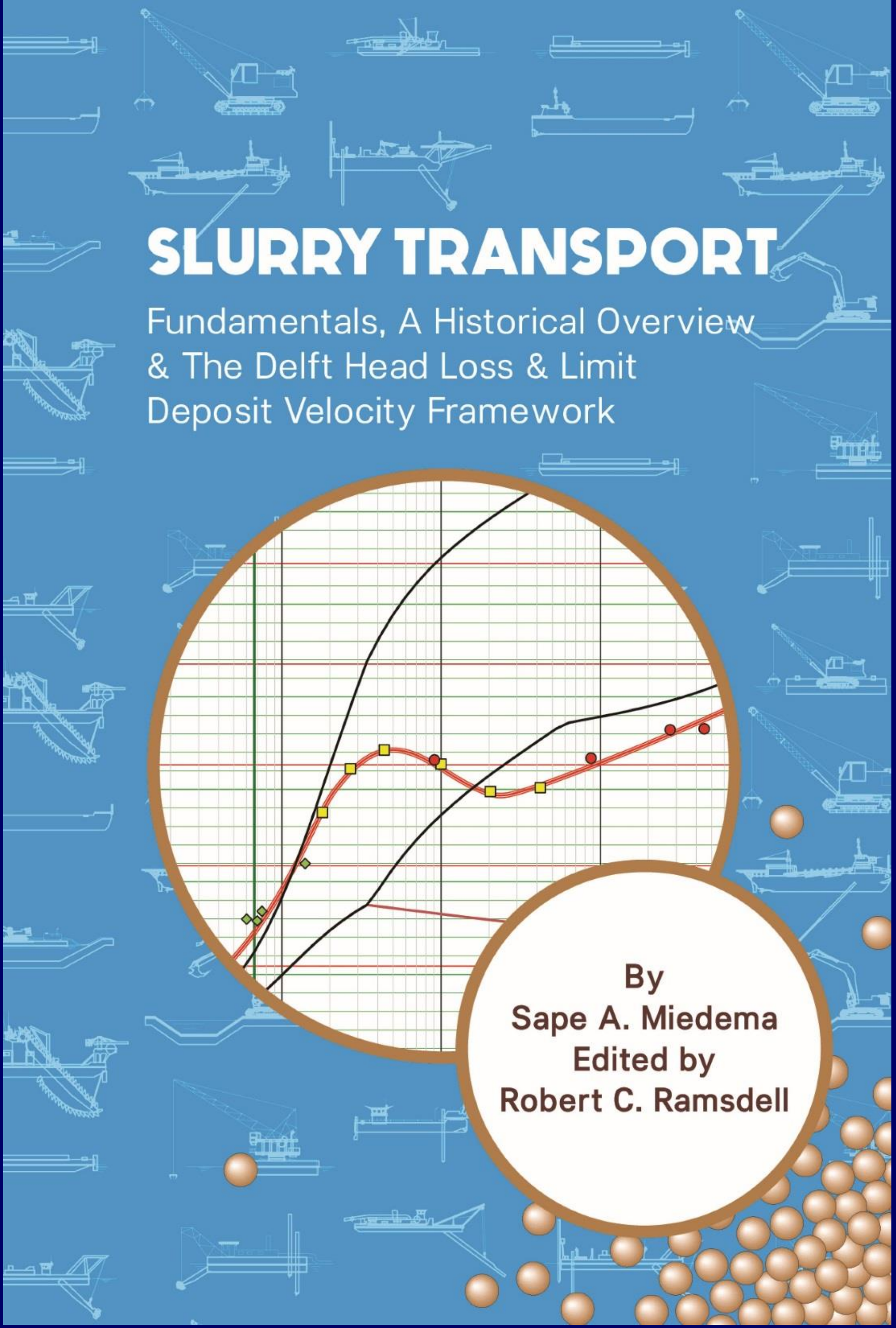

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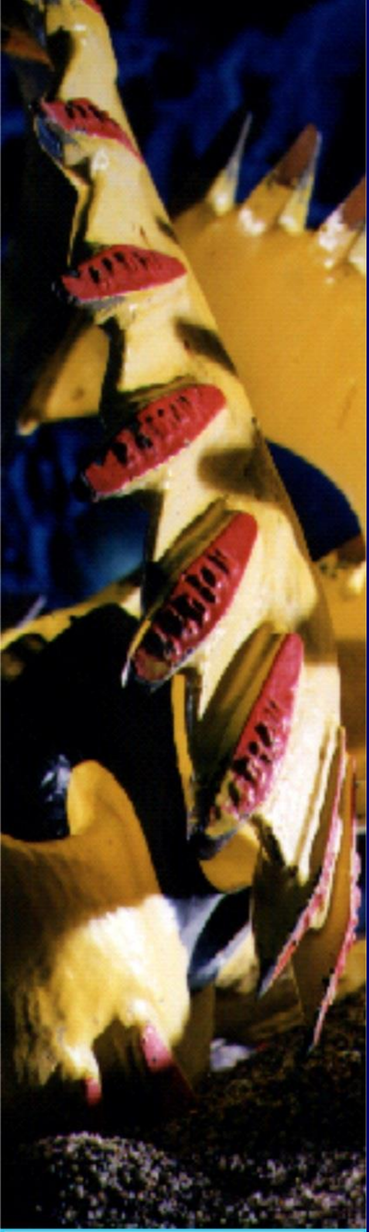

Introduction

Chapter 7.1

The Elephant of Wilson

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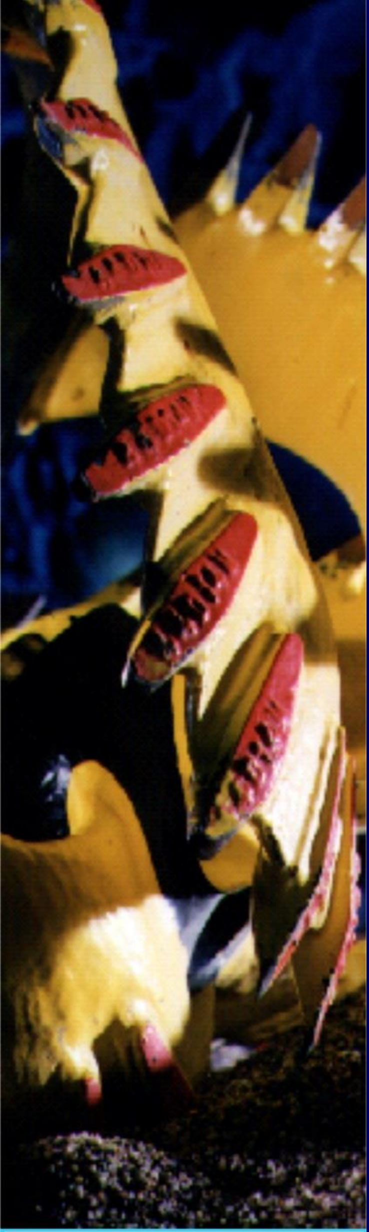


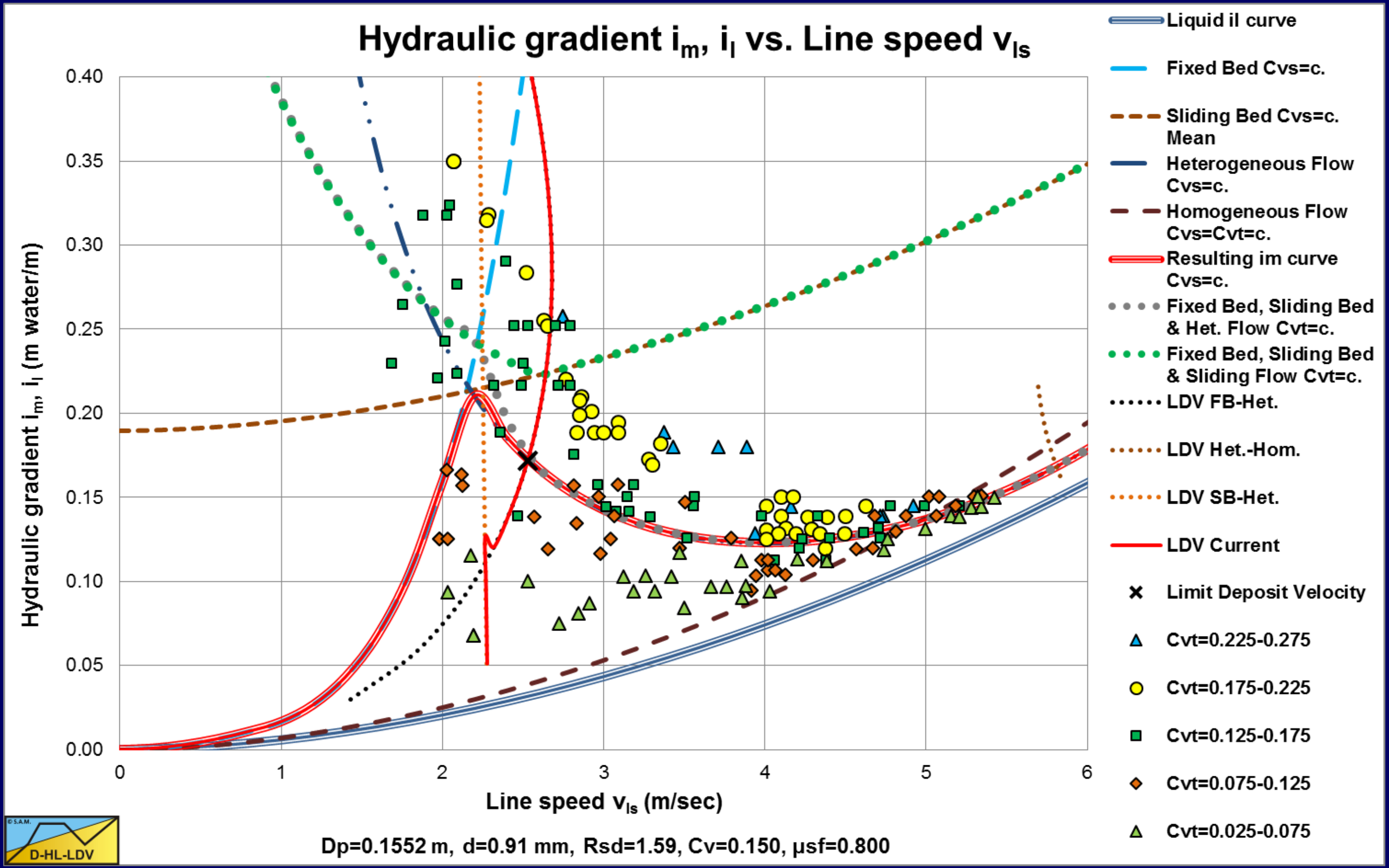
Possibilities

1. Small versus large pipe diameter
2. Small versus large particle diameter
3. Low versus high concentration
4. Low versus high line speed
5. Spatial versus delivered concentration
6. Uniform versus graded sands/gravels

1. Carrier liquid properties
2. Solids properties

For sands/gravels in water 64 combinations possible

Data from Yagi et al., C_{vs}



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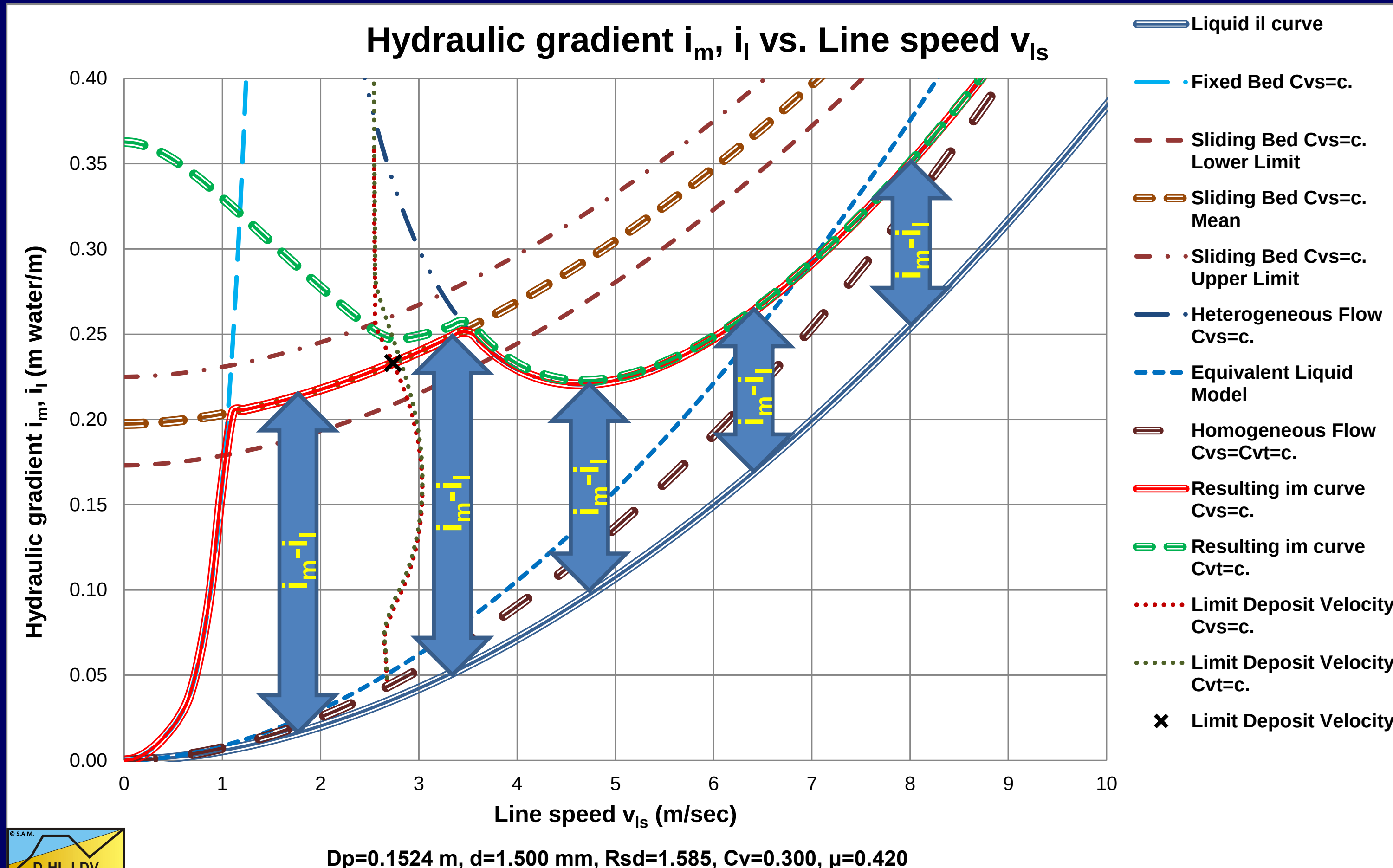
DHLLDV Model, The Solids Effect, C_{vs}



$$i_l = \frac{\Delta p_l}{\rho_l \cdot g \cdot \Delta L} = \frac{\lambda_l \cdot v_{ls}^2}{2 \cdot g \cdot D_p}$$

$$E_{rhg} = \frac{i_m - i_l}{R_{sd} \cdot C_v}$$

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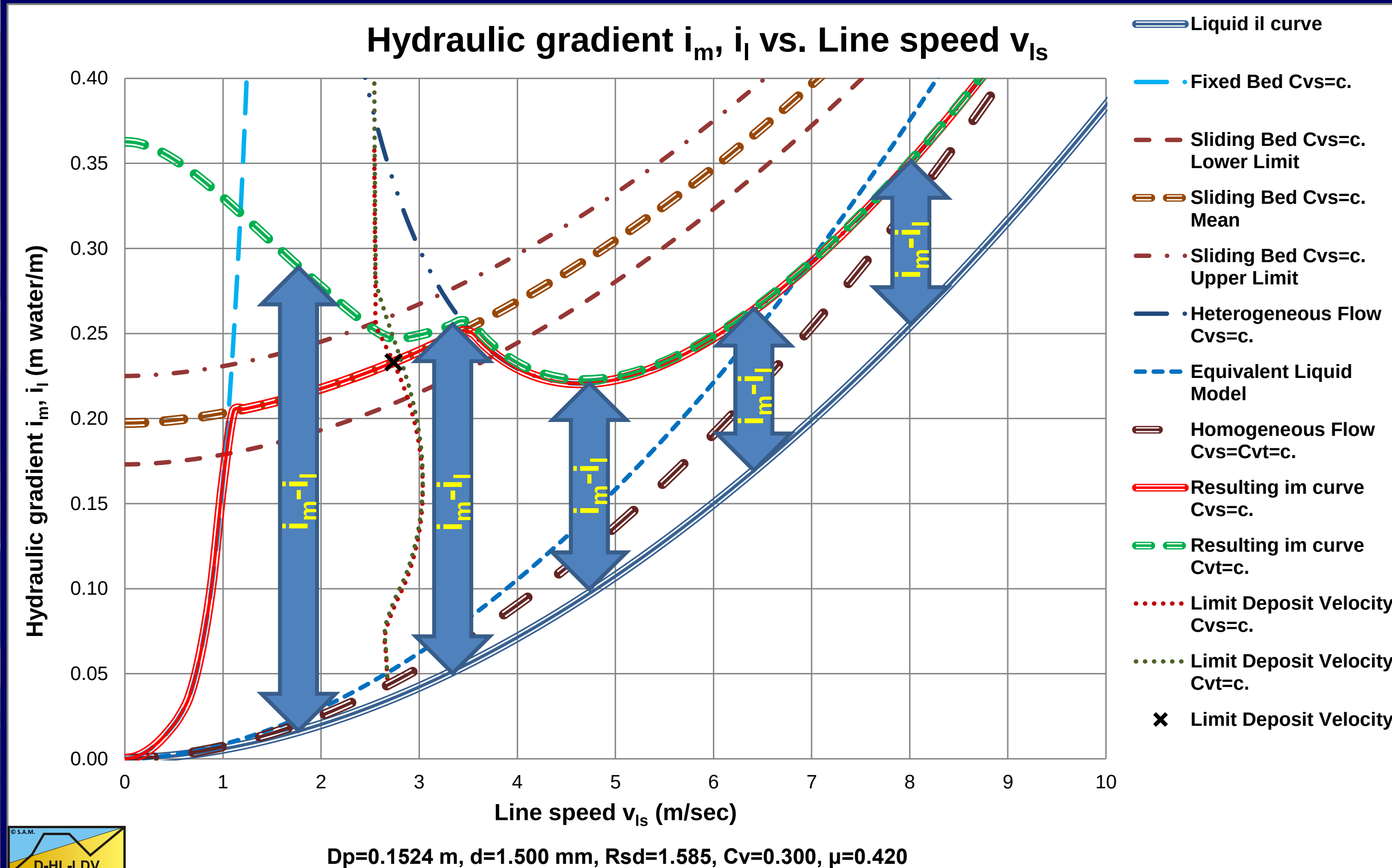
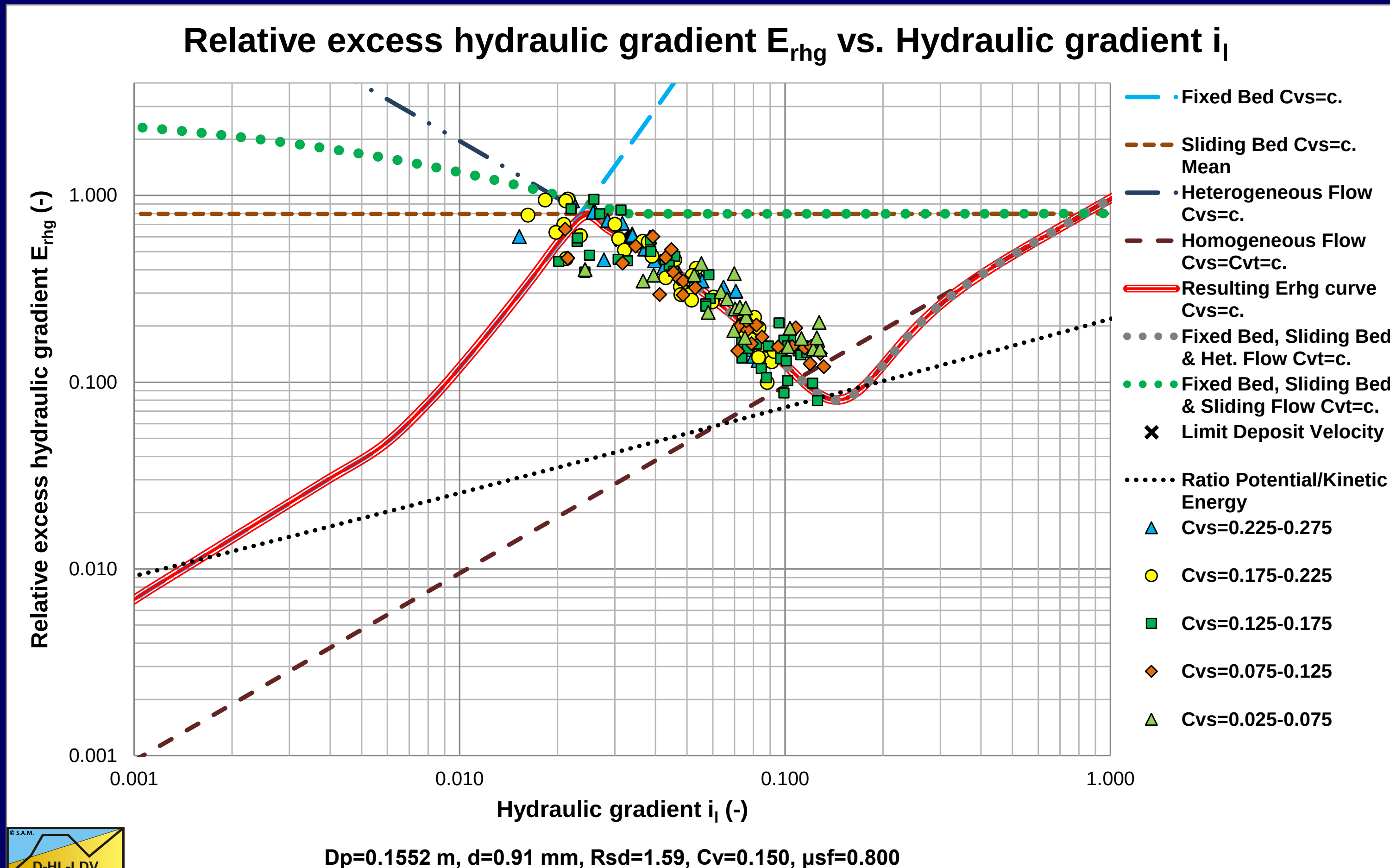
DHLLDV Model, The Solids Effect, C_{vt}



$$i_l = \frac{\Delta p_l}{\rho_l \cdot g \cdot \Delta L} = \frac{\lambda_l \cdot v_{ls}^2}{2 \cdot g \cdot D_p}$$

$$E_{rhg} = \frac{i_m - i_l}{R_{sd} \cdot C_v}$$

Data from Yagi et al., C_{vs}



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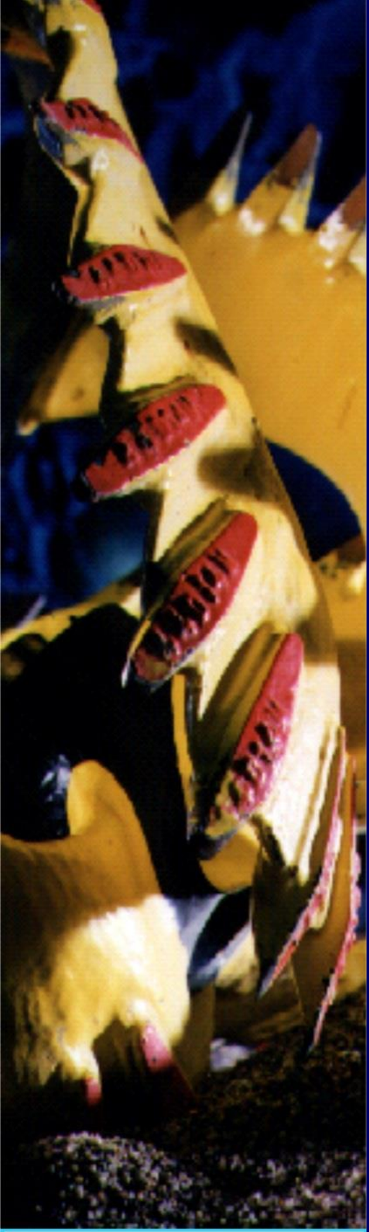
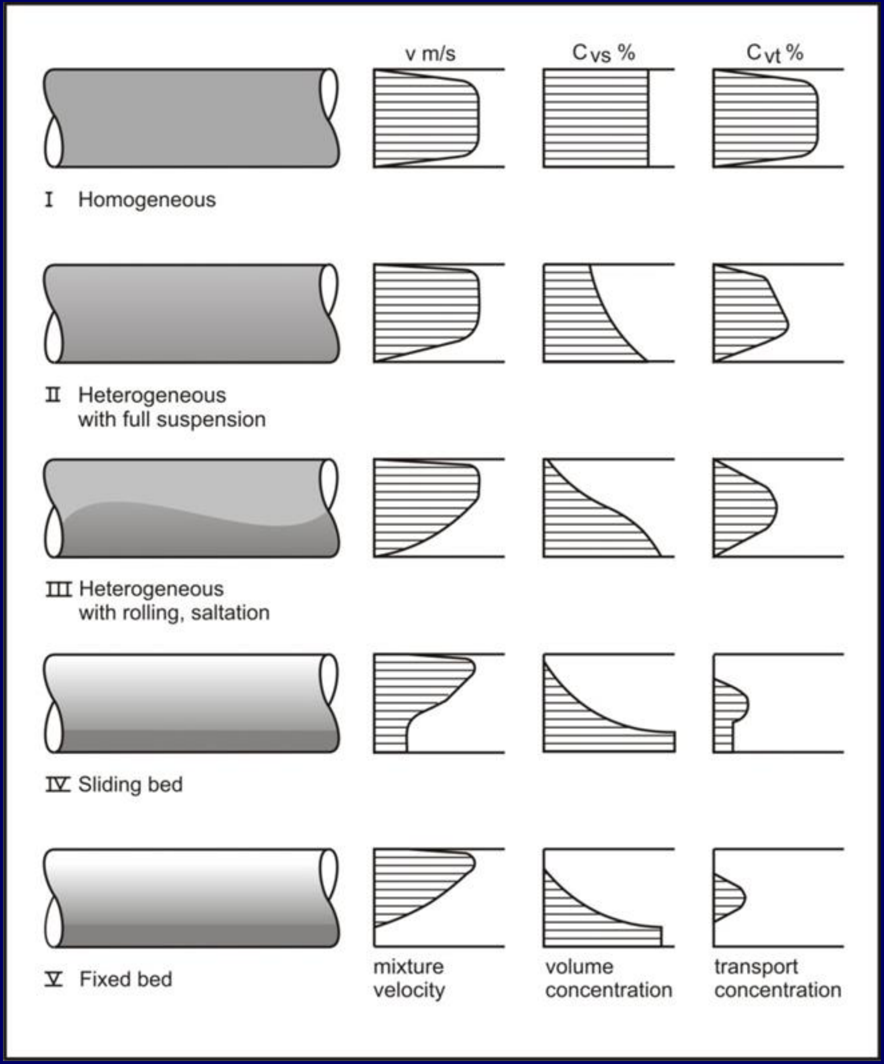


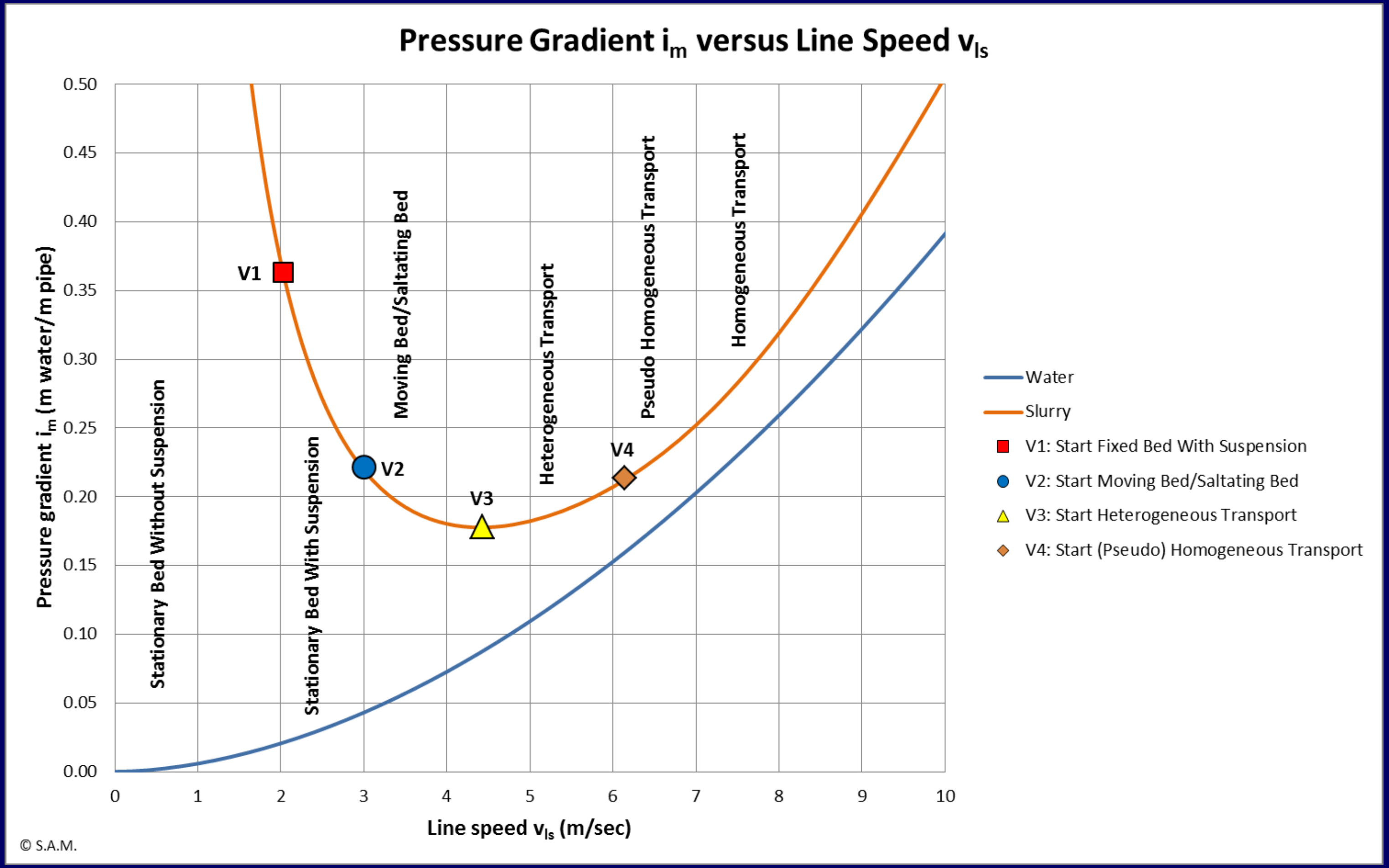
Regimes History

Chapter 1

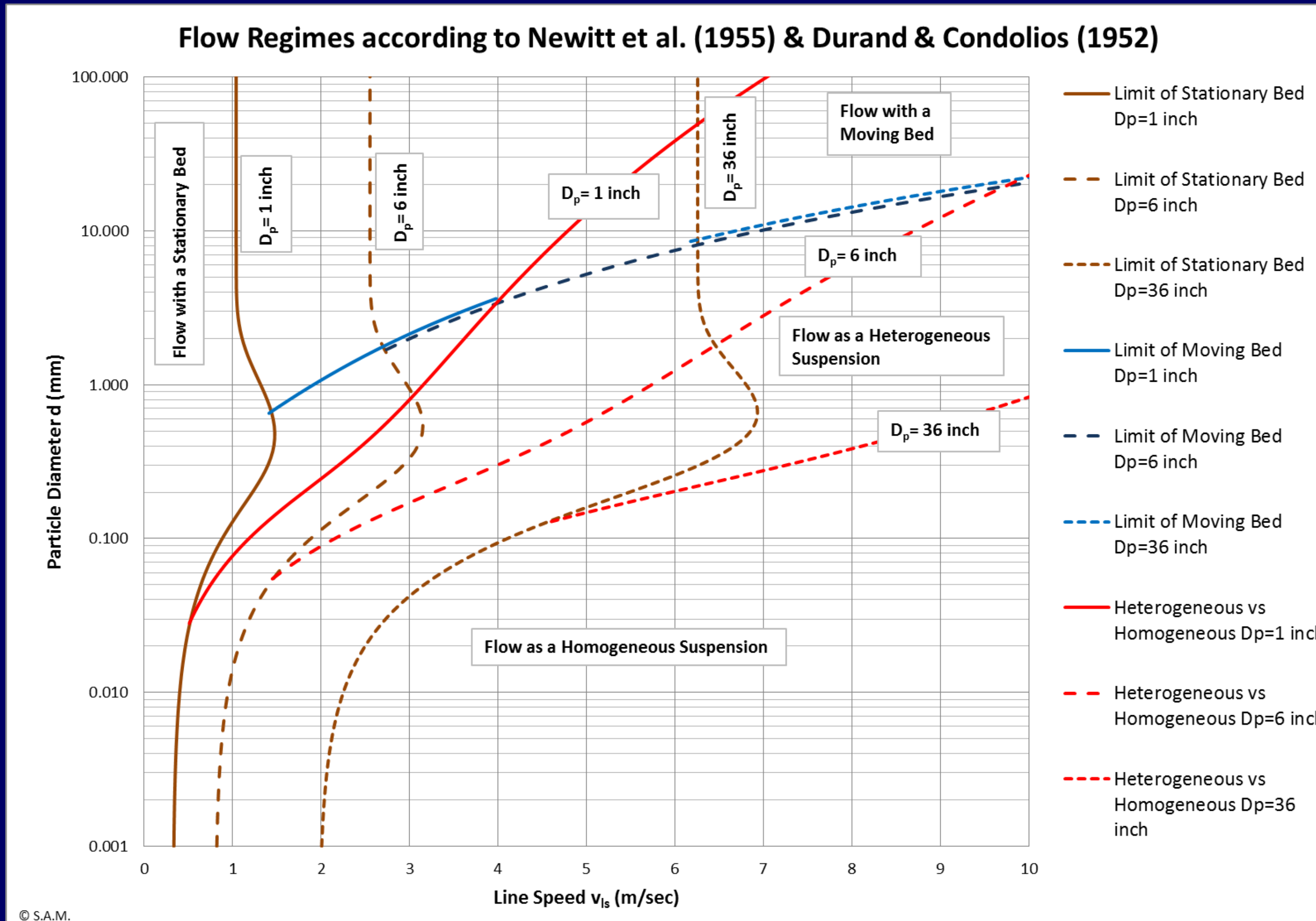
Regimes History



Abulnaga (2002)



Newitt/Miedema (2013)



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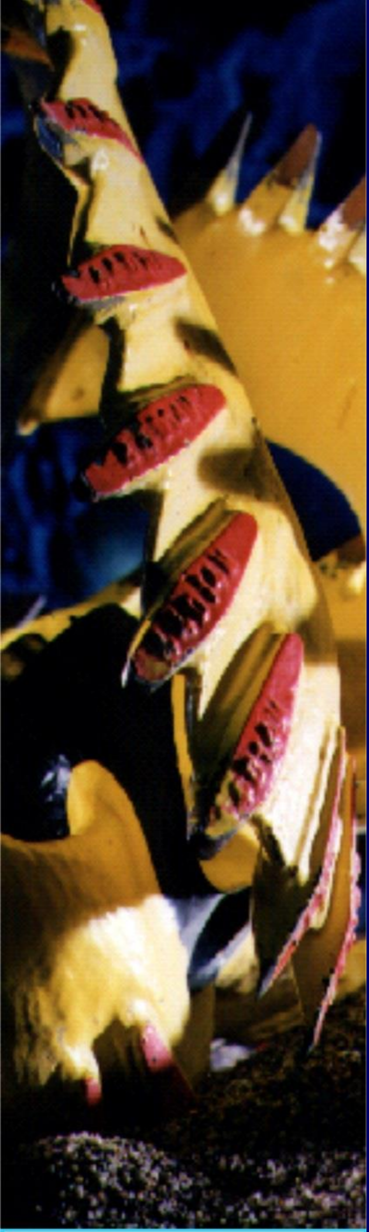
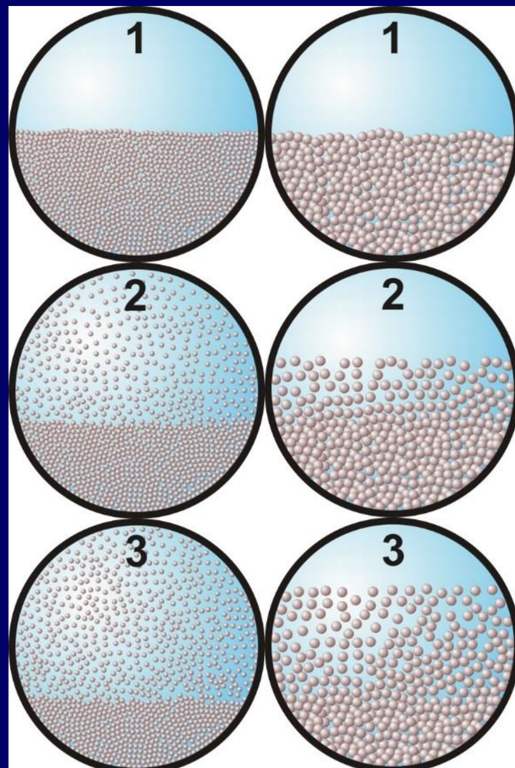


Flow Regimes

Chapter 7.2

Flow Regimes 1

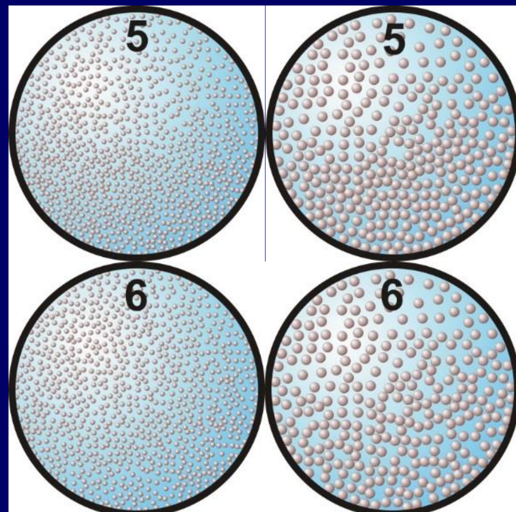


1: Fixed bed without suspension or sheet flow, constant C_{vs}.

2: Fixed bed with suspension or sheet flow, constant C_{vs}.

3: Fixed bed with suspension or sliding bed with sheet flow, constant C_{vs}.

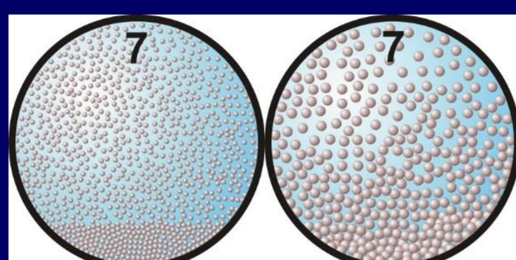
Flow Regimes 2



5: Heterogeneous transport, $C_{vt} \approx C_{vs}$.

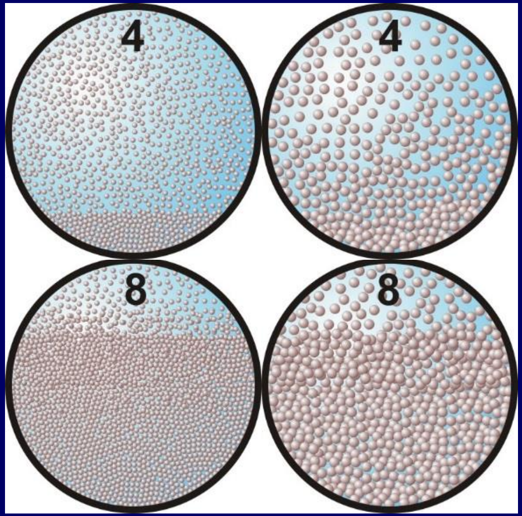
6: Homogeneous transport, $C_{vt} \approx C_{vs}$.

5/6: Pseudo homogeneous transport, $C_{vt} \approx C_{vs}$.



7: Sliding Flow if $d/D_p > 0.015$.

Flow Regimes 3

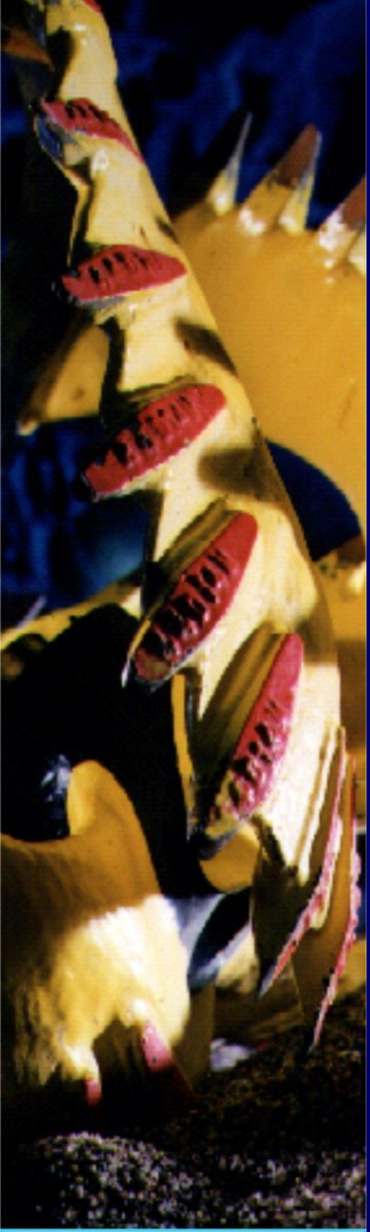


4: Fixed bed with suspension or sliding bed with sheet flow, constant C_{vt}.

8: Fixed bed with suspension or sliding bed with sheet flow, constant C_{vt}.

Distinguish C_{vs} & C_{vt}

Scenario's with L are with C_{vs}
Scenario's with R are with C_{vt}



Scenarios

Chapter 7.2

Equations in Graphs

Hydraulic Gradient i

$$i_l = \frac{\Delta p_l}{\rho_l \cdot g \cdot L} \quad \text{or} \quad i_m = \frac{\Delta p_m}{\rho_l \cdot g \cdot L}$$

for water as carrier fluid:

$$\frac{\lambda_l \cdot \frac{\Delta L}{D_p} \cdot \frac{1}{2} \cdot \rho_l \cdot v_{ls}^2}{\rho_l \cdot g \cdot \Delta L} = \frac{\lambda_l \cdot v_{ls}^2}{2 \cdot g \cdot D_p}$$

Relative Submerged Density R_{sd}

$$R_{sd} = \frac{\rho_s - \rho_l}{\rho_l}$$

Relative Excess Hydraulic Gradient E_{rhg}

$$E_{rhg} = \frac{i_m - i_l}{R_{sd} \cdot C_{vs}} \quad \text{or} \quad E_{rhg} = \frac{i_m - i_l}{R_{sd} \cdot C_{vt}}$$

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Spatial versus Transport Concentration & the Slip Velocity

Spatial Volumetric Concentration is volume based.
Transport Volumetric Concentration is volume flow based.

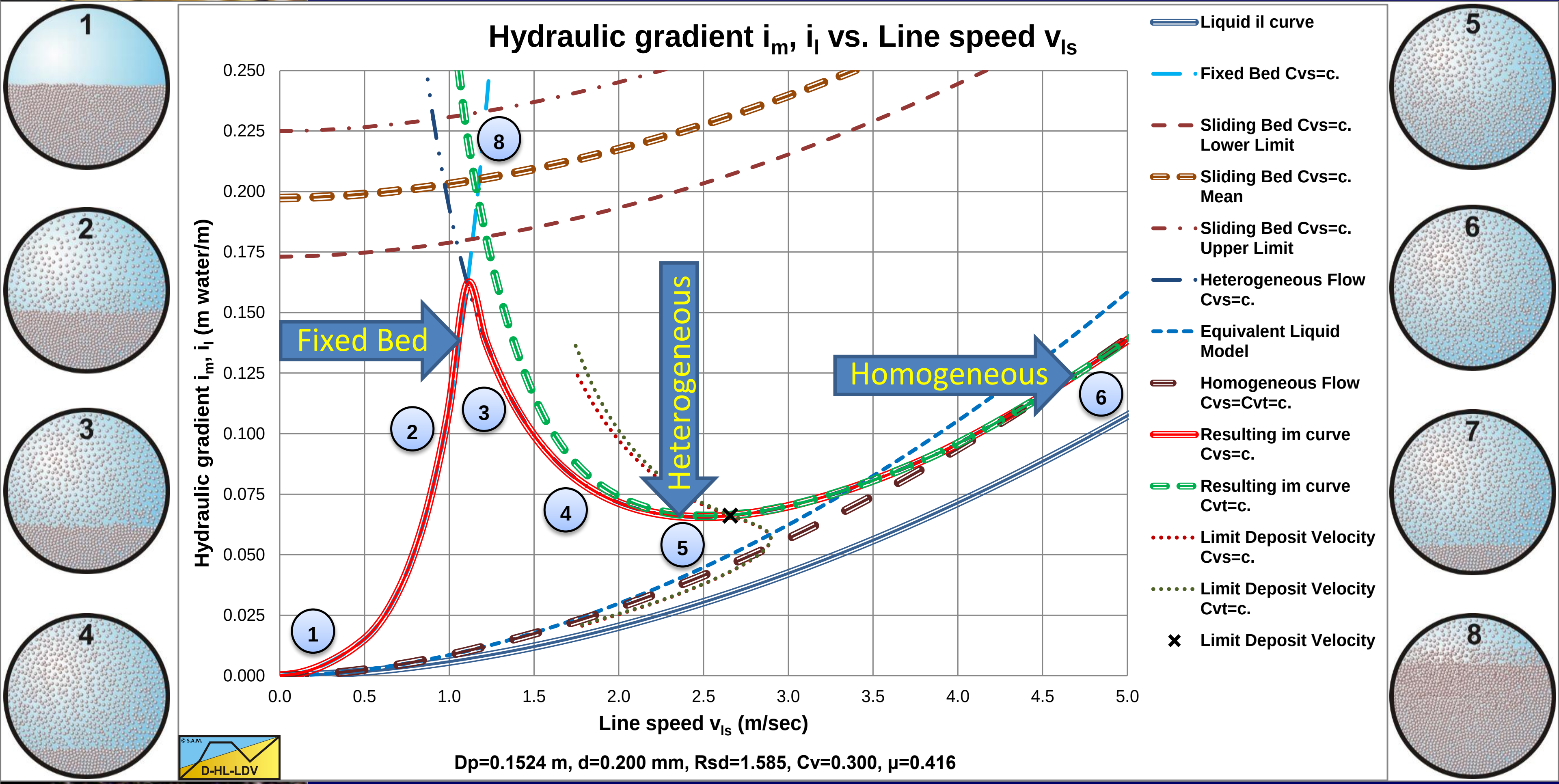
$$C_{vt} = \left(1 - \frac{v_{sl}}{v_{ls}}\right) \cdot C_{vs} \quad \Rightarrow \quad C_{vt} < C_{vs}$$

$$C_{vs} = \left(\frac{v_{ls}}{v_{ls} - v_{sl}}\right) \cdot C_{vt}$$

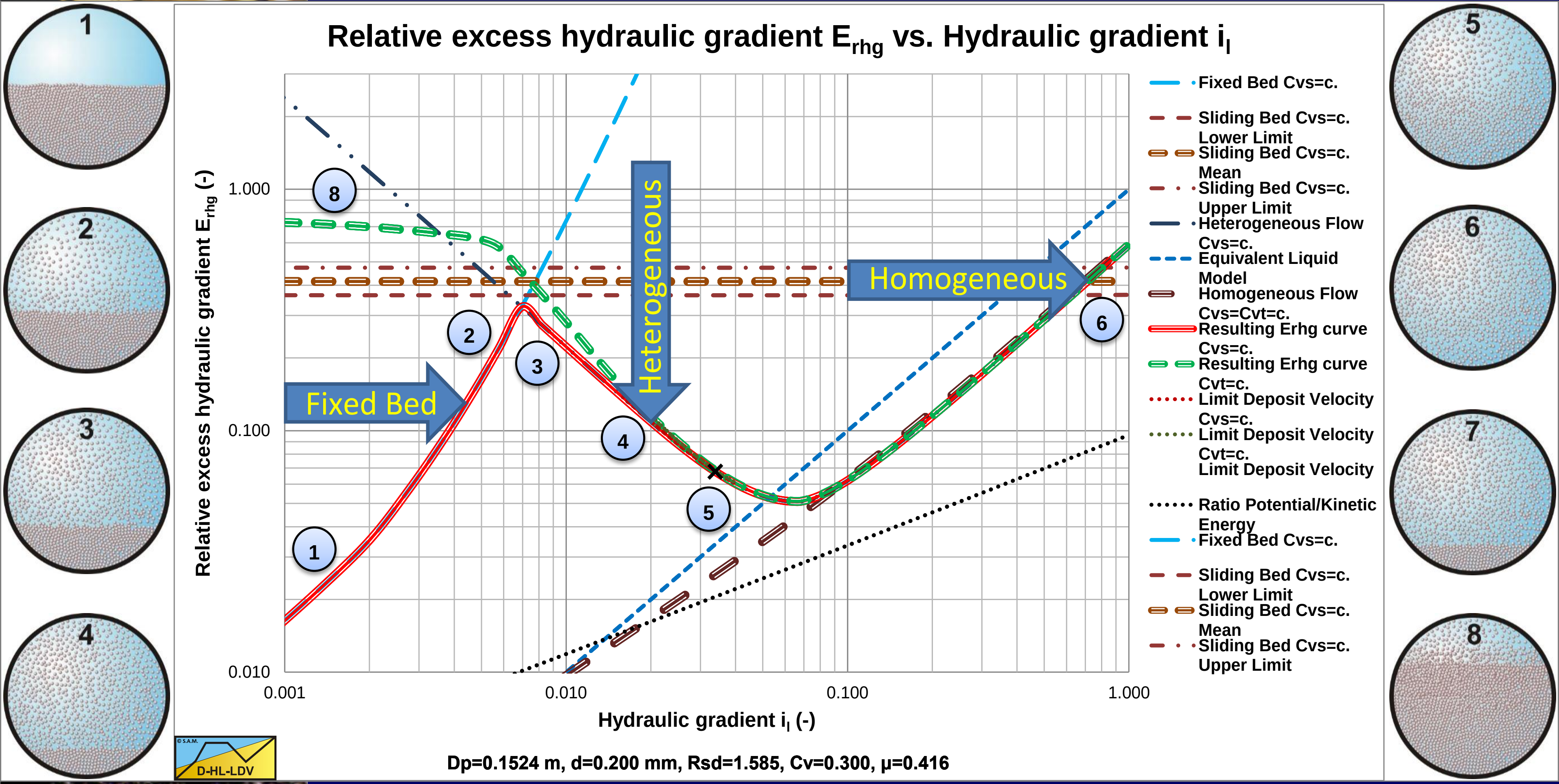
Relative Excess Hydraulic Gradient E_{rhg}, C_{vt}=constant

$$E_{rhg} = \frac{i_m - i_l}{R_{sd} \cdot \left(1 - \frac{v_{sl}}{v_{ls}}\right) \cdot C_{vs}} = \left(\frac{v_{ls}}{v_{ls} - v_{sl}}\right) \cdot \frac{i_m - i_l}{R_{sd} \cdot C_{vs}}$$

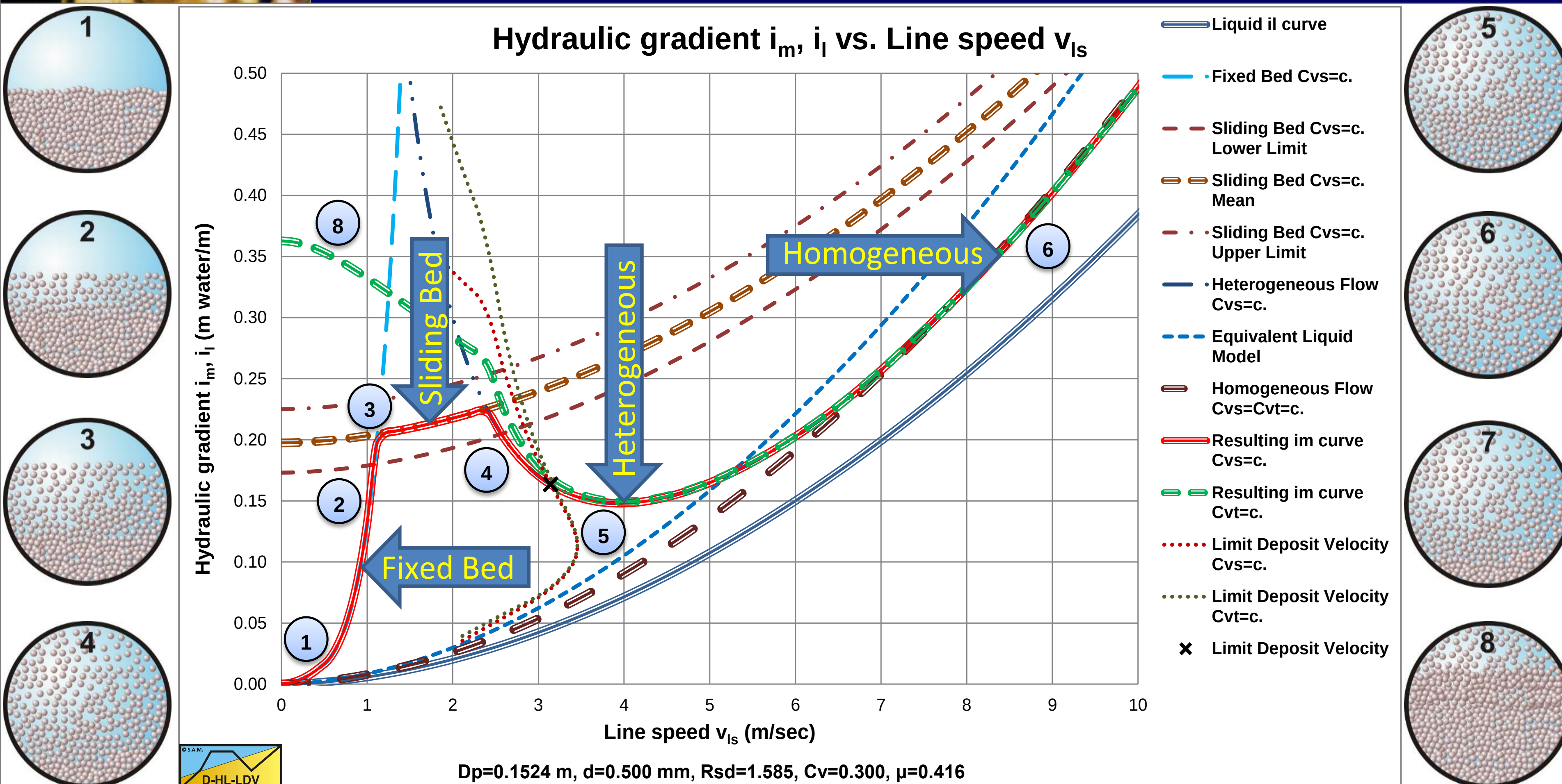
Scenario L1 & R1, i_m-v_{ls}



Scenario L1 & R1, E_{rhg}-i_l



Scenario L2A & R2A, i_m-v_{ls}



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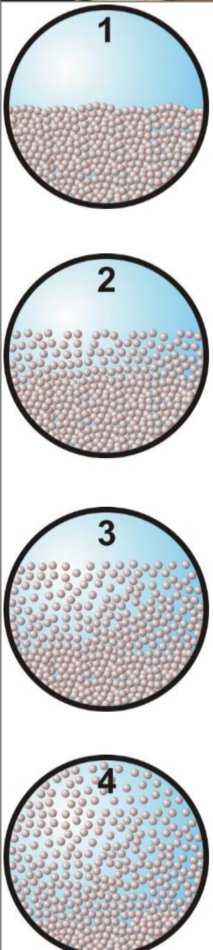
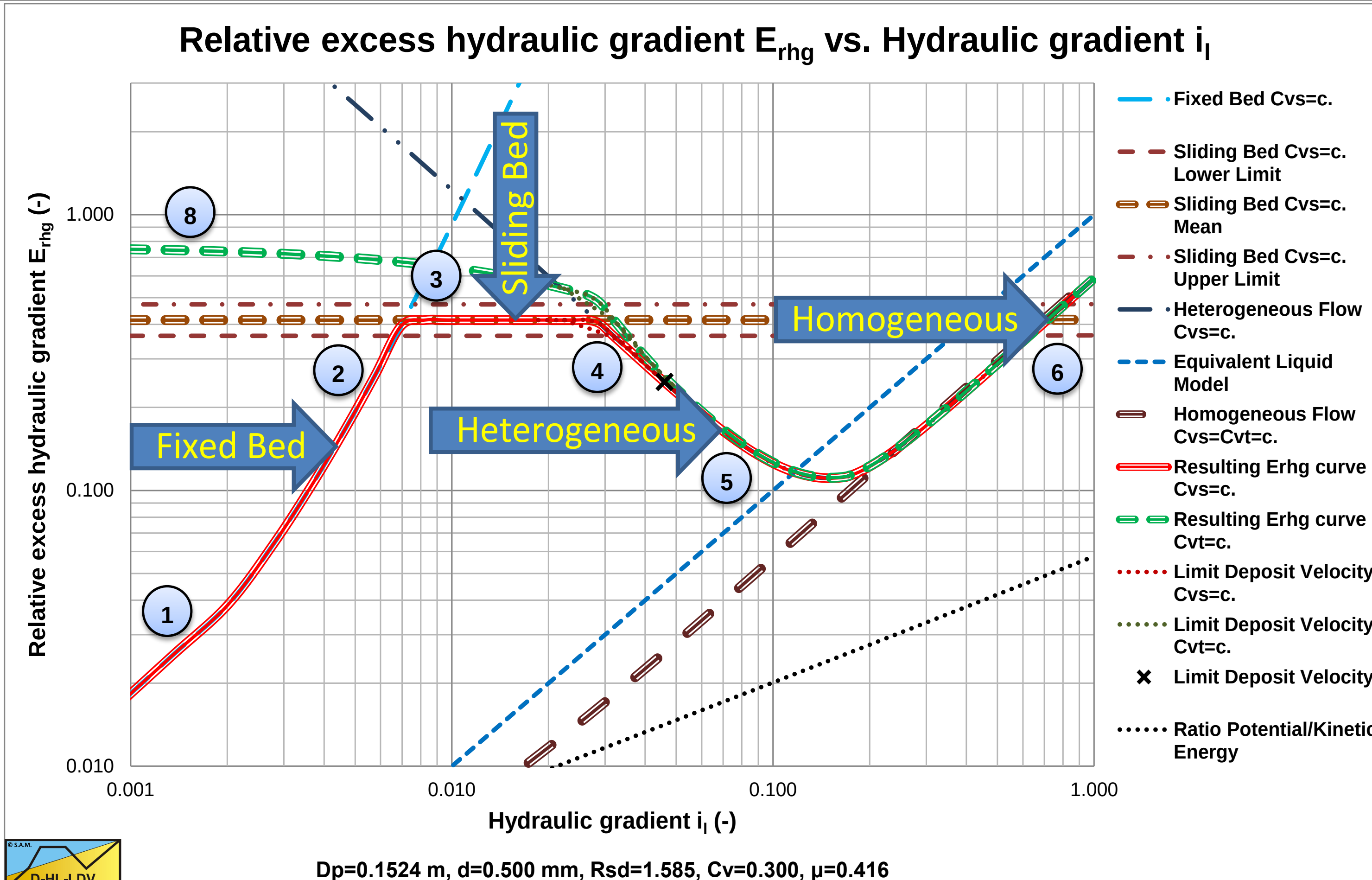
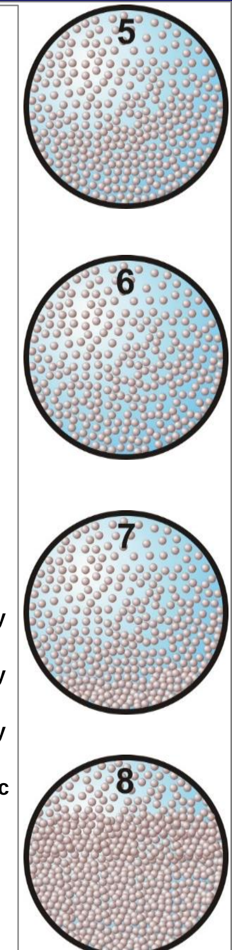
Scenario L2A & R2A, E_{rhg}-i_l







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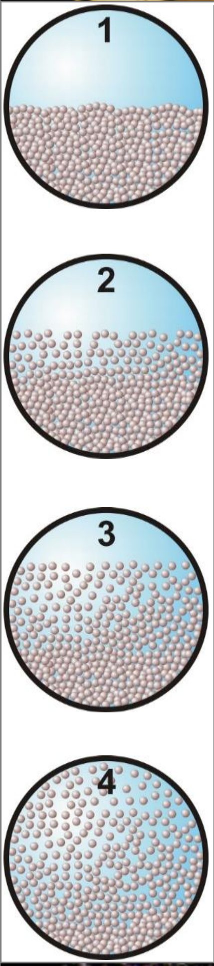
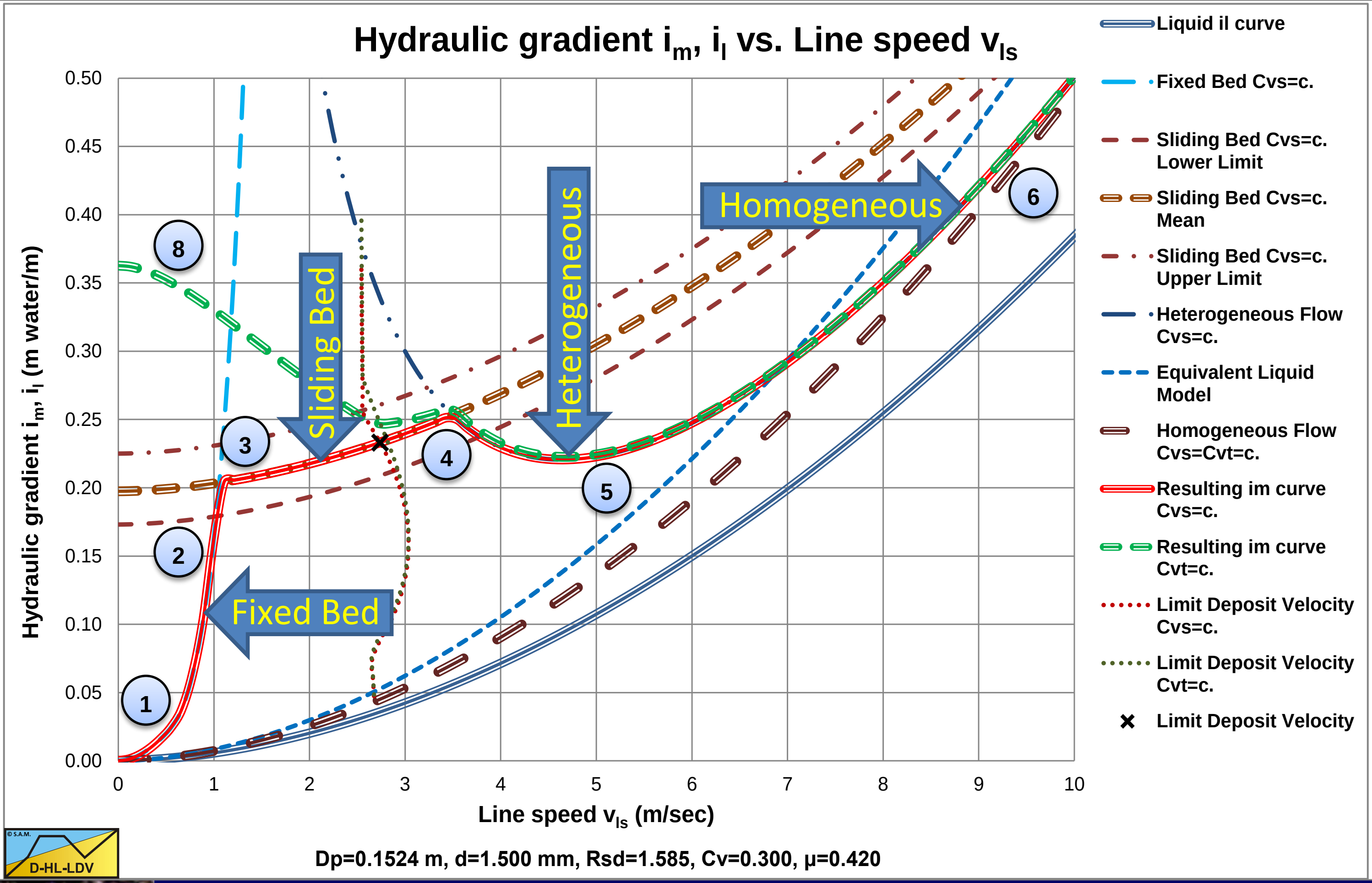
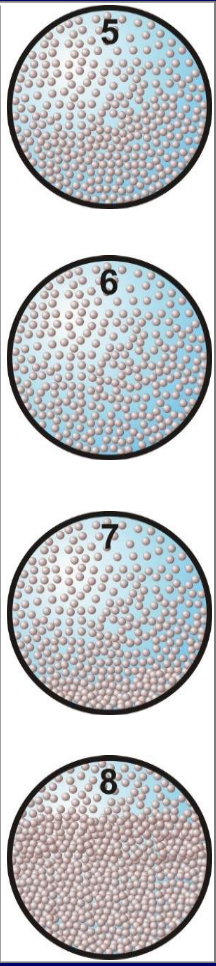
Scenario L2B & R2B, i_m-v_{ls}







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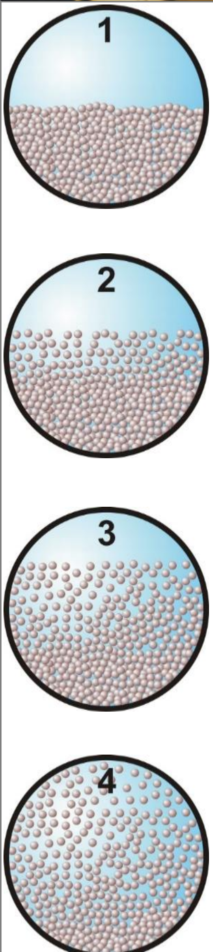
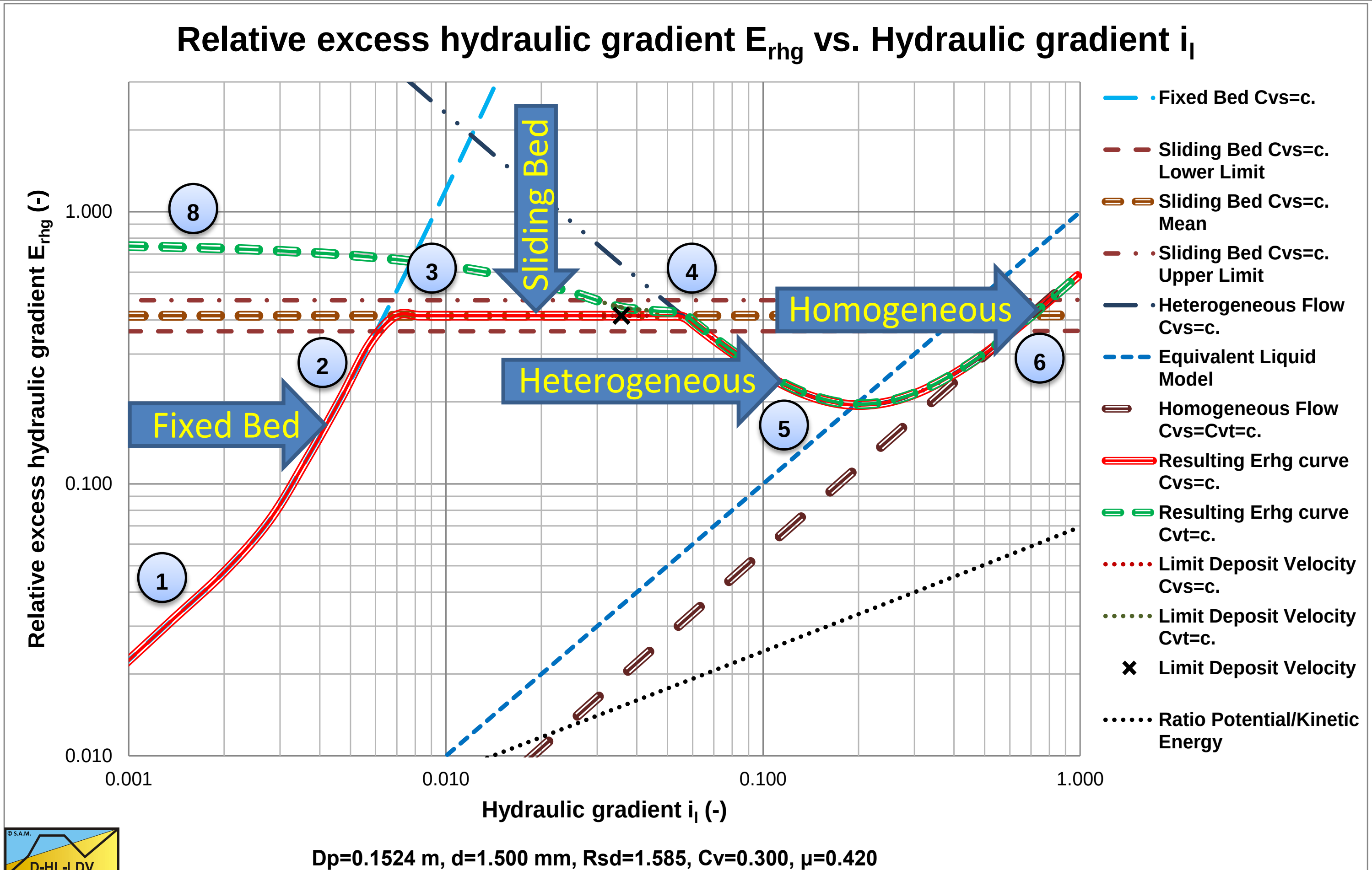
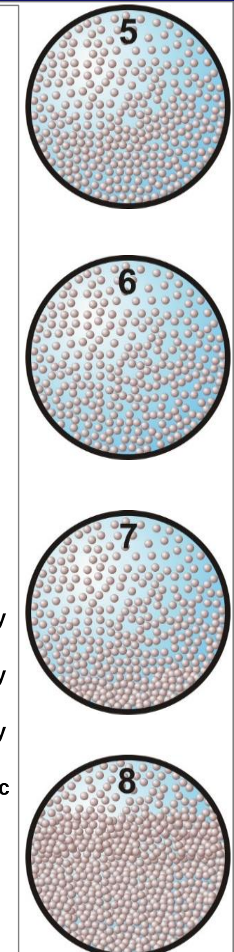
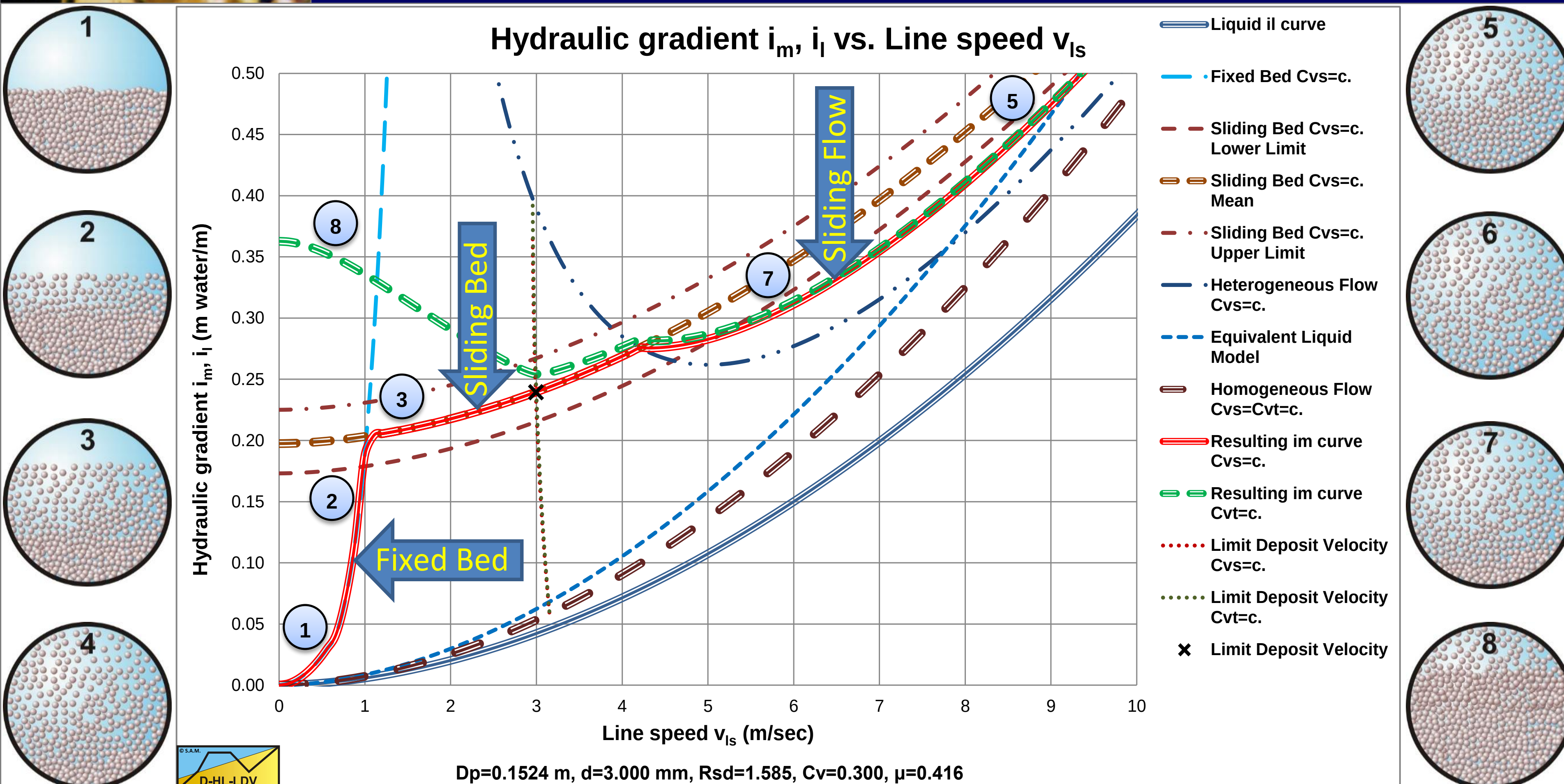
Scenario L2B & R2B, E_{rhg}-i_l



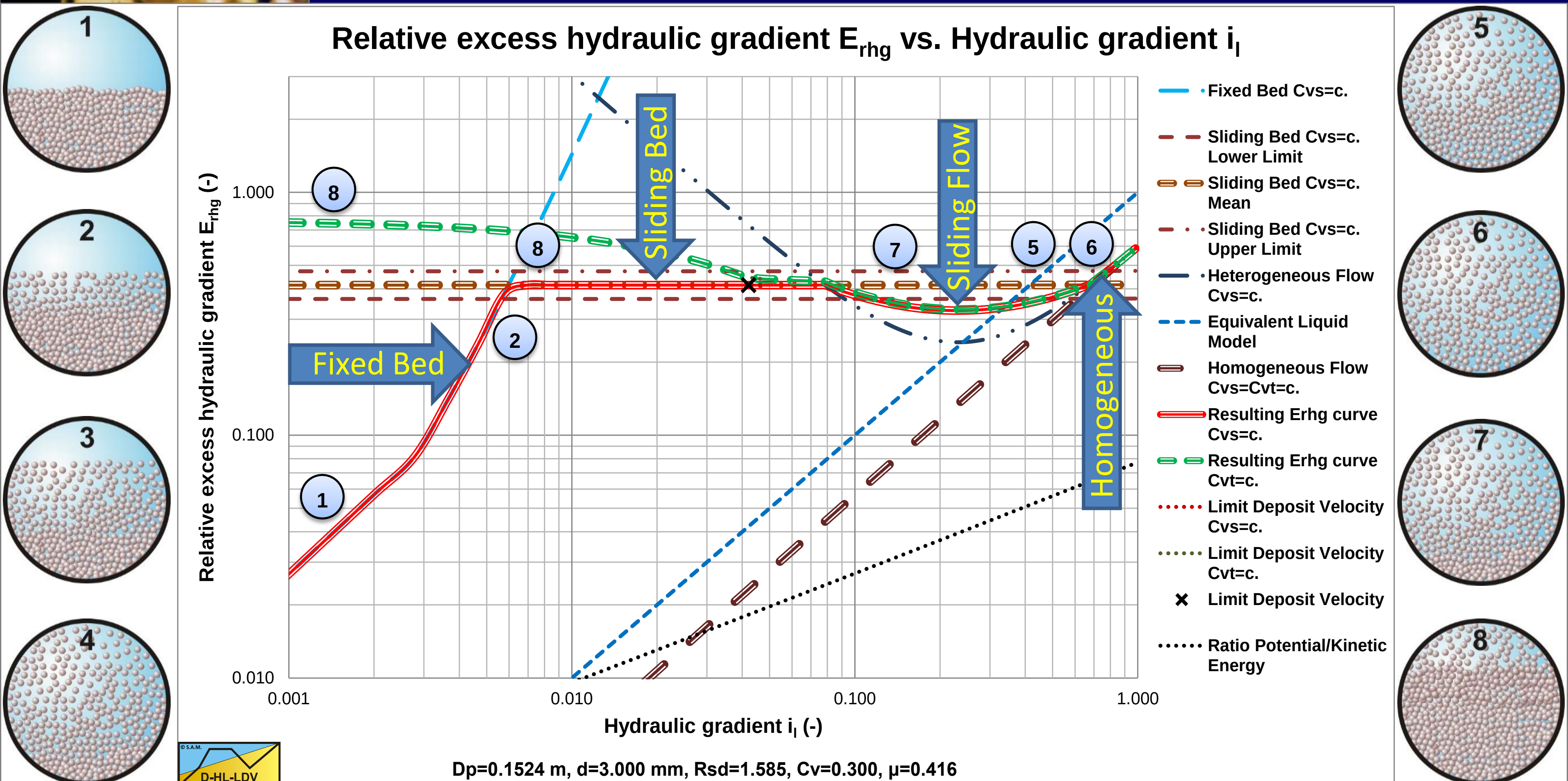


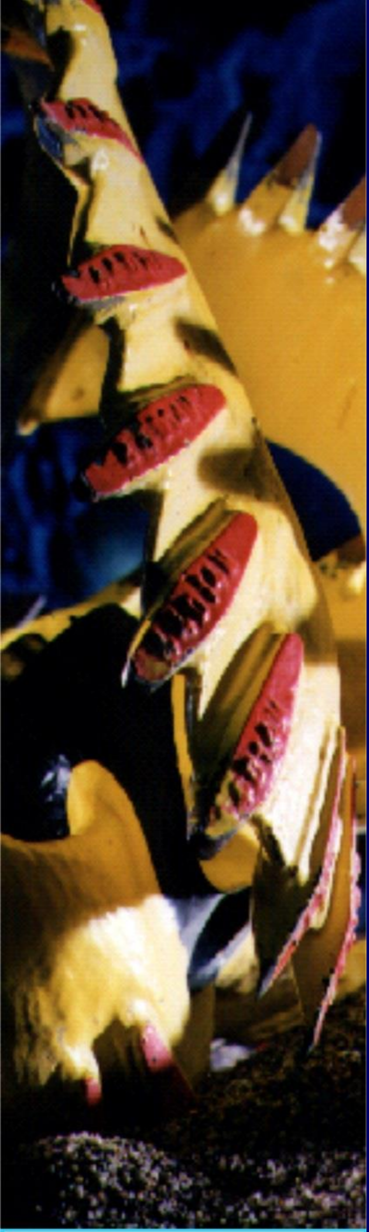


Scenario L3 & R3, i_m-v_{ls}



Scenario L3 & R3, E_{rhg}-i_l

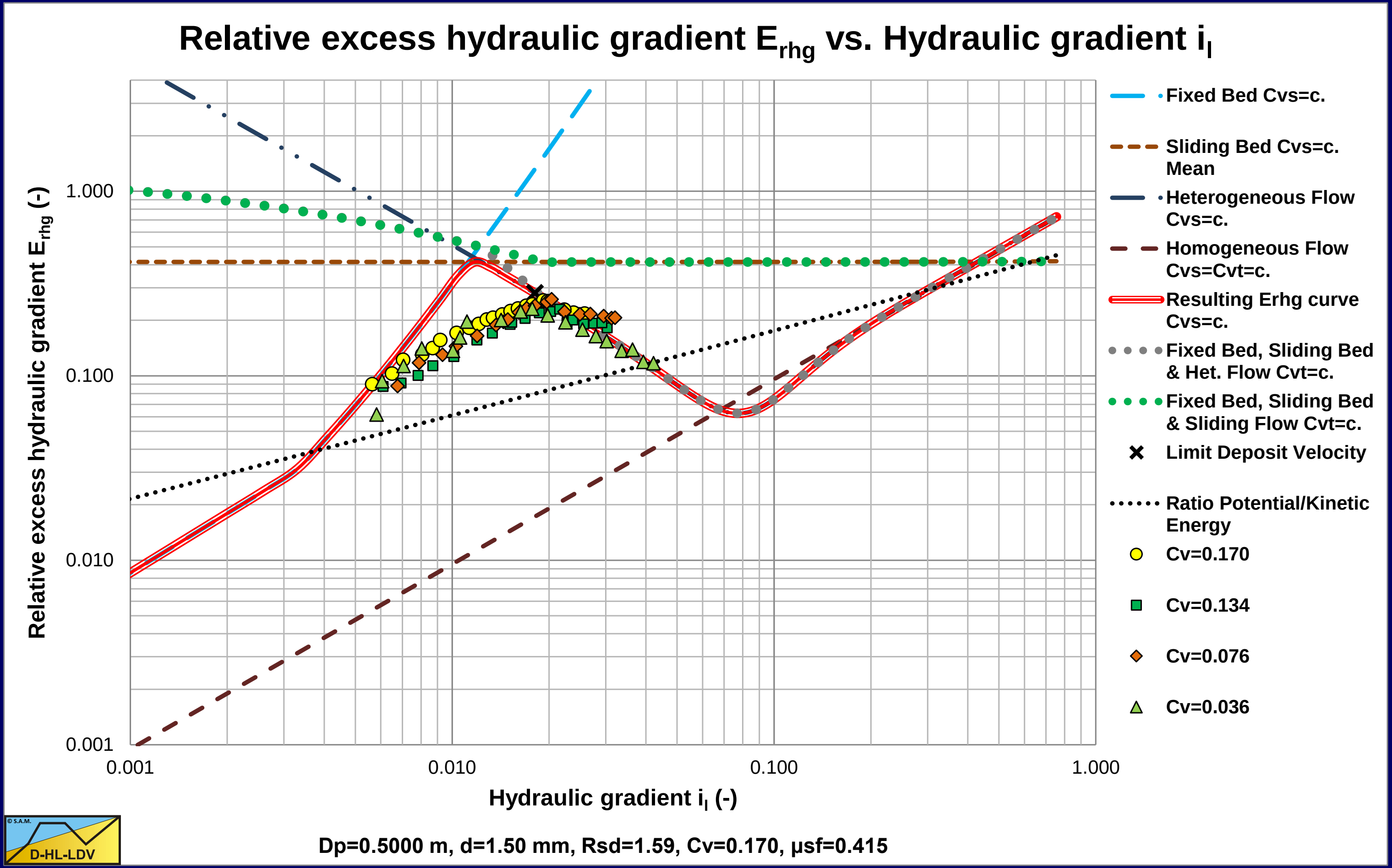




Verification/Validation Experiments

Chapter 7.2

Fixed Bed – Heterogeneous



Kazanskij (1980), C_{vs}=c.

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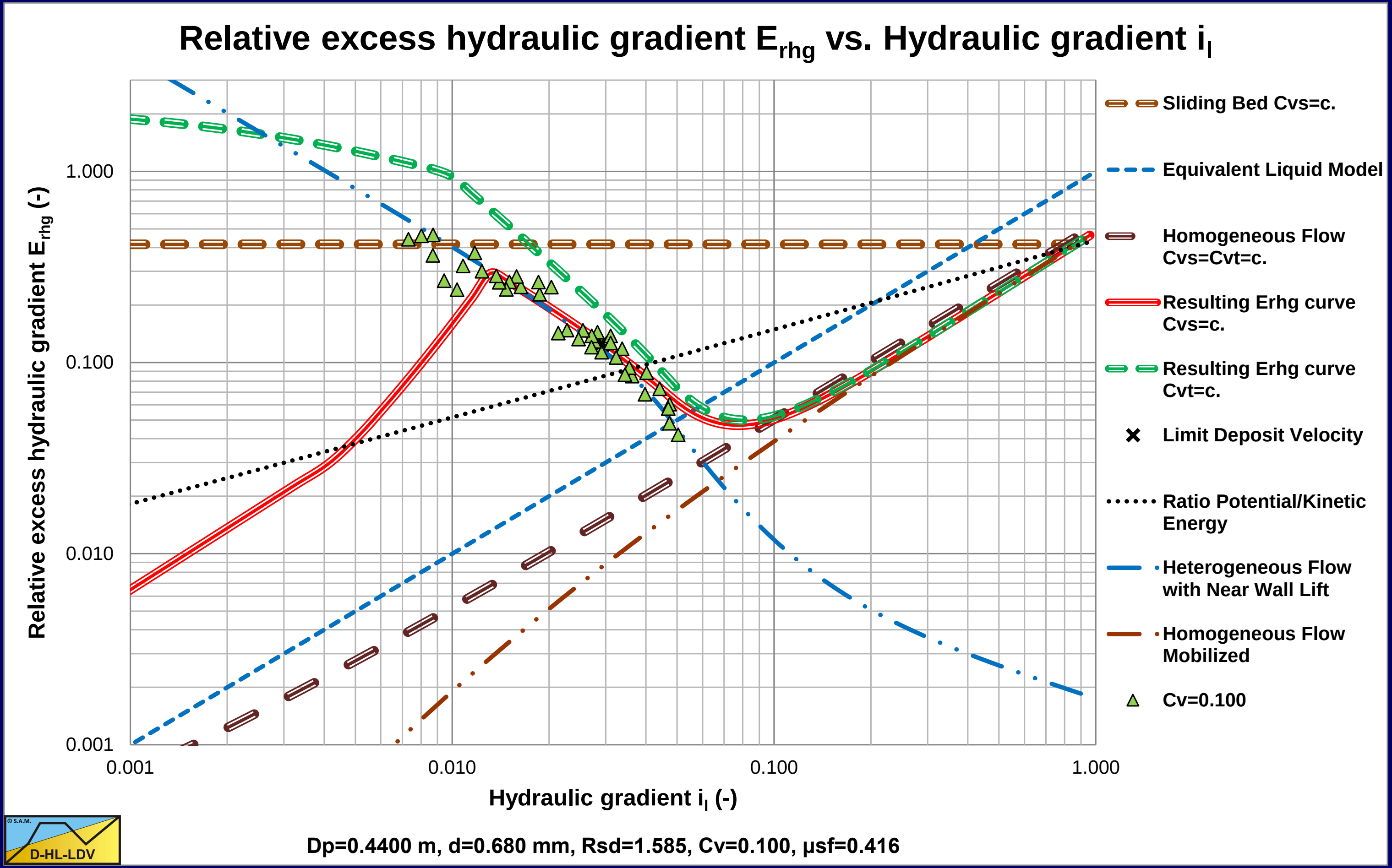
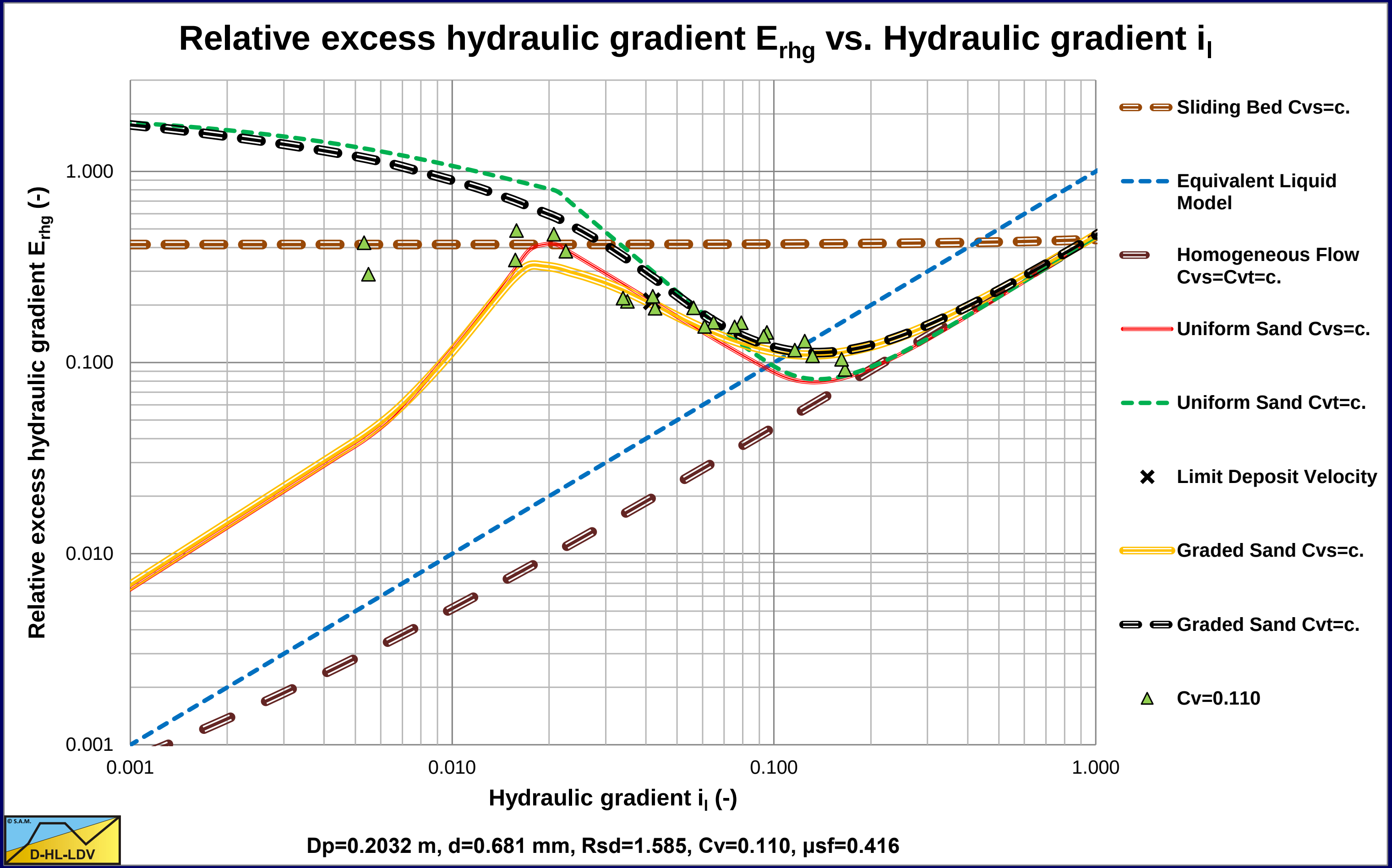
Heterogeneous



Clift (1982), C_{vt}=c.

Heterogeneous



Clift (1982), C_{vt}=c, Broad Graded.

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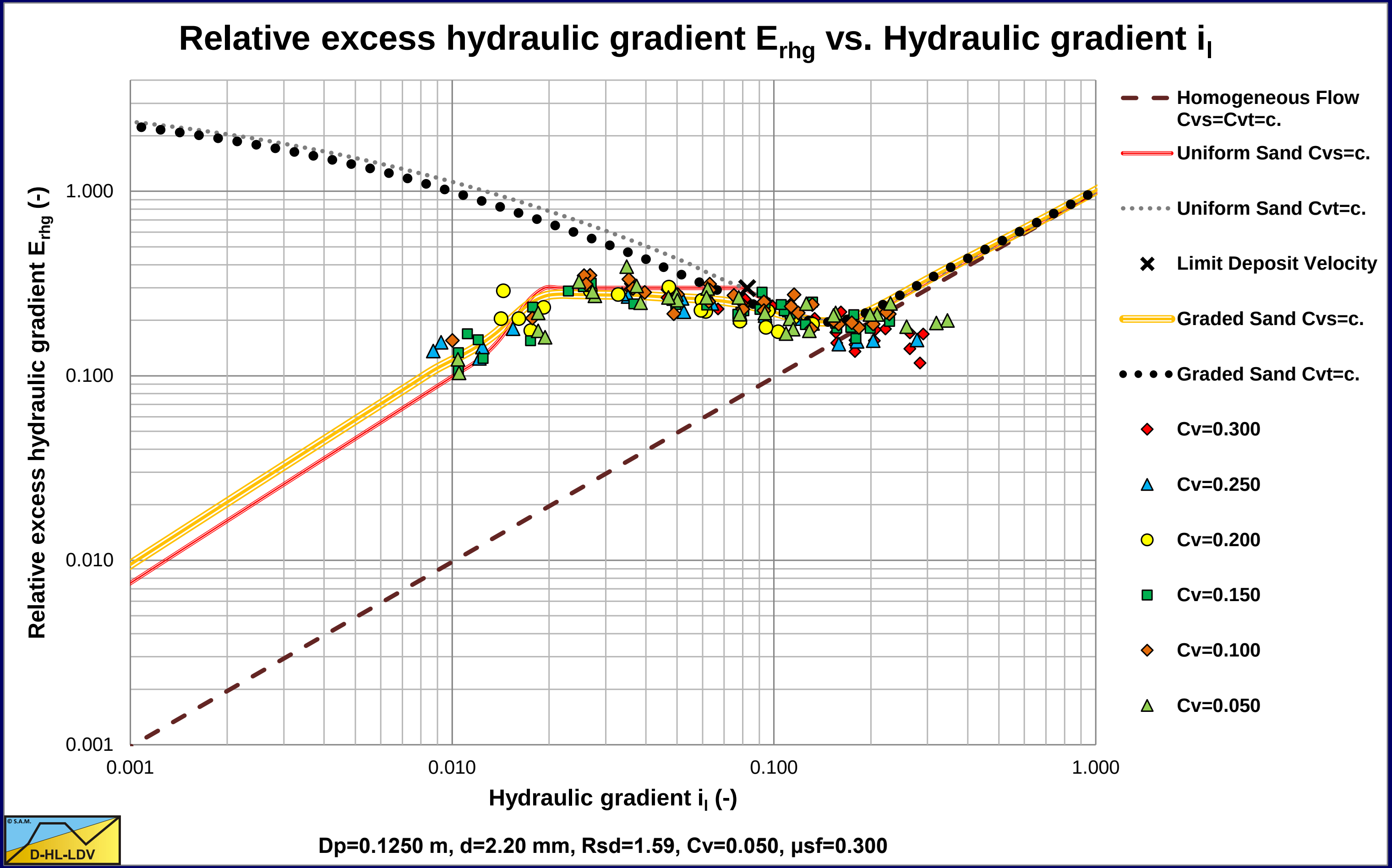
Fixed Bed - Sliding Bed - Heterogeneous



Wiedenroth (1967), C_{vs}=c., Coarse Sand

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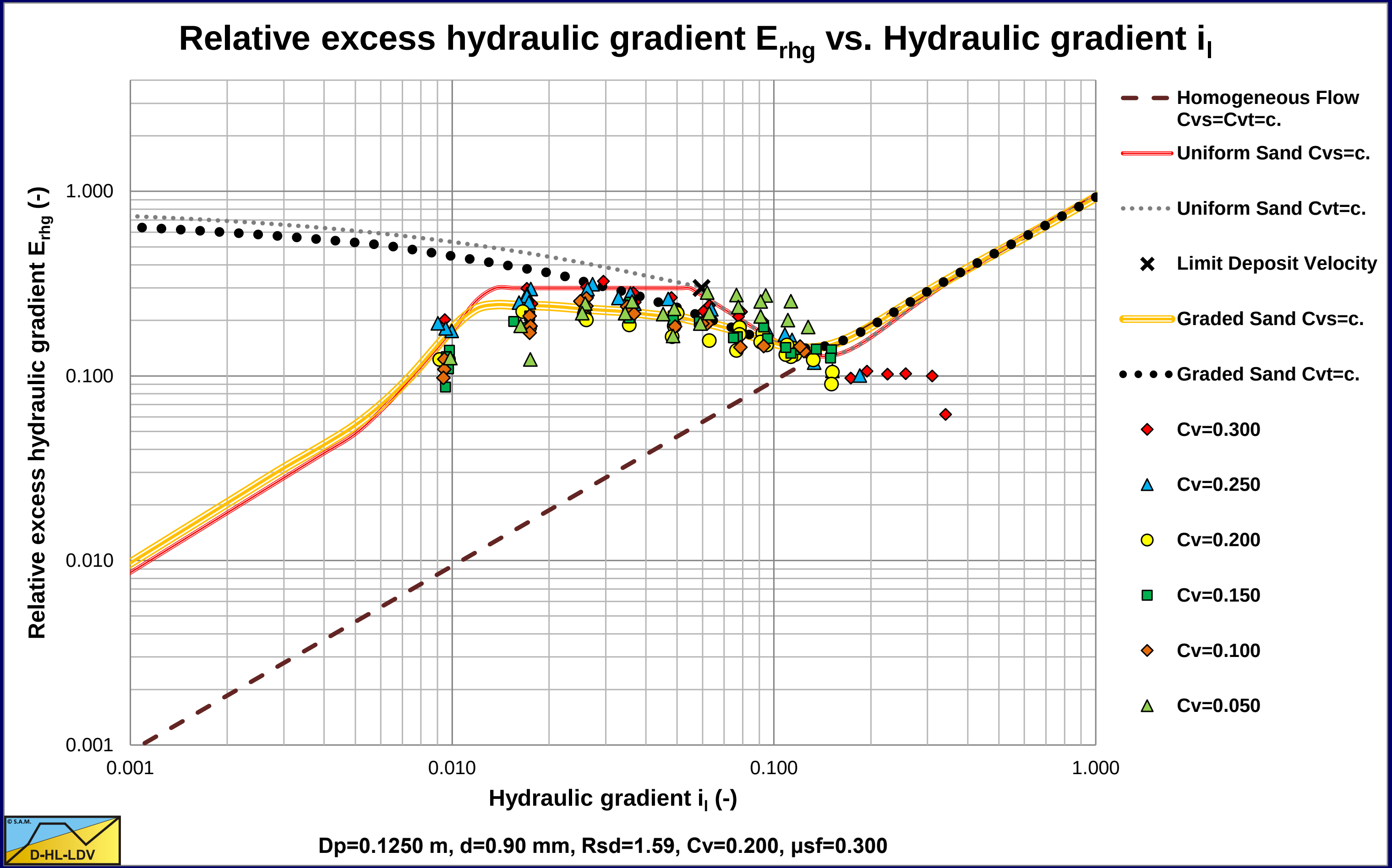
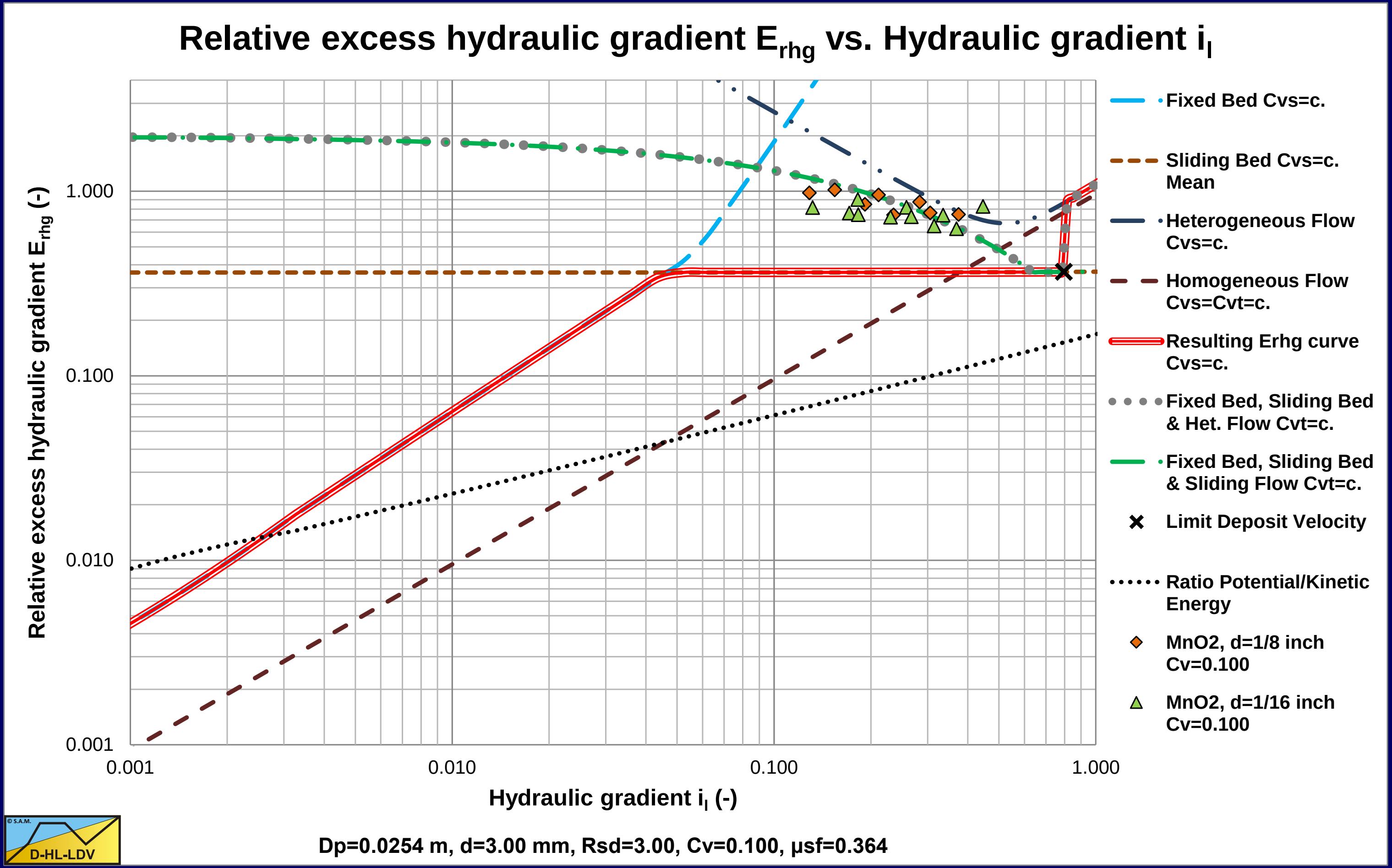
Fixed Bed - Sliding Bed - Heterogeneous



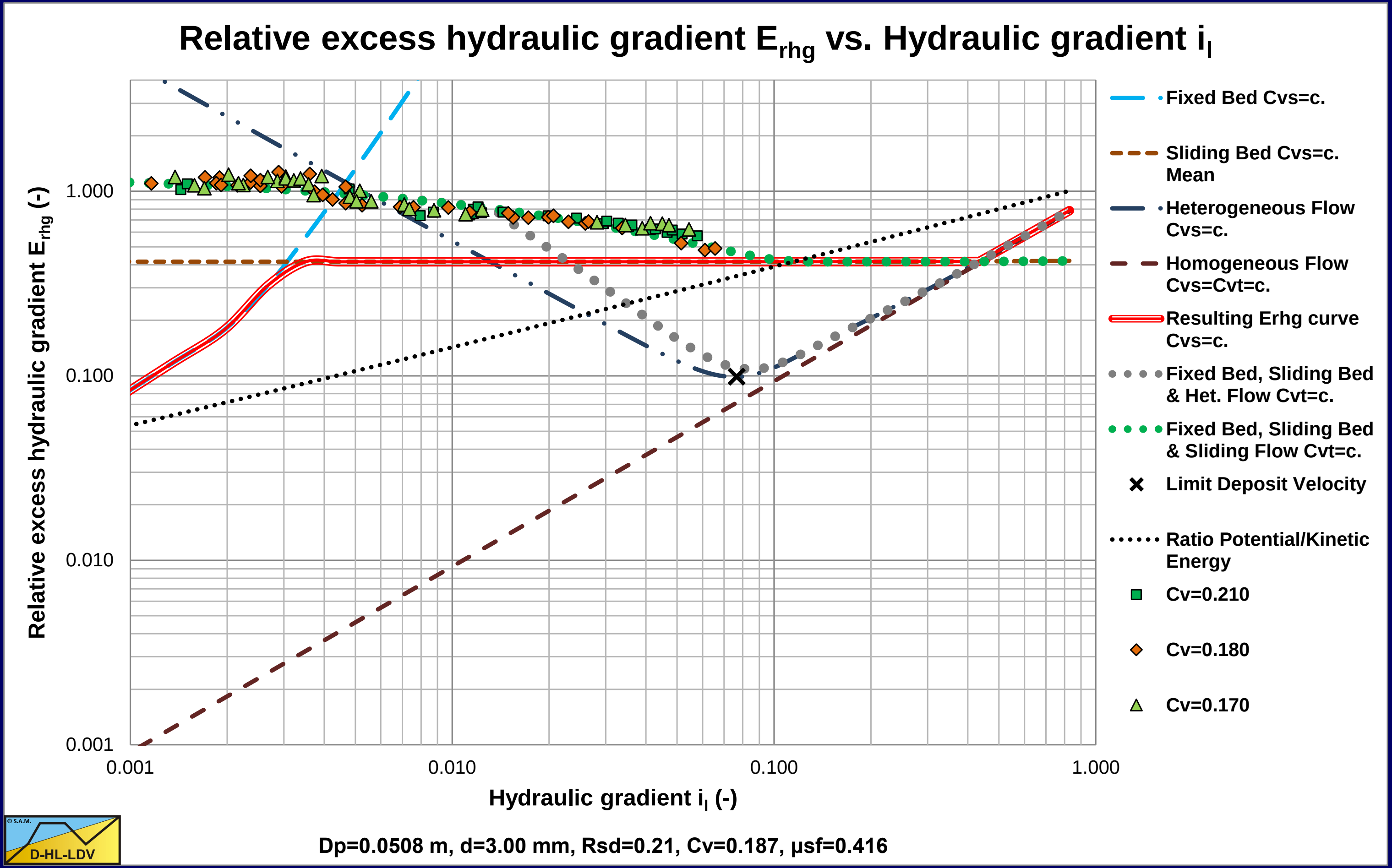
Wiedenroth (1967), C_{vs}=c., Medium Sand

Sliding Bed



Newitt et al. (1955), C_{vt}=c., MnO2

Sliding Bed, Sliding Flow



Doron & Barnea (1993), C_{vt}=c., Acetal

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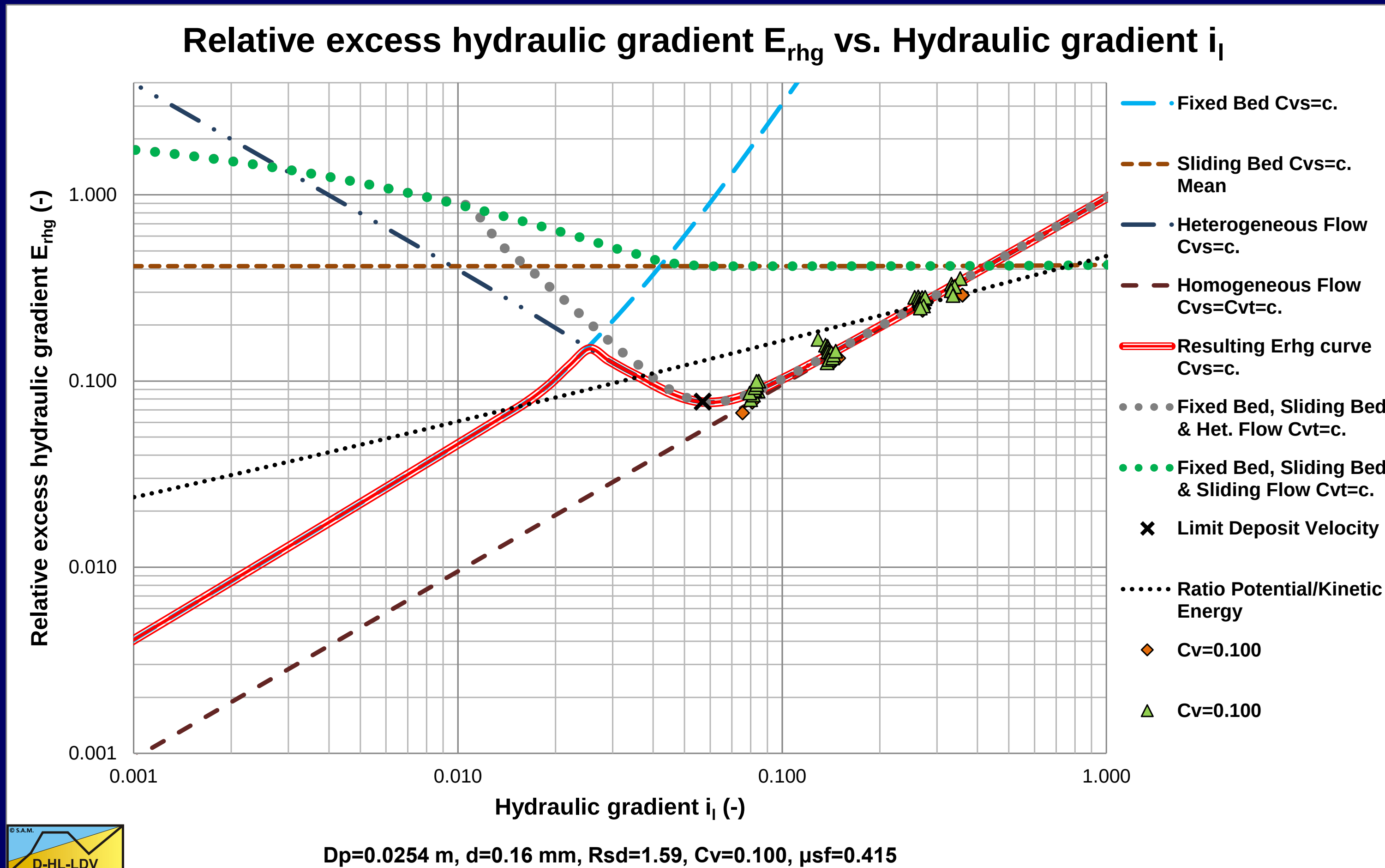
Homogeneous



Babcock (1970)

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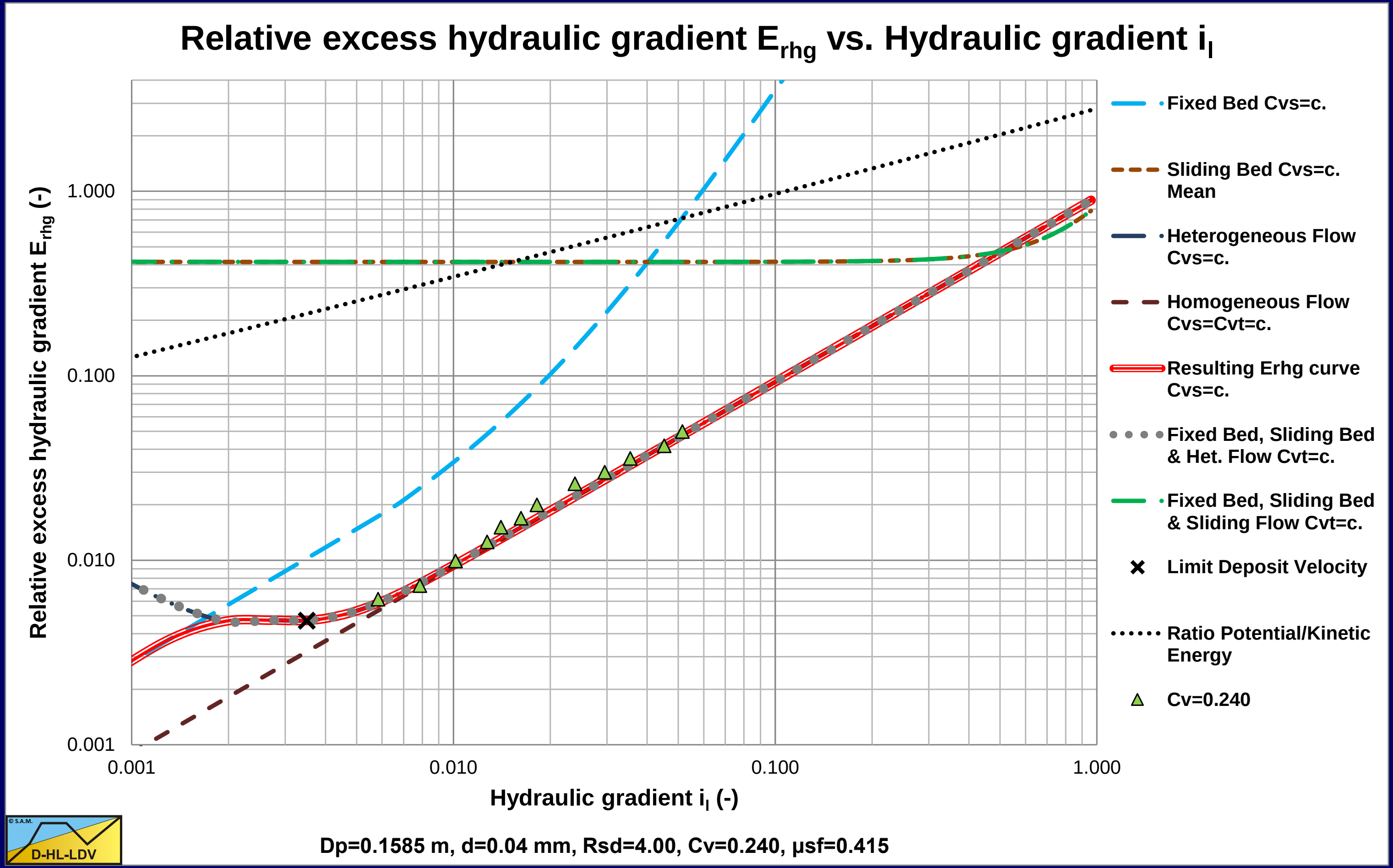
Homogeneous



Thomas (1976), Iron Ore

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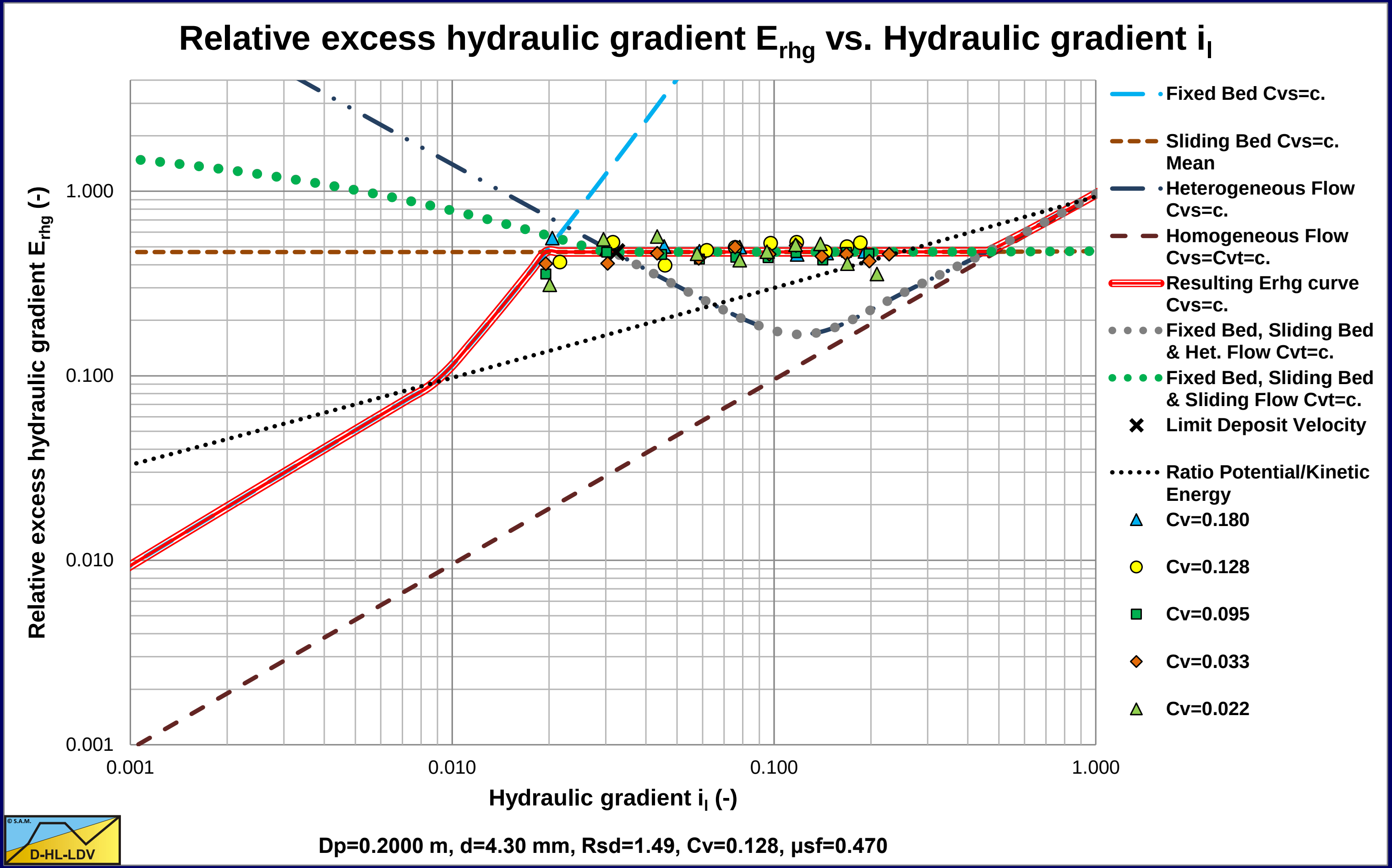
Fixed Bed – Sliding Bed – Sliding Flow



Boothroyde (1979), C_{vs}=c.

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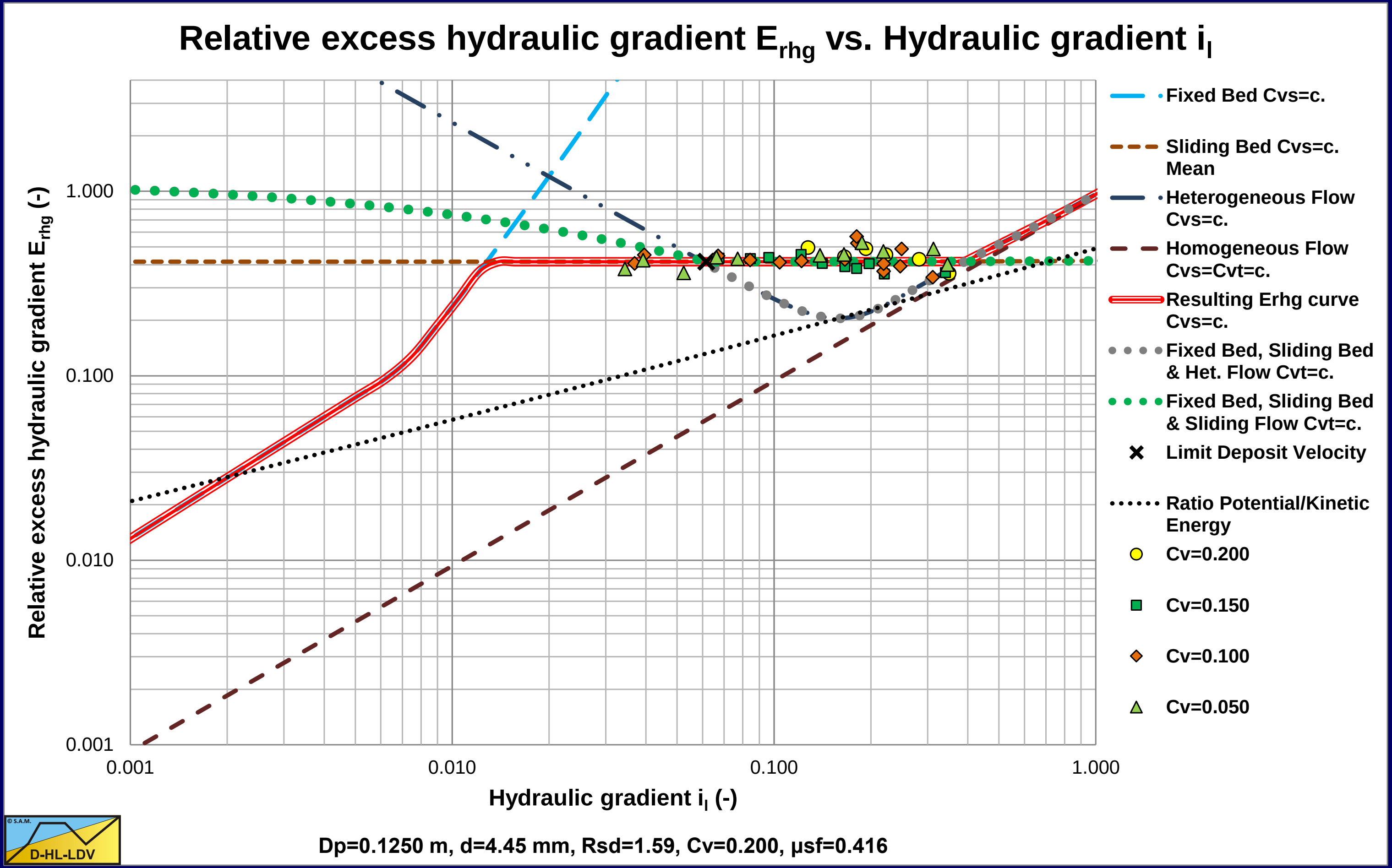
Fixed Bed – Sliding Bed – Sliding Flow



Wiedenroth (1967), C_{vs}=c., Gravel

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Transition Line Speed
Heterogeneous – Homogeneous

Chapter 9

The Transition Line Speed Heterogeneous-Homogeneous

Problem definition:

For slurry transport in general and specifically in dredging, there are many models. But how to decide which model to use in which situation, or, when are specific models valid especially in the heterogeneous flow regime.

Solution:

The transition line speed of the heterogeneous flow regime with the homogeneous flow regime is a good indicator and limits the number of graphs.

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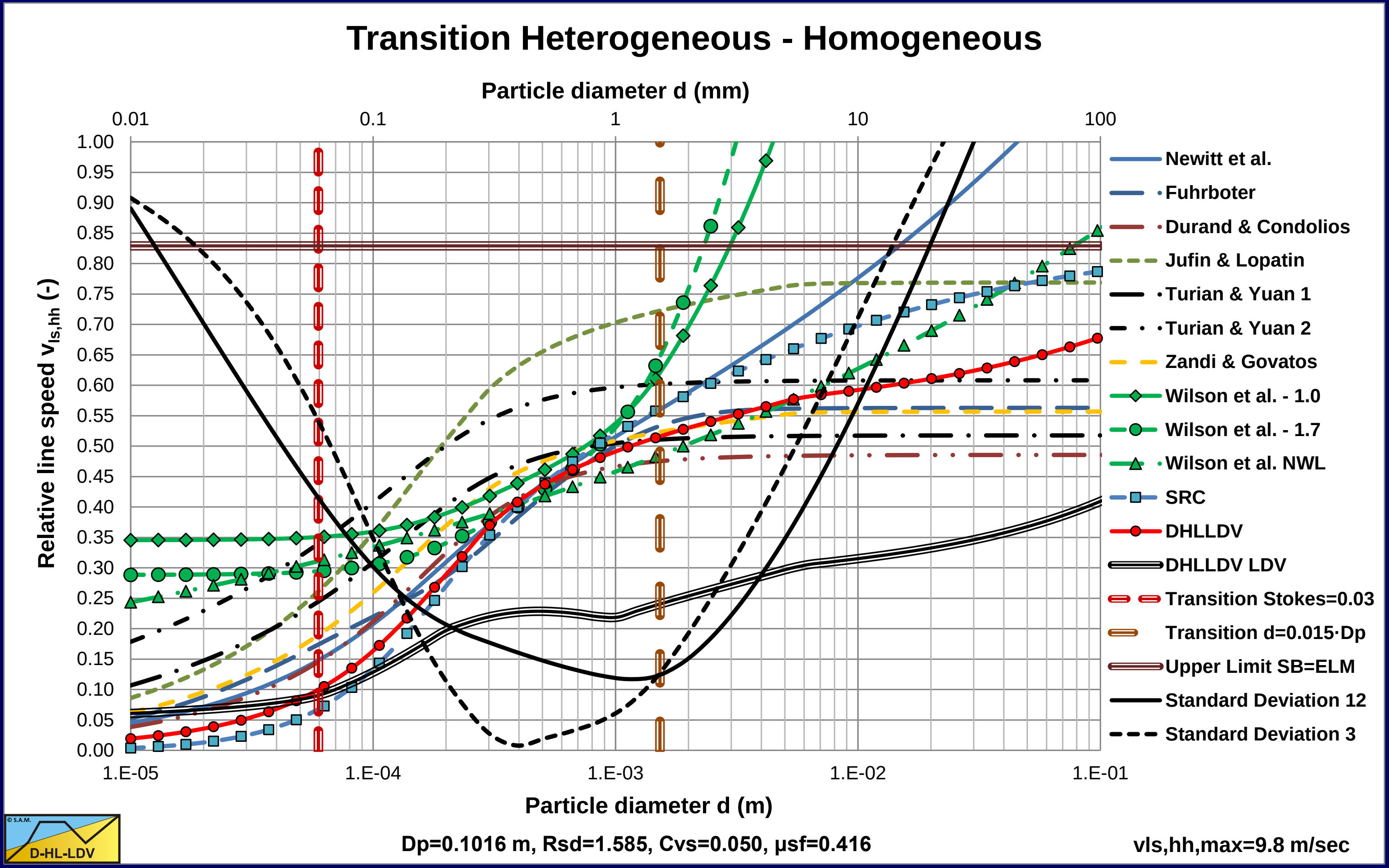
Relative Transition Line Speed D_p=0.1016 m, C_{vs}=0.05



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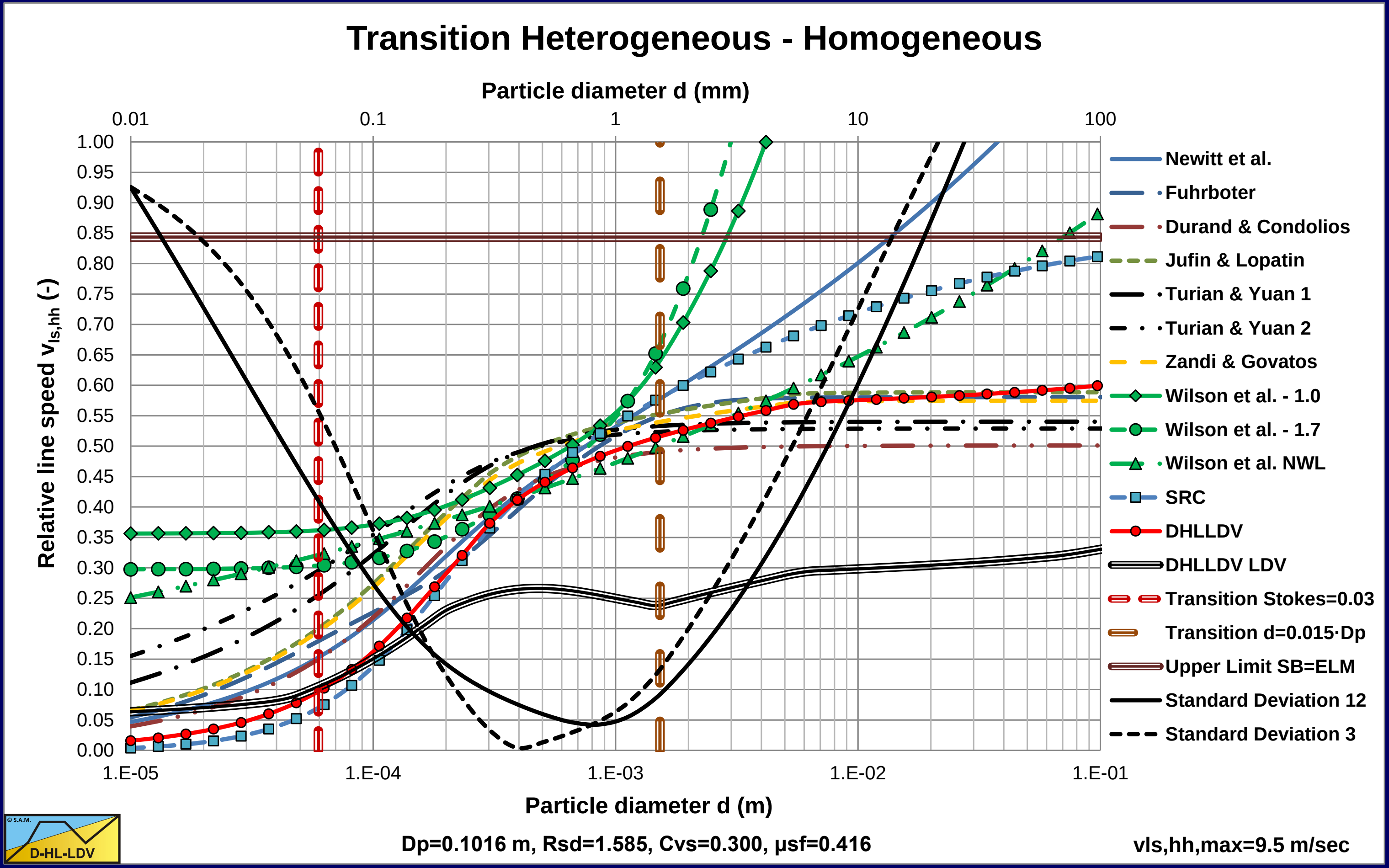
Relative Transition Line Speed
D_p=0.1016 m, C_{vs}=0.30



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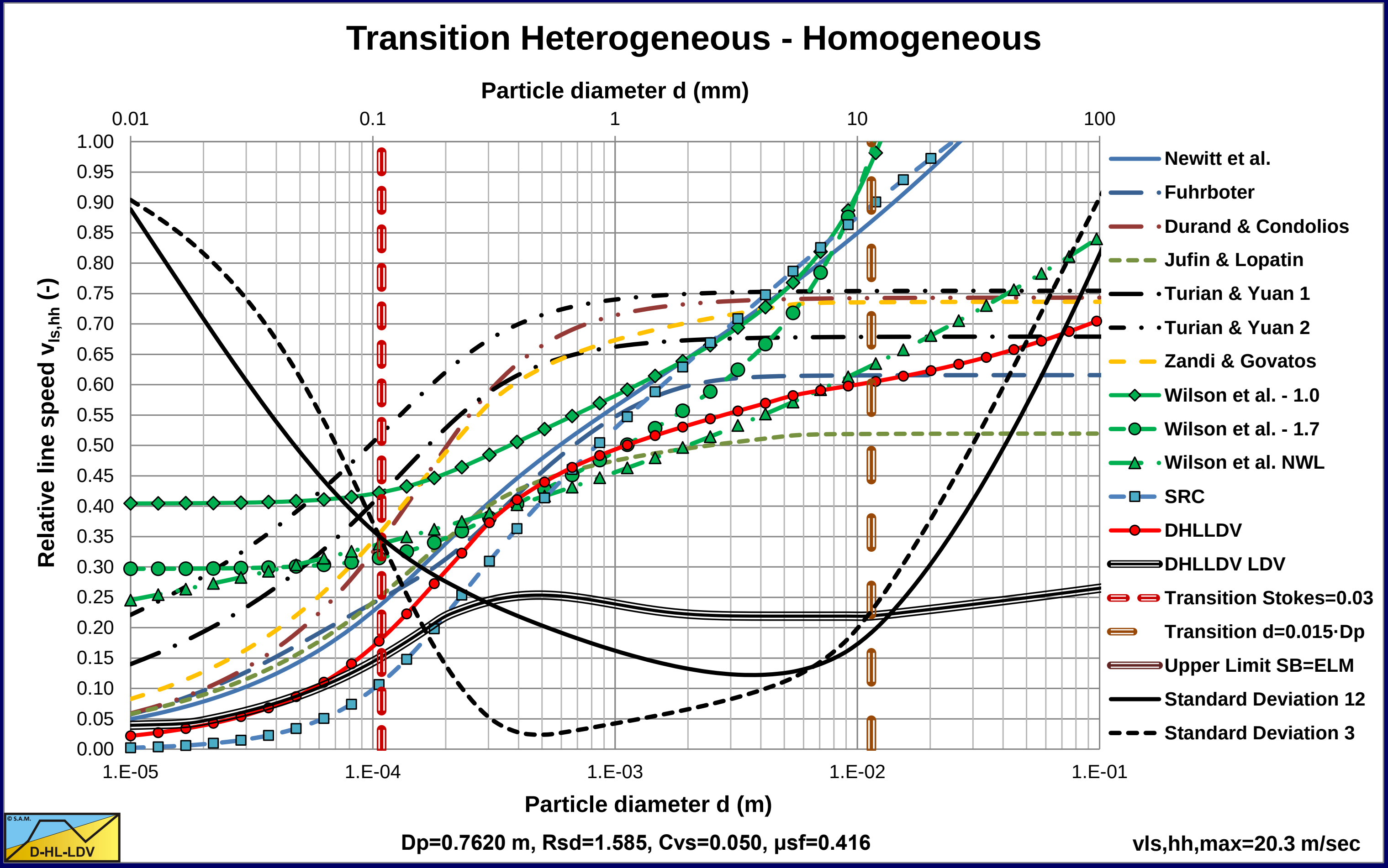
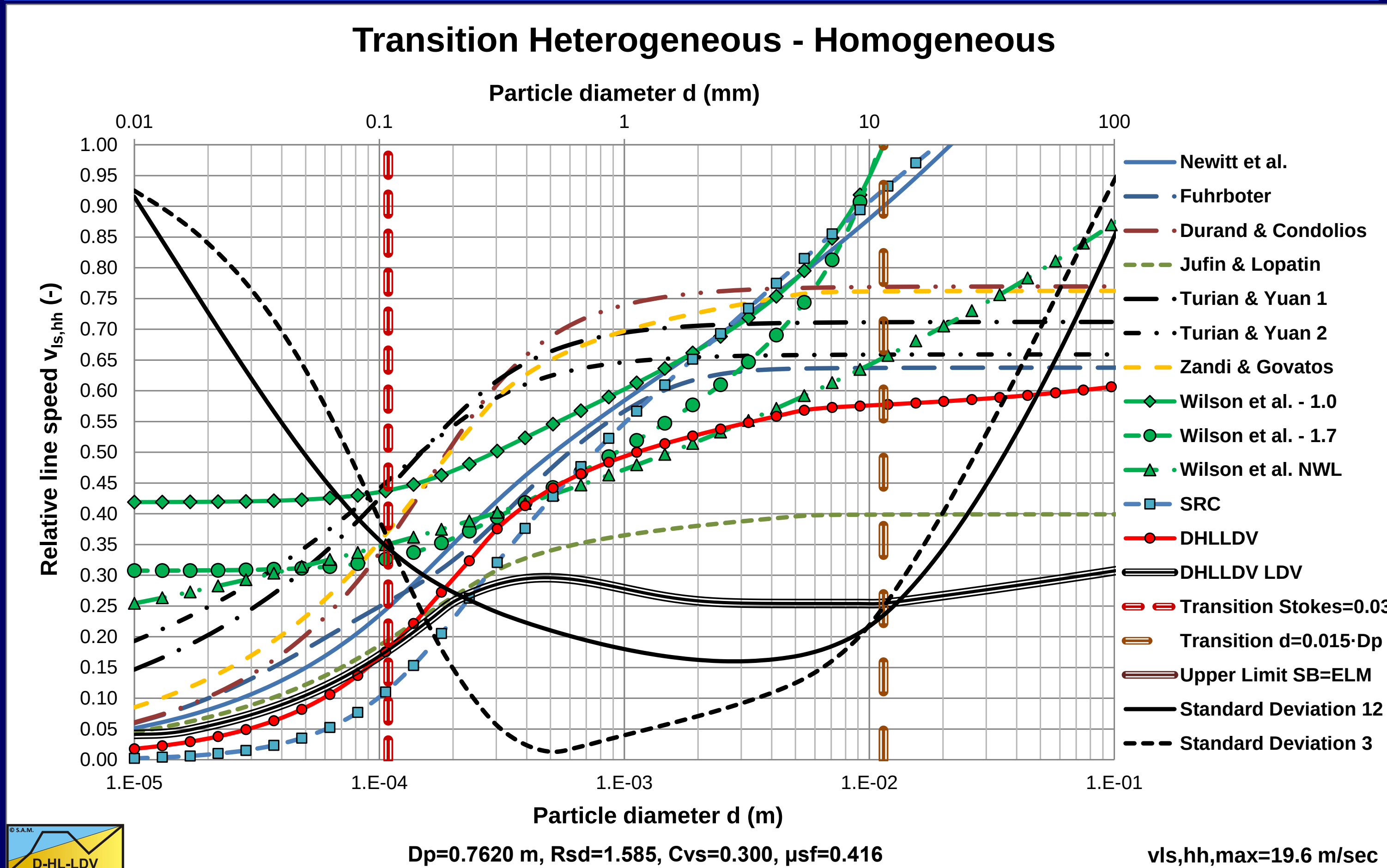
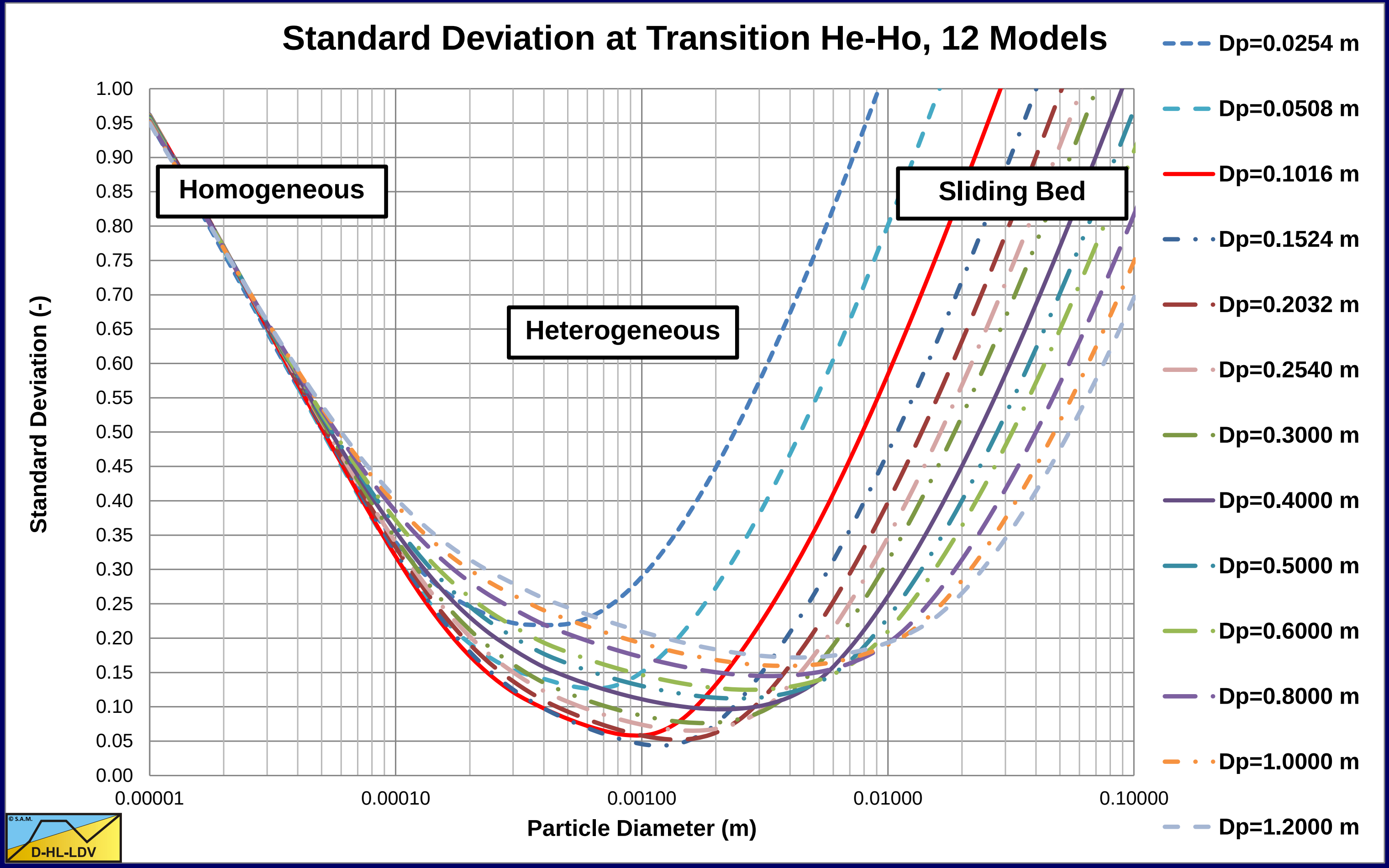
Relative Transition Line Speed
D_p=0.7620 m, C_{vs}=0.05



Relative Transition Line Speed
D_p=0.7620 m, C_{vs}=0.30



Standard Deviation 12 Models



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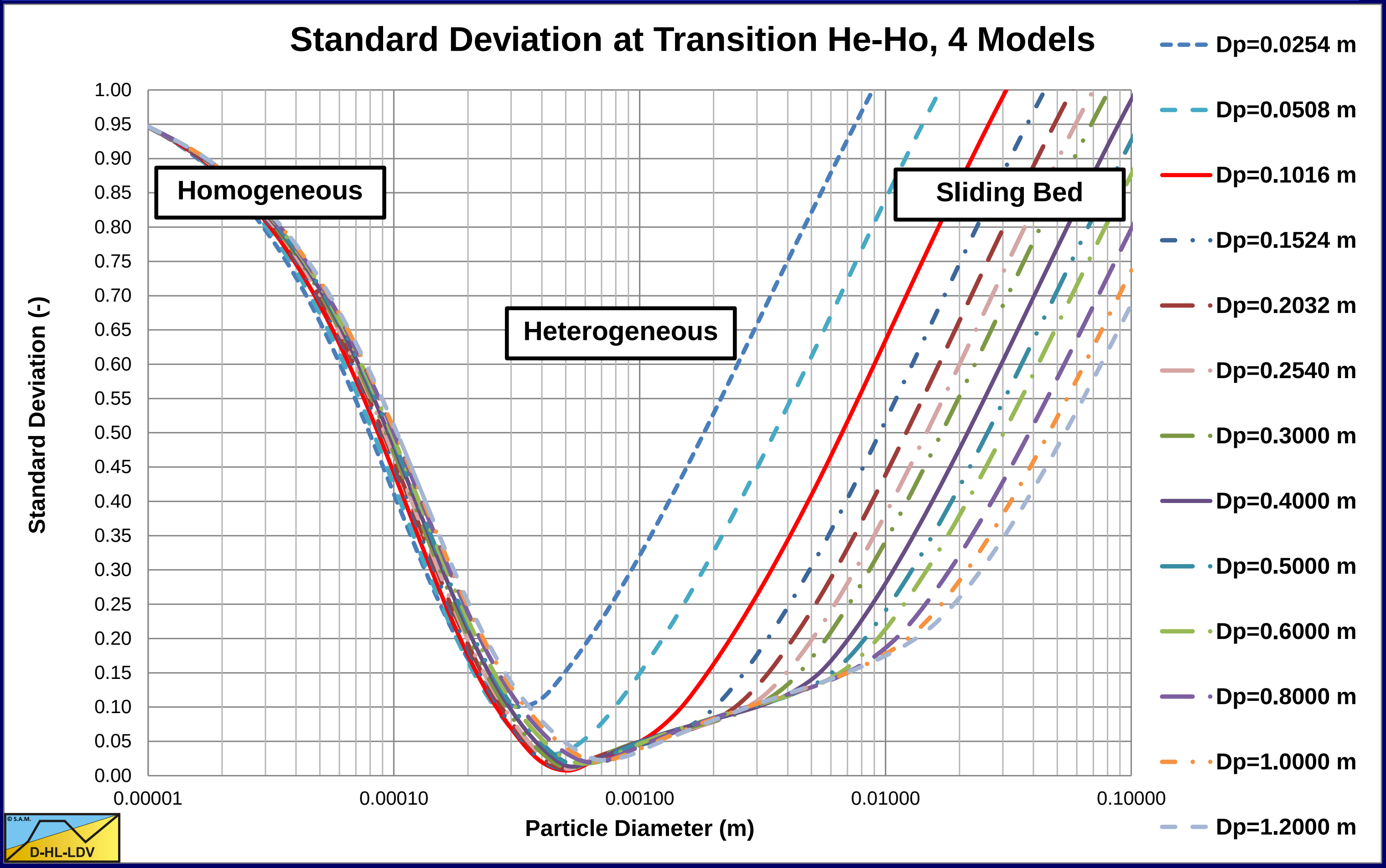
Standard Deviation DHLLDV-Wilson/SRC



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Flow Regime Diagrams

Chapter 7.8 & Appendix D

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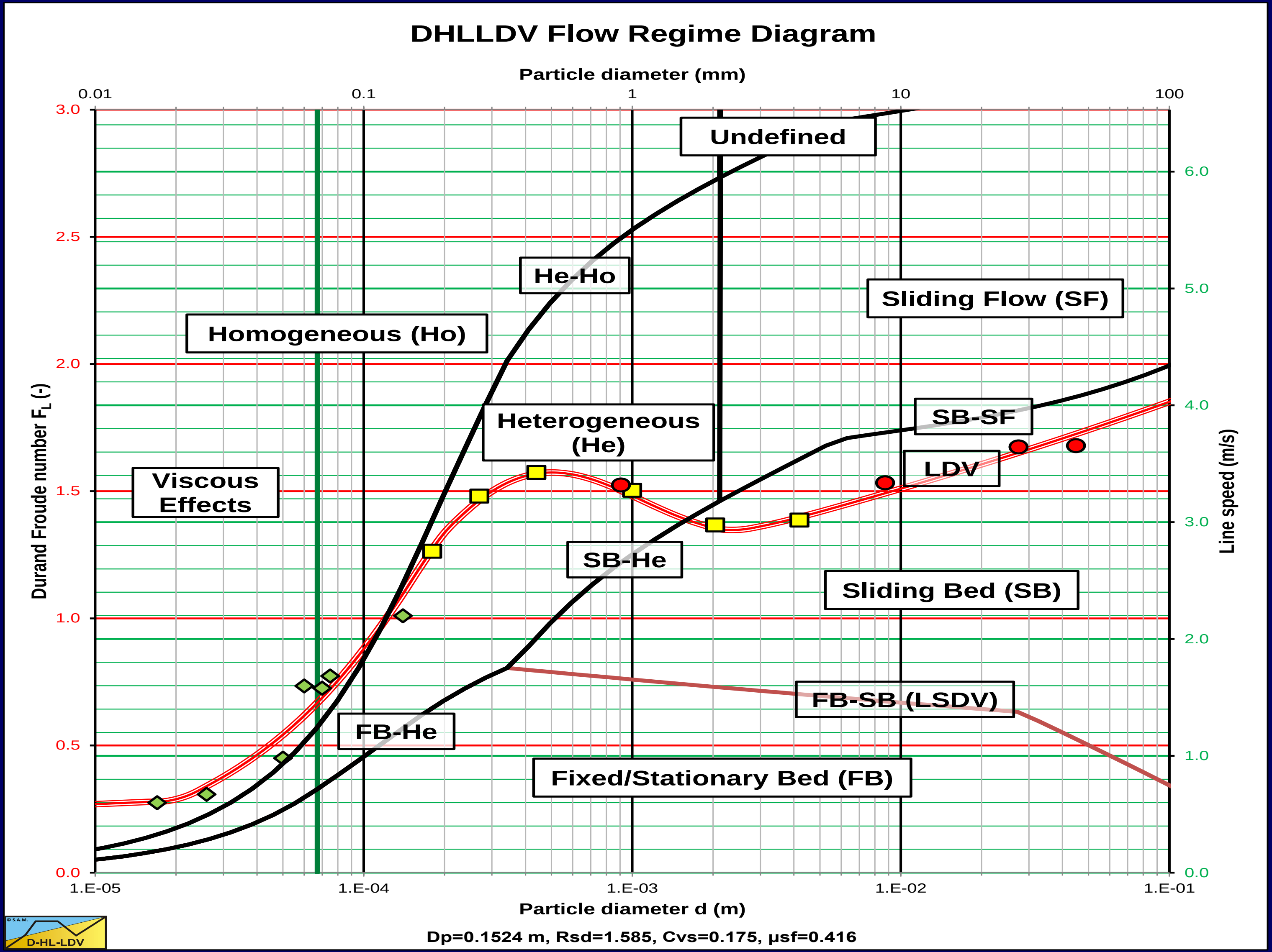
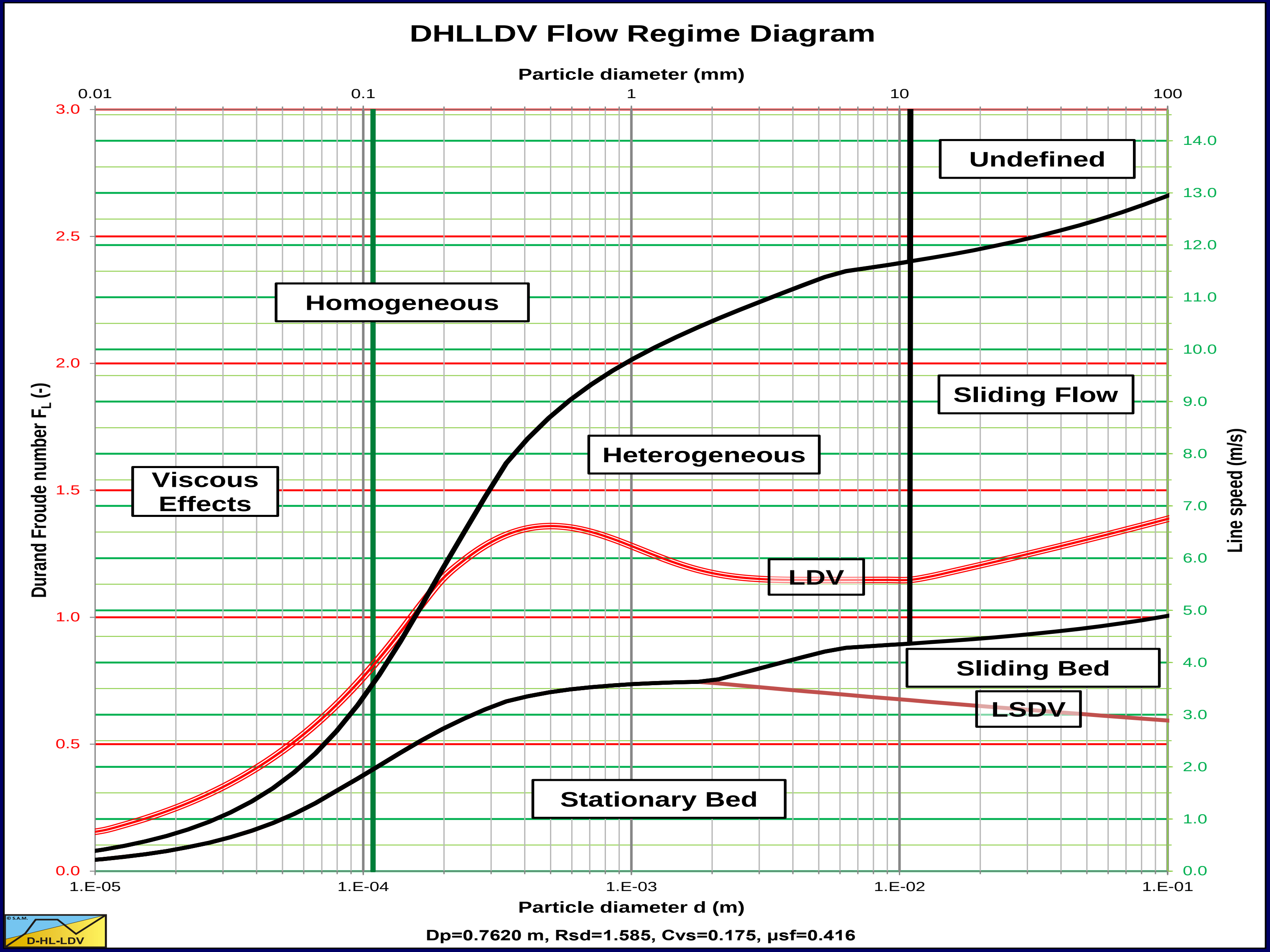
Small Pipe Diameter, C_{vs}=0.175



A Large Diameter Pipe, C_{vs}=0.175



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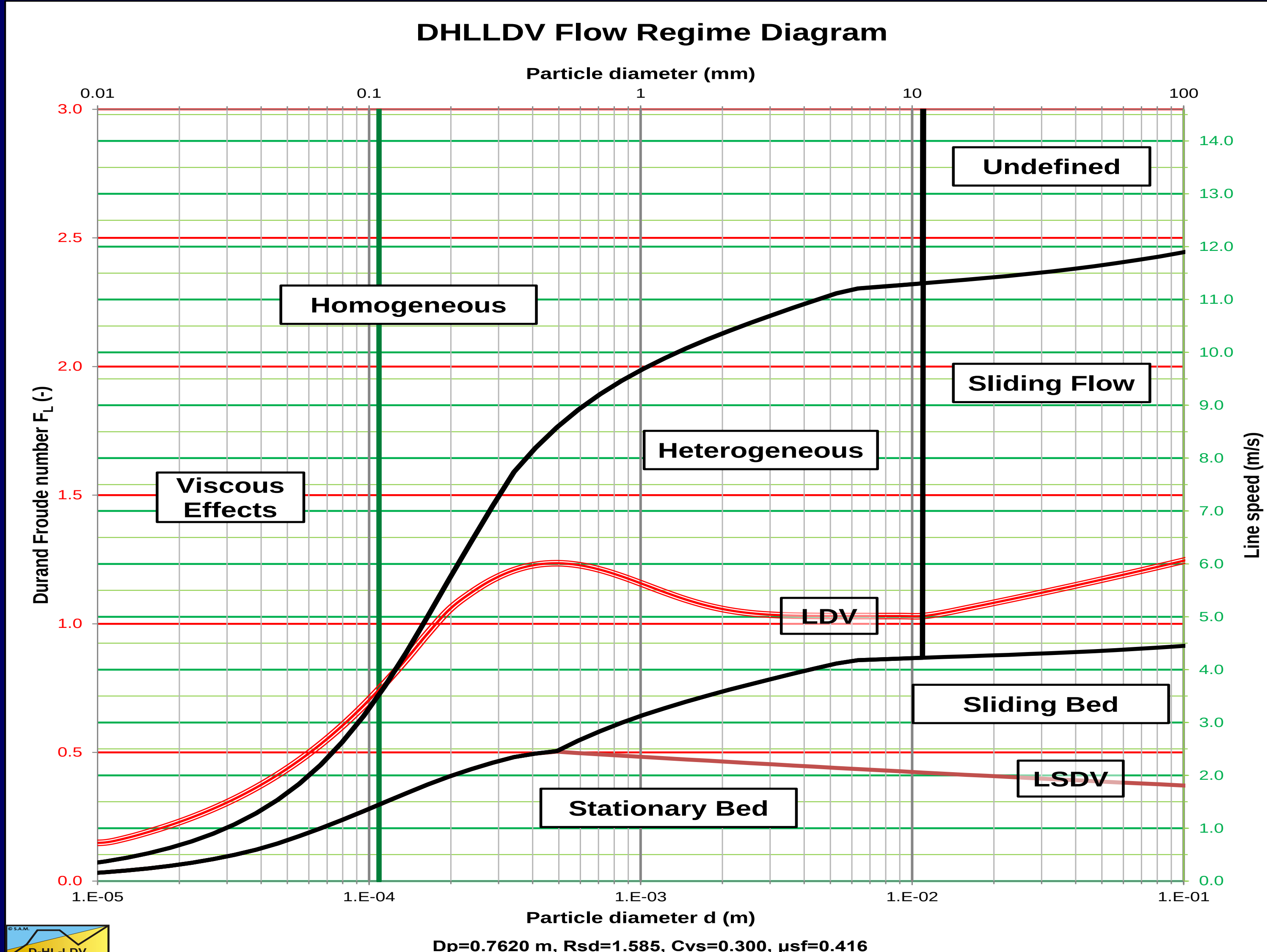
A Large Diameter Pipe, C_{vs}=0.3



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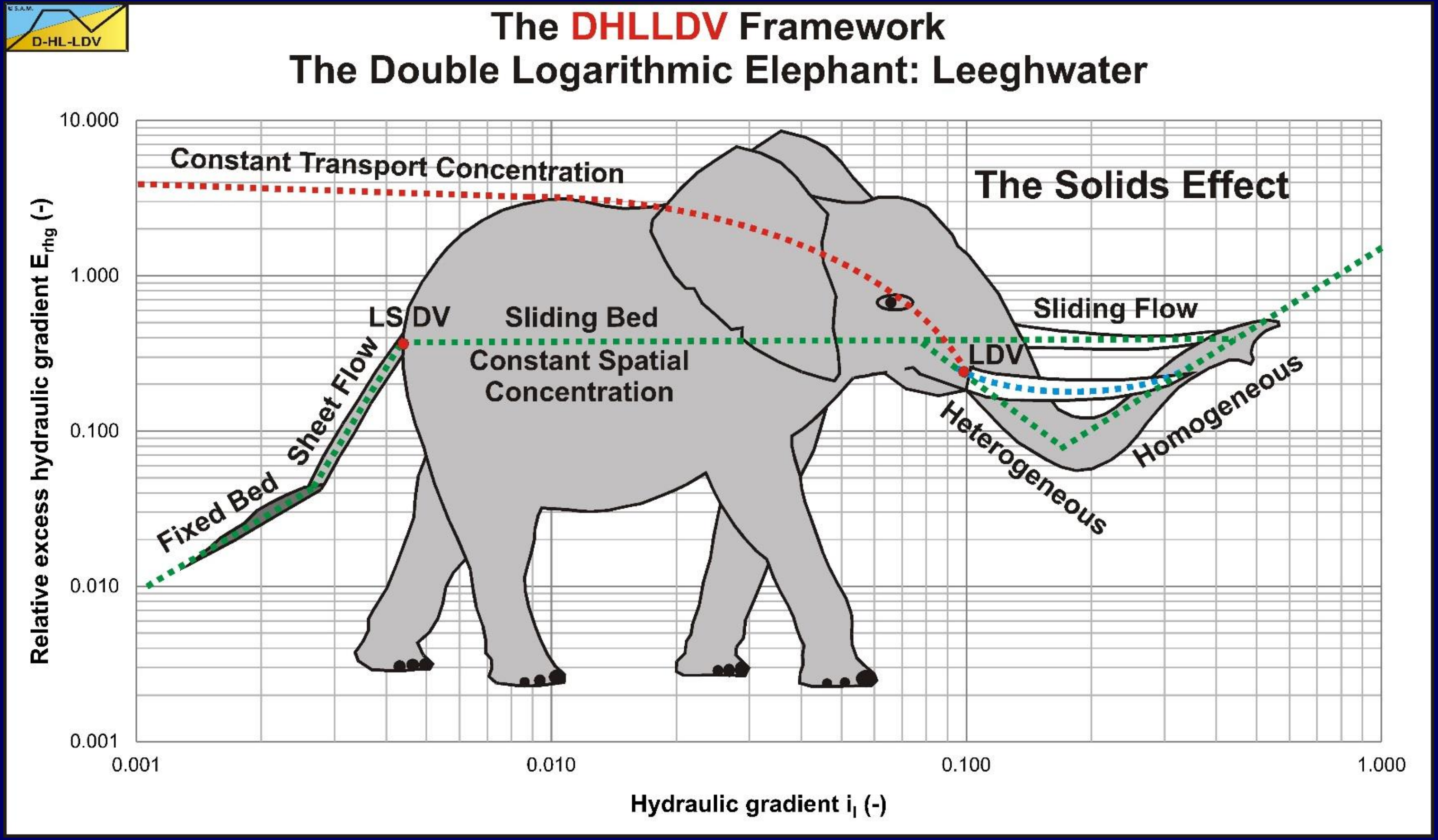
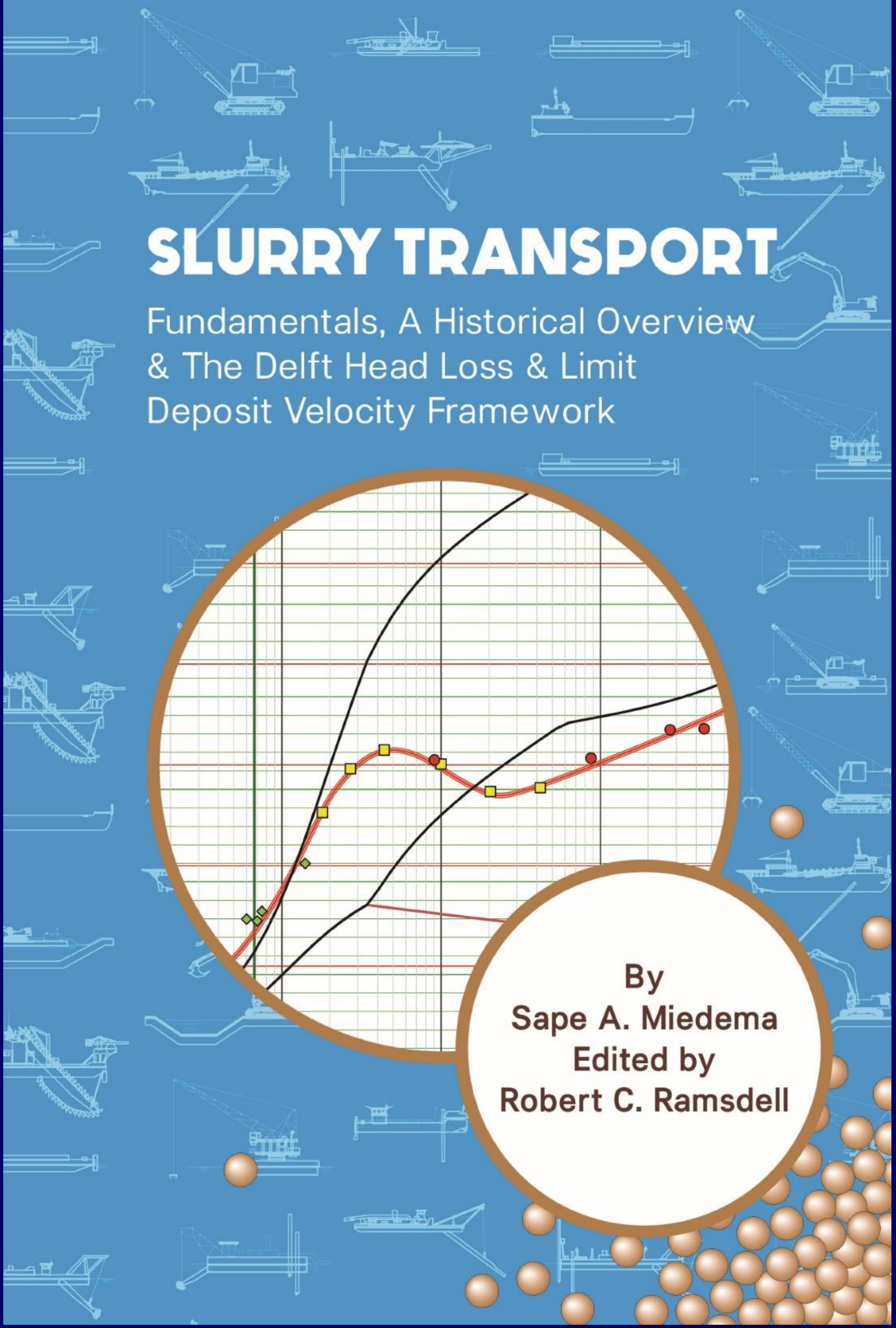
Conclusions

Leeghwater


D-HL-LDV
The DHLLDV Framework
The Double Logarithmic Elephant: Leeghwater
Constant Transport Concentration
The Solids Effect
LSDV
Sliding Bed
Constant Spatial Concentration
Sliding Flow
LDV
Sheet Flow
Fixed Bed
Heterogeneous
Homogeneous
Relative excess hydraulic gradient E_{rhg} (-)
Hydraulic gradient i_l (-)
10.000
1.000
0.100
0.010
0.001
0.001
0.010
0.100
1.000



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The Elephant of Wilson is our best Friend