DHLLDV Framework Graded Sands & Gravels

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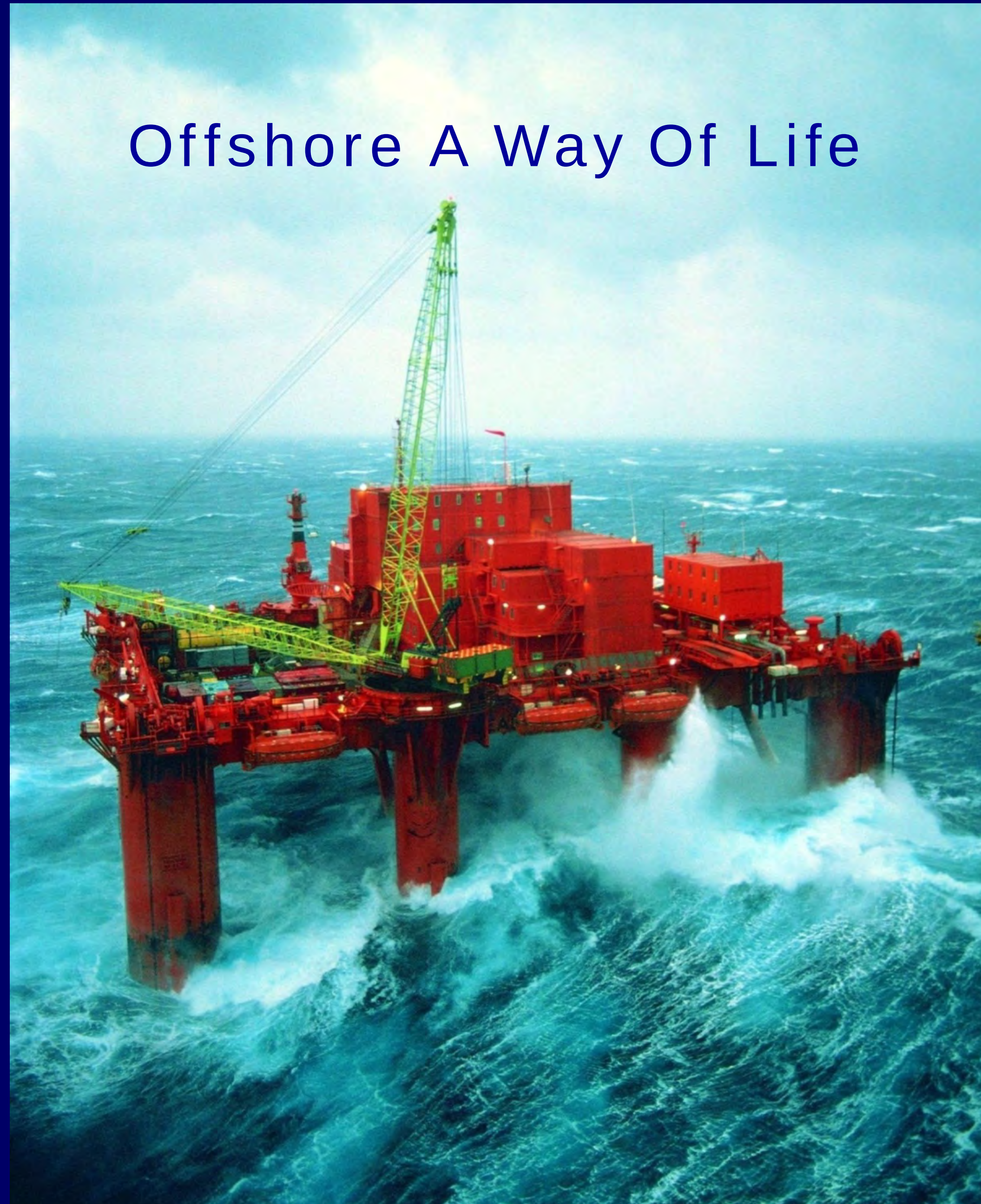

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What is Offshore & Dredging Engineering?

Offshore & Dredging Engineering covers everything at sea that does not have the purpose of transporting goods & people and no fishery.

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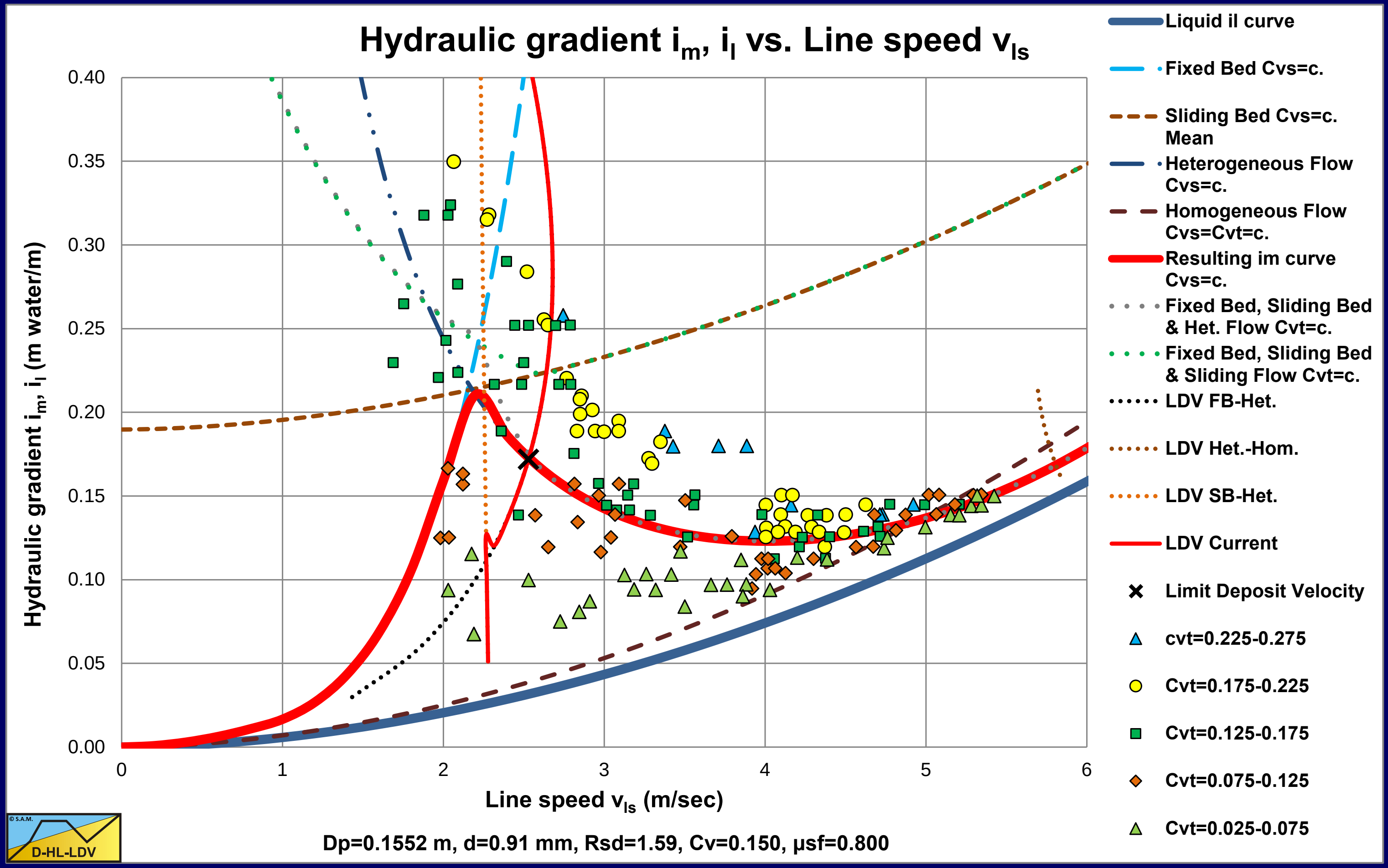
Introduction

Data from Yagi et al., C_{vs}



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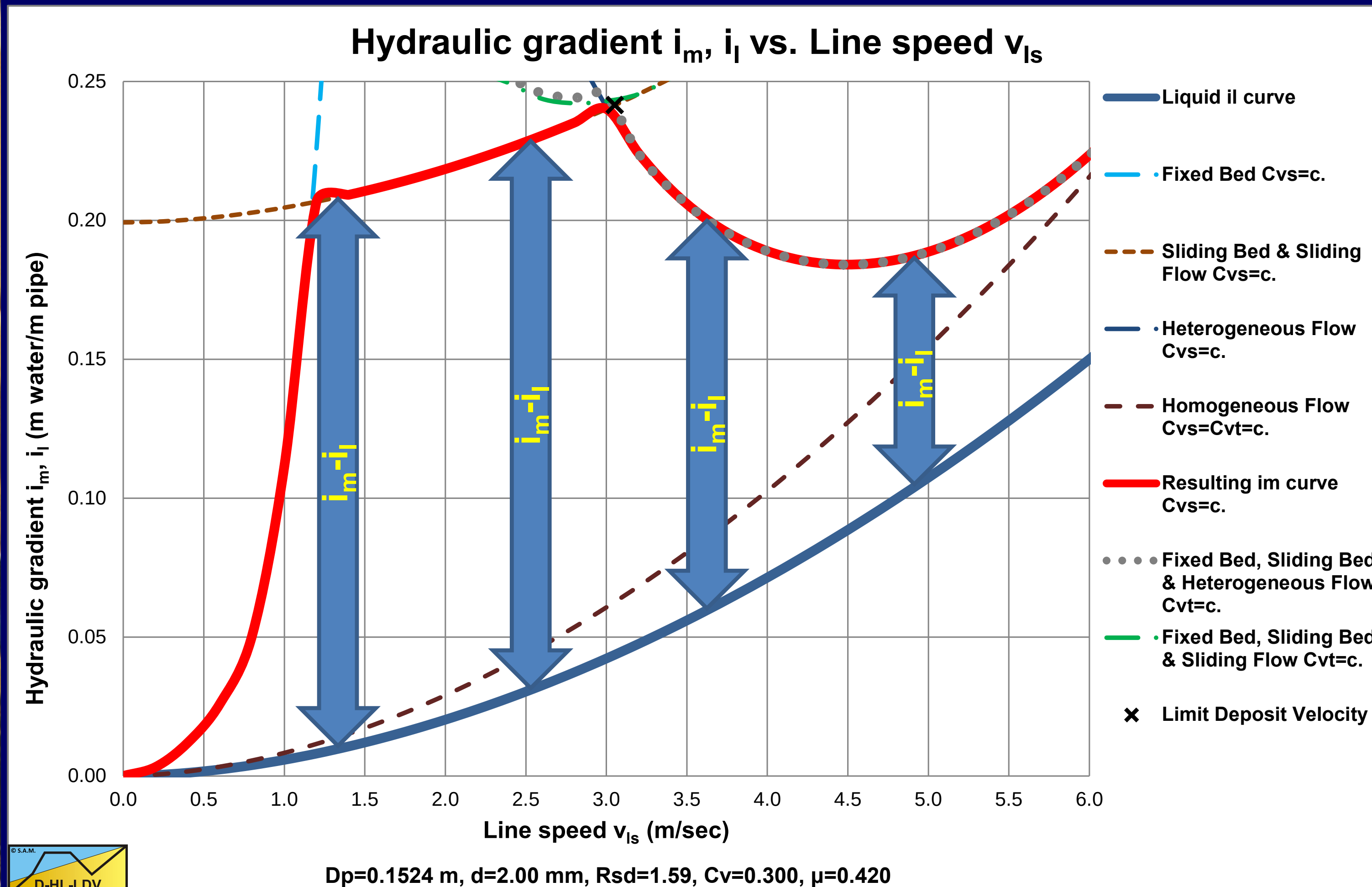
DHLLDV Model, The Solids Effect



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

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

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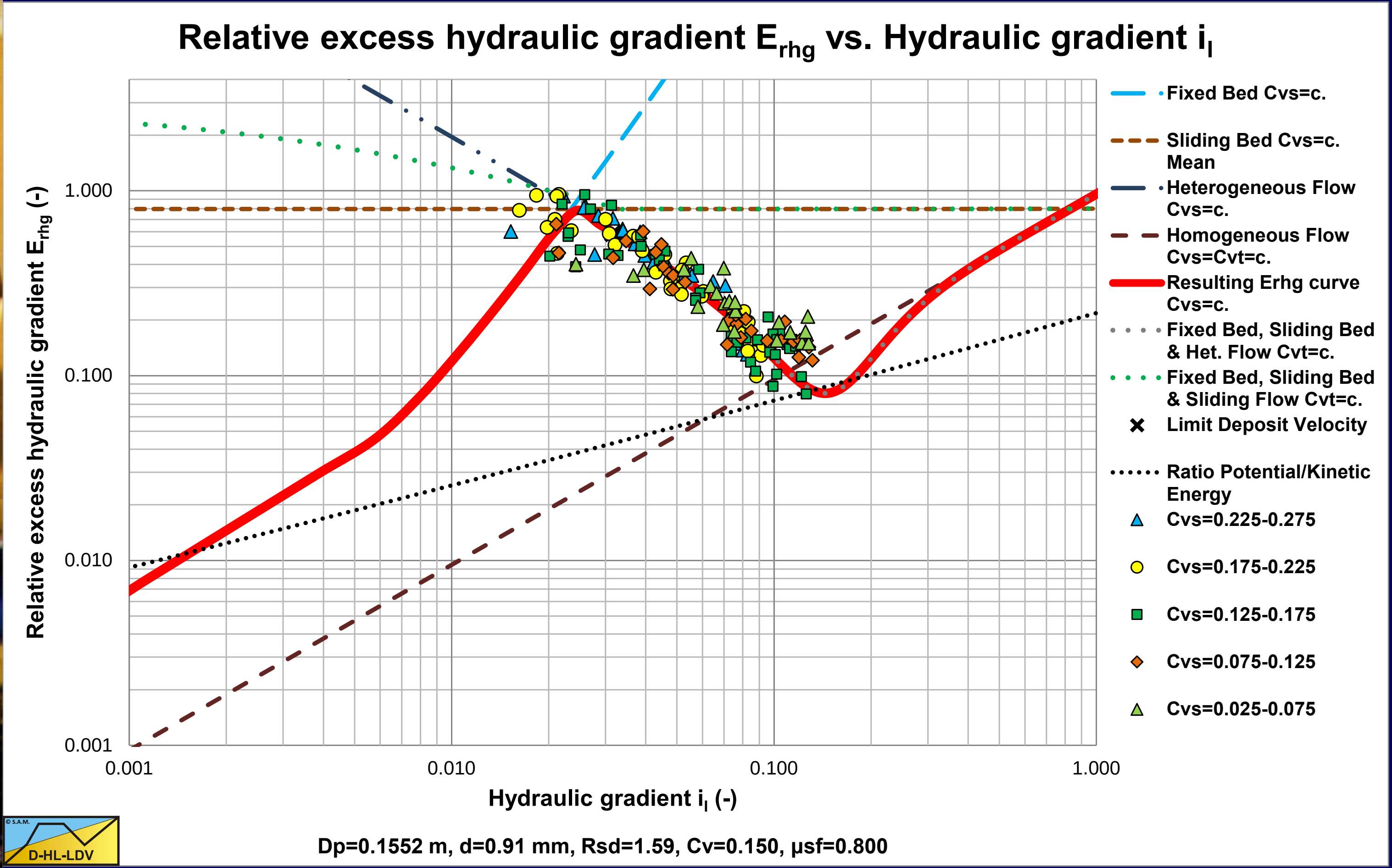
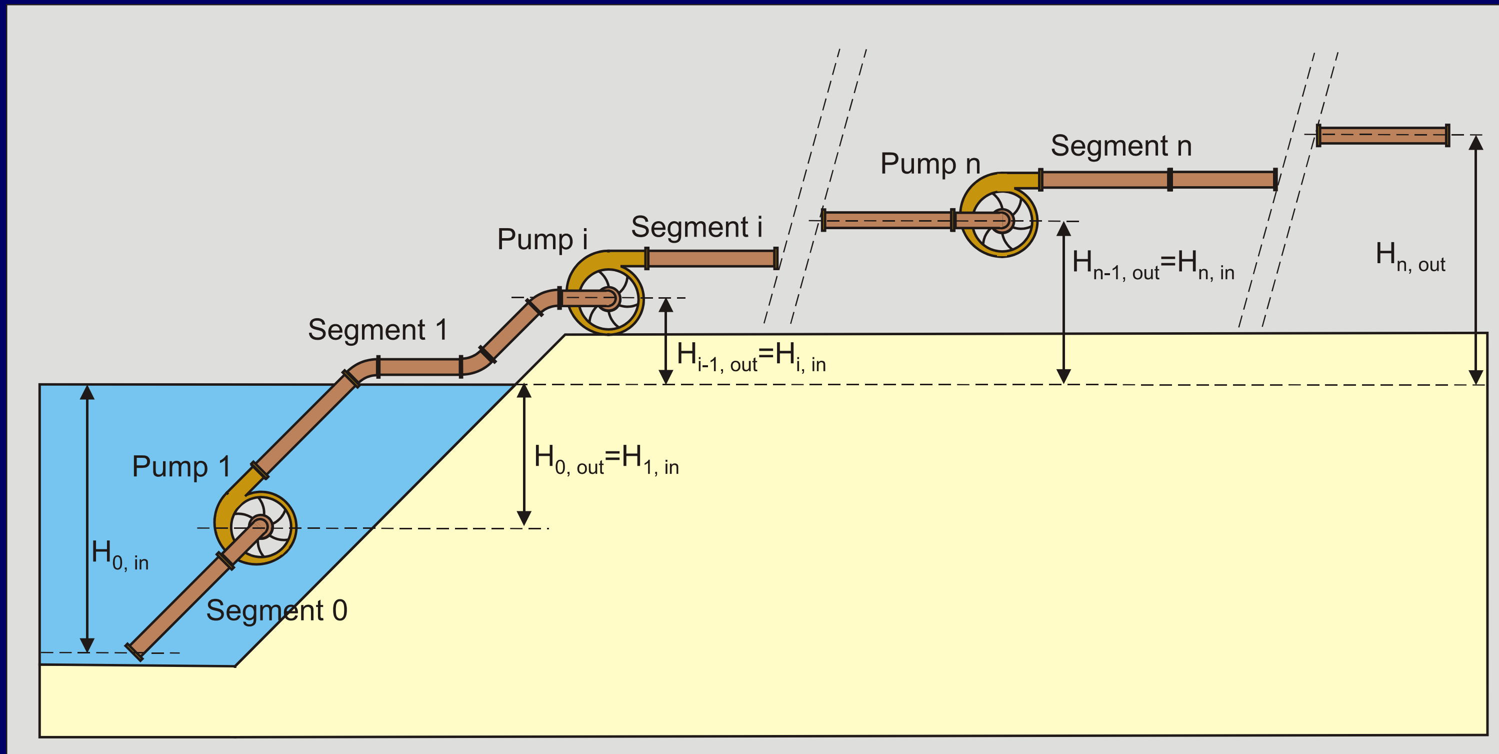
Data from Yagi et al., C_{vs}



Inclined Pipes

Chapter 7.14 & 8.15

Pump/Pipeline System



- Total pressure/power required
- Cavitation limit of each pump
- Deposition/plugging the pipeline
- Limit Deposit Velocity

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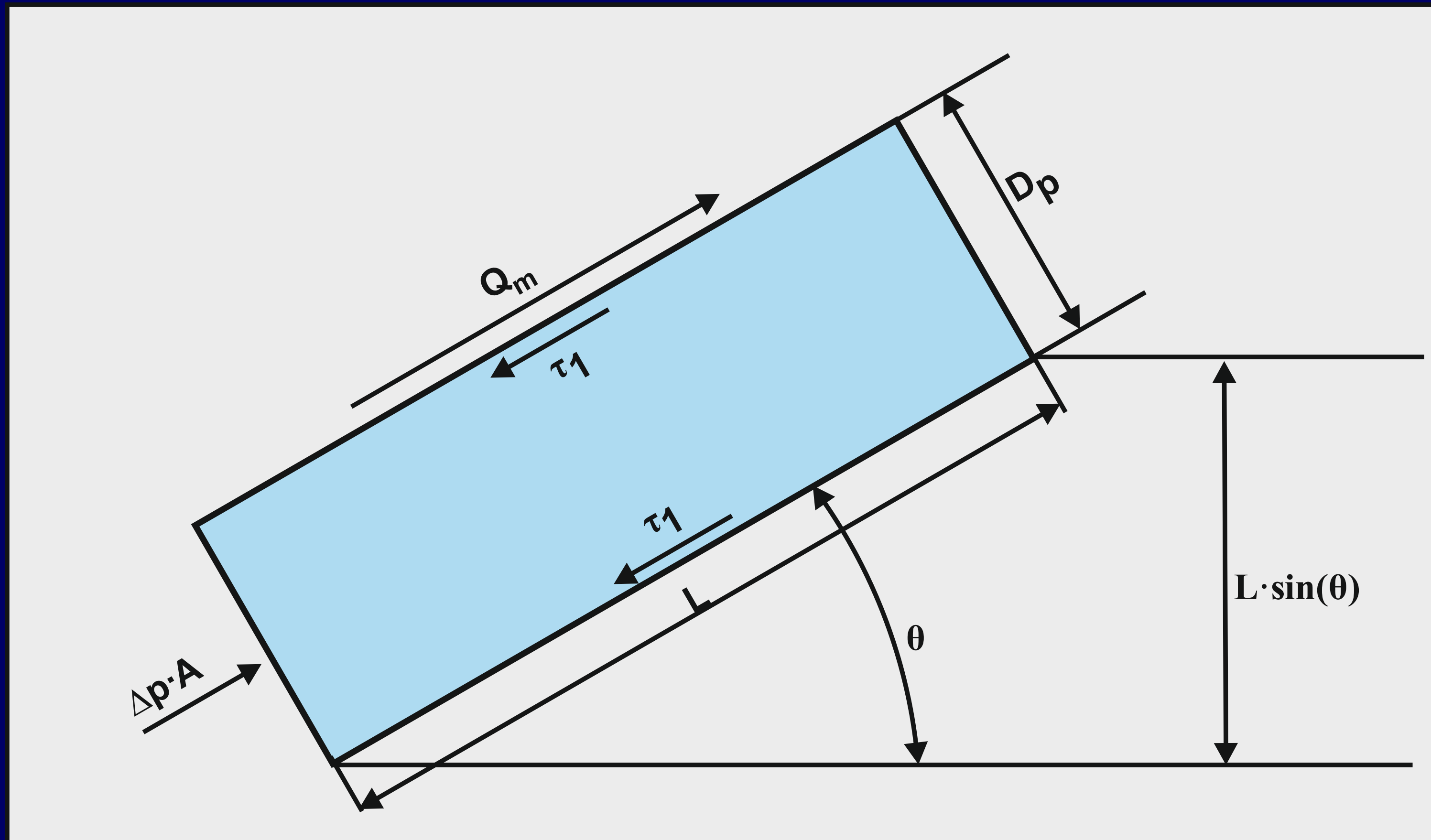
Research Question

Problem definition:

Existing methods for determining the hydraulic gradient (pressure losses) in inclined pipes simply multiply the hydraulic gradient of a horizontal pipe with the cosine of the inclination angle (to a certain power) and add the potential energy term. These methods do not consider the flow regimes.

- Flow regimes may respond differently to the inclination angle.
- The transition line speed between flow regimes may shift.
- Some flow regimes may not occur at all.
- The influence of the inclination angle has to be determined for each flow regime individually.

Pure Carrier Liquid



Pure Carrier Liquid

$$-\frac{dp}{dx}\cdot A\cdot L=\tau_l\cdot O\cdot L+\rho_l\cdot A\cdot L\cdot g\cdot \sin(\theta)$$

$$i_{l,\theta}=-\frac{dp}{dx}\cdot\frac{A\cdot L}{\rho_l\cdot A\cdot L\cdot g}$$

$$=\frac{\tau_l\cdot O\cdot L}{\rho_l\cdot A\cdot L\cdot g}+\frac{\rho_l\cdot A\cdot L\cdot g\cdot \sin(\theta)}{\rho_l\cdot A\cdot L\cdot g}$$

$$=i_l+\sin(\theta)$$

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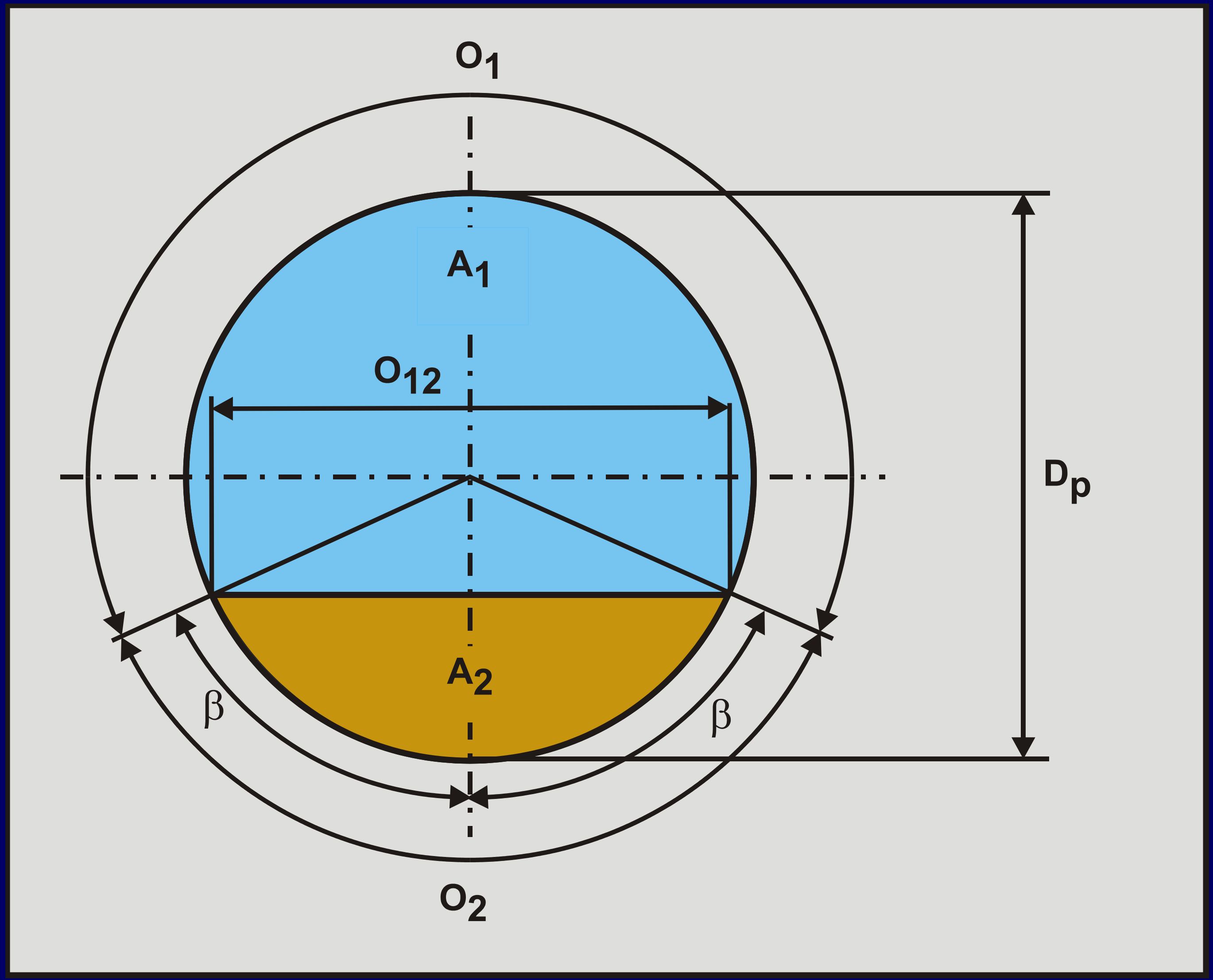
Fixed/Sliding Bed Regime



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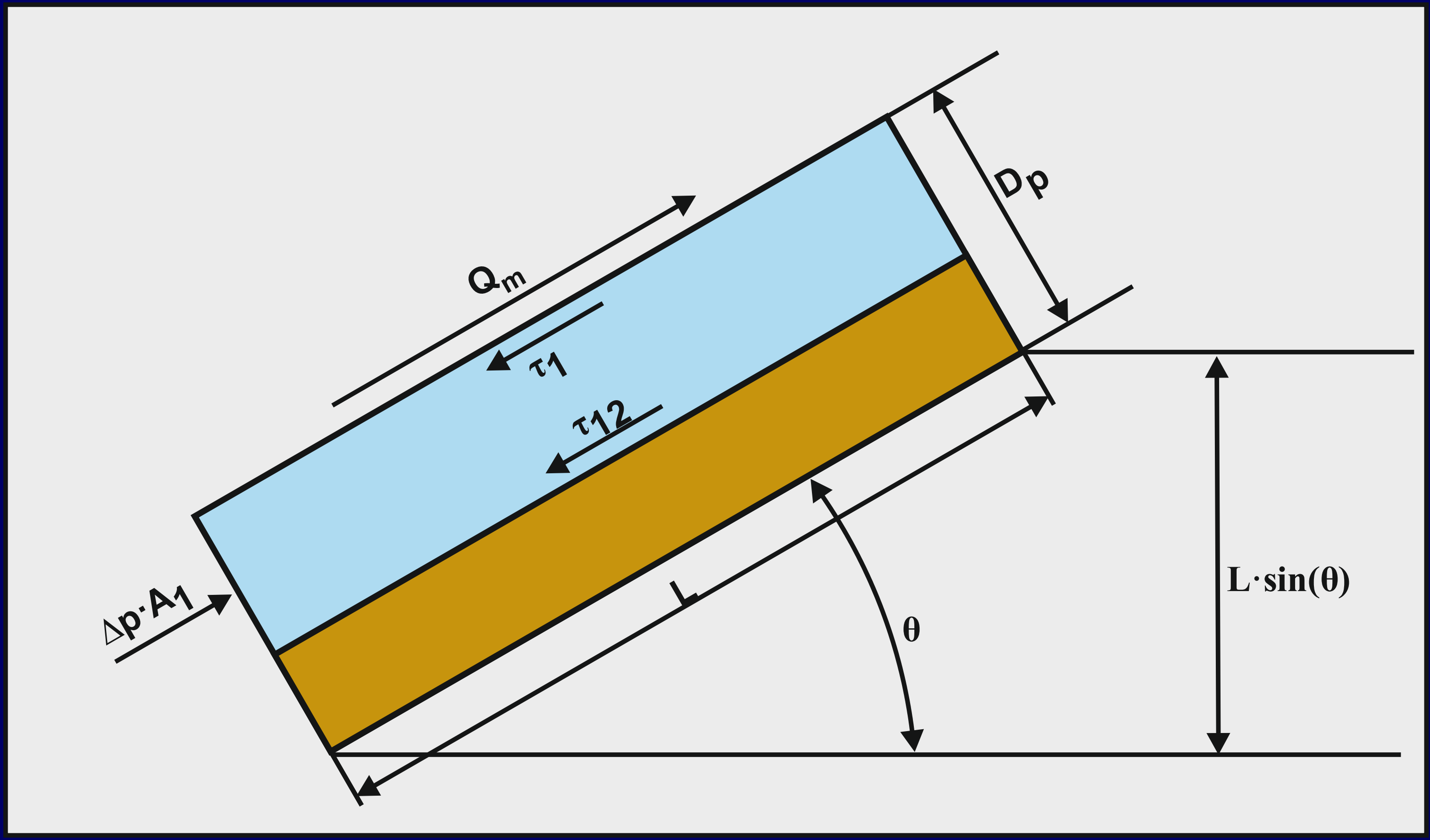
Fixed/Sliding Bed Regime



Fixed Bed Regime

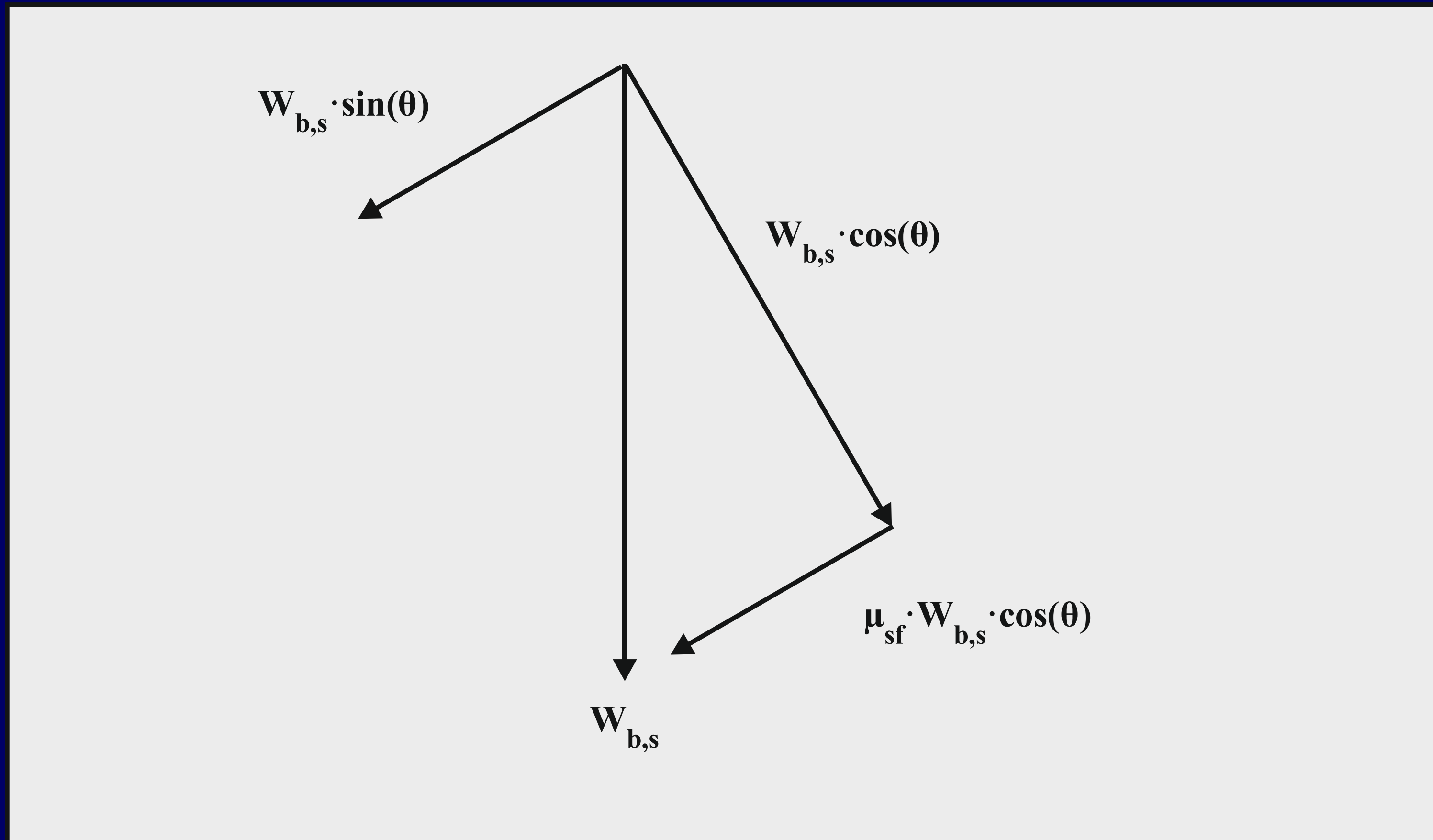
$$-\frac{dp}{dx}\cdot A_1\cdot L=\tau_l\cdot O_1\cdot L+\tau_{12}\cdot O_{12}\cdot L+\rho_l\cdot A_1\cdot L\cdot g\cdot \sin(\theta)$$

$$i_{m,\theta}=-\frac{dp}{dx}\cdot\frac{A_1\cdot L}{\rho_l\cdot A_1\cdot L\cdot g}$$

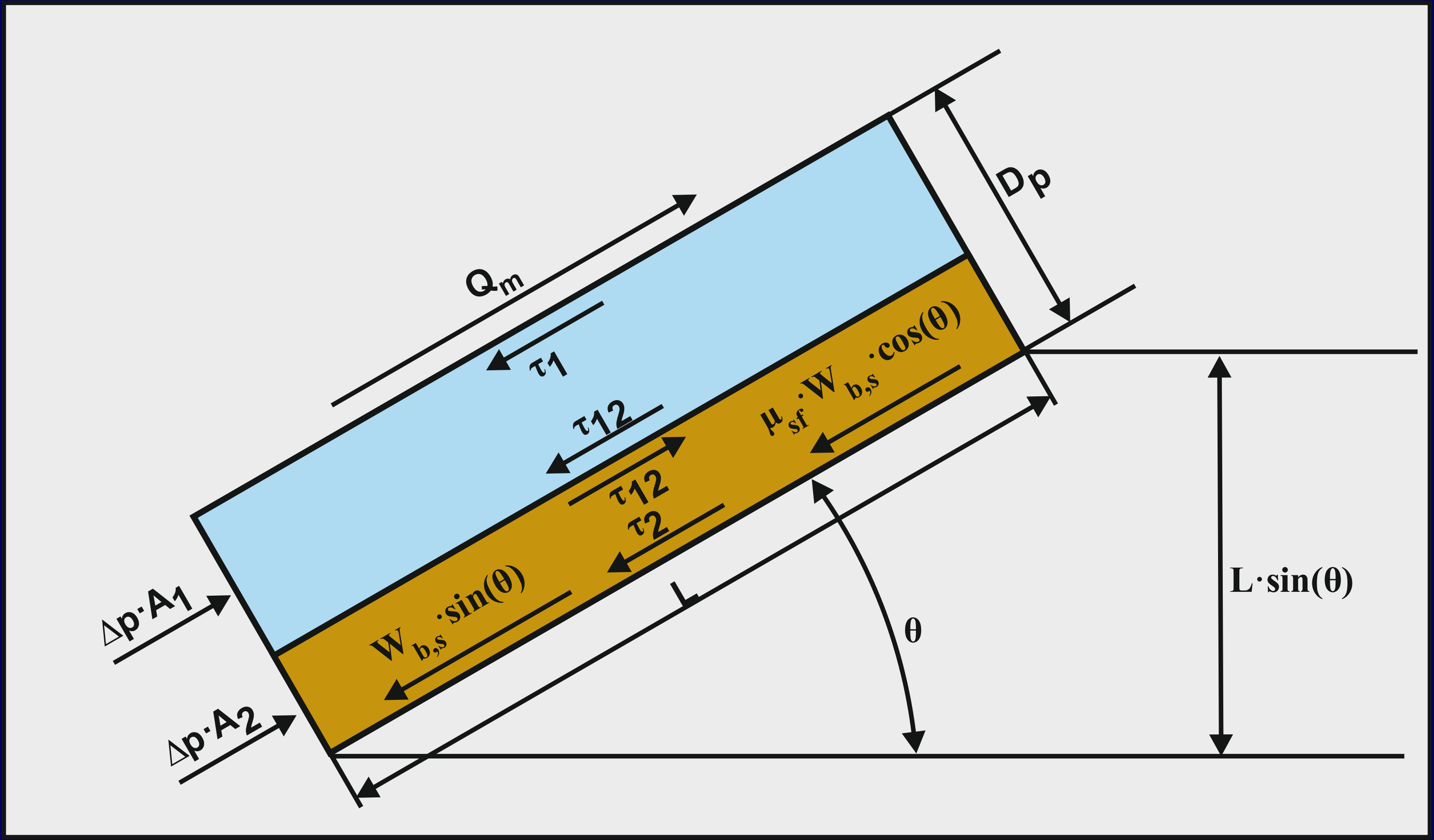
$$=\frac{\tau_l\cdot O_1\cdot L}{\rho_l\cdot A_1\cdot L\cdot g}+\frac{\tau_{12}\cdot O_{12}\cdot L}{\rho_l\cdot A_1\cdot L\cdot g}+\frac{\rho_l\cdot A_1\cdot L\cdot g\cdot \sin(\theta)}{\rho_l\cdot A_1\cdot L\cdot g}$$

$$=i_m+\sin(\theta)$$

Sliding Bed Regime, Gravity



Sliding Bed Regime, Forces



Sliding Bed Regime

$$i_{m,\theta} = i_{l,\theta} + R_{sd} \cdot C_{vs} \cdot \left(\mu_{sf} \cdot \cos(\theta) + \sin(\theta) \right)$$

$$E_{rhg,\theta} = \frac{i_{m,\theta} - i_{l,\theta}}{R_{sd} \cdot C_{vs}} = \mu_{sf} \cdot \cos(\theta) + \sin(\theta)$$

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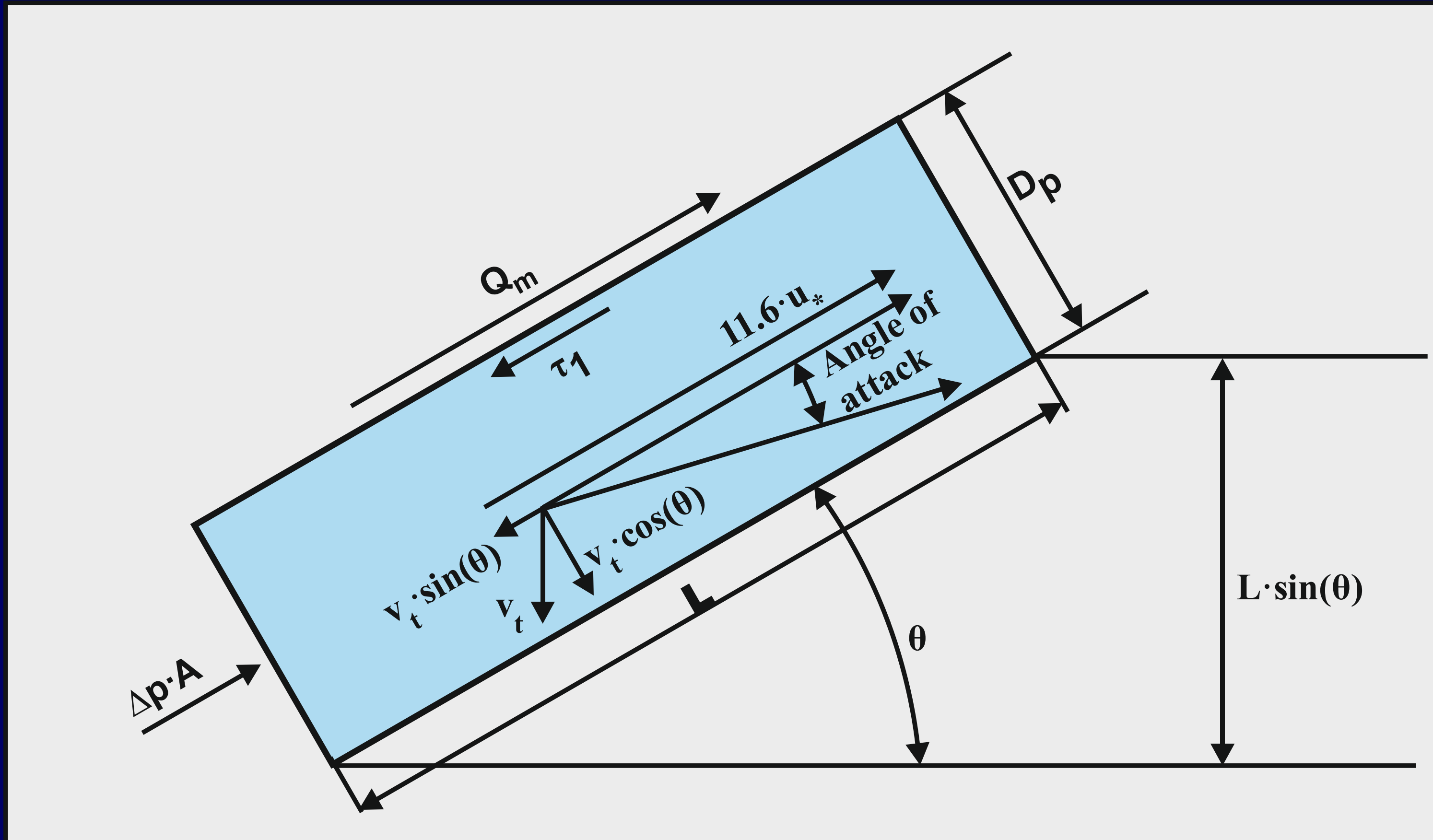
Heterogeneous Flow Regime



Heterogeneous Flow Regime

$$S_{hr,\theta} = S_{hr} \cdot \cos(\theta) = \frac{v_t \cdot \cos(\theta) \cdot \left(1 - \frac{C_{vs}}{\kappa_C}\right)^{\beta}}{v_{ls}}$$

$$S_{rs,\theta} = c \cdot \left(\frac{\delta_v}{d}\right)^{2/3} \cdot \left(\frac{v_t \cdot \cos(\theta)}{11.6 \cdot u_* - v_t \cdot \sin(\theta)}\right)^{4/3} \cdot \left(\frac{v_t}{\sqrt{g \cdot d}}\right)^{2}$$

$$E_{rhg,\theta} = S_{hr,\theta} + S_{rs,\theta} + \sin(\theta)$$

$$i_{m,\theta} = i_{l,\theta} + \left(S_{hr,\theta} + S_{rs,\theta} + \sin(\theta)\right) \cdot R_{sd} \cdot C_{vs}$$

Homogeneous Flow Regime 1

$$i_{lm,\theta} = \frac{\lambda_l \cdot \left(v_{ls} + v_{th} \cdot \sin(\theta) \cdot C_{vs}\right)^2}{2 \cdot g \cdot D_p} + \sin(\theta)$$

$$i_{lm,\theta} \approx i_l + \sin(\theta) + i_l \cdot \frac{2 \cdot v_{th} \cdot \sin(\theta) \cdot C_{vs}}{v_{ls}}$$

$$= i_{l,\theta} + i_l \cdot \frac{2 \cdot v_{th} \cdot \sin(\theta) \cdot C_{vs}}{v_{ls}}$$

Homogeneous Regimes

$$i_{m,\theta} = i_l \cdot \left(1 + \alpha_E \cdot R_{sd} \cdot C_{vs}\right) + \left(1 + R_{sd} \cdot C_{vs}\right) \cdot \sin(\theta)$$

Sliding Flow Regime

$$i_{m,\theta} = i_l \cdot \left(1 + \frac{2 \cdot v_{th} \cdot \sin(\theta) \cdot C_{vs}}{v_{ls}}\right) + \left(1 + R_{sd} \cdot C_{vs}\right) \cdot \sin(\theta)$$

Homogeneous Flow Regime 2

Homogeneous Regimes

$$i_{m,\theta} = i_{l,\theta} + R_{sd} \cdot C_{vs} \cdot \left(\alpha_E \cdot i_l + \sin(\theta)\right)$$

Sliding Bed Regime

$$i_{m,\theta} = i_{l,\theta} + R_{sd} \cdot C_{vs} \cdot \sin(\theta) + i_l \cdot \frac{2 \cdot v_{th} \cdot \sin(\theta) \cdot C_{vs}}{v_{ls}}$$

Homogeneous Regimes

$$E_{rhg,\theta} = \frac{i_{m,\theta} - i_{l,\theta}}{R_{sd} \cdot C_{vs}} = \alpha_E \cdot i_l + \sin(\theta)$$

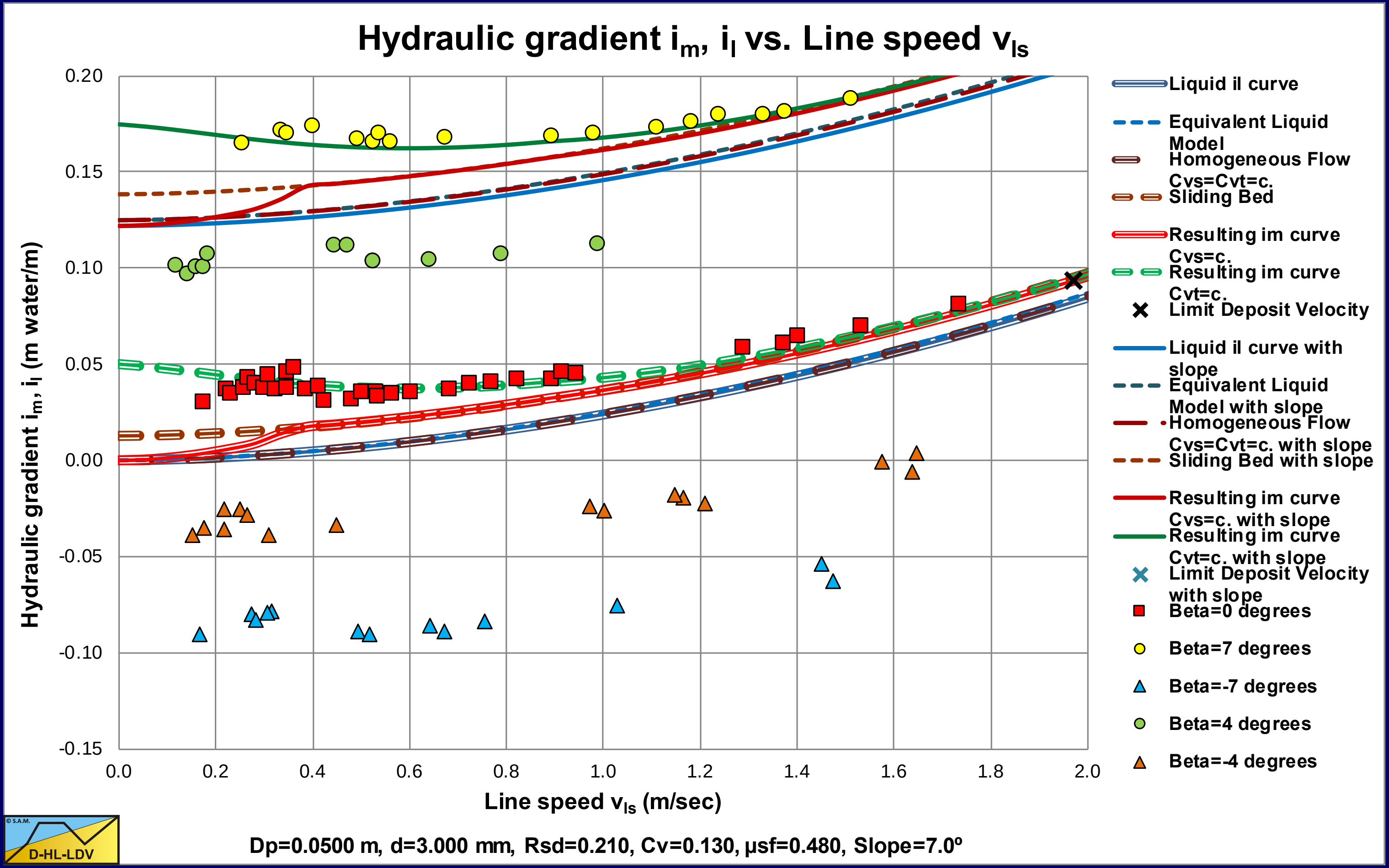
Sliding Bed Regime

$$E_{rhg,\theta} = \frac{i_{m,\theta} - i_{l,\theta}}{R_{sd} \cdot C_{vs}} = i_l \cdot \frac{2 \cdot v_{th} \cdot \sin(\theta)}{v_{ls} \cdot R_{sd}} + \sin(\theta)$$

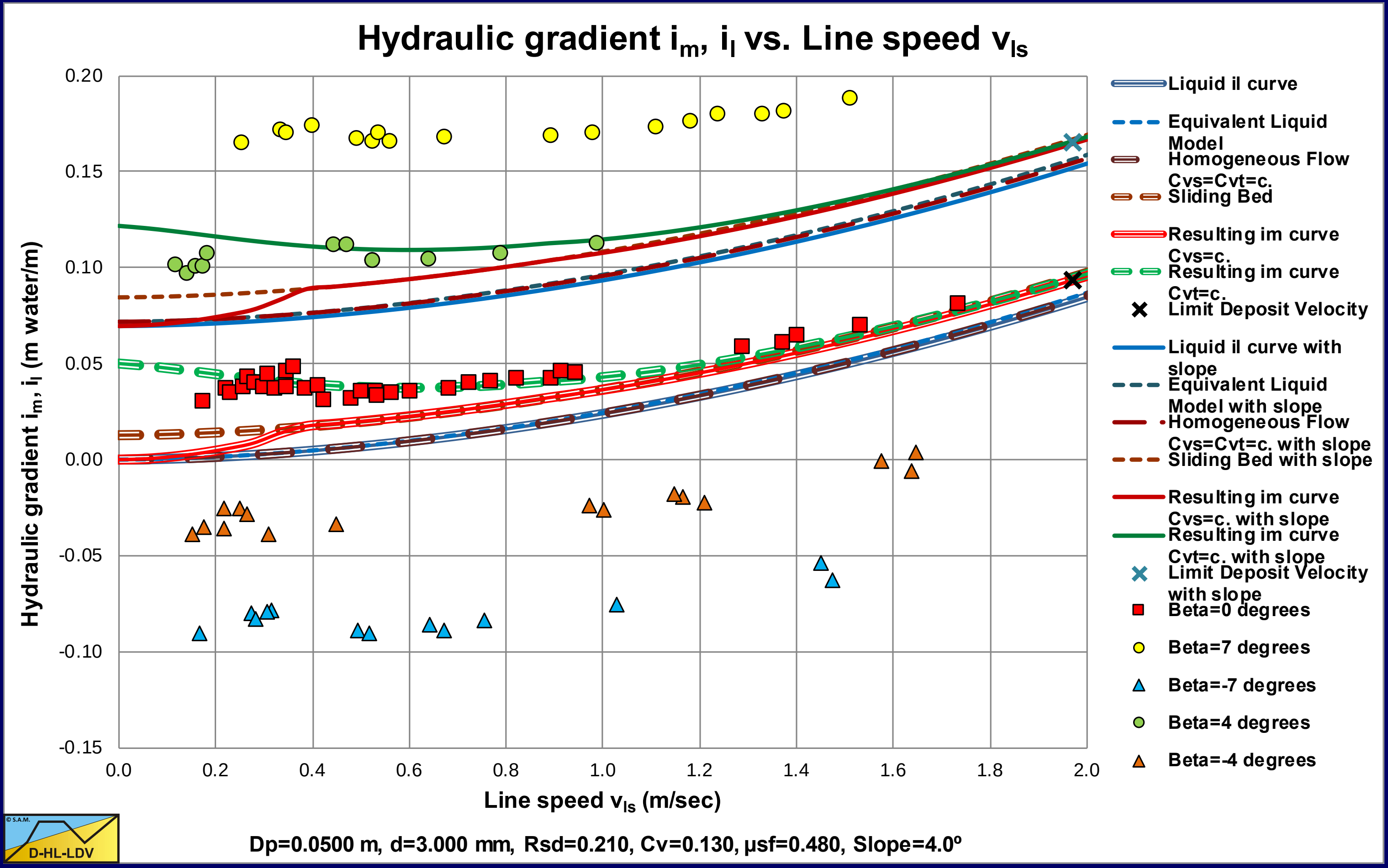
Limit Deposit Velocity

$$v_{ls,ldv,\theta} = v_{ls,ldv} \cdot \cos(\theta)^{1/3}$$

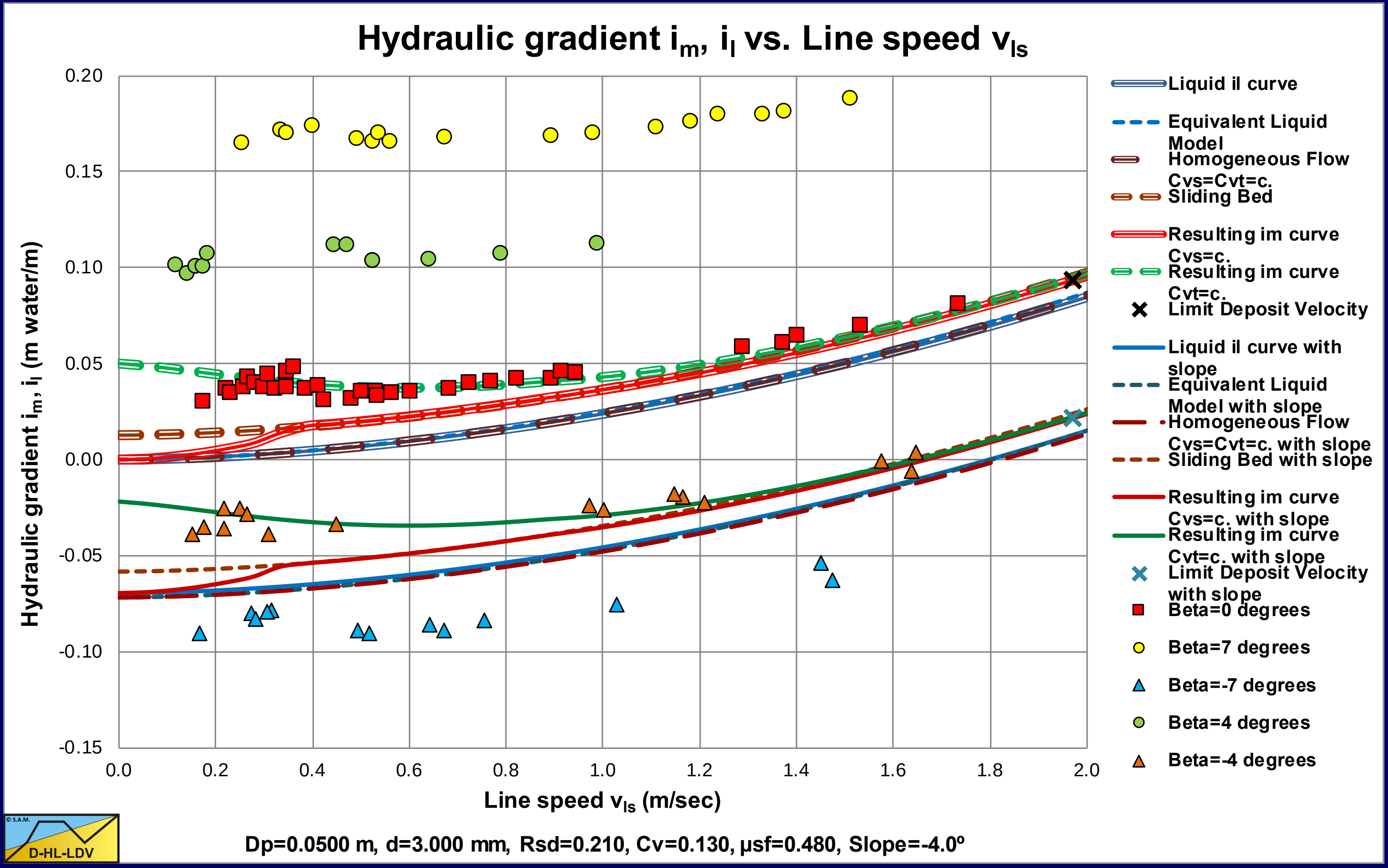
Inclined Pipe, Doron & Barnea (1997)



Inclined Pipe, Doron & Barnea (1997)



Inclined Pipe, Doron & Barnea (1997)



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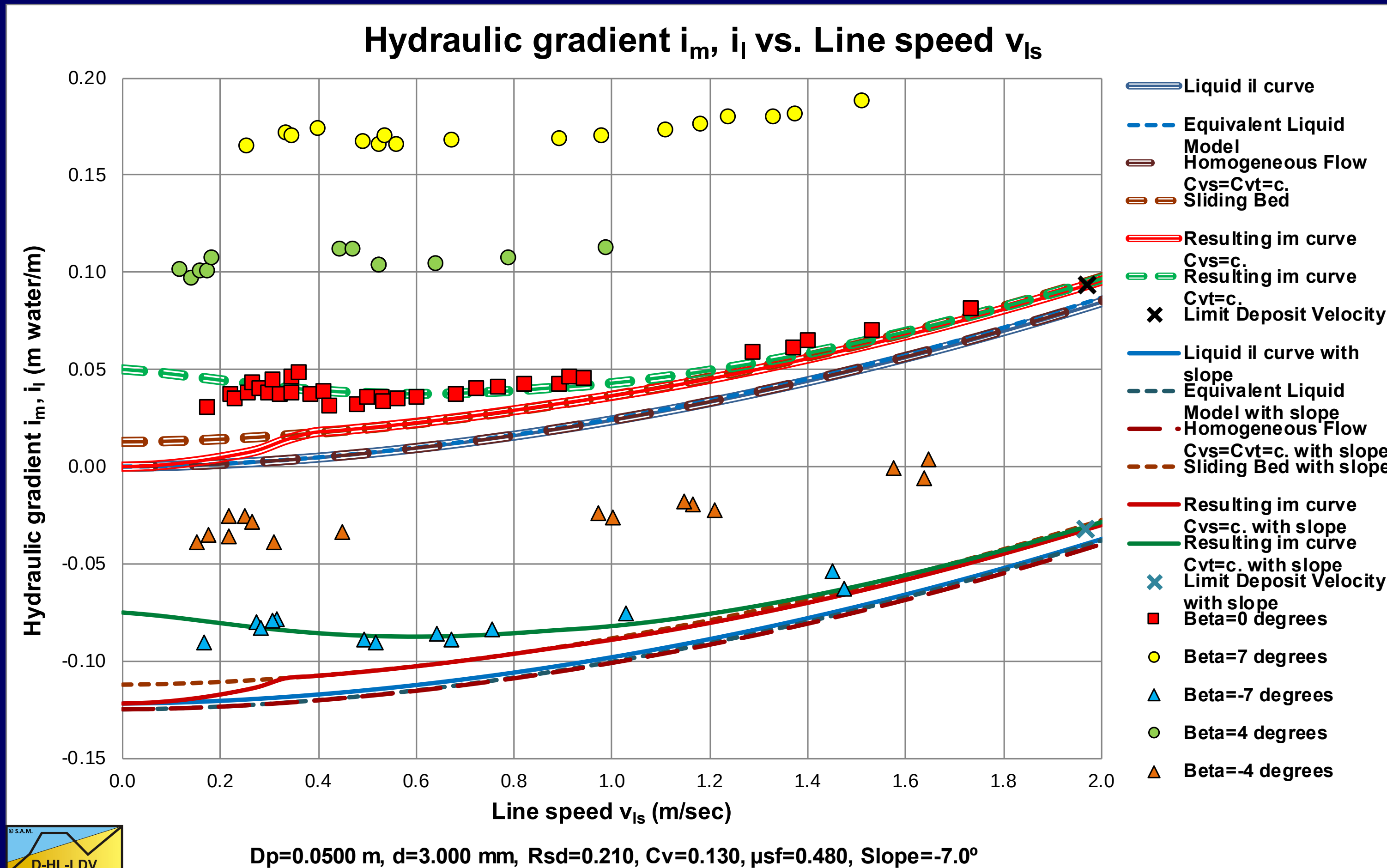
Inclined Pipe, Doron & Barnea (1997)



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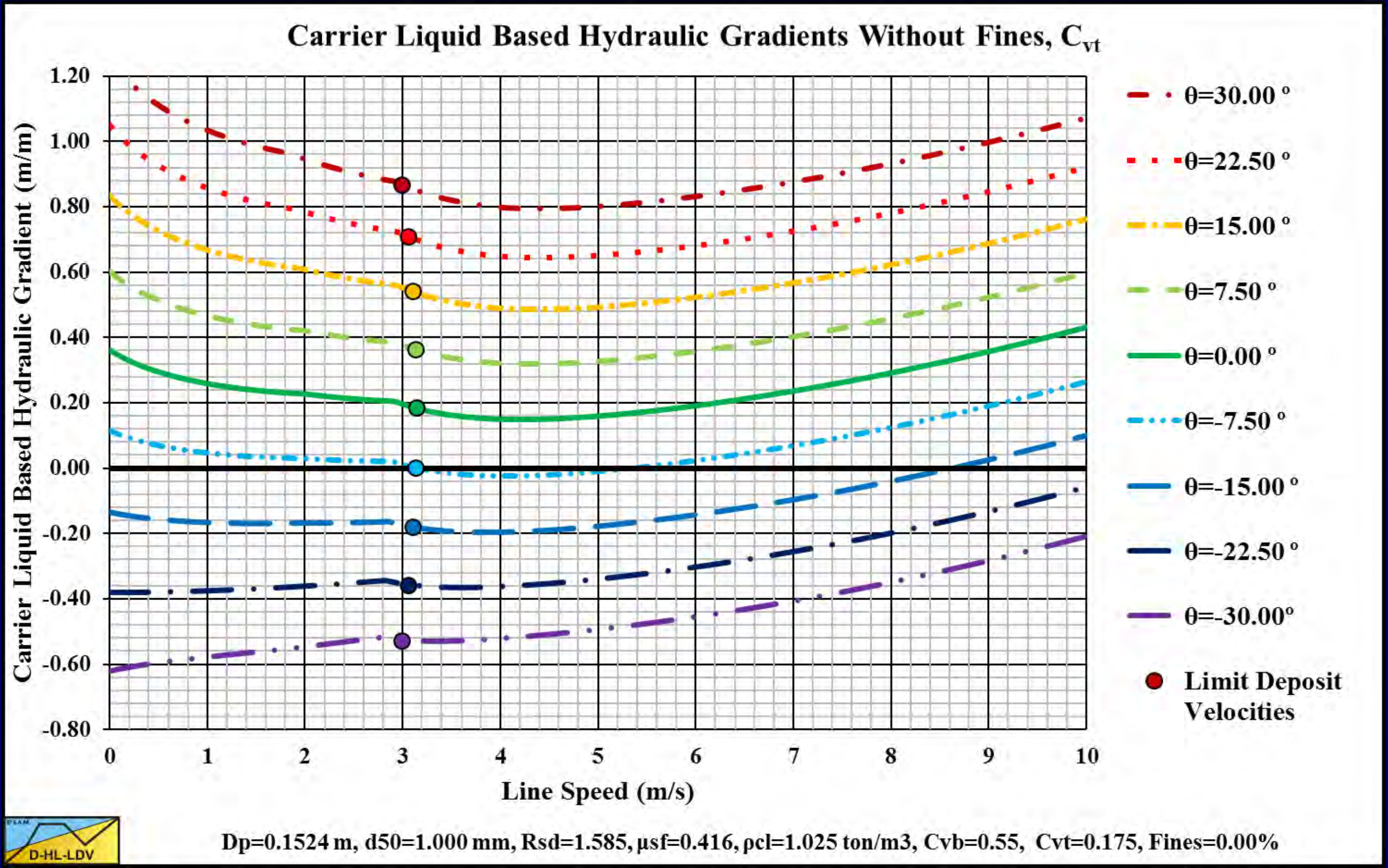
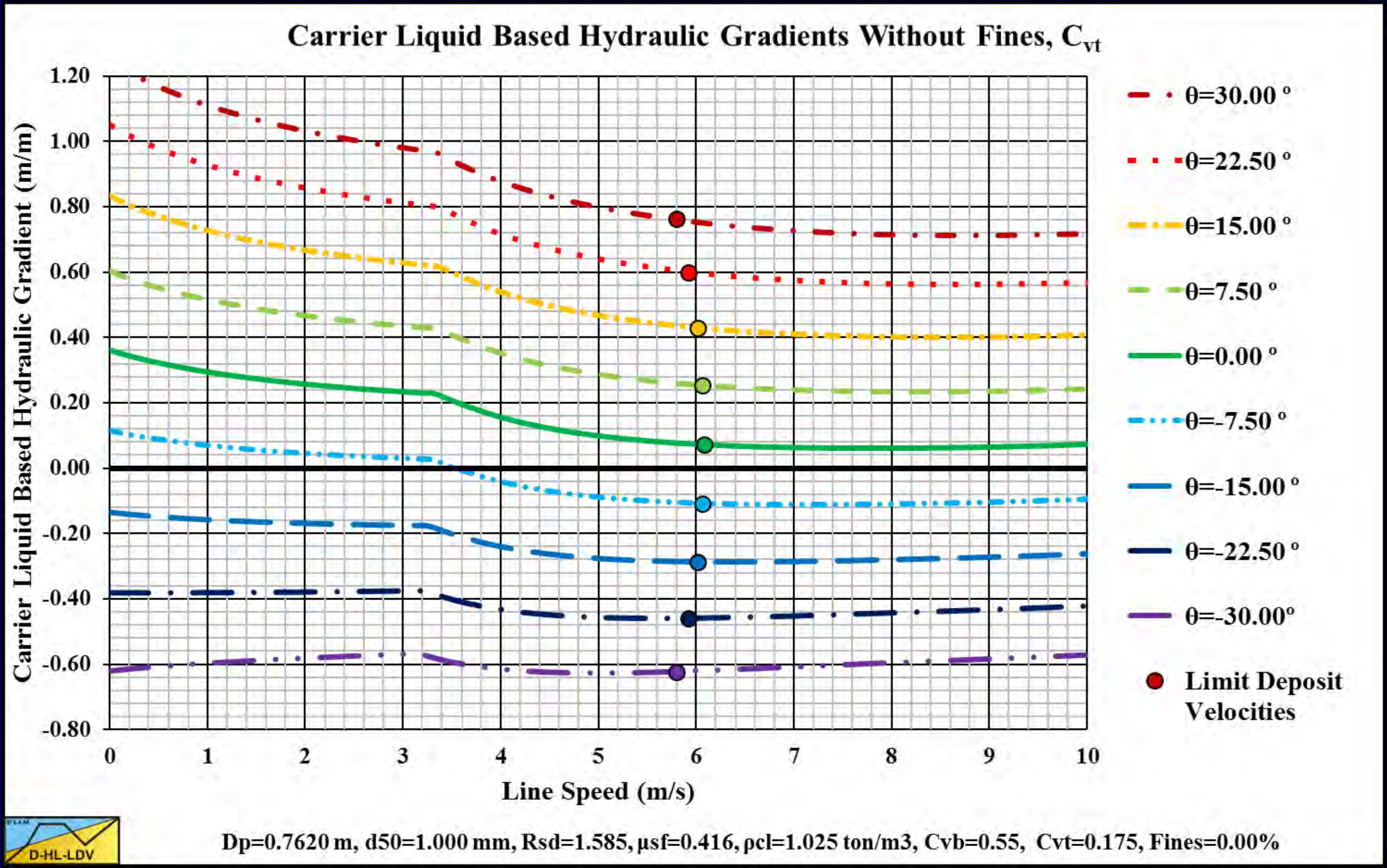
Inclined Pipe, D_p=0.1524 m, C_{vt}



Inclined Pipe, D_p=0.762 m, C_{vt}



Conclusions

- To construct the hydraulic gradient curve or relative solids effect curve for inclined pipes, first the curves for the different flow regimes have to be constructed.
- Secondly from the individual curves, a resulting curve can be constructed.
- The different flow regimes may behave differently with inclined pipes.
- The method described matches well with experimental data of Doron & Barnea, etc.

Questions?

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