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Slugging in Pipelines: What You NEED to Know

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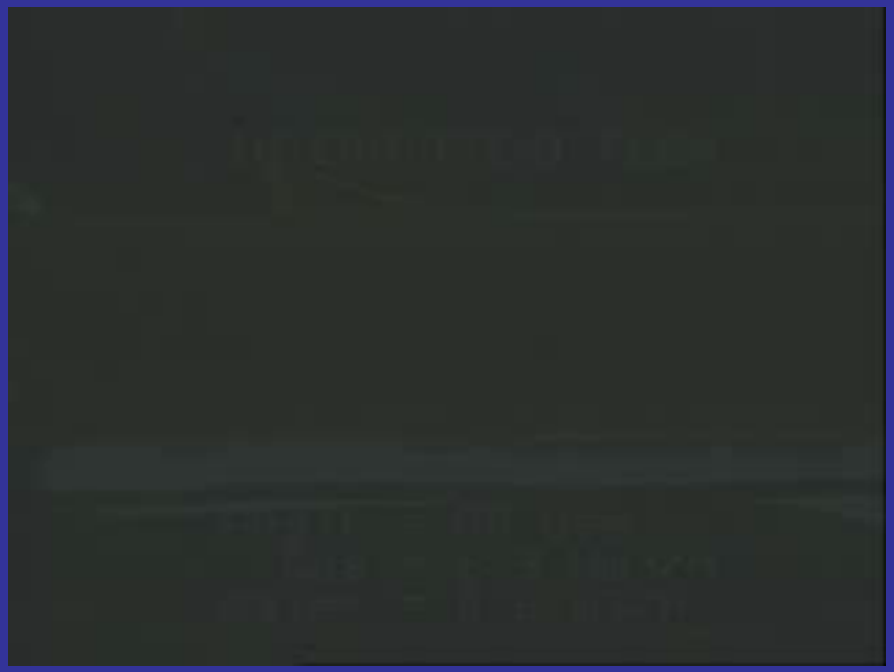
Outline

- Why Worry?
- Hydrodynamic Slugs
- Terrain Induced Slugs
- Turn Up Slugs
- Pigging Slugs
- Slug Modelling: Where Are We?
- Areas Currently Being Researched
- Conclusions

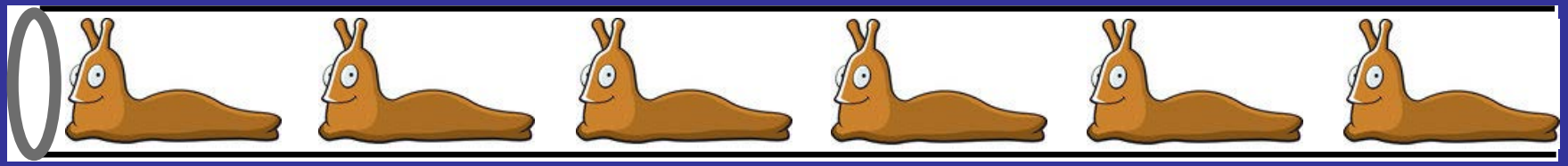
Why Worry?

- Damage to facilities
- Separators flooding
- Increased corrosion
- Starving compressors
- High back pressures



Hydrodynamic Slugs

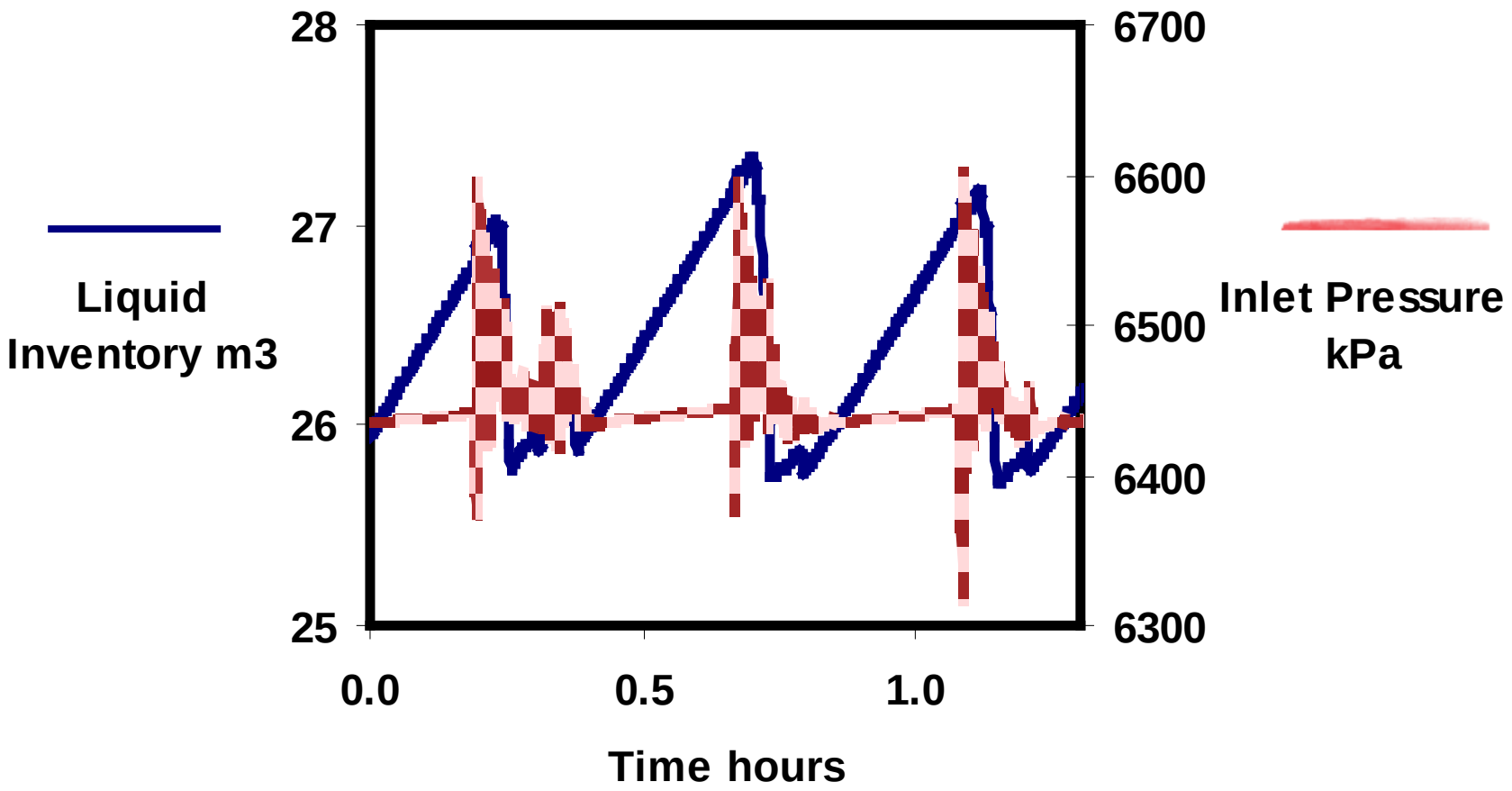
Slugs can be created by just flowing



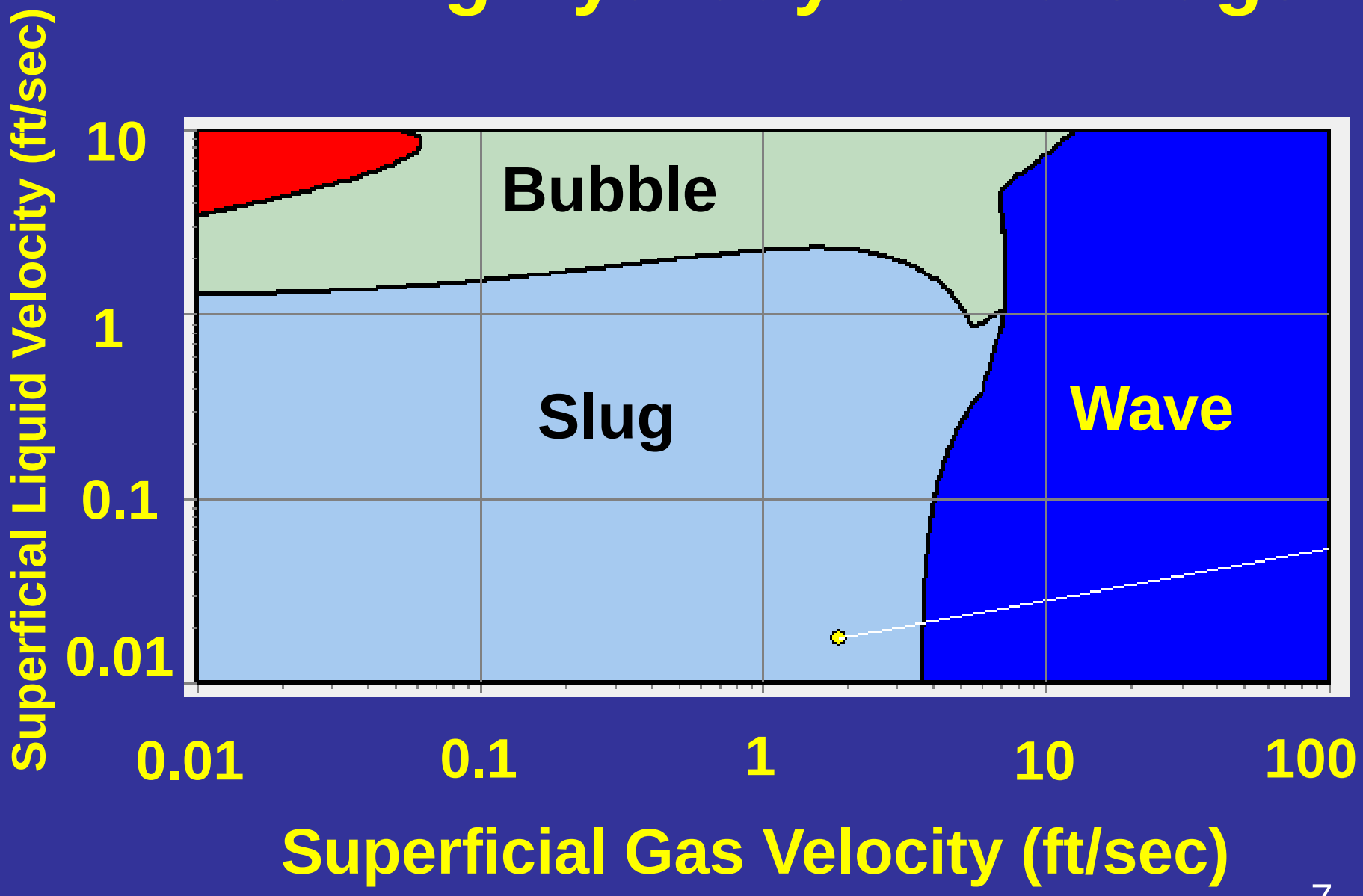
…and there might be lots of them …

Steady state mechanistic models will account for hydrodynamic slugging (OLGAS, XIAO models)

Hydrodynamic Slugs

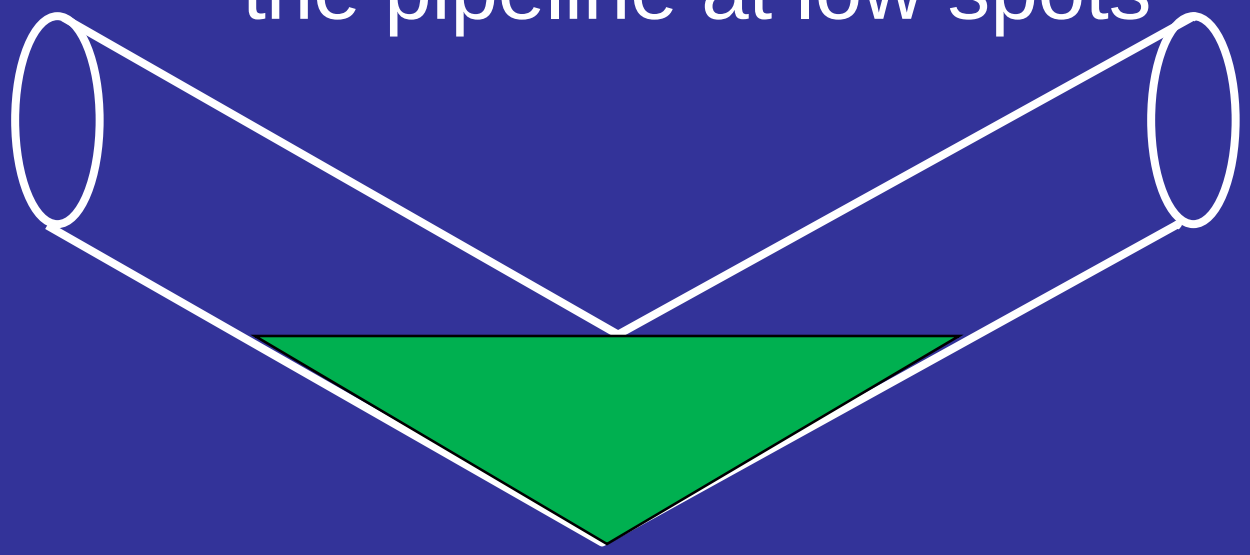


Avoiding Hydrodynamic Slugs



Terrain Induced Slugs

A Slug can be created by liquid trapped in the pipeline at low spots

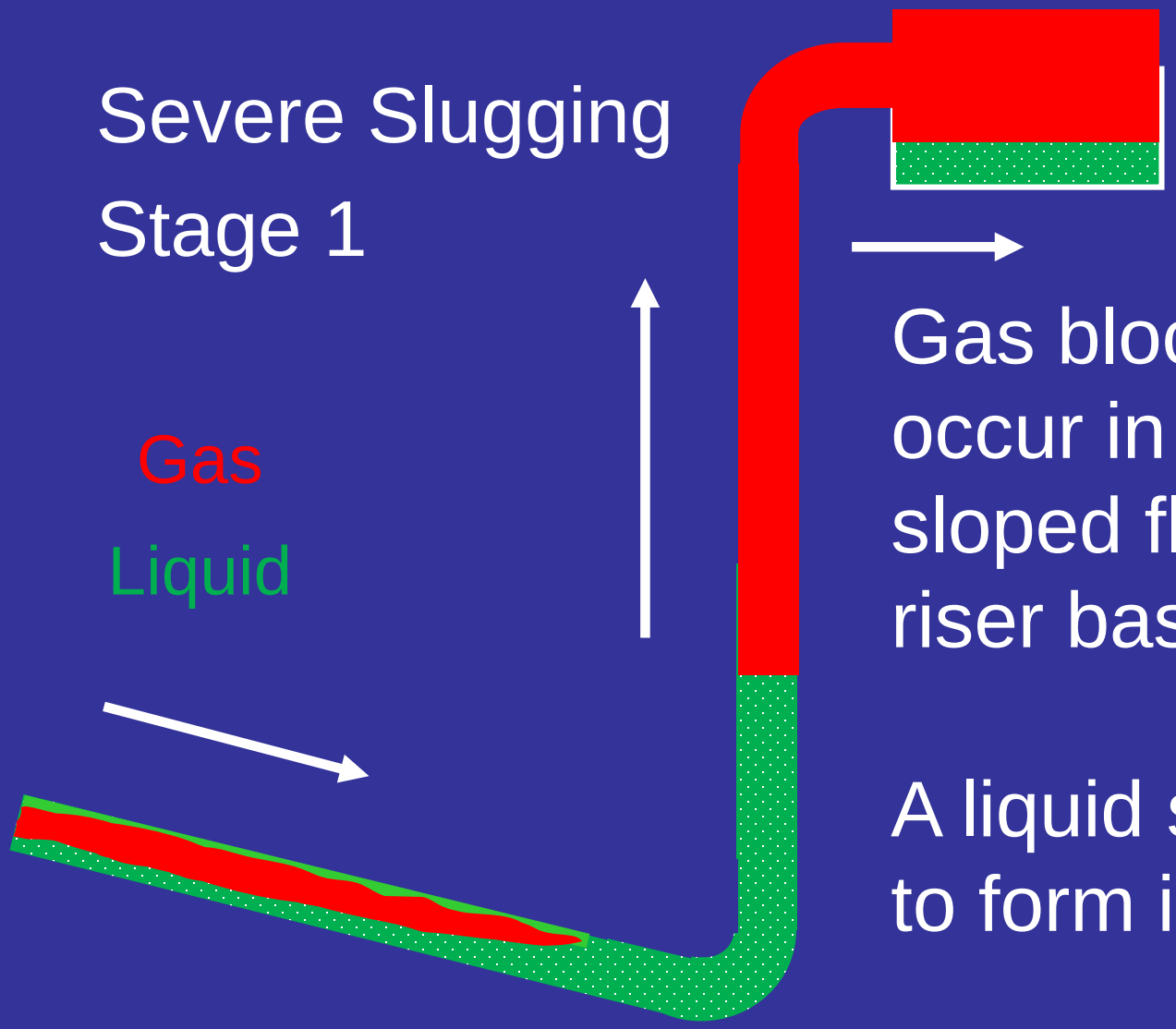


….. Irregular ……

Terrain Induced Slug - Severe

Severe Slugging

Stage 1



Gas blockage can occur in downward sloped flow line at riser base

A liquid slug begins to form in the riser

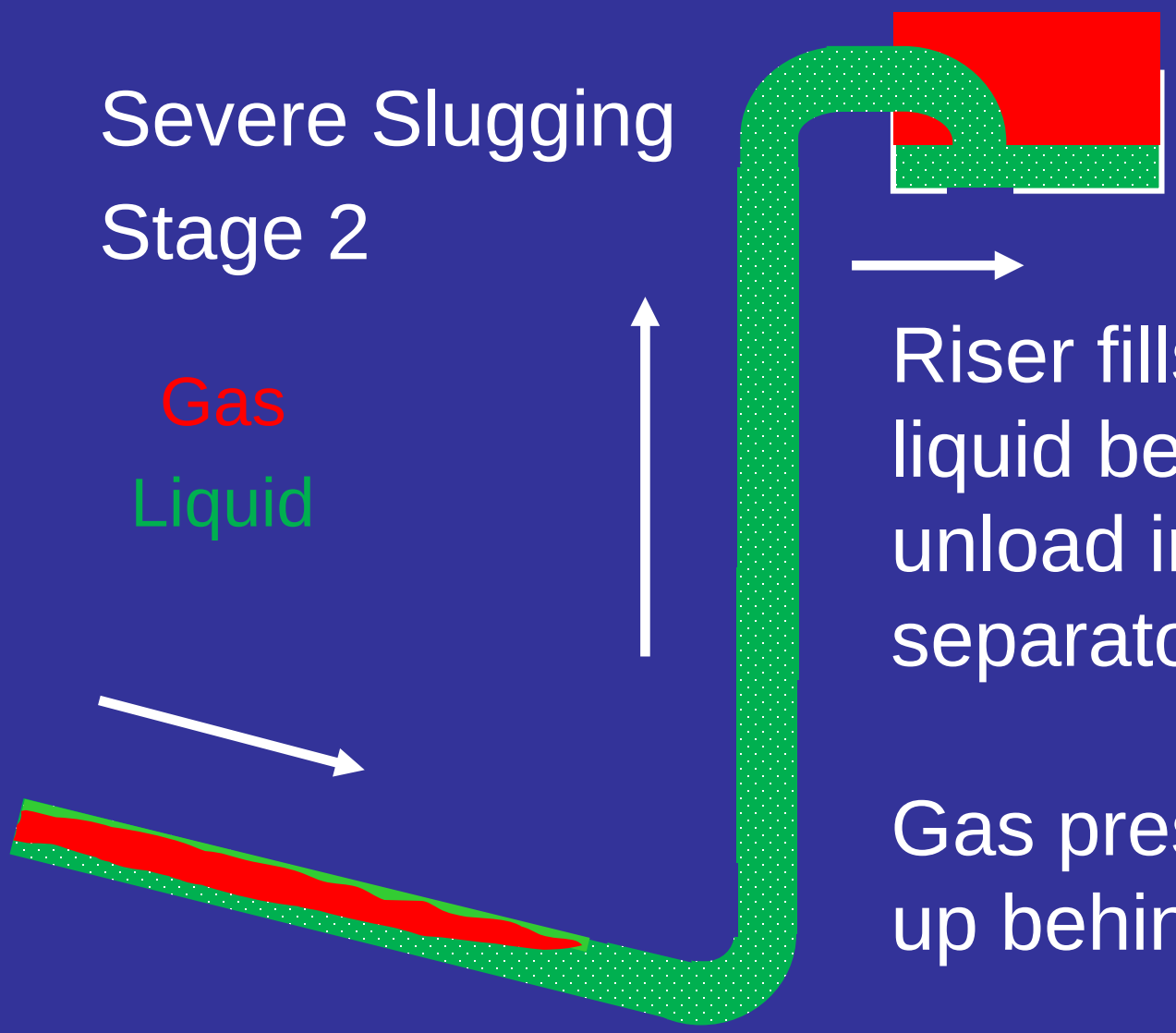
Terrain Induced Slug - Severe

Severe Slugging

Stage 2

Gas

Liquid



Riser fills, and liquid begins to unload into the separator

Gas pressure builds up behind slug!!!

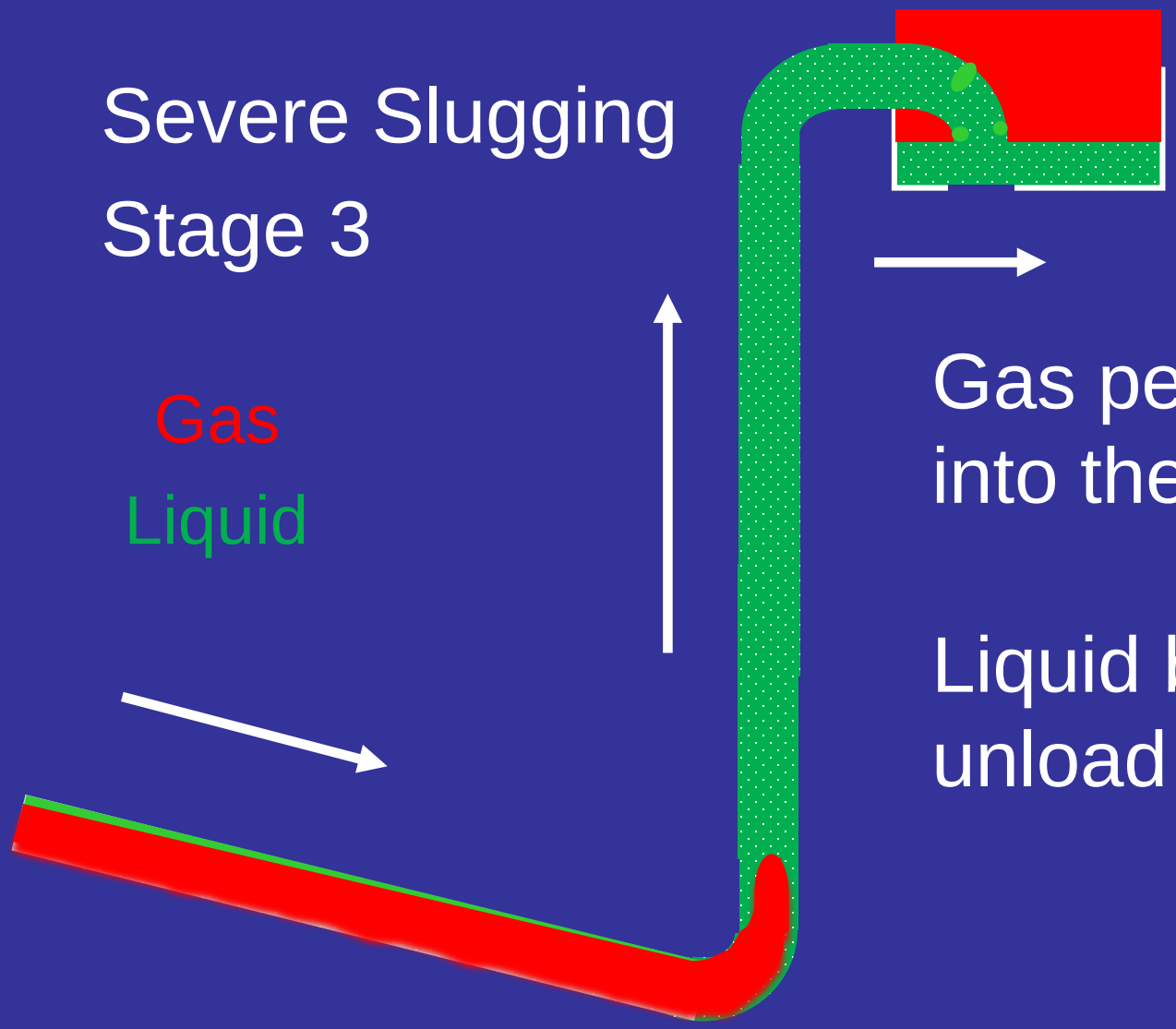
Terrain Induced Slug - Severe

Severe Slugging

Stage 3

Gas

Liquid



Gas penetrates into the riser

Liquid begins to unload rapidly

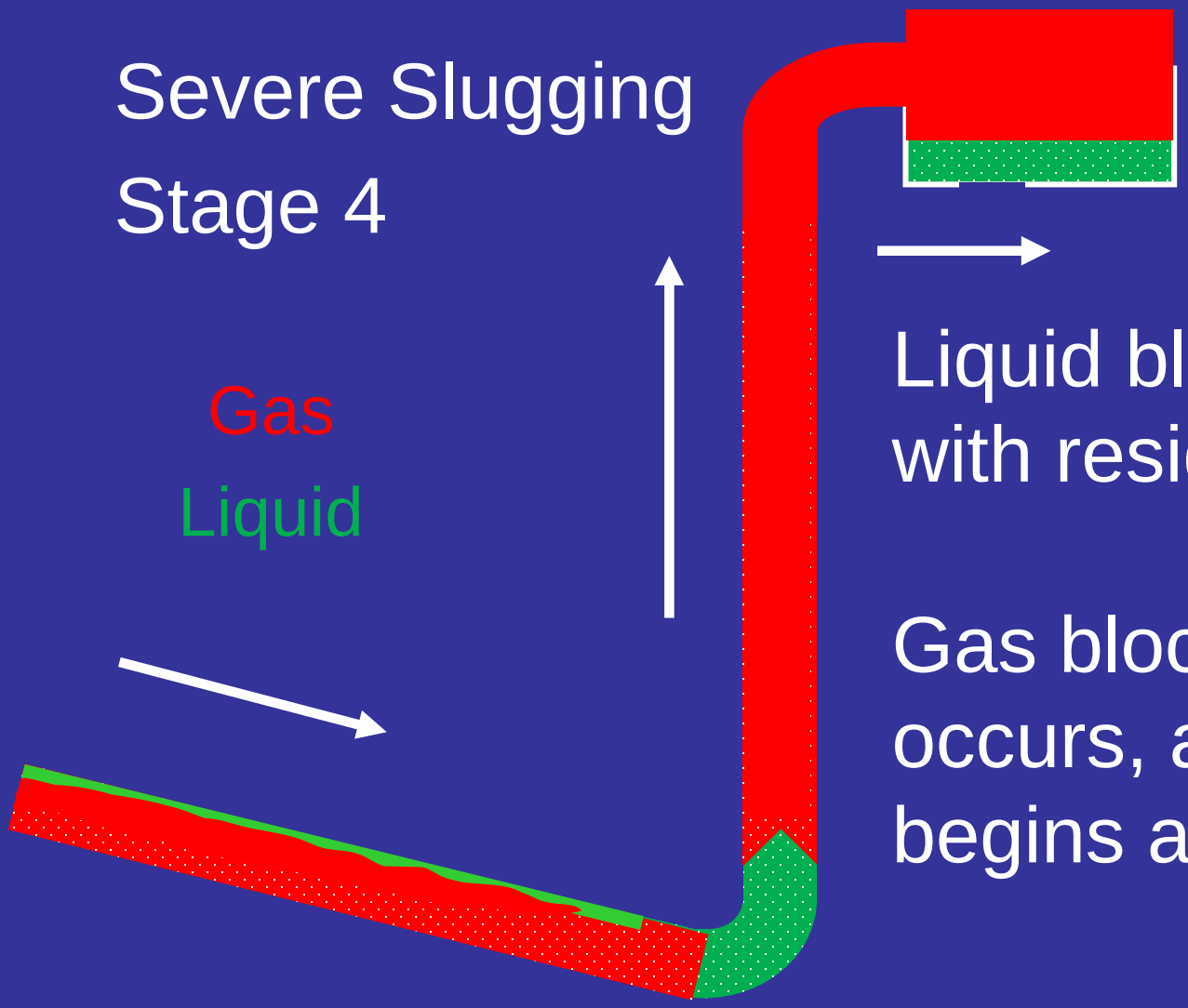
Terrain Induced Slug - Severe

Severe Slugging

Stage 4

Gas

Liquid



Liquid blows through with residual fallback

Gas blockage occurs, and cycle begins again

Terrain Induced Slug

Steady State Multiphase Software:

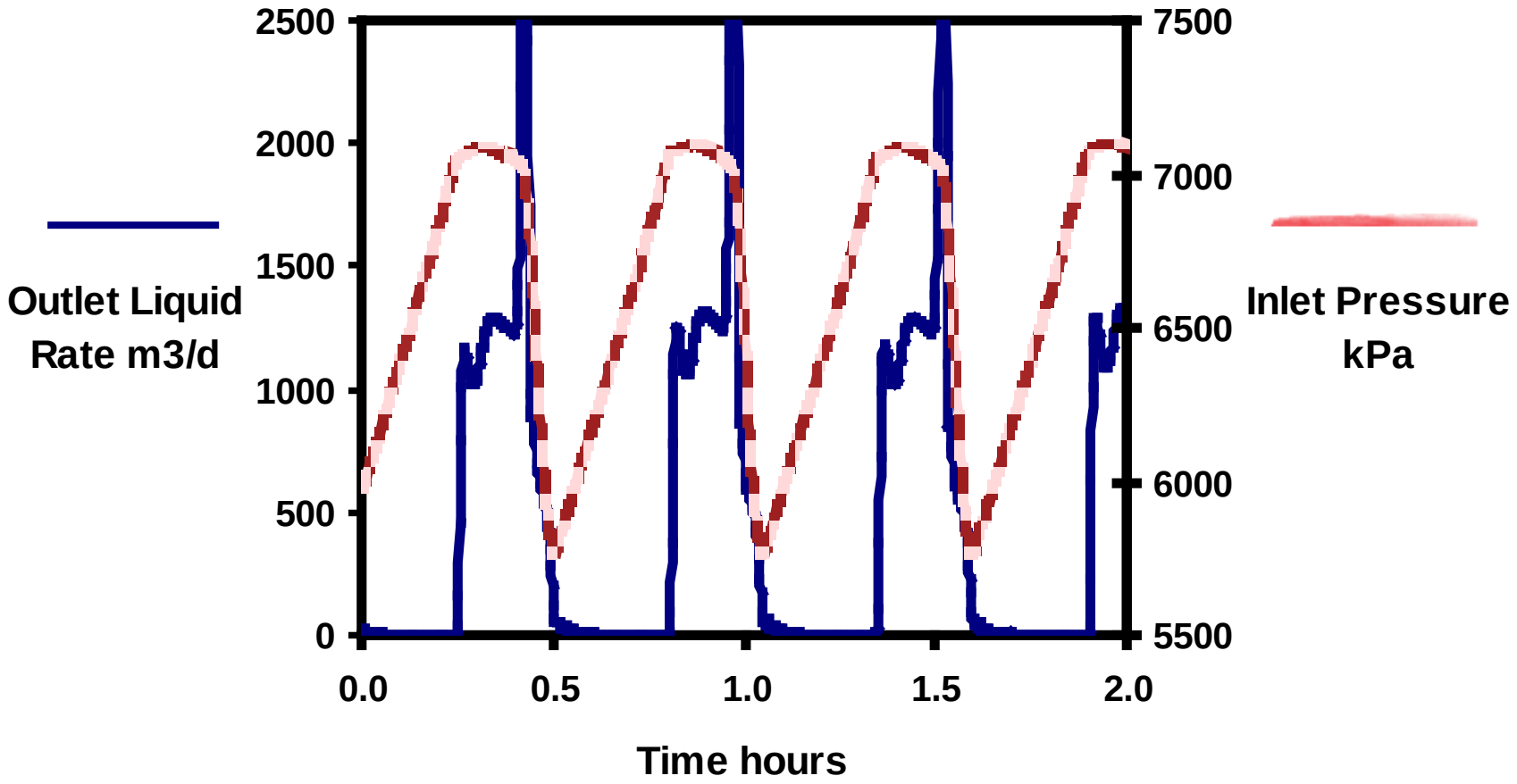
- Severe slugging: Fuchs and Pots correlations give contradictory results but Pots can give indication of potential severe slugging
- Cannot predict other terrain induced slugging
- Check for high liquid holdup in low spots and low liquid velocities

Terrain Induced Slug

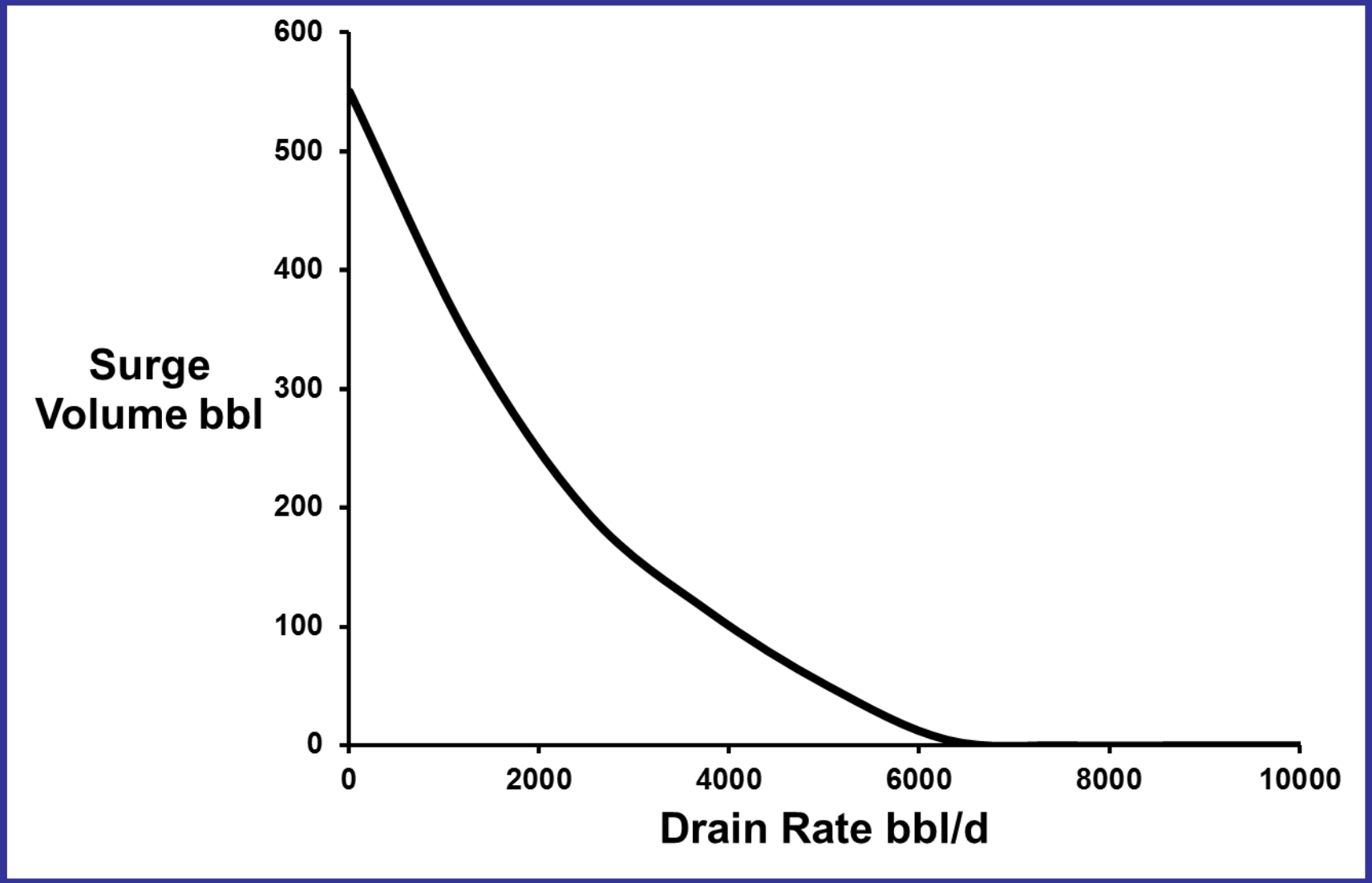
Use a Transient Multiphase Model to Determine:

- Whether terrain induced slugging will occur
- Length and size of slug
- Transit time of slug
- Frequency of slug
- Separator size required to handle the slug

Severe Slugging Liquid Flow Rate



Separator Size



Avoiding Terrain Induced Slugs

In Onshore Pipelines:

- Increase gas flow rates
- Decrease diameter

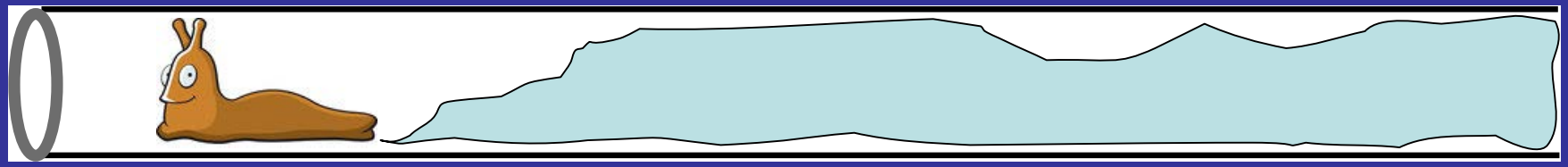
In Offshore Risers:

- Add riser base gas injection
- Increase backpressure

Turn Up Slugs

A Slug can be created by a Flow Rate change

.....

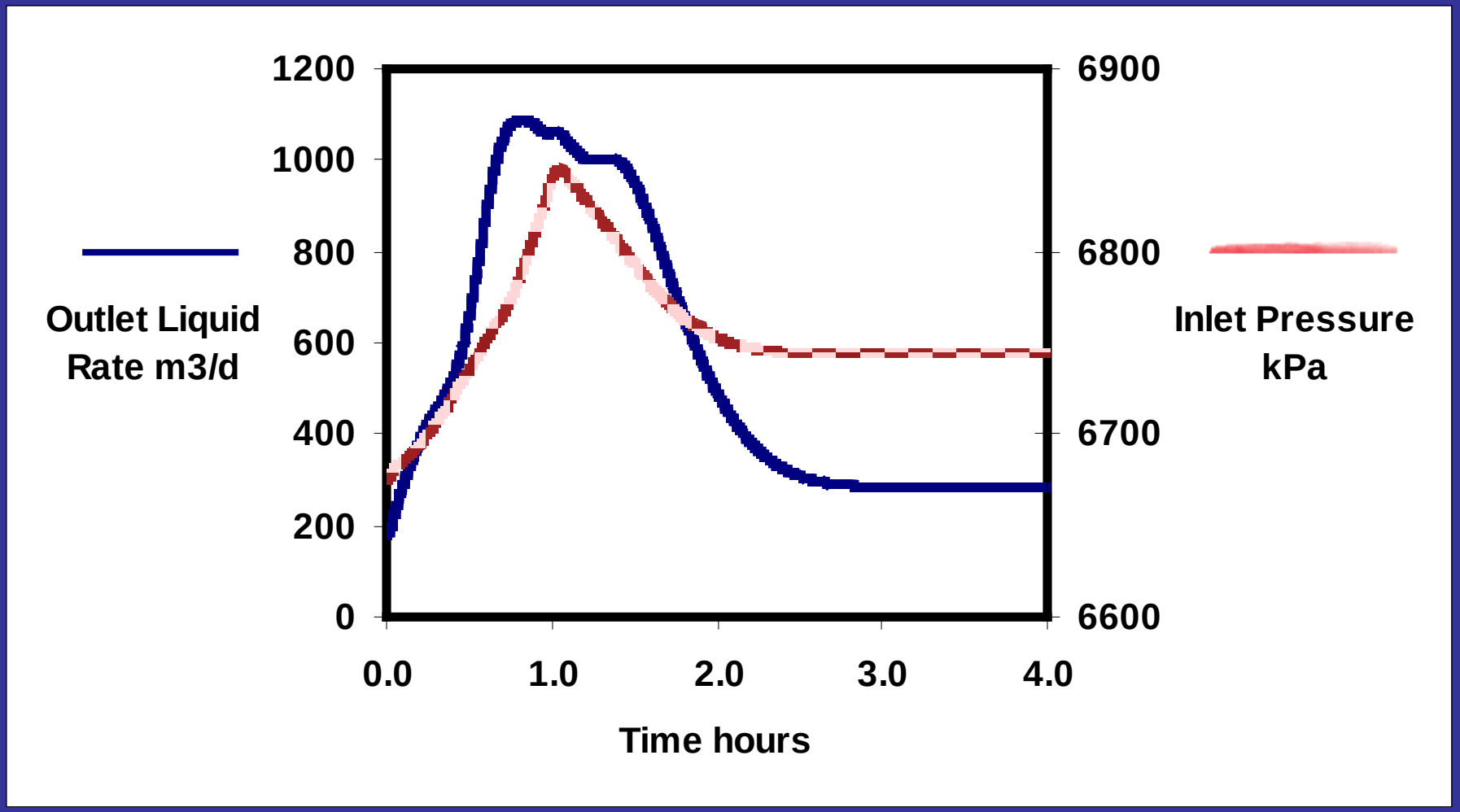


….. but only when it increases ……

Slug volume = difference between liquid holdup at 2 flow rates

Use transient model to rigorously model

Turn Up Slugs



Pigging Slugs

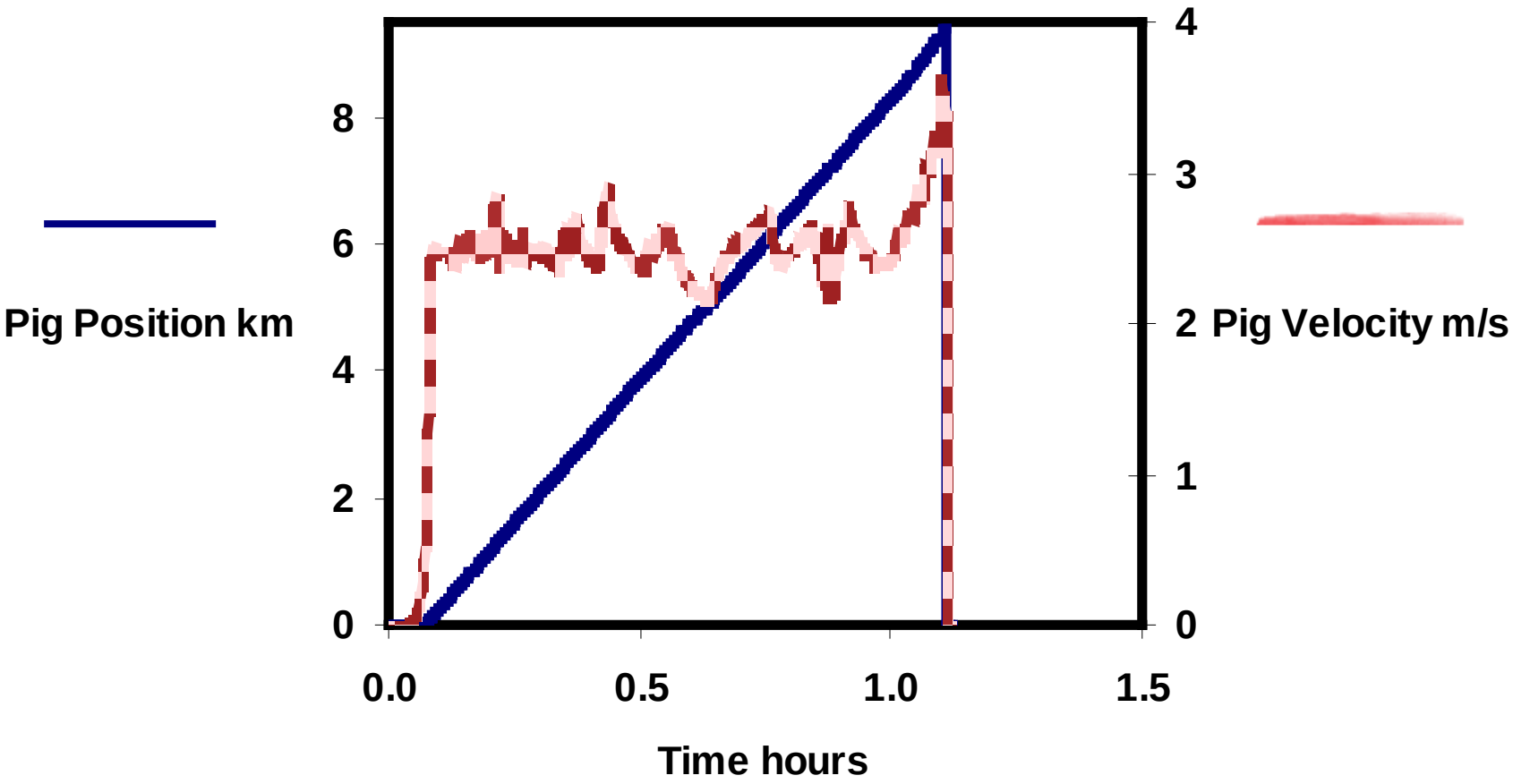
Slugs can be created by Pigging

.. but typically just one……

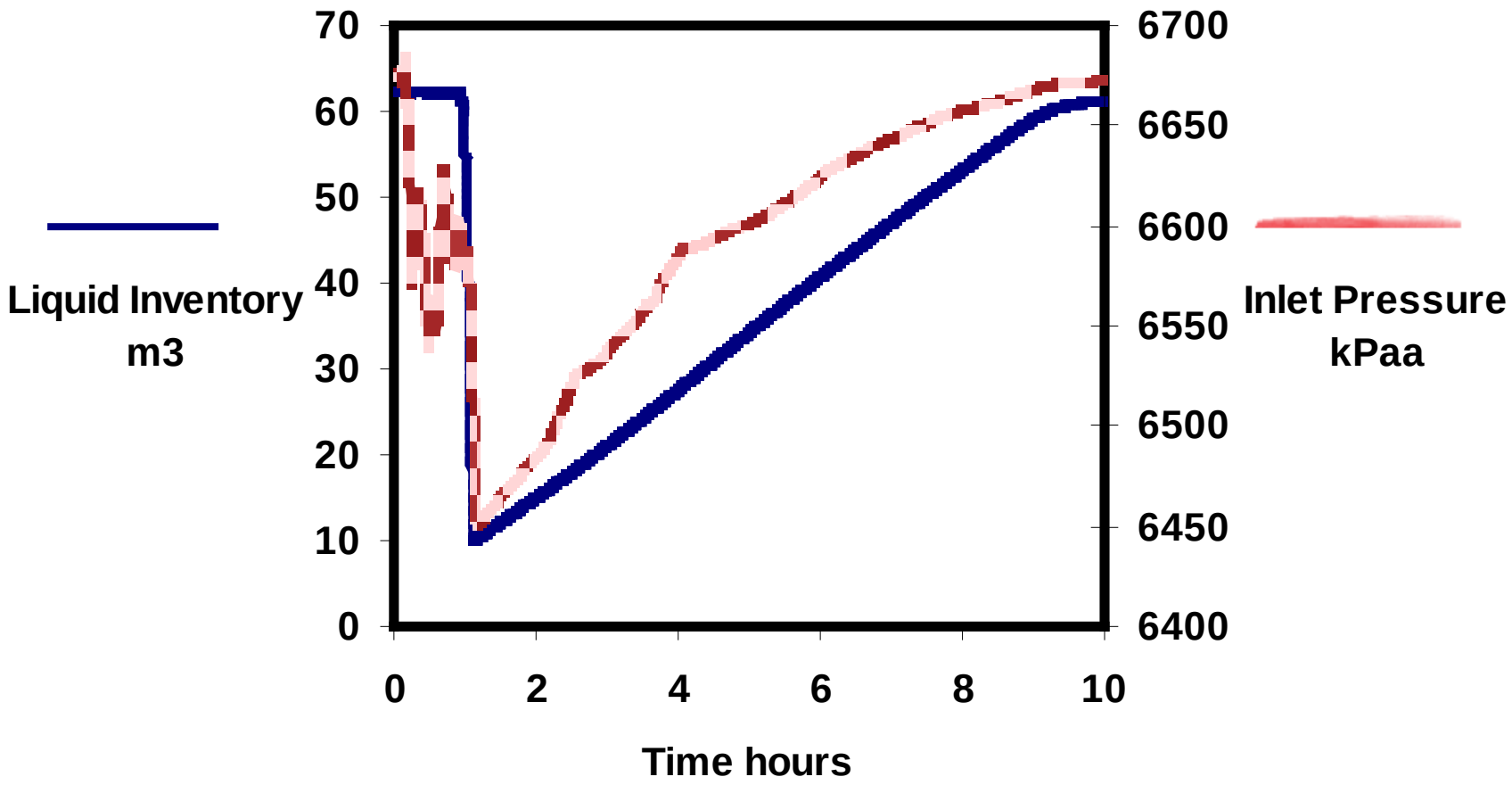
Slug volume = total liquid in pipe minus volume dumped into the separator during pig transit

Use transient multiphase model to accurately model pigging slug size and transit time

Pig Position and Pig Velocity

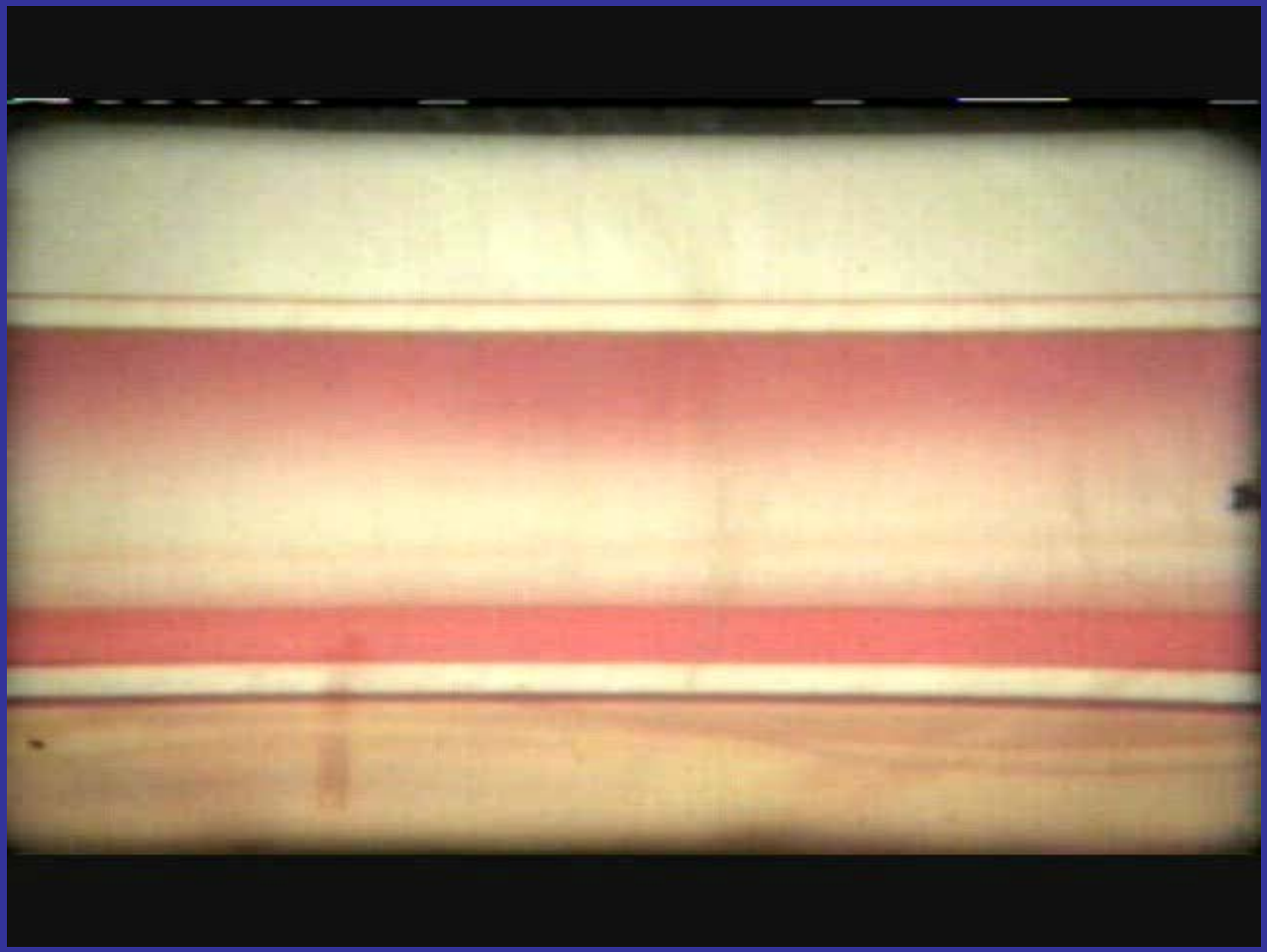


Liquid Inventory from Pigging



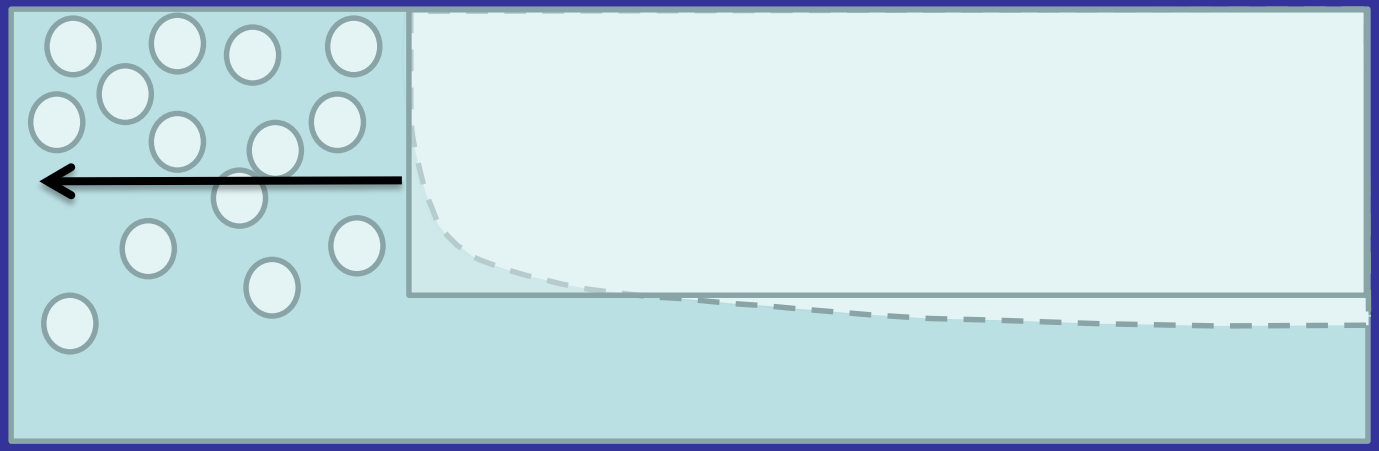
Slug Modelling: Where are We?

Slug Modelling: Where are We?



Slug Modelling: Where are We?

Mechanistic Models Use the "Unit Cell Model"



- Developed by Taitel in 1980's
- Liquid picked up from liquid film = liquid shed
- In mechanistic models now (OLGAS, XIAO)
- Accurate pressure gradients and holdup in fully developed slugs

Areas Currently Being Researched

- Flow pattern transition to / from slug flow in steady state
- More robust models for
  - Liquid holdup in liquid slug (gas entrainment)
  - Gas velocity in liquid slug (turbulence within the liquid slug)
  - Liquid holdup in elongated bubble
  - Liquid slug translational velocity

Conclusions

- Define what you mean by “slugging”
  - hydrodynamic
  - terrain induced
  - turn up
  - pigging
- Transient modelling provides additional information
- Mechanistic modelling of slug flow understood but still actively being researched and improved

Acknowledgements

- Dr. Garry Gregory and Dr. Khalid Aziz
  - For creating the multiphase video at the University of Calgary
  - For the images for severe slugging and slug flow
- Pablo Adames, Schlumberger
  - For updates on the current state of slug research and parsing the multiphase video
- Schlumberger for sponsoring
  - My time, visas, inoculations and hotels

Distinguished Lecturer Program

Your Feedback is Important

- Enter your section in the DL Evaluation Contest by completing the evaluation form for this presentation
- http://www.spe.org/dl/

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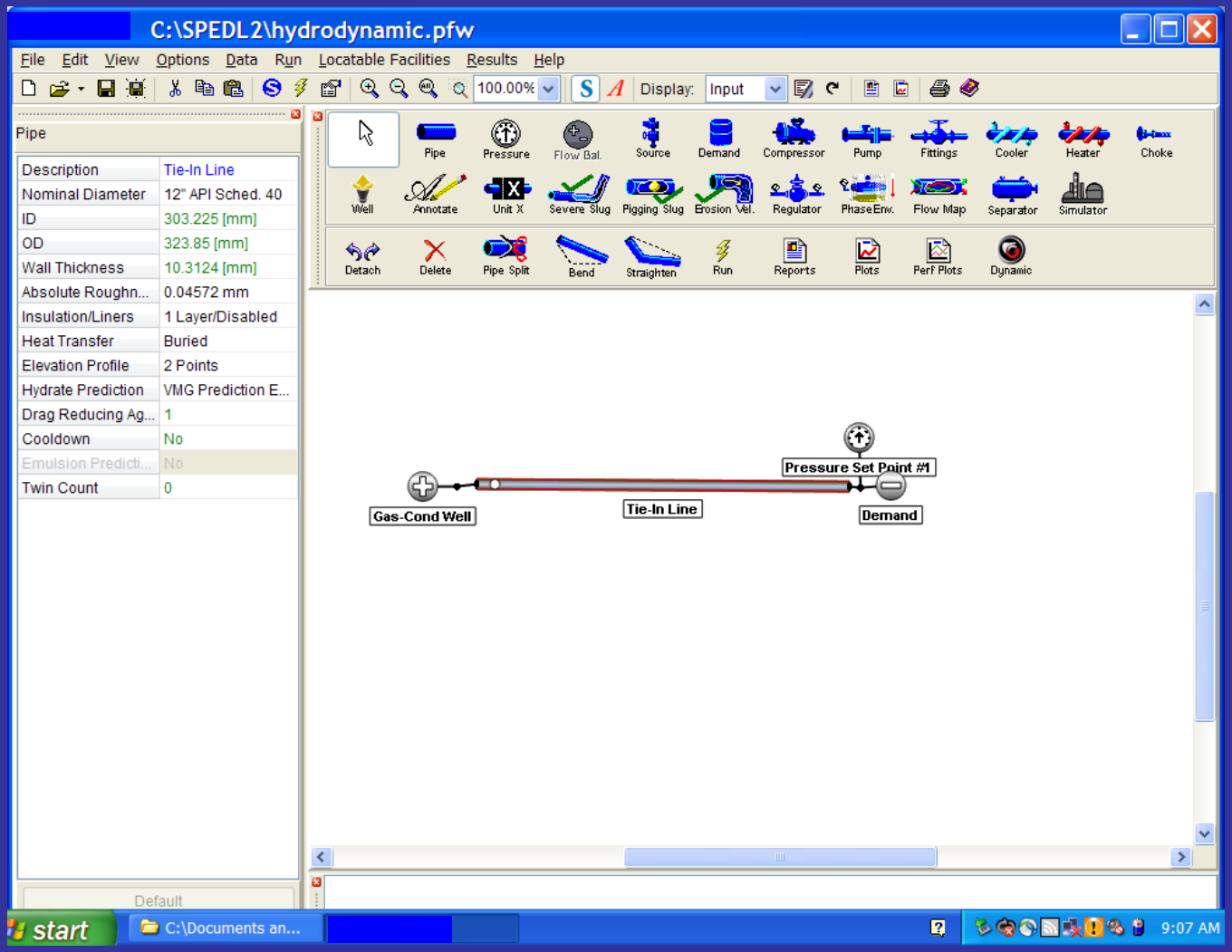
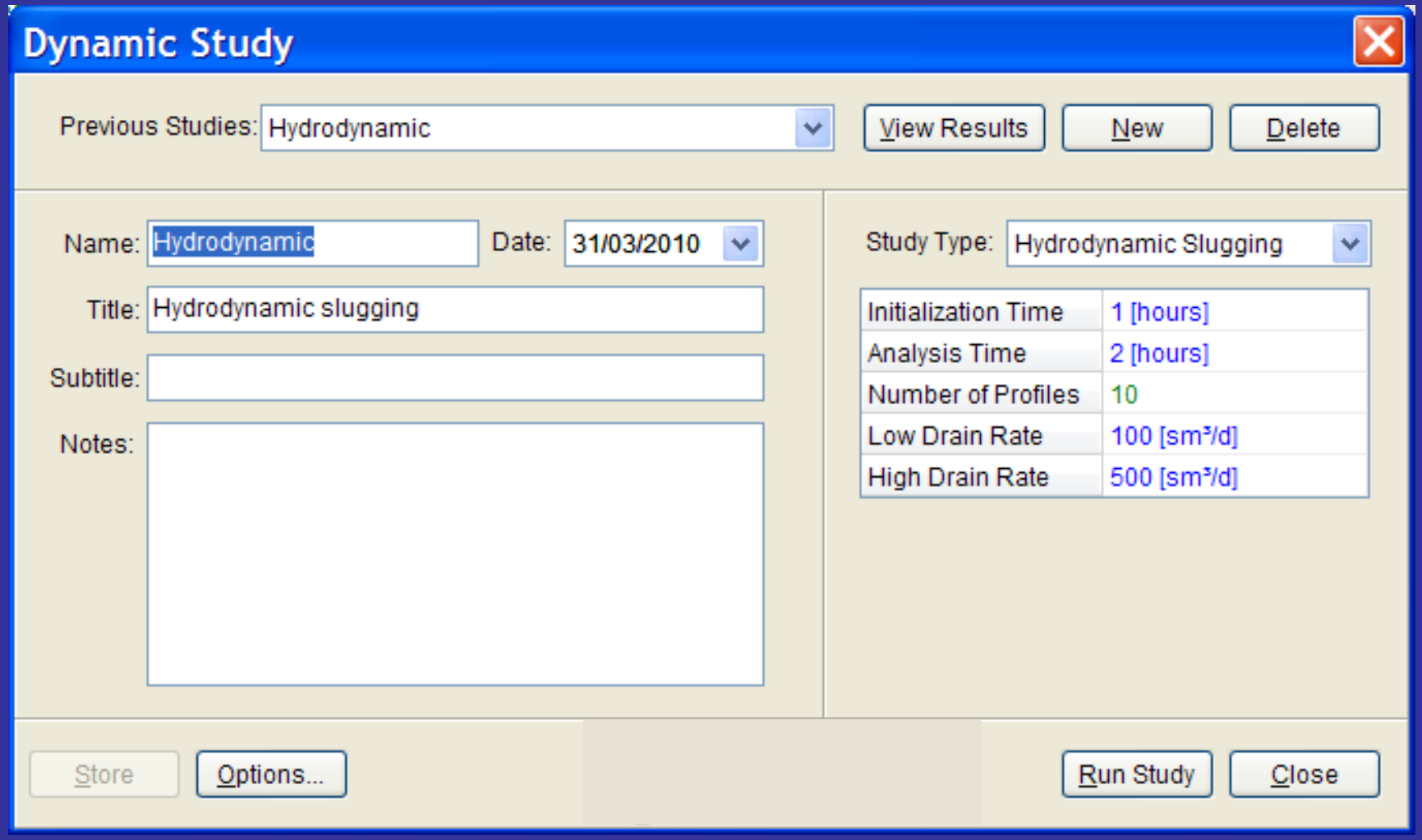
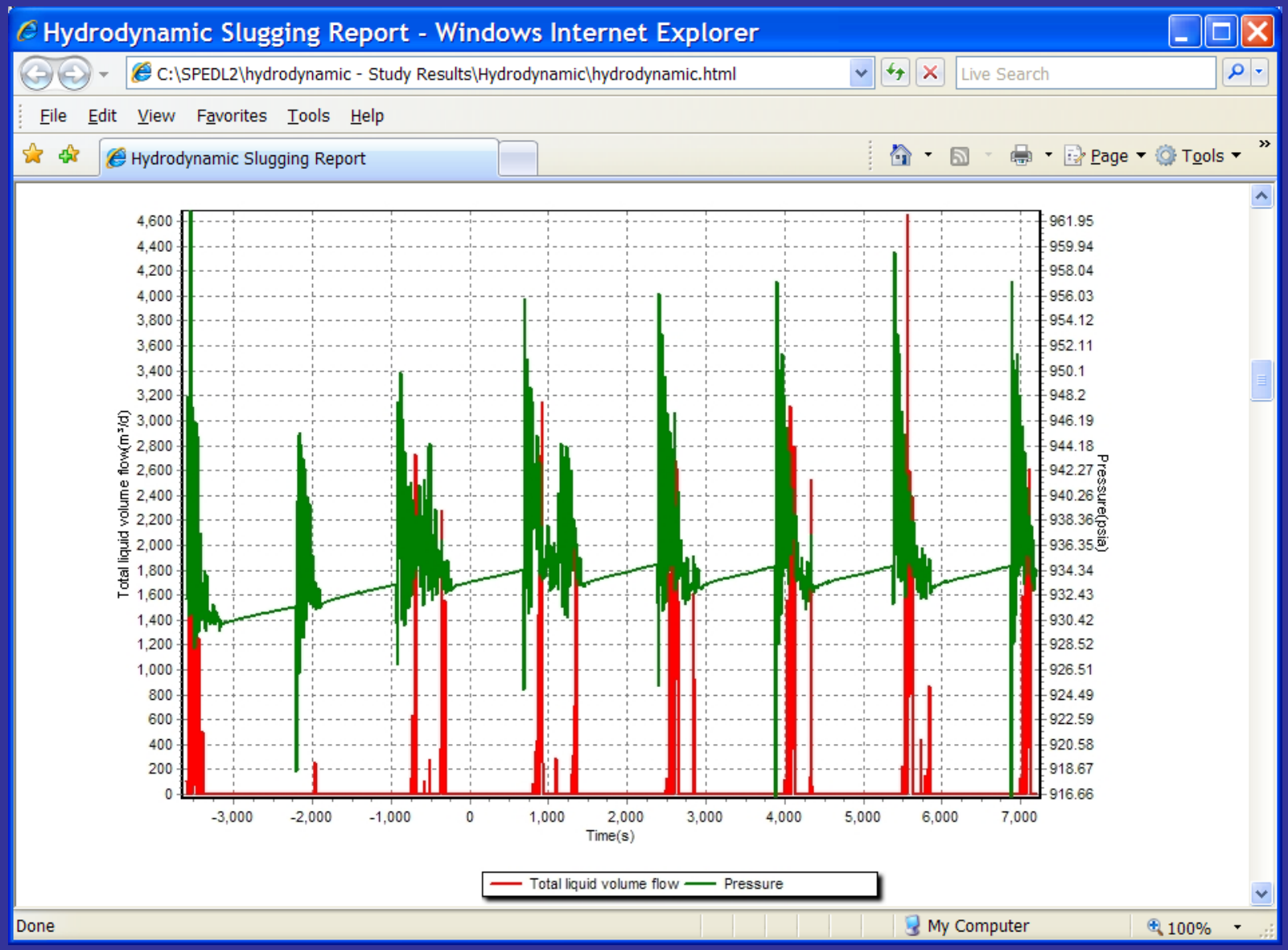
Hydrodynamic Slugging: Steady State



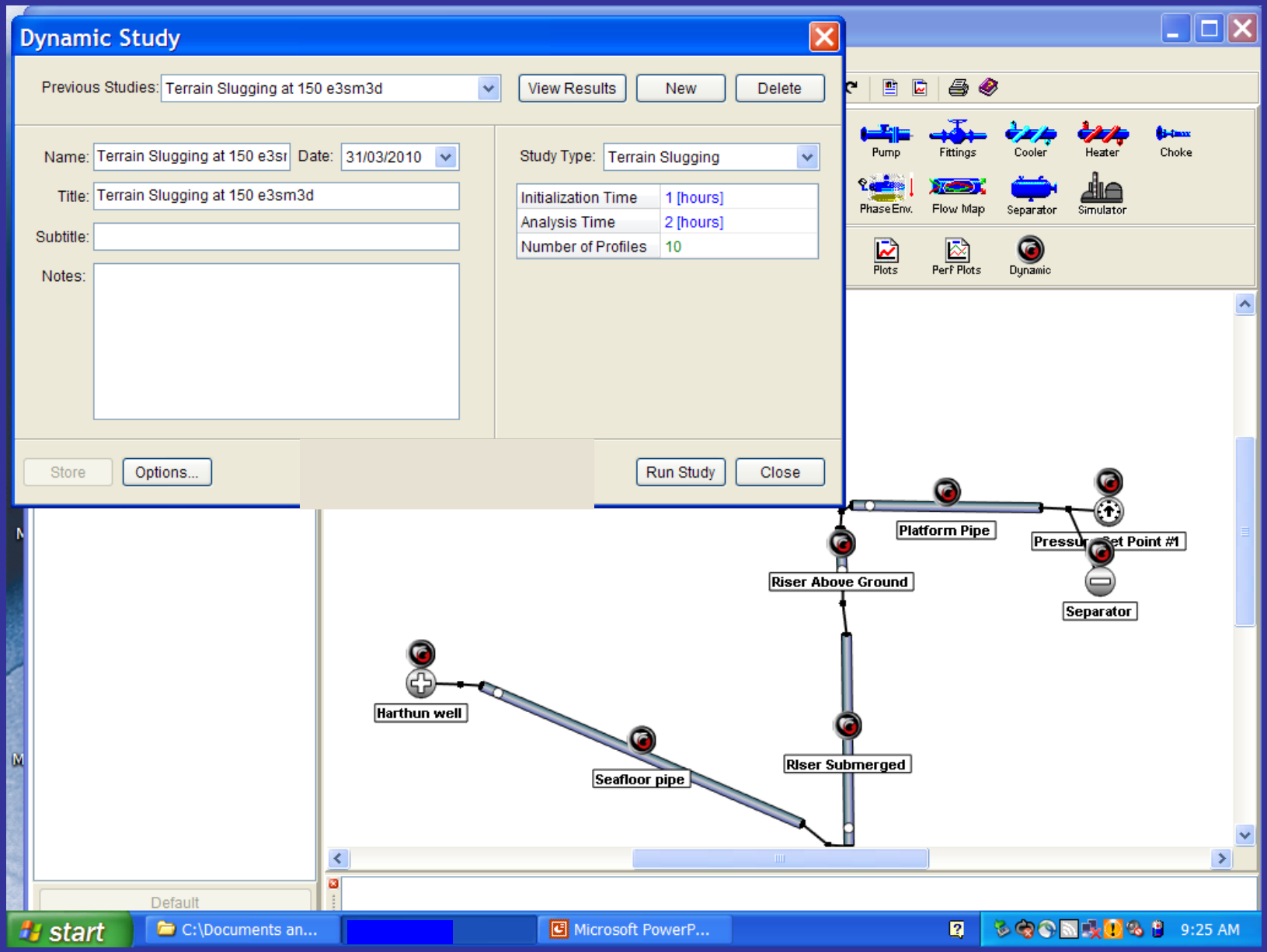
Hydrodynamic Slugging: Transient



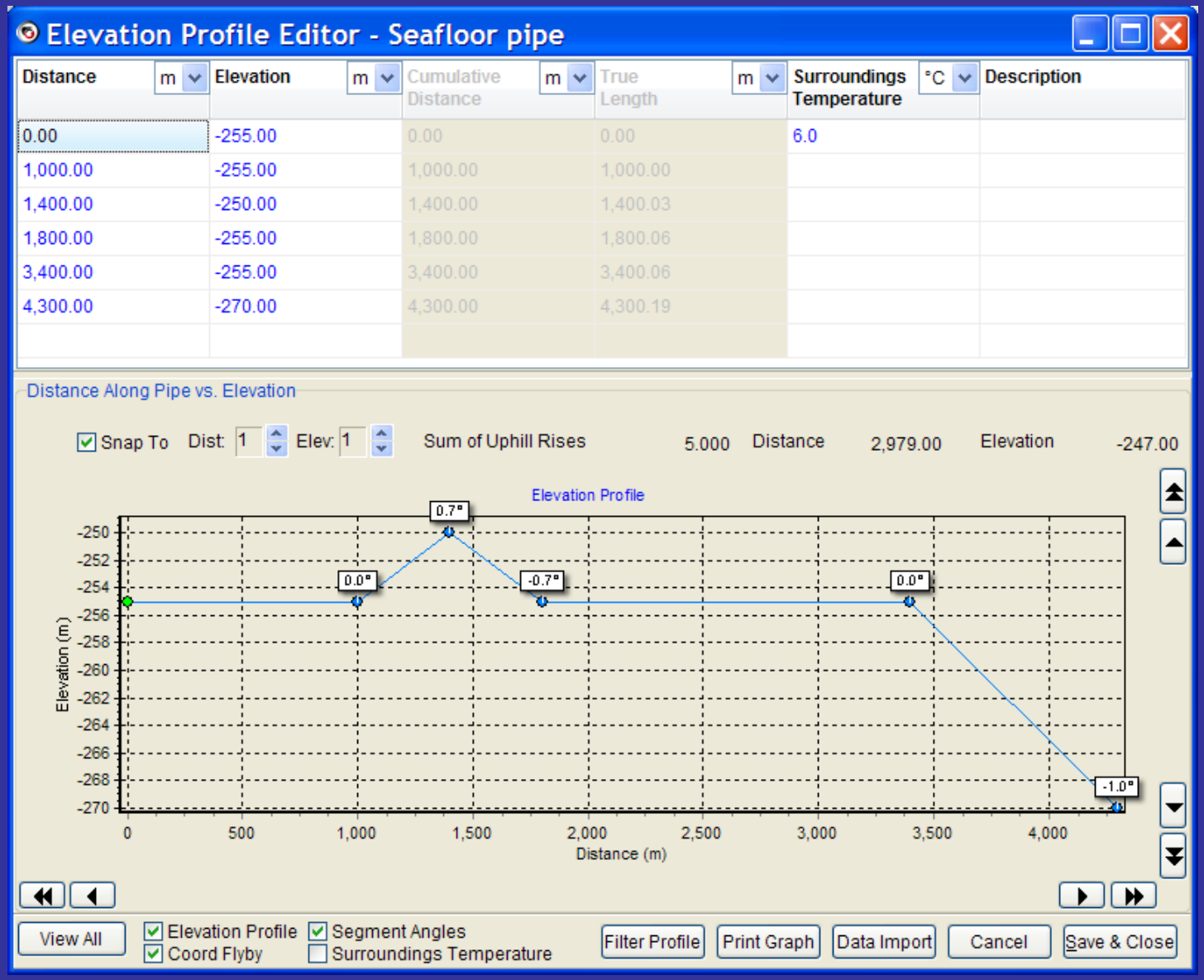
Hydrodynamic Slugging: Transient



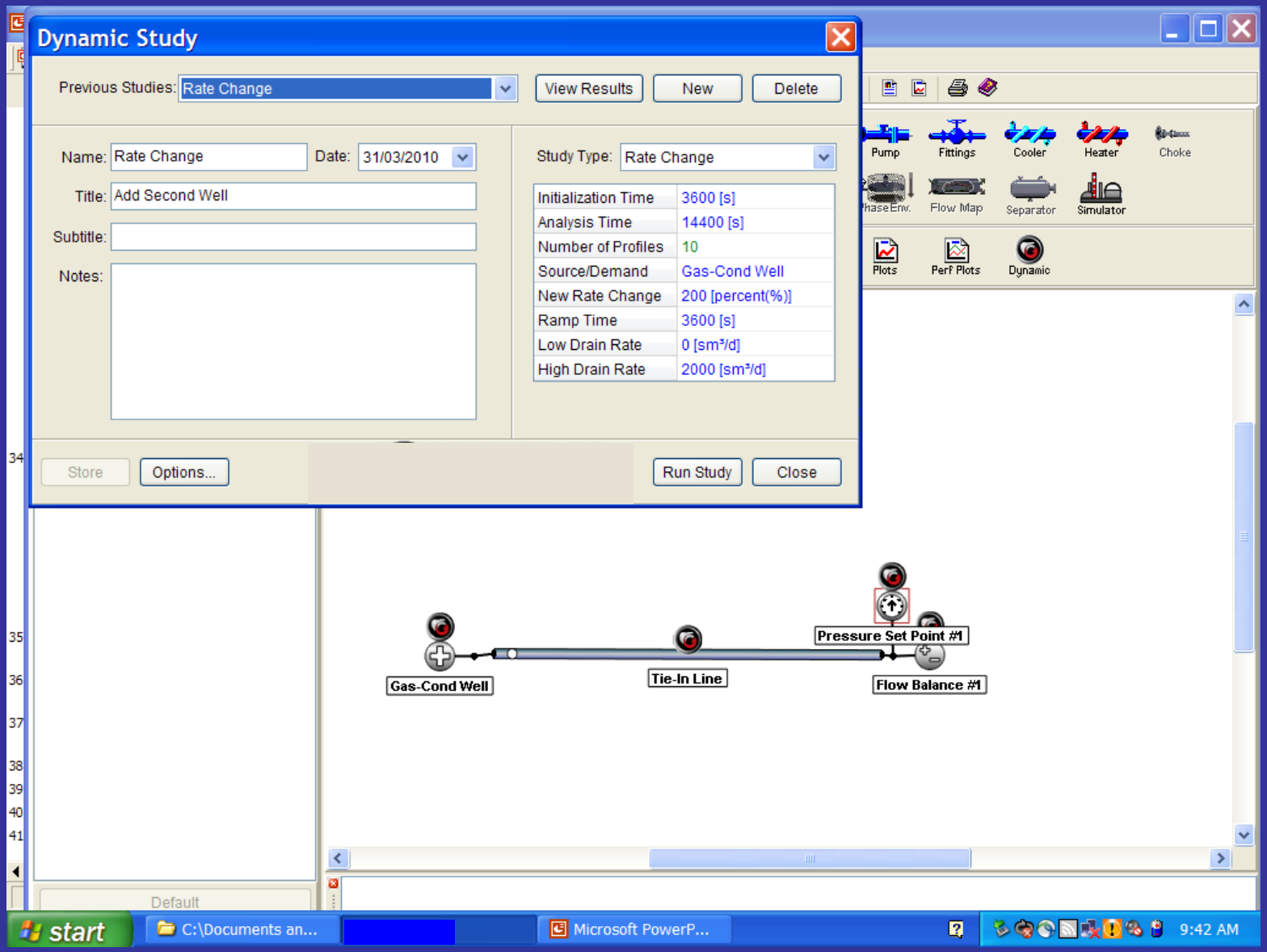
Terrain Induced Slugging



Terrain Induced Slugging



Turn Up


Dynamic Study
Previous Studies: Rate Change
View Results
New
Delete
Name: Rate Change
Date: 31/03/2010
Title: Add Second Well
Subtitle:
Notes:
Study Type: Rate Change
Initialization Time 3600 [s]
Analysis Time 14400 [s]
Number of Profiles 10
Source/Demand Gas-Cond Well
New Rate Change 200 [percent(%)]
Ramp Time 3600 [s]
Low Drain Rate 0 [sm³/d]
High Drain Rate 2000 [sm³/d]
Store
Options...
Run Study
Close
Pump
Fittings
Cooler
Heater
Choke
Flow Map
Separator
Simulator
Plots
Perf Plots
Dynamic
Pressure Set Point #1
Gas-Cond Well
Tie-In Line
Flow Balance #1
Default
start
C:\Documents an...
Microsoft PowerP...
9:42 AM

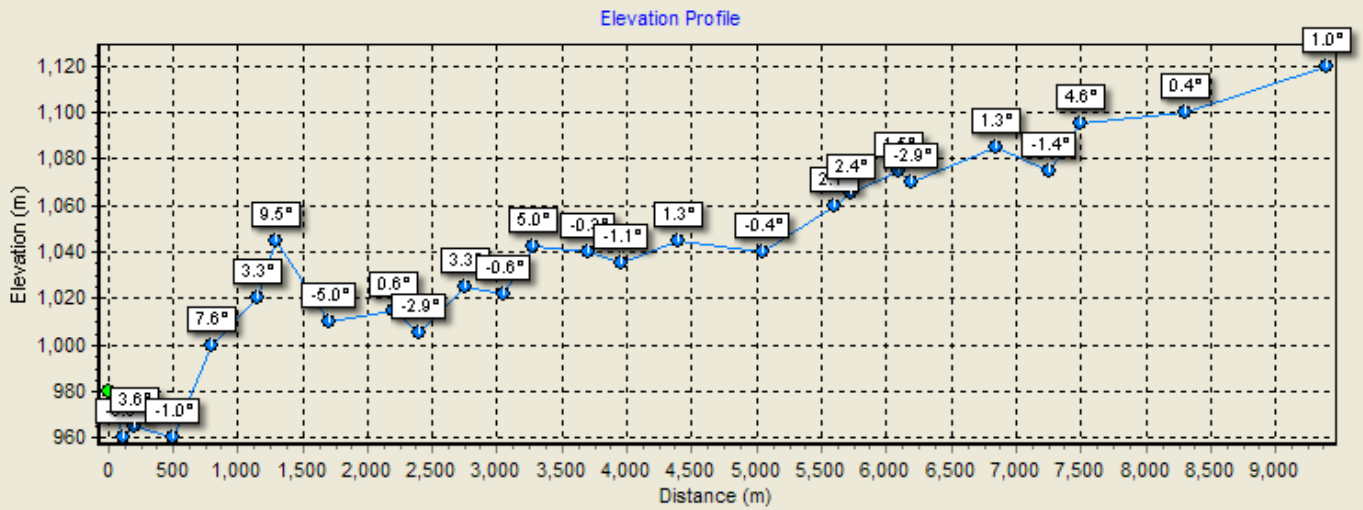
Turn Up: Elevation Profile

Elevation Profile Editor - Tie-In Line

Distance (m)	Elevation (m)	Cumulative Distance (m)	True Length (m)	Surroundings Temperature (°C)	Description
0.00	980.00	0.00	0.00	4.0	
120.00	960.00	120.00	121.66	4.0	
200.00	965.00	200.00	201.81	4.0	
500.00	960.00	500.00	501.85	4.0	
800.00	1,000.00	800.00	804.51	4.0	
1,150.00	1,020.00	1,150.00	1,155.08	4.0	
1,200.00	1,045.00	1,200.00	1,207.15	4.0	

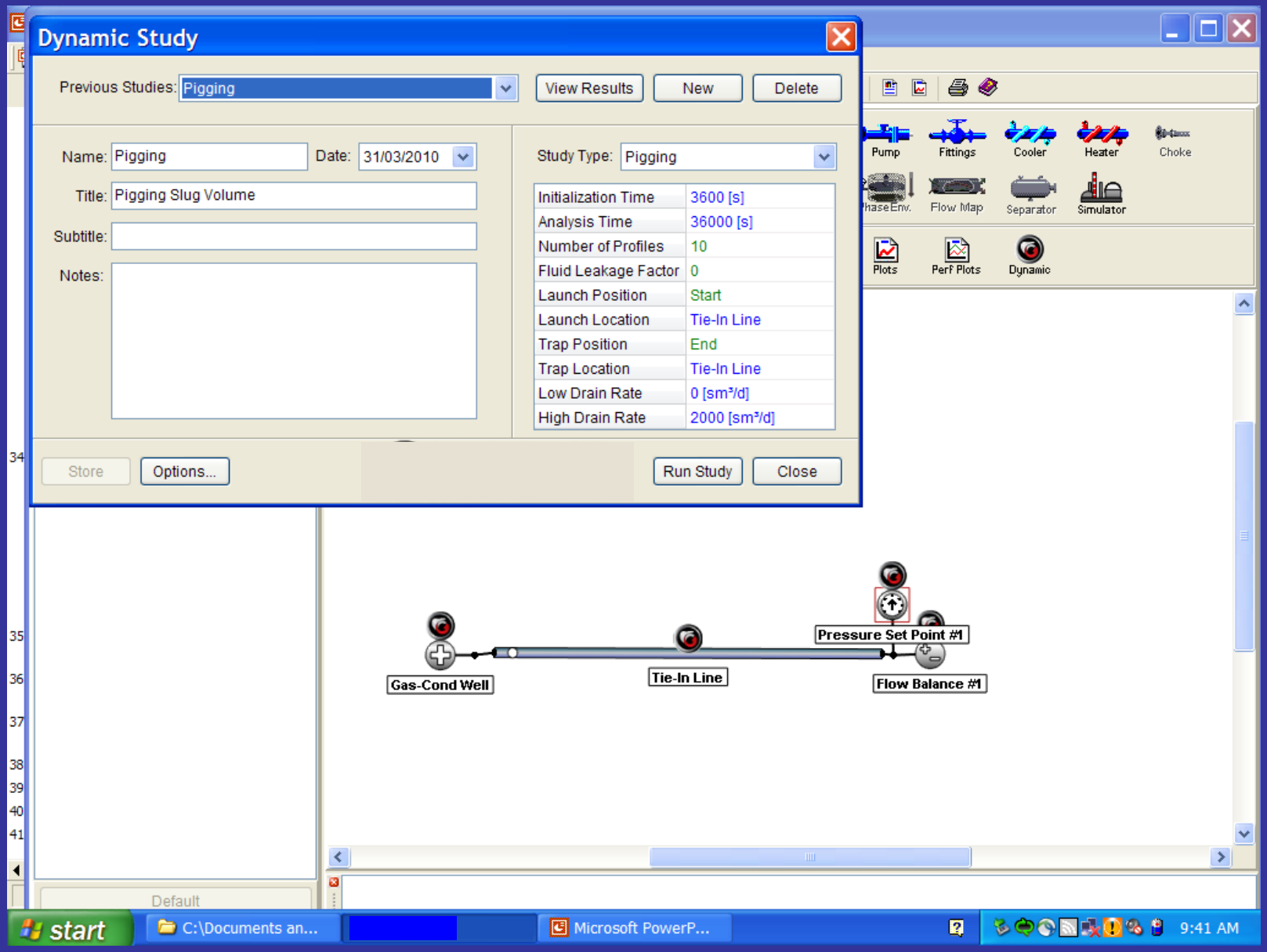
Distance Along Pipe vs. Elevation

Snap To Dist: 1 Elev: 1 Sum of Uphill Rises 240.000 Distance Elevation



View All | Elevation Profile | Segment Angles | Coord Flyby | Surroundings Temperature | Filter Profile | Print Graph | Data Import | Cancel | Save & Close

Pigging


Dynamic Study
Previous Studies: Pigging
View Results
New
Delete
Name: Pigging
Date: 31/03/2010
Title: Pigging Slug Volume
Subtitle:
Notes:
Study Type: Pigging
Initialization Time 3600 [s]
Analysis Time 36000 [s]
Number of Profiles 10
Fluid Leakage Factor 0
Launch Position Start
Launch Location Tie-In Line
Trap Position End
Trap Location Tie-In Line
Low Drain Rate 0 [sm³/d]
High Drain Rate 2000 [sm³/d]
Store
Options...
Run Study
Close
Pump
Fittings
Cooler
Heater
Choke
Flow Map
Separator
Simulator
Plots
Perf Plots
Dynamic
Gas-Cond Well
Tie-In Line
Pressure Set Point #1
Flow Balance #1
Default
start
C:\Documents an...
Microsoft PowerP...
9:41 AM