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OIL STATES Energy Services

Potential Effects of Water Hammer Pulses on Sand Transport

Flow Loop Tests &
Numerical Simulation

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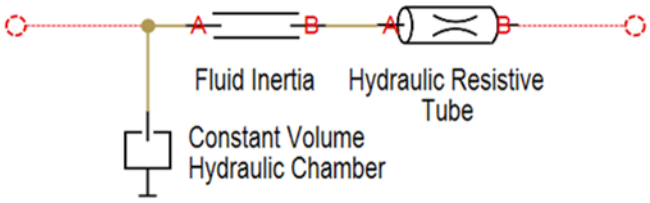
Sand Transport Test

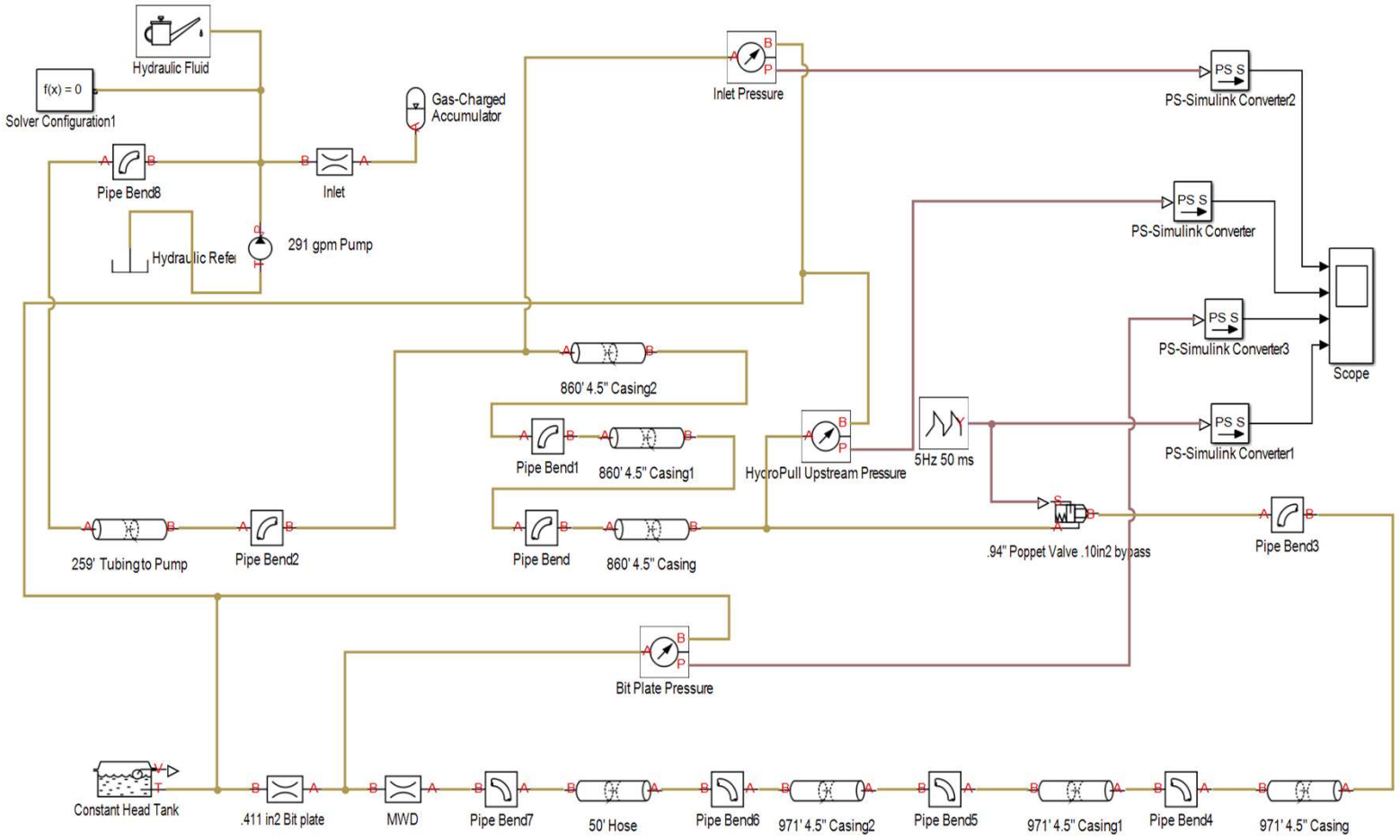
Water Hammer Pulse Propagation Test

- 2000-m x 4.5” flow loop
  - Water Hammer Valve at 786 m

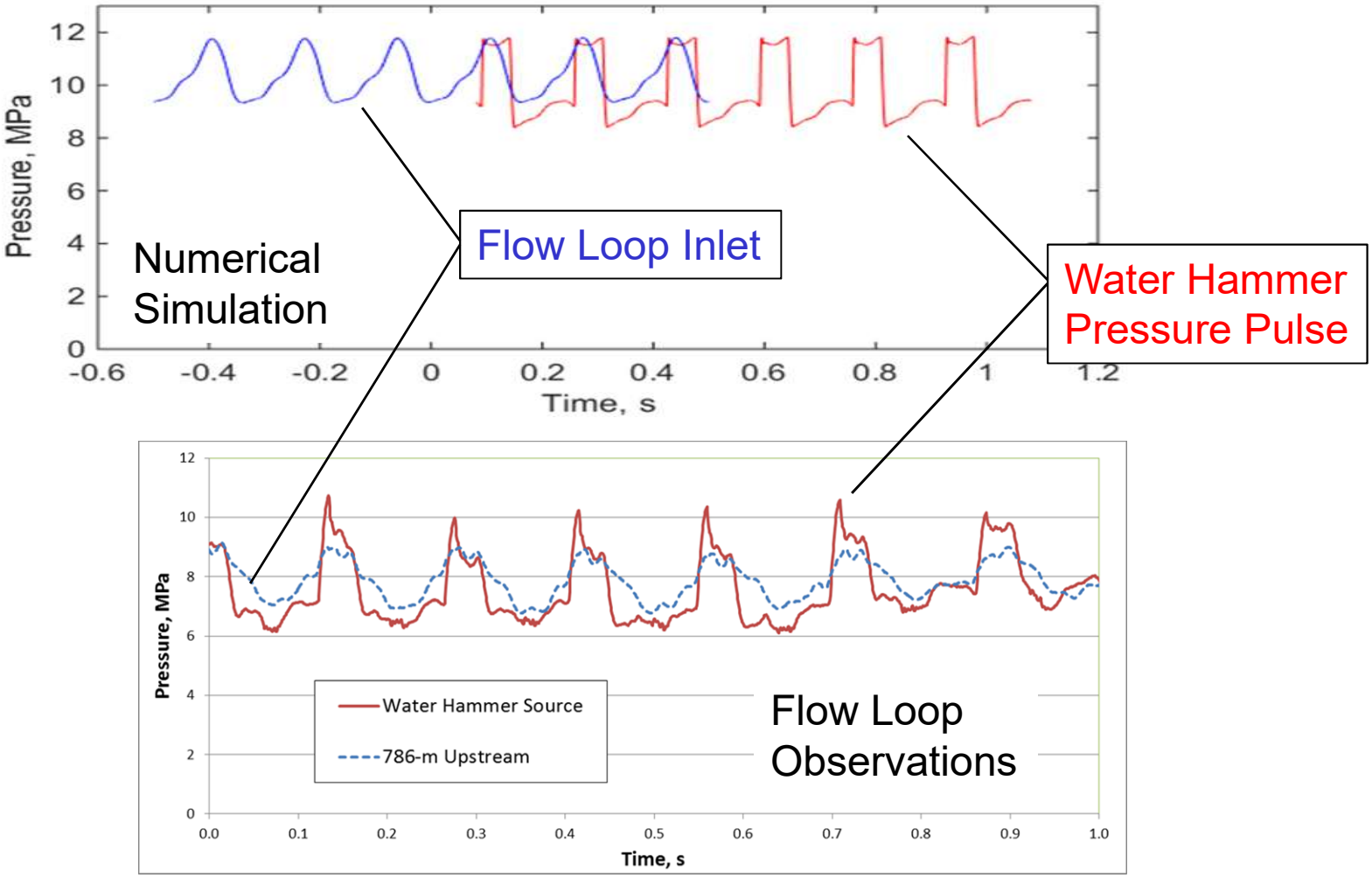
- Object-oriented hydraulic simulation with lumped parameter pipeline elements
  - 300 elements/1000m



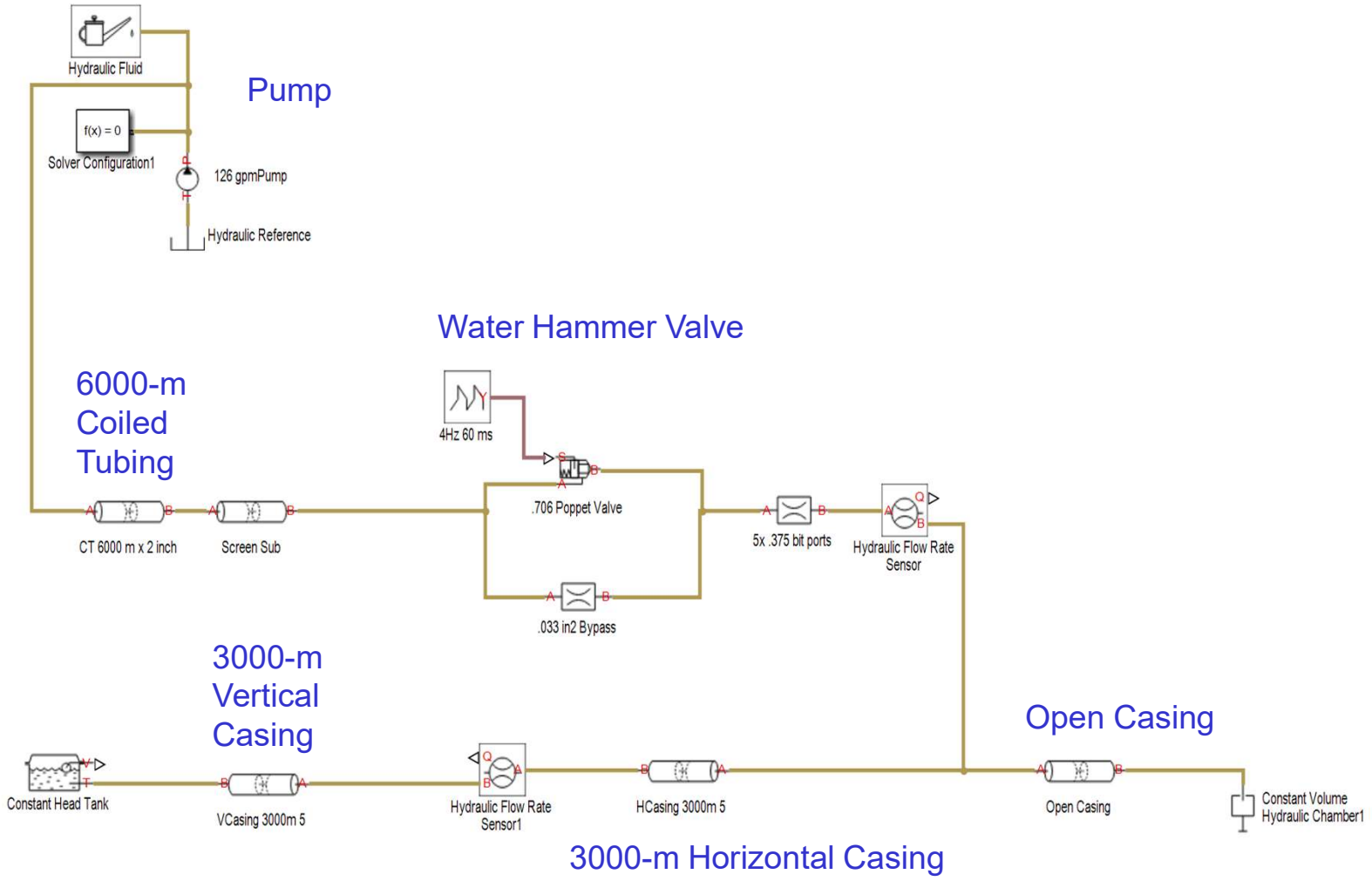
Flow Loop Simulation Model



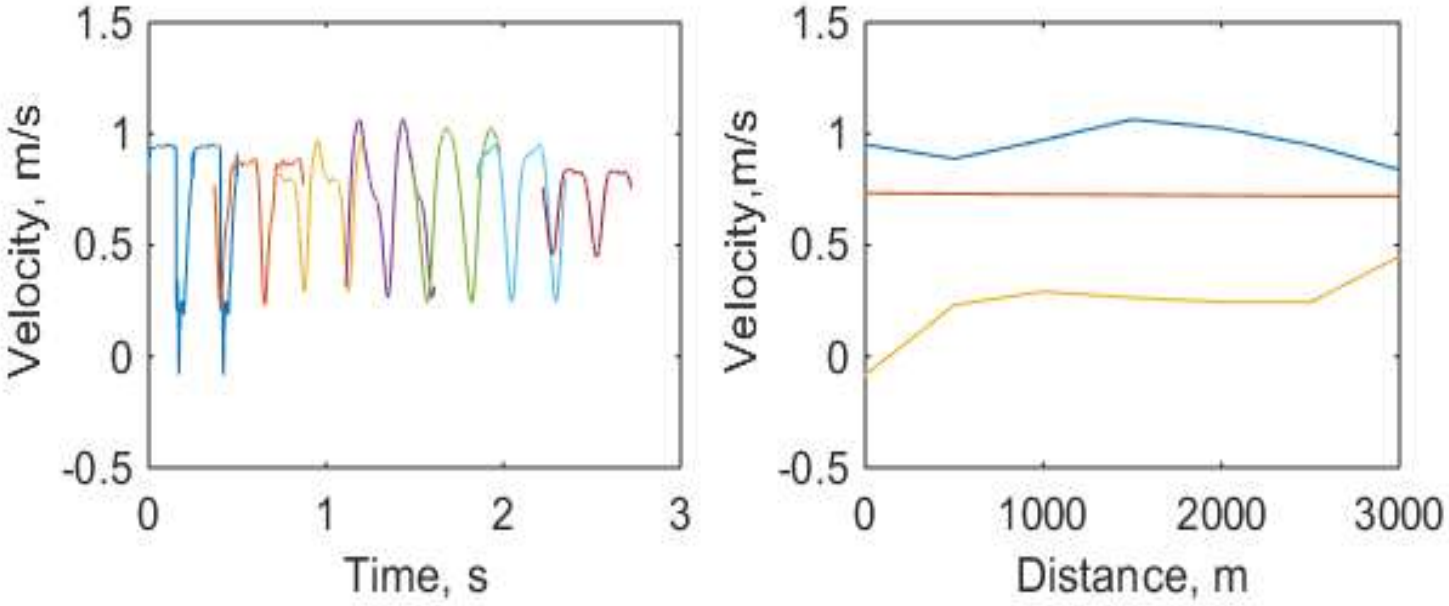
Good Agreement Between Simulation and Observations



CT in Casing Simulation Model



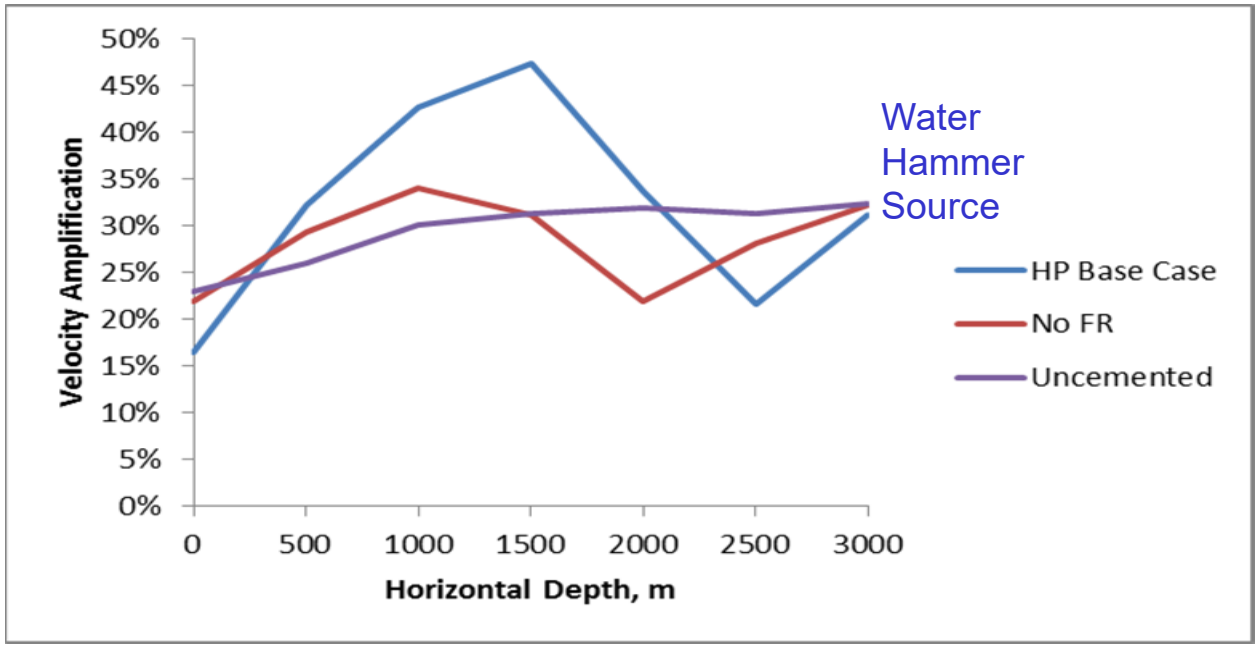
Annular Velocity Pulse



Time and distance from water hammer source

Velocity Amplification

- 20% to 45% increase in peak velocity relative to mean
  - 3.4 to 4.0 bpm peak flow at 2.8 bpm pump rate
- Cemented well with friction reducer (FR), no openhole
  - Amplification is smaller if casing is uncemented or if FR is not run



Conclusions

- Water hammer flow velocity amplification is significant if the mean flow is marginal
- Low frequency (4 Hz) pulses do not decay over 1000s of meters
  - Flow pulses are long – over 300-m
- Velocity amplification varies along the well
- Pulses should be observed at the wellhead