



**LOCAL HYDRODYNAMICS EFFECTS IN NARROW
AND SHALLOW CHANNELS. ITS IMPORTANCE IN
DESIGN AND TRAINING**

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Features



+25 years



**2.000
projects**



62 countries



30 people



PYME INNOVADORA
Válido hasta el 06 de noviembre de 2027



Maritime Simulation Center - Maritime Training Provider - DNV



2.000 seafarers



**800 training
programmes**



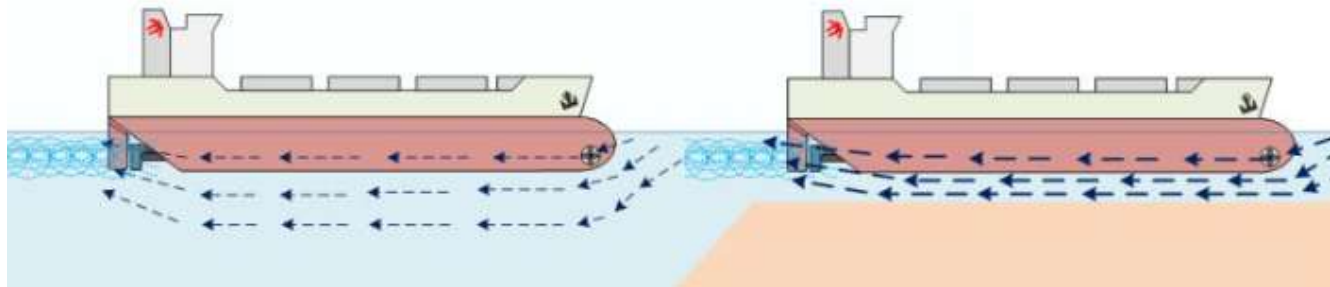
**60 international
shipping companies**





1. Introduction

- ▶ Growing challenge: Larger vessels navigating confined and shallow waterways face complex hydrodynamic effects (squat, piston effect, blockage)
- ▶ Key parameter: Water depth-to-draught ratio (H/T) crucially influences manoeuvring performance, especially as $H/T < 1.5$.
- ▶ Safety impact: Shallow and narrow conditions affect resistance, manoeuvring forces, and operational safety.
- ▶ Objective of the study: Develop and validate numerical models and real-time simulations (with pilot expertise) to support safe manoeuvring in constrained areas with realistic effects.

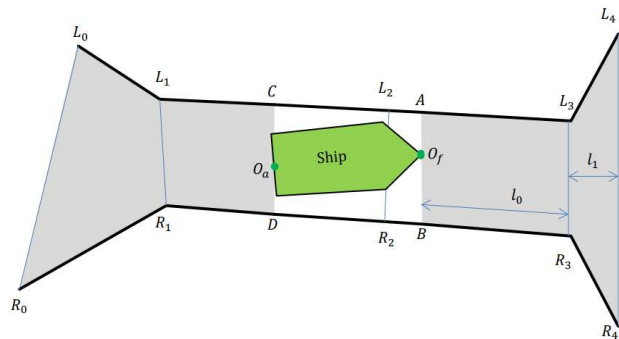




2. Methodology

Canal Geometry and Hydrodynamic Effects (Piston Effect)

- ▶ Key Hydrodynamic Effects in Narrow Canals
 - ▶ Vessel movement + lateral & depth restriction → Counter-current (piston effect)
 - ▶ Blockage effect → ↑ Hydrodynamic Resistance → ↓ Speed
- ▶ Importance of Canal Geometry
 - ▶ Canal geometry determines water flow restrictions around the vessel
- ▶ Calculation Approach
 - ▶ Geometry parameters
 - ▶ Numerical integration of submergence and width along cross-sections



Squat Effect

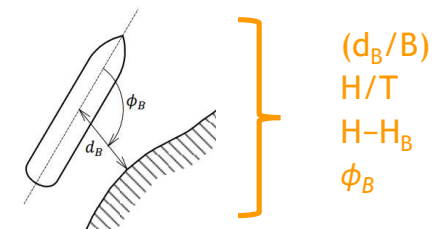
- ▶ Squat (draught & trim) influenced by u_1 and H
- ▶ ↑ u_1 & ↓ H → ↑ Squat
- ▶ Shallow-water effects incorporated via H/T (capturing flow confinement and pressure gradients), ensuring coherence without explicit Fr_h

$$\Delta T = L \overline{\Delta T} \left(Fr, \frac{H}{T} \right)$$

$$\Delta \tau = T \overline{\Delta \tau} \left(Fr_v, \frac{H}{T} \right)$$

Bank Effect

- ▶ Asymmetric flow → ↑ Lateral forces (Y) & yawing moments (N)
- ▶ Effects intensify when $W < 2B$
- ▶ ↑ Pressure gradients & force asymmetry → Rudder corrections
- ▶ ↑ Grounding/collision risk → Demands design & training adaptation





2. Methodology → Squat Effect

- ▶ Ship speed relative to water (u_1) and water Depth (H) influence squat (draught and trim)
- ▶ Squat increases as speed rises and water depth decreases

Draught → $\Delta T = L \overline{\Delta T} \left(Fr, \frac{H}{T} \right)$ where $Fr = \frac{u_1}{\sqrt{g L}}$ (Froude Number)

Trim → $\Delta \tau = T \overline{\Delta \tau} \left(Fr_{\nabla}, \frac{H}{T} \right)$ where $Fr_{\nabla} = \frac{u_1}{\sqrt{g \nabla^{\frac{1}{3}}}}$ (Froude displacement Number)

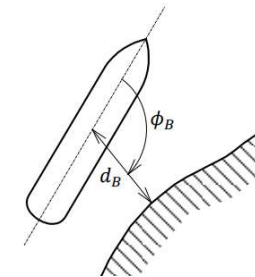
- ▶ Fr → wave resistance and wake formation analyses
 - ▶ Fr_{∇} → captures dynamic effects of buoyancy and hydrodynamic forces on the hull
- } selected for their proven relevance in shallow-water ship hydrodynamics
- ▶ Shallow-water effects incorporated via H/T ratio, capturing flow confinement and pressure gradients without explicit Fr_h use
 - ▶ The approach ensures consistency with models, accounting for shallow-water effects via H/T
 - ▶ Future studies: Fr_h inclusion to assess if it provides additional accuracy



2. Methodology → Bank Effect

- ▶ Proximity to banks causes asymmetric flow → generates lateral forces (Y) and yawing moments (N)
- ▶ Effects intensify when $W < 2B$

$$Y = mgFr^2 C_{BY} \quad N = mgLFr^2 C_{BN} \quad \left(Fr = \frac{u}{\sqrt{gL}} \right) \rightarrow \left. \begin{matrix} C_{BY} \\ C_{BN} \end{matrix} \right\} \begin{matrix} \cdot (d_B/B) \\ \cdot H/T \\ \cdot H-H_B \\ \cdot \varphi \end{matrix}$$



- ▶ Hydrodynamic Consequences
 - ▶ Amplified lateral forces pull vessel towards nearest bank
 - ▶ Increased yawing moments demand active rudder corrections
 - ▶ Constrained flow boosts pressure gradients and force asymmetries
- ▶ Navigation & Safety Implications
 - ▶ Continuous rudder adjustments needed to maintain course
 - ▶ Higher risk of grounding/collision in confined waterways
 - ▶ Design and training must consider enhanced bank effects





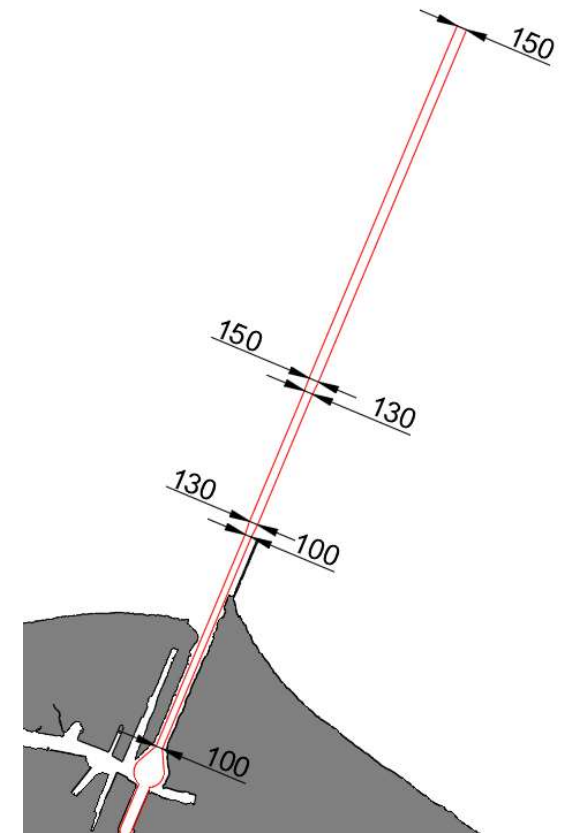
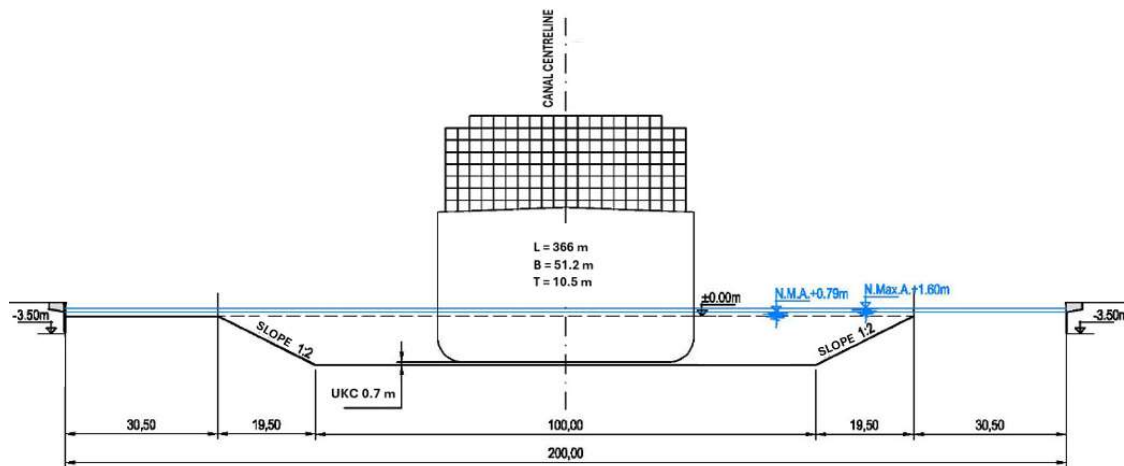
3. Modelling and Calibration → Canal Geometry and Hydrodynamic Effects (Piston Effect)

► Study Vessel

- New Panamax container ship (366 x 51.2 x 10.5 m) 119240 t displacement

► Channel dimensions

- 13.5 km length, 10.4 m depth
- Width: 150 m (first 5.5 km) narrowing to 130 m (7.7-5.5 km), then 100 m (last section)





3. Modelling and Calibration → Canal Geometry and Hydrodynamic Effects (Piston Effect)

- ▶ **Piston effect:** Occurs when channel width narrows, resulting in braking effects on the vessel.
- ▶ **Critical sections**
 - ▶ 150 m → 130 m
 - ▶ 130 m → 100 m
- ▶ Local pilots estimate the piston effect reduces speed by ~2 knots without any engine intervention
- ▶ Iterative process to calibrate using input from local pilots → 4 hydrodynamic effects adjusted (speed reduction & blockage)
- ▶ **Simulation details**
 - ▶ Mean high tide water level (+0.80 m) → $H/T = 1.07$
 - ▶ No wind, current, or waves
 - ▶ Target speed 10 knots (auto engine adjustment)



No pistón effect under these conditions

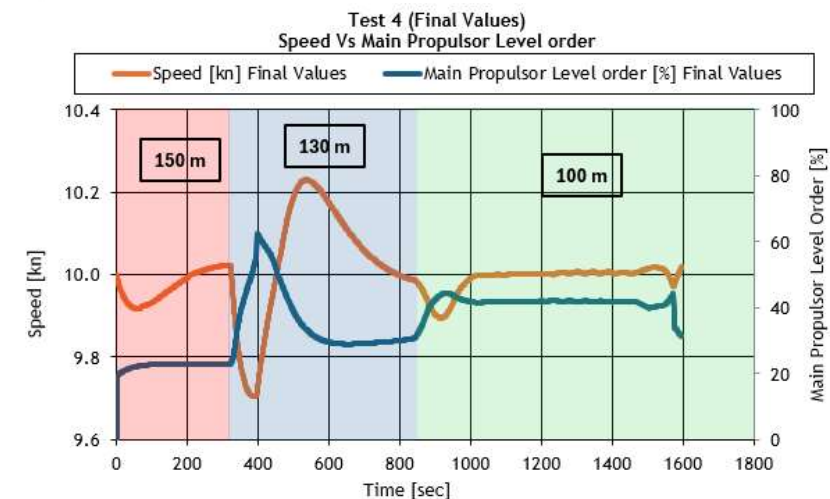
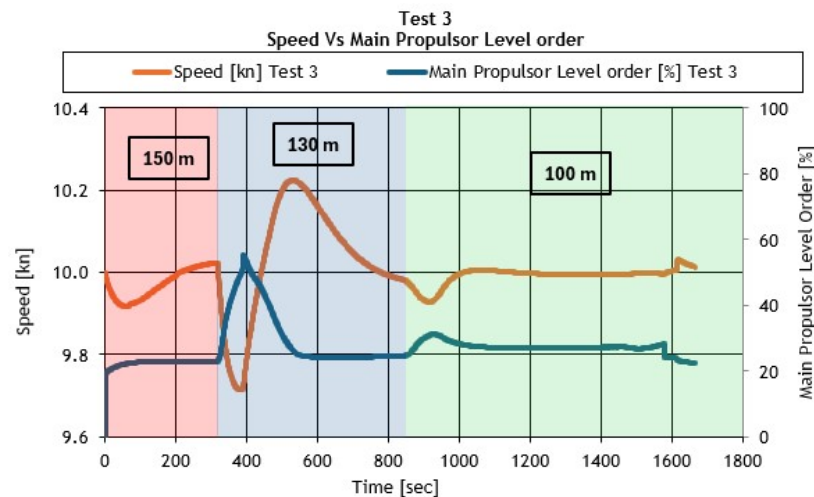
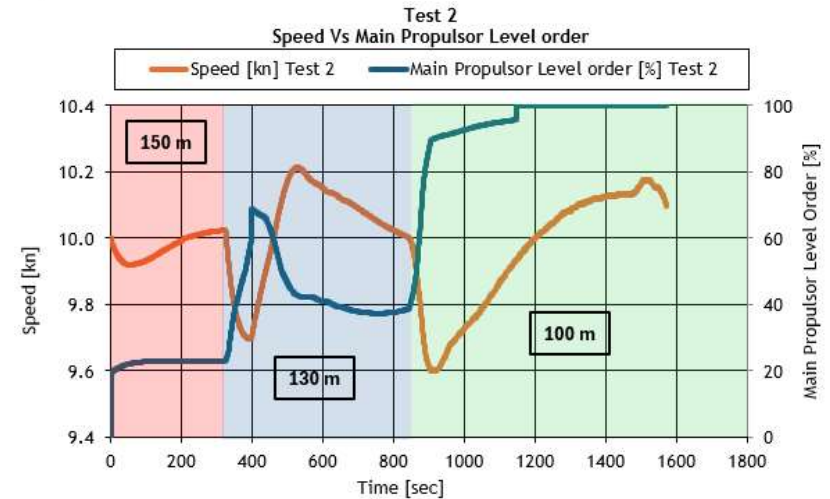
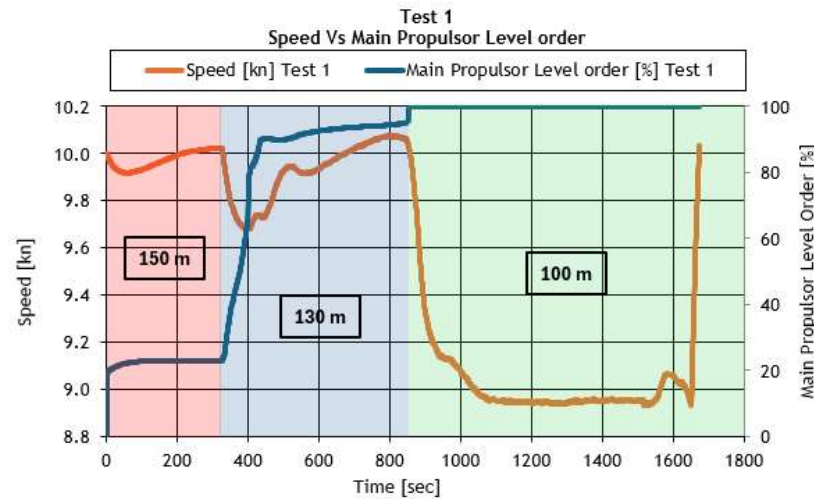


To maintain 10 knots, vessel requires
23% main propulsor level order



3. Modelling and Calibration

Canal Geometry and Hydrodynamic Effects (Piston Effect)





3. Modelling and Calibration → Squat Effect

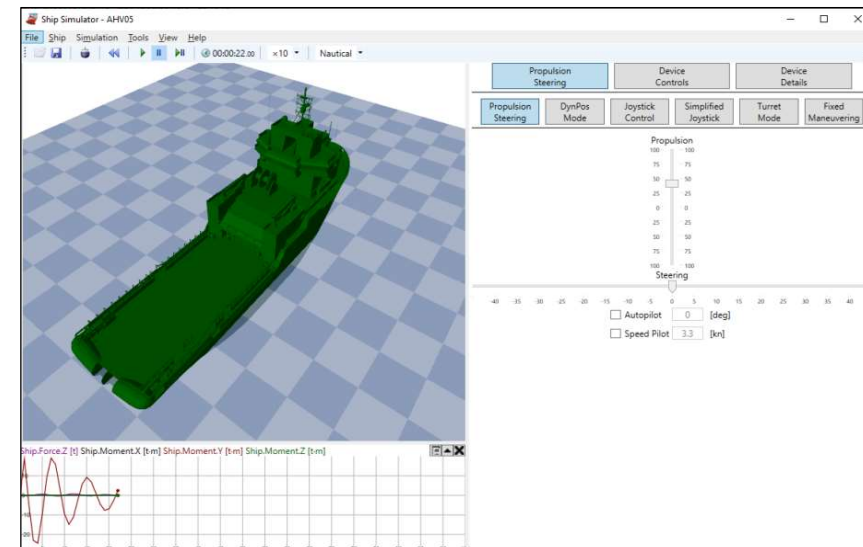
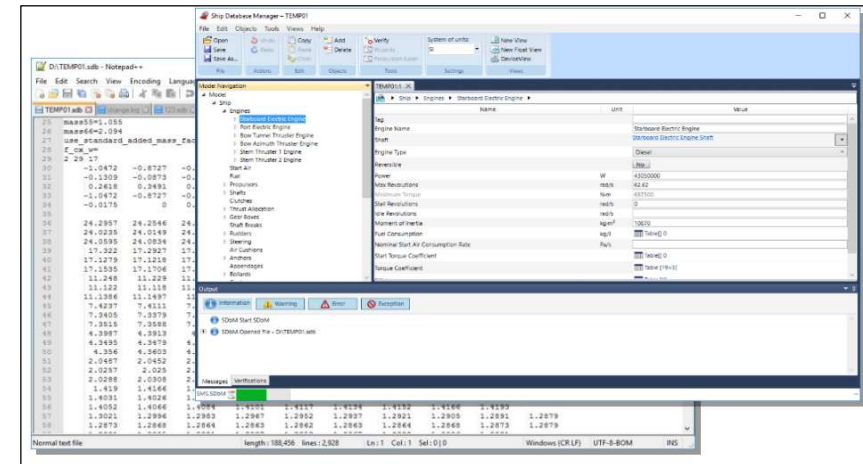
► Methodology

- A specialised Hydrodynamic Modelling Tool (HDMT): Ship Database Manager and Ship Simulator.
- Multiple squat formulations available (Ankudinov; Barrass; Standard; Huuska; Millward; Romisch; Yoshimura; etc.)

► Local pilots estimate squat effect of 0.5-0.55 m for the study vessel at 6 knots with $H/T = 1.07$

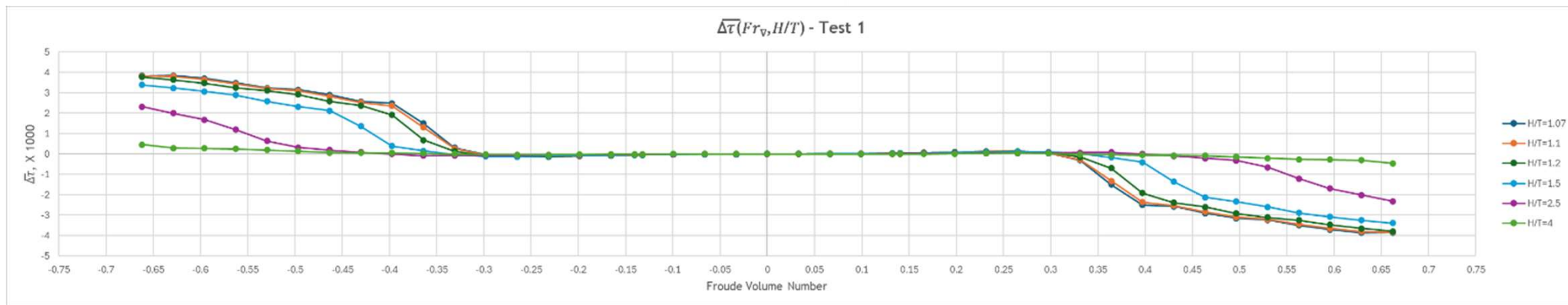
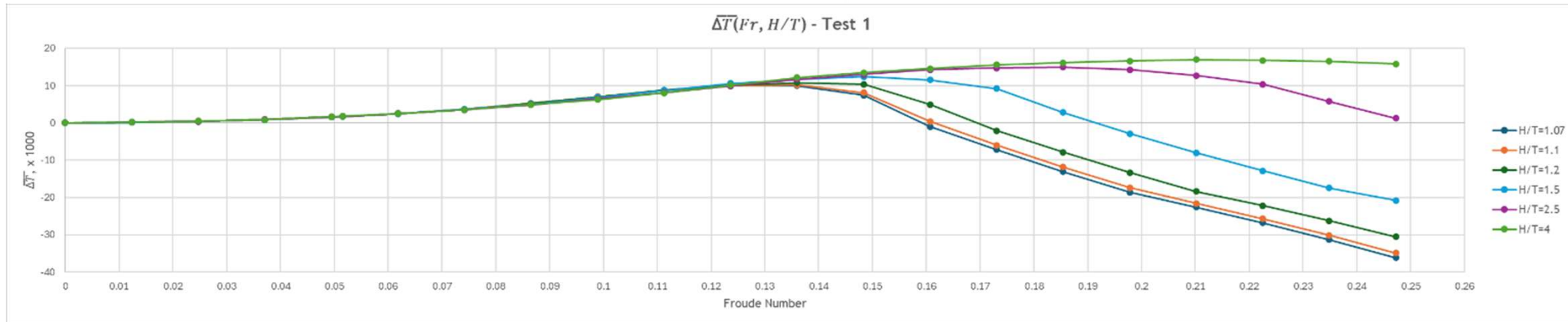
► Target calibration set conservatively at 0.55 m draught increase

- Three calibration tests conducted to validate $\overline{\Delta T}$ and $\overline{\Delta \tau}$
 - For various H/T ratios, $\overline{\Delta T}$ and $\overline{\Delta \tau}$ plotted against Froude Number



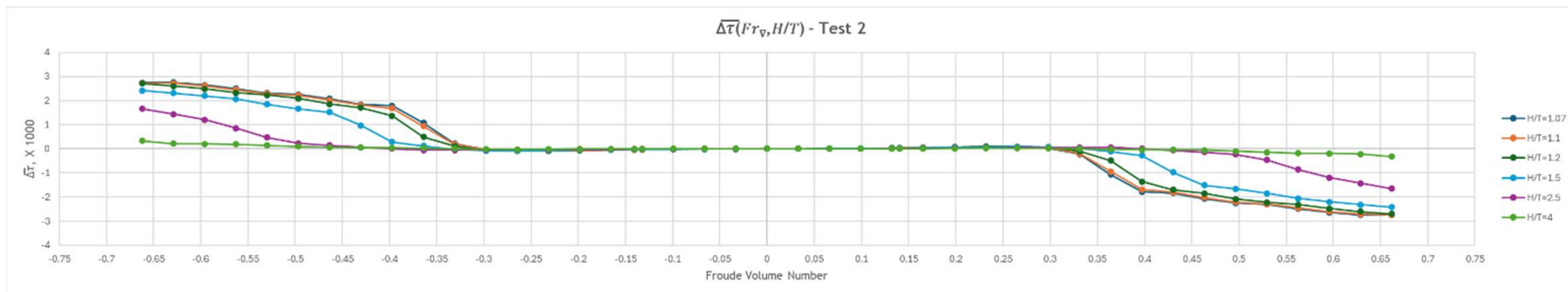
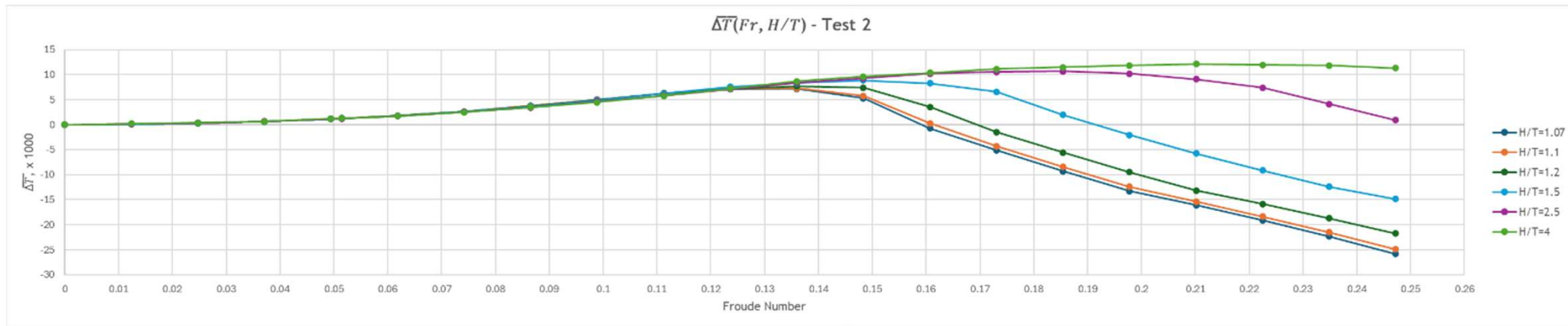


3. Modelling and Calibration → Squat Effect



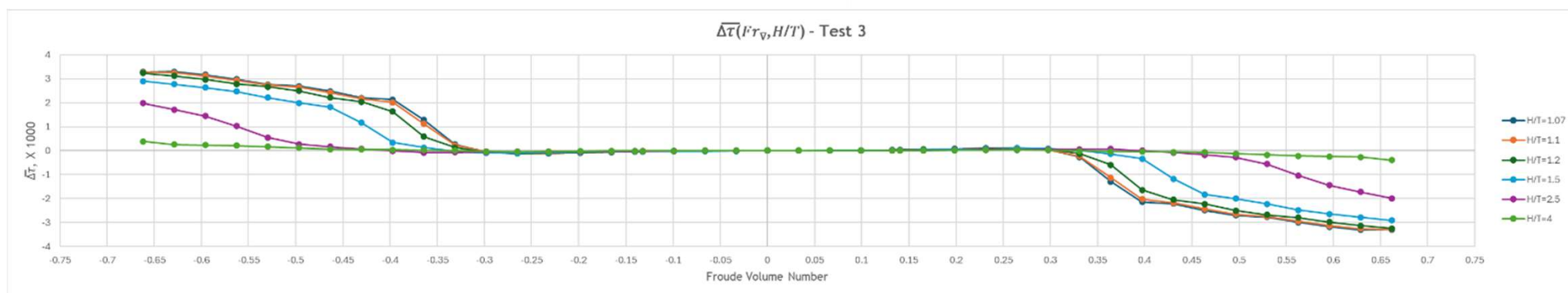
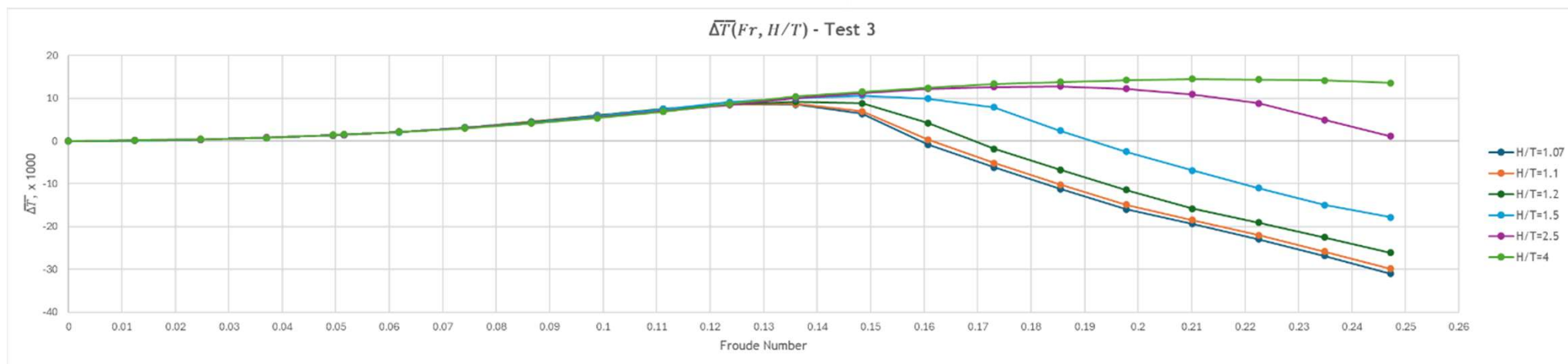


3. Modelling and Calibration → Squat Effect





3. Modelling and Calibration → Squat Effect





3. Modelling and Calibration → Squat Effect

- Fr and Fr_{∇} at 6 knots of speed and the H/T ratio of 1.07 for each of the tests

└→ $\overline{\Delta T} \left(Fr, \frac{H}{T} \right) [\text{m}]$ and $\overline{\Delta \tau} \left(Fr_{\nabla}, \frac{H}{T} \right) [^{\circ}]$

- Calculate draught and trim increase using the equations of methodology

└→ $\Delta T = L \overline{\Delta T} \left(Fr, \frac{H}{T} \right)$ and $\Delta \tau = T \overline{\Delta \tau} \left(Fr_{\nabla}, \frac{H}{T} \right)$

	Test 1	Test 2	Test 3
Draught Increase (ΔT)	0.642 m	0.458 m	0.550 m
Trim Increase ($\Delta \tau$)	-0.000160 ° 0.000160 °	-0.000114 ° 0.000114 °	-0.000137 ° 0.000137 °

- Test 3 selected → most accurate and reliable (Draught change is the key factor; trim impact negligible)



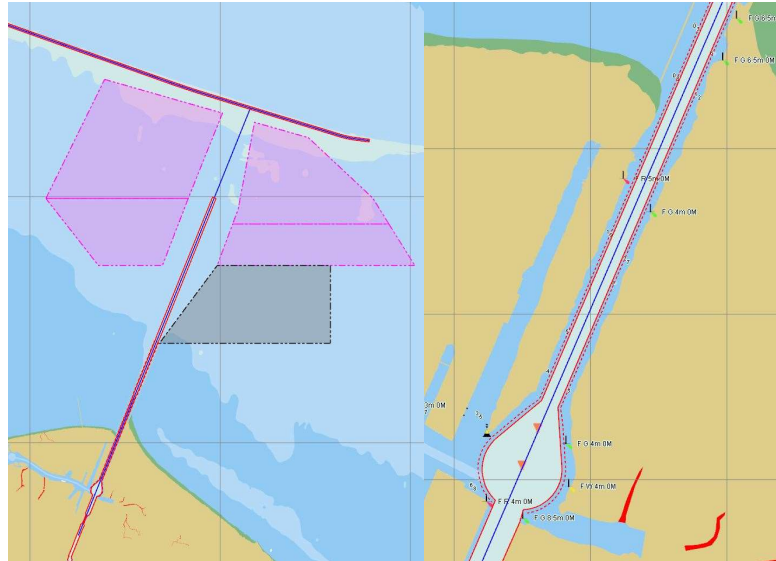
3. Modelling and Calibration → Bank Effect

- ▶ Bank effect has not been considered in the simulations (negligible based on local pilots' input)
 - ▶ Piston effect and squat are dominant in the study area
 - ▶ Modelling and calibration focused on these two effects for higher accuracy



4. Case study and validation by local pilots

- ▶ **Challenging conditions**
 - ▶ Crosswinds up to 15 knots (+33% gusts)
 - ▶ Cross currents >0.5 knots
- ▶ **Very low under keel clearance**
 - ▶ Minimum static UKC of 0.7 m ($H/T = 1.07$)
- ▶ **Accurate hydrodynamic modelling**
 - ▶ Piston effect
 - ▶ Squat effect
- ▶ **Validated by local pilots and port authorities**
 - ▶ Model closely matched real manoeuvres
 - ▶ First certified terminal in the country for New-Panamax vessels





5. Conclusions

- ▶ **Robust hydrodynamic modelling**
 - ▶ Accurate piston and squat effect calibration (aligned with pilot expertise)
 - ▶ Final squat: +0.55 m draught (with negligible trim variation) at 6 knots ($H/T = 1.07$)
 - ▶ Piston effect: ~2 knots speed reduction at 10 knots target speed
- ▶ **Validated through real-time simulation and Operation feasibility confirmed**
 - ▶ Reliable, feasible and safe manoeuvres under winds, cross currents, very low UKC and squat and piston effects
 - ▶ Endorsed by local pilots and port authorities → First certified terminal in the country for such vessel (milestone)
- ▶ **Challenges and Innovations**
 - ▶ Managed very low UKC + combined effects of squat and piston forces in narrow channels
 - ▶ Real-time models + pilot input ensured high accuracy
- ▶ **Implications for design and training**
 - ▶ Supports safer design and pilot training
 - ▶ Methodology applicable to other confined waterways





A different view of the engineering

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