Assessment of Causeway-Induced Loading on Penstock Towers

S.CT. Luis and T. Armstrong
SRK Consulting, Johannesburg, South Africa

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Photo: SRK archives - timber catwalk on platinum TSF

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Agenda

01

TSFs & Penstock Towers

The role of Penstock Towers in TSFs

- TSFs in South Africa – centrally located penstock towers.
- Towers raised with interlocking rings.
- Access via tailings constructed causeways (pool handles).
- Catwalks for inspection and maintenance.

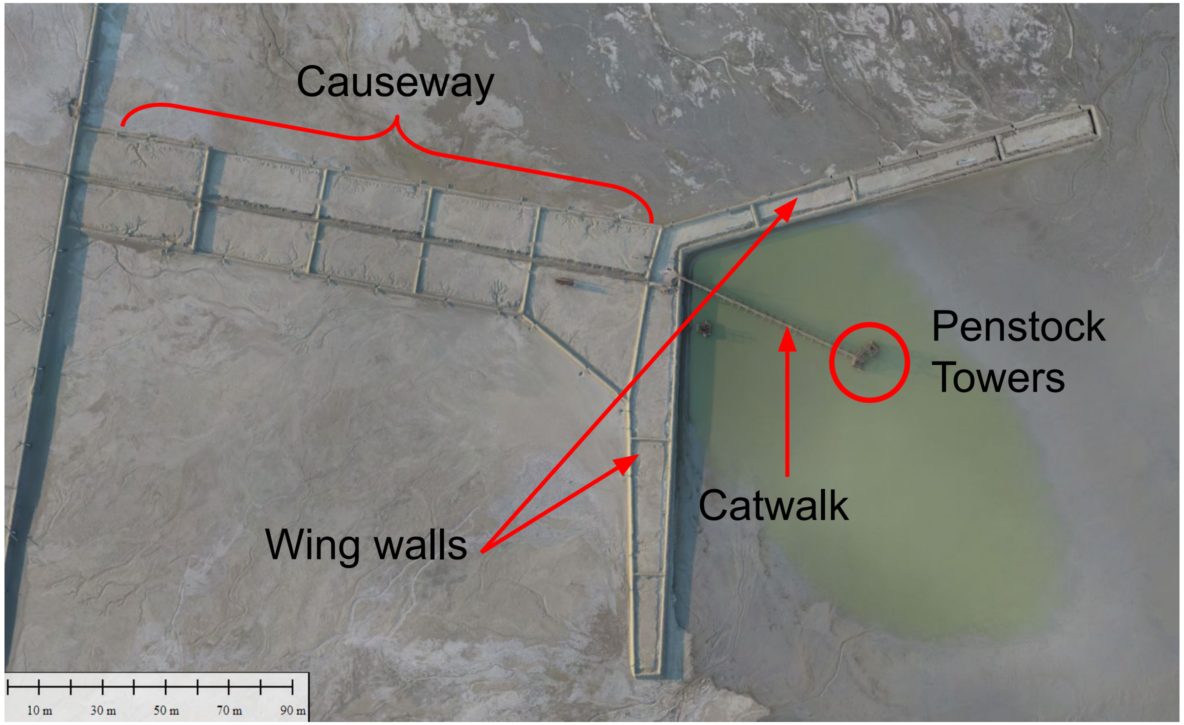


Photo: SRK archives – plan view of platinum TSF

02

The Hidden Problem

Causeways and wing walls: more than just access

- Causeway and wing walls = additional surcharge loads.
- Often not explicitly considered in design or operation.
- Potential for unbalanced horizontal forces.
- Risk: tilt, distress or overturning of the tower.

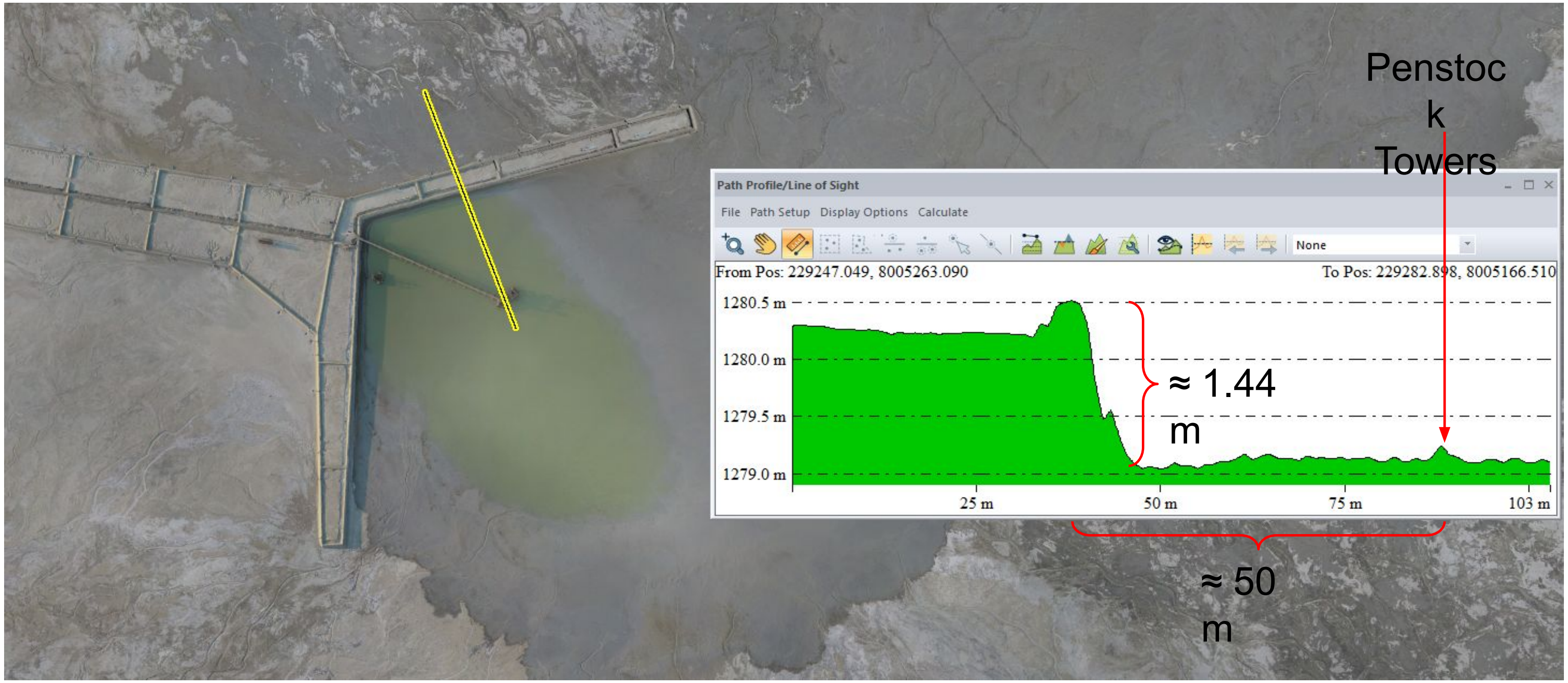


Photo: SRK archives – plan view of platinum TSF

03

Research Questions & Objectives

What questions were we trying to answer?

- How can we quantify the total stresses induced by a TSF causeway and wing wall on a penstock tower?
- Can we provide simple tools for design and operation?

Stability Assumptions:

- Wing walls and causeway are assumed to be a rigid body and are stable throughout the life of the TSF.
- Only induced loads from the causeway and wing walls were considered on the tower.
- Material surrounding the causeway and wing walls is assumed to be competent.

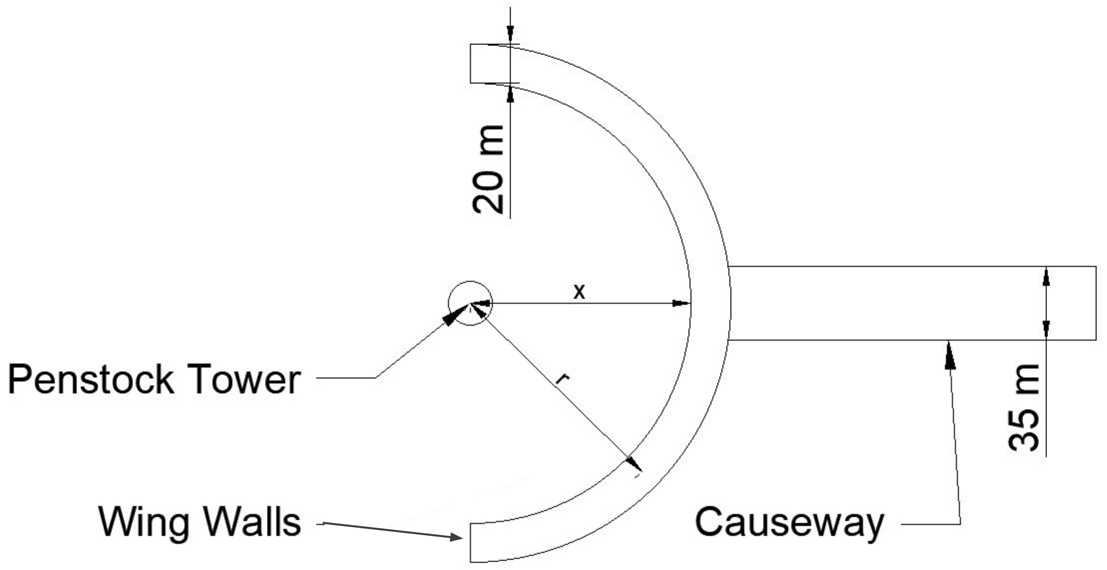
Photo: SRK archives - tailings causeway on platinum TSF

04

Typical Configuration & Scope

What system did we analyse?

- Ringed concrete penstock tower.
  - Height: 20 m below tailings surface (typical max design height).
- Tailings-constructed causeway and wing walls.
- Trapezoidal cross-section; wing walls simplified to semicircle.
- <u>Focus of the paper:</u> loading on tower (not the structural resistance of the tower).



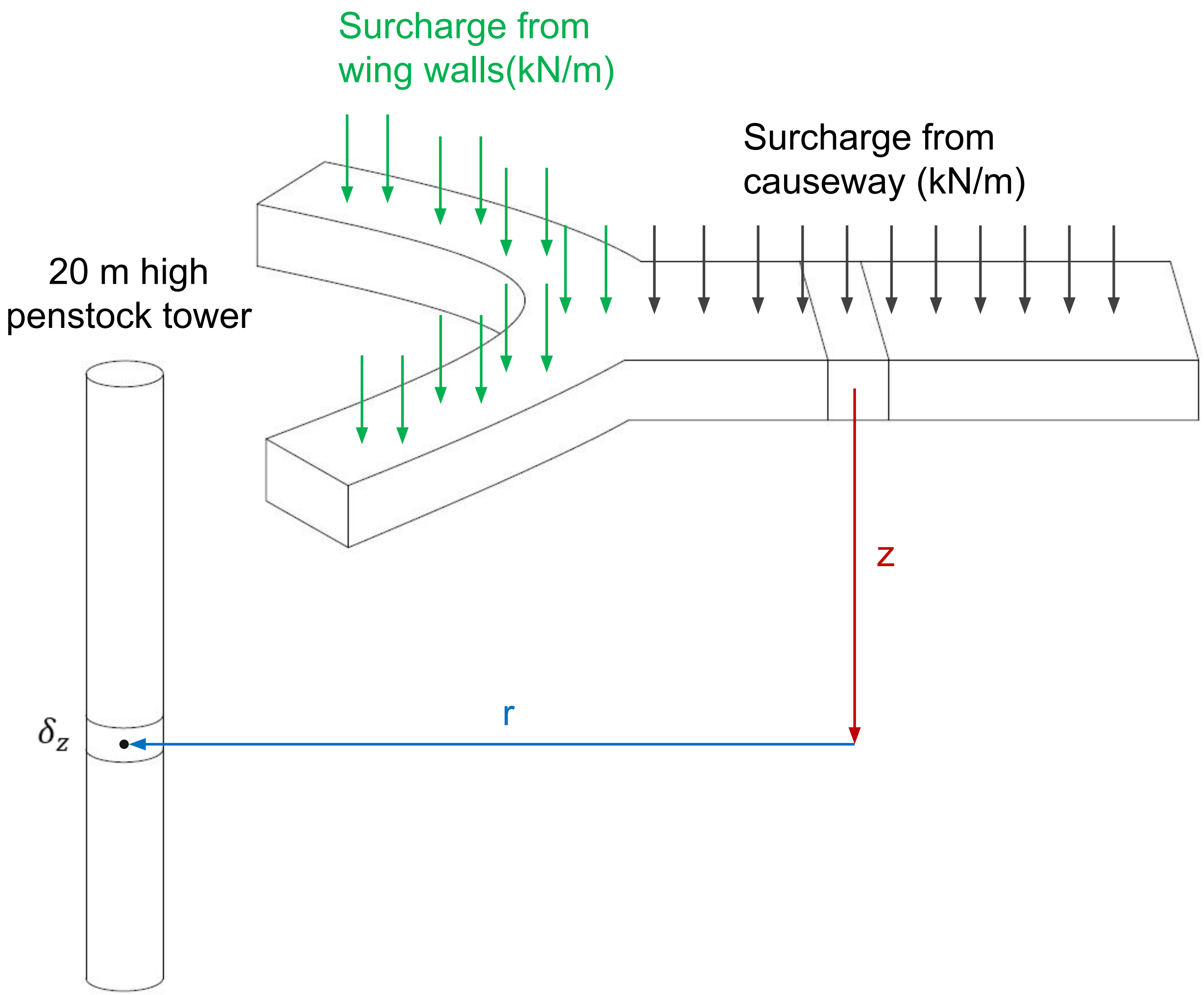
Simplified Configuration - Plan View

05

Methodology: From Surcharge to Horizontal Force

Analytical approach and assumptions

- Tailings assumed to be homogeneous, isotropic, elastic, semi-infinite.
- Vertical stress from surcharge: Boussinesq (1885).
- Convert vertical stress to horizontal via K_0: Jáky (1944):
  - $K_0 = 1 - \sin(\phi')$
- Summed stresses along tower height to get total horizontal force.



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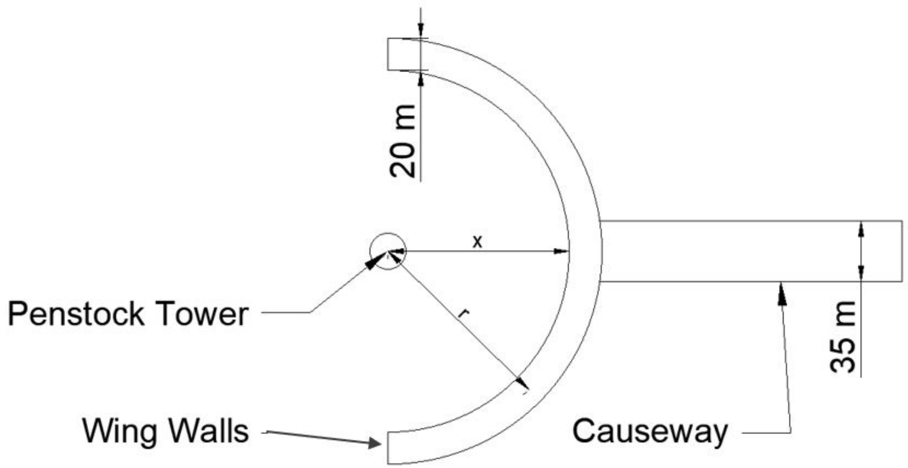
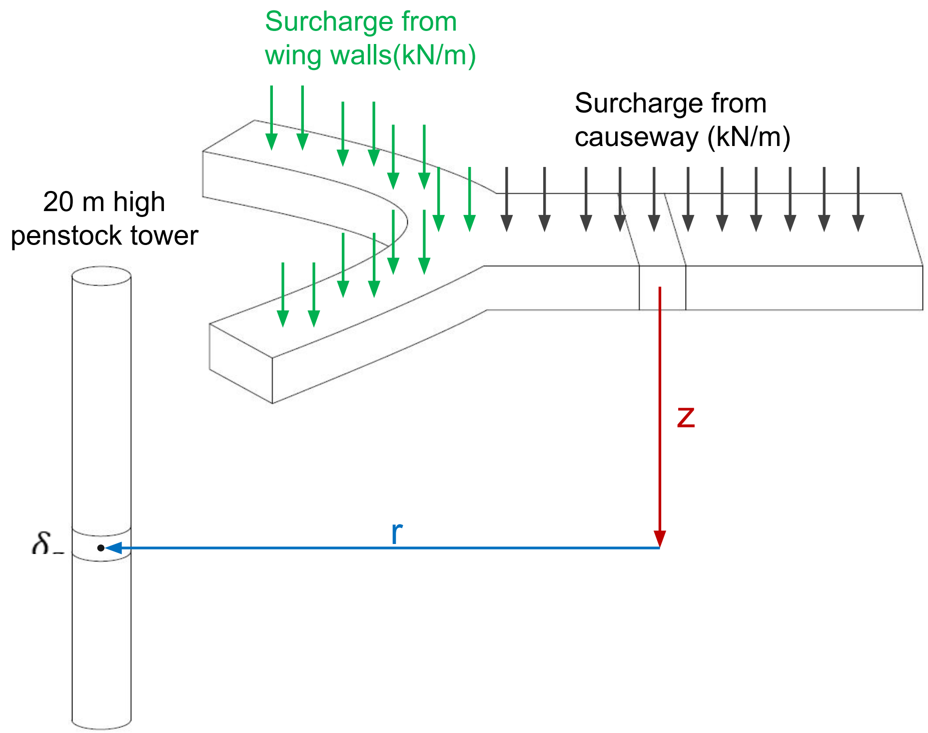
Geometry & Variables

Key geometric variables in our analysis

- x = distance from tower to start of wing wall
  - Varied from 5 m to 40 m (5 m increments)
- r = radial distance used in Boussinesq calculations
- Causeway and wing wall heights considered:
  - 1 m, 2 m, 3 m and 4 m
- Maximum value of r was 80 m





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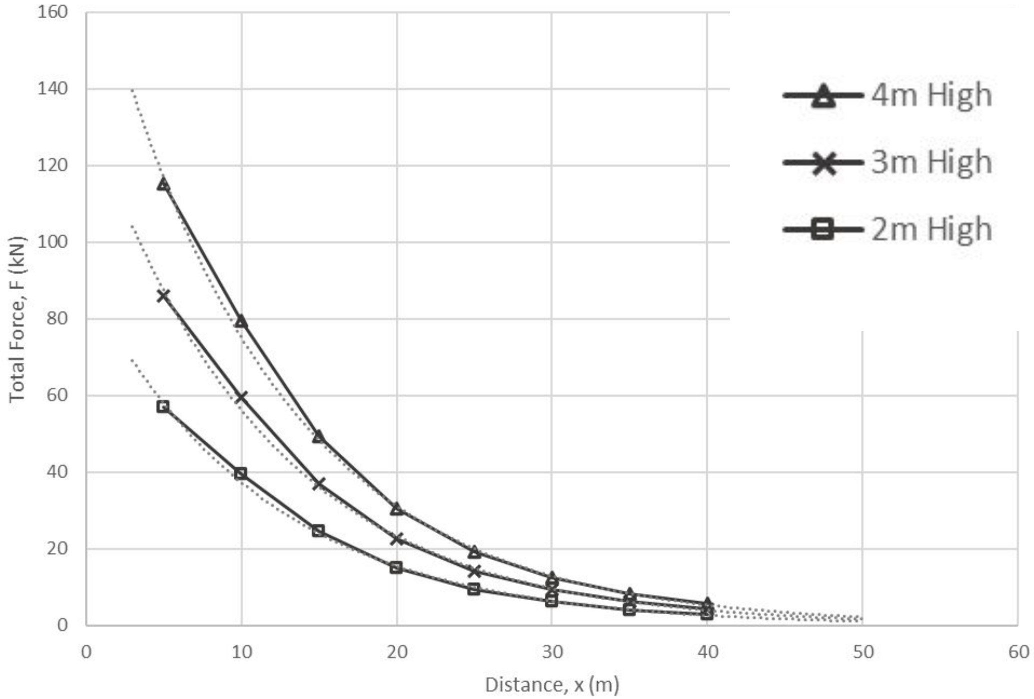
Results: Distance vs Total Horizontal Force

Forces reduce exponentially with distance

- Total horizontal force, F, on tower vs distance, x.
- Forces decrease exponentially as x increases.
- Higher structures = larger forces at any given x.
- Fitted exponential:
  - $F = ae^{bx}$
- No explicit structural resistance modelling.
- No partial safety factors applied.



Causeway and wing wall height	Equation for line of best fit
2 m	$F = 181.57\, e^{-0.088x}$
3 m	$F = 135.62\, e^{-0.088x}$
4 m	$F = 90.05\, e^{-0.088x}$

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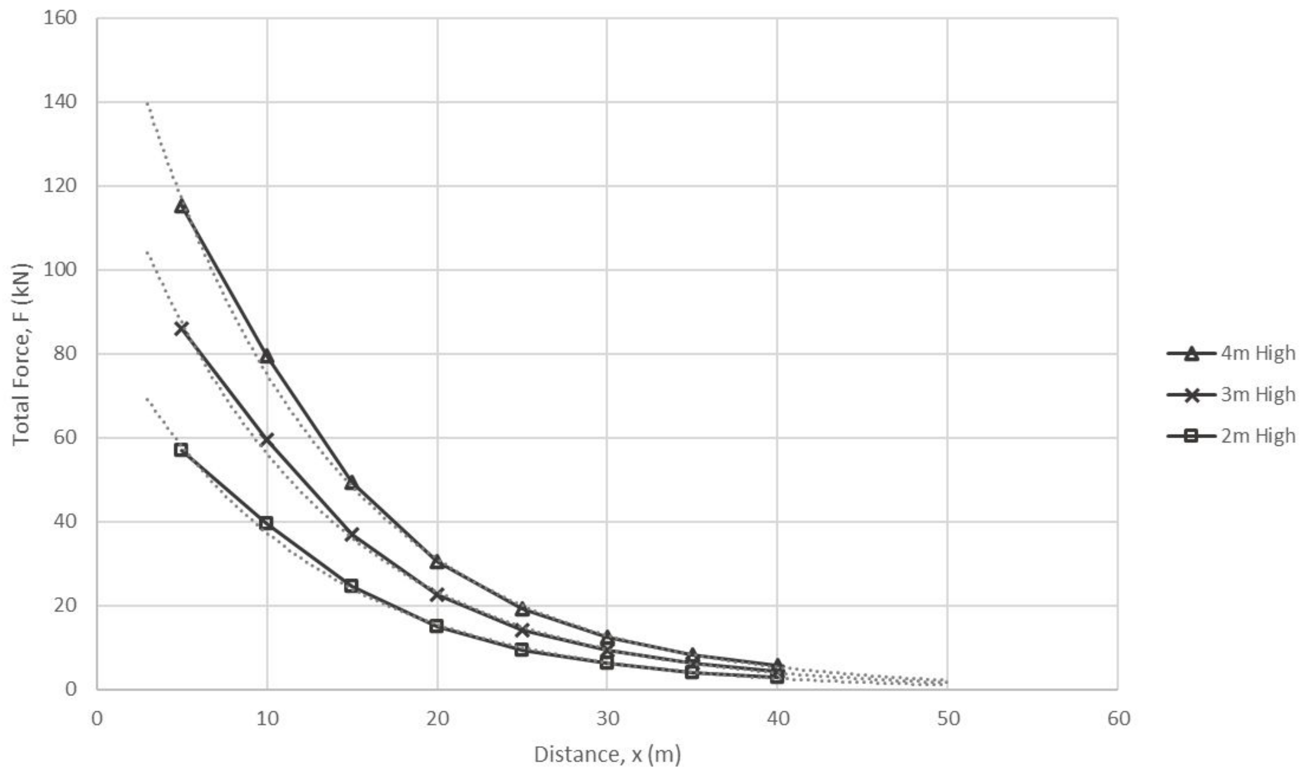
Key Distances: 40 m & 50 m

When does the causeway's impact effectively disappear?

- Beyond ~ 40 m, loading curves converge.
- Changes in height/density have little effect ≥ 40 m.
- Beyond ~ 50 m, forces become small to negligible.
- Additional point loads ≥ 50 m away are unlikely to affect stability.



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Idealised Graphs for Practitioners

From analysis to a practical tool

- Simplified configuration with conservative parameters.
- Graphs for causeway heights: 1, 2, 3, 4 m.
- Shaded “failure-risk” regions vs distance x.

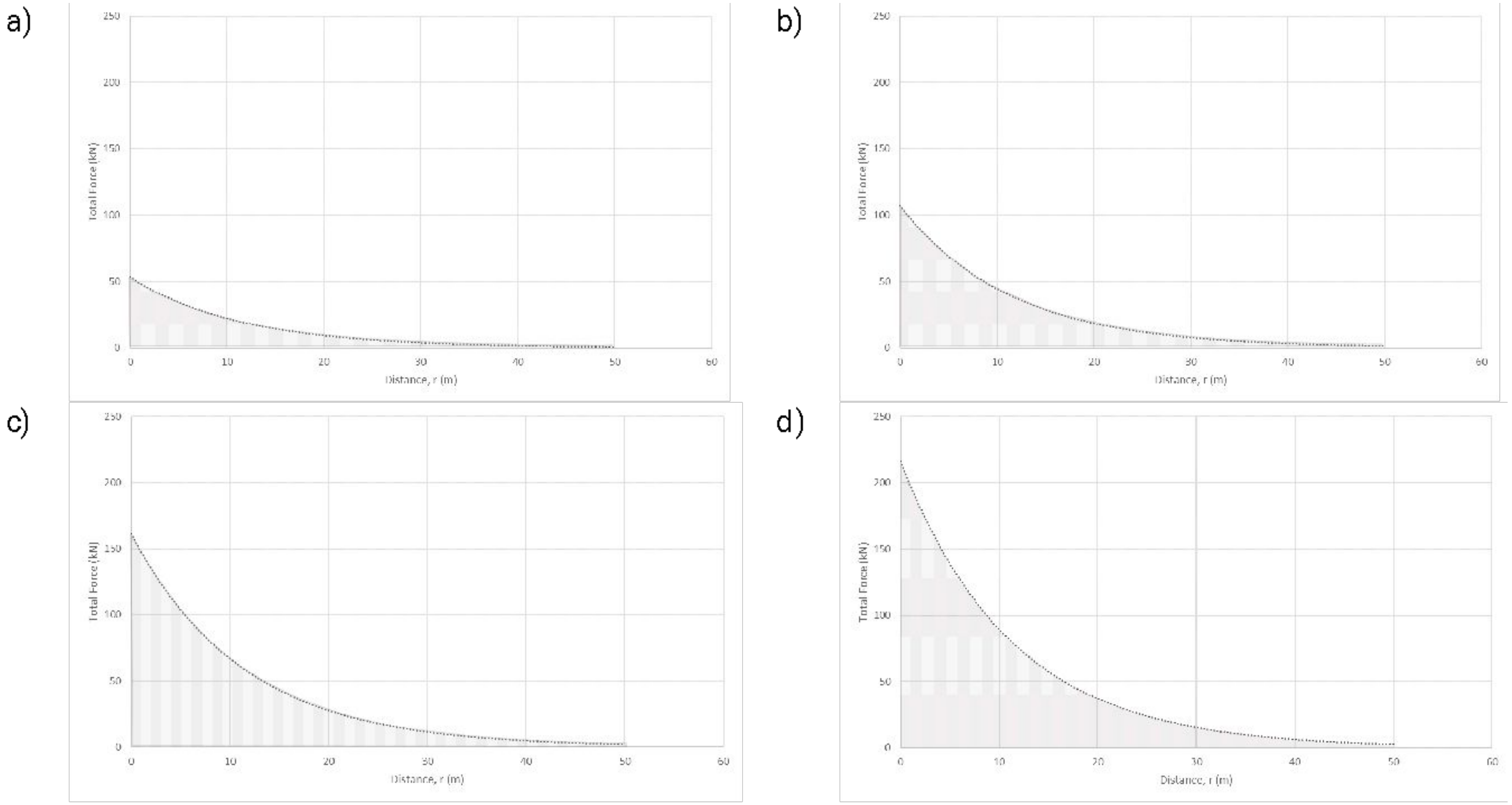
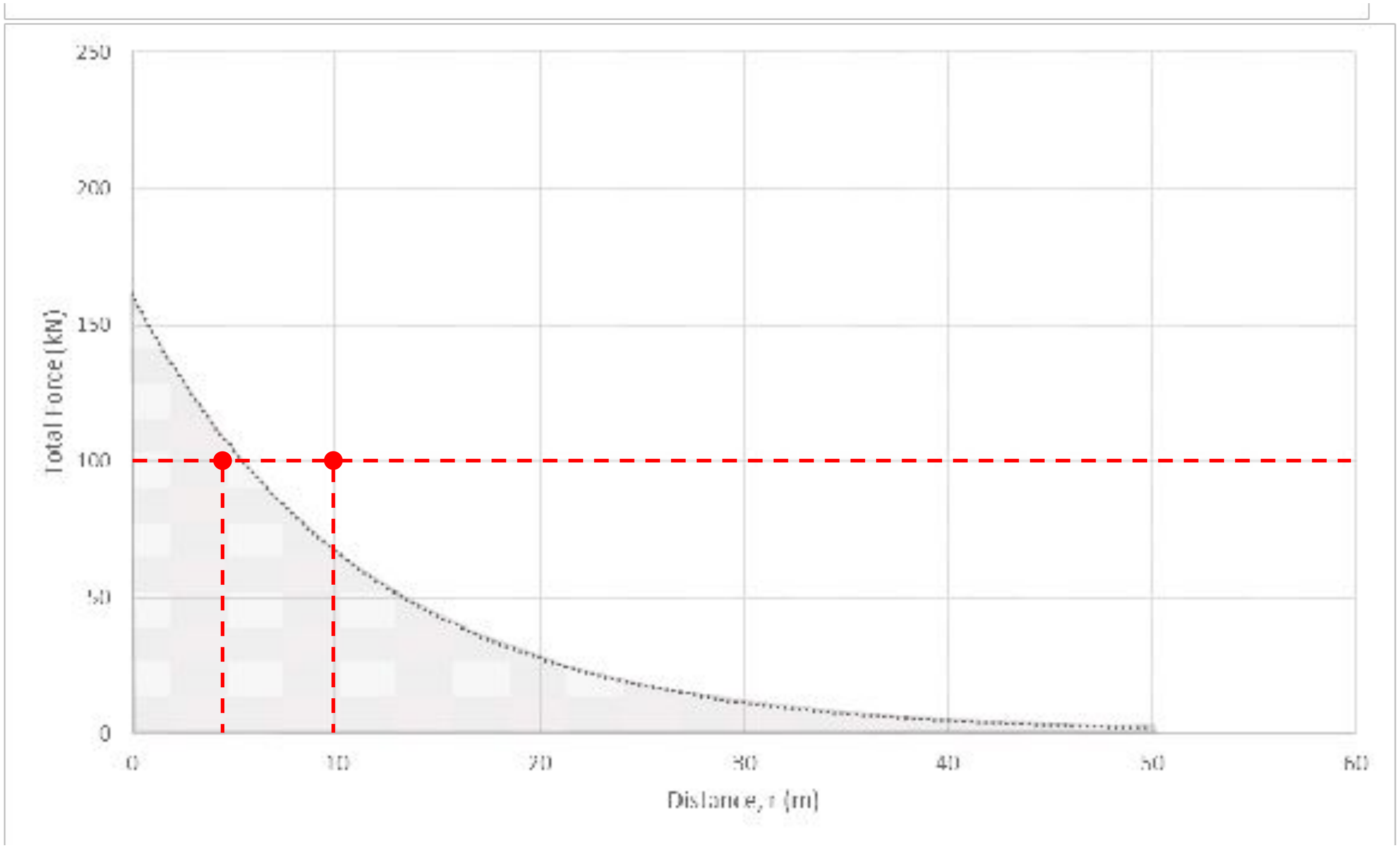


Photo: SRK archives – waste rock causeway


Photo: SRK archives – ringed penstock tower

From analysis to a practical tool - continued

- 3 m high causeway and wing walls



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Summary & Conclusions

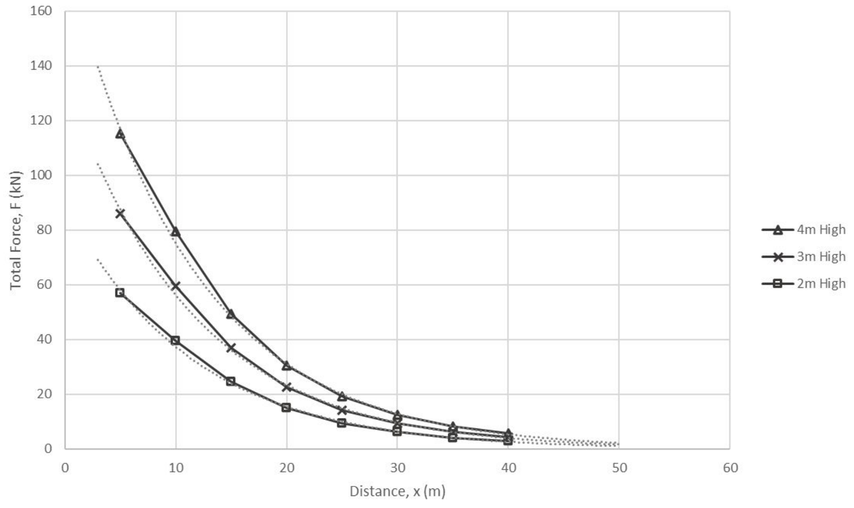
Practical considerations

Overview of findings

- Causeways and wing walls have the potential to impose a significant load on penstock towers, thus should be explicitly considered.
- Horizontal forces increase with height and reduce exponentially with distance.
- Use exponential relationship $F = ae^{-0.008x}$ as a screening tool.
- Keep high or heavy structures ≥ 40 – 50 m where possible.
- Integrate with full stability and structural checks.
- Supports safer, more robust TSF operation.

Future opportunities

- Coupled numerical modelling.
- Site-specific calibration and monitoring.



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Questions

Thank You

Presented by:

Simone Luis

Tyler Armstrong, *PrEng*

Johannesburg, South Africa

sluis@srk.co.za; tarmstrong@srk.co.za;

srk consulting