Correcting the N1 equation for improved leakage modeling and detection

Asaph Kabaasha

Prof Kobus van Zyl

Background

N1 Power Equation

$$Q = Ch^{N1}$$

$$Q = C * (AZNP)^{N1}$$

$$N1 = \frac{\log\left(\frac{Q_2}{Q_1}\right)}{\log\left(\frac{AZNP_2}{AZNP_1}\right)}$$

Modified Orifice (FAVAD)

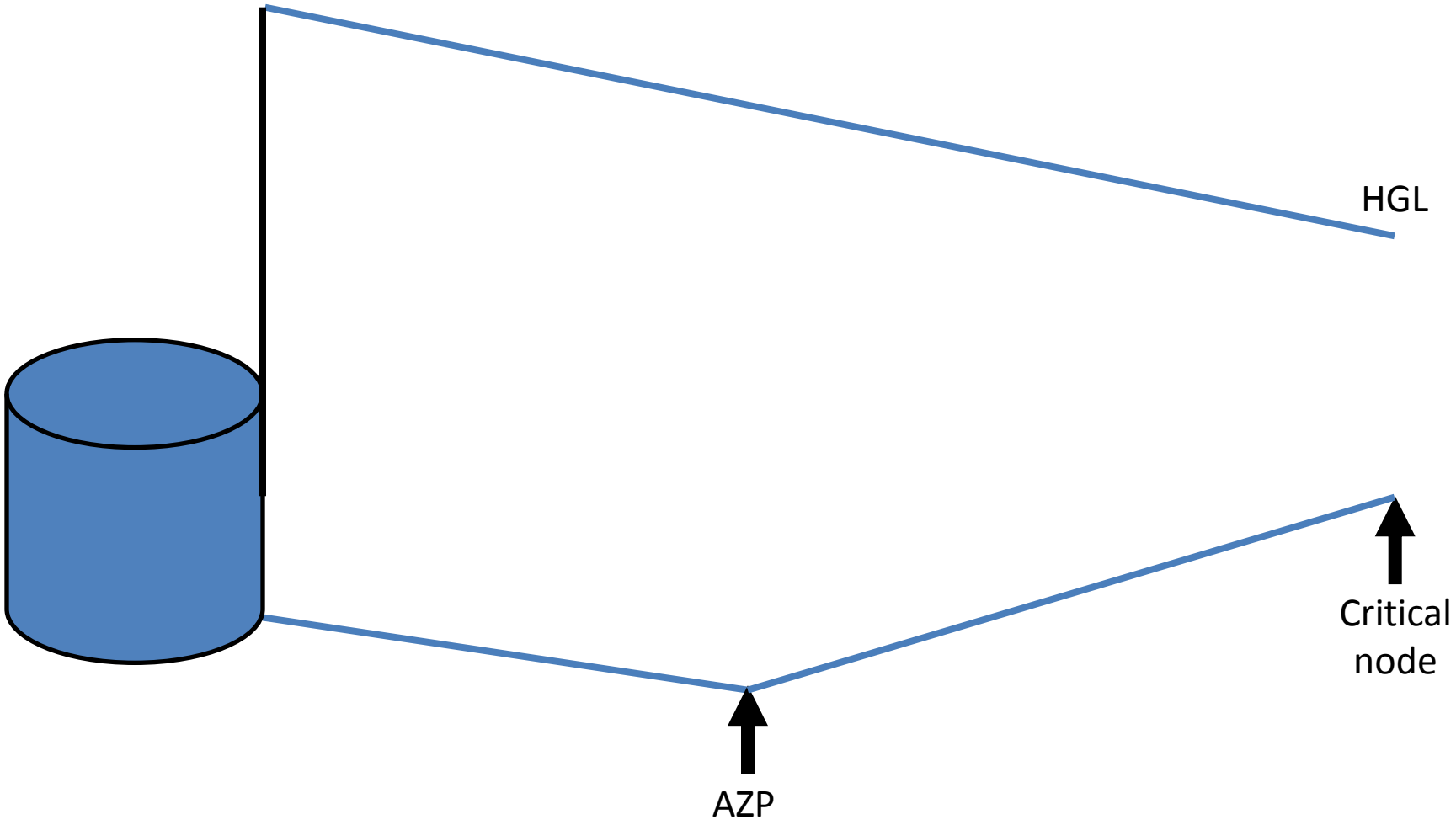
$$Q = C_d\sqrt{2g}(A_0 h^{0.5} + m h^{1.5})$$

$$L_N = \frac{mh}{A_0}$$

$$N_1 = \frac{1.5L_N + 0.5}{L_N + 1}$$

Sources of Errors (N1 Power Equation)

1. Elevation difference:



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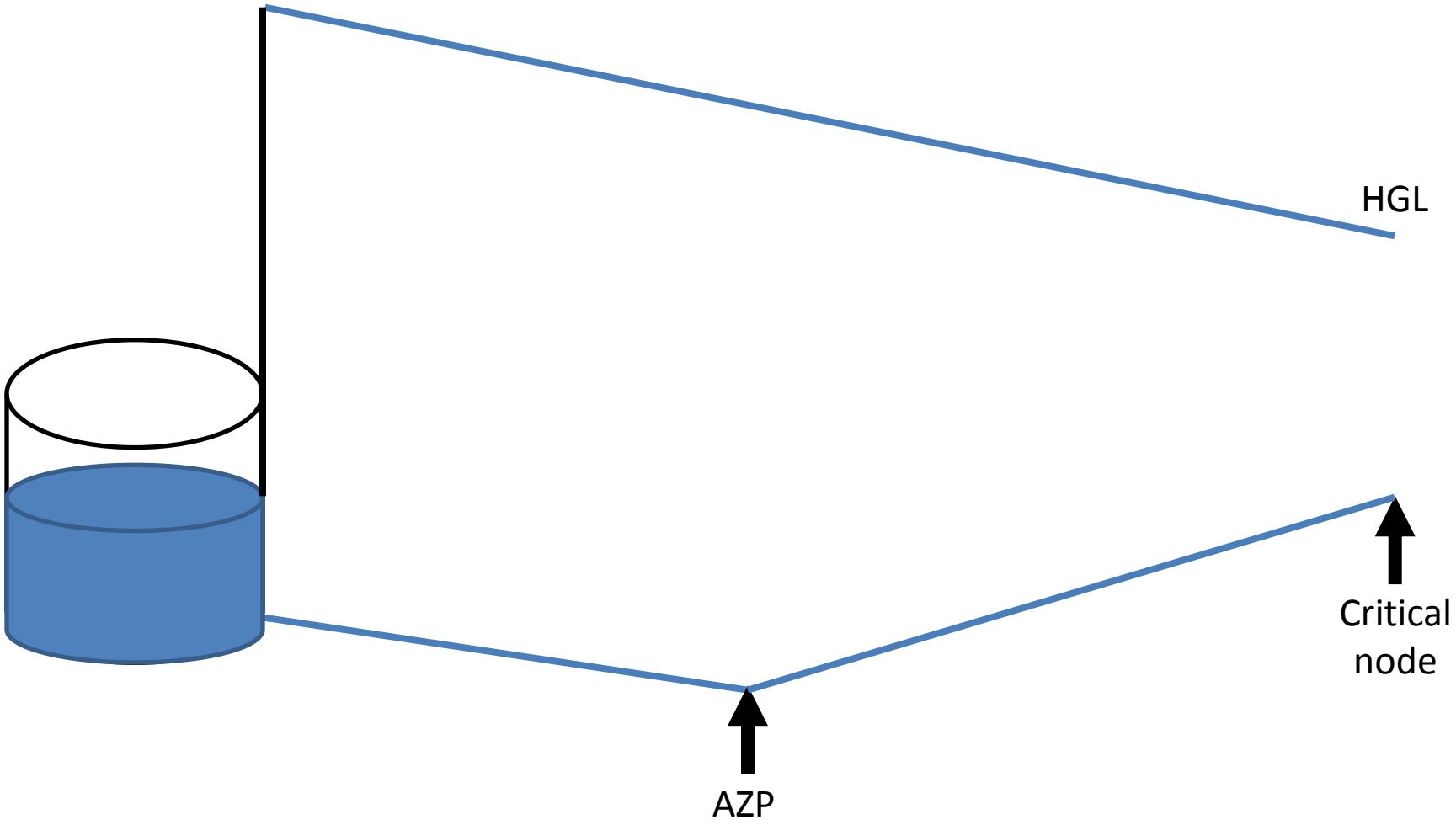

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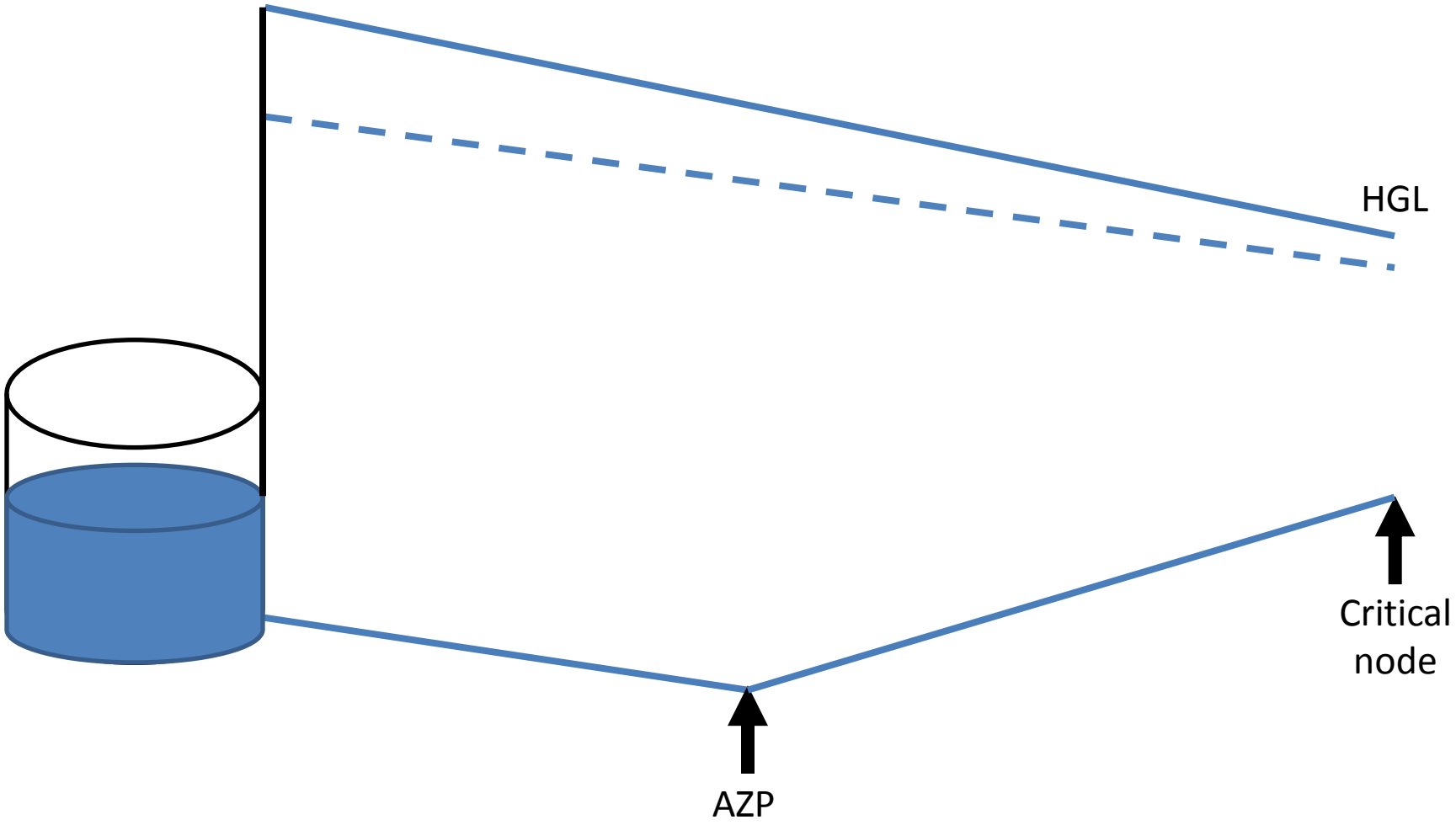

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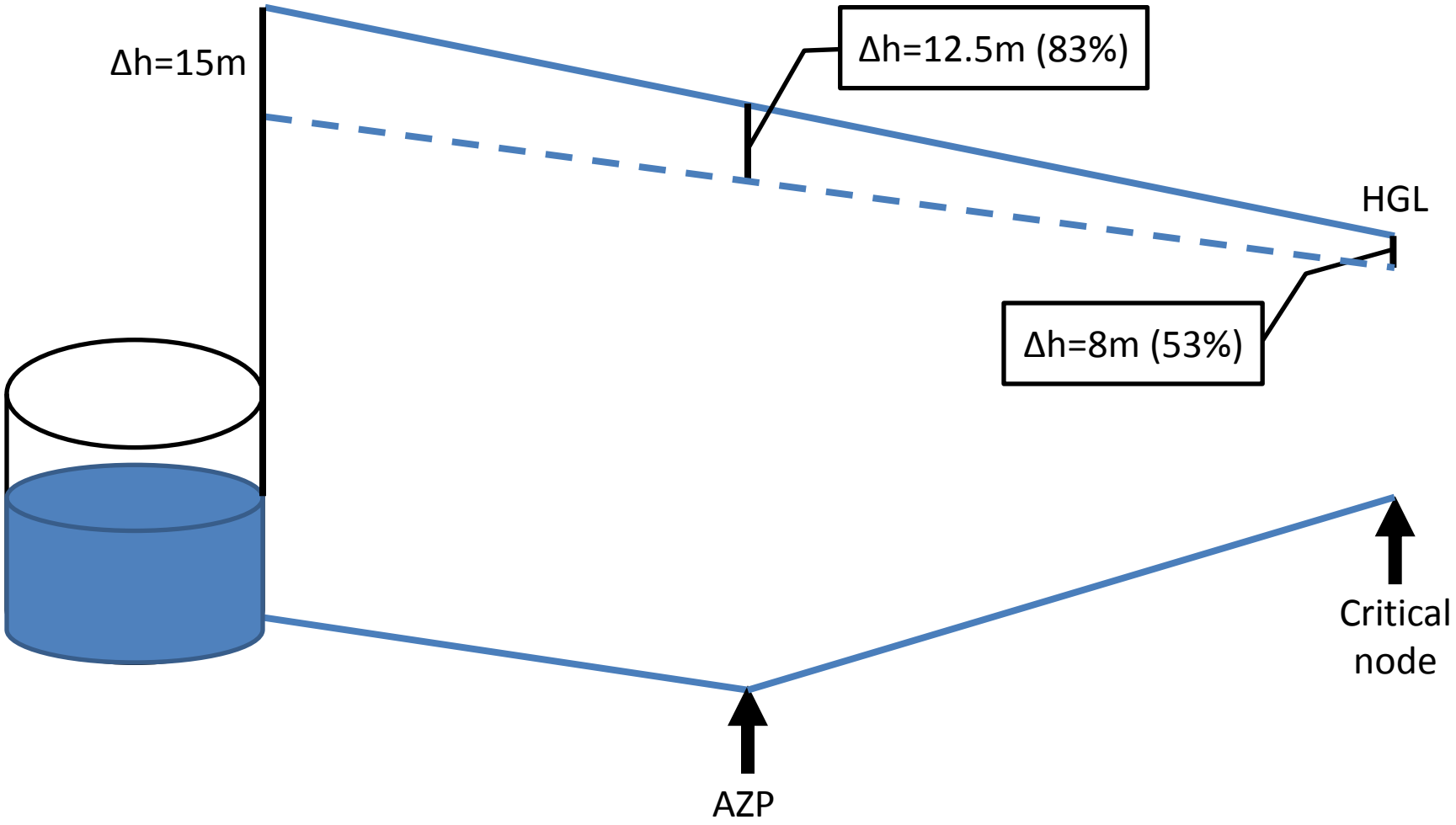
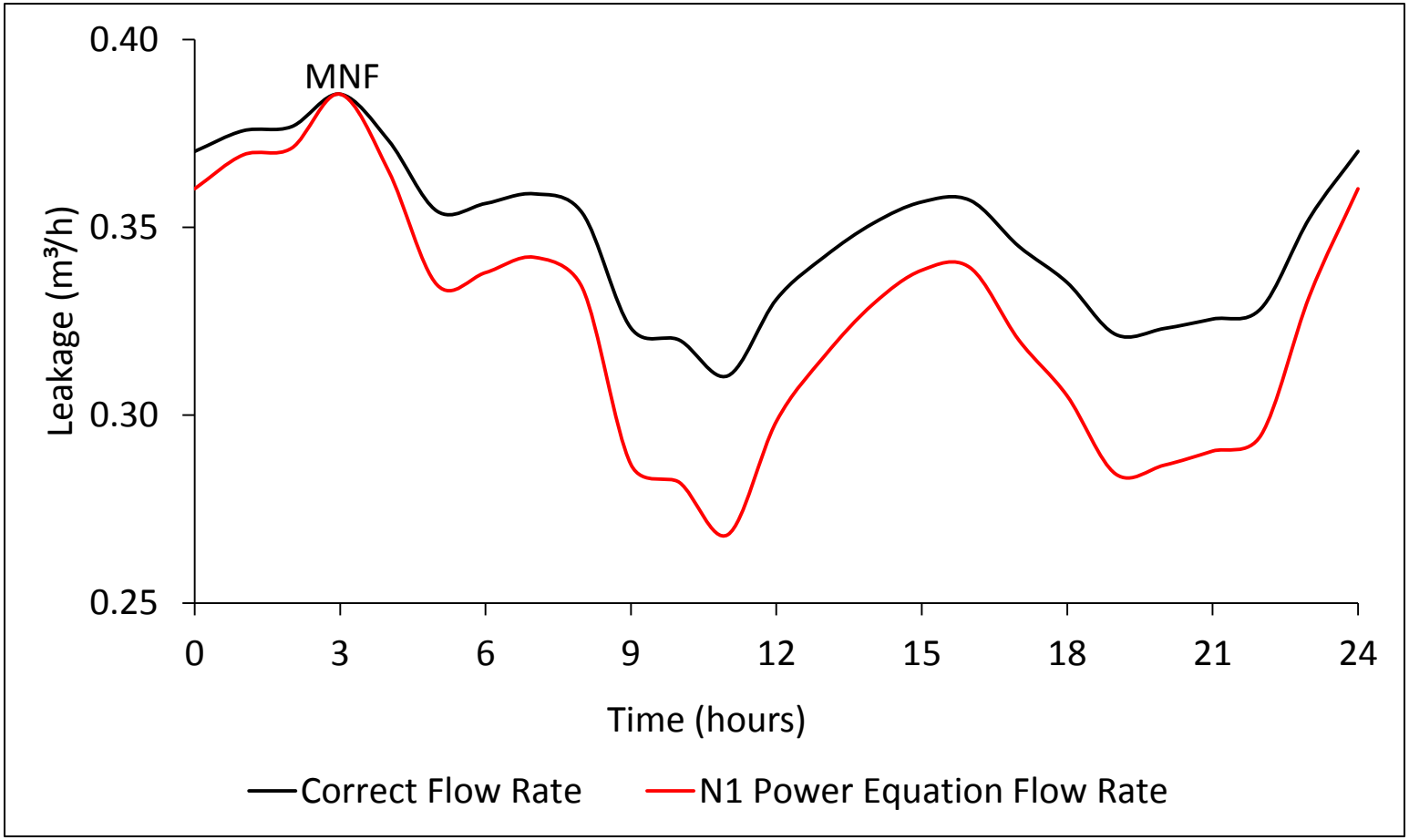


Sources of Errors (N1 Power Equation)

2. Pressure variation:



The Correction Methods

Elevation difference errors:

- Ratio method.
- Re-simulation method.

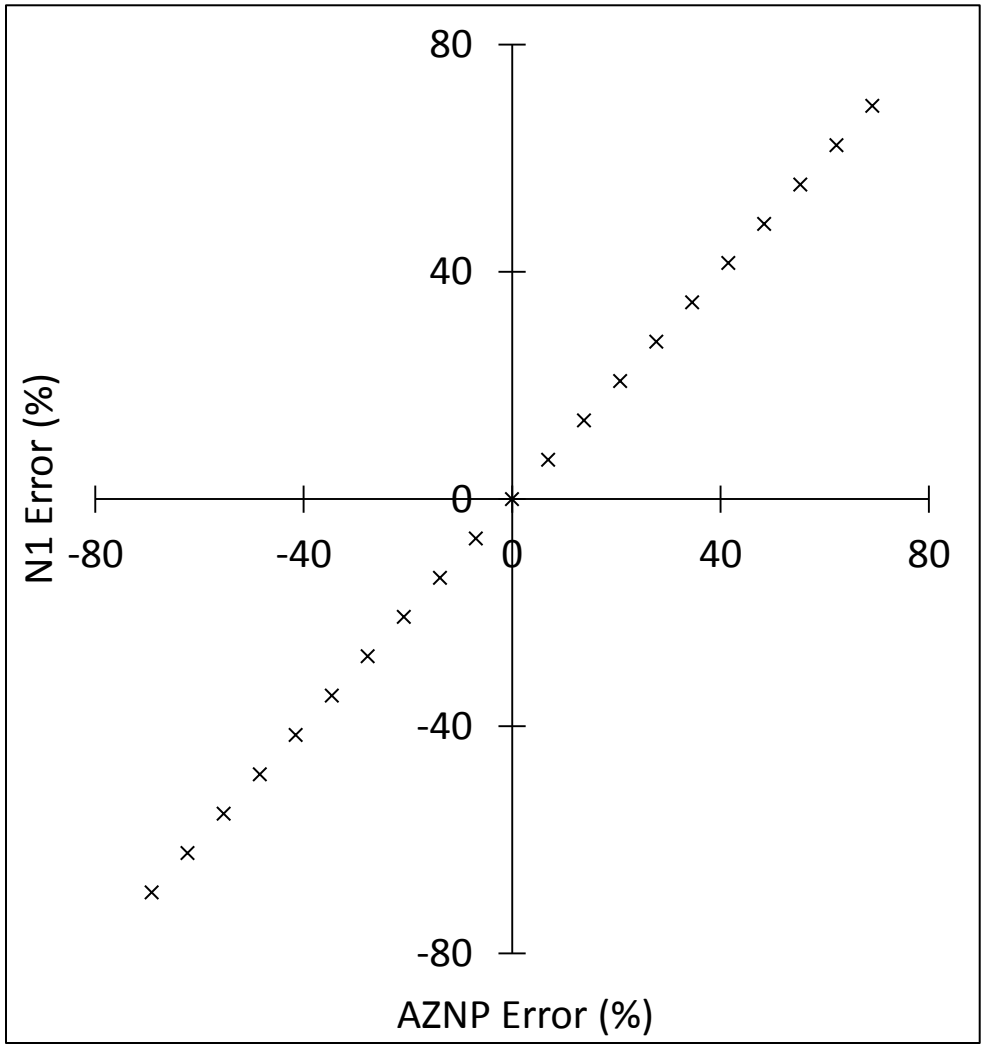
Pressure variation errors:

- Time-varying method.

Ratio Method

Friction headlosses negligible

$$N1_{leak} = \left(\frac{h_{leak}}{AZNP}\right) N1_{AZP}$$



Re-simulation Method

Step 1: Obtain Q_1 and Q_2 during MNF.

Step 2: Select node in network model to which leak is to be allocated.

Step 3: Allocate Q_1 and re-simulation to obtain pressure head h_1.

Step 4: Similarly, allocate Q_2 to obtain h_2.

Step 5: Correct N1 calculated from Q_1 and Q_2 plus h_1 and h_2.

Time-varying Method

1. Calculate leakage parameters *m* and A_0

2. Adjust leakage number for pressure head (each period) using:

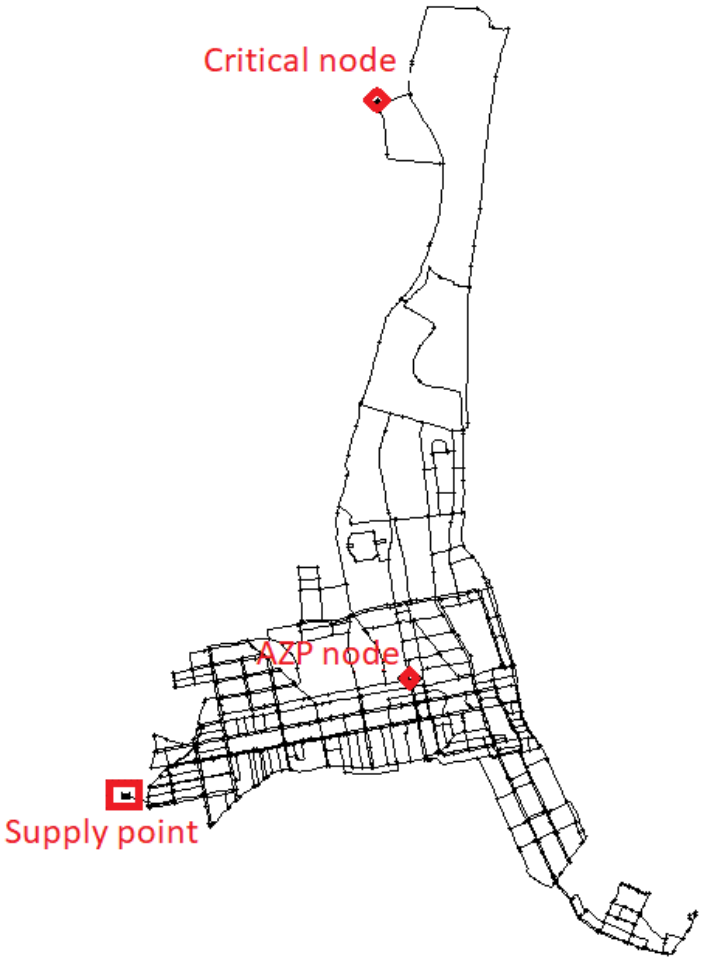
$$L_N = \frac{mh}{A_0}$$

3. Calculate correct N1:

$$N_1 = \frac{1.5L_N + 0.5}{L_N + 1}$$

Case studies

- Case study 1 (error sizes):
  - Leakage exponent (N1)
  - Flow rate.
- Case study 2:
  - Application to leak detection algorithm.



Case study 1 results (Leakage exponent)

During MNF period

ILI	Actual N1
4	1.1
16	1.1
64	1.1

Case study 1 results (Leakage exponent)

During MNF period

ILI	Actual N1	Before correction
		AZNP N1
4	1.1	1.17
16	1.1	1.12
64	1.1	0.68

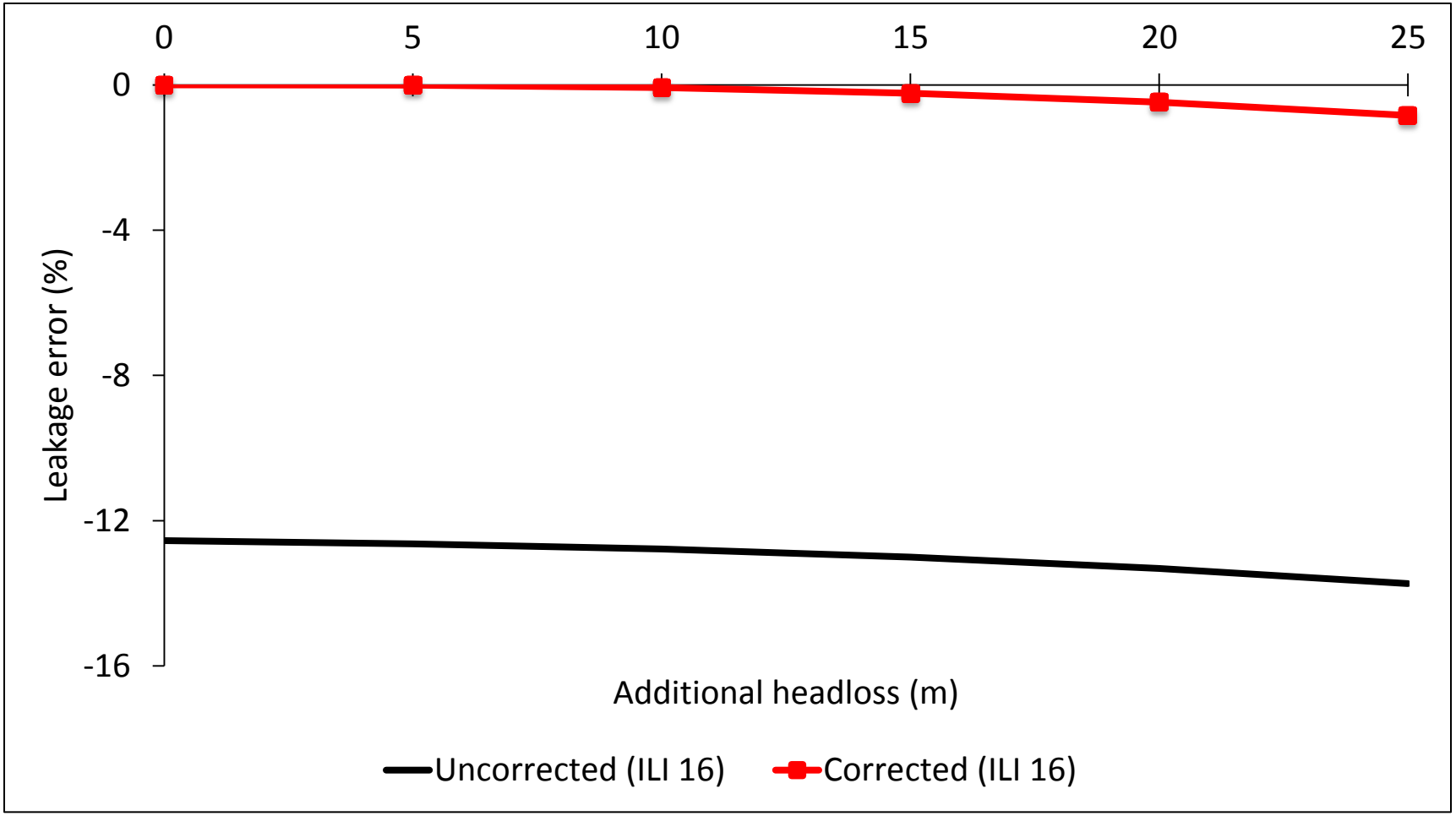
Case study 1 results (Leakage exponent)

During MNF period

ILI	Actual N1	Before correction	After correction	
		AZNP N1	Ratio	Re-simulation & Time-varying
4	1.1	1.17	1.09	1.1
16	1.1	1.12	0.99	1.1
64	1.1	0.68	0.19	1.1

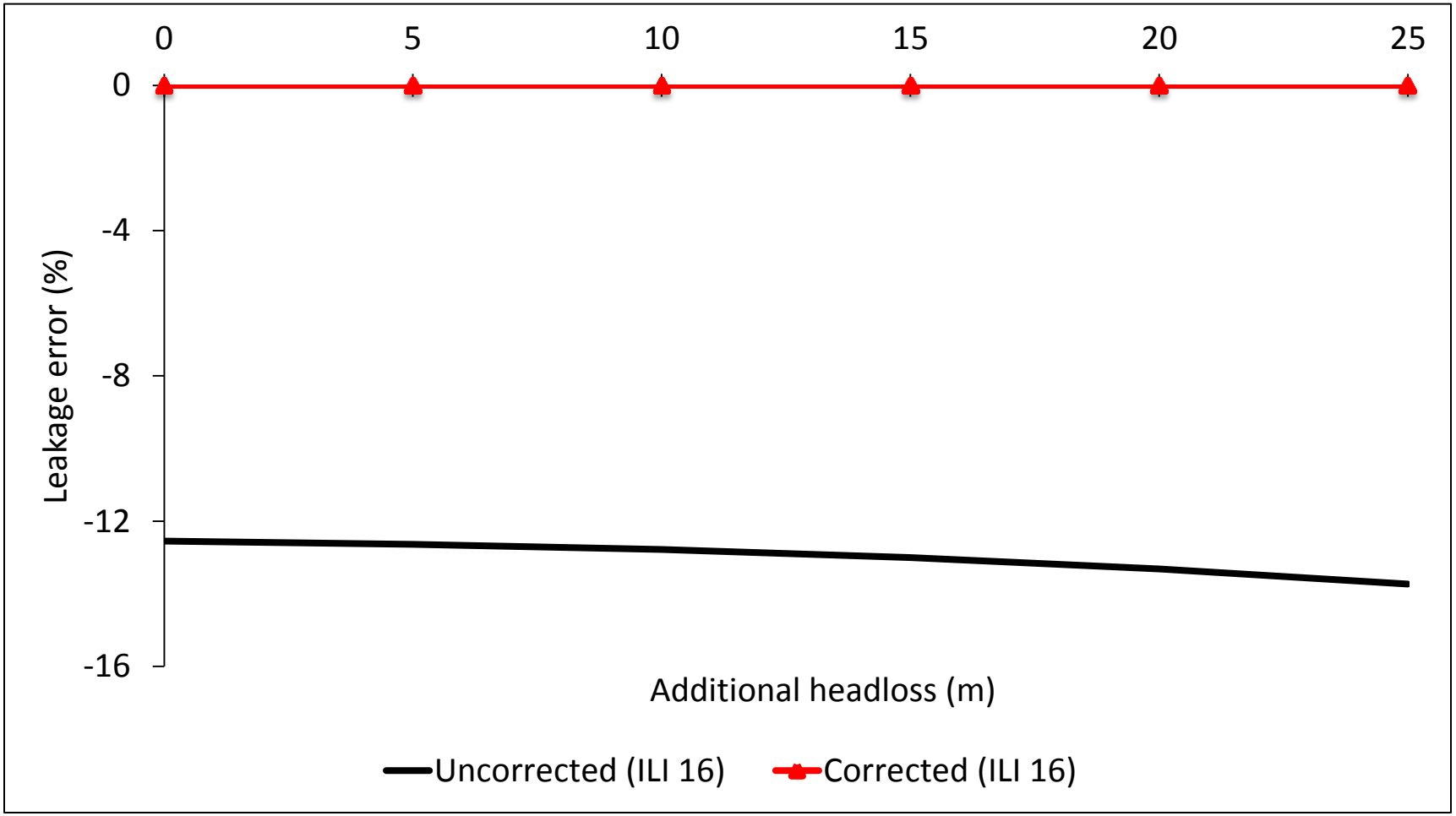
Case study 1 results (Leakage flow rate)

Re-simulation Method



Case study 1 results (Leakage flow rate)

Time-varying Method

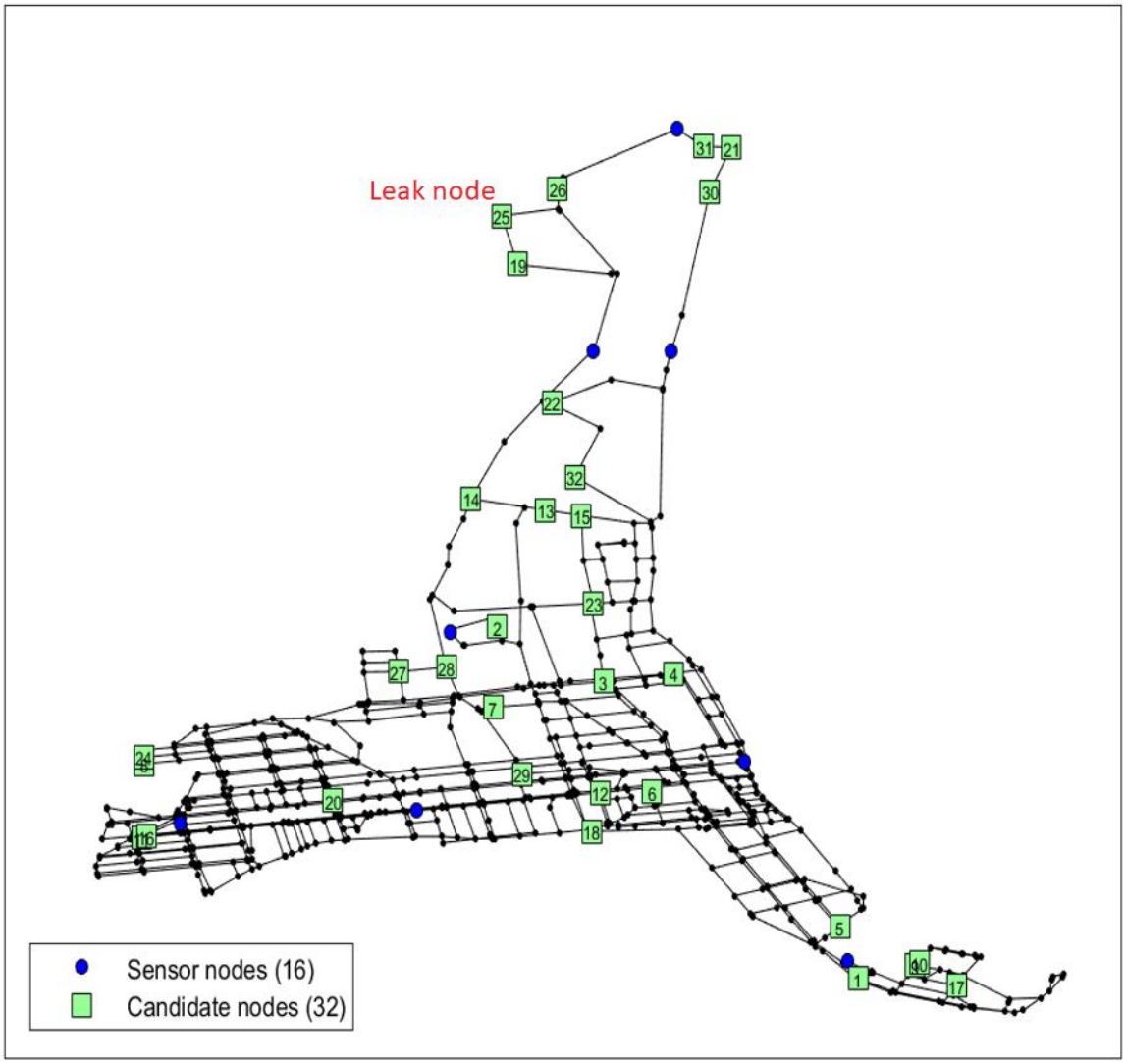


Case study 2 (Improved leak detection)

Existing leak detection model (Berglund et al):

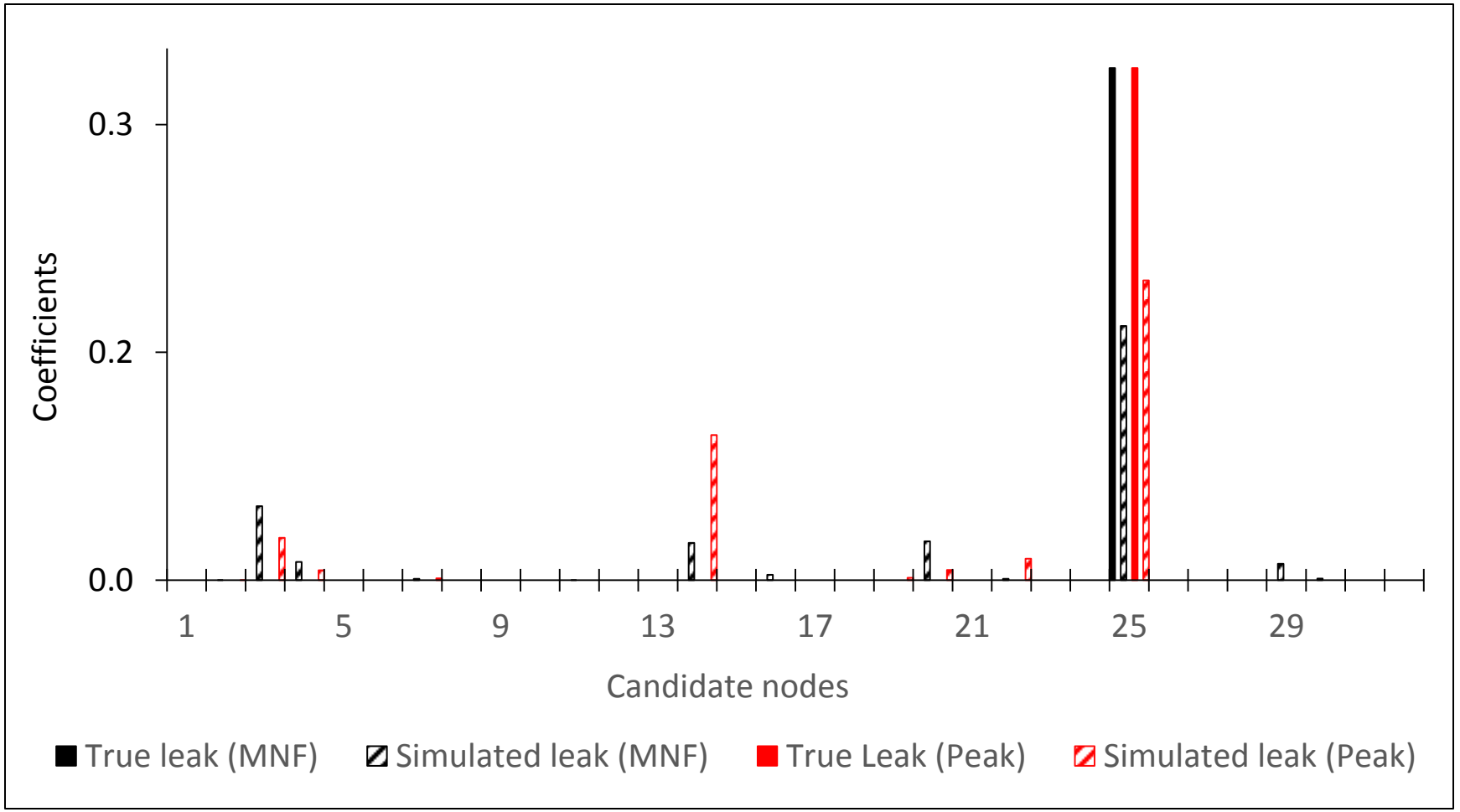
- Optimization model to identify leak **location** and **size**
- N1 is known
- Task is to determine leak coefficient C
- Minimizes difference between simulated and observed pressures

Case study 2 (Improve leak detection)



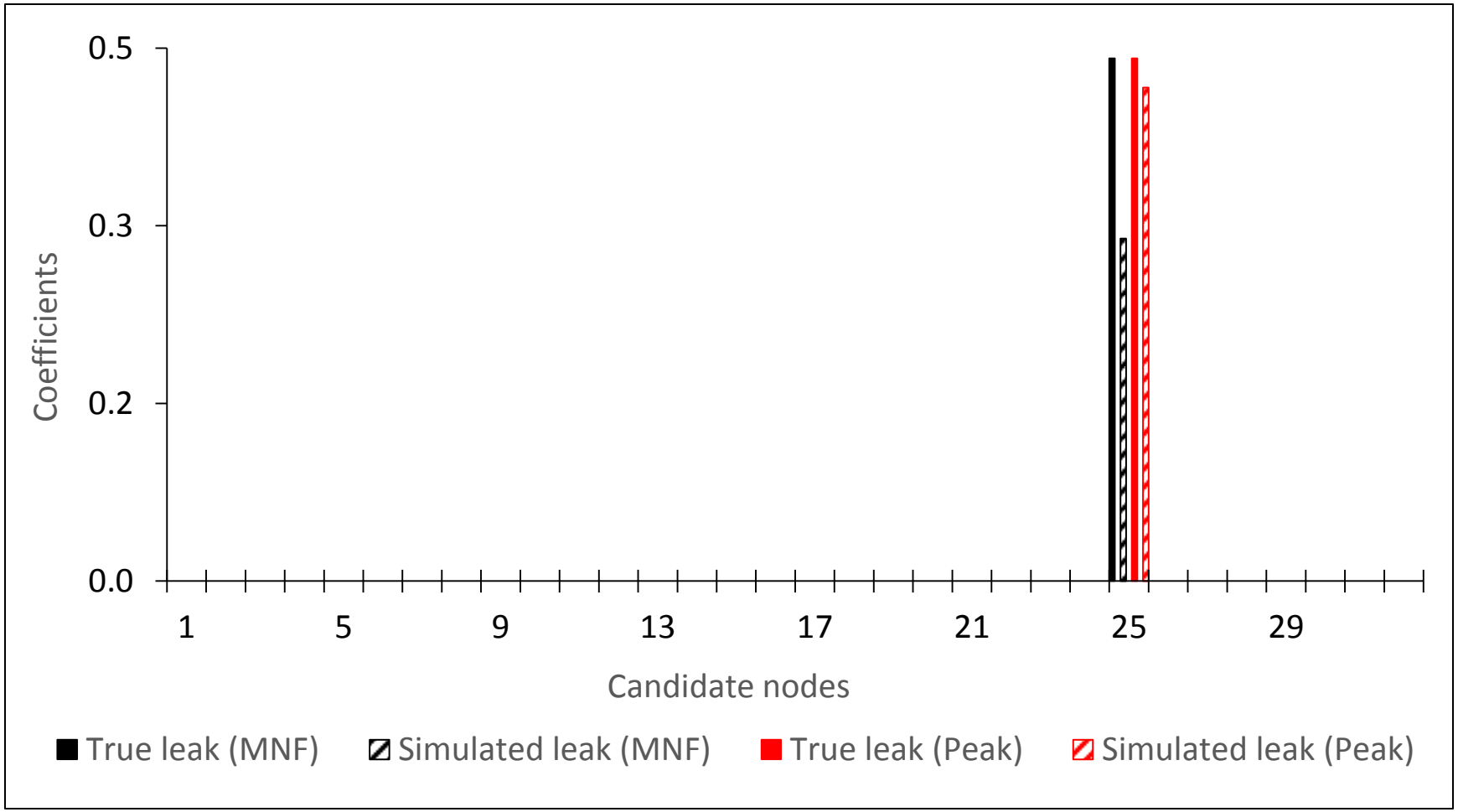
Case study 2 results

Uncorrected N1



Case study 2 results

Corrected N1 (Re-simulation)



Conclusion

- N1 varies with pressure
- The methods adjust for the errors
- Accurate simulation of system behavior.

Thank You