Estimation of the relationship between FAVAD N1 and ILI values for flexible pipe material water systems using field data in South Africa

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Introduction

- FAVAD N1 vs ILI for flexible pipe material water systems in South Africa

- New method to analyze the leakage taking into account the following variables:
  - Length of Mains (Lm)
  - Number of Connections (Nc)
  - Average Zone Pressure (AZP)
  - Night Day Factor (NDF)

Traditional Power Law

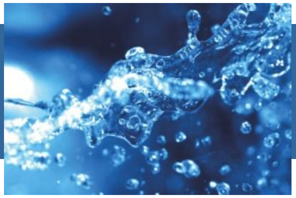
The traditional power law (proposed by John May):

$$\frac{L_a}{L_b} = \left(\frac{P_a}{P_b}\right)^{N1}$$

L: Leakage rate (before/after)
P: Pressure (before/after)
N1: FAVAD N1 value (0.5 – 2.5)

N1 ≈ 0.5 for rigid pipe water systems
N1 ≈ 1.0 for mixed pipe water systems
N1 ≈ 1.5 for flexible pipe water systems

Methods



- **FAVAD N1 Value**

$$N1 = log_{\left({AZNP_a}/{AZNP_b}\right)} \left[\frac{NL_a}{NL_b}\right]$$

- **Infrastructure Leakage Index (ILI)**

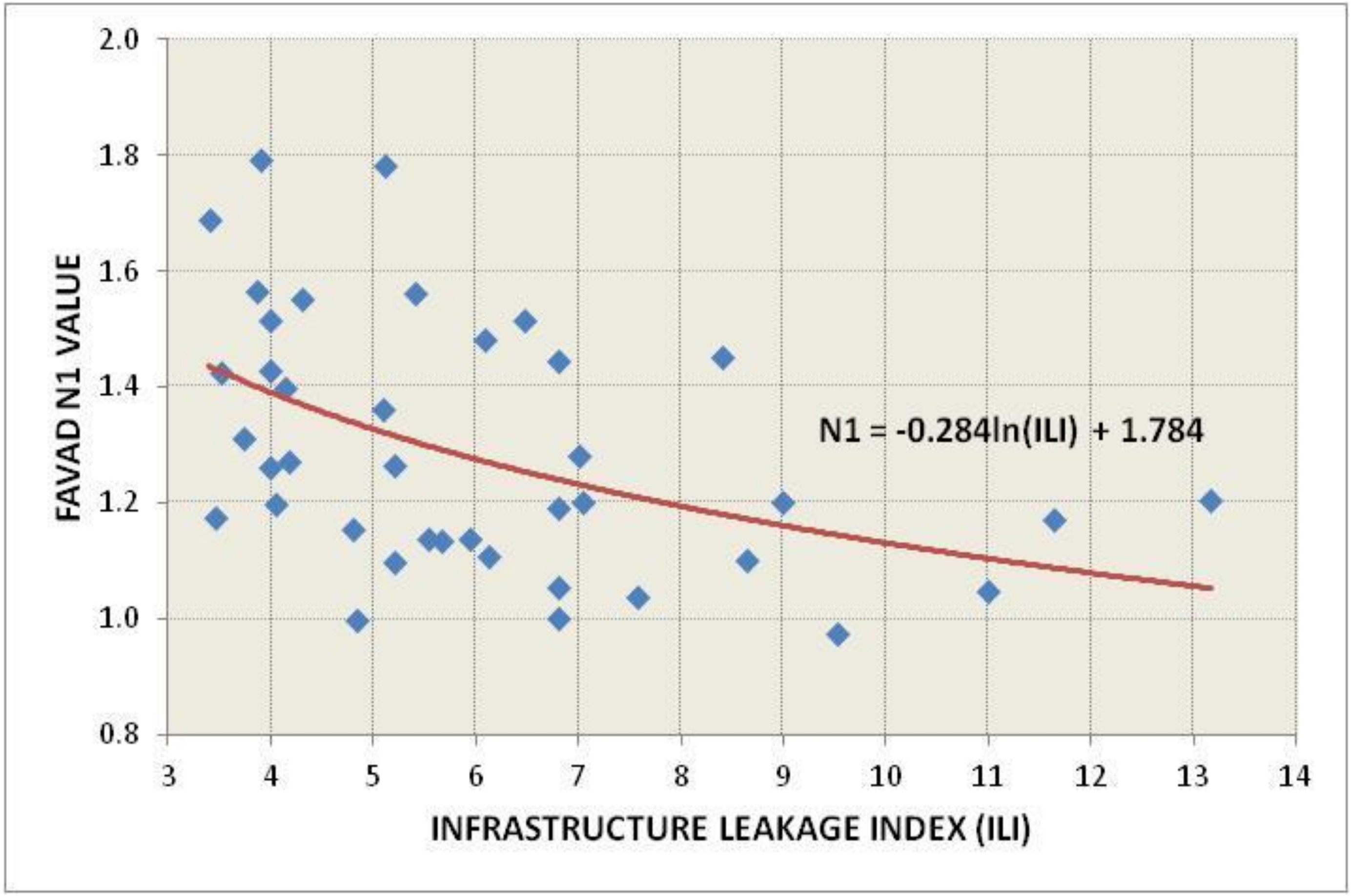
$$ILI = \frac{CARL}{UARL}$$

Pressure Reducing Valves

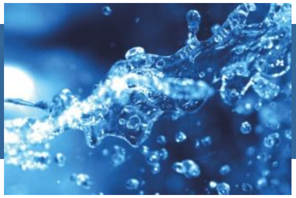
Main Characteristics of the Systems

Variable	Minimum	Average	Maximum
Nc [conn]	30	324	1866
Lm [km]	0.5	7.6	48.0
Dc [conn/km]	22	55	112
AZP [bar]	3.8-2.6	7.1-4.3	12.1-7.4
NDF [h]	18.5	23.1	26.7
N1	0.97	1.29	1.79
ILI	3.4	6.1	13.2

FAVAD N1 vs ILI



Applying the Pi Theorem



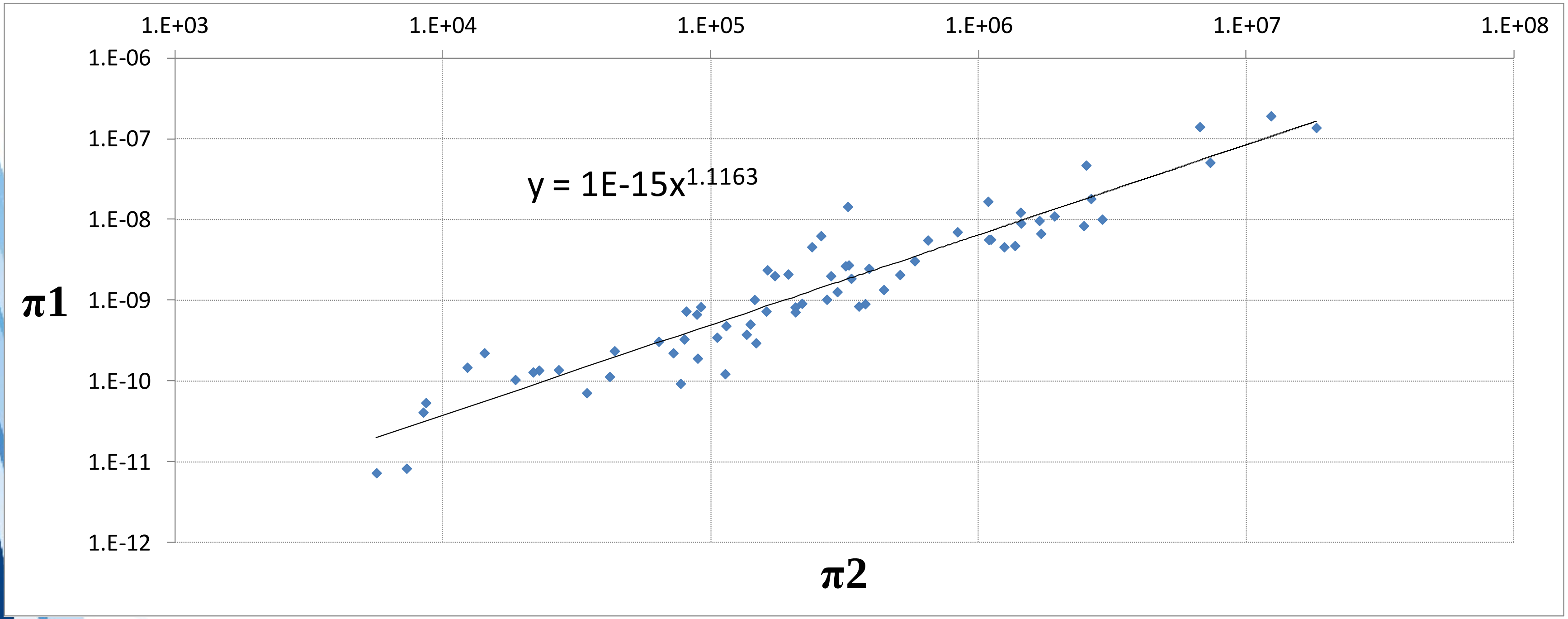
The π theorem is a method for reducing a number of dimensional variables into a smaller number of dimensionless groups, also called π numbers

$$\pi_1 = \frac{L.NDF.Nc}{Lm^3} = \frac{L.NDF.Dc}{Lm^2}$$

$$\pi_2 = \frac{AZP.NDF^2}{\rho.Lm^2}$$

Π1 = g (Π2)

Applying the Pi Theorem



$$\pi_1 = A.\pi_2{}^B \longrightarrow \frac{L.NDF.Nc}{Lm^3} = A.\left(\frac{AZP.NDF}{\rho.Lm^2}\right)^B$$

Applying the Pi Theorem

$$A = \frac{\pi_{1,before}}{\pi_{2,before}{}^{B}} = \frac{\pi_{1,after}}{\pi_{2,after}{}^{B}} = constant$$

$$A = \frac{\dfrac{L_b.NDF_b.\cancel{Nc_b}}{\cancel{Lm_b{}^3}}}{\left(\dfrac{AZP_b.NDF_b}{\cancel{\rho_b}.\cancel{Lm_b{}^2}}\right)^B} = \frac{\dfrac{L_a.NDF_a.\cancel{Nc_a}}{\cancel{Lm_a{}^3}}}{\left(\dfrac{AZP_a.NDF_a}{\cancel{\rho_a}.\cancel{Lm_a{}^2}}\right)^B}$$

$$La = Lb.\left(\frac{AZPa}{AZPb}\right)^B . \cancel{\left(\frac{NDFa}{NDFb}\right)^{2B-1}}$$

$$La = Lb.\left(\frac{AZPa}{AZPb}\right)^B$$

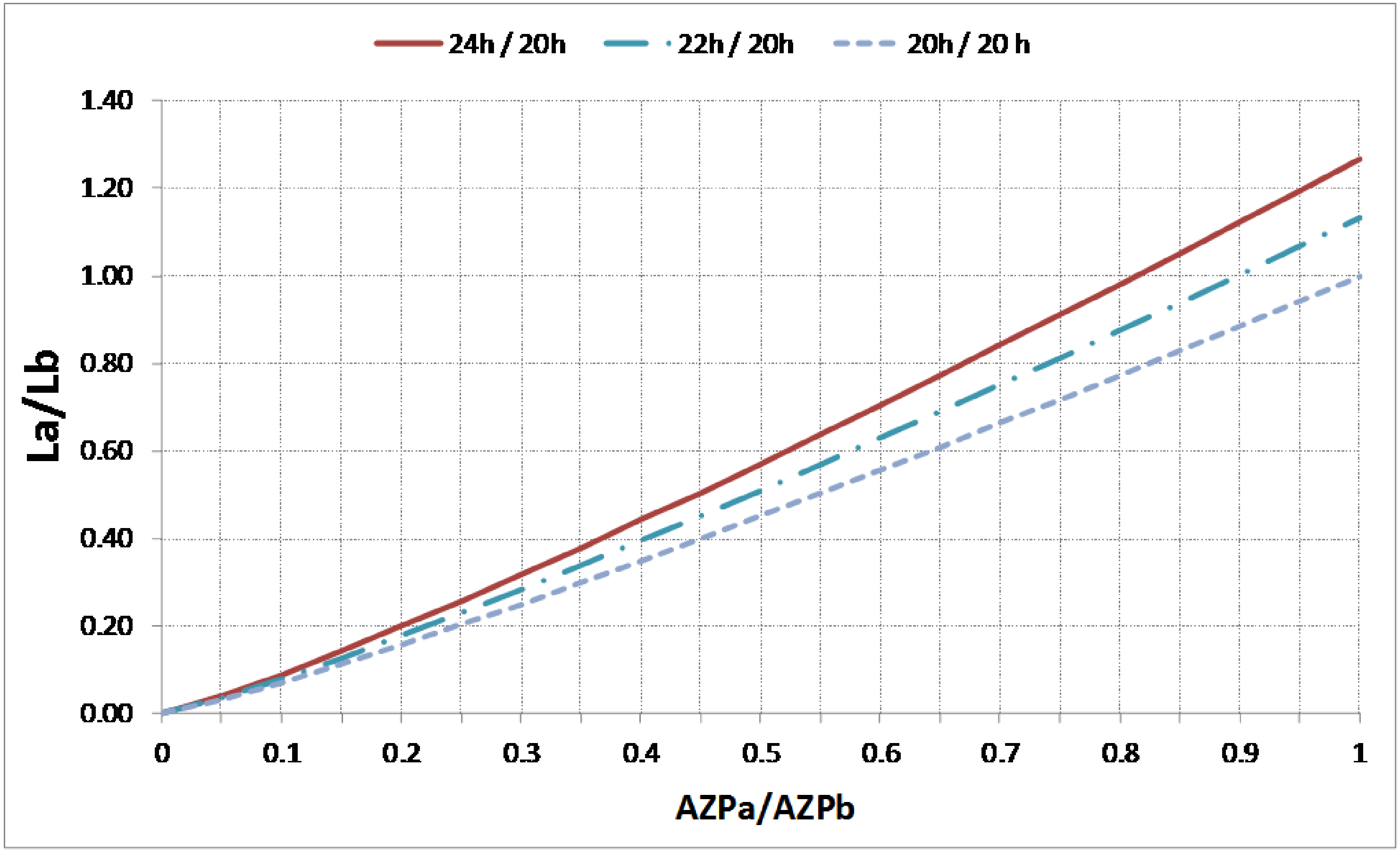
Traditional power law

B = FAVAD N1 Value

B = 1.15

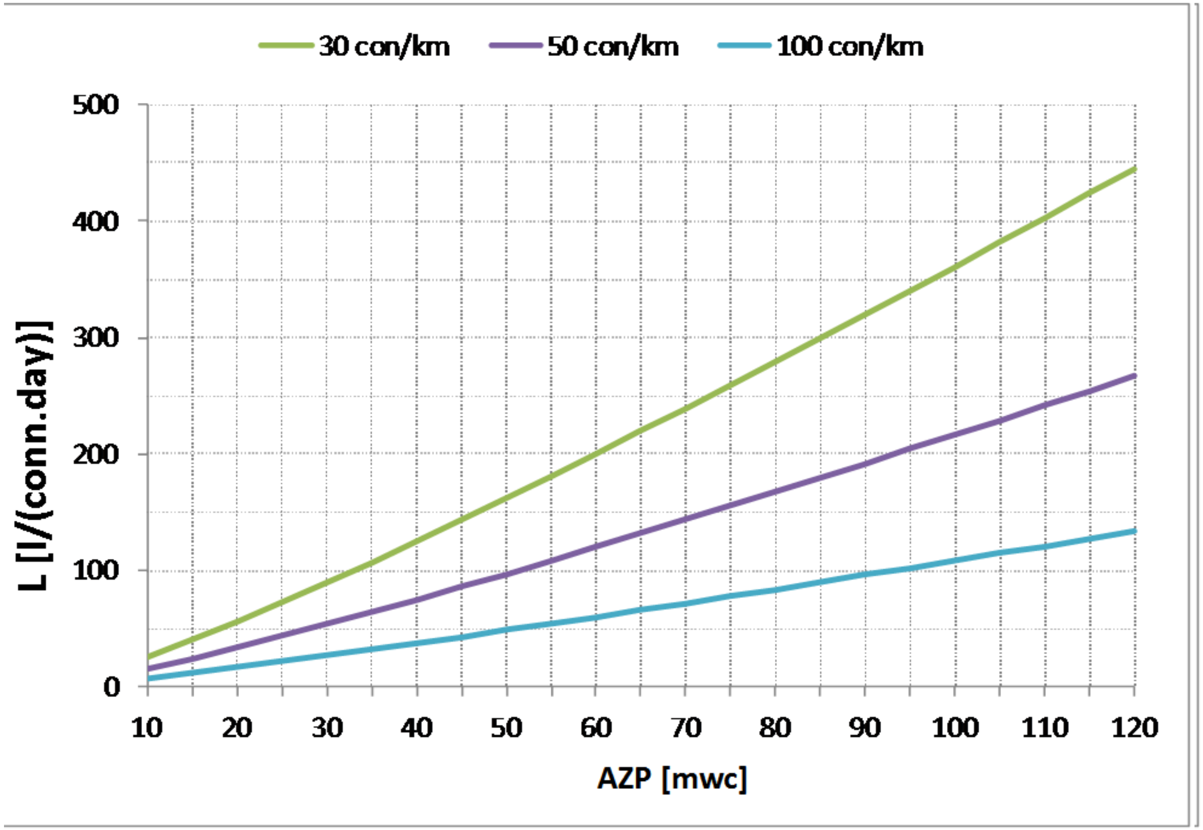
Applying the Pi Theorem

$$La = Lb.\left(\frac{AZPa}{AZPb}\right)^{B}.\left(\frac{NDFa}{NDFb}\right)^{2B-1}$$



Applying the Pi Theorem

$$L\left[\frac{litres}{conn.day}\right] = A.\frac{Lm}{Dc}.\left(\frac{AZP}{\rho}\right)^{B}.\left(\frac{NDF}{Lm}\right)^{2B-1}$$



Conclusions

- The FAVAD N1 values obtained for the flexible water systems analyzed range from 0.97 up to 1.79, being 1.29 the average value.

- The FAVAD N1 value decreases with an increment of the ILI, and this decrement is more pronounced as ILI becomes lower. The logarithmic trendline obtained from the PMZs analyzed suggests that N1 varies between 1.5 and 1.0; tending to be 1.5 for systems with low ILI (ILI < 4) and 1.0 for systems with high ILI (ILI > 10)

Conclusions

- The leakage can be explained by two dimensionless groups, which are related by a power law

  $\pi_1 = A.\pi_2{}^B$ where A = 7.10-16 and B = N1 = 1.15

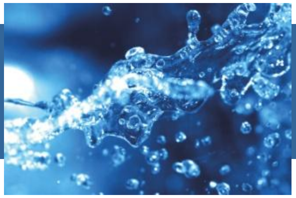
- Daily leakage per connection is proportional to AZP and NDF, and inversely proportional to Dc:

$$L\left[\frac{litres}{conn.day}\right] = A.\frac{Lm}{Dc}.\left(\frac{AZP}{\rho}\right)^B.\left(\frac{NDF}{Lm}\right)^{2B-1}$$

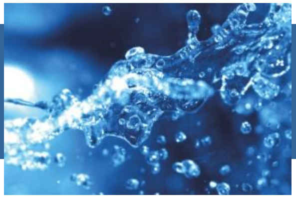
- For PMZ's, leakage reduction after pressure regulation can be estimated with the following formula:

$$La = Lb.\left(\frac{AZPa}{AZPb}\right)^B.\left(\frac{NDFa}{NDFb}\right)^{2B-1}$$

Thanks



Thanks!!



The basic equation for the calculation of UARL is:

UARL (litres/day) = (18 x Lm + 0.8 x Ns + 25 x Lp) x P ……….(2)

Table 2: Components of Unavoidable Annual Real Losses

Components of Unavoidable Annual Real Losses at 50 metres pressure (metric units)					
Infrastructure Component	Unavoidable Background Leakage UBL	Reported Breaks	Unreported Breaks	Unavoidable Annual Real Losses UARL	
Mains	480 litres/km/day	290 litres/km/day	130 litres/km/day	900 litres/km/day	18 litres/km/day/ metre of pressure
Service Connections, main to curb-stop	30 litres/conn/day	2 litres/conn/day	8 litres/conn/day	40 litres/conn/day	0.80 litres/conn/day/ metre of pressure
Service Connections, curb-stop to meter	800 litres/km/day	95 litres/km/day	355 litres/km/day	1250 litres/km/day	25 litres/km/day/ metre of pressure
Typical FAVAD N1	Close to 1.5	0.5 to 2.5, depends on pipe materials and types of leaks		Assumed as average of 1.0 for UARL formula	

Reference: Allan Lambert

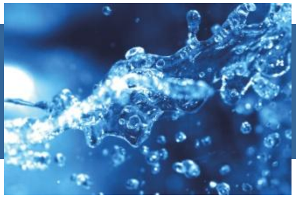


Table 3: Relaxation of limits of application of UARL formula, 1999 to 2009

Parameter	Limits	Lambert et al, AQUA	Lambert & McKenzie	Liemberger & McKenzie	Lambert
		1999	2001	2005	2009
Density of Connections/km	Minimum	20	20	Removed	No lower limit
	Maximum	100	Removed		No upper limit
Average Pressures (m)	Minimum	20	25	25	See Graph
	Maximum				See Graph
System Size	Minimum	Not stated	Nc > 5000	Nc > 3000	Nc + 20 x Lm > 3000

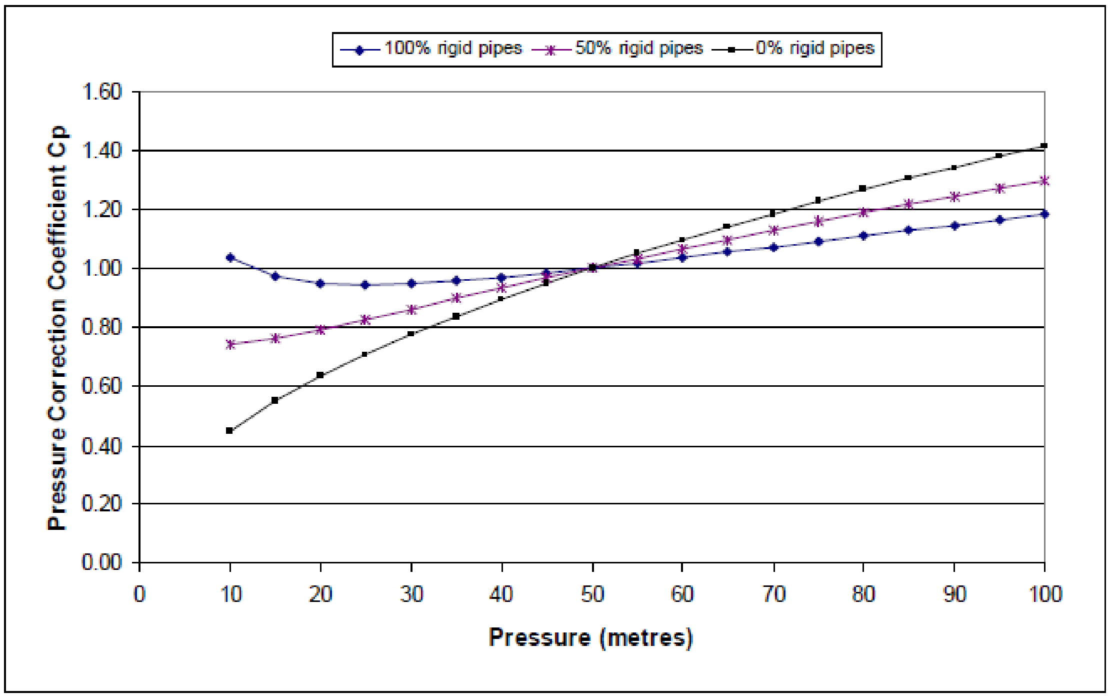


Figure 2: Influence of type of pipe materials on UARL as pressure changes

Reference: Allan Lambert

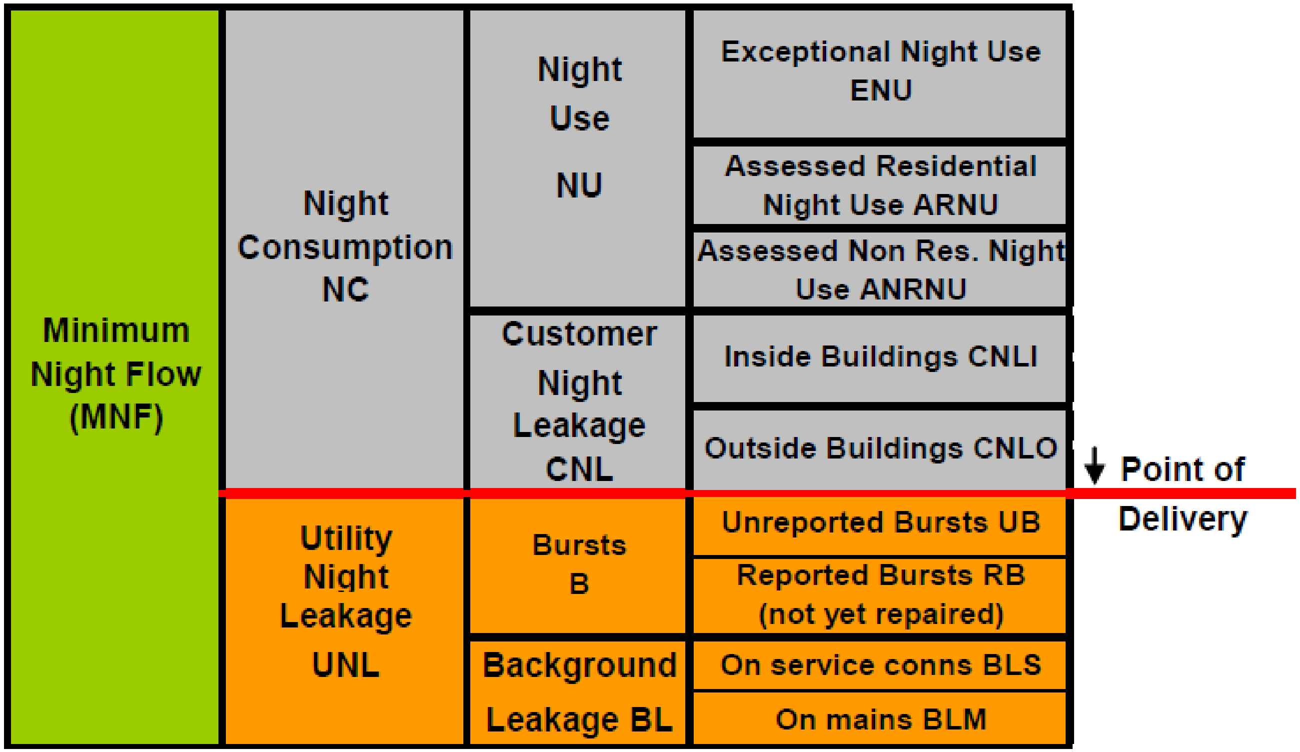


Figure 1 Components of Minimum Night Flow. Source: WLSG Night Flow Team: (2010)

Reference: Marco Fantozzi