Understanding and Predicting the Benefits of Distribution System Pressure Management

Power Point for AZP&NDFCalcs
July 2016

Defining Average Zone Point (AZP)
and other pressure management points,
and calculating Night-Day Factor (NDF)

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Guidelines for calculating Average Pressure in Zones and Systems

- Guidelines relating to the Assessment and Calculation of Average Pressure in Water Distribution Systems and Zones
  - by ILMSS Ltd, based on practical experiences

http://www.leakssuite.com/wp-content/uploads/2015/04/AvePressureGuidelinesIntVersion28Jul13.pdf

AZP&NDFCalcs Worksheets

- Licence
- Introduction
- Pressure Measurements
- Define PM Points
- Plan of Zone
- Night-Day Factor NDF Info
- Calculate NDF

Licence Worksheet

Welcome to the AZP&NDFCalcs Free software, International Version

which is part of the **'LEAKS'** Suite of **L**EAKAGE **E**VALUATION and **A**SSESSMENT **K**NOW-HOW **S**OFTWARE

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The purpose of this free program is to assist Water Utilities to quickly identify Average Zone Points (AZPs) in District Metered Areas and Pressure Zones, and to use 24-hour pressure readings at the AZP to calculate Night-Day Factors (NDFs) relating night leakage (m^3/hr) to daily leakage (m^3/day)

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AZP&NDFCalcs	Free	Average Zone Point and Night Day Factor: Concepts and Calculations
Version 1c	17th Nov 2013	

International	INT.EUR.000	Master Copy

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‘Introduction’ Worksheet

'LEAKS' Suite of LEAKAGE EVALUATION and ASSESSMENT KNOW-HOW SOFTWARE					
Introduction to AZP&NDFCalcs - A free Software that explains how to define an Average Zone Point, and calculate Night-Day Factors					
Average Zone Point and Night Day Factor: Concepts and Calculations	**Free**	**Version 1c**	**17th Nov 2013**	**International**	**© ILMSS Ltd**

In 1999 and 2000 the International Water Association (IWA) Task Forces on Water Losses and Performance Indicators published their Best Practice Water Balance and Performance Indicators, for Non-Revenue Water and its components. For the first time, leakage management performance of Utilities in different countries could be compared on a level playing field; the results were not generally comforting for our industry.

The traditional simple performance indicator '% by volume' for Non-Revenue Water and Real Losses is now known to be unsuitable for setting targets and measuring progress (process benchmarking), or comparing performance between different systems (metric benchmarking). This is due to significant differences and changes in consumption of water per service connection, and different methods of calculating %s. Many Water Utilities are seen to be operating at leakage levels that are in excess of economic leakage levels, and there is money, as well as water, to be saved.

Large sustained reductions in real losses have been achieved by progressive Utilities in an increasing number of countries since 2000, through use of best practice practical concepts promoted by the IWA Water Loss Specialist Group. Regional and National regulators in several countries have recognised that substantial opportunities exist for better management of losses in many water distribution systems.

The developers and distributors of **LEAKSSuite** software are leading advocates of advanced practical approaches to water loss management developed by the IWA Water Loss Task Force (now the Water Loss Specialist Group), and are committed to make a strong contribution to introducing these methods internationally. Reports and articles can provide useful overview information. However, our experience is that absolutely the best fast-track way to 'get started' is to use appropriately customised, user-friendly software, preferably with basic training, and easy access to such specialist support as may be necessary. They can be customised (for units, currency or language) and upgraded whenever any significant improvements in 'best practice' are identified, anywhere in the World.

The **'Pressure Measurements'** Worksheet explains the pressure measurement points required for leakage and pressure calculations in Zones of Distribution systems; and the **'Define PM points'** Worksheet helps you to define and record these points. You can then enter a plan of each Zone and the measurement points in **'Plan of Zone'**. **'Night-Day Factor NDF'** explains what is meant by Night-Day Factor, which links minimum hourly leak flow rates at night to 24 hour average leak flow rates. **'Calculate NDF'** allows you to calculate Night-Day factors, from pressure measurements taken at the 'Average Zone Point'. **www.leakssuite.com** provides further information on other LEAKSSuite software, with free downloads of technical papers.

Worksheet tabs are colour coded as follows:	Worksheets containing information only		Worksheets for data entry
Cells are colour coded as follows:	Data from another Worksheet	Data entry	Calculated values

‘Pressure Measurements’ Worksheet

Upper Part of Worksheet

'LEAKS' Suite of LEAKAGE EVALUATION and ASSESSMENT KNOW-HOW SOFTWARE					
Average Zone Point and Night Day Factor: Concepts and Calculations	Free	Version 1c	17th Nov 2013	International	© ILMSS Ltd
THIS WORKSHEET DESCRIBES PRESSURE MEASUREMENTS POINTS REQUIRED FOR PRESSURE MANAGEMENT ANALYSIS AND PREDICTIONS					

INLET POINT(S) AND CRITICAL POINT(S)

Various pressure measurements at different locations are required for pressure management analyses and predictions, in District Metered Areas (DMAs) and Pressure Management Zones (PMZs). The most obvious location is at the **Inlet point(s).** Pressures may be recorded on site, or transmitted by various means to distant locations. The **'Define PM Points'** Worksheet contains a Section for entering data on the Inlet Points.

Most High Income Countries, and some Low and Middle Income (LAMIC) Countries, specify minimum standards of service for pressure at the boundary of properties. So it is also usual to measure pressures at the **Critical Point** (sometimes known as the **Target Point**), which experiences the lowest pressures. It is usually not too difficult to identify the Critical Point(s) in a System or Zone. The **'Define PM points'** Worksheet contains a Section for entering data on the Critical Point(s).

AVERAGE ZONE POINT (AZP)

When pressure management is being used (or is being considered), it is also necessary for analysis and prediction purposes to identify an **'Average Zone Point' (AZP)**. This is a location in a Zone that is considered to be approximately representative of the average pressure in the Zone, during the variation of inflows on a daily and seasonal basis. The Average Pressure for a whole system can then be calculated by using the weighted average of all the Zones in the System, preferably using 'Number of Service Connections' as the weighting factor.

It is worthwhile to adopt a systematic approach to identifying the Average Zone Point, as the Average Zone Pressure is an essential parameter in a wide variety of pressure management and leakage calculations and predictions. These include:

- calculations and predictions involving Night-Day Factor (which relates Night Leakage Rate to 24-hour leakage volume)
- calculations involving FAVAD N1 exponents, which are used to calculate how sensitive leak flow rates are to changes in pressure
- calculations and predictions involving leakage and components of leakage, including estimates of recoverable leakage from night flows
- calculations and predictions of payback periods for different types of PRV installations, based on 24-hour tests
- calculations involving FAVAD N3 exponents, which are used to calculate how sensitive elements of consumption are to changes in pressure
- calculations of Best Practice performance indicators such as the Infrastructure Leakage Index (ILI)

It has not been traditional practice in most countries to identify an **'Average Zone Point' (AZP)**, and measure AZP pressures. However, the User of this program is strongly advised to use the **'Define PM points'** Worksheet in this Software to identify an AZP point in ***every*** Zone for occasional field measurements. Using the Inlet pressure or the pressure at the Critical Point for such calculations produces unreliable results and conclusions, because of unknown differences in pressure between the Inflow Point and the AZP point, or between the Critical Point and the AZP point.

Average Zone Point (AZP)

- A location in a Zone considered to be representative of the average pressure in the zone, during the variation of inflows on a daily and seasonal basis

- Measurements (or reliable estimates) of pressure at the AZP are essential for all but very approximate analyses and predictions

- Measurements at the inlet point and critical point are not adequate substitutes for AZP pressures

AZP pressure usually differs from Inlet and Critical Point pressure

It can be much higher, or much lower, depending on the topography

Figure 1a

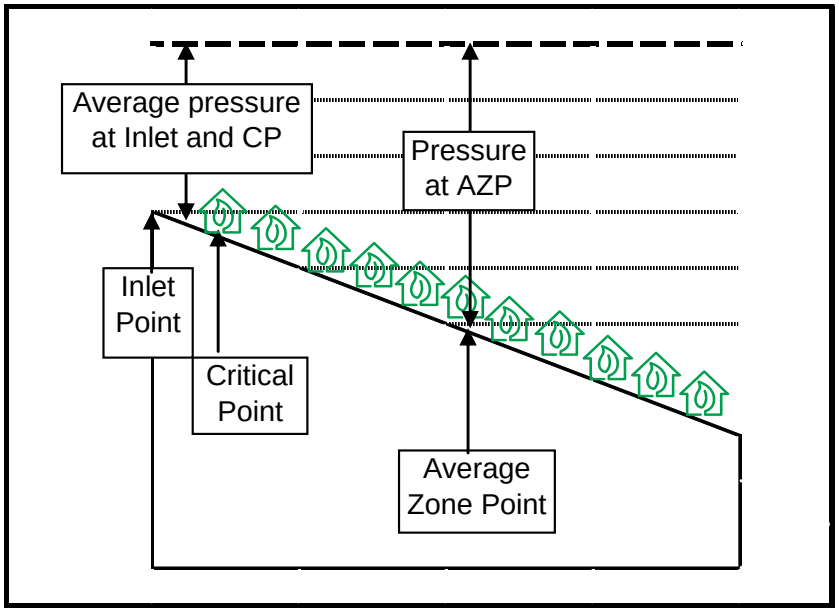
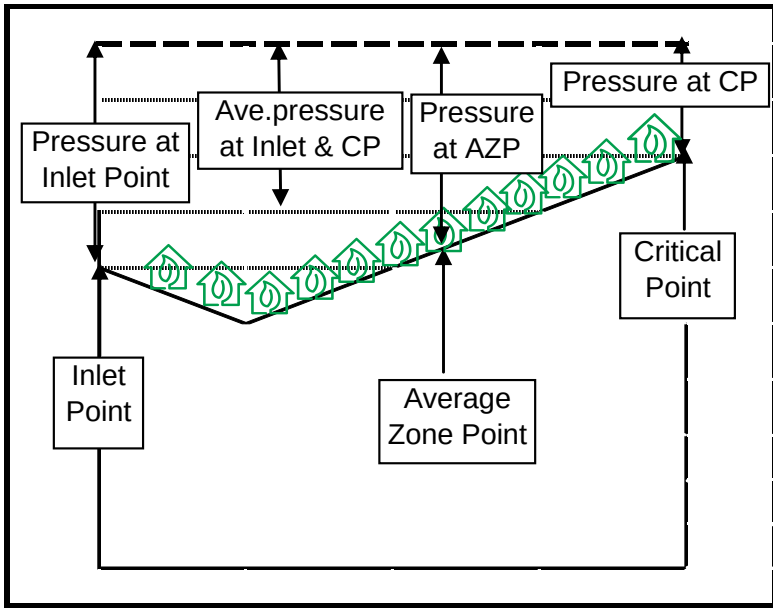


Figure 1b



The above figures appear in the middle part of the 'Pressure Measurements' Worksheet

‘Pressure Measurements’ Worksheet

Lower Part of Worksheet:
Maximum Zone Pressures and Transients

It is not so difficult to identify the AZP point - there are several ways of doing so, on the **'Define PM points'** Worksheet. These include:

- Network Analysis models (if available) - useful for larger Zones
- Methods based on sample 24-hour recordings of pressure at a number of sites throughout the Zone; these are then averaged and one or two representative sites chosen
- Methods based on estimating weighted average ground level of infrastructure parameters such as service connections, hydrants, properties or mains length - a calculation table is provided in the '**Define PM points'** Worksheet, or Global positioning System (GPS) data

For more information on calculation of AZPs and Average Pressures, contact www.LEAKSSuite.com to request a copy of ***'GUIDELINES relating to the Assessment and Calculation of AVERAGE PRESSURE in Water Distribution Systems and Zones (July 2011)'***

MAXIMUM ZONE PRESSURE

For predictions of changes in burst frequency arising from pressure management, the Maximum pressure (rather than the average pressure) appears to be the most important parameter; this will need to include the effect of pressure transients (surges) if they are present (see below). For Zones with relatively uniform ground levels, it may be sufficient to use the maximum pressure recorded at the Average Zone Point; but for Zones with large variations in ground level, a separate occasional measurement may be required at the lowest ground level in the Zone.

MAXIMUM AND MINIMUM PRESSURES DUE TO SURGES (PRESSURE TRANSIENTS)

Most pressures are recorded as averages over a pre-set time period such as 5 minutes, 15 minutes etc., and the presence of pressure transients over very short time periods will not be identified from such data. Accordingly, when investigating existing or proposed pressure management schemes, it is always recommended that short period measurements of pressure at intervals of 1 second or less should be taken over 24 hours at one location in the Zone - even in Zones supplied by gravity.

Options to calculate the “weighted average value” of the ground level at the Average Zone Point (AZP)

1. Using Network Analysis Model node points (Network Analysis Model), using elevation at nodes ‘weighted’ on:
   - Number of connections
   - Or Number of properties

2. Count number of Service Connections, hydrants or properties between contours, to get the Weighted Average Ground Level (using the Excel Worksheet)

3. Other method of estimation (to be specified)

‘Define PM Sites’ Worksheet: Parts A to C

'LEAKS' Suite of LEAKAGE EVALUATION and ASSESSMENT KNOW-HOW SOFTWARE						
Average Zone Point and Night Day Factor: Concepts and Calculations	Free	Version 1c	17th Nov 2013	International	© ILMSS Ltd	
WORKSHEET USED TO DEFINE KEY POINTS FOR ZONE PRESSURE AND INFLOW MEASUREMENTS: INLET POINT(S), CRITICAL POINT AND AVERAGE ZONE POINT (AZP)						
Colour coding	Data Entry	Calculated	From another Worksheet			

Utility	Anytown	Ground Levels	Maximum	56	metres above sea level (asl)	Contour Interval 2 metres
Zone	AnyZone		Minimum	34		

Part A: SPECIFY INFLOW POINT(S), OUTFLOW POINT(S) AND CRITICAL POINT(S)	Key locations for pressure measurement		Ground Level metres above sea level	Description and location
Identify, and enter the ground levels of, any Inflow Points	Inflow Points	I1	45.0	300 mm main opposite Church
		I2	40.0	
		I3	50.0	
Identify, and enter the ground levels of, any Outflow Points	Outflow points	O1	45.0	
		O2	40.0	
		O3	50.0	
Identify, and enter the ground level of, the Critical Point(s)	Critical Point	CP1	50.0	Outside 35 High Street
		CP2	50.0	

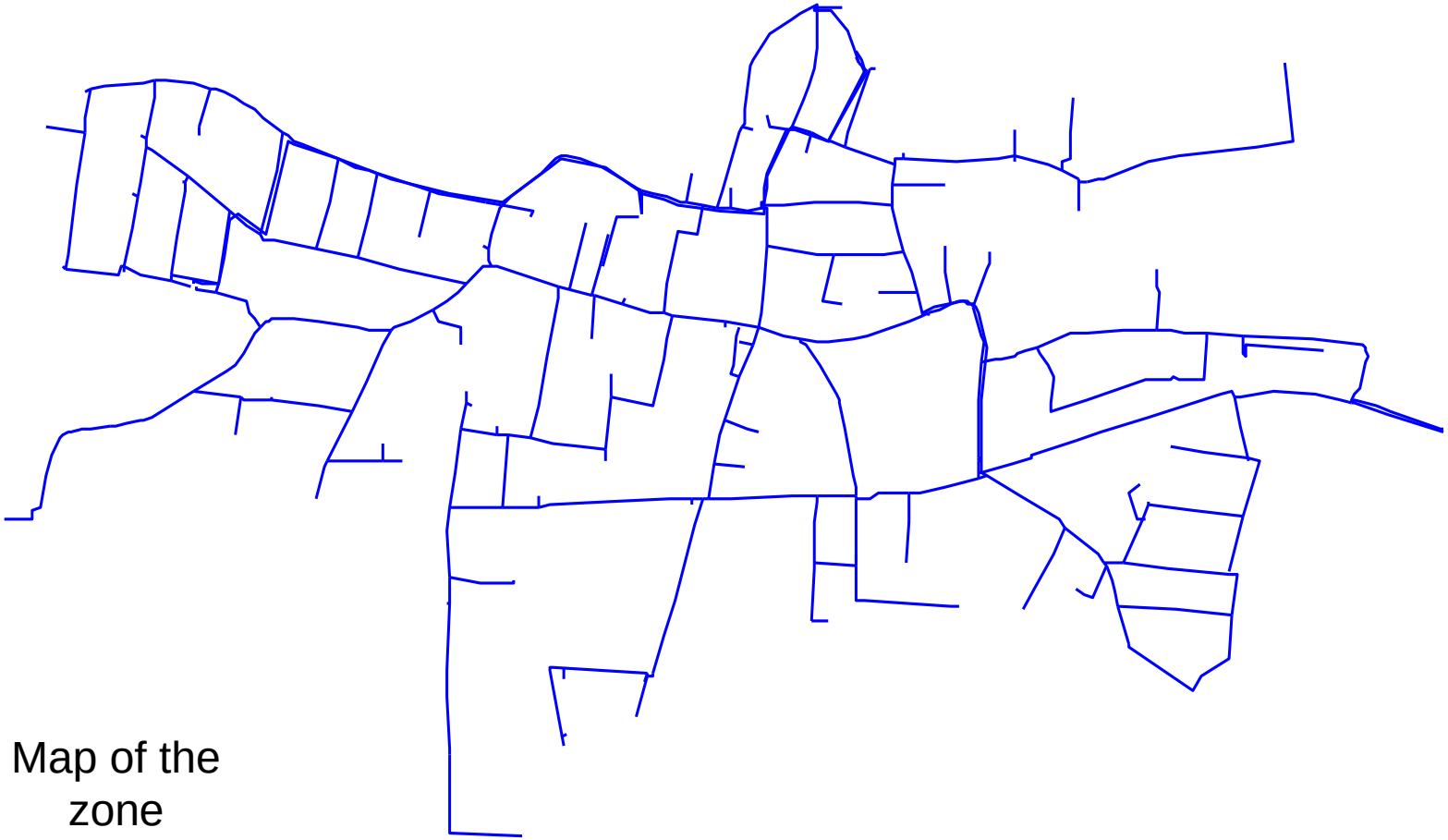
Part B: SELECT METHOD TO BE USED TO CALCULATE WEIGHTED AVERAGE GROUND LEVEL IN ZONE			
Method	Description of Method	Weighted Average Ground Level metres above sea level	
1	Using Network Analysis Model node points		< If using Method 1, enter value here
2	Calculated average value from [ ] pressure measurements taken in the Zone		< If using Method 2, enter value here, show data and points on ZonePlan Worksheet
3a	Count number of Service Connections between contours		To use Method 3, select chosen parameter (Services, Hydrants, Properties or Mains length); enter data in Part D, then transfer calculated Average Ground Level in Cell J49 to Cell H27 or H28 or H29 or H30.
3b	Count number of Hydrants between contours	42.9	
3c	Count number of Properties between contours		
3d	Use mains length between contours		
4	Other method of estimation (e.g. GIS, GPS)		< If using Method 4, enter value here

Part C: SELECT A CENTRALLY LOCATED AVERAGE ZONE POINT (AZP) with ground level close to weighted average ground level				
Selected AZP is at	Hydrant outside 23 Watery Lane	ground level is	43.5	metres above sea level
The Inlet, AZP and Critical points, and contours, should be entered in the Plan of Zone Worksheet				

Comments:

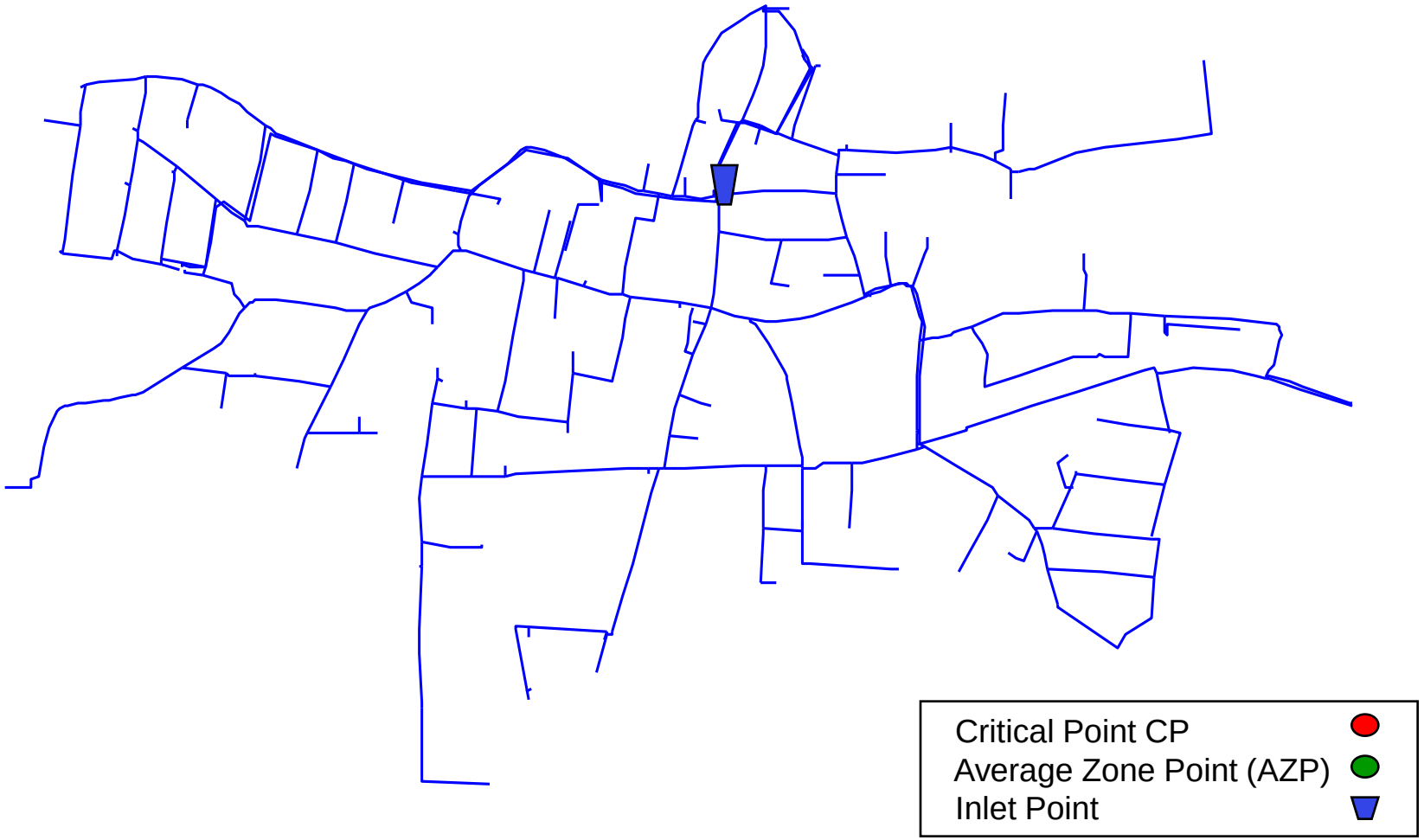
Calculation by	A.N.Other	Date	20th July 2007	e-mail contact	

Example: Identification of pressure measurement points

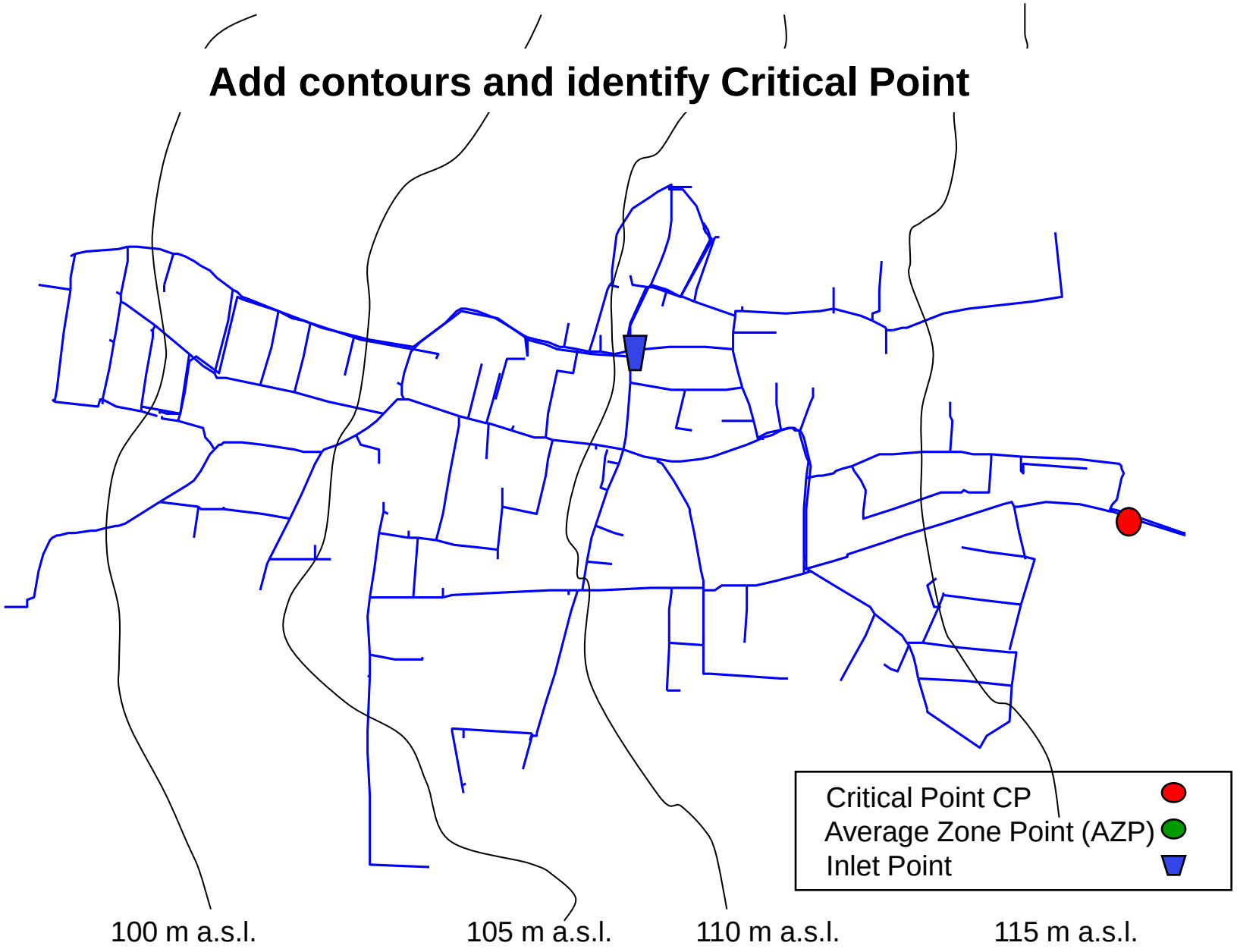


Map of the zone

Inlet Point



Add contours and identify Critical Point



‘Define PM Sites’ Worksheet: Part D

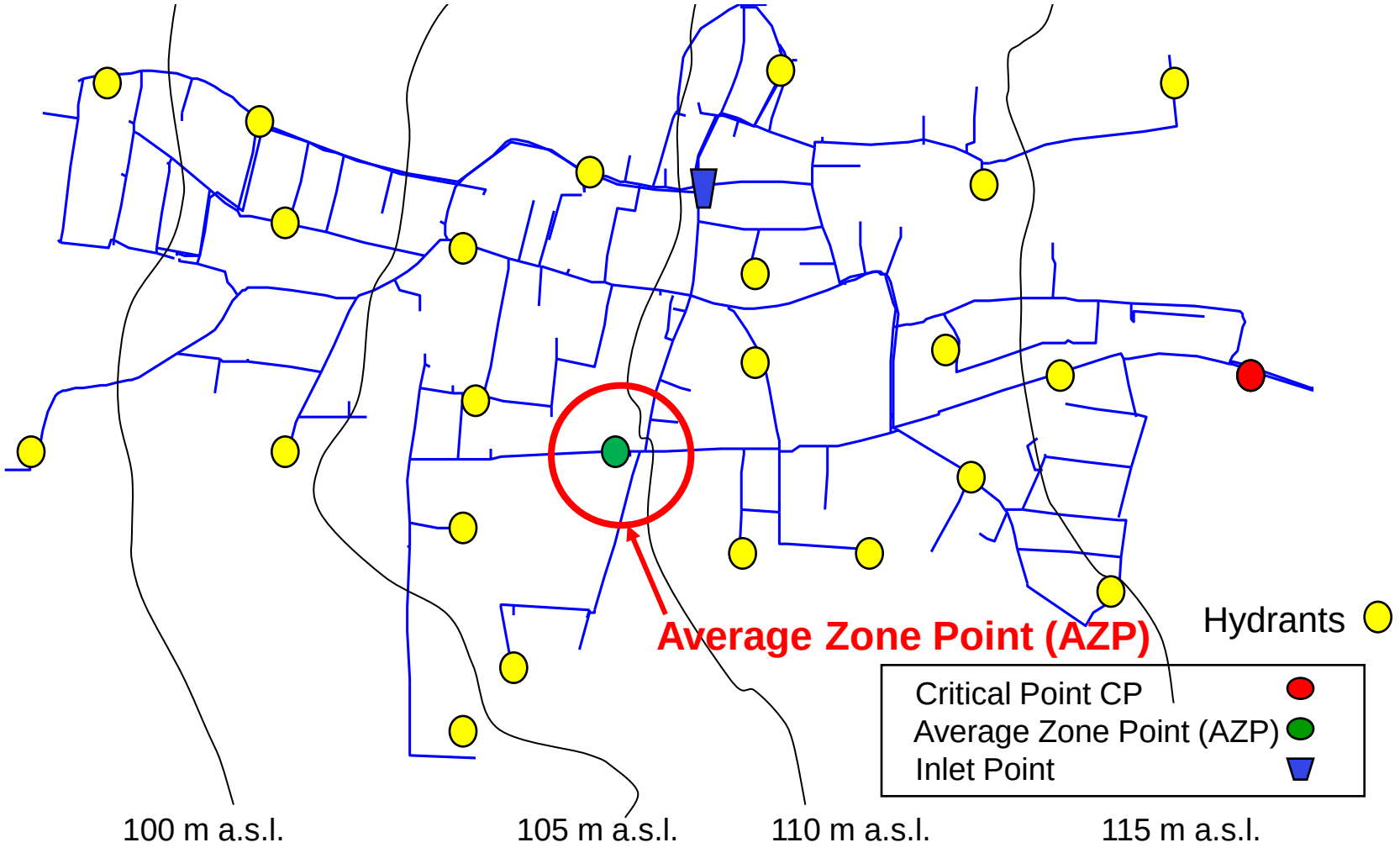
Part D: CALCULATION OF WEIGHTED AVERAGE GROUND LEVEL using Infrastructure numbers or lengths between Contours

Using the information in Cells H6, H7 and J7, the software sets up contour bands on Rows 48 onwards, between the minimum and maximum ground levels in the Zone. Choose one of the four parameters (Number of Service Connections, or Hydrants, or Properties; or Mains Length) and enter the number (or mains length) that occurs in each contour band, on rows 48, 49 etc. When you have completed this action, the calculated weighted average ground level is shown in Cell J47. This should then be manually transferred to the appropriate Cell in Part B (H25, H26, H27, or H28).

Contour Bands metres above sea level			Number of			km	Chosen parameter	Σ(Mid-pt x number or length)	
Lower Limit	Upper Limit	Mid-point	Service Connections	Hydrants	Properties	Mains length			
			0	360	0	0.00	360	15448	< Column totals
			Enter data in only one of these columns					42.9	Weighted < average ground level
34	36	35		18			18	630	
36	38	37		43			43	1591	
38	40	39		43			43	1677	
40	42	41		41			41	1681	
42	44	43		63			63	2709	
44	46	45		70			70	3150	
46	48	47		41			41	1927	
48	50	49		18			18	882	
50	52	51		12			12	612	
52	54	53		8			8	424	
54	56	55		3			3	165	

Calculate Weighted Average Ground Level,

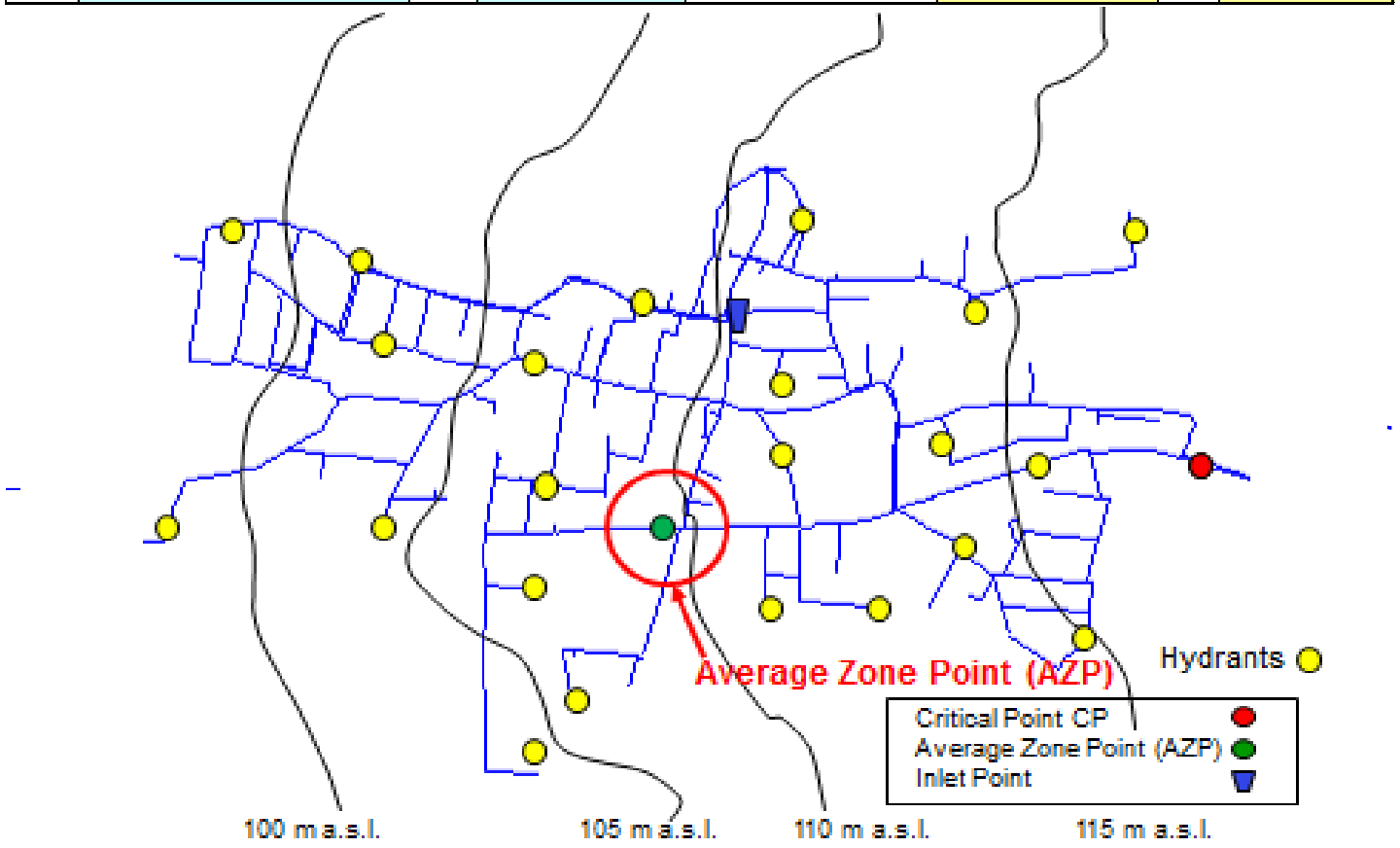
Select a Hydrant to represent the Average Zone Point



‘Plan of Zone’ Worksheet

'LEAKS' Suite of LEAKAGE EVALUATION and ASSESSMENT KNOW-HOW SOFTWARE					
Average Zone Point and Night Day Factor: Concepts and Calculations	Free	Version 1c	17th Nov 2013	International	INT.EUR.001
WORKSHEET FOR ENTERING PLAN OF ZONE (PREFERABLY WITH CONTOURS), TO ACCOMPANY 'Define PM points' WORKSHEET					
The Worksheet is protected without a password, so that you can insert graphs below the Comments box.					

Utility	Anytown	Zone	AnyZone	Worksheet completed by	A.N.Other	Date	20th April 2012



When Zone AZP is defined …

- Measure the pressure at the AZP and calculate the average for each Zone

- To assess the average pressure for the whole system, calculate weighted average pressures based on:
  - number of service connections in each Zone
  - mains length in each Zone

- Select the most appropriate value (based on service connection density)
  - if > 20 service conns/km, use service connections for weighting
  - if < 20 service conns/km, use mains length for weighting

Calculation of Weighted Average System Pressure for multiple Zones

Table 1: Example Calculation, Weighted Average System Pressure, 7 Zones

Zone Reference	Length of Mains Lm	Number of billed properties Np	Ratio Ns/Np	Number of Service Conns Ns	Density of Connections	Average annual pressure in Zone Pav	Ns x Pav	Lm x Pav
	km				per km mains	Metres	Conns x metres	km x metres
A	253.9	8206	0.990	8124	32.0	52.5	426507	13330
B	153.0	5878	0.980	5760	37.6	38.1	219473	5829
C	175.1	5596	0.930	5204	29.7	61.0	317461	10681
D	135.3	4719	0.950	4483	33.1	43.4	194564	5872
E	110.7	2835	0.960	2722	24.6	62.0	168739	6863
F	54.8	2380	0.980	2332	42.6	55.1	128515	3019
G	60.0	2300	0.940	2162	36.0	48.7	105289	2922
Column Totals or Weighted Average	**943**	**31914**	**0.965**	**30788**	**32.7**	**Column Totals =**	**1560549**	**48517**
Number of Zones	**7**	**7**		**7**		**Divide by**	**Ns = 30788**	**Lm = 943**
Average Zone	**134.7**	**4559**	**0.965**	**4398**	**32.7**	**System Pav estimate =**	**50.7**	**51.5**
System density of connections is >20/km so best estimate of System Pav =							**50.7**	**metres**

Example of this Table is shown in Guidelines for calculating Average Pressure http://www.leakssuite.com/wp-content/uploads/2015/04/AvePressureGuidelinesIntVersion28Jul13.pdf.

Key Messages about the AZP Point

- Pressure at the AZP is a fundamental requirement for analysis and predictions
  - every Zone **must** have a defined AZP point
- If you don't have defined AZPs, the analysis concepts and prediction methods described in this Workshop will not work.
  - Night-Day Factors will be incorrect
  - Analysis of Minimum Night Flows unreliable
  - Predictions of reductions in bursts useless

Questions on AZP Point?

Night-Day Factors

- Leak flow rates vary with average zone pressure
  - to a greater or lesser extent, depends on FAVAD N1
- Average zone pressure in most Systems and Zones varies over 24 hour periods
  - which makes the flow rate of existing leaks also vary
- So you cannot simply multiply night leakage rate in m^3/hr by 24 hours, to get leakage in m^3/day
  - or divide daily leakage by 24 hours to get night leakage rate

‘Night-Day Factor NDF’ Worksheet

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Average Zone Point and Night Day Factor: Concepts and Calculations	Free	Version 1c	17th Nov 2013	International	INT.EUR.001	© ILMSS Ltd

THIS WORKSHEET EXPLAINS WHAT THE 'NIGHT-DAY FACTOR' (NDF) IS, AND HOW TO CALCULATE NDF USING MEASUREMENTS OF PRESSURE AT THE AZP POINT

The Night Leakage Rate in a District Metered Area (DMA) is assessed by deducting Customer Night Use from Measured Minimum Night Flows. The Night Leakage Rate is influenced by the pressure at the Average Zone Point. The methodology for identifying the Average Zone Point can be found in the **'Define PM points'** Worksheet.

To calculate the Average Daily Leakage (in volume/day) from the Night Leakage Rate (in volume/hour), it is necessary to multiply the Night Leakage Rate by a 'Night-Day Factor' or NDF (known also in the United Kingdom as an 'Hour-Day Factor'). If the pressure at the Average Zone Point is constant during the 24 hours of any particular day, then the Average Daily Leakage (in volume/day) would be 24 x the Night Leakage Rate in volume/hour; and the 'Night-Day Factor' would be 24 hours/day. However, the average pressure in distribution systems in normally not constant, but varies over 24 hour periods.

Figure A below shows Zone Inflow (split into customer use and leakage) and Average Zone Pressure, for a system supplied by gravity. The Average Zone Pressure is highest at night, but is lower during the rest of the day, resulting in a reduced leakage rate for most of the 24 hours. It is evident that, in this situation, if the Night Leakage Rate in volume/hour were to be multiplied by 24 hours/day, the Average Daily Leakage would be over-estimated. The Night-Day Factor for a gravity system is therefore normally less than 24 hours/day.

Figure B below shows Zone Inflow (split into customer use and leakage) and Average Zone Pressure, for a pressure controlled system, in which the pressure at night is deliberately reduced by pump scheduling, or by a pressure reducing valve with time modulation or flow modulation. The Average Zone Pressure is now lower at night than during the rest of the day, resulting in an increased leakage rate for most of the 24 hours. It is evident that, in this situation, if the Night Leakage Rate in volume/hour were to be multiplied by 24 hours/day, the Average Daily Leakage would be under-estimated.

In practice, NDFs can range from less than 12 hours/day (for gravity systems with high frictional losses) to more than 36 hours/day (for flow modulated systems).

Figure A: Variation of Leakage Rate with Average Zone Pressure for a Gravity System: NDF <24 hrs

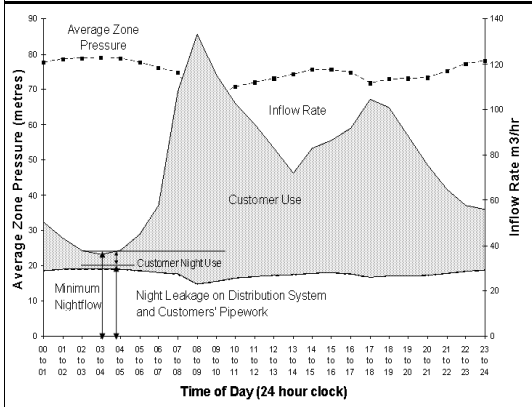
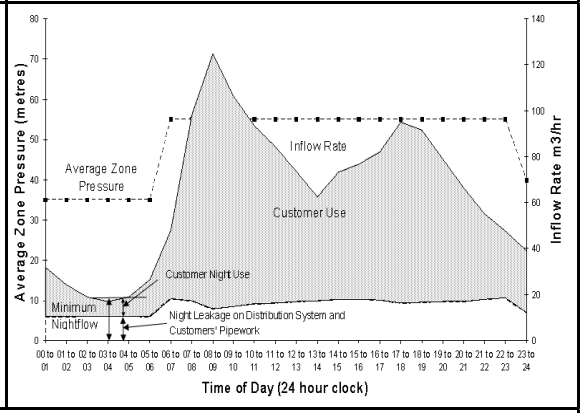


Figure B: Variation of Leakage Rate with Average Zone Pressure for a Pressure Controlled System: NDF >24 hrs



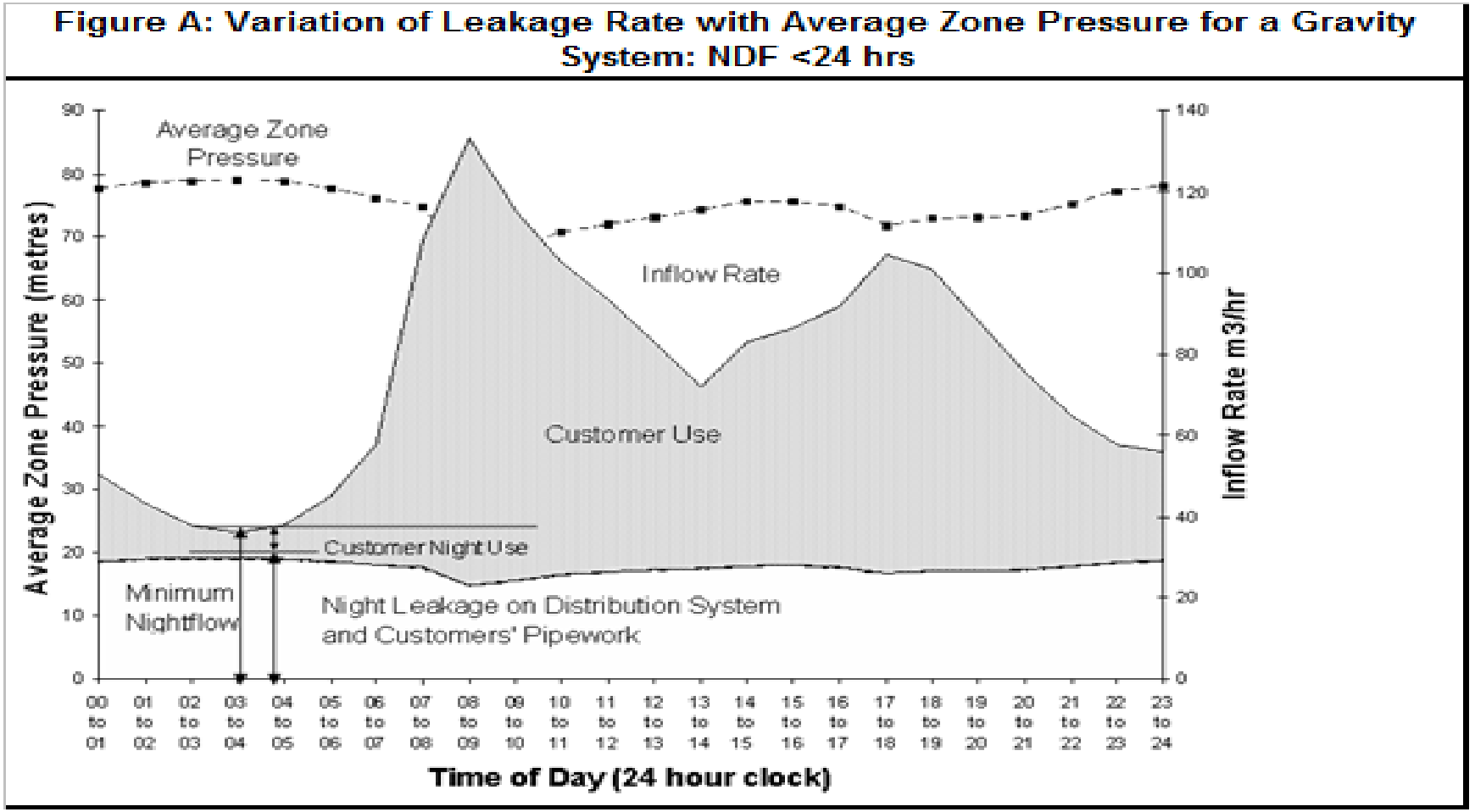
However, it is quite a simple matter to calculate the Night-Day Factor for any particular distribution system or sub-system.

- First, identify an Average Zone Point (using the **Define PM points** Worksheet).
- Next, fix a pressure logger at the AZP and leave it to record average hourly pressures for a 7 day period.
- Then estimate the FAVAD N1 exponent for the system.The usual range of N1 is between 0.5 and 1.5, if in doubt use N1 = 1.0
- Finally, enter the 7 days of hourly AZP data and the appropriate N1 exponent in the **'Calculate NDF'** Worksheet

It will be found that, for most distribution systems, the AZP pressure (and therefore the NDF) varies from day to day during the week, and also seasonally during the course of a year. Accordingly, when comparing Real Losses calculated from a 'top-down' water balance with a 'bottom-up' estimate based on night flows, it is preferable to use 4 x 7 day recordings of AZP pressure, spread throughout the year, to calculate the average NDF for the year.

NDF < 24 hrs/day for gravity systems

Figure A: Variation of Leakage Rate with Average Zone Pressure for a Gravity System: NDF <24 hrs



Calculating the Night-Day Factor

- Define the Average Zone Point in a Zone
- Put a pressure logger there for 1 week
- Enter the hourly average flows into the ‘Calculate NDF’ Worksheet
- Enter an appropriate FAVAD N1 value and the Worksheet will calculate the Night-Day Factor

‘Calculate NDF’ Worksheet:
Part 1: Explanation of steps in the calculation

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Average Zone Point and Night Day Factor: Concepts and Calculations		Free	Version 1c	17th Nov 2013	International	© ILMSS Ltd
THIS WORKSHEET IS USED FOR CALCULATING NIGHT-DAY FACTORS FROM SEVEN DAYS OF PRESSURE MEASUREMENTS AT THE AZP POINT						
Colour coding	Data entry	Calculated	From another Worksheet	See 'Calculate NDF' Worksheet for background information		
Utility	Munich Course			Calculation by:	A.N. Other	Date 11th Feb 2009
Zone	West Zone			e-mail contact:	Anyone@anywhere.com	
Average Zone Point	Hydrant outside 23 Watery Lane			where the ground level is	43.5	metres above sea level
Is the zone supplied mainly by Gravity (G) or Pumping (P)?		P		Comments >		
Is there any active management of pressure in the Zone?		No		Comments >		

Step 1	Enter the Zone name in Cell B6. Enter on Row 7 information on the AZP point (see **Define PM points** Worksheet)
Step 2	Specify if the Zone is mainly supplied by gravity or pumping on Row 8, and add comments if appropriate
Step 3	Specify on Row 9 if there is any active pressure management in the Zone, and add comments if appropriate
Step 4	Set up a pressure recorder at the AZP point and leave it to run until 7 x 24 hourly average AZP pressures have been recorded
Step 5	Enter the date of the first day in Cells B24, the days of the week in Cells B25 to H25, and the units for pressure measurement in Cell B26
Step 6	Enter average hourly pressures for each day in Cell Block B27 to H50. Average, Maximum and Minimum appear on Rows 51 to 53
Step 7	Identify, in one of Cells J27 to J32, the hour you choose to use for minimum night flow (MNF) in this analysis.
Step 8	Copy the pressures at the selected MNF hour, for each day, into Cells B54 to H54
Step 9	Rows 62 to 64 show calculated Night-Day Factors each day, and weekly average, for N1 exponents of 0.5, 1.0 and 1.5 respectively.
Step 10	The Night Day Factors for any other N1 exponent can be calculated on Row 65 by entering an alternative N1 value in Cell A65.
Note	N1 varies from 0.5 to 1.5 for different leak types. See **www.leakssuite.com, 'Concepts' section, 'FAVAD N1' webpage**, or use average N1 = 1.0

‘Calculate NDF’ Worksheet:

Part 2: Calculations

Time of Day	Date and day of the week on which pressure readings were taken							Weekly Average	Select and Identify hour for Minimum Night Flow MNF
	23/02/2009	24/02/2009	25/02/2009	26/02/2009	27/02/2009	28/02/2009	01/03/2009		
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday		
Hours	metres	metres	metres	metres	metres	metres	metres	metres	
00 to 01	71.8	69.7	70.3	69.8	74.0	73.0	71.3	71.4	
01 to 02	73.2	71.5	71.2	72.7	74.5	73.3	72.2	72.7	
02 to 03	74.8	71.3	71.5	74.7	75.5	74.2	74.3	73.8	
03 to 04	75.3	72.2	71.7	74.3	75.7	74.8	74.3	74.0	Use 03 to 04 hrs
04 to 05	75.0	72.3	71.3	75.0	75.7	75.7	74.7	74.2	
05 to 06	73.7	68.7	72.5	74.0	74.7	73.8	72.2	72.8	
06 to 07	71.5	70.2	72.0	71.8	72.2	72.5	71.2	71.6	
07 to 08	59.3	63.7	60.0	62.5	62.8	66.3	69.2	63.4	
08 to 09	53.3	62.5	61.5	58.3	61.3	59.8	59.7	59.5	
09 to 10	45.8	53.7	56.8	53.7	50.3	37.0	47.2	49.2	
10 to 11	49.5	55.5	55.5	57.8	54.7	52.0	50.2	53.6	
11 to 12	43.7	58.2	50.7	62.8	54.0	54.2	49.3	53.3	
12 to 13	43.2	64.3	57.3	63.8	59.5	57.2	57.2	57.5	
13 to 14	55.3	61.2	65.2	65.5	64.2	58.2	60.8	61.5	
14 to 15	56.3	62.8	66.0	66.3	64.7	55.7	58.7	61.5	
15 to 16	52.0	63.3	60.0	64.8	66.5	56.0	55.0	59.7	
16 to 17	56.7	60.5	51.8	63.3	60.7	54.3	55.8	57.6	
17 to 18	52.5	55.8	52.8	55.3	51.8	44.7	43.5	50.9	
18 to 19	48.7	46.0	50.7	49.3	45.8	43.0	43.0	46.6	
19 to 20	53.0	54.5	50.0	53.8	47.5	48.0	50.8	51.1	
20 to 21	59.2	55.2	59.3	59.5	53.0	51.2	54.2	55.9	
21 to 22	61.2	65.3	63.3	67.3	64.5	59.8	68.2	64.2	
22 to 23	62.7	65.0	63.3	71.5	65.7	65.3	67.3	65.8	
23 to 24	65.8	68.0	68.2	71.8	69.8	65.0	68.7	68.2	
Average	59.73	62.98	62.20	64.98	63.30	60.21	61.21	62.09	
Maximum	75.30	72.30	72.50	75.00	75.70	75.70	74.70	74.46	
Minimum	43.20	46.00	50.00	49.30	45.80	37.00	43.00	44.90	
MNF hour	75.3	72.2	71.7	74.3	75.7	74.8	74.3		

Assumed N1 Exponent	23/02/2009	24/02/2009	25/02/2009	26/02/2009	27/02/2009	28/02/2009	01/03/2009	Weekly Average NDF	
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday		
	NDF	NDF	NDF	NDF	NDF	NDF	NDF		
0.50	21.3	22.4	22.3	22.4	21.9	21.4	21.7	21.9	Hours per day
1.00	19.0	20.9	20.8	21.0	20.1	19.3	19.8	20.1	Hours per day
1.50	17.1	19.6	19.5	19.7	18.5	17.6	18.1	18.6	Hours per day
1.00	19.0	20.9	20.8	21.0	20.1	19.3	19.8	20.1	Hours per day

How is NDF calculated?

- Suppose L_{3-4} is the minimum night leakage rate at 03 to 04 hrs, at pressure AZP_{3-4}
- Then $L_{4-5} = L_{3-4} \times (AZP_{4-5} / AZP_{3-4})^{N1}$ is the leakage rate at 04 to 05 hrs
- Then $L_{5-6} = L_{3-4} \times (AZP_{5-6} / AZP_{3-4})^{N1}$ is the leakage rate at 05 to 06 hrs
- NDF = {sum of 24 hourly leakages}/ L_{3-4}
  - but L_{3-4} cancels out from the NDF numerator and denominator
- So $NDF = \{(AZP_{0-1} / AZP_{3-4})^{N1} + (AZP_{1-2} / AZP_{3-4})^{N1} \ldots (AZP_{23-24} / AZP_{3-4})^{N1}\}$

How do you use NDF?

- Calculate Night Leakage Rate NLR in m^3/hour from minimum night flow
  - deduct estimate of customer night consumption from hourly Minimum Night Flow
- Multiply Night Leakage Rate x NDF
- Example:

  Night Leakage Rate = 5.0 m^3/hr

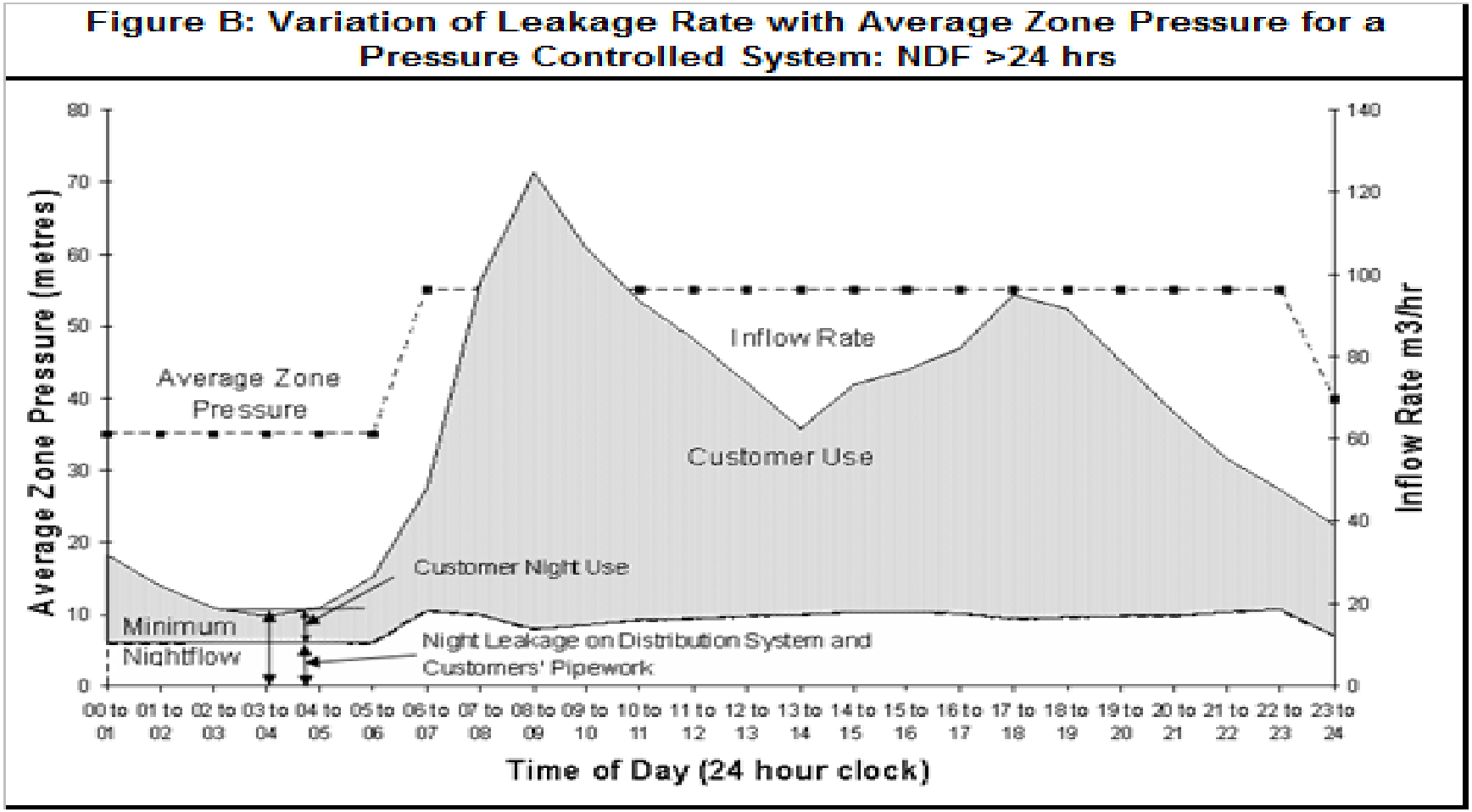
  Night Day Factor = 20 hours/day

  Daily leakage = 5.0 x 20 = 100 m3/day

A common source of error

- Suppose that night flows are measured before and after pressure management
- Suppose you calculate the saving in leakage in m^3/day as reduction in night flow (m^3/hour) x 24
- This calculation would only be correct if:
  - the Night Day Factor is 24 hrs/day, before and after pressure management
- This can be a major source of error, particularly in:
  - pumped systems
  - pressure management by time or flow modulation

NDF > 24 hrs/day for time or flow modulated, or some pumped systems



Example calculation (flow modulation)

- Before pressure management, gravity supply:
  minimum night flow = 10 m^3/hour
- After pressure management, flow modulation
  minimum night flow = 6 m^3/hour
- Incorrect calculation of leakage reduction
  = (10 - 6) = 4 m^3/hour x 24 = **96** m^3/day **WRONG!**
- Night Day Factor before pressure management = 20 hrs/day
- Night Day Factor after pressure management = 30 hrs/day
- Estimated night consumption = 3 m^3/hour
- Reduction in daily real losses
  = (10 – 3) x 20 – (6 – 3) x 30 = 140 - 90 = 50 m^3/day
- Over-estimate of savings from superficial calculation
  = 96 m^3/day – 50 m^3/day = **46** m^3/day, a **100%** over-estimate

Comments on NDF

- NDFs as low as 12 hours/day, and as high as 36 hours/day, have been observed and measured
- So relating average daily leakage to night leakage using 24 hours (or vice versa) can give up to +/- 50% error
- Many countries are unaware of this effect
  - for example, Germany expresses real losses as ‘Specific Loss’ in m^3/km/hour, based on annual real losses (from a water balance) divided by 8760 (365 days x 24 hours/day)
- Calculations of NDF are particularly important when advanced pressure management is introduced

Influences on Night-Day Factor

- Variation of AZP 24-hour pressure profile
  - Daily (weekdays and weekends different)
  - Seasonal (changes in demand)
  - Assumed or predicted FAVAD N1
- Questions?