Water Management and Water Loss

LOGGING OF PRESSURE AND FLOWS

Chapter 6 by Ronnie McKenzie

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LOGGING OF PRESSURES AND FLOWS

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Mckenzie, R	**Remote flow logging as tool to drive down leakage.** International Water Association ,Water Loss 2014, Specialist Conference, Vienna, March 2014.	2014

1 INTRODUCTION

1.1 General

With the rapid developments in internet based technology, the value of using the internet as a platform for data access and display is being recognised throughout the world. Remote logging through GSM and GPRS devices in particular are commonplace and easily accessible to all water suppliers in virtually every country. The costs associated with both the hardware as well as the software and associated communication charges have all decreased in recent years with the result that the financial viability of using such technology to assist with leakage reduction activities is now clearly evident.

This chapter will provide a brief overview of the use of flow and pressure loggers in a water reticulation system to highlight the value of such information as part of any leakage reduction programme. It will also present details and interesting examples from a wide variety of case studies to highlight the key issues associated with both flow and pressure logging.

1.2 Importance of Logging

Logging involves recording pressures and/or flows entering a zone and can be compared to a doctor recording the blood pressure and heart rate in order to determine the health of a patient. From a management viewpoint, the logging results often highlight problems within the water supply system which can then be addressed. Without regular logging results and associated analyses, such problems can exist unnoticed for months if not years and result in higher leakage and/or poor service delivery. It is the view of the authors, that regular logging of both flows and pressures are an essential component of any well managed water supply system.

Having stressed the importance of undertaking regular flow and pressure loggings in a water supply system, it is equally important for the technician or manager receiving the information to understand what it represents. Analysing and interpreting logging results is often very confusing and difficult and can be compared to “detective work”. The remainder of this section is devoted to the interpretation and understanding of logging results and all graphs shown are from real examples collected by the authors.

Logging of pressures and flows is one of the most important aspects of any WDM programme and one that is generally neglected if not ignored completely. In recent years, with the advent of GSM and GPRS based loggers it is now possible to capture and transmit logging information with relative ease. Such information, if used properly, can help water managers to manage their water distribution systems effectively and efficiently and they can often identify problems before they become major crises.

There is no substitute for reliable “real-time” flow and pressure information and where available, it will facilitate the analysis of Minimum Night Flows which was the original foundation of any proper WDM programme. Over the years, more effort seems to have been placed on high-tech electronic solutions and software which eliminates the need to visit the site or to get one’s hands dirty. Recording and analysing Minimum Night Flows, has in fact become less common as the new technology and software models eliminate the need for any such analyses. In reality, many water reticulation managers have lost the ability to properly manage their systems in many parts of South Africa and there is a real need to move back to the basics and start using logging results to monitor the water reticulation systems and to find problems. Reliable logging information provides a manager with real-time data on what is really happening in the system as opposed to what the hydraulic models say should be happening. In most cases, the modelled flows and pressures bear little resemblance to what is being measured on the ground. Such discrepancies are not a reflection on the software models that are used to design the reticulation systems. Such models are only as reliable as the information on which they are based. When the models and reality diverge, the problem is a reflection on the reticulation managers and maintenance personnel who are not operating the system in the manner in which it was designed.

In the remainder of this section, the value of real-time flow and pressure logging information will be discussed and many actual flow and pressure logging results will be examined to highlight some of the common issues that will be found in most water reticulation systems.

1.3 Interpretation of minimum night flows

The minimum night flow entering a zone is one of the most important and useful indicators for assessing potential leakage in an area. For it to be useful, the zone in question must be properly sectorised and discrete. In very general terms, the minimum night flow, is the flow entering a zone during the time at which most of the normal legitimate water use is at its lowest. During the period of minimum night flow, it is often (not always) possible to estimate the likely level of legitimate night use as well as the background leakage which cannot be eliminated. Both components are to be expected and can be added together to provide an estimate of the expected night use. Once this expected night use has been estimated, it can be compared to the actual recorded night flow. If the two are reasonable similar, then it suggests that there is little unexplained leakage in the zone and if the recorded night use is significantly higher than the expected value it suggests that there is a significant amount of unexplained leakage that should be investigated. This is effectively the basis for the well-known Burst and Background Estimate (BABE) methodology as developed by the UK water industry to identify zones with potentially high leakage levels. As the name suggests, it is based on certain estimates which are often unknown and therefore may be overestimated or underestimated. In general, however, it is usually found that the methodology is relatively robust and even if one or two of the estimated parameters are inaccurate, the overall result remains useful in identifying areas with high leakage.

1.4 Assessing the minimum night flow

Many simple models have been developed throughout the world using the BABE methodology to analyse minimum night flows and are usually freely available through the internet. One such model is the SANFLOW model developed through the South African Water Research Commission which is fully discussed in the original SANFLOW User Guide (WRC, 2001). The user guide provides a comprehensive explanation of the BABE methodology for analysing the minimum night flow in an area and a brief summary of the approach is provided below for reference.

The measurement of background night flows is one of the most important actions that can be taken to identify leakage problems. It is often possible to identify many problem issues by simply looking at the minimum night flow. The minimum night flow is usually found to occur sometime between midnight and 4 am when the consumption in the network is at its lowest. In some countries the usual approach is not always applicable especially in areas where many residents or municipalities irrigate at night with automatic sprinkler systems or in areas where there is continuous water-use activity throughout the night. The approach developed un the UK is suited to normal residential or industrial areas that have little active water use between midnight and 4am – the flow entering such an area is shown in **Figure 1.**

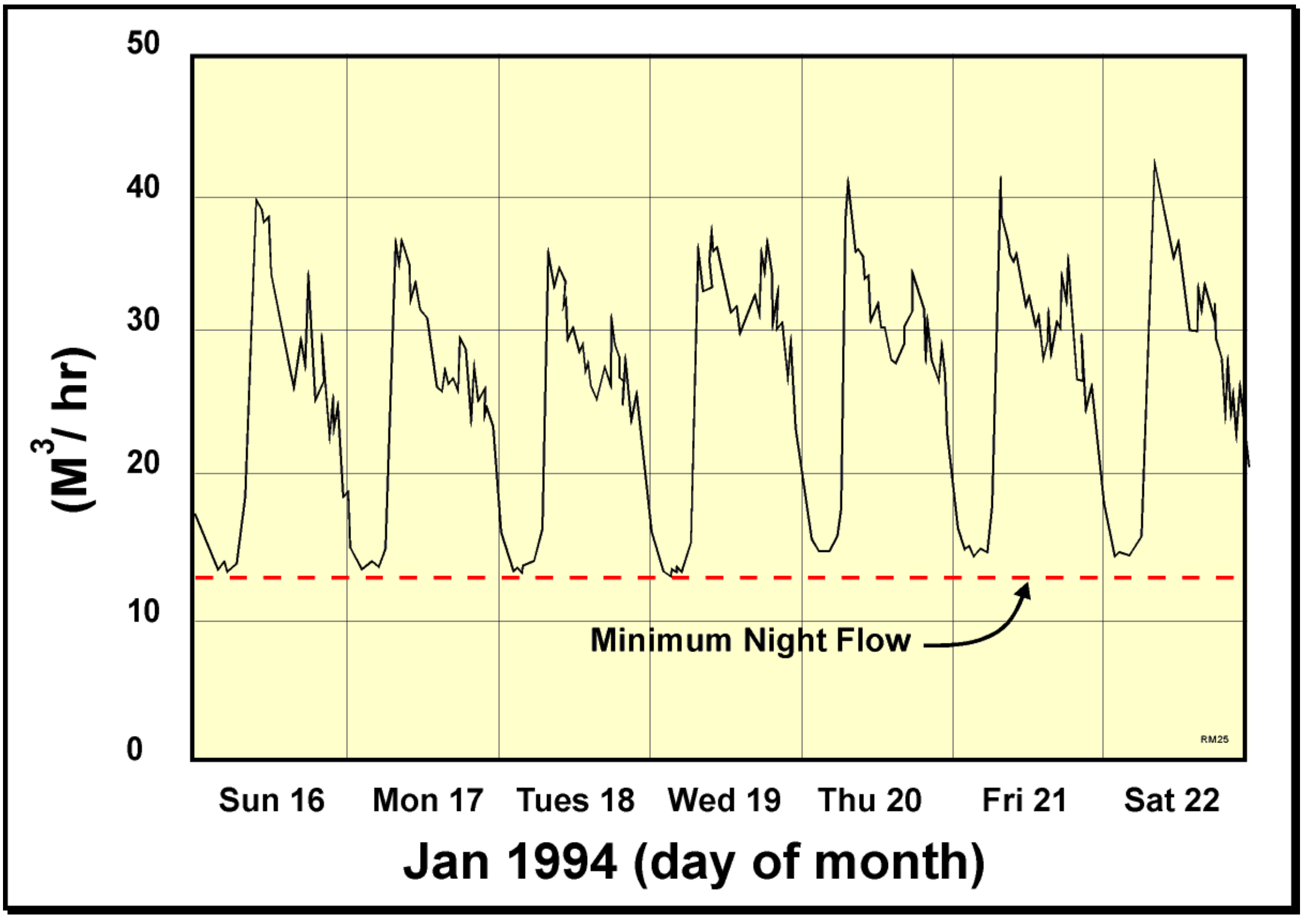

Figure 1: Typical flow logging for zone showing minimum night flow

Having logged a zone meter in order to establish the minimum night flow, it is then necessary to establish the various components of the night use in order to estimate the level of unexplained leakage. The key issue is to establish whether or not the zone has a problem or if it is healthy and has no problems. Through the use of the BABE methodology, the minimum night flow is considered to consist of three main components namely :

- Normal legitimate night use
- Background losses
- Burst pipes.

This breakdown is shown in **Figure 2** from which it can be seen that the normal use and background losses have each been further divided into three smaller components which can be estimated using certain simple and basic assumptions that tend to be surprisingly close to what is found in the field. The normal night use and background leakage can be estimated for any specific zone given a few basic parameters which are either measured or estimated depending on the level of information available for the specific zone. After logging the flow into a zone for a few days or weeks to establish a realistic estimate of the minimun night flow, the unexplained leakage, which is due mainly to bursts, can be determined by simply subtracting the estimated background leakage and normal night use from the measured minimum night flow.

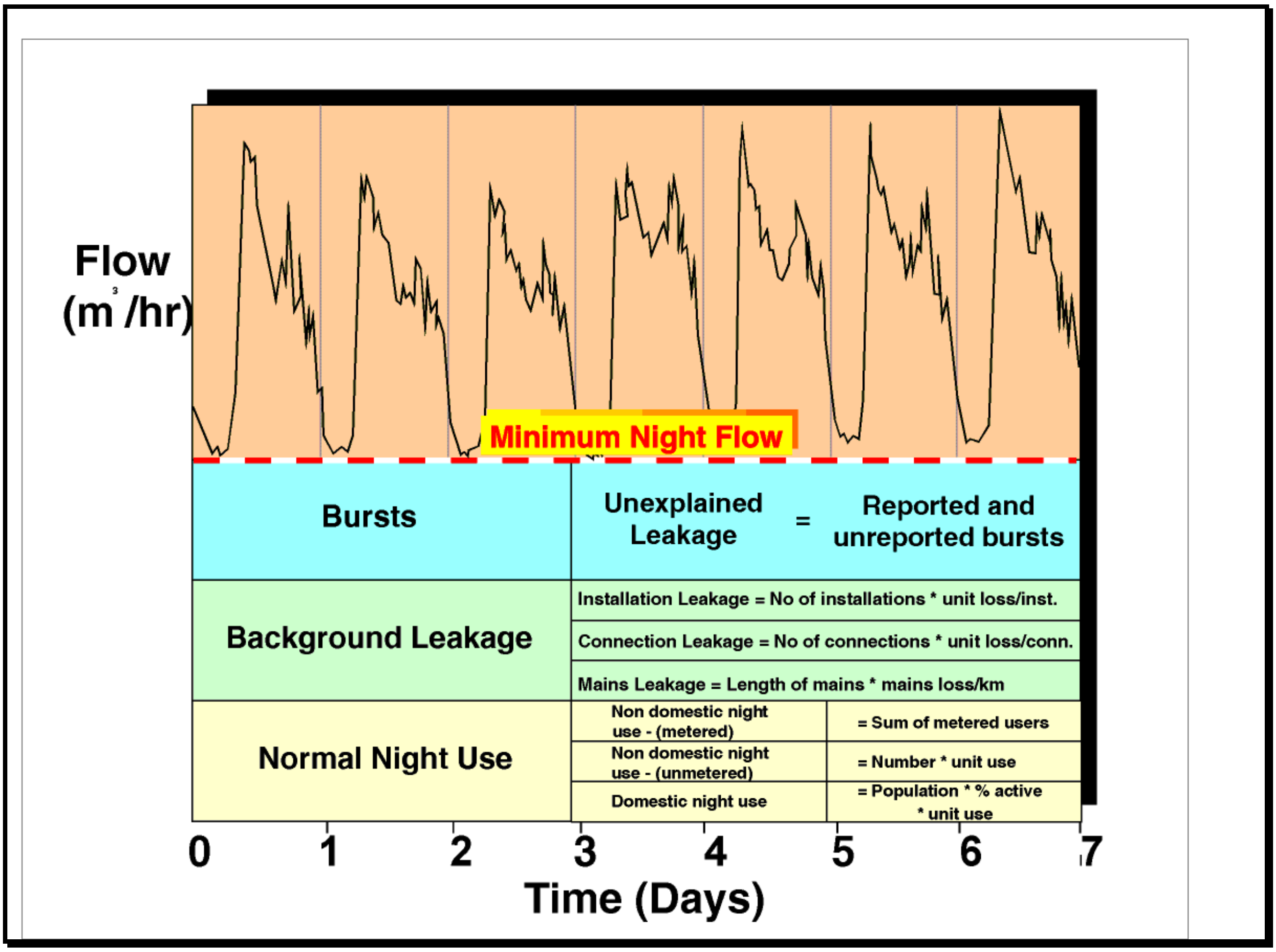

Figure 2: Interpretation of the minimum night flow

1.5 Normal Night Use

The expected legitimate water use in a zone cannot be measured accurately every evening since it comprises a large number of small users – sometimes more than 2 000. As it is impractical to try and measure the use for each small user during the period of the minimum night flow analysis, it is estimated, based on certain norms and variables that have been refined over the years through practical research around the world.

For the purpose of the analysis, the expected normal night use is split into three components namely:

- Normal domestic night use – mainly toilet flushing

- Small non-domestic night use such as hotels and garages etc
- Larger users such as hospitals or factories etc (recorded individually).

1.5.1 Normal domestic night use

Normal domestic night use represents the water used during the night in a household and is predominantly due to toilet use. Use of water for making coffee or tea represents a very small portion of the overall household use and is effectively ignored. Experience in various parts of the world has shown that approximately 6% of the population are active during each hour and that the water used per toilet flush is in the order of 10 litres. Based on these estimates the normal domestic night use is estimated.

Normal night use = 6% of population * 10 litres per hour

This may seem over simplistic which is true, however, it usually provides a reasonable estimate of what to expect in an area and will most likely err slightly on the high side. It should be noted that in areas with high internal plumbing losses, the water being "used" at night in the households will be much higher than the estimated normal night use. If this is the case, the analysis of the minimum night flow will suggest very high burst leakage – much of which will in fact be internal household leakage. The purpose of the analysis is to identify if something is wrong and if the assessment shows that there is very high burst leakage, then it must first be checked to establish if, in fact, the leakage is burst leakage or a combination of burst leakage and household leakage. Checking the sewer flows at night will often answer this question.

1.5.2 Small non-domestic night-use

The small non-domestic night use is more difficult to evaluate and depends to a large extent on the type of businesses (if any) operating in the zone. The assessment is not ideally suited for industrial areas or residential areas which have a high component of industrial use at night. Although each small non-domestic user is metered individually it is again impractical to record each of the meters during the night flow exercise. Instead, the users are lumped into various categories and a typical night use is assumed for the group. For example, there may be several all-night garages or all-night cafes where the unit use is relatively small although when added together the total use may be significant. A range of typical night use values for various different commercial enterprises has been produced based on extensive studies undertaken overseas and guidelines are provided in the SANFLOW user-guide.

1.5.3 Large non-domestic users

In some zone metered areas, it is often found that there may be one or more large water consumers whose consumption can have a significant influence on the night flow analysis. In such cases it is necessary to meter such consumers individually to determine how much water has been used during the night flow exercise. Only one or two such consumers would reside within a specific zone and therefore they can easily be checked during the night to assess exactly how much water they consume during the period of minimum night flow. Consumers falling into this category would include airports, large hotels, breweries, swimming pools, etc.

1.6 Background Leakage

Background leakage is the cumulative leakage from all relatively small leaks in the reticulation system. Such leaks occur from valves, joints, hydrants, stop-taps, meters, dripping taps, toilet cisterns, roof tanks etc. Individually such leaks are generally uneconomic to find and repair with the result that background leakage is accepted as a fact of life in all water reticulation systems within certain limits.

In general, background leakage can be split into three main components namely:

- Background leakage from each km of mains
- Background leakage from each connection
- Background leakage from each property

1.6.1 Background leakage from mains

There will always be some background leakage from any distribution system, some of which occurs from the water mains. Small leaks often occur at the pipe joints or from small cracks or holes in the pipes and the magnitude of the leakage is dependent upon the condition of the infrastructure and of course the operating pressure. For the purpose of the assessment of the minimum night flow, all leakage parameters used in the calculation are based on a standard operating pressure of 50 m. When assessing the expected level of background leakage from systems operating above or below this pressure, the calculated background leakage must simply be adjusted upwards if the pressure is greater than 50m and adjusted downwards if it is operating below 50m., The adjustment for pressure is fully discussed in the SANFLOW User Guide and is not repeated in this section. Typical background leakage rates for normal diameter water mains suggest average values of around **40 l/km of mains**

per hour. A new pipeline may have lower leakage, sometimes even below 20 litres/km /hr while older pipelines can have much higher leakage rates of 100 litres/km /hr or even higher.

1.6.2 Background leakage from connections

Poor workmanship coupled with general wear and tear often results in leaks from pipe connections. In general, we usually work on the basis of one pipe connection to each property although in many systems a single connection can sometimes be used to supply multiple properties. This issue has been discussed and debated at many venues and in the view of the author, it is appropriate to assume that the number of connections or "equivalent connections" is equal to the number of properties except in cases of apartments where the actual number of connections should be used. Connection leakage is considered as the leakage occurring from the connection at the water main to the water meter at the property or to the property boundary in cases where no meters exist. In most water distribution systems, the connection losses are often the major source of loss from the system. For most purposes, a value of **3 litres per property per hour** can be used which will provide a reasonable estimate of the expected background property leakage.

1.6.3 Background leakage from properties

The third and final component of background leakage used in the calculation reflects the property leakage for each property after the consumer meter - as opposed to the previous component which relates to leakage on the connection pipe before the customer meter. This component is intended to allow for some leakage on the pipe from the meter to the property and also some leakage inside the property. Under normal circumstances, an allowance of 1 litre/property per hours is appropriate.

A common criticism of this component based methodology is often raised concerning areas where the most significant source of leakage is from the plumbing fixtures inside the properties. This has been mentioned previously but as it is such an important issue it deserves further explanation.

In South Africa, household leakage is often the most serious leakage issue in the zone and the household leakage can dominate the whole water balance and therefore also the Minimum Nigh Flow. In such cases, the household leakage will not be close to 1 litre/property per hour but may be several hundred litres per property per hour. In such cases, all of the other components of the Minimum Nigh Flow analysis are irrelevant and the analysis with suggest that there is a huge burst problem. On closer examination, it will be found that there is no sign of such high burst leakage and from experience, the individual looking at the analysis results will often be able to confirm that the problem is most likely inside the properties. In reality, this is not a difficult issue to identify and in cases where household leakage is found to be the problem, it will usually be so significant and clear cut that there is no question about where the problem lies.

1.7 Calculation of Unexplained Bursts

Having measured or estimated the various components of normal night use and background night use, the two figures are added together and then subtracted from the measured minimum night flow. The difference is the unexplained losses that are attributable to either unreported bursts or to errors in the assumptions made during the calculation.

To demonstrate the analysis of a minimum night flow using the BABE methodology, it is easier to make use of a simple example. In this example a case will be used where the average zone night pressure is at 50 m which is the base pressure where no pressure correction factors are required. The basic information required for the calculation is provided in **Table 1**

Table 1: Basic information needed for MNF analysis

Description	Value
Length of mains	9 300 m
Number of connections	600
Number of properties	672
Estimated population	3 000
Average zone night pressure (AZNP)	50 m
Measured minimum night flow (MNF)	14.4 m^3/h
Background losses from mains	40 l/km/h
Background losses from connections	3 l/connection/h
Background losses from properties	1 l/connection /h
% of population active during night flow exercise	6%
Quantity of water used in toilet cistern	10 l
Number of small non-domestic users	30
Average use for small non-domestic users	50 l/h
Use by large non-domestic users	1.2 m^3/h

Table 1 also includes the various default parameters that are normally used to calculate the background leakage and the normal nigh use as mentioned previously. Having established

the default loss parameters it is now possible to estimate both the normal night use and the background leakage. The respective calculations are provided in **Table 2** and **Table 3.**

Table 2: Estimate of Normal Night Use

Description	Calculation	Value
Domestic night use	3 000 @ 6%/h @ 10 l	1.8 m^3/h
Small non-domestic use	30 @ 50 l/h	1.5 m^3/h
Large non-domestic use	1 @1.2 m^3/h	1.2 m^3/h
Total normal night use		4.5 m3/h

Table 3: Estimate of Background Leakage

Description	Calculation	Value
Mains losses	9.3 km @ 40 l/km/h	0.37 m^3/h
Connection losses	600 @ 3 l/connection/h	1.80 m^3/h
Property losses	672 @ 1 l/property/h	0.67 m^3/h
Total background leakage at 50 m pressure		2.84 m3/h
Pressure correction factor	$(50/50)^{1.5}$	1.00
Total background leakage at 50 m pressure		2.84 m3/h

It should be noted that a pressure correction factor is indicated in the above table. In the case of this example the operating pressure is known to be 50 m which is considered to be the standard pressure. At standard pressure, no pressure corrections are required and it can be seen that the pressure correction factor is calculated to be 1.0 (i.e. no change). The topic of pressure correction is discussed in the SANFLOW User Guide (WRC, 2001).

Having estimated the two main night time water use components, it is possible to calculate the difference between the measured minimum night flow and the expected legitimate night time use. **Table 4** provides the calculation that identifies the level of unexplained leakage in the given zone metered area.

Table 4: Estimate of Burst Leakage

Description	Value
Expected background leakage	2.84 m^3/h
Expected normal night use	4.50 m^3/h
Total expected night use	7.34 m3/h
Measured minimum night flow	14.40 m^3/h
Unaccounted-for leakage (14.40 – 7.34)	7.06 m3/h

As can be seen from the table, it is estimated that in this example the unexplained leakage is in the order of 7 m^3/h. The remainder of this section is devoted to the interpretation of various real logging results to demonstrate the value of such information and to assist those new to such logging results to understand and interpret the various examples, each of which highlights a specific problem.

1.8 Using minimum night flow for leakage management

This is possibly one of the most important sections in the book and it will highlight the value and potential for using the logged minimum night flow in an area to assess the likely physical leakage as well as the potential for improvement.

The first figure to be shown is that of the flow measured entering a zone over a 24-hour period as shown in **Figure 3.** The flow logging result for the same zone over a 3-day period is shown in **Figure 4**. As can be seen from **Figure 4**, the 3-day logging result indicates a typical domestic demand pattern which is repeated each day and has a morning and evening peak demand together with a minimum demand sometime during the late evening or normally around 02h00 in the morning. Although it is possible to derive some information from the 24-hour graph in **Figure 3,** the 3-day logging result is of greater value and where possible a 10-day logging result is preferred.

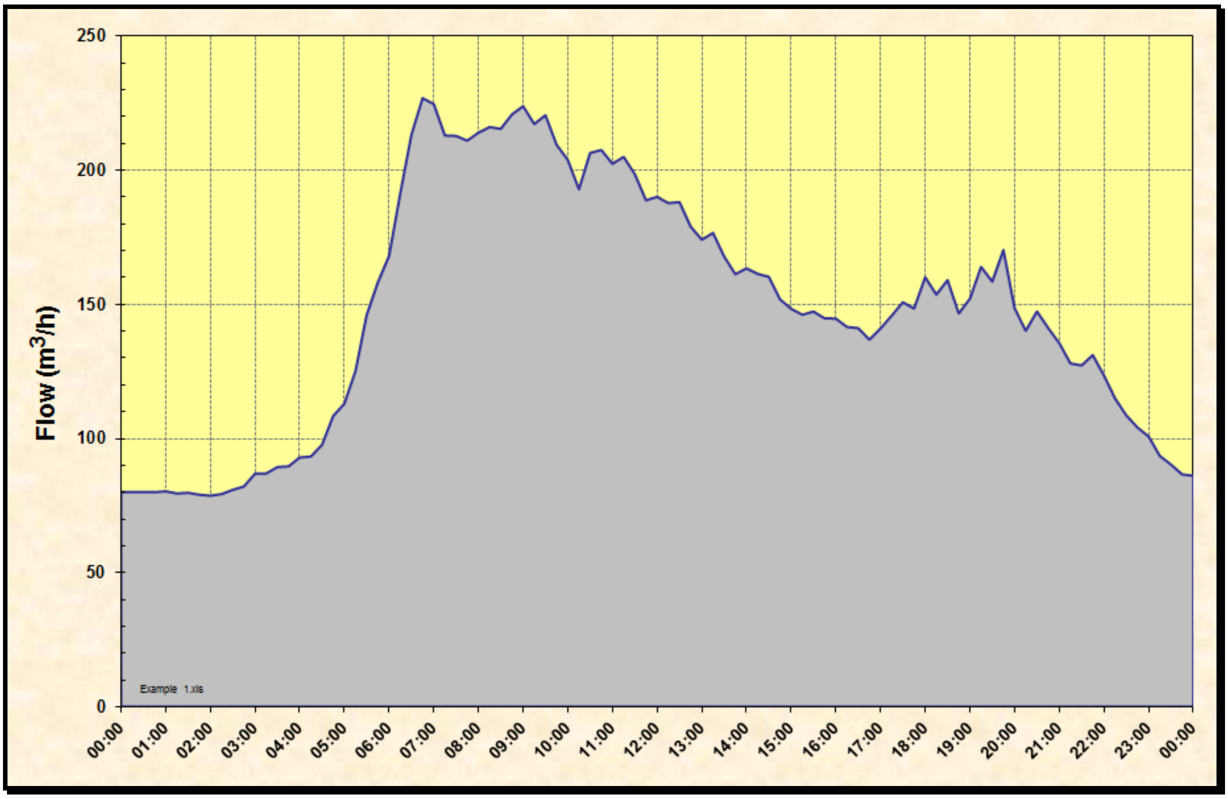

Figure 3: Flow entering a zone over a 24-hour period

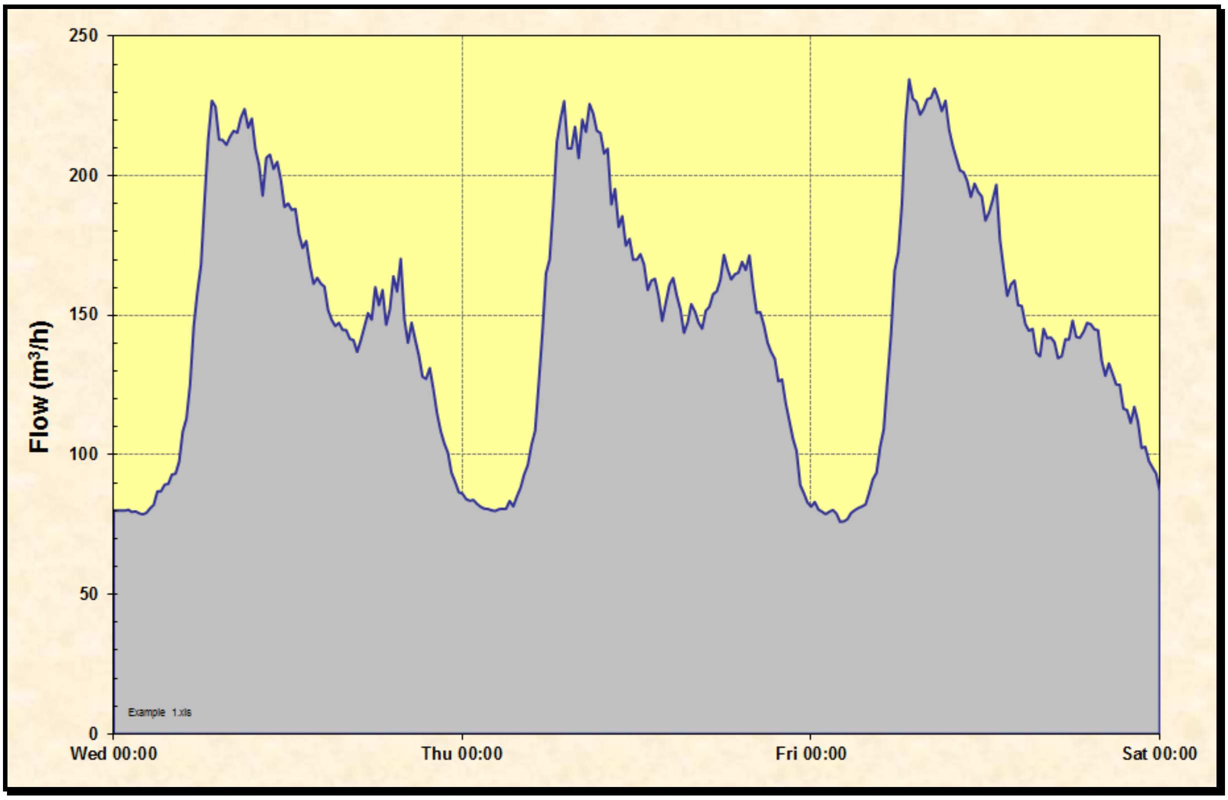

Figure 4: Flow entering a zone over a 3-day period

From the results shown in **Figure 4**, several key points can be noted which are of great help to the water supply manager. The following points can be concluded from the graph:

- the logging results indicate a consistent and repeating demand/supply pattern which is typical of a residential area with a morning and evening peak.
- the logging results show a minimum night flow of ±80 m^3/hr - this is one of the key indicators that water supply managers wish to see.
- The average daily demand is in the order of ±150 m^3/hr and this indicates that the minimum night flow is in excess of 50% of the average daily flow.

These basic indicators are shown on **Figure 5** which indicates that there may be a serious leakage problem in the zone since the minimum night flow should normally be less than ±20% of the average daily demand. It must be stressed at this point that ideally a detailed analysis of the minimum night flow should be undertaken using the BABE methodology as discussed previously. The ±20% guideline provided above is simply a very rough indicator based on the analyses of many thousands of flow logging results. If in doubt, a thorough BABE analysis should be undertaken from which the likely level of leakage in the area can be established with greater confidence.

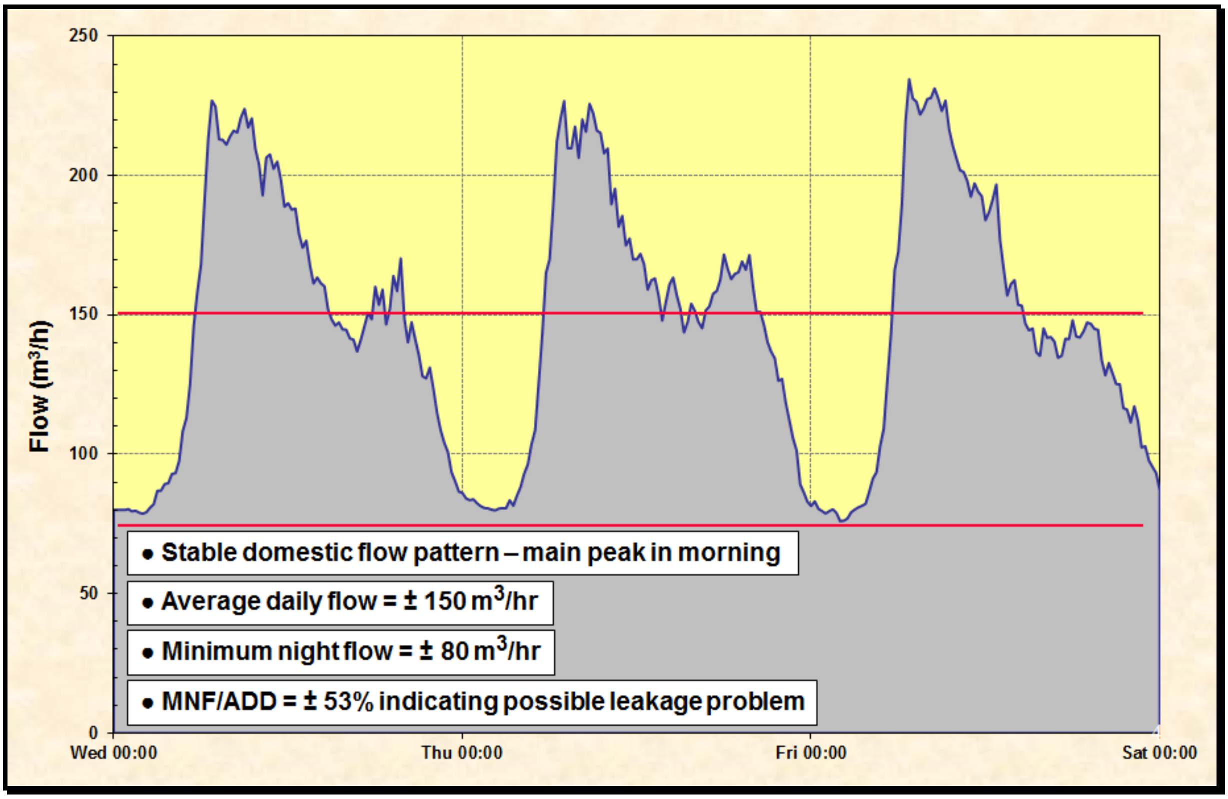

Figure 5: Annotated 3-day flow logging

It must also be stressed that the typical figures used to determine if there is in fact a leakage problem may vary from zone to zone and country to country. Each water supply manager will be able to develop his/her own "expected" indicators from which he/she will be able to identify if there is a problem in the zone or not. In this example, the expected minimum night flow was estimated to be ±20 m3/hr while the measured value was ±80 m3/hr as shown. In very simplistic terms, this suggests that there is a high level of unexplained leakage of ±60 m3/hr as shown in **Figure 6**. The calculations are never exact and the main purpose of the analysis is to establish whether or not there is a major leakage problem. If the calculation suggests that the potential leakage problem is marginal, then effort should be placed elsewhere since there will normally be zones where the results are conclusive.

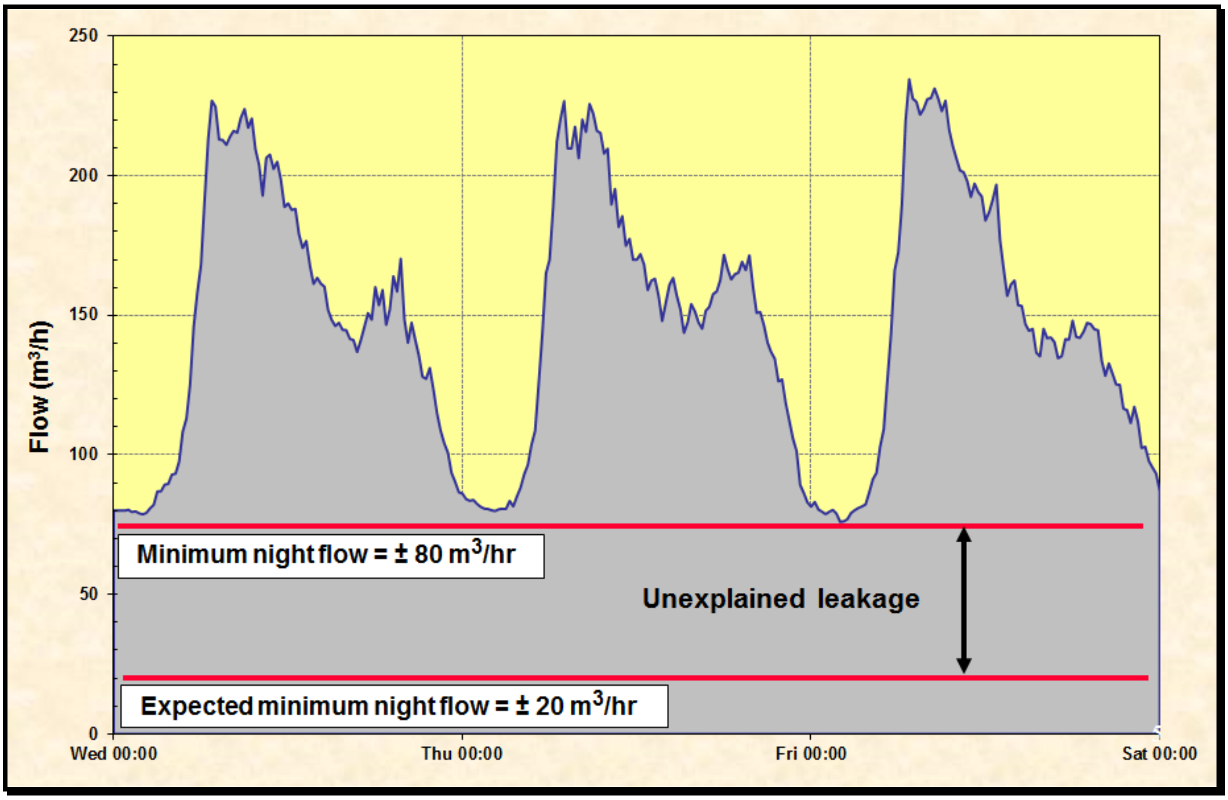

Figure 6: Simplified calculation of leakage

Having investigated the flow logging results for the specific zone in question, it is then useful to look at the pressure logging results as shown in **Figure 7** which have been included together with the previous flow loggings.

It is often very helpful to analyse the flow and pressure logging results simultaneously since they are part of the same puzzle and the flows often help to explain pressure variations and vice versa. From **Figure 7** it can be seen that the minimum pressure of approximately 30m occurs each morning during the main morning peak demand while the maximum pressure occurs during the early hours of the morning and corresponds to the minimum night flow.

This is typical of a normal zone with a normal demand pattern and no form of advanced pressure control.

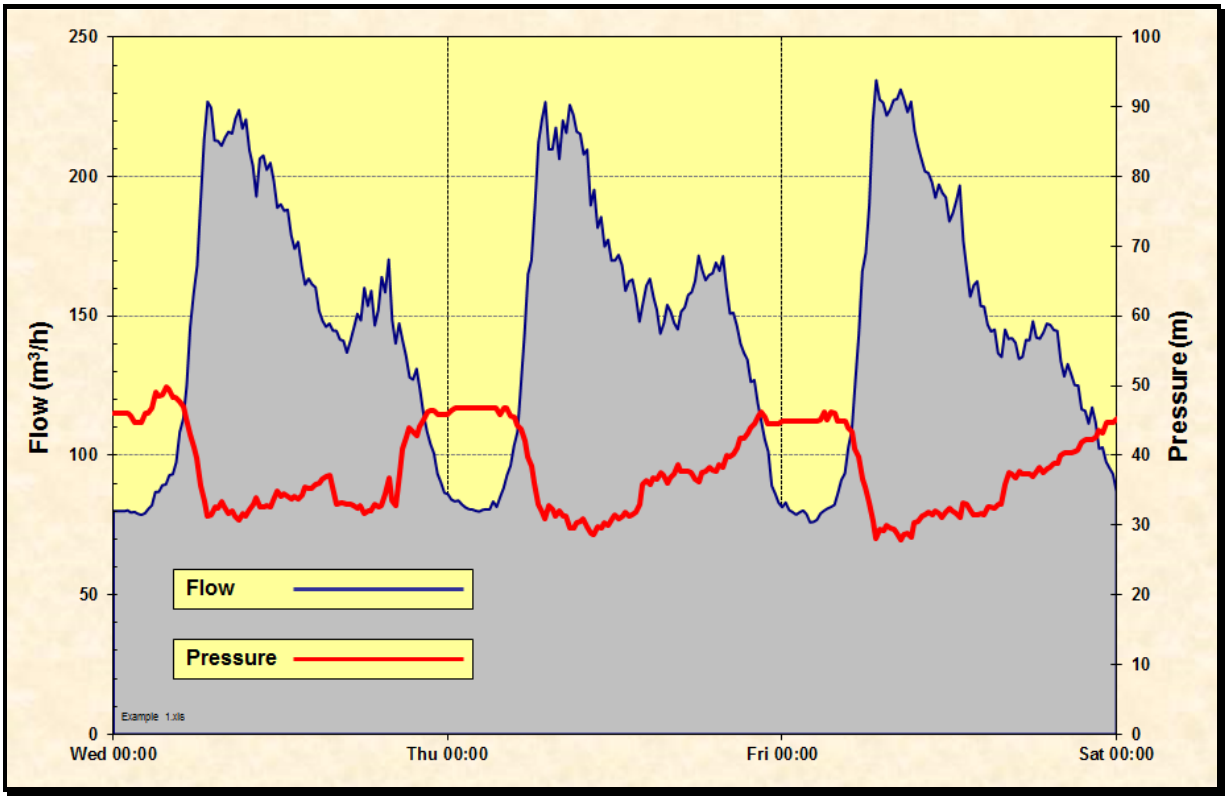

Figure 7: Logging with flow and pressure

The flow logging example shown in **Figure 8** is typical of zones which experience intermittent supply. Unfortunately when zones are subjected to regular periods of pressure followed by periods of no pressure, the leakage levels in the zone tend to become very large. The logging result is interesting in several respects and the following observations can be made from this example:

- The zone experiences intermittent supply with only one day of complete supply
- Each time the water is restored to the zone there is an immediate spike in the flow due to the refilling of the network. Such spikes are extremely damaging and will often damage the water meter beyond repair if the meter is a mechanical meter.\
- The one day during which the water was not cut off provides valuable information on the minimum night flow and thus also the level of leakage in the system. It can be seen that the minimum night flow is ±165 m^3/hr with an average daily demand of ±200 m^3/hr which suggests an extremely severe leakage problem.

Such leakage levels are typical of zones that experience intermittent supply.

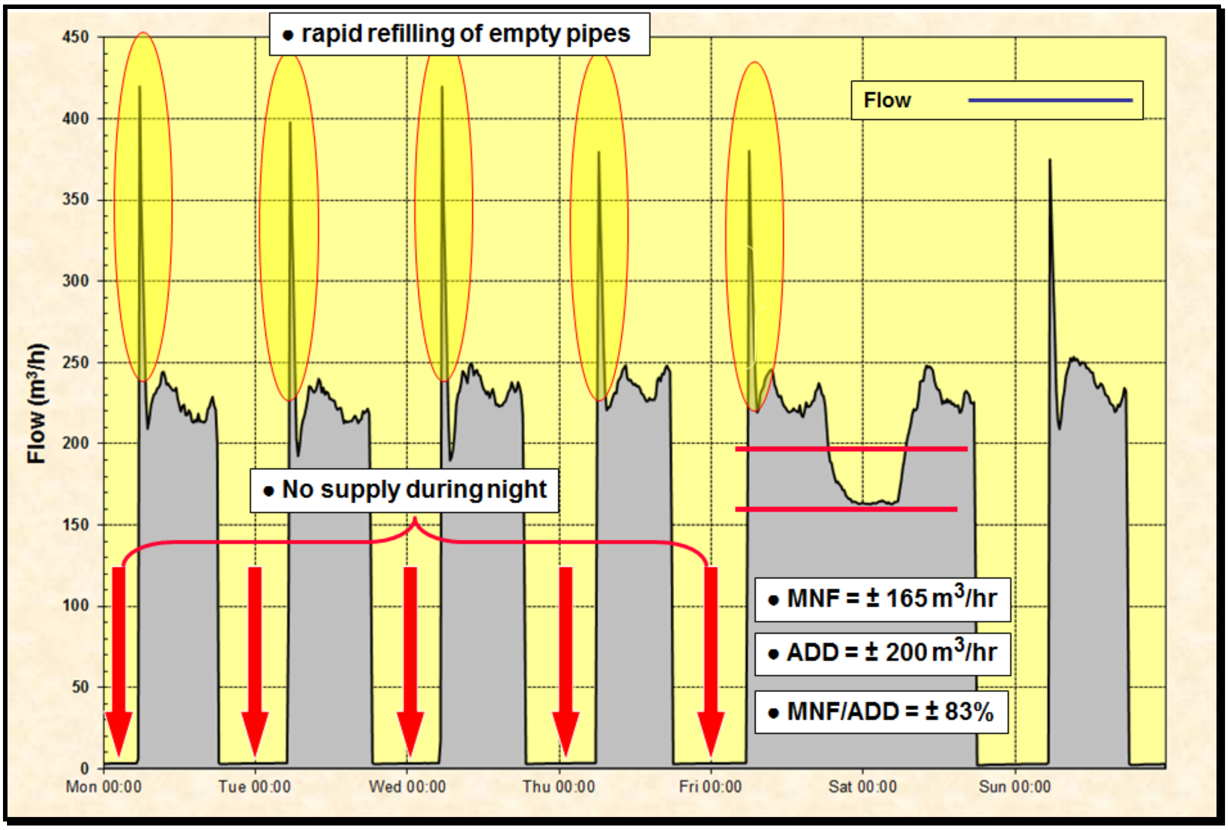

Figure 8: Zone with intermittent supply

Figure 9 is a very interesting logging result as it highlights one of the most common problems experienced in water reticulation systems. It highlights the flow and pressure results that can be expected when a zone cross boundary valve is opened by mistake (sometimes deliberately). The logging result shows the pressure at a pressure reducing valve (red) as well as the pressure downstream of the valve as it enters the zone (purple). The flow through the PRV into the zone is shown in blue.

When trying to understand such a complicated logging result, it is often helpful to work from left to right and start by examining the minimum night flow. If the changes to the minimum night flow can be explained, it is usually possible to explain what has happened. In this case, the minimum night flow is initially ±12 m^3/hr and after a few nights appears to drop to zero. This indicates that either all leakage, including background leakage, has been eliminated or the valve has closed and there is no flow through the valve. Since it is impossible to eliminate all leakage completely, it can be concluded that the valve has closed. On examination of the pressure downstream of the valve, it appears that there is a pressure increase each night corresponding to the zero flow through the valve. This is due to back pressure into the zone from some adjacent zone which in turn closes the PRV and results in zero minimum night flow. The previous leakage has not been eliminated and in fact will be higher during the night as a result of the increased pressure. This is a nice example to highlight what to look out for when there are problems with unauthorised opening and closing of valves within the system.

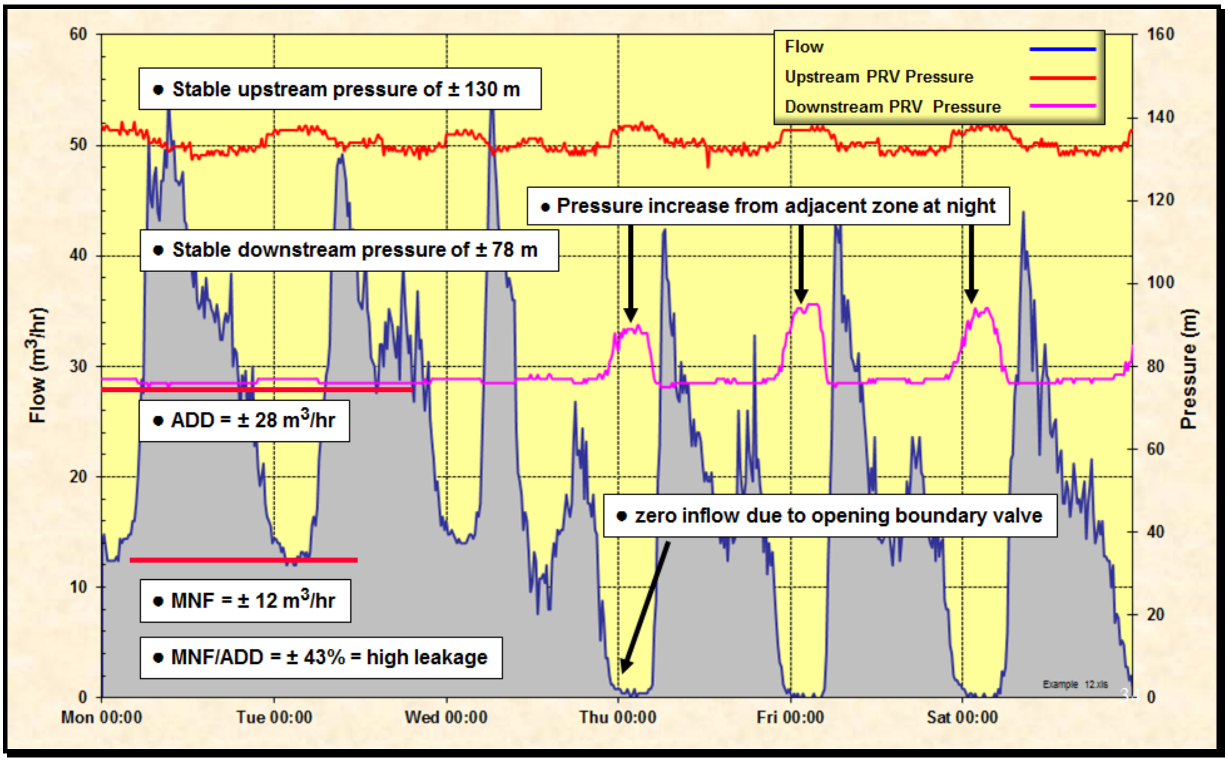

Figure 9: Zone compromised by open boundary valve

The example shown in Figure 10 is one of the more complicated and interesting logging results which was recorded by the City of Johannesburg at one of their PRV installations. Once again it is best understood by starting at the left and working towards the right and attempting to explain the changes to the minimum night flow. The story in this case reads as follows:

- Zone initially experiences relatively high night flow of ±40 m^3/hr
- Night flow jumps by ±20 m^3/hr in day2 due to a mains burst which pushes the minimum night flow up to ±60 m^3/hr
- The leak is repaired during day3 as indicated by a refilling spike and the drop in minimum night flow back to ±40 m^3/hr
- Over the next 6 nights, the PRV starts to experience problems and is unable to maintain a fixed pressure. During the day, the pressure appears stable due to the higher demand;

- The minimum night flow also gradually increases each night in response to the higher pressures. This is an excellent example to highlight the fact that pressure drives leakage.
- After the 6 nights of gradually higher pressures due to the failure of the PRV, it fails completely and no longer provides any pressure control. The minimum night flow rises significantly in response to the higher pressure.

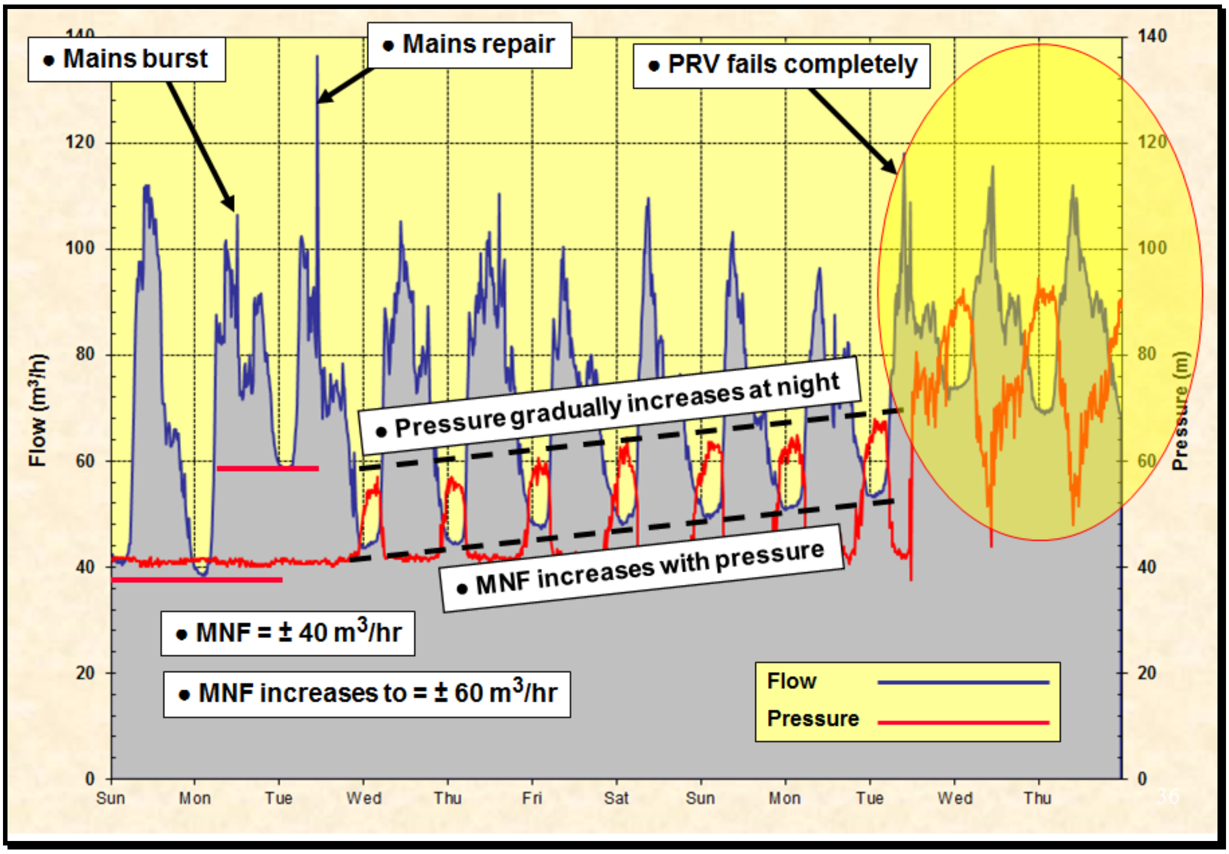

Figure 10: Failure of pressure reducing valve

Figure 11 provides a flow logging result taken directly from the City of Tshwane's (Pretoria, SA) real time logging system and it shows the flow recorded at an installation containing both a meter and a PRV. The flow at the meter indicates that a serious leak of ±30 m^3/hr developed between the 14th and 15th of December. This leak was identified by the municipality within a day and it took a further 3 days to find and repair it. It was an interesting leak in the respect that it occurred in an area of open ground where a construction vehicle had accidently knocked over a hydrant which was leaking into an open field. No damage had been caused and there was no evidence of this leak from the nearby road as the water was flowing directly into a small stream and caused no damage or inconvenience. Without the monitoring system in place, this leak would not have been identified for weeks if not months. After finding the source of the leak, it was quickly repaired and the MNF returned to the levels prior to 14 December.

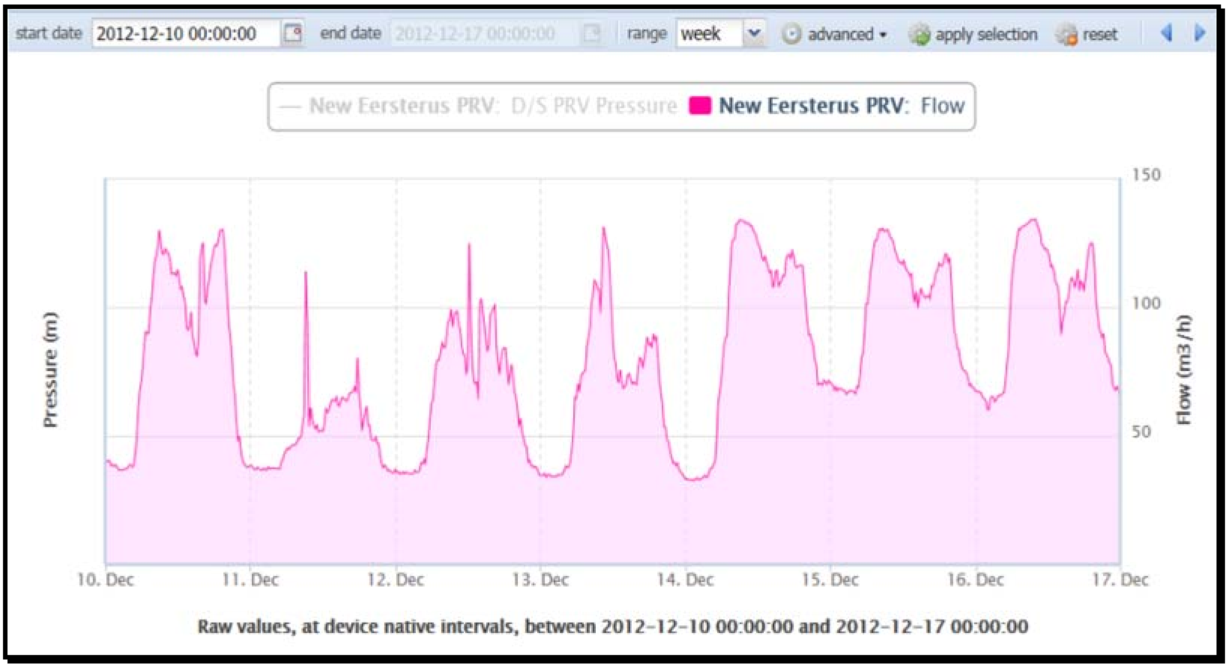

Figure 11: Example of mains leak from City of Tshwane

The example in **Figure 12** shows a leak of 40 m^3/hr that developed between 4th and 5th April. In this case, the leak was identified from the real-time logging system and took almost a week to find and complete the repair. It is important to appreciate that not all leaks create problems or are immediately visible.

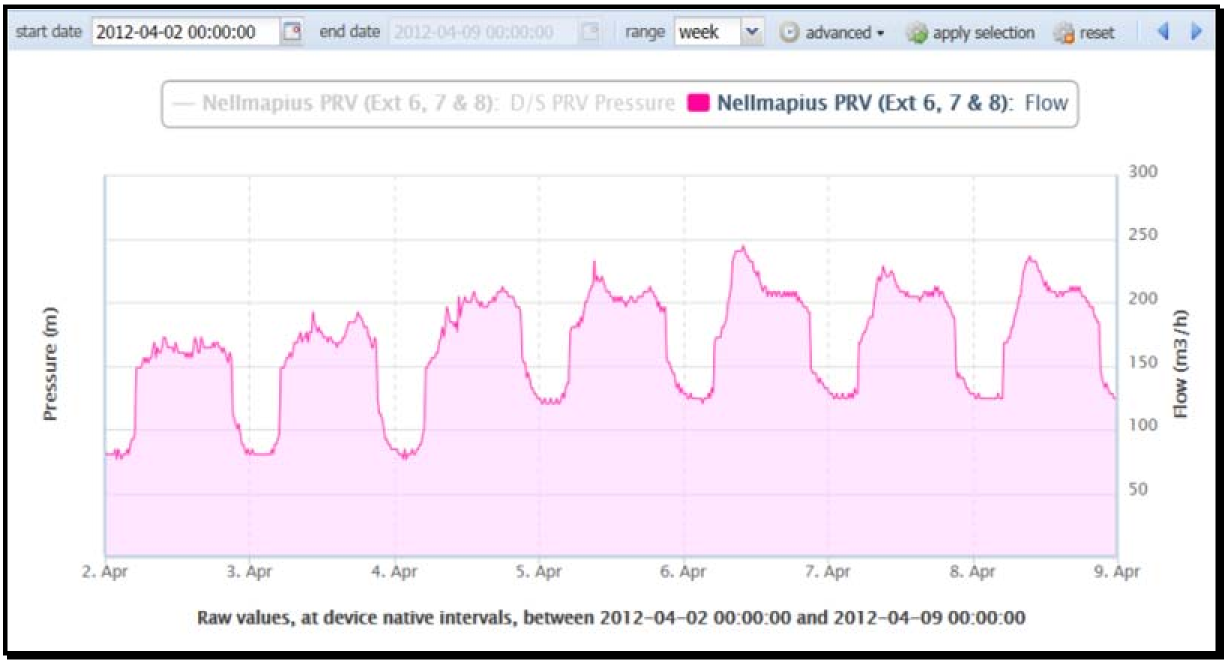

Figure 12: Second mains leak from City of Tshwane

This specific leak was caused by the end cap on a 150mm diameter pipe being damaged by a contractor once again in an area of open field where the water from the leak ran into a stream. The contractor did not inform the municipality of the damage caused to the pipe and it would have run indefinitely had the municipality not been actively monitoring the flow into the area.

The third example shown in **Figure 13** was identified through an alarm from the logger as soon as the leak occurred. As can be seen, this was an enormous leak of around 1 000 m^3/hr from a 300mm diameter pipe which had completely failed at high pressure.

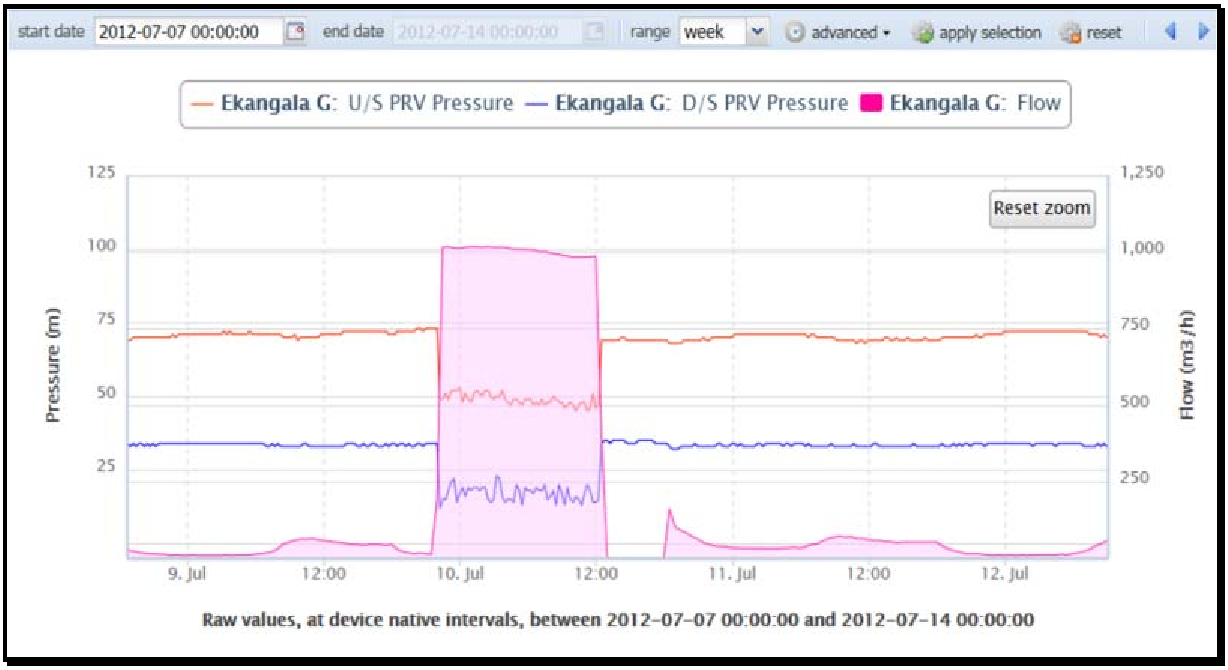

Figure 13: Example 3 from City of Tshwane

Managers at the City of Tshwane were in contact with the satellite office personnel within minutes of the leak occurring. It was a difficult leak to isolate and repair but was repaired within hours of it occurring. This leak did cause serious damage to the surrounding area and would have been identified with or without the real-time monitoring system. The system does, however, provide a record of the leak from which the volume of water lost and time taken to find and repair the leak can be established.

The graph shown in **Figure 14** highlights a leak that had been running for some time and was repaired on 7 July after which the MNF dropped by about 50 m^3/hr. This is a very sizeable leak but had not been reported and was eventually identified and repaired by Tshwane Water Department. It is important to appreciate that it is not only small leaks but also large leaks that can remain undetected for many days, weeks, months or even years.

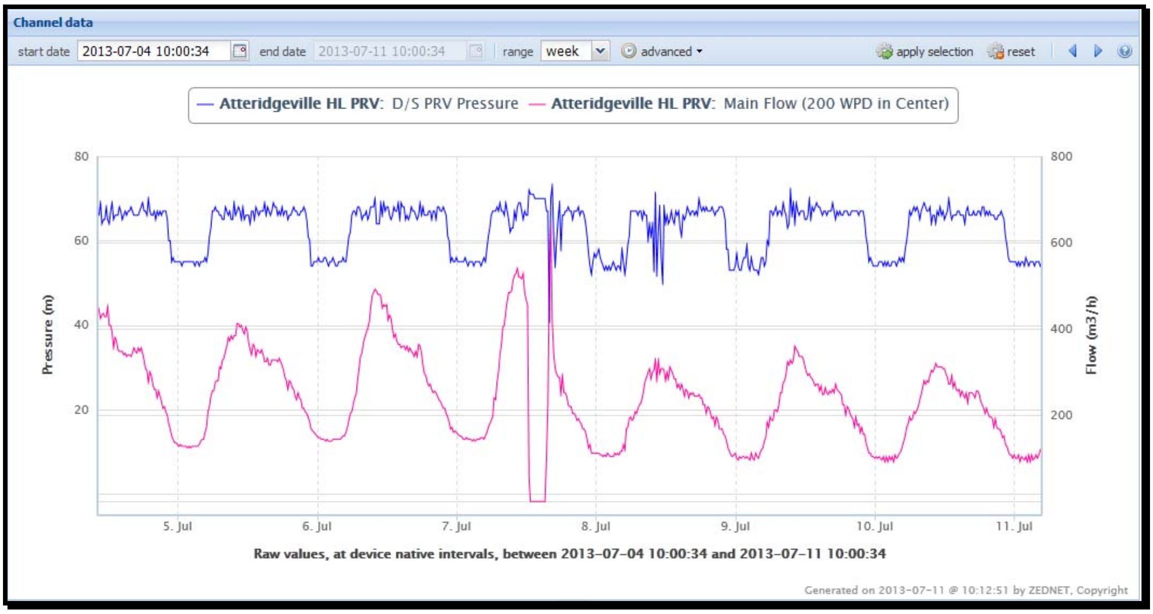

Figure 14: Leak and repair in Attridgeville

1.9 Live logging of flows at bulk consumer meters

Most of the logging results discussed so far, relate to bulk management meters installed by the municipality to monitor and manage the distribution of water in the reticulation system. The remainder of examples discussed in this section are recorded at bulk consumer meters which are used to measure water used by individual industrial consumers. Such bulk consumer meters are generally not used to analyse minimum night flows but are rather used mainly to generate revenue. With the advent of new logging technology and the internet, it is now not only possible but in many cases, highly cost effective to log and analyse the water being supplied to a single large consumer. Such consumers are often the main source of income to the municipality and therefore it is very important to ensure that all water used by the consumer is properly metered and billed. From the customer's viewpoint, it is also important that they can identify any wastage and leakage on their network since the costs involved can often be significant.

The example shown in **Figure 15** is an interesting case where a small industrial consumer was found to have a buried connection with a functional meter which did not appear on the billing system. When the connection was discovered through the use of metal detectors, it was found that the meter was running continuously suggesting the presence of a leak. The meter was logged to assess the extent of the leak and the results of the logging exercise are as shown in **Figure 15**. As can be seen, the leak appeared to have been running at ±24 m³/hr which is a very substantial leak. Under normal circumstances, such a leak would often create some evidence on the surface in the form of a puddle or a damp area. In this case, however, it was found that the leak was running directly into a sewer and was causing no damage or visible signs of dampness. After the leak was repaired, the water supply through the meter dropped dramatically as can be seen in **Figure 16**.

The damaged pipe that created this particular leak is shown in **Figure 17** which indicates that it was a split in a 63mm uPVC pipeline. Based on the meter reading, it was estimated that this leak ran for over 3 years and cost the municipality ±$300 000 based on their bulk water purchase cost.

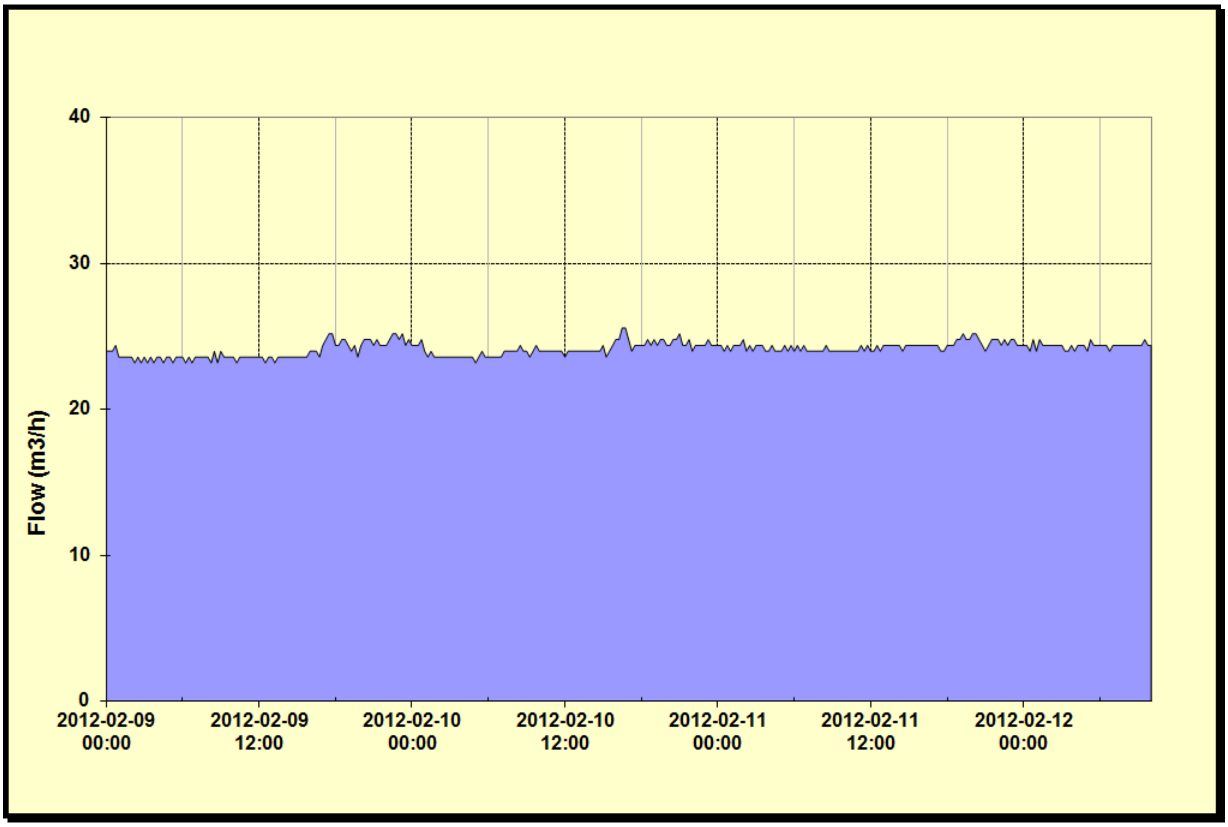

Figure 15: Industrial flow logging before leak repair

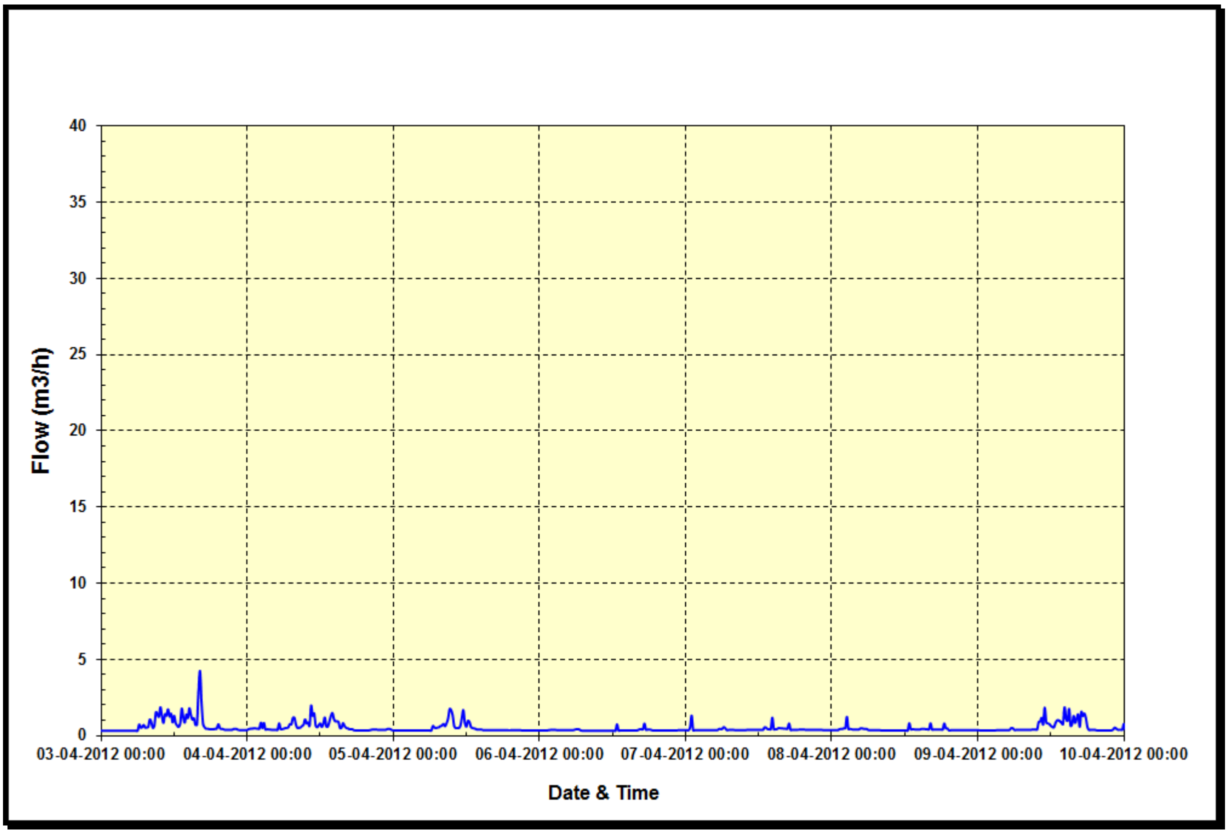

Figure 16: Industrial logging after leak repair

Figure 17: Damage to 63mm diameter pipe

The logging result from another project where real time logging has proved very beneficial and highly cost effective is shown in **Figure 18**. This logging result may at first glance seem very complicated but is in fact the flow and pressure logging into a major industrial factory. The results which are shown in more detail in **Figure 19**, clearly highlight the impact of a pump being switched on and off throughout the day which in turn creates large pressure variations throughout the network in the vicinity of the factory. Such large fluctuations should be discouraged and the industries concerned should introduce some form of on-site storage to attenuate the variations in demand and pressure.

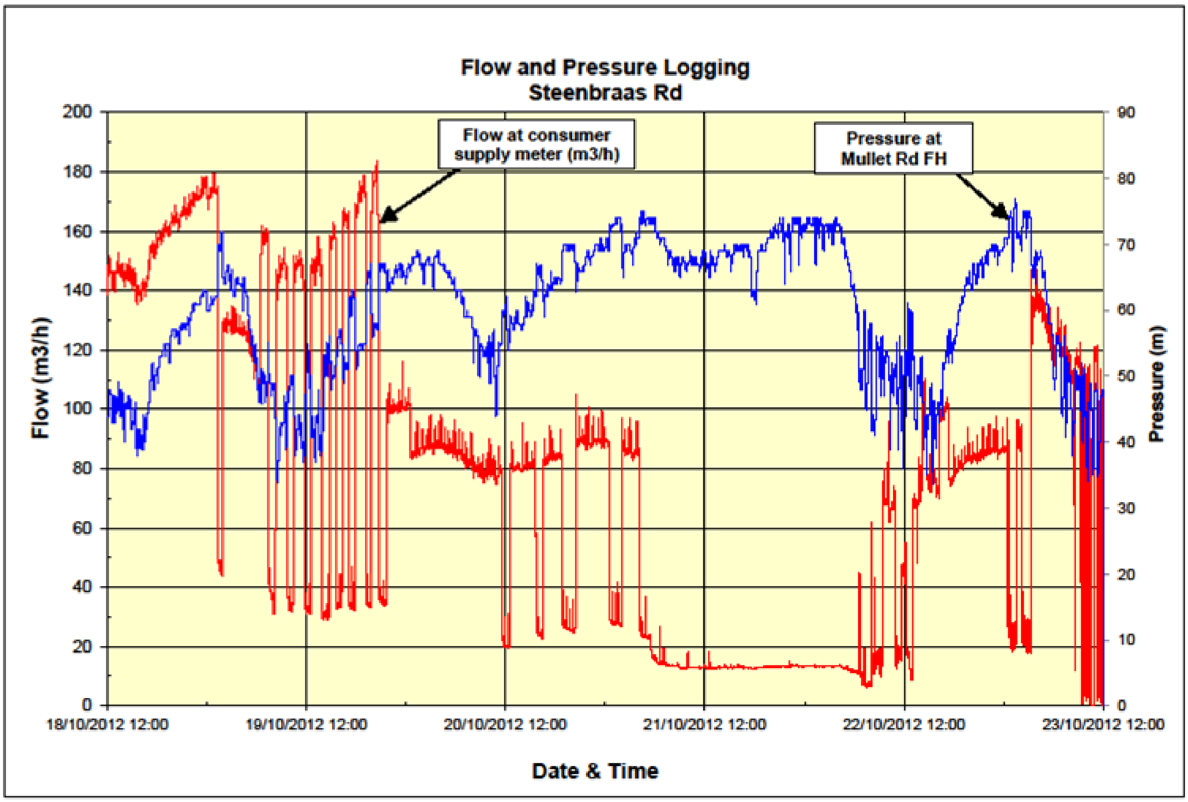

Figure 18: Logging Result from Wadeville Project in Ekurhuleni

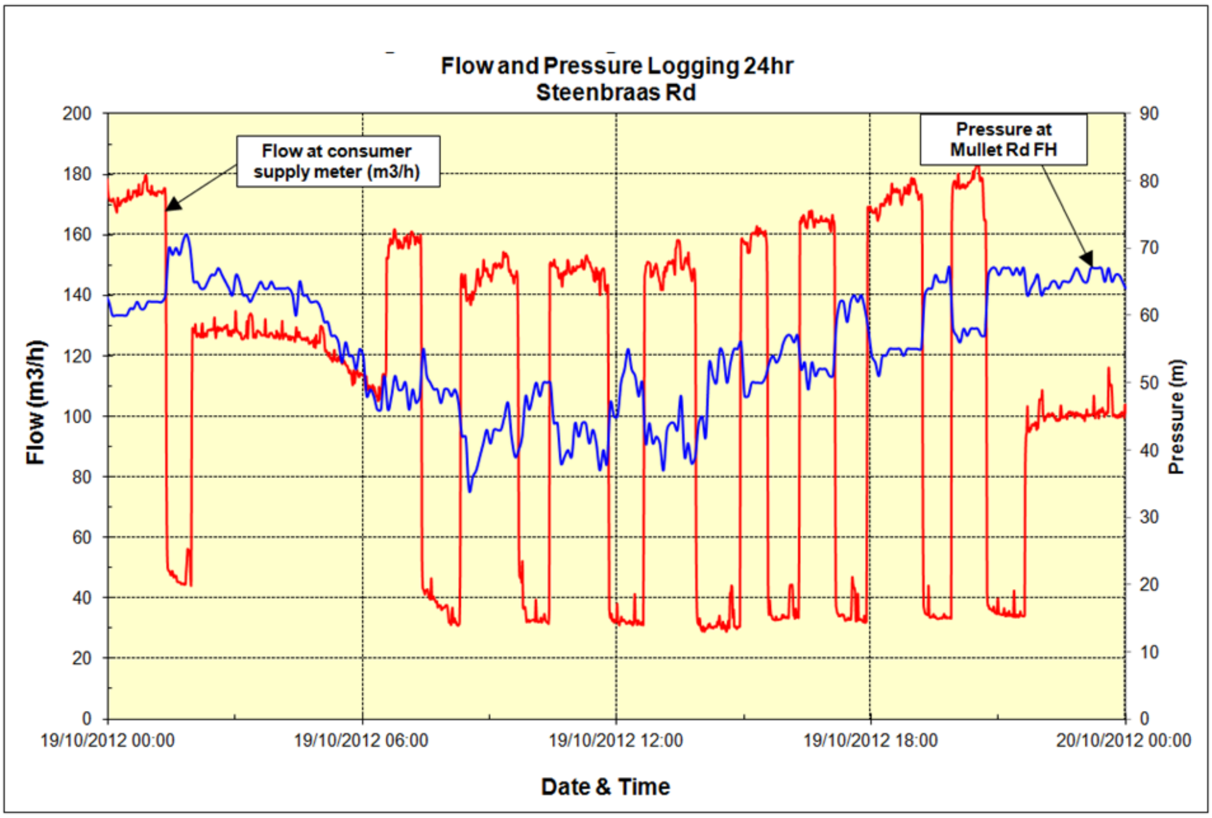

Figure 19: More detailed examination of industrial water consumption

The graph shown in **Figure 20** provides an example of a relatively small leak which had been running inside a town-house complex for many months. The residents of the complex had approached the Municipality for assistance regarding their monthly water bill which had been slowly increasing over a period of two years. After installing the logger at the water meter to the complex, it was clear that there was a serious leak on the system of almost 15 m^3/hr.

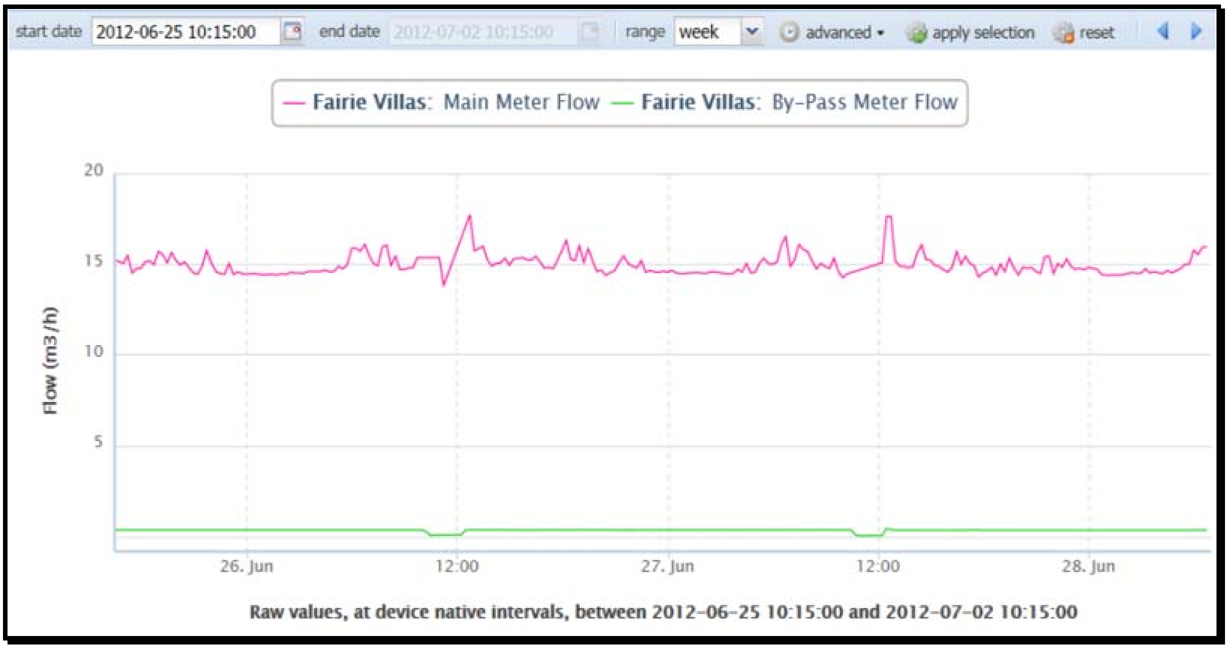

Figure 20: Example of leak in Townhouse complex (courtesy City of Tshwane)

Within a week, the leak had been found and repaired and the water consumption dropped back to normal levels with a Minimum Night Flow of only 0.3 m^3/hr as can be seen in **Figure** 21.

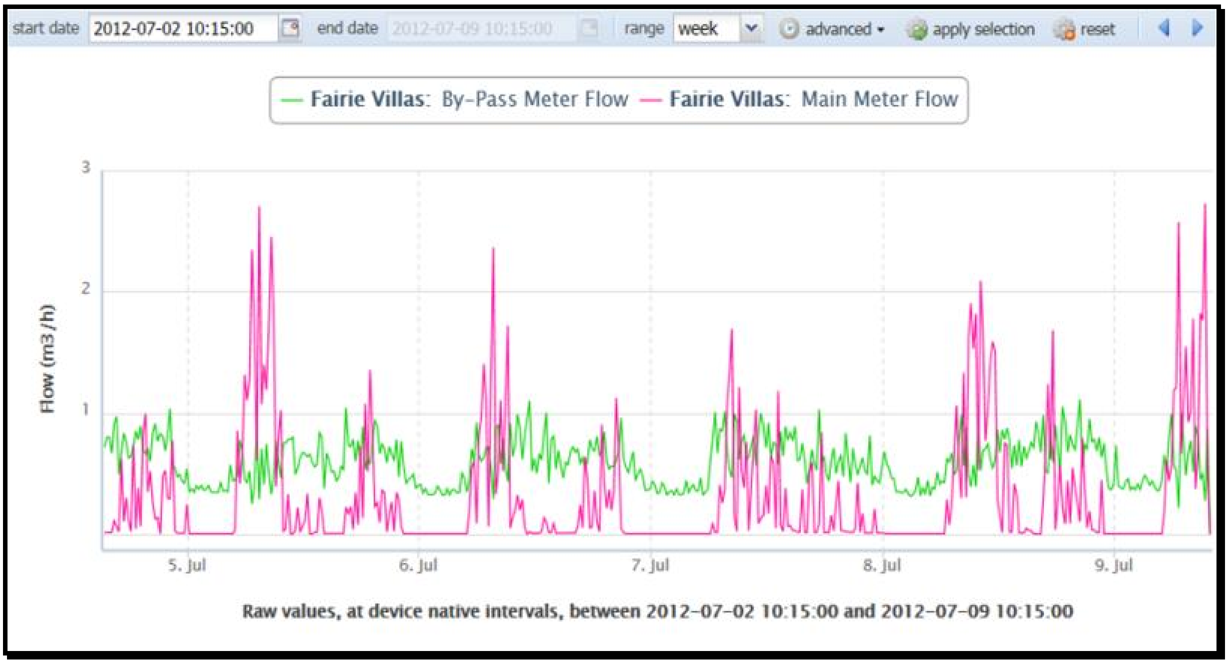

Figure 21: Post repair graph from Example 4 (courtesy City of Tshwane)

This particular example highlights the benefits for such logging on bulk meters into large consumers – in this case a townhouse complex with approximately 50 properties. It can be seen that there are two flow records on each graph – one shown in pink and the other in green. This is typical of a combination meter where there are two water meters in a single housing and therefore the logger must record both meters. The pink flow record represents the flow through the main meter while the green line represents the flow through the low-flow by-pass meter. In **Figure 20**, it can be seen that virtually the full flow passes through the main meter which is due to the large leak. In **Figure 21**, it can be seen that the low-flow by-pass mater is again functioning properly and taking up much of the flow during periods of lower demand.

Another nice example demonstrating the value of continuous monitoring of the bulk water use into an industrial facility is shown in **Figure 22** which clearly highlights a leak running at approximately 2 m^3/hr. Without continuous monitoring, the industrial user would simply have received an abnormally large water account and would not have realised the extent of the leak which is quite clear from the graph. This leak represents a loss or rather an additional expense of almost $2 000 per month to the industrial user based on the current industrial water tariff in the area.

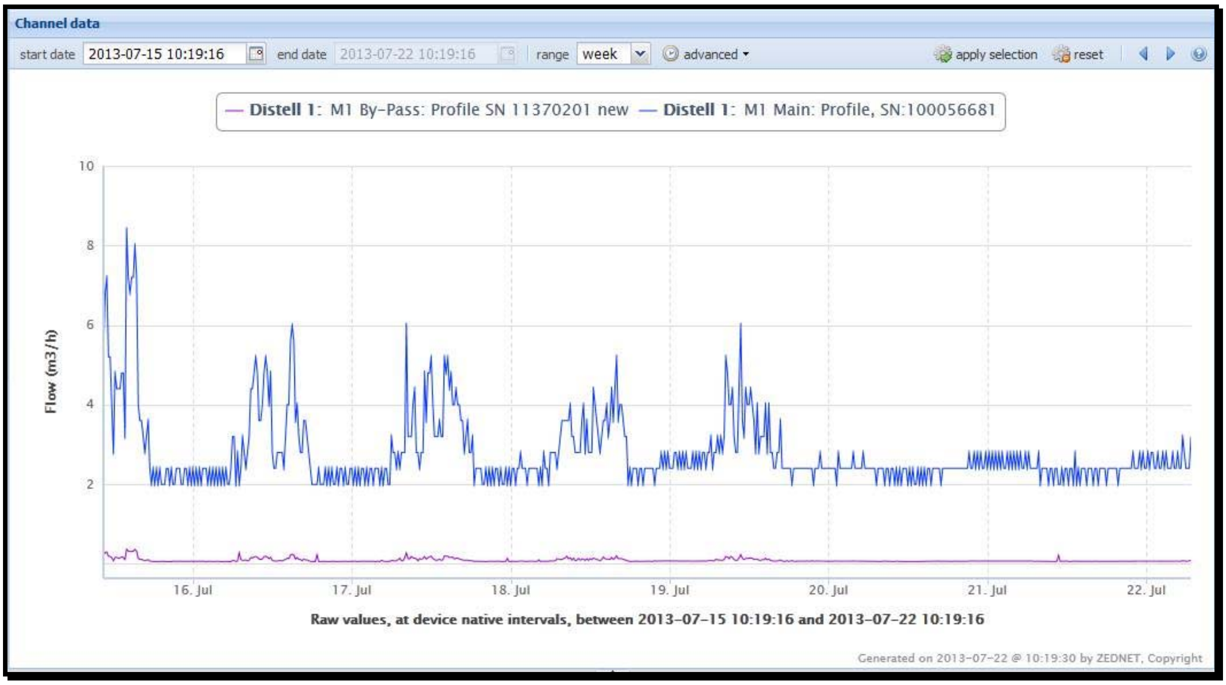

Figure 22: Bulk consumer leak (Courtesy Distell Pty Ltd)