Applying the IWA approach to water loss performance indicators in Australia

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Abstract In 1999 and 2000, IWA Task Forces on Water Losses and Performance Indicators published their conclusions of over three years research, analysis and discussions. For the topics of Non-Revenue Water, Water Losses, Apparent Losses and Real Losses, these included:

- a recommended standard terminology, with definitions and procedures for assessing these components of the Annual Water Balance;
- recommended performance indicators for each of these components.

This work represents a major step forward in defining the “best practice” approach to assessing and presenting components of Non-Revenue Water, for more rational comparisons of performance in diverse systems within a single organisation, within the same country, and between countries.

The 21 members of the Water Services Association of Australia (WSAA) provide water and wastewater services to 12.9 million Australians. WSAA seeks to promote “best practice”, and act as a national focus for all interested parties. In February 2000 WSAA organised a national Workshop in Melbourne to discuss the IWA methodology. Arising from this Workshop, WSAA commissioned the production of customised Software and an Associated User Manual known as “Benchloss”, to promote and facilitate the application of the IWA recommended methodology throughout Australia. The paper will describe the development and application of “Benchloss” to date, with a comparison of Australian performance data against an International Data Set used by the Water Losses Task Force.

Keywords Apparent losses; non-revenue water; real losses; water losses

Publications of the IWA task forces

The principal publications of the IWA Water Losses Task Force were:

- an article in AQUA in December 1999 (Lambert et al., 1999) which examined the topic of performance indicators for Real Losses from first principles, using Component Analysis techniques coupled with wide international consultation;
- a “Blue Pages” in August 2000 (Lambert and Hirner, 2000), covering the recommended standard water balance and terminology, and the recommended performance indicators for Non-revenue Water (NRW) and Real Losses.

The principal output of the IWA Performance Measures Task Force was a “Best Practice” Manual (Alegre et al., 2000) on structuring, selecting and calculating 133 Performance Indicators for different purposes (Financial, Operational, Quality of Service etc). Parts of the “AQUA” and “Blue Pages” were repeated in the section of the Manual that deals with 7 Water Losses Performance Indicators.

Annual water balance in “WSAA facts”

In the annual publication “WSAA facts 2000”, WSAA used the water balance terminology in Figure 1 as shown:
Total water supplied is the sum of all water supplied downstream of the headworks master meters.

“Other” includes Total metered and estimated non-metered consumption by other (i.e. non-residential/commercial/industrial) properties/sources. This includes an estimate of water used for fire fighting, mains flushing, water taken by councils or contractors and any other consumption due to operations.

“System Water Losses” is what is left after all other components, measured and estimated, have been deducted from the Total Water Supplied; it represents the WSAA “best estimate” of Real Losses (leakage plus overflows) from the system between the sources and the customer meters.

In “WSAA facts 2000”

- Volumes are quoted in Megalitres (ML, or m³ × 10³).
- The volume of water supplied divided by the Total Number of Properties ranges from 276 to 990 KL/property/year (average 397 KL/property/year or 1087 L/property/day).
- Most WSAA members meter all properties close to the street/property boundary.
- The consumption per residential property ranges from 196 to 525 KL/property/year (average 256 KL/prop/year or 701 litres/property/day).
- Plumbing fittings are subject to direct pressure.
- Customer meter under-registration varies from 1.9% to 7.4% of metered residential and Commercial/Industrial Consumption.
- “Other” varied from 0% to 31.4% of water supplied – a very large range.

At the February 2000 Workshop, WSAA recognised the logic behind the IWA Task Forces recommendation (Lambert et al., 1999; Lambert and Hirner, 2000; Alegre et al., 2000) that percentages are not suitable for comparing operational performance in management of Real Losses, because of differences and changes in consumption. This conclusion had also previously been reached and implemented by the Office of Water Services (OFWAT) the Economic Regulator for England and Wales (Office of Water Services, 2001). WSAA facts 2000 endorses international best practice for assessing operational management of Real Losses, by not quoting System Water Losses as a per cent of Total Water Supplied.

The components of the water balance must be set up in the IWA standard recommended format before the calculation of “best practice” performance indicators is made. To facilitate these two actions, WSAA commissioned Dr R. McKenzie of Global Water Resources Ltd (GWR) to produce appropriate software, and a User Manual. Dr McKenzie had previously produced a similar item of software, with User Manual, for the South African Water Research Commission (McKenzie, 2002), to facilitate implementation of the IWA “best practice” procedure for assessing performance in water loss management in South Africa. General guidance was provided by Mr A. Lambert of IWDC Ltd, who had led the IWA Task Force on Water Losses and been the main speaker at the February 2000 WSAA Workshop.

The final version of the WSAA BENCHLOSS software and User Manual was completed late in 2000. The software (an Excel Workbook) consists of 10 Worksheets –
Licence, Introduction, UARL, Terminology, Waterbal, Consumption, WBComponents, PICalcs, Summary, Why not percentages. In addition to explaining how to use the software, the User Manual discusses the key issues in selecting appropriate PIs for Non-Revenue Water and Real Losses, and has Appendices outlining the concepts used for:

- Component Analysis of Real Losses using Background and Bursts Estimates (BABE).
- Pressure: Leakage Rate relationships based on Fixed and Variable Area Discharges (FAVAD).
- System-Specific Calculation of Unavoidable Annual Real Losses (UARL).
- Methods of Calculating Average Pressure in Distribution Systems.

**The IWA water balance used in BENCHLOSS**

Figure 2 shows the Water Balance from the BENCHLOSS “Terminology” Worksheet. This is almost identical to the original IWA version (Lambert and Hirner, 2000; Alegre et al., 2000), except that the System Input Volume is corrected for any known source metering errors, to avoid mixing these with customer metering errors in the “Apparent Losses”.

**BENCHLOSS data received from WSAA members**

The 21 WSAA members based in Australia were invited to re-analyse their 2000/01 Water Balance data using BENCHLOSS. Ten of the 17 Utilities responsible for distribution provided data in time for the preparation of this paper.

Key characteristics required for assessing Unavoidable Annual Real Losses are:

- Density of service connections (per km of mains).
- Location of customer meters (relative to street/property boundary).
- Average operating pressure.

In all 10 cases, all customers are metered close to the street/property boundary.

Table 1 summarises the information and performance indicators obtained from the BENCHLOSS calculations carried out by the 10 WSAA members; these calculations have not been independently checked. Statistics for Density of Connections and average pressure are shown in the 2nd and 3rd columns of Table 1.

Table 1 shows that, for the 10 WSAA systems reviewed:

- Density of Connections ranges from 20 to 69 per km of mains, average 47 per km; the international data set (Lambert and Hisner 2000) has a wider range, from 24 to 114/km, and a slightly higher average of 52.5/km mains.
- Average pressure ranges from 37.3 to 72 metres, average 48.8 metres; the international data set has a wider range, from 30 to 106 metres, with a slightly lower average of 46.5 metres.
In systems such as these where the Density of Connections exceeds 20 per km of mains, the “best practice” choice (Lambert and Hirner, 2000; Alegre et al., 2000; WSAA facts, 2000) of traditional simple performance indicator for Real Losses is “per service connection per day”. If Density of Connections is less than 20/km, it would be “m³ per km of mains per day” (see Figure 3).

Note that the “Number of Service Connections” is used, not “Number of Properties”; this is because Real Losses occur on the service connections, but some service connections serve multiple properties. For the 10 WSAA members, the ratio of Service Connections to Properties appears to vary from around 0.76 to 1.0 for different systems, with an average around 0.90, but in some countries the ratio can be as low as 0.2.

### Unavoidable annual real losses

Where service connections are metered close to the street/property boundary, as in these 10 cases, the corresponding system-specific equations for Unavoidable Annual Real Losses, derived from Component Analysis assuming well maintained infrastructure in good condition, are: (Lambert and Hirner, 2000; Alegre et al., 2000)

\[
\begin{align*}
\text{UARL (litres/day)} & = (18 \times L_m + 0.8 \times N_c) \times P \\
\text{UARL (litres/service conn/day)} & = (18/DC + 0.8) \times P \\
\text{UARL (litres/service conn/day/m of pressure)} & = (18/DC + 0.8) \\
\text{UARL (litres/km mains/day/m of pressure)} & = (18 + 0.8 \times DC)
\end{align*}
\]

For large systems with mixed pipe materials, research in Japan, the UK and elsewhere

### Table 1

Statistics for 10 WSAA systems which provided data

<table>
<thead>
<tr>
<th>System</th>
<th>Density of conns, per km of mains</th>
<th>Average pressure (metres)</th>
<th>UARL l/conn/day</th>
<th>CARL l/conn/day</th>
<th>CARL l/conn/d/m. of pressure</th>
<th>Inf. leakage index ILI</th>
<th>NRW, % by volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>35.8</td>
<td>55.3</td>
<td>55.1</td>
<td>63</td>
<td>1.14</td>
<td>0.87</td>
<td>9.5</td>
</tr>
<tr>
<td>B</td>
<td>62.0</td>
<td>72.0</td>
<td>78.5</td>
<td>87</td>
<td>1.21</td>
<td>1.10</td>
<td>12.8</td>
</tr>
<tr>
<td>C</td>
<td>53.9</td>
<td>54.3</td>
<td>61.6</td>
<td>69</td>
<td>1.27</td>
<td>1.11</td>
<td>9.9</td>
</tr>
<tr>
<td>D</td>
<td>42.5</td>
<td>45.0</td>
<td>55.1</td>
<td>95</td>
<td>2.11</td>
<td>1.72</td>
<td>10.4</td>
</tr>
<tr>
<td>E</td>
<td>48.2</td>
<td>40.9</td>
<td>48.0</td>
<td>90</td>
<td>2.20</td>
<td>1.90</td>
<td>15.3</td>
</tr>
<tr>
<td>F</td>
<td>28.5</td>
<td>40.5</td>
<td>64.5</td>
<td>140</td>
<td>3.11</td>
<td>2.17</td>
<td>14.0</td>
</tr>
<tr>
<td>G</td>
<td>68.9</td>
<td>48.5</td>
<td>51.5</td>
<td>112</td>
<td>2.30</td>
<td>2.20</td>
<td>11.6</td>
</tr>
<tr>
<td>H</td>
<td>44.4</td>
<td>49.8</td>
<td>60.1</td>
<td>162</td>
<td>3.25</td>
<td>2.70</td>
<td>19.2</td>
</tr>
<tr>
<td>I</td>
<td>20.0</td>
<td>42.0</td>
<td>71.4</td>
<td>220</td>
<td>5.24</td>
<td>3.38</td>
<td>22.0</td>
</tr>
<tr>
<td>J</td>
<td>64.7</td>
<td>35.3</td>
<td>38.0</td>
<td>141</td>
<td>4.00</td>
<td>3.68</td>
<td>13.4</td>
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<tr>
<td>Average</td>
<td>46.9</td>
<td>48.8</td>
<td>60.0</td>
<td>118</td>
<td>2.58</td>
<td>2.08</td>
<td>13.8</td>
</tr>
</tbody>
</table>

Specify:
- Number of Service Connections (Nc)
- Length of Mains (Lm km)

Calculate:
- Density of Service Connections/km
  \( DC = \frac{N_c}{L_m} \)

Use litres/service connection/day as Real Losses Level 1 PI

Figure 3 Process to determine Basic PI for Operational Management of Real Losses
has shown that the general relationship between average pressure and leakage rates is approximately linear (Lambert, 0000), so a linear relationship between UARL and average pressure is used in the UARL equations. The 4th column of Table 1 shows that the UARL values calculated using Eq. (1b) range from 38 to 78.5 litres/connection/day, depending upon the individual system characteristics of Density of Connections and Average Pressure.

“Best practice” PIs for non-revenue water

The PIs calculated in the WSAA BENCHLOSS software are as follows (Lambert and Hirner, 2000; Alegre et al., 2000; WSAA facts, 2000). Financial performance indicators for non-revenue water:

Basic : NRW volume as % of System Input Volume
Detailed : NRW value as % of Annual System running costs

NRW percentages by volume are shown in the 8th Column of Table 1. They range from 9.5% to 22%, with an average of 13.8%. A comparison with the International Data set (Lambert and Hirner, 2000) is shown in Figure 4a. From this, it would appear that the performance of the 10 WSSA systems in management of Non-Revenue Water is “middle of the road” with no outstandingly good, or bad performers. It is worth noting, however, that in 3 of the WSSA systems with significant exports of water, the calculated percentage NRW is lower than it would have been if the percentage NRW was calculated with the exported volumes excluded from the calculation – this is a further problem with using percentages for performance comparisons.

Only 6 WSAA members provided details of the Detailed NRW PI (percentage by value), and as there is no international data set for this PI, the results are not presented in this paper.

“Best practice” PIs for operational management of real losses

The PIs calculated in the WSAA BENCHLOSS software are as follows (Lambert and Hirner, 2000; Alegre et al., 2000; WSAA facts, 2000):

Basic PI : litres/service connection/day
Intermediate PI : litres/service connection/day/metre of pressure
Detailed PI : Infrastructure Leakage Index (ILI)

Figure 4b shows the comparison of the Basic Operationall PI for Real Losses (litres/service connection/day) for the WSAA systems (see 5th column of Table 1), with the International data set. An immediate difference in perceived performance is noted, as compared to Figure 4a (NRW % by volume), with two of the WSAA systems moving into the top 3 performers. The basic reason for this is that around 2/3 of the systems in the International Data Set have average consumption per service connection significantly greater than the WSAA average (around 1000 litres/service connection/day). The higher the consumption, the lower the NRW volume expressed as a percentage. For this reason the IWA “Best Practice” recommends against use of %s by volume as PIs for assessing operational management of Real Losses.

Figure 4c shows the comparison of the Intermediate Operational PI for Real Losses (litres/service connection/day/metre of pressure) for the WSAA systems (6th column of Table 1), with the International data set. Three of the WSAA systems are now in the top 5 systems, the latest addition being a system with high average pressure (72 metres) largely due to varied topography.

Figure 4d shows the comparison of the Detailed Operational PI for Real Losses (Infrastructure Leakage Index, ILI) for the WSAA systems (7th column of Table 1), with the International data set. This, the most comprehensive of the Operational PIs for Real Losses, shows 3 of the WSAA systems in the top 4, having ILIs close to 1.0. The remaining
7 systems have ILIs between 1.7 and 3.7, in the central range of the mixed WSAA and International data set.

The infrastructure leakage index

A brief explanation of the Infrastructure Leakage Index (ILI) is offered for this useful and diagnostic Performance Indicator. The Infrastructure Leakage Index is the ratio of the Current Annual Real Losses (CARL) to the Unavoidable Annual Real Losses (UARL).

In Figure 5, suppose that the area of the large rectangle represents the volume of Current Annual Real Losses (CARL) for a specific system. As the system ages, there is a natural rate of rise of Real Losses through new leaks and bursts, some of which will not be reported to the Utility. This tendency is controlled and managed by a combination of the four primary components of Real Losses Management, namely:

- Pipeline and Assets Management
- Pressure Management (which may mean increases or decreases of pressure)
- Speed and quality of repairs
- Active Leakage Control, to locate unreported leaks

The extent to which each of these four activities is carried out will determine whether the volume of annual Real Losses increases, decreases or remains constant. Real Losses cannot be eliminated totally. The lowest technically achievable annual volume of Real Losses for well maintained and well managed systems is the Unavoidable Annual Real Losses (UARL), represented by the smaller rectangle in Figure 5. System-specific values of UARL can be calculated using the component-based methodology developed by the Water Losses Task Force (Lambert and Hirner, 2000). The ratio of the Current Annual Real Losses (CARL) to the Unavoidable Annual Real Losses (UARL) is the non-dimensional Infrastructure Leakage Index (ILI).

The ILI measures how effectively the infrastructure activities in Figure 3 – repairs, active leakage control and Pipeline/Assets Management – are being managed at the current operating pressure. An ILI close to 1.0 represents operational management of the highest standard.
Other information on Australian applications of the IWA methodology

In Queensland, a group consisting of the Environment Protection Agency, Wide Bay Water, and other organisations and Companies interested in promoting demand management, are using the IWA methodology and Performance Indicators. A roadshow to promote demand management and leakage control, and to explain the principles was held at several locations in May 2001. A calculation of ILI for Wide Bay Water gives a value of around 1.1, equal to the best of the WSAA data sample, and in the top rank of internationally.

The Australian National Report submitted to IWA for the Berlin Congress in October 2001 refers to the WSAA initiative – the February 2000 Workshop, and the BENCHLOSS software “which will allow water utilities to undertake the task easily and in a consistent standardised manner.” The National Report concludes that Australia is “in an early stage of adopting the IWA methodology”. It also identifies a problem arising from different definitions of Non-Revenue Water by the various regulatory agencies, making benchmarking difficult – “in time, it is expected that the IWA methodology will become more widely adopted by water utilities and regulators”.

Discussion

The previous material in this paper has reviewed the international comparisons aspect of the IWA and BENCHLOSS methodology. The unsuitability of using NRW% by volume as a Performance Indicator for international comparisons of operational management of Real Losses is demonstrated in Figure 6, which compares the NRW% and the ILI for the mixed WSAA and International data set. The correlation coefficient is only 0.20. If the comparison is limited to WSAA data, the correlation coefficient increases, but only to 0.69.

The range of Densities of Connections (20 to 69) in Table 1, for the 10 WSAA members, is such that the “best practice” basic traditional PI for Operational management of Real Losses will be “litres/service connection/day”. Dividing by pressure, to obtain “litres/service connection/day/metre of pressure” makes allowance for the 2 to 1 range of average pressures, related substantially to different topography. However, because the ILI takes account of pressure and actual density of connections, it will be the best PI for National Comparisons in Australia, given the wider range of conditions experienced throughout the country (when non-WSAA members and smaller systems are included).

The improvement in perception of performance in managing Real Losses can best be seen by close examination of Table 1, looking at how the relative rank order of the Utilities changes as one moves from:
NRW% by volume (8th column), to
litres/service connection/day (5th column) to
litres/service connection/day/metre of pressure (6th column) to
Infrastructure Leakage Index (7th column).

The ILI can also be used for “within-utility” comparisons of operational management performance for Real Losses in discrete sectors of the whole system, with lower limits of 5000 service connections, and/or 25 metres pressure, and these lower limits would apply to individual small stand-alone systems operated by municipalities. The ILI approach has not been extensively tested yet on systems with less than 20 connections/km of mains, as few such systems exist.

The IWA methodology and Performance Indicators, using the Benchloss customised software approach, has now been adopted and promoted in South Africa by Water Research Commission (Office of Water Services, 2001), in Australia by Water Services Association of Australia, and in New Zealand by New Zealand Water and Wastes Association (10). The Leak Detection and Water Accountability Committee of the American Water Works Association has also recently resolved to promote the methodology in North America (11). Many other utilities and consultants are using it, for example in Brazil, Malta, Malaysia. Some recent software applications (e.g. 10) allow 95% confidence limits to be entered as %s for all data, so that 95% confidence limits are automatically calculated for all components of Non-Revenue Water, and for all Performance Indicators.

Conclusions

- Following a Workshop in February 2000, WSAA commissioned a customised version of the BENCHLOSS software and User Manual, to allow water utilities to use the IWA methodology and undertake the task easily and in a consistent standardised manner.
- Ten members of WSAA provided data for the initial review of the application of the methodology described in this paper.
- Comparison of the WSAA members’ performance with the International data set shows that:
  - NRW% by volume isn’t a reliable Performance Indicator for operational management of Real Losses.
  - Using the Infrastructure Leakage Index as the most comprehensive PI, several of the WSAA members’ performance are in the top rank internationally; others are in the middle range.
- Comparison of the WSAA members’ data with each other shows that the use of the Infrastructure Leakage Index improves the basic performance comparison in litres/service connection/day, given the range of density of connections and operating pressures.
• The BENCHLOSS software facilitates and encourages a more detailed evaluation of components of the Water Balance.
• WSAA will continue to promote the methodology as “best practice” in Australia, with the active support of organisations in Queensland with interest in demand management.

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References