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1 Introduction

Using Microbial Health Based Targets to assess public health risks associated with drinking water supplies is an emerging practice. The objective of this approach is to ensure that the burden of disease caused by waterborne pathogens is no more than one µDALY. Within the drinking water context, this equates to less than two cases of giardia infection for a population of one million people.

The pathogen load presented to treatment plants is estimated through a source water assessment. The pathogen load defines the minimum LRV required to meet the 1 µDALY target. The HBT Manual also defines a suite of decision rules to estimate the LRV credit for various types of pathogen barriers. These rules are based on operational parameters, such as filtered water turbidity or disinfection contact time. Basic principle is that the LRV credit has to be higher than the minimum LRV required to achieve the 1µDALy limit. The LRV shortfall is defined by the difference between the minimum required level and the estimated actual LRV. The LRV shortfall is an indicator of the possible burden of disease in a community and is used as a performance indicator.

Coliban Water has developed software to implement the decision rules in the HBT Manual. The following four sections describe how the software estimates the LRV, based on the HBT Manual. Section six describes how the software converts SCADA data used to undertake the analysis. The latter sections of this manual describes software design, installation and maintenance.
2 Health Based Targets Reporting

This manual describes software developed to assist with the reporting of the performance of drinking water treatment systems in accordance with the HBT Manual. Reporting is backward looking, based on monthly performance data. Health-Based Targets reporting is not a replacement for appropriate operational monitoring.

The software can be used to assist with the governance of water quality management through monthly reports to management and board. The software can also be used to justify changes to barrier configuration and capital investment proposals. The software can also be configured to undertake scenario analysis based on real or simulated data.

The Health Based Targets reporting software consists of four modules:

1. Information is extracted from SCADA Historian and transformed to create Virtual Tags to allow for the analysis to occur (section 6).
2. The configuration of each treatment system (processes and source water categories) is entered through an input screen (section 3).
3. The Water System Configuration and Virtual Tags are combined to undertake the Water Treatment Assessment and estimate LRV credits, in accordance with the HBT Manual (section 4).
4. Results are reported at three levels: service region, water supply system and individual barrier (section 5).

The overall process is illustrated in Figure 2. The blue sections are described in this manual. The Source Water Assessment process is described in the HBT Manual.

Source water assessments are undertaken in accordance with section 3 of the HBT Manual. The HBT Monitoring system is based on Tier 1 source water assessments.

The water system configuration consists of a description of all water treatment plants, the source water category and the types of pathogen barriers used in each plant.

Data is extracted from SCADA Historian on a daily basis and converted to Virtual Tags. These are equally-spaced time series that combine information from
various SCADA tags into one single tag. At the end of each calendar month, LRV credits are estimated following the decision rules from the HBT Manual.

The HBT reporting module presents a three level report of the data and the HBT assessment results: at the regional, system and barrier scale.

General users will only use the HBT reports. Only approved users can access the water system configuration files. The system is not developed for general use and requires IT expertise to maintain beyond what is available in the configuration screens.
3 Water System Configuration

Configuration of the system is undertaken using an MS Access front-end to the database. The configuration file contains the list of treatment sites, the barriers used at each treatment site and the relevant Virtual Tags required for analysis (Figure 3).

Please note that the system configuration control screen does not contain any validation rules. Entering wrong data will result in the software not being able to calculate Log Reduction Values.

3.1 Water Treatment Sites

The software is able to assess the performance of all water treatment sites within a service region. The water system configuration screen connects to a database that contains the water system configuration (refer to Section 7.2 for technical details).

The asset number for each location is identified to connect the system to Coliban Water’s Asset Management Information System. Spatial information is used for regional level reporting of monthly results.

Figure 3: Water Treatment Plant configuration screen.

3.2 Source Water Category

The source water category (category 1–4) is determined for each water treatment site in accordance with the HBT Manual (Tier 1 assessment). These categories are used to determine the recommended minimum pathogen reduction requirements as listed in Table 3 in the HBT Manual.

The software is not able to accommodate minimum Log Reduction Values derived through a Tier 2 Quantitative Microbial Risk Assessment (QMRA). For systems where a QMRA has been undertaken the relevant control table in the database needs to be amended (see section 8.2.3).
Source water categories can periodically change and the software records the period during which a system is assigned to a particular source category. The end date of 31 December 2099 is used to indicate the current situation. The user needs to ensure that time periods for the same system do not overlap.

The comment field is used to refer to the relevant Source Water Category Assessment (file number, issue number etc.).

The example in Figure 3 shows that Bridgewater was originally assessed as a category 3 catchment, but was downgraded to a category 4 on 15 August 2015 due to new data.

### Table 1: Recommended minimum pathogen Log Reduction Values

<table>
<thead>
<tr>
<th>Source Water Category</th>
<th>Minimum pathogen log reduction required</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bacteria</td>
</tr>
<tr>
<td>1</td>
<td>4.0</td>
</tr>
<tr>
<td>2</td>
<td>5.0</td>
</tr>
<tr>
<td>3</td>
<td>5.0</td>
</tr>
<tr>
<td>4</td>
<td>6.0</td>
</tr>
</tbody>
</table>

### 3.3 Process Configuration

Each water treatment site contains at least two barriers. The HBT manual defines eleven types of barriers across filtration and disinfection.

- **Filtration**
  - Coagulation, Flocculation & Dissolved Air Flotation (CFDAF)
  - Coagulation, Flocculation & Sedimentation (CFS)
  - Direct filtration (DF)
  - Conventional Treatment (COT)
  - Second Stage Filtration (SSF)
  - Micro-Filtration (MF)
  - Ultra-Filtration (UF)

- **Disinfection**
  - Chlorination (CH)
  - Chloramination (CHM)
  - Ultraviolet Disinfection (UV)
  - Ozone (OZ)

The relevant treatment train can be assigned to each site. Each pathogen barrier is assigned a time period, allowing for changes to the treatment process to be accounted for, as shown in the example below.
The example control screen shows that this treatment plant currently uses two streams of Conventional Treatment (COT). Chloramination (CHM) was used for primary disinfection until 14 August 2014, after which this system started Chlorination (CH). The Virtual Tags used to assess chlorination and chloramination are the same because of the decision rules for each are mathematically equivalent.

For situations where a treatment process changes in the middle of a calendar month, the assessment is undertaken with the process type that was active at the end of that month. In the example above, the report for August 2014 will use Chlorination as the relevant disinfection process.

3.3.1 Virtual Tag Assignment

Each barrier needs to be linked to the relevant tag(s) in the Virtual Tag table (Refer to page 18). The tag number is entered into the column related to the relevant process. If the required data is not available for the decision rule, the LRV credits are set at zero.

Each process requires certain types of information to be provided for the decision rules to be assessed. For example, the chlorination (CH) decision rule requires information about turbidity (NTU1), Contact Time (C.t), pH and temperature (temp), as indicated in Table 2.

The abbreviations on the horizontal lines are the variables that each process requires to assess the Log Reduction Value. The abbreviations on the vertical line represent the process types, described above.

Any wrong assignments, e.g. adding an NTU field number for a chlorination process, will be ignored. Where a required Virtual Tag is missing, the assessment will not be undertaken or will produce invalid results.

<table>
<thead>
<tr>
<th>Process</th>
<th>NTU1</th>
<th>NTU2</th>
<th>NTU3</th>
<th>MIT</th>
<th>C.t</th>
<th>pH</th>
<th>temp</th>
<th>UV</th>
<th>UVT</th>
<th>UVT%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFDAF</td>
<td>Y</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFS</td>
<td>Y</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DF</td>
<td>Y</td>
<td>O2</td>
<td>O</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COT</td>
<td>Y</td>
<td>O3</td>
<td>O</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSF</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MF</td>
<td>Y</td>
<td></td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UF</td>
<td>Y</td>
<td></td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH</td>
<td>Y</td>
<td></td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHM</td>
<td>Y</td>
<td></td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UV</td>
<td>Y</td>
<td></td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OZ</td>
<td>Y</td>
<td></td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Y – Required value. O – Optional value.

Variables:

- NTU1, NTU2 and NTU3: Filter water turbidity (NTU)
- MIT: Membrane Integrity Test (fail/pass)
- C.t: Contact time (mg/L.min)
- temp: Water temperature (°C)
- UV: UV dose (mJ/cm²)

\(^{2}\) The NTU2 and NTU3 tags are used in situations where treatment is a combined DF and CFDAF. Adding NTU2 and NTU3 is only required when a combined process is used.

\(^{3}\) The NTU2 and NTU3 tags are used in situations where treatment is a combined COT and CFDAF. Adding NTU2 and NTU3 is only required when a combined process is used.
- UVT: UV transmittance (%)
- UVT%: manufacturer specified percentage
4 Water Treatment Assessment

The HBT performance reporting system estimates LRV credits on the first day of each calendar month for the period of the whole of the previous calendar month, using the relevant system configuration and Virtual Tags.

4.1 Log Reduction Value Credits

Each of Coliban Water’s water treatment plants consists of two or more pathogen barriers (or treatment processes). The HBT Manual identifies eleven process types. For each of these processes the HBT Manual provides one or more decision rules to estimate the LRV credits.

For example, if the 95th percentile of filtered water turbidity of a conventional treatment process is less than 0.15 NTU and no spikes over 0.30 NTU for more than 15 minutes have been detected, then that process is considered to have the following LRV credits: Protozoa: 4.0, Bacteria: 2.0, Viruses: 2.0. Each of these decision rules is based on one calendar months’ worth of data (Table 7 of the HBT manual).

The HBT Manual does not always provide clarity on the computational definition of these decision rules. Where the used decision deviates from the HBT Manual clarification is provided in the footnotes below.

Performance levels for pathogen barriers have been indicated by a level: A, B, C or D, which corresponds with Log Reduction Values specified in the HBT Manual.

4.1.1 Reporting Period

The HBT Manual mentions a time period of “one month” for the filtration decision rules. No time period is specified for the disinfection decision rules. The software uses one calendar months’ worth of data to undertake the assessments and assessments are undertaken and reported at the first of each month. From a scientific perspective, this interpretation introduces issues with unequal periods of analysis. This method has been chosen to align with governance reporting.

Alternatively, the software can be configured to analyse over 28 day periods (13 month year) or undertake a daily assessment of barrier performance, using a 28 or 30 day rolling time window. This latter change requires enhancements to the code.

4.1.2 Coagulation, Flocculation & DAF/Sedimentation

The HBT Manual identifies two types of coagulation processes: Coagulation, Flocculation & DAF (CFDAF) and Coagulation, Flocculation & Sedimentation (CFS), which are assessed using the same decision rule. The decision rule for these processes comprises of two parts:

- For all turbidity measurements over one calendar month:
  - a. Under-float or settled water turbidity < 2 NTU for 95% of calendar month, OR
  - b. Average under-float or settled water turbidity is 70% of average raw water turbidity.\(^4\)

---
\(^4\) The manual refers to the second rule as an “alternative target”, which is interpreted here as a secondary condition when the first criterion is not met, using a non-exclusive OR logic.
The coagulation decision rule uses the tags listed in the NTU1 (Under-float or settled water) and NTU2 (settled water) Virtual Tags.

When these conditions are met the following LRV credits can be applied to the process:

<table>
<thead>
<tr>
<th>Process</th>
<th>Performance Level</th>
<th>Bacteria</th>
<th>Viruses</th>
<th>Cryptosporidium</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFDAF</td>
<td>A</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>CFS</td>
<td>A</td>
<td>1.0</td>
<td>1.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>

The performance level is a variable that is used in the software to denote the level of performance, which links to a level of Log Reduction value. An A represents the highest possible level of performance, B a lower level and so on. The number of levels depends on the decision rules defined in Tables 7a and 8 in the HBT Manual. The letter “X” denotes treatment rains that did not comply with any of the decision rules.

### 4.1.3 Filtration

The HBT Manual identifies three types of filtration that use the same decision rule:

- Direct filtration (DF)
- Conventional treatment (COT)
- Second stage filtration (SSF)

The decision rule for these processes consists of two parts:

a. The 95th percentile of individual filter turbidity (NTU1) ≤ x NTU, AND
b. No spikes ≥ y NTU for longer than 15 minutes.

This is based on individual filter turbidity. Each of the streams provided in the configuration screen is assessed and the worst performing stream is used to report the attained Log Reduction Values.

The decision rule for combined filtrate turbidity has not been implemented.

<table>
<thead>
<tr>
<th>Process</th>
<th>Performance Level</th>
<th>x</th>
<th>y</th>
<th>Bacteria</th>
<th>Viruses</th>
<th>Cryptosporidium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct filtration</td>
<td>C</td>
<td>0.30</td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.20</td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>0.15</td>
<td>0.3</td>
<td>1.0</td>
<td>1.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Conventional Treatment</td>
<td>C</td>
<td>0.30</td>
<td>0.5</td>
<td>2.0</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.20</td>
<td>0.5</td>
<td>2.0</td>
<td>2.0</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>0.15</td>
<td>0.3</td>
<td>2.0</td>
<td>2.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Second Stage Filtration</td>
<td>A</td>
<td>0.15</td>
<td>0.3</td>
<td>1.0</td>
<td>1.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>

The filtration decision rule uses the Virtual Tag listed in the NTU1 field. This tag is combined with filter flow and the decision rule only uses turbidity measurements for when the filter was operational.

---

5 Extract from Table 7 of the HBT Manual.  
6 Extract from Table 7 of the HBT Manual.
If the filtration barrier contains more than one stream (filtration cells), then the LRV credit is estimated for all streams and the worst performing stream is used in reporting.

In cases where separate turbidity measurement for each stream is unavailable, the manual provides an alternative rule using the combined filter turbidity. This decision rule has not been implemented in the HBT reporting system.

4.1.3.1 Combined Conventional Treatment with CFDAF (COTD)

For systems that include both Coagulation, Flocculation & DAF/Sedimentation and Conventional Treatment a separate logic is followed.

The system assesses the conventional treatment barrier in accordance with the above described decision rules.

If conventional treatment does not provide LRV credits, then the second and third NTU Virtual Tag (NTU1 and NTU2) are used to assess the system in accordance with the decision rules for Coagulation, Flocculation & Dissolved Air Floatation (Section 4.1.2). If the second and third NTU tag are not in use, this rule will be ignored.

Table 5: Log Reduction Values for combined Conventional Treatment with CFDAF.⁷

<table>
<thead>
<tr>
<th>Process</th>
<th>Performance Level</th>
<th>x</th>
<th>y</th>
<th>Bacteria</th>
<th>Viruses</th>
<th>Crypto^</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Treatment with CFDAF</td>
<td>A</td>
<td>0.30</td>
<td>0.5</td>
<td>2.0</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.20</td>
<td>0.5</td>
<td>2.0</td>
<td>2.0</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>0.15</td>
<td>0.3</td>
<td>2.0</td>
<td>2.0</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td></td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

^ Cryptosporidium

4.1.4 Micro- and Ultra Filtration

The decision rule for these two processes is the same as the decision rule that applies to filtration (Section 4.1.3).

Additionally, the barrier also has to pass a Membrane Integrity Testing (MIT), as specified by the manufacturer, for the whole of the month.⁸

This decision rule uses the NTU1 and MIT Virtual tags and assigns the following LRV credits:

Table 6: Log Reduction Values for MF and UF.⁹

<table>
<thead>
<tr>
<th>Process</th>
<th>Level</th>
<th>x</th>
<th>y</th>
<th>Bacteria</th>
<th>Viruses</th>
<th>Crypto^</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microfiltration</td>
<td>A</td>
<td>0.10</td>
<td>0.15</td>
<td>3.0</td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Ultrafiltration</td>
<td>A</td>
<td>0.10</td>
<td>0.15</td>
<td>3.0</td>
<td>2.5</td>
<td>3.0</td>
</tr>
</tbody>
</table>

^ Cryptosporidium

4.1.5 Chlorination

The LRV credit decision rule for chlorination is based on the contact time (C.t) value. Contact time is a derived Virtual Tag, calculated using tank level, chlorine residual and flow rate. Refer to section 6.1.4 for an example.

---

⁷ Extract from Table 7 of the HBT Manual.
⁸ The HBT Manual does not specify a logic operator. It has been assumed that both the filtration decision rule AND the membrane integrity test (MIT) have to pass in order to claim the log credit.
⁹ Extract from Table 8 of the HBT Manual.
The HBT Manual does not specify a time period for the disinfection rules. To match the reporting period of the disinfection decision rules with filtration rules a period of one calendar month has been used.

To allow for anomalies in the data, the minimum values have been replaced by using the 1st percentile, and for maximum values the 99th percentile is used, making the decision rules:

- 1st percentile \( C_t > 15 \text{ mg/L.min}^{10} \) AND
- 99th percentile of pH < 8.5, AND
- 99th percentile of feed water turbidity < 1.0 NTU\(^{11}\)

The minimum \( C_t \) value (x) for the month is derived from Table D4 in the HBT Manual, based on the minimum temperature over the month. The LRV for Cryptosporidium is set at zero for all performance levels.

### Table 7: Minimum \( C_t \) values for chlorination,\(^{12}\)

<table>
<thead>
<tr>
<th>Process</th>
<th>Level</th>
<th>( x )</th>
<th>( y )</th>
<th>Bacteria</th>
<th>Viruses</th>
<th>Crypto^|</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorination</td>
<td>A</td>
<td>0.10</td>
<td>0.15</td>
<td>4.0</td>
<td>4.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

#### 4.1.6 Chloramination

The Chloramination decision rule is defined as:

- 1st percentile \( C_t > x \text{ mg/L.min} \) AND
- 1st percentile pH > 6 AND
- 99th percentile pH < 9

The minimum \( C_t \) value (x) for the month is derived from Table D4 in the HBT Manual (reproduced below), based on the minimum temperature (1st percentile) over the month. The LRV for Cryptosporidium is set at zero for all performance levels.

### Table 8: Minimum \( C_t \) values for chloramination,\(^{13}\)

<table>
<thead>
<tr>
<th>Log Inactivation (bacteria and virus)</th>
<th>Performance Level</th>
<th>( C_t ) values (mg/L.min) at water temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>( \leq 1 )</td>
</tr>
<tr>
<td>2</td>
<td>C</td>
<td>1243</td>
</tr>
<tr>
<td>3</td>
<td>B</td>
<td>2063</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>2883</td>
</tr>
</tbody>
</table>

#### 4.1.7 UV Disinfection

The decision rule for UV disinfection is:

- 1st percentile UV dose > x \text{ mJ/cm}^2 \) AND
- 99th percentile Feed water turbidity < 1.0 NTU AND
- 1st percentile UVT% > manufacturer’s specification

The LRV are determined using data over one calendar month, using Table 8 of the HBT Manual, reproduced below:

---

\(^{10}\) Table 8 specifies minimum and maximum values. To allow for short spikes, the 1st percentile has been used for minimum values and the 99th percentile for maximum values.

\(^{11}\) The manual does not allow for aberrant variability (short spikes). This methodology uses the average pH and the 95th percentile NTU over the calendar month.

\(^{12}\) Extract from Table 7 of the HBT Manual.

\(^{13}\) Extract from Table D4 of the HBT Manual.
Table 9: Log Reduction Values for UV disinfection.\textsuperscript{14}

| Level | \(x\) | Bacteria | Viruses | Crypto\textsuperscript{^}\n|-------|------|---------|---------|---------|
| C     | 40   | 4.0     | 0.5     | 4.0     |
| B     | 60   | 4.0     | 1.0     | 4.0     |
| A     | 190  | 4.0     | 4.0     | 4.0     |

\textsuperscript{^} Cryptosporidium

4.1.8 Ozonation

The decision rule for Ozonation is:

- 1\textsuperscript{st} percentile of Contact Time \(C.t > x\) mg/L.min, AND
- 99\textsuperscript{th} percentile pH < 8, AND
- Turbidity < 1 NTU, AND
- Water temperature = 5 °C

The LRV are determined using data over one calendar month, using Table D4 of the HBT Manual. The LRV for Cryptosporidium is set at zero for all performance levels.

Table 10: Minimum \(C.t\) values for Ozonation.\textsuperscript{15}

<table>
<thead>
<tr>
<th>Log Inactivation (bacteria and virus)</th>
<th>Performance Level</th>
<th>C.(t) values (mg/L.min) at water temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(\leq 1)</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>0.9</td>
</tr>
<tr>
<td>4</td>
<td>B</td>
<td>1.8</td>
</tr>
</tbody>
</table>

4.2 Minimum Required Log Reduction Values

The minimum required Log Reduction Values are derived from the source water category assigned to the water system and the recommended minimum values listed in Table 3 of the HBT Manual.

The source category valid at the end date of the estimation window will be used for the assessment. For example, if a site changes site category on the 13\textsuperscript{th} day of a given month and the LRV credits are estimated at the 30\textsuperscript{th} day of that month, then the category that WAS valid on the 30\textsuperscript{th} day will be used to estimate the LRV shortfall.

The minimum Log Reduction Values per source water category are stored within the system and can only be changed by administrator-level access.

4.3 Results

The system applies the decision rules to the Virtual Tag information and stores the results, as shown in the example below.

<table>
<thead>
<tr>
<th>Site</th>
<th>Process</th>
<th>From</th>
<th>To</th>
<th>Protozoa LRV</th>
<th>Bacteria LRV</th>
<th>Viruses LRV</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBR-TP01</td>
<td>CHM</td>
<td>01/03/2014</td>
<td>31/03/2014</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>WBR-TP01</td>
<td>CoT</td>
<td>01/03/2014</td>
<td>31/03/2014</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>WBR-TP01</td>
<td>CHM</td>
<td>01/04/2014</td>
<td>30/04/2014</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>WBR-TP01</td>
<td>CoT</td>
<td>01/04/2014</td>
<td>30/04/2014</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

\textsuperscript{14} Extract from Table 8 of the HBT Manual.

\textsuperscript{15} Extract from Table D4 of the HBT Manual.
This table shows the achieved LRV for two months of the Bridgewater (WBR-TP01) water treatment plant for each of the available processes. The performance of a water treatment plant over a reporting period is defined as the sum of all Log Reduction Values. In the above example, the performance at the Bridgewater water treatment plant in March 2014 was: LRV of 3, 4 and 4 for protozoa, bacteria and viruses, respectively. Refer to section 5 for a detailed overview of reporting.

4.4 Scenario Analysis

The Virtual Tag approach also allows for the development of scenarios by using simulated data stored in dummy tags. For example, a virtual UV disinfection system can be added to a treatment plant by duplicating the existing plant and making the required changes in the control screen.

Simulated data can be added using a Dummy Tag (section 6.1.1). The system will then estimate LRV using existing data and adds the UV system based on the simulated data.
5 Reporting

Reporting of the HBT assessments occurs on three levels. One report provides a service region overview of Log Reduction Value shortfalls. The second level report provides an overview of the performance of a particular water treatment site and the third level shows the virtual tag results.

The release number of the manual is shown on all reports to clarify which methodology the results are based on.

5.1 Service Region

The monthly service region report is based on the LRV shortfall for each water treatment site for each pathogen group. Performance is reported using a ‘cheesecake diagram’. This type of visualisation is similar to a pie chart, but information is visualised through the colour of the slice, rather than its size. This allows for the communication of all three levels of performance for each location to be displayed spatially.

![Cheesecake diagram example](image)

Figure 5: Service region monthly report (example only).

The shortfall is defined as the difference between the achieved LRV and the required LRV, for each of the three pathogen groups. A negative shortfall indicates that excess treatment has been applied. The shortfall is communicated using indicators to assign a level of risk to the system (Table 11).

---

16 The HBT Manual (figure 3) uses negative numbers to denote shortfall. This leads to confusing language as a shortfall of -4 is worse than a shortfall of -3, but is numerically smaller. The approach in this reporting system has been reversed, the higher the shortfall, the worse the situation.
Credit implies that the treatment plant removes more pathogens than is strictly required. Safe implies that the plants operates at an estimated one µDALY. Medium and High Risk imply that treatment plant optimisation is required.

Clicking on any of the water systems provides detail on the specific water supply system.

### 5.2 Water Supply System

This water supply system report provides three stacked bar charts, showing the estimated LRV for each pathogen type and each pathogen barrier over the period of the past twelve months. The shaded stacked bar on the right hand of the diagram shows the theoretically achievable performance for that system.

![Water supply system report](image)

**Figure 6: Water supply system report.**

### 5.3 Virtual Tag Data

Clicking on any of the bars in the water supply system report provides further detailed information on the selected pathogen barrier over that month. The first report provides an overview of daily maximum, mean and minimum values for the parameter relevant to the bar (Figure 7). Clicking within this report provides the raw data for the date clicked at (Figure 8).
Figure 7: Virtual Tag overview (daily statistics).

Figure 8: Virtual tag overview (raw data).
6 Virtual Tags

The data stored in SCADA Historian is not suitable for post-hoc analysis without transformation. Firstly, the data in Historian is stored as an irregular time series (dead-banding), which complicates advanced analytics. Secondly the relationship between individual SCADA tags is not recorded, for example, filtered water turbidity is recorded regardless of whether the filter was running or not. The Virtual Tag approach has been implemented to alleviate these problems.

6.1 Definitions

Virtual Tags are derived from SCADA tags stored in Historian. The Virtual Tag table contains three types: dummy tags, source tags and derived tags. Each Virtual Tag is identified using a unique number that consists of a leading identifier and an identification number. The leading number indicates the Virtual tag type (7, 8 or 9) and the trailing number set relates to the SCADA tag ID from which the Virtual Tag was derived, e.g. 90043216 is the derived tag based on SCADA tag 43216.

6.1.1 Dummy Tag (prefix 7)

A dummy tag is a virtual tag for which no measured value exists in SCADA Historian or other data source, for example water temperature. Dummy tags are set to a default value to allow for assessment to occur. The Virtual Tag number for dummy tags starts with a 7.

Dummy tags need to be avoided where possible and hardware should be installed or configured to allow for physical measurement.

6.1.2 Source Tag (prefix 8)

A Source Tag consists of a regular time series obtained from the SCADA Historian. Source Tags have a direct relationship with SCADA tags. There are two types of source tags:

- Measurements: Numerical assessment of the state of the system (e.g. turbidity, flow, tank level)
- Observations: Status of a system (e.g. valve position, alarms)

Due to the dead-banding of SCADA Historian, not all instrument measurements are stored. The irregular time series presented by SCADA Historian are converted to a regular time series with an interval of one minute.

The Virtual Tag process stores the measures values available in Historian (rounded to the nearest minute). Values between measured points are derived using nearest-neighbour interpolation. To be able to distinguish between measured and interpolated values, measured values are marked as “actual” (Figure 9).

The reliability of actual values depends on the accuracy and calibration status of the instrument (e.g. ± 2%). The reliability of interpolated values depends on the instrument accuracy, plus the dead-band setting (e.g. ± 2% ± 5% = ± 7%).
6.1.3 Derived Tag (prefix 9)

A derived tag is a combination of two or more Virtual Tags. A derived tag is constructed from one or more dummy tags, source tags or other derived tags.

Example of a Derived Tag is tank volume, whereas the Source Tag shows percentage the tank is filled, the Derived Tag provides the volume in kL.

6.1.4 Virtual Tag Example

The following case illustrates the Virtual Tags approach, using the Pyramid Hill water treatment plant.

![Diagram of Pyramid Hill Process Flow Diagram](image)

Figure 10: Extract from Pyramid Hill Process Flow Diagram.

This water treatment plant has two processes: conventional treatment and chlorination. To measure these processes, eight Source Tags are extracted from SCADA Historian.

<table>
<thead>
<tr>
<th>Source Tag</th>
<th>SCADA Tag</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>80002967</td>
<td>Coliban.WPY_CWCRA01_PV</td>
<td>mg/L</td>
<td>Treated Water Free Chlorine</td>
</tr>
<tr>
<td>80002968</td>
<td>Coliban.WPY_CWLTO1_PV</td>
<td>%</td>
<td>TWS Level</td>
</tr>
<tr>
<td>80002969</td>
<td>Coliban.WPY_CWPHA01_PV</td>
<td>pH</td>
<td>Filtered Water pH</td>
</tr>
<tr>
<td>80002973</td>
<td>Coliban.WPY_FNFM01_PV</td>
<td>L/s</td>
<td>Filtered Water Flow</td>
</tr>
<tr>
<td>80002975</td>
<td>Coliban.WPY_FNTM01_PV</td>
<td>NTU</td>
<td>Filtered Water Turbidity 1</td>
</tr>
</tbody>
</table>
These Source tags are transformed to Derived Tags using a series of processes:

- Treated Water Free Chlorine, and pH are cleaned by ignoring all data where the Treated Water Flow is less than 1 L/s.
- Turbidity measurements are cleaned by only using those readings where the Filtered Water Flow is more than 1 L/s.
- The Treated Water Storage (TWS) Level is reported as a percentage and needs to be converted to kilolitres, which is achieved by multiplying the percentage by the total volume (325 kL).
- Contact Time is calculated by combining the Derived Tags for Treated Water Free Chlorine, TWS Volume and Treated Water Flow, multiplied by a baffle factor (0.30).

After this data transformation the following tags can (Table 12) be used for Log Reduction Value assessments. The data shows two streams for Conventional Treatment, using two Derived Tags, and Chlorination, which uses two Derived Tags and one Source Tag.

The remainder of the Source and Derived Tags created during the transformation process are not removed and can be used for other business intelligence projects.

Table 13: Log Reduction Value assessment for Pyramid Hill.

<table>
<thead>
<tr>
<th>Process</th>
<th>Source/ Derived Tag</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>80002975</td>
<td>NTU</td>
<td>Filtered Water Turbidity 1</td>
</tr>
<tr>
<td>Treatment</td>
<td>80002976</td>
<td>NTU</td>
<td>Filtered Water Turbidity 2</td>
</tr>
<tr>
<td>Chlorination</td>
<td>90002967</td>
<td>mg/L.min</td>
<td>Contact Time</td>
</tr>
<tr>
<td></td>
<td>80002977</td>
<td>NTU</td>
<td>Pre TWS Turbidity</td>
</tr>
<tr>
<td></td>
<td>90002969</td>
<td>pH</td>
<td>Filtered Water pH</td>
</tr>
</tbody>
</table>

^ Tags starting with 8 are Source Tags; Tags starting with 9 are Derived Tags

6.2 Virtual Tag Creation

The software starts with creating Source Tags for each of the identified SCADA tags. A series of transformation rules is available to create Dummy Tags and Derived Tags. These rules use any of the existing Virtual Tags as input.

In some instances these rules need to be applied multiple times in order to reach the final result. To calculate Contact Time (C.t), Derived Tags have to be created for tank volume (convert percentages to volumes). This Derived tag is then used to create C.t as a new Derived Tag.

The database can hold two constants for each Virtual Tag. These constants can be, for example, baffle factor, maximum tank volume, minimum flow, and so on. These values can only be changed directly in the database, no front-end screen is yet available to manage these settings.

6.2.1 Create From Constant

This rule creates a dummy Virtual Tag based on a constant value.
This rule is used in instances where no Source Tag is available for a required variable.

6.2.2 Ignore Under Threshold

Only uses values for a given tag where the value of a related tag is below a given value.

This rule is most commonly used to exclude filtered water turbidity values when the flow rate from the filters is less than a certain value. The value is most commonly set as 1 L/s. This ensures that analysed data only relates to times when the filter was active.

6.2.3 Ignore Over Threshold

This rule is the reverse of the Ignore Under Threshold rule. This rule can be used to filter values based on valve status.

6.2.4 Cone and Cylinder Volume

This rule calculates the volume of a tank ($V$) that includes a conical section at the bottom. Where tank level sensor is $h$ and cone height is $h_c$:

$$
V = \begin{cases}
\frac{\pi r^2 h}{3}, & h \leq h_c \\
\frac{\pi r^2 h_c}{3} + \pi r^2 (h - h_c), & h > h_c
\end{cases}
$$

6.2.5 C.t Value

Calculates $C.t$ value based on disinfectant concentration ($C$), tank volume ($V$) and flow ($q$), multiplied by a baffle factor ($f$):

$$
C.t = C \times \frac{1000V}{60q} f
$$

The $C.t$ value is calculated in mg/L.min, over a period of one minute and assumes that the volume is provided in kilolitres and the flow is in litres per second.

6.2.6 Multiply and Divide by Constants

Multiplies the values of a Virtual Tag with one constant and divides it by a second constant.

An example of this type of transformation rule is: multiply tank percentage by maximum volume and divide by 100 to get tank volume.

6.2.7 Pass of Fail: Over Threshold

Assigns a value of 1 or 0 (pass or fail) to the Virtual Tag when another Virtual tag is greater than a given value.

6.2.8 Pass or Fail: Under Threshold

Assigns a value of 1 or 0 (pass or fail) to the Virtual Tag when another Virtual tag is less than a given value.
This rule and the previous one is used to assess status signals provided by membrane filters.

6.2.9 On or Off Within Range

Sets the value of the Derived Tag at 1 (on) when the input is between two values. Sets the value at 0 (off) when this condition is not met.

This can be used to assess the status flag of, for example, a UV system and determine when the system was running.

6.2.10 Sum of Samples

Uses the sum of a range of similar measurement to determine a new value. Used for flow meters to determine total flow.

6.2.11 Weighted Average

Provides a weighted average of two (turbidity) tags, based on two other (flow) tags. This method is used to create a weighted turbidity for a two-cell filter unit based on individual flow rates, to be used to assess the effectiveness of a disinfection downstream process:

\[ NTU = \frac{NTU_1 \times q_1 + NTU_2 \times q_2}{q_1 + q_2} \]

6.2.12 Or

This rule is used to determine equipment status based on the value in two Virtual Tags. The outcome is a 0 or 1. This is used to manage equipment status signals sent by proprietary equipment.
7 Software Implementation and Maintenance

The following sections discuss the design, operation and maintenance of the HBT Reporting software.

At Coliban Water, the software is located on the HydroInformatics server and uses two databases:

- **SCADAData**: Raw data copied from the SCADA server(s).
- **HealthBasedTargets**: Decision rules and results (sections 8.1 and 8.2).
- **VirtualTags**: Contains all Virtual Tags (section 8.3).

7.1 Installation

This software requires SQL Server 2012 or higher. To install the software, undertake the following steps:

1. Create three databases: SCADAData, VirtualTags and HealthBasedTargets
2. Run the following scripts
   a. SCADAData_Setup.sql
   b. VirtualTags_Setup.sql
   c. HealthBasedTargets_Setup.sql
3. Copy and paste data from green tabs in provided spreadsheets into the corresponding control tables in the database.
4. Use the data in the other tabs as a guide to entering your own site specific data into the corresponding tables in the database.
5. Create a new SSIS project and import the SCADA Data Refresh.dtsx package. This package will need to be modified to suit your SCADA system (this may include the database user defined functions used by the queries). This package will need to be repointed to your specific databases.
6. Create a new SSIS project and import the VT Refresh.dtsx package. This package will need to be repointed to your specific databases.
7. Create a new SSRS project and import the two RDL files:
   a. HBT_overview.rdl
   b. HBT_system.rdl
   c. These reports will need to be repointed to your specific databases and modified to suit your region

7.2 Configuration Module

The configuration screen consist of an MS Access front-end to the HBT database (refer to section 3).

7.3 Virtual Tag Module

The Virtual Tags model relies on a connection with the relevant SCADA systems and uses its own sampling function to derive equally space time series from the raw data.

---

17 Any database names or field names are indicated in Monospace font.
If any changes are made to the configuration of SCADA, especially renaming or changes to tag ID numbers, then changes also have to be made to the Virtual Tag module in order for the LRV estimation to remain functional.

The basic running order is:

1. Obtain required Source Tags from the SCADA server
2. Create Dummy Tags
3. Create Derived Tags by looping through the creation rules (Section 8.3.6).

### 7.4 LRV Estimation Module

The module contains six functions to estimate LRV values, as described in section 4.1. Some functions cover more than one process type to increase computational efficiency:

#### 7.4.1 Coagulation, Flocculation and Dissolved Air Floatation or Sedimentation (CFDAF_CFS)

This function estimates the LRV for the Coagulation, Flocculation and Dissolved Air Floatation and Coagulation, Flocculation and Sedimentation processes.

#### 7.4.2 Contact Time (Ctime)

This function estimates the LRV by using contact time tags, used for chlorination, chloramination and ozone dosing.

#### 7.4.3 Media Filtration (CoT_DF)

This function estimates the LRV for conventional treatment and direct filtration.

#### 7.4.4 Membrane Filtration (MF_UF)

This function estimates the LRV for micro filtration and ultra filtration.

#### 7.4.5 Second Stage Filtration (SSF)

This function estimates the LRV for second stage filtration.

#### 7.4.6 UV Disinfection (UV)

This function is specific to the Ultraviolet Disinfection process.

#### 7.4.7 New Functions

The system can be expanded with new functions to account for different types of processes.
8 Table Structure

8.1 Water System Configuration

The water system configuration tables are accessible through the MS Access front-end. This form uses access three tables, described below.

8.1.1 Water Treatment Sites

The site configurations are stored in the HBT_Sites table. This table contains the following fields:

- SiteCode: Asset identifier, e.g. WLA-TP01
- SiteType: “Water Treatment Plant” or “Recycled Water factory”
- SiteLocation: Description of location, e.g. Laanecoorie
- LatWGS84: Latitude
- LonWGS84: Longitude

Latitude and longitude are used for reporting performance across the service region (Figure 5). These are in principle spatially accurate, but can be modified to prevent overplotting for systems in proximity of each other.

8.1.2 Source Water category

The source water category for each site is stored in the HBT_Site_Category table, which contains the following fields:

- SiteCode: Asset identifier, e.g. WLA-TP01. This field allows the system to be related to the Asset management Information System.
- DateFrom: Starting date of categorisation
- DateTo: End date of categorisation (use 31/12/2099 for current processes)
- Category: Source Water category [1–4]
- Comment: Reference to source water assessment.

8.1.3 Process Configuration

The configuration of processes is described in the HBT_Site_Process table, which contains the following fields:

- SiteCode: Asset identifier, e.g. WLA-TP01
- ProcessCode: Type of barrier
- ProcessStream: Stream number within the process
- DateFrom: Starting date the process was commissioned
- DateTo: Date the process was decommissioned (use 31/12/2099 for current processes)
- Include: Yes or No.
- NTU_VT: Turbidity virtual tag number (NTU1)
- NTU2_VT: Turbidity virtual tag number (NTU2)
- NTU3_VT: Turbidity virtual tag number (NTU3)
- MIT_VT: Membrane integrity test virtual tag number (MIT)
- CT_VT: Contact Time virtual tag number (CT)
- pH_VT: pH virtual tag number (pH)
- Temp_VT: Temperature virtual tag number (temp)
- UV_VT: UV dose virtual tag number (UV)
- UVT_VT: UVT virtual tag number (UVT)
- UVT_Perc: UVT virtual tag to describe manufacturer’s specification

All fields ending in “VT” relate to the relevant Virtual Tag numbers.

### 8.2 Water Treatment Assessment

The table structure for water treatment assessment determines how the calculations are conducted. These tables are not accessible through the front-end.

#### 8.2.1 Barrier type configuration

This table provides a list of the decision rules that apply to each of the process types and the Virtual Tag required to run the decision rule.

The configuration is date driven and allows for changes to decision rules over time. The HBT_Process table contains the following fields:

- ProcessCode: Abbreviated process type (see Table 2 on page 7)
- DateFrom: Date process was applicable from
- DateTo: End date of the process.
- ProcessName: Human readable name
- HBT_Function: Name of the stored function (refer to section 7.4)
- NTU_VT: Filtered water turbidity (Y/N)
- NTU2_VT: Raw water turbidity virtual tag (Y/N)
- MIT_VT: membrane integrity test virtual tag (Y/N)
- CT_VT: Contact Time (Ct) virtual tag (Y/N)
- PH_VT: pH virtual tag (Y/N)
- TEMP: Temperature virtual tag (Y/N)
- UV: UV dose virtual tag (Y/N)
- UVT: UVT virtual tag (Y/N)
- UVT_Perc: UVT percentage (Y/N)

#### 8.2.2 Log reduction Values

The Log reduction values for each process result level, as specified in tables 7 and 8 of the HBT manual, are stored in the HBT_LogReductionValues table, which contains the following fields:

- ProcessCode: Abbreviated process type (see Table 2 on page 7)
- Result: Process result code, level A–D or X for a fail.
- Protozoa_LRV: LRV credit for protozoa
- Bacteria_LRV: LRV credit for bacteria
- Virus_LRV: LRV credit for virus
- DisplayCode: Reported process name.

#### 8.2.3 Minimum Required Log Reduction Values

The minimum Log reduction Values stated in Table 3 of the HBT Manual are stored in the HBT_Category table, which contains the following fields:
- Category: catchment category
- Protozoa_LRV_req: Minimum required LRV for protozoa
- Bacteria_LRV_req: Minimum required LRV for bacteria
- Virus_LRV_req: Minimum required LRV for virus

This table can be amended to include the results of a Quantitative Microbial Risk Assessment.

### 8.2.4 Contact Time values for inactivation

The HBT_CtValues table defines the log inactivation based on contact time for disinfection processes and water temperature, as displayed in table D4 of the HBT manual. The following fields are used:

- **ProcessCode**: Abbreviated process type (see Table 2 on page 7)
- **Temperature**: Water temperature in °C
- **ContactTime**: Contact time in mg/L.min.
- **Result**: A, B, or C for processes with multiple decision rules.

This table replicates table D4 in the HBT Manual.

### 8.2.5 Results

The results of the assessment are stored in the HBT_ProcessStreamResults. This table contains the achieved process level (A–D, or “X”) and calculated values relevant to the process. The following fields are used:

- **SiteCode**: Asset identifier, e.g. WLA-TP01
- **DateFrom**: Start date of assessment window
- **DateTo**: End date of assessment window
- **ProcessCode**: Abbreviated process type (see Table 2 on page 7)
- **ProcessStream**: Stream number
- **Result**: achieved process level (A–D, or “X”)
- **NTUPerc95**: 95th percentile for NTU
- **Spikethreshold**: NTU threshold for detected spikes
- **Spikecount**: Number of spikes in reporting period
- **SpikeTailCount**: Number of spikes spanning two reporting periods
- **Av_NTU_In**: Average influent turbidity
- **Av_NTU_Out**: Average filtered water turbidity
- **PercRed**: Percentage of reduction in turbidity
- **CFS_NTU_Perc95**: 95th percentile of turbidity
- **MIT**: Pass or Fail for membrane Integrity Test
- **NTUPerc99**: 99th percentile for turbidity
- **CTPerc01**: 1st percentile contact time
- **pHPer01**: 1st percentile pH
- **pHPerc99**: 99th percentile pH
- **DosePerc01**: 1st percentile dose
- **UVTPerc01**: 1st percentile UVT

### 8.2.6 Analysis Window

The window of analysis is stored in the HBT_Ctrl_Parameters table. The content of the table is updated to provide monthly reporting. The table can also
be used to repeat analysis over a previous period when, for example, decision rules have changed. The table also contains a duration and interval field. These cannot not be changed as the system currently only allows for monthly calculations.

- **StartDate:** Start of analysis window
- **FinishDate:** End of analysis window
- **Duration:** Duration of the reporting period (one)
- **Interval:** Reporting period interval (month)

### 8.2.7 LRV per Process

This view (HBT_Process_LRVs) provides a summary of performance per pathogen barrier (process):

- **SiteCode:** Asset identifier, e.g. WLA-TP01
- **DateFrom:** Start date of assessment window
- **DateTo:** End date of assessment window
- **ProcessCode:** Abbreviated process type (see Table 2 on page 7)
- **Protozoa_LRV:** Achieved LRV for protozoa
- **Bacteria_LRV:** Achieved LRV for bacteria
- **Virus_LRV:** Achieved LRV for virus

### 8.2.8 Shortfalls

This view (HBT_Shortfalls) provides a summary of performance per treatment plant:

- **SiteCode:** Asset identifier, e.g. WLA-TP01
- **DateFrom:** Start date of assessment window
- **DateTo:** End date of assessment window
- **Category:** catchment category
- **Protozoa_LRV_Req:** Required LRV for protozoa
- **Bacteria_LRV_Req:** Required LRV for bacteria
- **Virus_LRV_Req:** Required LRV for virus
- **Protozoa_LRV:** Achieved LRV for protozoa
- **Bacteria_LRV:** Achieved LRV for bacteria
- **Virus_LRV:** Achieved LRV for virus
- **Protozoa_LRV_Shortfall:** LRV shortfall for protozoa
- **Bacteria_LRV_Shortfall:** LRV shortfall for bacteria
- **Virus_LRV_Shortfall:** LRV shortfall for virus

### 8.3 Virtual Tags

#### 8.3.1 Import Parameters

The VT_Ctrl_ImportParameters table defines the interval of the regular time series in minutes. Any changes in this parameter will impact all Virtual Tags. All tags have to be imported using the same time interval.

- **DateFrom:** Starting date
- **DateTo:** End date
- **IntervalMinutes:** Regular time series interval in minutes.
8.3.2 Integers

The VT_Ctrl_Integers table contains integers from 1 to 2000 and is used for calculation purposes.

8.3.3 Virtual Tags

The VT_Ctrl_VirtualTag table defines the relationship between the Virtual Tag ID used in the main table and the tag description:

- VirtualTagID: Virtual tag id
- VirtualTagName: Virtual tag description

8.3.4 Virtual Tag SCADA sources

The VT_Ctrl_VirtualTagSource table lists the SCADA sources of the source Virtual Tags (8-series):

- VirtualTagID: Virtual tag id
- DateTimeFrom: Start of period
- DateTimeTo: End of period
- Source: Digital or numeric samples
- SourceID: SCADA source number
- SourceTagID: Tag SCADA ID number
- SourceTagName: Tag ID SCADA name
- Units: Units of measurement
- Comments: Description

8.3.5 Samples

The virtual SCADA tag table (VT_Temp_RTS_Samples) has the following structure:

- DateTimeFrom: Start of the signal
- DateTimeTo: End of the signal
- VirtualTagID: Tag number
- RawValue: Value of the measurement
- SampleValue: After the calculations
- Unit: Unit of the measurement
- Include: Include this value in calculations?
- Actual: Actual or interpolated?

The start and end date-time indicate the period over which the measurement was valid. Virtual SCADA tags are equally spaced time series. The difference between the end and start data is the sample period, which has been set at 1 minute.

The ‘include’ field provides information about the relevancy of the measurement. This indicator is context dependent and in most cases provide information on the status of the barrier, 1 (running) or 0 (idle).

The Actual status indicates whether the value was copied directly from SCADA Historian or interpolated between actual values. The status can be either 1 or 0.
8.3.6 Virtual Tag Elements

The VT_Ctrl_VirtualTagElements table describes each of the Virtual Tags and defines how they are derived.

- **VirtualTagID**: Virtual Tag number
- **CalculationType**: Type of data transformation
- **CalculationOrder**: Order in which calculations are undertaken
- **Units**: Unit of measurement
- **SampleTagID**: Virtual Tag ID
- **RelatedTag1ID**: Virtual Tag 1
- **RelatedTag2ID**: Virtual Tag 2
- **RelatedTag3ID**: Virtual Tag 3
- **Value1**: Calculation parameter 1
- **Value2**: Calculation parameter 2

The script loops through all entries in this table, following the calculation type order field, until all transformations have been completed. The calculation order is required because some Derived Tags require the input of other Derived Tags.

Section 6.2 provides descriptions and formulas for these rules. This section explains relationships between variables. The following twelve calculation types are available to create Virtual Tags:

- **ConeAndCylinderVolume**: Calculates the volume of a tank with a conical section at the bottom. Radius of the tank is stored in Value1 and the height of the cone in Value2. Tank level is based on SampleTagID.
- **ContactTime**: Calculate C.t value based on dose rate (SampleTagID), tank volume (RelatedTag1ID) and flow (RelatedTag2ID), multiplied by baffle factor (Value1).
- **CreateFromConstant**: Create a dummy Virtual Tag based on a constant (Value1).
- **IgnoreOverThreshold**: Only uses value for SampleTagID where the value of RelatedTag1ID is greater than Value1 or greater than Value2.
- **IgnoreUnderThreshold**: Only uses value for SampleTagID where the value of RelatedTag1ID is less than Value1 or greater than Value2.
- **MultiplyDivideByConstants**: Multiply the values in SampleTagID with Value1 and divide by Value2. Example: multiply tank percentage by maximum volume and divide by 100 to get tank volume.
- **On1Off0WithinRange**: Sets the value of the Derived Tag at 1 (on) when SampleTagID is greater or equal than Value1 and less or equal than Value2. Sets the value at 0 (off) when this condition is not met.
- **OR**: Sets the value of the Derived Tag to 1 (on) when either of the values in SampleTagID or RelatedTag1ID is larger than zero.
- **Pass1Fail0OverThreshold**: Assigns a pass/fail value (0/1) when the SampleTagID is greater than Value1.
- **Pass1Fail0UnderThreshold**: Assigns a pass/fail value (0/1) when the SampleTagID is less than Value1.
- **SumOfSamples**: Adding all listed tags (SampleTagID, RelatedTag1ID and RelatedTag2ID).
- **WeightedAverage**: Creates a weighted average for two parameters, based on the value of two other parameters.
9 Future Development

9.1 Code Sharing
This software is shared with other water utilities as Open Source software under the GNU General Public License v.3. License which gives anyone the freedom to:

- Use the software for any purpose
- Change the software to suit their needs
- Share the software with anyone
- Share the changes they make

The source code is explicitly provided ‘as-is’, the License provides no warranty to anyone using the software and limits the liability of the developer.

The license also requires that any derivatives of the software remain under the same license so that any future improvements can be freely shared.

9.2 Future Improvements

9.2.1 Technical Improvements

- Remove unnecessary Virtual Tags from the tables to clear space. Some Source Tags contain essentially the same information as the Derived Tags.
- Ability to define a time interval per tag. Currently set at one minute for each tag.
- Add location field to VT_Ctrl_VirtualTag to improve how Virtual Tags can be used for other reporting.
- Revise the decision rules for chlorination to include temperature-based values.

9.2.2 Additional Functionality

- Enable user defined source water categories to allow for QMRA input.
- Expand the functionality of the configuration module (Virtual Tag configuration)