Equation Changes in the Water Loss Standard Model (Updated August 17, 2022)

Several model changes have been made in response to helpful feedback.

1. Leaks found per part of the system with intervention

The equation in the previous version of the model for leaks found per part of the system with intervention used the proportion of current unreported leakage to total unreported leakage to determine the number of leaks. The proportion was multiplied by the number of unreported leaks that occurred each year. This method of determining the unreported leaks per part was incorrect and created several unexpected results:

- when all other variables were held constant, a system with a lower baseline real loss had a lower calculated loss rate per leak. The loss rate per leak should not change when a system's baseline real loss changes. The loss rate per leak is lower because the annual unreported leakage (the denominator) is decreasing when the baseline real loss decreases. Because it is the denominator, a smaller annual unreported leakage results in more leaks, not fewer.
- when all other variables were held constant, a system with a lower baseline real loss was calculated to have more leaks, which caused the expected repair costs to increase. This relationship was counter-intuitive. A system with lower real loss should have fewer leaks and lower repair costs.

To address these issues, the equation now uses the average volume per leak and the leakage level to determine how many leaks should be repaired. The average volume per leak is determined by multiplying the volumes of the respective leak types (mains and laterals) by the frequency that they occur, and adding those values together.

The volume of leakage from laterals and mains were calculated by multiplying the respective average flow rates by the average duration of the leaks (half the survey period) and converted to acre-feet.

Previous Equation:

$$\frac{(\mathit{Initial\ Leakage\ Level\ for\ part\ surveyed\ each\ month}\ [acre - feet/year])}{\mathit{Average\ Volume\ per\ Leak}\ \left[\frac{acre - feet/year}{leak}\right]}$$

Final Equation:

$$\left(\frac{(\mathit{Initial\ Leakage\ Level\ for\ part\ surveyed\ each\ month}\ [acre - feet/year])}{\mathit{Average\ Volume\ per\ Leak}\ \left[\frac{acre - feet/year}{leak}\right]}\right)$$

Average Volume Per Leak per year:

$$\left(\frac{\mathit{Volume\ leakage\ from\ mains}\ [acre - feet/leak/year] \times \mathit{Total\ Unreported\ leaks\ on\ mains}\ \left[\frac{\#\ leaks}{year}\right]}{\left(\mathit{Total\ unreported\ leaks\ on\ mains}\ \left[\frac{\#\ leaks}{year}\right] + \mathit{Total\ Unreported\ leaks\ on\ service\ connections}\ \left[\frac{\#\ leaks}{year}\right]\right)}\right) + \left(\frac{\mathit{Volume\ of\ leakage\ from\ service\ connections}\ [acre - feet/leak/year] \times \mathit{Total\ Unreported\ Leaks\ on\ service\ connections}\ \left[\frac{\#\ leaks}{year}\right]}{\left(\mathit{Total\ Unreported\ Leaks\ on\ main}\ \left[\frac{\#\ leaks}{year}\right] + \mathit{Total\ Unreported\ Leaks\ on\ service\ connections}\ \left[\frac{\#\ leaks}{year}\right]\right)}\right)$$

Volume Leakage from mains and laterals per leak per year:

Volume of leakage from service connections per leak per year:

$$\mathit{Estimated\ average\ flow\ rate\ for\ unreported\ leaks\ on\ service\ connections}\ \left[\frac{gallons}{minute}\right] \times \left(\frac{60\ minutes}{1\ hour}\right) \times \left(\frac{24\ hours}{1\ day}\right) \times \left(\frac{365\ days}{1\ year}\right) \times \left(\frac{1\ acre - foot}{325{,}851\ gallons}\right)$$

Volume of leakage from mains per leak per year:

$$\mathit{Estimated\ average\ flow\ rate\ for\ unreported\ leaks\ on\ mains}\ \left[\frac{gallons}{minute}\right] \times \left(\frac{60\ minutes}{1\ hour}\right) \times \left(\frac{24\ hours}{1\ day}\right) \times \left(\frac{365\ days}{1\ year}\right) \times \left(\frac{1\ acre - foot}{325{,}851\ gallons}\right)$$

2. Incremental cost associated with leak repair in each month with intervention

The equation in the previous version of the model for incremental cost associated with leak repair in each month with intervention used the proportion of initial leakage level to annual unreported leakage to calculate the number of leaks and the leak repair costs. This was incorrect and created counter-intuitive effects in the model (discussed above). The equation now multiplies the proportion of leaks on mains and laterals with their respective costs, divides by the leak detection efficiency, and multiplies by the total number of leaks found per part, determined as mentioned above.

Previous Equation:

$$\left(\frac{\dfrac{Initial\ Leakage\ Level\ for\ part\ surveyed\ each\ month\ [acre-feet]}{Annual\ Unreported\ Leakage\ \left[\frac{acre-feet}{year}\right]}}{Efficiency\ of\ Leak\ Detection\ Equipment\ [percent]}\right) \times \left(\left(Unreported\ leaks\ on\ mains\ \left[\frac{\#\ leaks}{year}\right]\right) \times Repair\ Costs\ for\ Leaks\ on\ Mains \left[\frac{dollars}{leak}\right] + Unreported\ Leaks\ on\ Laterals\ \left[\frac{\#\ leaks}{year}\right] + Repair\ Costs\ for\ Leaks\ on\ Laterals\ \left[\frac{dollars}{leak}\right]\right)$$

Final Equation:

Cost of leak repair during each month shall be calculated as follows:

$$Leaks\ found\ per\ part\ of\ system\ with\ intervention\ [\#leaks] \div Efficiency\ of\ Leak\ Detection\ Equipment [percent]$$
$$\times \left(\left(\frac{Total\ Unreported\ Leakage\ on\ mains\ \left[\frac{\#\ leaks}{year}\right]}{\left(Total\ Unreported\ leaks\ on\ mains\ \left[\frac{\#\ leaks}{year}\right] + Total\ Unreported\ leaks\ on\ service\ connections \left[\frac{\#\ leaks}{year}\right]\right)} \times Repair\ costs\ for\ leaks\ on\ mains \left[\frac{\$}{leak\ repaired}\right]\right) + \left(\frac{Total\ Unreported\ Leakage\ on\ service\ connections\ \left[\frac{\#\ leaks}{year}\right]}{\left(Total\ Unreported\ leaks\ on\ mains\ \left[\frac{\#\ leaks}{year}\right] + Total\ Unreported\ leaks\ on\ service\ connections \left[\frac{\#\ leaks}{year}\right]\right)} \times Repair\ costs\ for\ leaks\ on\ service\ connections \left[\frac{\$}{leak\ repaired}\right]\right)\right)$$

3. Water loss occurring without intervention

The equation in the previous version of the model for water loss occurring without intervention used to determine water loss occurring without intervention was incorrect. Because water loss without intervention is monthly and system-wide in the model, the equation for water loss without intervention should account for the whole system for one month. Therefore, the term for water loss without intervention should include the unreported leakage per month and the rate of rise of leakage for the 12 months since the end of 2020 (the end of the baseline period before the model begins in 2022). Because our assumption is that systems will maintain their current leakage starting in 2022, the water loss occurring without intervention stays constant in the model.

Previous Equation:

$$\left(Months\ taken\ to\ survey\ the\ system \left[\frac{mont\ hs}{survey}\right]\right) \times \left(Unreported\ leakage\ per\ part\ \left[\frac{acre-feet}{year}\right]\right) + \left(Annual\ average\ rise\ in\ leakage\ \left[\frac{acre-feet}{year^2 \times part}\right] \times (1-0.5) \times \left(\frac{1\ year}{12\ mont\ hs}\right) \times \left(\frac{1\ year}{(12\ mont\ hs)}\right)\right)$$

Final Equation:

$$Annual\ Unreported\ Leakage\ \left[\frac{acre-feet}{year}\right] \times \left(\frac{1\ year}{12\ months}\right) + \left(Rate\ of\ rise\ in\ leakage\ \left[\frac{acre-feet}{year^2}\right] \times \left(\frac{1\ year}{12\ months}\right)^2 \times 12\ months\ since\ the\ end\ of\ 2020\right)$$

4. Water loss due to natural rise in leakage in never surveyed parts in each month

The equation in the previous version of the model did not include the natural rise in leakage for the 12 months since the end of 2020 (from the end of the baseline period before the model begins in 2022). The natural rise in leakage should be included because this natural rise in leakage was included in the water loss occurring without intervention (#3), and it is important for the “with intervention” case and the “without intervention” case to have the same baseline assumptions. The following equations apply before the entire system is surveyed once. After the system has been surveyed once, this value is always zero because all parts have been surveyed.

Previous Equation:

$$(Months\ taken\ to\ survey\ system - Month\ of\ Implementation + 1)[months] \times Average\ annual\ rise\ in\ leakage\ \left[\frac{acre-feet}{year^2 \times part}\right] \times (Month\ of\ implementation - 0.5)[months] \times \left(\frac{1\ year}{12\ months}\right)^2$$

Final Equation:

$$(Months\ taken\ to\ survey\ system - Month\ of\ Implementation + 1)[months] \times Average\ annual\ rise\ in\ leakage \left[\frac{acre - feet}{year^2 \times part}\right] \times (12\ months\ since\ the\ end\ of\ 2020 + Month\ of\ implementation - 0.5)[months] \times \left(\frac{1\ year}{12\ months}\right)^2$$