Peter's Problem 2015 – The Solution

1. Rainfall in Mullingar:

See: http://www.met.ie/climate/monthly-data.asp?Num=875

2012: 1024.2mm

2013: 963.9mm

2014: 1203.5mm

Average Yearly Rainfall in Mullingar:

1063.9mm

Average: $\frac{1024.2+963.9+1203.5}{3} = \frac{3191.6}{3} = 1063.9$mm correct to 1 decimal places or 106.39cm.

2. Water harvesting:

Roof Area: $8 \times 8 = 64\text{m}^2 = 640000\text{cm}^2$.

Volume gathered per 1cm of rainfall: $640000\text{cm}^3 = 640$ litres.

Water gathered: $640 \times 106.39 = 68089.6$ litres gathered in 1 year.

Water gathered: 68089.6 litres

Wastage: 5%

Water harvested: 64685 litres

Wastage: 3% evaporation + 2% car/garden usage = 5% wastage.

Water harvested: 68089.6 – 5% of 68089.6 = 68089.6 – 3404.48 = 64685.12 litres = 64685 litres correct to the nearest litre.

3. Household water usage:

Note: Use 52 weeks per year for weekly usage figures; 365 days per year for daily usage figures.

Kitchen:

Dishwasher: 5 litres; 10 times per week: $5 \times 10 \times 52 = 2600$ litres.
Washing machine: 46 litres; 6 times per week: $6 \times 46 \times 52 = 14352$ litres.
Water tap: 7 litres per min.; 33 min. per day: $7 \times 33 \times 365 = 84315$ litres.
Bathroom:

Cistern full flush: 15 litres; 8 times per day: $15 \times 8 \times 365 = 43800$ litres.
Cistern mini-flush: 6 litres; 28 times per day: $6 \times 28 \times 365 = 61320$ litres.
Bath: 120 litres: 3 times per week: $120 \times 3 \times 52 = 18720$ litres.
Shower: 9 litres per min.; 45 times per week; 3min. 45 sec. each: $9 \times 45 \times 3.75 \times 52 = 78975$ litres.
Hand basin taps: 5 litres per min.; 28 min. per day: $5 \times 28 \times 365 = 51100$ litres.
Total household usage: 355182 litres.

Usage:
Dishwasher: 2600
W/machine: 14352
Tap: 84315
Cistern: 105120
Bath: 18720
Shower: 78975
Basin tap: 51100

Total: 355 182 litres

Q1. Answer: The total household usage is 355 182 litres.

4. The Costs:

Domestic Usage: 355182 litres.

Free usage Allowance: 30000 litres basic; 5 person-household - 10000 litres each: 50000 litres. Total: 80000 litres.

Harvested: 64685 litres.

Billable: 355182 – 80000 – 64685 = 210497 litres.

First 80000 litres @ 0.05c per litre: $80000 \times \frac{0.05}{100} = €40$. Total billed so far: 80000 litres.

Next 50000 litres @ 0.09c per litre: $50000 \times \frac{0.09}{100} = €45$. Total billed so far: 130000 litres.

Next 80000 litres @ 0.14c per litre: $80000 \times \frac{0.14}{100} = €112$. Total billed so far: 210000 litres.

Next: 210497 – 210000 = 497 litres @ 0.42c per litre: $497 \times \frac{0.42}{100} = €2.0874 = €2.09$ to the nearest cent.

Total bill: Standing Charge €50 + Usage bill (€40 + €45 + €112 + €2.09) = €249.09.

5. The Savings:

Harvested amount: 64685 litres.

The final billable amount was within the 'next 60000 @ 0.42c per litre' range.

60000 – 497 = 59503 litres @ 0.42c per litre: $59503 \times \frac{0.42}{100} = €249.9126 = €249.91$ to the nearest cent.

Remainder: 64685 – 59503 = 5182 @ 0.65c per litre: $5182 \times 0.65 = €33.683 = €33.68$ to the nearest cent.

Total: €249.91 + 33.68 = €283.59 [€249.9126 + €33.683 = €283.5956 = €283.60 to the nearest cent.]

Q2. Answer: The total amount saved through harvesting water is €283.59.

Cost	**355182 litres:**		**Remaining litres**
€0	**64685**	**harvested**	**290 497**
€0	**80000**	**free**	**210 497**
€40.00	**80000**	**0.05c/l**	**130 497**
€45.00	**50000**	**0.09c/l**	**80 497**
€112.00	**80000**	**0.14c/l**	**497**
€2.09	**497**	**0.42c**	**0**
€50.00	**0**	**Standing Charge**	
Total: €249.09 Bill			

Savings through harvesting:

Harvested: 64685 litres

€249.91	**0.42c/l**	**59503**
€33.68	**0.65c/l**	**5182**
		64685

Total: €283.59 Savings

[Note: The total bill without harvesting would have been €532.68]

6. A bill involving leaks:

New Bill amount: €353.68. Old Bill: €249.09.

Increase in bill amount: €353.68 - €249.09 = €104.59.

The final 497 litres of the Old Bill were within the 'next 60000 litres at 0.42c per litre' band. The remaining 59503 litres @ 0.42c per litre would cost €249.09 extra. Therefore, the increase in the bill does not bring the usage of water beyond the '0.42c per litre' band.

Then $104.59 \times \frac{100}{0.42} = 24902$ litres have been lost due to leaks (to the nearest litre).

Q3. Answer: 24 902 litres have been lost due to leaks.

New Bill: €353.68 Old Bill: €249.09 Increase: €104.59 **All within the Band 0.42c/l** **24902 litres lost due to leaks**

7. A change in the bill due to a change in rainfall

New bill: €240

Old bill: €249.09.

Reduction in bill: €249.09 - €240 = €9.09.

Rainfall figure of 106.39 cm in a year gives the bigger bill. Therefore there must have been an increase in rainfall to allow more harvesting of water in order to reduce the bill.

Looking at the bands:

The final 497 litres @ 0.42c per litre cost €2.09 which was saved.

€9.09 - €2.09 = €7.00 was further savings.

The previous band of 80000 litres @ 0.14c per litre cost €112 in total. Therefore a fraction of this amount has been saved.

$80000 \times \frac{7}{112} = 5000$ litres have been saved.

Total litres reduced from the billable amount: 497 + 5000 = 5497 litres.

Total increase in harvesting of water: 5497 litres which is 95% of water gathered.

Total increase in water gathered: $5497 \times \frac{100}{95} = 5786.3$ litres = 5786 litres correct to the nearest litre.

Since 640 litres are gathered per cm of rainfall this means that $\frac{5786}{640} = 9.040$ cm of extra rain fell.

Total rainfall: 106.39 + 9.04 = 115.43 cm of rainfall.

Q4. Answer: The actual rainfall for the year was 115.43 cm or 1154.3 mm.

New Bill: €240 Old Bill: €249.09 Reduction: €9.09
Implication: An increase in rainfall with extra harvesting.

From the Old Bill:			**Remaining to remove: €9.09**
€2.09	**497**	**0.42c/l**	**€7.00**
€7.00	**5000**	**0.14c/l**	**€0.00**

Total: 5497 litres harvested; 5786 litres gathered.

Extra rainfall above average: 9.04cm
Actual rainfall for the year: 115.43cm or 1154.3mm