

2007-09-12

Water Savings and Rainwater Harvesting – Pilot Project in Ireland

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Recommended Citation

O'Hogain, S., Reid, A., McCarton, L., Pender, J., McNtyre, N.: WATER SAVINGS AND RAINWATER HARVESTING – Pilot Project in Ireland. Proceedings of the European Water and Wastewater Management (EWWM) Conference, 12th - 14th Sept, 2007, Newcastle, edited by Horan, N, Aqua Enviro Sept 2007. ISBN: 1-903958-24-5

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Funder: National Federation of Group Water Schemes

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WATER SAVINGS AND RAINWATER HARVESTING – A PILOT PROJECT IN IRELAND

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ABSTRACT

A pilot project to harvest rainwater was set up in Ireland in 2005 to examine the potential of using rainwater harvesting systems to replace treated mains water, for non-potable uses. The Project has two strands to it. The agricultural application assessed the feasibility of incorporating rainwater supply to supplement/replace mains or other water supplies for farms. The second strand involves rural water supply to domestic dwellings. Here the project installed rainwater harvesting and water conservation devices as part of a pilot project to assess the reduction in domestic demand.

This paper will examine the water use recorded on both sites. It will present the findings of flow monitoring carried out on the agricultural site. Water savings will be presented in terms of rainwater volumes substituted for mains water, and in terms of economic savings, to the end-user and to the water producer. Water use will be compared with existing data available on water use on the farm. In the domestic situation, baseline results from non-rainwater harvesting houses monitored as part of the project will be compared with results from those fitted with rainwater harvesting. Water savings will be presented and discussed in terms of volume reduction in public water use and economic savings to user and producer.

KEY WORDS

Agricultural water demand, domestic water demand, per capita consumption, rainwater harvesting

INTRODUCTION

Rainwater harvesting (RWH) maybe described as the capture, diversion and storage of rainwater for different purposes [Texas Water Development Board, 2005]. These include:

- domestic use, toilet flushing, washing machine supply, showering, potable supply
- agricultural use, animal consumption and irrigation
- commercial use, toilet flushing and potable supply

Rainwater harvesting is not a new technology, it can be traced from ancient times to its continued practice in many parts of the world today [Spinks, *et al.* 2003 a].

Traditionally rainwater harvesting has been practised where conditions are particularly favourable or where alternative sources of supply are particularly difficult [Thomas 1998]. Rainwater Harvesting systems may be quite simple - a waterbutt attached to a downpipe at the side of a house or shed, or a more complex system, involving storage tanks, pumps and filters. A rainwater harvesting system may be broken into six basic sections

- **Catchment area.** This refers to the area of rain run off to the collection system. In most systems the catchment area is a roof.
- **Collection system.** This includes gutters and downpipes to convey the rain to the storage tank.
- **Water quality protection.** This includes leaf filters or screens and first flush devices, which help to exclude dirt and debris from entering the storage tank.
- **Storage system.** A tank or tanks which store the water for immediate and future use.
- **Supply system.** This supplies the water to its point of utilisation using either a gravity and/ or pumped feed.

- **Treatment system.** Where the harvested rain is to be used for potable supply, filters and other treatment systems are used to ensure the water is safe for consumption.

The advent of centralised water distribution networks led to a decline in the practice of rainwater harvesting in western society. However, a growing interest in sustainable water resource use and the quality of rainwater has seen a growing interest in using rainwater to supply part or, indeed all water requirements [Texas Water Development Board, 2005].

Rural Group Water Supply in Ireland

In rural Ireland, water is supplied to non-mains users i.e. those who do not have access to a local authority scheme, by the Group Water Sector. These comprise of private and part-private schemes, charged with sourcing and distributing potable water. This sector accounts for water provision to 29% of all rural households in the Republic of Ireland. The National Federation of Group Water Schemes (NFGWS) is the representative organisation for this sector in Ireland. New water treatment plants are being constructed by the NFGWS using the Design Build and Operate (DBO) method of procurement for capital works. Current Irish government policy requires that local authorities should apply charges to the non-domestic sector that reflect the costs (both capital and operational) of provision of water and wastewater services. These charges are applied on the basis of a unit charge in respect of metered water supply and/or a flat rate charge per annum. Local authorities are required to achieve universal metering of water supplied to the non-domestic sector by 2006. Rural Group water scheme users currently pay a unit charge for water supply; local authority domestic users currently pay no charge for water use.

PILOT RAINWATER HARVESTING PROJECTS

Ireland's growing demand for water coupled with a growing awareness of the need to provide sustainable water supply, has put the spotlight on rainwater harvesting as a potential viable source of water supply.

To investigate the feasibility of installing a rainwater harvesting system for two different purposes, one in a domestic setting, the second for agricultural use, a pilot study was initiated. The project leaders are the Department of Civil & Structural Engineering, Dublin Institute of Technology (DIT), in association with the Department of Environment, Heritage & Local Government, the National Rural Water Monitoring Committee and Carlow County Council. In the domestic setting, rainwater is used only to supply the household toilets, in the agricultural setting rainwater is used to supply the farm cattle troughs. The agricultural site is at Clonalvy, Co. Meath and the domestic site is at Ballinabrannagh, Co. Carlow (Figure 1).

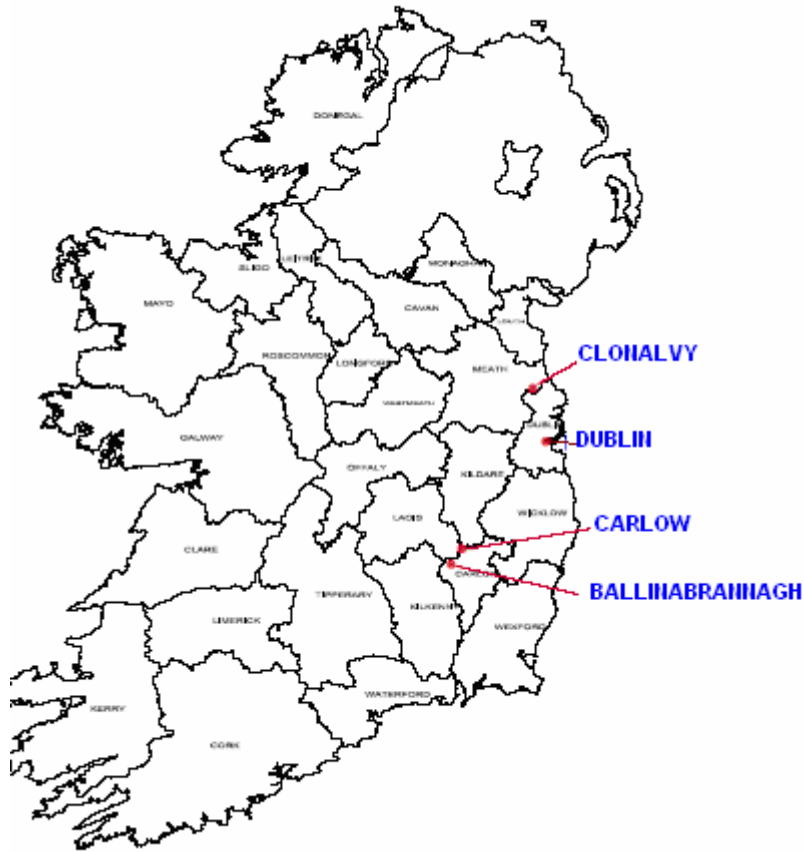


Figure1: Agricultural and Domestic Sites for Pilot Project

AGRICULTURAL SITE

The farm chosen for the installation of the rainwater harvesting facility is situated approximately 30 miles from Dublin. The farm was originally a dairy farm, but in recent years the farmer has switched to beef production. The farm encompasses 250 acres and is home to 114 cattle as of March 2007.

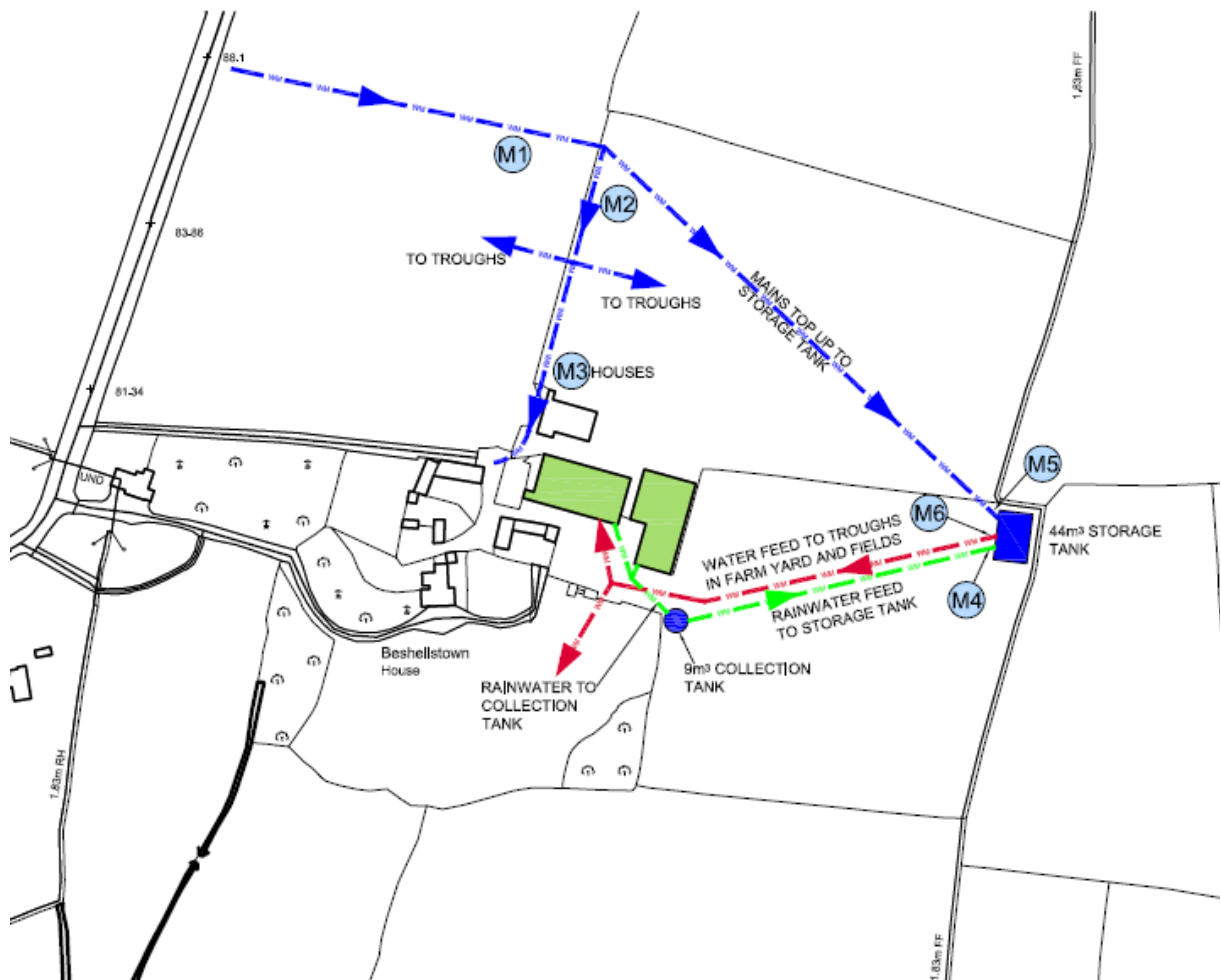


Figure 2: Farm Schematic (Background Map Source: Os Map No. 2648)

Site Works

A plan of the RWH installations is given in Figure 2. Two of the farmyard buildings (coloured green) were chosen as rain catchment areas, with a total catchment area of 1910m². The installation of the RWH facilities required construction/excavation and installation work to be carried out.

Pipe trenches were cut and excavated for the laying of pipes in the farm yard to convey the collected rainwater from the downpipes to a collection tank adjacent one of the farm buildings. The guttering and downpipes on the farm buildings were replaced. Three 100mm downpipes are used to convey the rainwater from the buildings' roofs to the RWH system.

A 9m³ precast concrete tank to act as an initial collection vessel for the rainwater was installed. The site for this tank required excavation as it was installed underground. Excavations were carried out to lay a 25mm pipe between the collection tank and the storage tank. A submersible Multigo pump was installed in the collection tank to allow pumping of rainwater up to a storage tank.

A detailed analysis of potential rainwater yield was carried out. The storm duration versus intensity profile for 1, 2, 5, 10, 20, 50 and 100 year return periods was calculated. From this data storage volumes for the individual farm buildings were established. The theoretical water use analysis indicated that the farm uses 12.15m³/d for farm washings and 10.75m³/d for animals. In order to maximise rainwater yield a balance between supply and demand is critical. Design data suggested that the farmer may be able to augment 35% of mains water supply with rainwater.

Following the detailed design, a 44m³ rainwater storage tank was chosen. Two 22m³ tanks interconnected via a 100mm pipe were installed. An overflow facility decreases the total capacity of the storage tank to approximately 40m³. Hardcore foundations were laid for the storage tank, which is situated above ground, at an elevation of approximately 10m above the farm yard. 25mm pipe was laid between the storage tank and the yard and field troughs to supply drinking water to the cattle.

How the Rainwater Harvesting System is Controlled

An electrical control panel connected to the pump in the collection tank was installed in the farm building adjacent to the collection tank.

Ballcocks are used to control the movement of water within the RWH system; these are connected to the control panel.

Two ballcocks were installed in the storage tank; one controls the infilling of rainwater from the collection tank, the second to control flow of mains water to top up the system. (Figure 3)

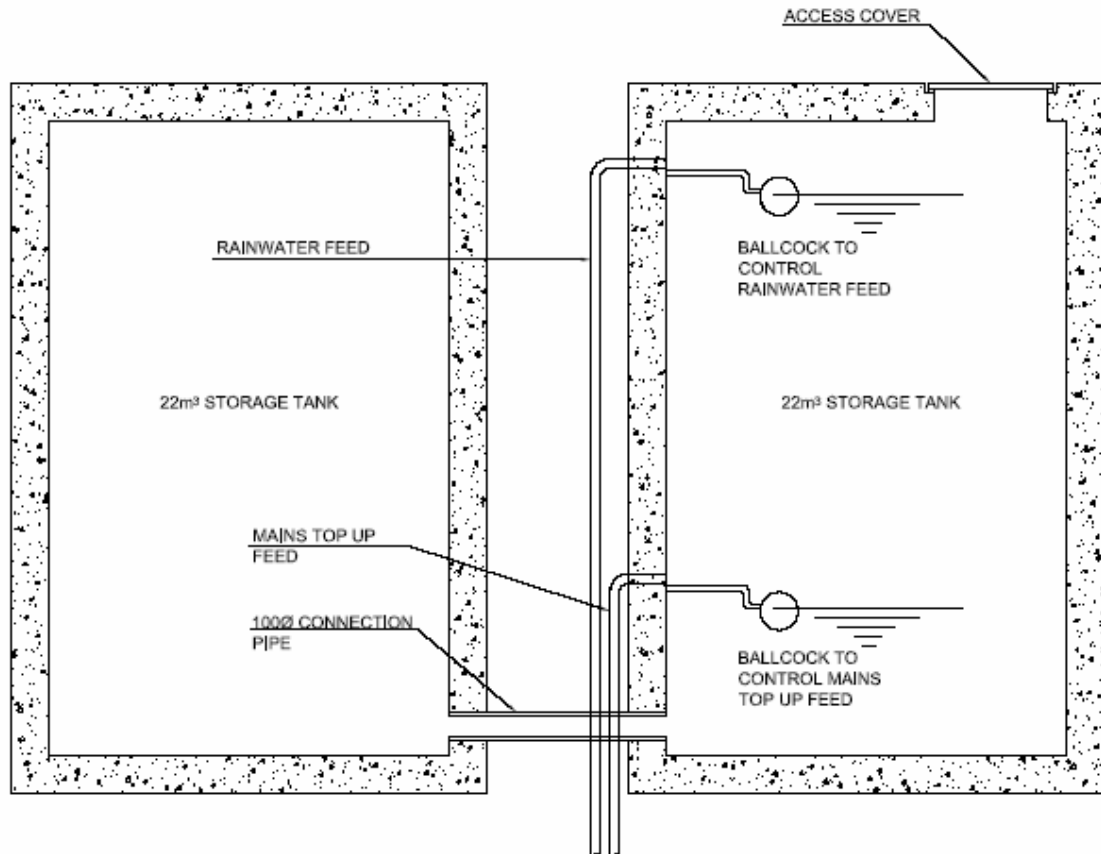


Figure 3: Water Level Controls in Storage Tank

The ballcock controlling the rainwater flow to the storage tank is set at approximately 3m above the tank floor. It controls the pump in the collection tank, switching it on and off as required. The second ballcock was installed at approximately 1m above the tank floor providing mains water back up to the storage tank. This ensures water supply to the cattle troughs during periods of dry weather when there is insufficient rainwater available or if the pump fails.

On the side panel of the control panel a red light was connected and mounted giving a quick visual check that the pump is functioning properly.

Gravity is used to distribute water to the farmyard troughs and some of the field troughs. To monitor water on the farm, meters were installed; their location is detailed in Figure 2.

Monitoring System

Meters used are Bonyto Klasse C 1.5m³/h type; each meter is connected to an Endress + Hauser MinilogB data logger. Meter readings are recorded and stored by the data logger at 4 hourly intervals. This stored data is downloaded via a laptop and the Endress + Hauser software ReadWin 2000.

Meters M1, M2 and M3 (Figure 2) measure the demand for mains water at various points on the farm. M1 meters the total demand for mains water on the farm. M2 and M3 measure demand for mains from the three houses on the property along with field troughs not connected to the RWH system. M3 does not have a Minilog B data logger connected, it is read manually.

	M1	M2	M4	M6			
Feb-07	109.996	74.479	29.153	29.192	35.517	0.039	35.478
Mar-07	185.641	116.146	10.417	36.613	69.495	26.196	43.299
Apr-07	152.222	116.935	6.530	30.999	35.287	24.469	10.818
May-07	151.571	110.922	1.558	37.266	40.649	35.708	4.941
Jun-07	138.928	104.495	0.000	23.131	34.433	23.131	11.302
Total	738.358	522.977	47.658	157.201	215.381	109.543	105.838

The demand for mains water (M1) peaked at 185.641m³ in March. From February onwards the cattle were let out into the fields. Mains top up increased from 0.39m³ in February to meeting total demand of 23.131m³ for troughs June. Once the cattle are in the fields the supply source for drinking water will depend on their location. In some fields the troughs are connected to the RWH system; in others they are connected to the mains supply.

While the largest monthly total (29.153m³) of harvested rainwater supplied to the storage tank (M4) was in February, rainwater supplies fell to just 1.559m³ in May and no rainwater was pumped to the tank in June. The reason for this is problems encountered with the pump in the collection tank. In March and April the pump tripped out on a number of occasions and was not reset for a few days at a time; this resulted in less rainwater than expected being pumped to the storage tank.

Part of this pilot study includes investigating the chemical and microbiological quality of the harvestable rainwater on the farm. As part of this strand of the pilot project it was decided not to install any filter or first flush device to determine a worst case scenario as regards water quality. This has impacted on the efficiency of the RWH system to supply rainwater to the storage tank. The floating inlet on the pump in the collection tank has become damaged and clogged by debris entering the collection tank. It was decided to switch the pump off to avoid any further damage to the pump until a filter and first flush device can be installed.

In the five months shown in Table 1 the total demand for water for the cattle troughs connected to the RWH system was 157.201m³, of which 47.458 m³ or 30% was supplied from harvested rainfall.

Table 2: Water Rate Cost Associated With Water Use on the Farm

	Mains	Mains houses /troughs	Rainwater to storage tank	Water to yard / field troughs (RWH fed)	Top up / Troughs (M1-M2)	M6 - M4 (Mains Top Up to RWH)	Field Troughs (mains fed)
Total water used m ³	738.358	522.977	47.658	157.201	215.381	109.543	105.838
Cost €	€871.26	€617.11	€56.24	€185.50	€254.15	€129.26	€124.89

The cost of mains water is set at €1.18 per m³ for non domestic metered customers by the local authority Meath County Council [Meath County Council, 2007]. From Table 2 excluding capital and running costs the farmer made a gross saving of €56.24 over the five months. A full financial analysis of cost savings to the producer is ongoing.

DOMESTIC SITE

The site chosen for investigation for the domestic use of rainwater was a new housing estate 6 miles outside Carlow town at Milford Park, Ballinabrannagh, Co. Carlow where mains water is supplied by Ballinabrannagh group water scheme. Initially 4 houses were selected for study, one, a bungalow fitted with rainwater harvesting (RWH) facilities, and three 2 storey houses with standard plumbing. The three standard houses act as controls so that savings made by the RWH system installed can be evaluated. Additionally, monitoring the four

households allows for patterns of water use to be investigated and calculation of per capita consumption (PCC).

In the second phase, 6 houses all with rainwater harvesting facilities are due for completion and sale over the coming months. Show houses including one with RWH facilities were opened to the public on July 1st 2007.

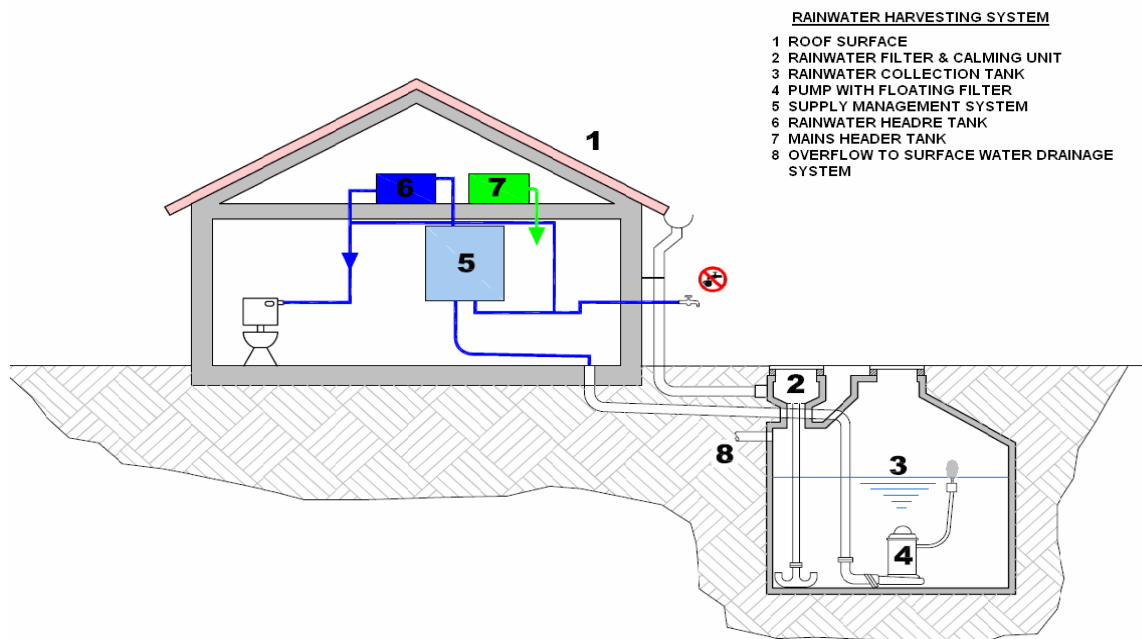


Figure 5: Schematic of Rainwater Harvesting (RWH) House

Figure 5 shows the components of the RWH system installed. The house roof is the catchment area (1), rain is collected by the gutters and flows through the downpipes through a filter and calming inlet (2) to the underground collection tank (3). A submersible pump (4) controlled by the supply management system (5) pumps rainwater on demand to the rainwater header tank (6) for supply to the household toilets and garden tap. A mains header tank (7) supplies all other water requirements as per normal plumbing practice.

Site Works

The house fitted with the rainwater harvesting facilities had additional work done during construction. The RWH system was designed for water use of 45 litres per head per day (l/hd/d) for toilet use in a 4 person household and 30 days dry storage period. A 9m³ precast concrete collection tank was installed underground on a foundation of gravel in the front garden (Figure 5). The downpipes which normally drain rainwater from the roofs to the drainage system were connected via an inline Rainman Type1 filter to the inlet of the collection tank in the garden. A calming or smoothing inlet in the collection tank calms the water as it enters the tank preventing any settled material at the tank bottom being disturbed. Extra pipe work was required to connect the collection tank's overflow and the filtered rainwater waste containing roof debris such as leaves to the drainage system. To help ensure that the rainwater quality is not compromised by debris and dirt from paths around the house, points where the downpipes connect with the ground pipes were sealed using silicone. While this seal stops dirt inflow to the RWH system, it is easily removable if required.

In addition to the normal mains header tank in the attic, a second header tank has been fitted. In the three control houses the mains header tank supplies the hot and cold water systems including the toilets. In the RWH house the mains header tank supplies the hot and cold water systems excluding the toilets. The extra header tank acts as storage for the rainwater supplying the toilets in RWH house.

A submersible Multigo pump placed in the collection tank in the garden pumps the collected rainwater to the rainwater header tank in the attic. The pump's floating filter inlet lies just below the water level, preventing any floating debris entering the pump. The pump has a safety mechanism which prevents the pump switching on if water level in the tank is below a certain level. This protects the pump and prevents any settled material being disturbed, thus clogging the pump inlet or entering the rainwater header tank.

Control of the RWH System

To control and ensure the smooth running of the system a control management system was installed. Similar to the system installed on the agricultural site, a ballcock is used to control the water level within the rainwater storage tank. When the level of the ballcock falls, it signals to the management system to pump rainwater from the garden collection tank to the rainwater storage tank in the attic.

If during periods of dry weather there is insufficient rainwater available in the collection tank, the pump signals the management system. In this case, the management system switches on the mains top up ensuring sufficient water at all times for toilet flushing. This mains top up device employs an air gap and tundish ensuring that no cross-contamination between the rainwater and the mains plumbing systems is possible.

A metering plan shown in Figure 6 was designed for monitoring water use within the control houses.

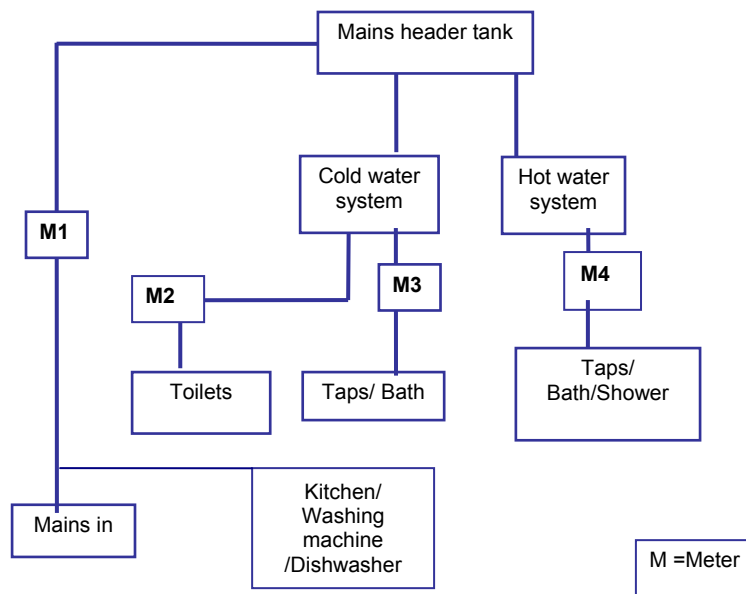


Figure 6: Metering Schematic for the Control Houses

The meters used are Bonyto Klasse C 1.5m³/h type. Meter 1 (M1) monitors the mains demand within the household, M2 records water used in toilet flushing, M3 and M4 measure cold and hot water use respectively in the household at sink and bath taps and any appliances such as washing machines and dish washers.

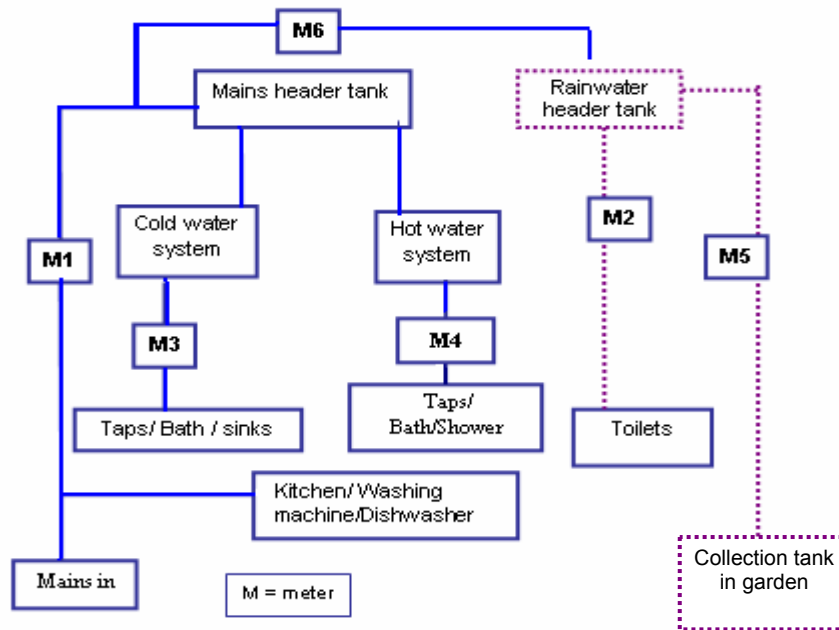


Figure 7: Metering Schematic for Initial Rainwater Harvesting House

Figure 7 outlines the metering system in the RWH house. Meters M1 – M4 monitor the same water parameters as for the three control houses. The additional meters, M5 and M6 monitor rainwater flow from the collection tank to the rainwater header in the attic (M5) and the volume of mains top up entering the rainwater header tank in the attic (M6).

Monitoring System

To minimise disruption to the householders a remote monitoring system, Hydrometer’s Hydro-Center is used. Meters were fitted with a radio transmitter allowing meter data to be transmitted to the Hydro-Center’s data logger for storage. Each meter’s reading is transmitted to and stored by the Hydro-Center 4 times per day: at 00:00, 06:00, 12:00 and 18:00.

The Hydro-Center has mobile phone SIM card technology facilitating the remote downloading of stored data via telephone and Hydrometer’s software package Hydro-Center 2.35.

Due to site conditions, one Hydro-Center is incapable of picking up the transmitted meter readings from all 4 houses. Therefore two Hydro-Centers are employed one was set up in one of the control houses; the second Hydro-Center in the RWH house.

A Vantage PRO2™ Weather Station was set up close to the houses to monitor local weather, similarly to the agricultural site weather data is downloaded every 6 weeks.

Results

Per capita consumption (PCC) for the four houses is given in Table 2. 132l/hd/d is taken to be the average value for domestic water consumption in Carlow in 1997 [Atkins, 2001]. Table 2 shows that all four houses fall below this value, with such a small sample size it is difficult to draw any conclusions.

Table 2: Estimated Per Capita Consumption (PCC) for Four Households *

House / No. Persons per house	PCC l/hd/d
House 1 5 persons	126.46
House 2 3 persons	70.68

House 3 5 persons	119.15
RWH House 2 persons	68.89

* Values for PCC given in Table 2 are estimated due to commissioning issues.

In Figure 8 a breakdown of PCC is given for each house. House 2 and RWH House PCC water use is for period the Nov 06 – Jun 07, House 1 data period is Nov 06 – Feb 07, and for House 3 the period covered is Mar 07 – Jun 07. The kitchen value includes mains for washing machine and dish washer use; the cold water feed to these appliances is connected directly from the mains. The PCC value for the rainwater harvesting house includes the rainwater used to flush the toilets and any mains top up required.

Figure 8 shows that toilet flushing in the four houses accounted for between 22–41% of water use within the households this compares with 32% from study carried out in 2001 [O’Sullivan, 2001]. In the RWH house, 85% of the water used for the toilets was supplied by rainwater. The only reason that rainwater did not supply all of the toilet flushing needs was a problem with the ballcock which prevented rainwater replenishing the rainwater header tank as required.

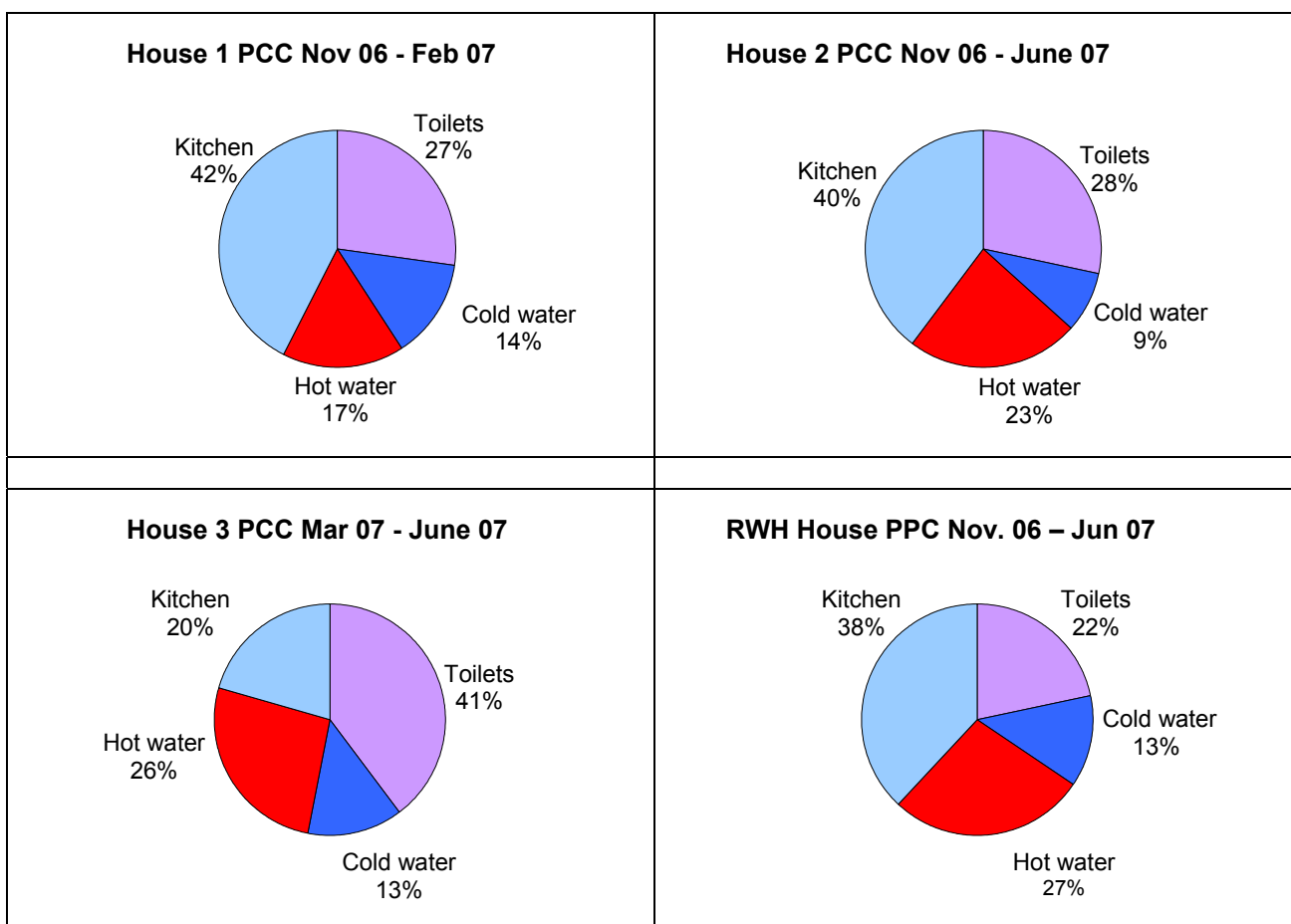


Figure 8: Breakdown of Average Estimated Daily PCC Water Use Within 4 Houses

Supply Vs. Demand (Harvestable Rainfall Vs. Toilet Use)

In terms of the RWH system installed two questions may be asked.

1. How has the RWH system installed in Carlow performed in terms of meeting the demand from the householders for toilet flushing?
2. What is the potential for additional water demands of the RWH house to be met by rainwater supply

To calculate supply of harvestable rainfall, we require the monthly rainfall values, the runoff coefficient, the filter efficiency and the catchment area. Harvestable rainfall may be calculated as follows:

Harvestable rainfall = rainfall (mm) x runoff coefficient x filter efficiency x catchment area (m²). Total rainfall for the period Jan to June 2007 was 200mm. Average annual rainfall for the region ranges between 800-1000mm [Met Eireann, 2007]. The runoff coefficient is 0.9 for the roof tiles, filter efficiency is 0.75 and the catchment area is 75m²

Over the six months Jan – Jun 07 the total harvestable rainfall was 10.13 m³ (200mm x 0.9 x 0.75 x 75m²). The demand for toilet use over the same period was 5.18m³; supply was almost double the demand.

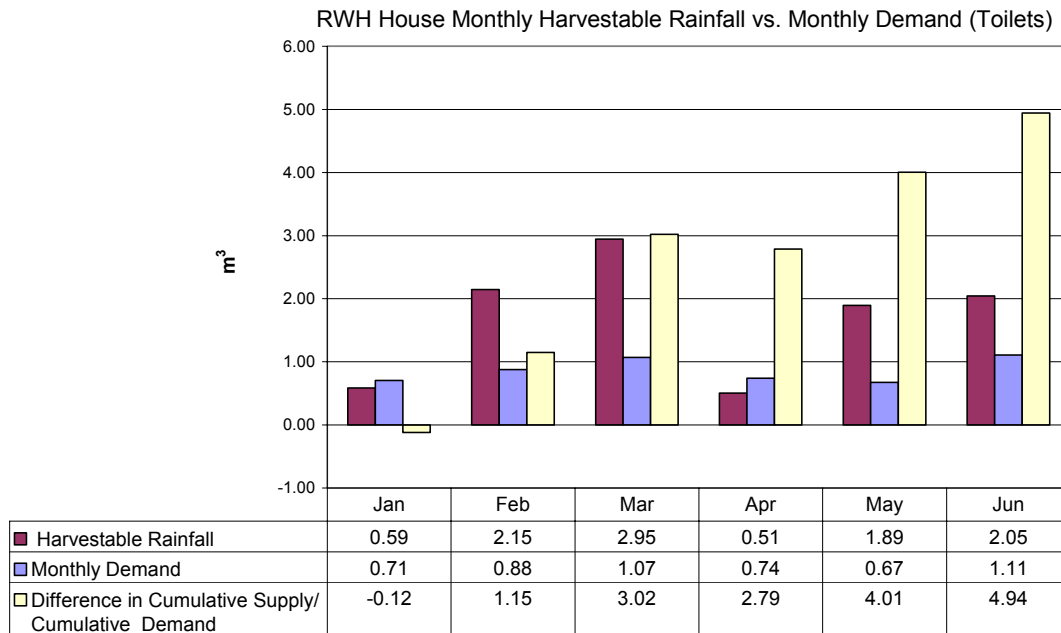


Figure 9: RWH House Monthly Harvestable Rainfall Vs. Monthly Demand (Toilets)

Figure 9 shows the relationship between the harvestable rainfall each month between January and June 2007 and the demand for water for toilet flushing in the RWH house.

It can be seen that, with the exception of January and April, more harvestable rainfall was collected than was required for toilet use. Plotting the difference in cumulative supply vs. cumulative demand over the six months shows the extent of the excess in rainwater harvested compared to that used by the household. All of this excess could be stored as the RWH system has a 9m³ collection tank. However in the first 6 months of the year the greatest monthly demand was in June at 1.11m³. In fact the harvested rainfall is 195% of demand for the six months January to June 2007. This data would suggest that the tank installed has additional capacity. Based on the observed toilet demand in the RWH house of 15 l/hd/d in this 2 person household, a 1m³ tank would give sufficient volume for 32 days storage. The correct sizing of the tank is critical to the RWH system and involves balancing supply (i.e. yield), demand and longest dry period to give an economic solution. Smaller tanks could be employed for the demand observed in the RWH house; however the demand for water is quite low compared to the values initially taken at the design stage of 45l/hd/d for toilet flushing, in this case for a four person household a 5.4m³ tank would supply 30 days storage. As the RWH system is producing excess supply over demand, what additional demand could be met by the RWH system? Studies have shown [Spinks *et al.* 2003,b], that temperatures achieved in Australian domestic hot water systems are sufficient to reduce to safe levels any pathogenic organisms that may be found in harvested rainwater. As part of a microbiological study into water quality of the rainwater harvested at this site, experiments are due to commence which will study the effects of temperatures in Irish domestic systems on potential pathogens.

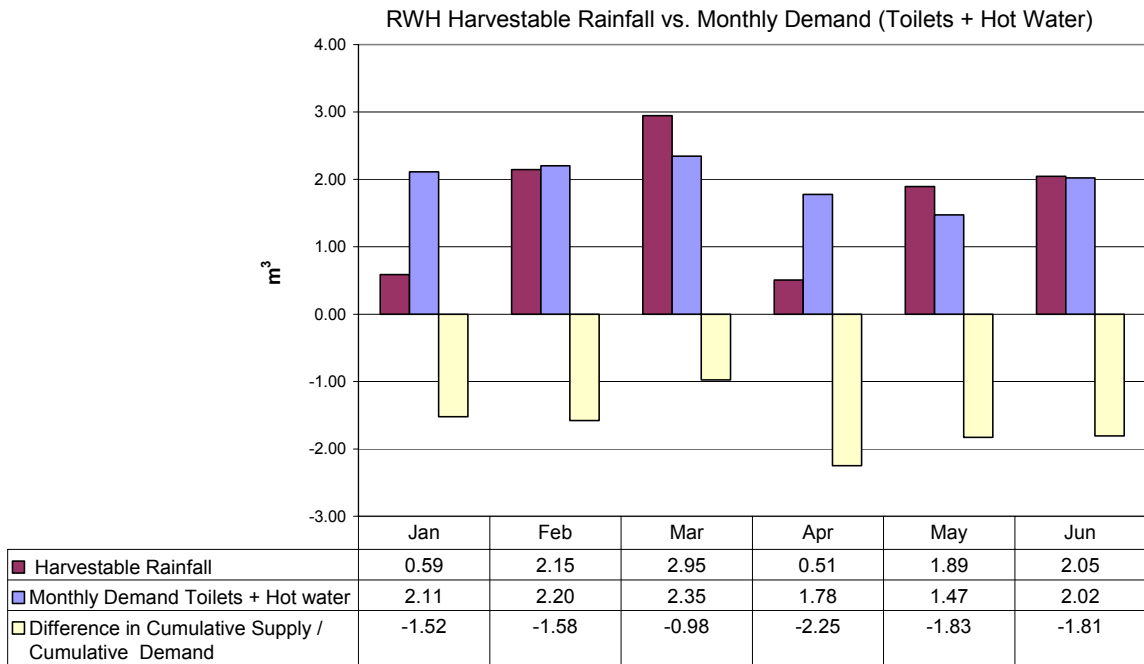


Figure 10: RWH House Monthly Harvestable Rainfall Vs. Monthly Demand (Toilets + Hot Water)

Figure 10 shows how the RWH system would cope with a potential added demand of supplying the hot water needs of the household in the RWH house. Harvestable rainfall in January, February and April is less than monthly demand. The total demand over the six months is 11.93m³; the RWH system could potentially meet almost 85% or 10.13m³ of the household's toilet and hot water demand.

Even with the added demand of hot water on the RWH system, the installed 9m³ tank has additional supply capacity in excess of demand being placed on it by the householders. The greatest monthly demand observed for toilet and hot water use was 2.35m³, again a smaller tank could be employed to meet the needs of this household.

CONCLUSIONS

Taking the agricultural site first, the installed RWH system replaced 47.458m³ of mains water with rainwater in supplying the cattle with drinking water over five months. It has experienced commissioning issues that have to be solved before an accurate picture of its true potential can be assessed.

At the domestic site, the installed RWH system has met the demand for toilet flushing with excess supply, which could potentially be used to meet hot water use within the RWH house. The RWH system could have replaced 5.18m³ of mains supply over the first six months of the year. Due to a ballcock problem it actually replaced 4.4m³ of mains water. If the RWH system was adapted to supply hot water use in addition to toilet use 10.13m³ of mains water could potentially be replaced by rainwater over the six months.

The RWH system at the domestic site is working well. The 9m³ collection tank has extra capacity to potentially supply other needs for example hot water and washing machine use thus further reducing the demand for mains water.

This ongoing study will:

- install and monitor further RWH systems at the Carlow site and widen the flow monitoring to include all houses in the development and confirm findings of the initial pilot study;
- calculate the economic costs to producer for both the agricultural and domestic project;
- carry out financial assessment of the projects;
- assess rainwater quality;
- explore additional benefit of storm storage by installation of RWH tanks.

ACKNOWLEDGMENTS

This research is supported by the Dublin Institute of Technology, National Federation of Group Water Schemes, Department of Environment, Heritage & Local Government, Carlow County Council and the National Rural Water Monitoring Committee.

The authors would also like acknowledge the assistance of the Ballinabrannagh Group Water Scheme, the householders in Milford Park, Co. Carlow and Mr. Hugh Hayes, Clonalvy Co. Meath.

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