TIMELY INFORMATION

Agriculture & Natural Resources

Rainwater Harvesting from Rooftops for Non-potable Uses in Alabama: Part I – Design and Operation

Rainwater is naturally distilled soft water (< 10 mg/liter mineral content) which is readily available when captured and stored. Catching and utilizing rainwater is a thousands-of-years-old technique for human survival in arid and semi-arid regions of the world. Rainwater falling on a rooftop can be effectively harvested and stored in a storage tank for non-potable uses (i.e., small garden irrigation, outdoor washing, toilet flushing, etc). With a disinfection system such as UV (ultra violet) treatment the water may be also used for washing machines and showers. This article will present a rainwater harvesting system that can be easily installed by home owners with no or minimum professional support. The system presented is the RCR (Roof Catchment of Rainwater) system developed at Auburn University with the funds supported by the Alabama Agricultural Experiment Station.

The long-term annual average rainfall in Alabama is 55 inches with monthly rainfall ranging from 2.8 – 6.1 inches with an average of 4.0 inches/month or 1.0 inches per week. But distribution of rainfall has been erratic. A 1.0 inch rainfall on 100 square feet roof top produces 60 gallons of rainwater. If 80% of the rainwater falling on a rooftop is harvested in a storage tank the weekly average rainfall would supply beneficial water for the following water uses and others:

- A single family house (25 ft by 50 ft roof area) can harvest as much as 600 gallons of water which would supply more than 300 toilet flushes at 2 gallons per flush rate.
- A roof top area of 50 ft by 100 ft such as a Welcome Center building on Interstate highways would provide more than 2,500 gallons of water for over 1,200 toilet flushes.
- A school building with 50 ft by 200 ft rooftop would save more than 5,000 gallons of treated municipal water for over 2,500 toilet flushes.
- A typical poultry housing unit (40 ft by 500 ft) can harvest more than 10,000 gallons of fresh water which would supply four days of evaporative cooling water at 4 hr per day operation (600 gallons/hr evaporation rate).

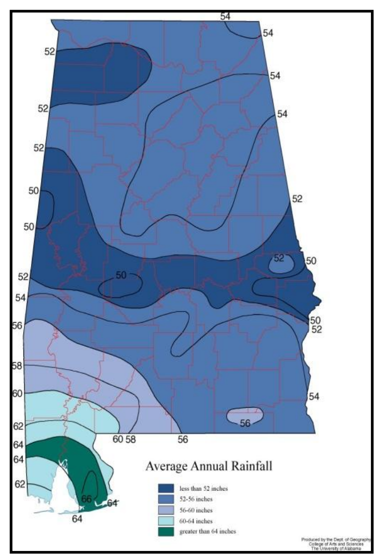


Figure 1. Long-term Average Annual Rainfall in Alabama

The calculations shown above do not guarantee a sustained volume of rainwater due to unpredictable variations of rainfall events. However, the harvested rainwater can certainly supplement conventional water sources. An RCR system also provides the following benefits to the users:

- Reduces the water demand from the existing water sources which results in lower water cost and conservation of local water resources,
- Provides water with low mineral contents (low water hardness) – lower maintenance cost of water use and deliver system,
- Reduces surface runoff, soil erosion, and other environmental and structural impacts to the surrounding areas of the RCR.

Researchers at Auburn University studied the RCR systems in Lee and Madison counties for education and demonstration. Installing an RCR is relatively simple providing gutters, storage tank, and water flow control are available. Anyone can install an RCR with minimum knowledge in plumbing and electricity at a designated site with or even without hiring a professional. An RCR system is composed of the following four major components.

- Solid roof,
- Gutters with screen,
- Storage tank, and
- Water flow control

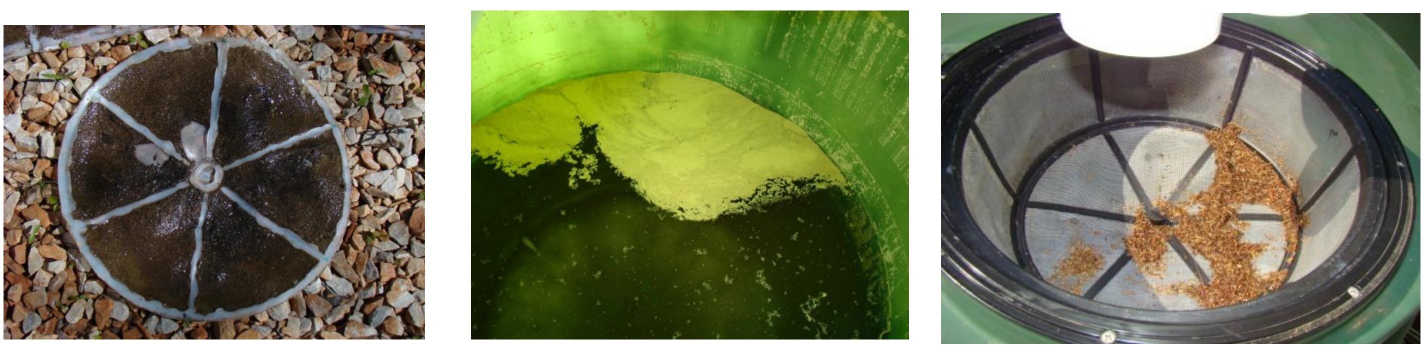
A compact water flow control system was developed at Auburn University for an automatic operation to provide a backup water supply in case of low water level in the rainwater storage tank. A solenoid valve (normally open) is used to switch the water supply from the rainwater storage tank to a backup water supply such as municipal or well water. A few backflow preventers such as check valves should be installed to keep the pump primed as well as to prevent backflow of the rainwater to the conventional water source. Most municipalities require backflow preventers in its ordinance to protect its water source. During this study the following problems were found when an RCR is used in Alabama. However, these problems can be solved or minimized if the system is properly installed and maintained.

1. Less than normal precipitation - The temporal variation of rainfall events sometimes cause a shortage of rainwater. A method was developed to solve this problem by automatically switching the supply source from the rainwater harvesting system to the backup water source, i.e. municipal water or well. When water level in the tank drops below a designated minimum water level the float switch turns off the power to the system. This simultaneously turns off the pump to stop water flow from the storage tank and opens the solenoid valve to allow flow from the backup water source. The normally open solenoid valve closes when energized and opens when power is cut off.

2. Below freezing temperature – Northern half of Alabama sometimes experiences long duration cold weather which drops temperature below freezing point. Any exposed part of RCR may be damaged by the freezing temperature. To protect the system under this extreme weather condition the pump and pipes should be either buried or be installed under a protected area such as basement, crawl space or even inside the building. Another option to protect the system is to shut down the system and drain pipelines ahead of a forecasted long duration cold weather. One RCR system, which had the control system (pump, valve, etc) inside a small wooden structure, a thermostatically controlled incandescent bulb was used to insure temperatures were kept above freezing.

3. Tree pollen in spring – The heavy pollen in spring can cause a water quality problem in the storage tank; namely, a foul smell when the pollen decomposes. The system may need to be closed (disconnection of tank inlet from the rainwater supply line) during the heavy pollen season. In Lee county, this season varies from March – May with the peak in April. A fine filter material (200-mesh) was tested to filter tree pollens at the site 5. The amount of pollen falling on rooftops is very high during the pollen season in Alabama. This filter captured all pollen from the rooftop. However, the large volume of pollen captured in the filter plugged the filter. Unless the filtered pollen is cleaned from the filter after each rainfall event during the heavy pollen season this size filter may not be appropriate for an RCR. Instead, a 100-mesh filter material was effectively used to clean the harvested water as shown in Figure 2-a. However, this filter is not fine enough to capture the size of tree pollen. Figure 2-b shows the pollen passed into a storage tank. The pollen eventually settles on the bottom of the tank and causes a foul smell when decomposing. This problem can be solved by adding 1/2 gallon of common washing machine liquid chlorine per 1000 gallon of water. Another better option to avoid the problem with tree pollen is to by-pass the rainwater from the roof during the pollen season. Figure 2-c shows the original 20-mesh filter which captured most large materials, leaves and seeds but tree pollen was passed through.

4. To minimize the hydraulic losses of the system some components of an RCR system, the storage tank, pump, and water flow control should be installed close by (within less than10 ft). Due to the landscape a system tested in this study had the storage tank positioned at more than 100 ft in horizontal distance and 15 ft lower than the pump and flow control panel. The excessive hydraulic head loss prevented the pump from moving water to the house. A submersible deep well pump had to be used at this site to solve the problem.



a. Filtered material (100 mesh filter) b. Tree pollen floating in an RCR tank after a storm event during c. Filtered material (20 mesh filter)

Figure 2. Materials captured in filters of different meshes from roof and tree pollens left in an RCR tank.

Design and operation of an RCR

As discussed before an RCR system is composed of;

- ✓ Solid roof top
- ✓ Gutters with screen
- ✓ Downspout with outlet to storage tank
- ✓ Storage tank with filtered inlet
- ✓ Pump with a pressure switch and an optional pressure tank
- ✓ Water flow control

If applicable all these components should be installed as close as possible (within 10 ft) and under protected conditions from freezing temperatures (i.e., small shed, basement or crawl space). The first three components should be available at a designated RCR site before other components are installed. Next step is to purchase a storage tank with filtered inlet and a pump. Sizing a storage tank is determined by the size of roof to harvest rainwater, volume of water needed and average monthly or weekly rainfall in the area. This study found that a 650 gallon storage tank is the optimum size for a family of four in Auburn-Opelika area, which supplies toilet flushing for two weeks at full tank. The system should be connected to the existing water source as a backup in case of low water level in the tank during no- or low-rainfall periods. It was found that a ½ HP above ground centrifugal pump or deep well submersible pump would be sufficient for single family uses. A larger pump and storage tank may be necessary for institutional uses to provide sufficient pressure and flow rate.

The most critical component of an RCR system is the water flow control unit which is set so that supplemental water can be added to the system when water level in the tank is lower than the designated minimum level. Figure 3 shows a photo of a compact water flow control developed during this study and Figure 4 shows a schematic diagram of the layout of pipes and power lines of the water flow control panel along with other components. An RCR system operates as follows assuming that the tank is initially empty.

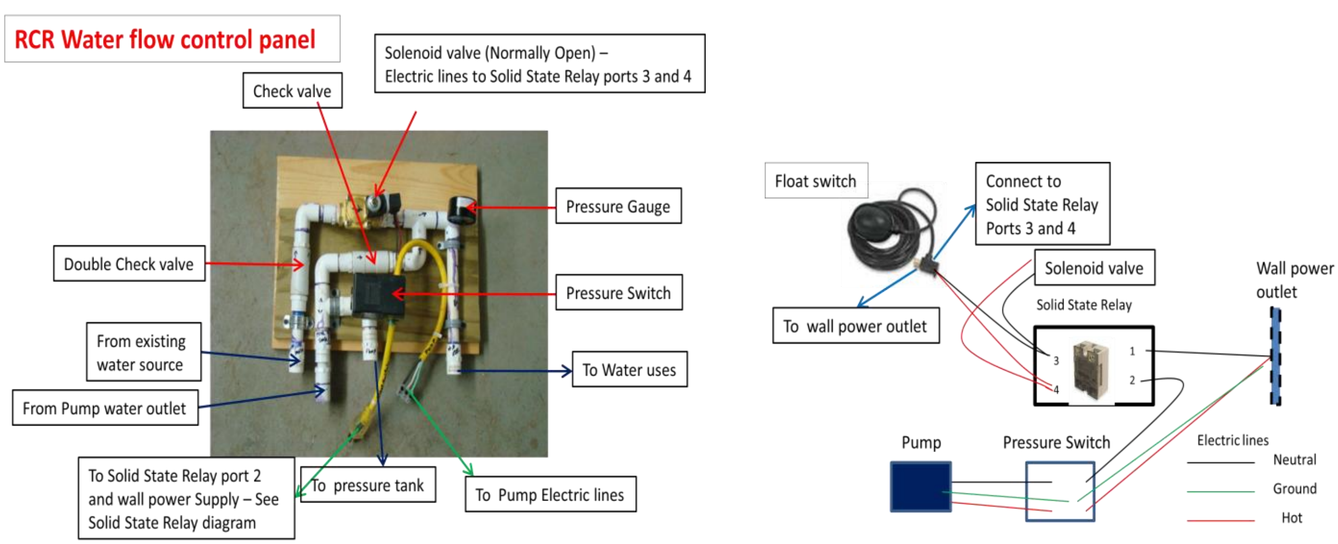


Figure 3. A photo of a compact water flow control for an RCR

1. When rain starts to fall on the roof the rainwater enters the storage tank through a filtered inlet.
2. When water level in the tank reaches the designated minimum water level in the tank the float switch turns on to energize the pump and the solenoid valve. The energized solenoid valve closes the valve from the backup water source, (i.e., city main or well). The pump turns on if water pressure in the system is lower than the cut-on pressure (10 – 15 psi) of the pressure switch until the pressure reaches cut-off pressure (40 – 45 psi). Pump turns on again when the pressure in the system drops lower than the cut-on pressure when any valve is open to use the water. When the water use valve is closed pressure in the system starts to rise as the pump continues running until the pressure reaches the cut-off pressure.
3. The solenoid valve is used to control water flow from the backup water source when water level in the tank drops to lower than the designated minimum water level. During a dry period the water level in the tank may drop below the designated minimum water level. This causes the float switch to turn off the pump and solenoid valve, which stops pumping and allows water flow from the backup water source.
4. When a valve is open to use the rainwater, water stored in the pressure tank is delivered first until the pressure reaches the pump cut-on pressure. Using a pressure tank between the pump and the water user sources helps the system avoid pump operation for a small volume water use such as a single toilet flushing. This, in turn, extends the life of the pump.
5. A double check valve is used to prevent backflow of the rainwater to the existing water source. Municipalities require such device when non-city water source is directly connected to city main. A single check valve is also used to prevent water flow from the backup source to the storage tank. If an above ground tank is used an additional single check valve should be used to keep the priming of the pump. This check valve should be installed between the pump and storage tank.
6. If a problem occurs with the RCR system, such as a malfunctioning pump the system will automatically supply water directly from the backup water source by disengaging the float switch or the system power source. This turns off the pump and opens the solenoid valve to the backup water source.

Table 1 shows the current prices (as of November, 2010) of the essential parts to build an RCR. Other materials needed include electric wire (14 AWG or heavier), PVC pipe or PEX line (1/2” ID for delivery and 1” - 1 ½” for suction), and concrete blocks. However, a concrete pad may be necessary for a larger RCR system with over a 2,000-gallon tank. The table also shows internet sites of the suppliers. Some of the parts may be available at local hardware stores. An RCR system to supply toilet flushing water for a family of four would cost $1,000 – $1,500 depending on who installs the system, by the home owner with or without professional help. If the components of an RCR are located within 10 ft of each other, most plumbing and electric installation may be done by the home owners with minimum skill and tools. Aboveground water storage tanks may be safely installed over concrete blocks instead of an expensive concrete pad if the blocks are arranged to uniformly support the weight of a full tank (830 lbs per 100 gallons). If a pump can be installed in a temperature protected area and have a small suction head (less than 10 feet vertical distance between pump and the bottom of storage tank), a shallow well pump is recommended for convenience and cost. Otherwise a deep well pump should be used to protect the pump from freezing temperature and a loss of suction head.

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Figure 4. Schematic diagram of an RCR system with a non-submersible pump.

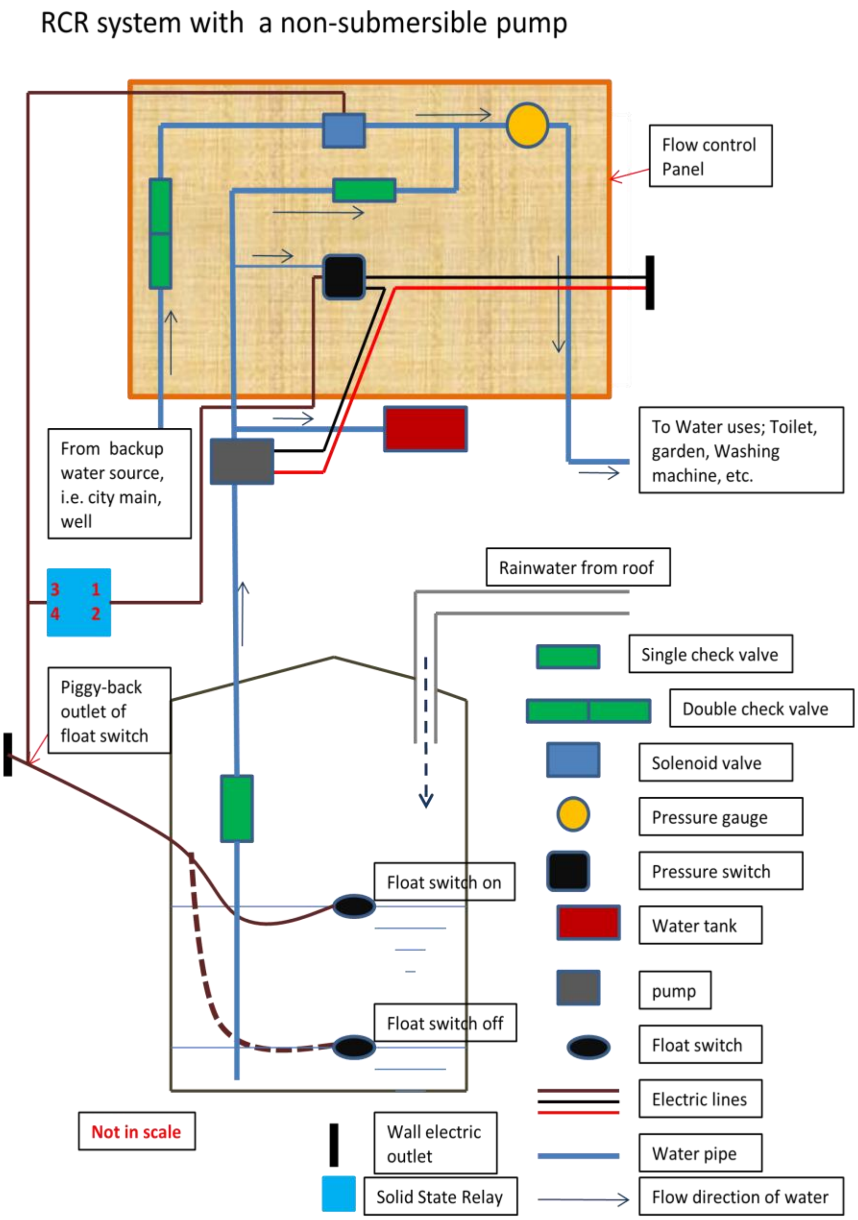

Table1. List of parts needed for an RCR system and suppliers. Prices as of November, 2010.

Items	Description	Source	w/o tax and S&H
Shallow well Pump	 Shallow Well Jet Pump System, Cast Iron, 1/2 HP, Voltage 115/230, Suction Pipe Size 1 1/4 In., 3/4 NPT Outlet, 7.2/3.6 Amps AC, 6 Gal water tank, pressure switch	www.grainger.com	$397.13
Deep well pump	 ½ HP, 230 v, 10 GPM	www.grainger.com	$375.98
Pump water tank	 5.3 Gal	www.grainger.com	$101.39
Float switch – Normally Open	 **Float Switch HD** Item # 3BY61 Float Switch, Mechanical, Tether, Normally Open, Max. Amps Running 13, Voltage 115, Cord Length 20 Ft., Wire Gauge 16, Pumping Range Min./Max. 5 to 30	www.grainger.com	$50.36
Pressure switch	 30-50 psi	www.grainger.com	$20.57
Solid State Relay	 120 v AC	www.grainger.com	$29.39
Solenoid valve – Normally Open	 Energy Efficient Buna-N Diaphragm. Normally Open – Open until electrically energized. ½" 115 volts AC	www.mcmaster.com	$91.89
Dual-Check Valve	 Copper NSF-Certified Backflow Prevention Valves ½"	www.mcmaster.com	$37.09
Pressure gauge	100 psi max with 2 psi graduation and 10 psi numeral increment	Any hardware store	$5 - $10
Water tank – above ground	 550 gallon fresh water tank – Size 64" (Dia.) x 46" (H). Tank includes an 18" vented lid and comes with a 1-1/2" bulkhead fill fitting and 2" bolt-on drain fitting with siphon. Tanks are manufactured from medium-density polyethylene with U.V. inhibitors. A concrete pad is recommended for installation. However, tanks may be placed on any flat level "compacted" surface. 125 lbs.	www.gototanks.com	$368
Water tank – Underground	 Norwesco 550 Gallon Below Ground Cistern **Capacity:** 550 Gallons **Size:** 64"D x 64"H **Weight:** 198 lbs.	www.tank-depot.com	$648.99
Water tank inlet filter	 16" rainwater collection adapter	www.tank-depot.com	$57.59
Plastic filter material	140 x 104 mesh 0.0059 sq inch opening 40" wide	www.mcmaster.com	$11.28 per ft