Tapping into the Water Cycle

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Introduction

70,444 gallons of water runs off my 2462 square foot roof yearly, and still, water scarcity is a major threat to humanity. Water scarcity occurs when we overuse water and release it back into the ocean too quickly. It is estimated that 38000 cubic kilometers of water is transported from the ocean to land yearly. About 38000 cubic kilometers of water makes its way back to the ocean yearly through surface runoff and groundwater flow (Bengtsson 2010). Increasing the rate of land-to-ocean flow while the ocean-to-land flow stays stagnant will result in drought and famine. Water scarcity is a major issue worldwide. Water is a finite resource that has a constantly increasing demand. Agriculture requires water; without it we would not have food. To support our global population, agriculture requires 7130 cubic kilometers of water yearly (Mancuso et al. 2015). Agriculture consumes 19% of the yearly ocean-to-land water transport. We need to make sure we tap into the water cycle sustainably to ensure not to disrupt it.

The water cycle is the natural flow of water through the atmosphere and throughout the planet. The water cycle is complex and made up of multiple different processes (Figure 1). Water evaporates into a vapor that condenses into clouds. Clouds precipitate into rain or snow and fall back to earth. Water flows across the land as runoff. Once on the ground, water can infiltrate or percolate into the earth. Water flows through the ground as groundwater. This groundwater can be taken up by plants, eventually transpiring out of the plants into the atmosphere (Water Cycle). The amount of water precipitated from saline water sources into fresh water is dynamically limited. Precipitation changes depending on the location and time of the year. If we overuse water and increase the flow of fresh water to the ocean, water scarcity is likely to be an issue. Sewer systems are the current normal for diverting used water back into the water cycle. The big issue with sewer systems is they fast track the water to the ocean skipping over ecosystems downstream that require water to thrive.

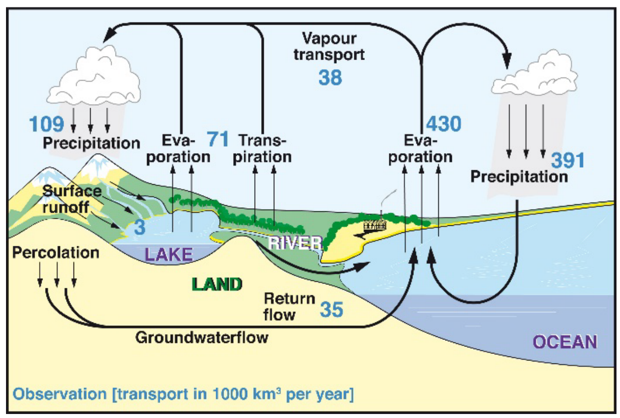

Figure 1 Water Cycle (Bengtsson 2010)

Humans consume a lot of water; Americans consumes the most. The Average US citizen consumes around 156 gallons a day. High consumption causes water scarcity and pollution. Water scarcity occurs when we circumvent the natural flow of water through the ecosystem, skipping parts of the water cycle. If we keep the water cycle in mind, there are ways to sustainably tap into it. Approaches will vary depending on the local climate and hydrologic context. Active rainwater collection and passive groundwater collection will be examined. Determining the water potential, methods of collection, and filtering needs will be discussed for each approach. To close the loop and return water back into the water cycle, bioinfiltration will be discussed.

Active Rainwater Collection

In areas with adequate rainfall, rainwater collection is a viable option to tap into the water cycle. Calculating the amount of potential rainfall runoff is the first step in deciding if this is the ideal method for one's property. Once it is decided that there is enough runoff, the focus turns to water collection. It is important for one to examine the entire collection path to limit pollution potential. Intended water use will dictate the level of filtration required. It is important to test the water for any impurities before consuming or using it. Once filtered, the water needs to be stored in a way to avoid contamination. Some situations are better suited to active rainwater harvesting compared to others.

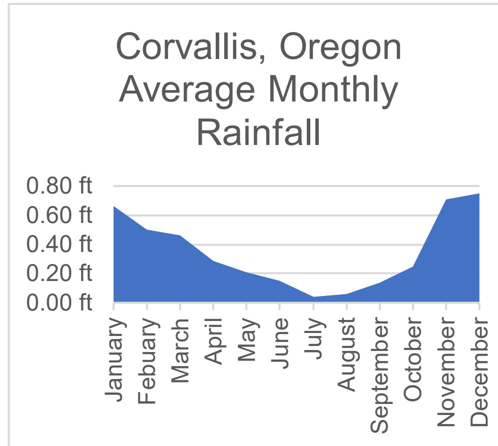

Figure 2 Corvallis Ave. Monthly Rainfall

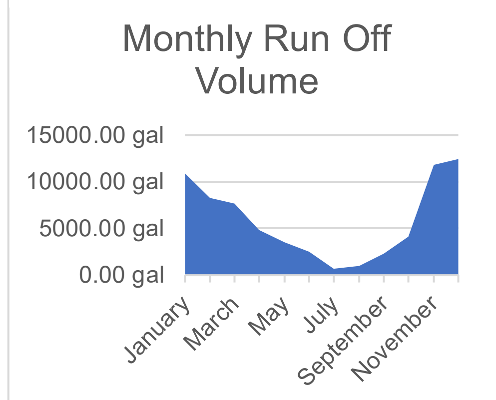

Figure 3 Potential Monthly Runoff of my Roof.

Calculating potential rainwater runoff volume is a fairly simple process. First, one should look up the average yearly rainfall for a location. Corvallis, Oregon, receives an average of 4.25ft of rainfall annually (Figure 2). Then, calculate the area of the rainwater collection surface. The roof of my house in Corvallis has an area of 2462 square feet. A runoff coefficient relates the amount of runoff to the amount of precipitation received. More permeable membranes will have a lower coefficient number. A galvanized iron roof has a runoff coefficient of 0.9 (Kumar 2004). Multiplying average precipitation by the surface area of the roof by the runoff coefficient, will give a runoff volume in cubic feet. A total of 9,417 cubic feet of water runs off my roof yearly (Figure 3).

Roof Runoff Volume Formula

Yearly Precipitation x Roof Area x Runoff Coefficient = Yearly Runoff Volume

$$4.25\ ft \times 2462\ ft^2 \times 0.9 = 9417\ ft^3$$

The method of collection is an important factor to consider (Figure 4). If rainwater is intended for human, animal, or plant consumption, it is important to have clean water. The collection path needs to be made of materials that won't leach impurities into the water. Metal roofs provide an ideal surface to collect rainwater for human consumption. Gutters ideally are made of galvanized steel that is seamless. The gutters being seamless allows water to flow freely to the downspout with out restriction. Leaf screens are useful to install between the gutter and downspout. As the water flows off the gutter into the downspout, a slanted screen is installed to filter out large particulate. This screen is the first filtering stage. The screen diverts leaves and other large particulates out of the stream of water. First-flush diverters are placed after the leaf screen and are the second stage of filtration. When rain runs off the roof and down the downspout, it first flows into and fills the lower volume of the first flush diverter. As the water fills the volume, sediment settles in the bottom. The water fills the diverter and overflows into a storage tank. Anything denser than water should be left in the diverter.

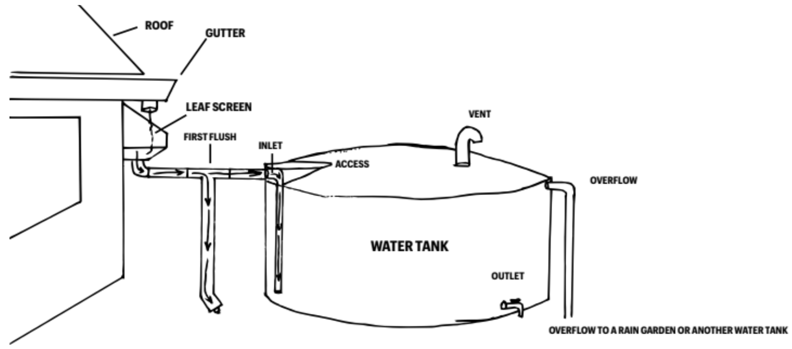

Figure 4 Ideal Rainwater collection Setup (Millison, A. 2021)

The runoff will be collected and stored in large water tanks. Storage tanks should be located at high elevations to allow gravity to help with water dispersal. These water tanks have an inlet where water flows in from the first flush diverter. It is wise to have a downpipe at the inlet to release the inflowing water near the bottom of the tank to reduce water disturbance. This helps purify water by settling contaminants that are denser than water. The tank needs a vent to prevent a vacuum from imploding in the water tank. The outlet valve should be slightly higher than the bottom of the tank to prevent sediment from flowing out. To avoid the sediment at the bottom of the tank, one can attach a hose on the inside of the tank to the outlet port. On the other end of the hose a float should be attached to keep the intake of the hose a couple inches below the water level (Figure 5). This ensures the outlet valve intake is positioned in areas of relatively clean water. An overflow pipe should be placed slightly lower than the inlet. So, when the tank fills, it has a place to overflow to. This overflow should be directed into either another water tank or back into the water cycle through infiltration, possibly through a rain garden. When multiple tanks are lined up, each tank should remove settled sediment, cleaning the water as it progresses through the storage tanks. While this does help clean the water, further filtration may be needed depending on usage.

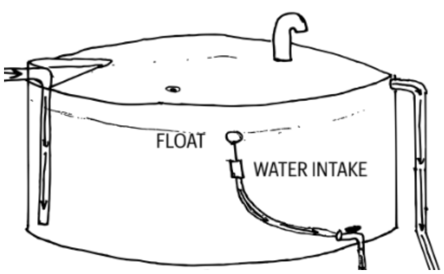

Figure 5 Float valve positioned on intake to ensure intake of the cleanest water available in storage. (Millison 2021)

Rainwater should be filtered before humans, animals, and plants consume it. Exposure to air can contaminate the water, causing it to become acidic and possibly pollute with heavy metals like lead (Khayan, et al. 2019). Any material in the path of the collection has the potential to leach heavy metals and contaminate the water. A solution is to treat the water with a water filter. A simple filter can be made from three commonly available media; sand, activated carbon, and gravel. Water first flows through the sand, filtering out larger particles. Then the water flows through activated carbon. The many pores and immense surface area of carbon help remove contaminants from the water. The water can flow down, up, or horizontally. In my experience building carbon filters, I prefer to have the water flow upwards, so gravity can help in the filtering process. Although, others have had success with a downward or horizontal flow.

A study conducted in West Kalimantan used mollusk sand, active carbon, and gravel to build filters for multiple test sites. The mean before-treatment concentration of lead across four different villages was 131.7 μg/l. After the water was treated with the filters, the mean concentration of lead was 0.71 μg/l. Water is safe to drink if its lead concentration is less than 10 μg/l. The mean turbidity levels were reduced by treatment from 20.00 NTU to 5.67 NTU. Turbidity measures the number of suspended solids in the water. The filter treatment adjusted the mean pH of the water to change from 5.16 to 6.95. Safe drinking water has a pH of between 6.5 and 8.5 (Khayan, et al. 2019). These filters can purify water to safe to consume levels. Adding on redundant filters and possibly using a Reverse Osmosis filter can further purify water.

Active Rainwater Harvesting is a terrific option for tapping into the water cycle. In places of abundant precipitation, tons of water can be harvested at a relatively affordable cost. Lack of rain to harvest in dry months can create water insecurities. If water use is unmanaged, tanks will likely stay dry during the summer or in droughts. Passive groundwater harvesting is an alternative to active rainwater harvesting.

Passive Groundwater Collection

Passive groundwater collection may be the ideal option for tapping into the water cycle if there is access to an aquifer. A well can be drilled to access the aquifer, and a pump is used to harvest the water. The entire connected watershed acts as a rainwater harvester, and the aquifer is the planet's storage tank. Geographic information systems can be used to evaluate the potential of groundwater zones. A recharge test and impurities testing should be conducted to assess the groundwater's availability and quality. Once the quality and availability of groundwater are assessed, collection and storage can be designed and established. Groundwater quality and intended usage will determine the filtration required.

Geographic information systems are a useful tool in determining the availability of groundwater. Groundwater availability can be assessed by analyzing the geology, soil, land use, lineament density, and drainage density on GIS maps. Areas of high groundwater potential exist downstream in flat zones, which maximize infiltration due to low runoff coefficients (Andualem 2019).

Before removing water from an aquifer, it is important to assess how fast it will refill, or recharge. A recharge test can be performed to figure out the rate of recharge. Heart Rock Ranch in San Miguel, California, receives only 17 inches of rain a year but luckily resides on a large aquifer. Before the property was purchased a recharge test was performed by Filipponi & Thompson Drilling Inc on a preexisting 287 foot deep and 5 inch wide well. The well's static level was reported to have a depth of 79 feet from the surface. The well pump was set at a depth of 260 feet. During the recharge test 39,075 gallons of water was pumped out of the well over a period of 26 hours. (Figure 6) After which the pumps are turned off and the rate of recharge is observed (Figure 7). Over a duration of one hour the water level rose from a depth of 182.7 inches to 146.9 inches from the surface. Heart Rock

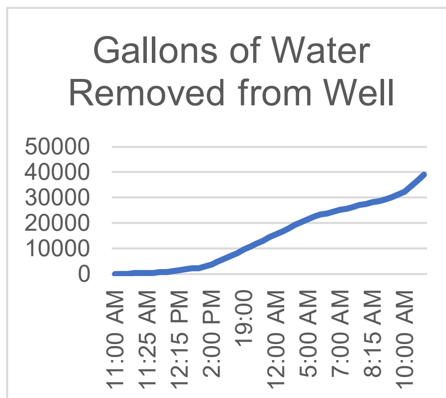

Figure 6 Gallons of Well Water Removed (Filipponi & Thompson Drilling Inc 2013)

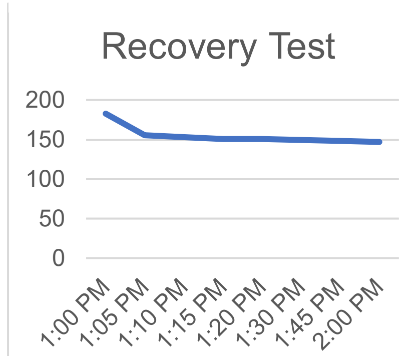

Figure 7 Well Recovery Test (Filipponi & Thompson Drilling Inc 2013)

Ranch's well recharges at a rate of 35.8 feet per hour (Filipponi & Thompson Drilling Inc 2013). The well recharges at 353 gallons per hour, 8462 gallons per day.

While the earth works as a fantastic biofilter, groundwater must be tested for impurities before consumption. Well water samples can be analyzed by one of the many water testing labs in operation. Well water tests can evaluate the pH, total dissolved solids, turbidity, conductivity, and hardness of the water. They can determine the concentration of contaminants as well. The same tests used to test rainwater can be used to test well water. Heart Rock Ranch sent samples of their well water to the Consolidated Chemistry Laboratory of the Monterey County Health Department to be analyzed. Due to the high limestone content of the land, their water is slightly alkaline and has a high hardness level. This hardness can be treated with water softener systems. The total dissolved solids were found to be at a concentration of 1400mg per liter. An active carbon filter system like the rainwater filter could help increase the purity of the groundwater.

Closing the Loop – Bio-infiltration

Bioinfiltration is an important part of sustainably tapping into the water cycle. Bioinfiltration encourages water to infiltrate into the soil reducing surface runoff while recharging aquifers. America is one of the biggest consumers of water, and sewer systems are the common method of returning water to the water cycle. Sewers divert the used water and fast track it to the ocean, skipping the flow over land or infiltration into aquifers. With the amount of ocean-to-land water transport being limited, fast tracking water back to the ocean will cause water scarcity. To combat this, bioinfiltration techniques like grey water filters, rain gardens, and earth works can be implemented. These methods reintroduce water back into the water cycle by allowing it to slowly infiltrate into the earth at the point where the water was used. Earthworks are a way to adjust the landscape to help reduce runoff and encourage water to recharge aquifers.

The first step of bioinfiltration is to ensure not to add pollutants back into the water cycle. Grey water filters are a simple way to do this. Grey water is domestic wastewater that is not contaminated with fecal matter or other highly toxic contaminates. Grey water can be diverted to grey water filters to purify before releasing back into the water cycle. A grey water filter consists of a gravel filled basin that is lined with an impervious liner (Figure 8). Wetland plants are planted into the basin. These plants' rhizosphere contains biology that can break down pollutants (Millison, A. 2021). Grey water flows slowly from one end of the system to the other, maximizing water contact with the plants rhizosphere's that filters the water. Barriers can be placed in the filter to ensure the water moves throughout the full system. Greywater filters are simple systems that can help remove contaminants from domestic wastewater before returning the water into the water cycle.

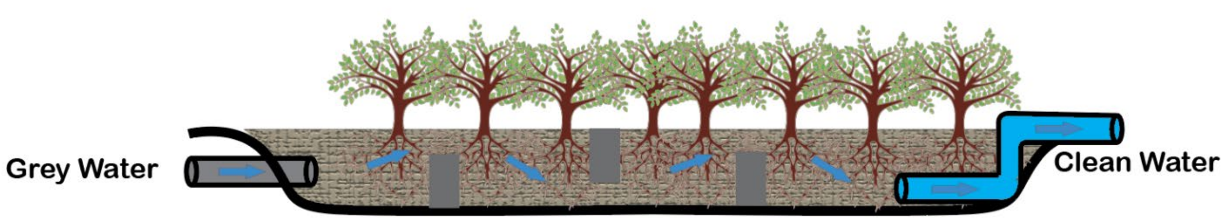

Figure 8 Grey Water System (Millison 2021)

After greywater has moved through the filter, it should be reintroduced into the water cycle by infiltrating back into the earth. Rain gardens or biorentions are way to accomplish this. A rain garden is a native plant garden located in a depression in the landscape (Figure 8). Rain gardens allow runoff to pool up and slowly infiltrate back into the ground. The plants' roots allow pathways for the water to flow into aquifers. These plants also uptake some of the water that flows into the garden and transpires it back into the atmosphere, back into the water cycle.

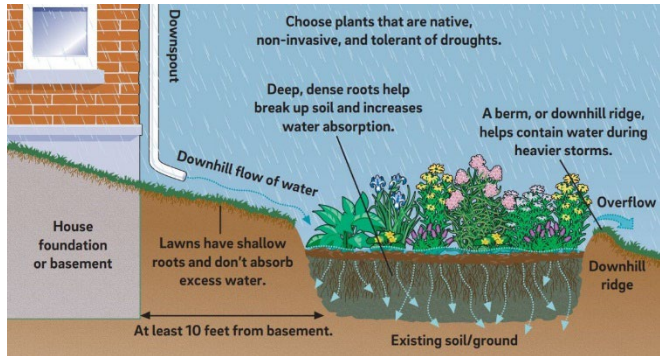

Figure 8 Rain Garden (Residential Rain Garden Diagram.)

The final topic of bioinfiltration is earthworks. Earthworks help slow the land-to-ocean transport of water. This can help increase available fresh water and recharge aquifers. Earthworks are changes made to the landscape to slow surface runoff and increase bioinfiltration. A rain garden is a type of earthwork. Swales, terraces, and berms are all forms of earthworks. Swales are a shallow trench dug along the terrain contour lines (Figure 9). These trenches spread the runoff evenly across the contour line increasing infiltration while decreasing runoff. Earthwork design starts with examining topography maps of your location. Areas with steep terrain will have a high level of surface runoff. Bio infiltration can be increased by reading the land and placing swales and berms in areas to reduce the flow of runoff. Swales can be used to divert rainwater into areas that require irrigation. Reducing the amount of water required to pull from the water cycle.

Figure 9 Swale with water infiltrating into the soil. (Stross 2022)

Conclusion

As the threat of water scarcity increasing becomes a larger issue, we need to make a change. Earth's human population just passed 8 billion people, and the ocean-to-land transport of water remains at a stagnant rate. We need to be conscious of our water usage and work symbiotically with the water cycle to ensure water for everyone. While it would be great to see a large change in the current hydrologic system by city planners and politicians, the best first step is to make changes at home. Analyze water usage and see how much could be supported from the water that falls on a roof or may potentially be available in a nearby aquifer. Establish filter systems to ensure the local community has access to clean drinking water. The most important step is properly closing the loop and returning the water back into the cycle through means of bioinfiltration. Landscape should be view as a large rainwater harvesters and earthworks should be used to help reduce runoff and recharge aquifers.

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