Automatic Rainwater Collection and Storage System

An Interactive Qualifying Project Report
Submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science.
Submitted April 28, 2024
Worcester Polytechnic Institute & American University of Armenia

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Abstract

In collaboration with Armenia Tree Project (ATP), this project sought to contribute to efforts that mitigate deforestation and water scarcity in Armenia. It included the installation of two automated rainwater collection and storage systems at the Karin Nursery, in addition to providing construction and maintenance manuals to ATP. This aimed to make the rainwater collection system operate independently, making it more useful in the nursery, thus decreasing their reliance on other water sources.

Acknowledgements

There were many individuals who helped this project come to fruition. We would like to thank Laura Bond for her teachings during the ID2050 preparatory course. We also would like to thank Ani Melkonyan, Hovhannes Sahakyan, Jeanmarie Papelian, and Roussane Arustamyan from Armenia Tree Project for their support. Additionally, we would like to than Dr. Garabet Kazanjian from the American University of Armenia (AUA) for his aid. Finally, we would like to thank our advisors for all of their continued support throughout this project: Karen Oates, Hrachya Kocharyan, and Norayr Ben Ohanian.

Executive Summary

Armenia is a landlocked country located in the lesser Caucasus Mountains. One of the major challenges to the biodiversity and general health of Armenia is widespread and severe deforestation. The history of deforestation in Armenia is long and has devastating effects on the capabilities of the nation. First starting in the late 18th century, the discovery of copper and other minerals led to unchecked use of forests for charcoal production and as fuel. Under the early years of the Soviet Union, unchecked use of the forests combined with ineffective forestry practices which led to tree coverage dropping significantly. While the later years of the Soviet Union saw a rebound in the tree coverage of the country, the fuel crisis in the early 1990's led to another significant drop in tree coverage. The fuel crisis saw nearly all natural gas supplies cut off, leading most people to rely on wood to heat their homes and cook food. The amount of people reliant on wood for fuel, combined with the duration of the crisis, led to forest coverage to be lowest it's been since the early Soviet Union.

In tandem with the issue of deforestation, increasing water scarcity is also a motivator for this project. Water availability is starting to become an issue across the country. Current estimations for the water level of Lake Sevan are poor, with expected water level decreases, and access to well water becoming more constricted as a response to overuse, obtaining water has been getting more difficult. The implementation of this prototype is meant to reduce the amount of water being used from Lake Sevan, while still being able to keep the nursery running at its usual capacity. Collected rainwater is a good first step in this direction.

In response to the significant deforestation that the country experienced in the 1990's, Armenia Tree Project (ATP) was founded by Mrs. Carolyn Mugar to help alleviate the stress on the forests. ATP specializes in the raising of tree saplings, utilizing a combination of nurseries

and backyard nurseries to raise trees from seeds to saplings ready to be planted. The tree nurseries work by employing people from local villages, providing jobs while also raising trees. ATP has several nurseries throughout Armenia, each one raises different types of plants. For example, the Margahovit nursery focuses heavily on raising pine trees while the Karin nursery raises a wide variety of plants, including some that are not trees. The prototype that our team developed was meant specifically for the Karin nursery, as it is the nursery that experiences the least amount of rainfall.

The goal of this project was to design a prototype system that can automate the collection and storage of rainwater. The prototype is meant to function with minimum human input and primarily supplement the current water source in the spring and fall. To achieve this goal, our team outlined three objectives.

1. Evaluate design characteristics for the Karin Nursery and the project feasibility.
2. Prototype the electrical components of an automated rainwater distribution system in the Karin Nursery, then turn it over to ATP for deployment.
3. Create construction and maintenance manuals for employee and general use.

To achieve objective 1, several steps had to be taken. This objective began in the prep class for this project. Over the course of several meetings, the team asked questions about the layout of the nursery, relevant data on water use, as well as looking at google maps to get approximate distances and layout information. Once the team arrived in Armenia, it was possible to ask questions in person about the capabilities of the Karin nursery. During these meetings, we figured out more about the nursery that could not be communicated over online meetings. Finally, we visited the nursery where our team took measurements and got a better understanding of the layout and needs of the Karin Nursery. Our team then used precipitation data for the region along with our understanding of the layout to determine the project's feasibility and estimate how much rainwater could be collected.

To carry out objective 2, the team had to research components that would make the prototype work as requested. This involved an extensive search, the team looked at designs that worked in similar ways, consulted with people with electrical backgrounds, and analyzed local material availability to determine what was possible for the prototype. The team also had to consider the sponsor's requests, making sure all requested features were either included or substituted. Safety was the first thing considered with this design, and as a result, much research was done on how to safely manage the voltage and current that the system will demand. Combining research and consultation, a final prototype design was proposed to ATP.

To achieve objective 3, the team did research into various software's that can be used to make an effective manual that could be understood regardless of the background of the reader. Several platforms were considered, and the team decided that Canva works the best for the manual. The manual consisted of several different methods for communicating information and instructions. The team focused on including text instructions, in English and Armenia, simplified electrical diagrams, and images taken from the installation of the prototype by ATP.

Based on the findings and results of these objectives, several conclusions and recommendations can be made. The team's first recommendation for ATP is continued maintenance of the prototype and any modifications made to it. As previously mentioned, safety was a major concern when designing this prototype, and part of ensuring that safety remains the focus is the continued maintenance of the prototype. Seeing as ATP decided to implement the prototype, several steps should be taken to ensure that it works as intended and operates safely. These steps include routine checkups on the integrity of components, being aware of the risks that come with the combination of water and electricity, as well as ensuring that all staff is aware that the prototype is in place and what that means for daily operations.

The next recommendation that this team has is the upgrading of the metal rainwater collection tank behind the education center. As of the time of writing this paper, the tank is rusted and leaking. While this rust and leakage do not pose any threat to the safety of nearby electronics or the amount of water able to be stored, in the future these issues could arise and cause serious damage, and the tank should be replaced before it fails.

The third recommendation is the connection of the 5000 L tank behind the education building and the set of tanks farther from the building. This is already planned by the lead engineer, Mr. Sahakyan. The prototype is designed to allow this expansion with

The final recommendation is to complete the gutter coverage on the roof of the education building. As of writing this paper, there is a section of the roof that cannot collect rainwater; this lack of coverage significantly decreases the amount of water available to be collected. Completing this section of coverage will increase the amount of water collected by a notable amount.

Based on the project results and the deliverables and recommendations made, the team feels that the project goals were met, and the prototype can function as intended. The manuals made as part of objective 3 communicate the instructions effectively for users with multiple backgrounds and the tests conducted with the prototype have proved successful so far.

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1. Introduction

Water scarcity, deforestation, and sustainability are critical issues facing the planet today. In Armenia, deforestation has been a significant issue historically, and it has had negative effects on both the community and the environment. Copper mining during the Industrial Revolution, an increase in population, the Soviet Union's forest-surveying techniques, and the fuel crisis during the war with Azerbaijan are some of the main causes of deforestation throughout history in Armenia. Reforestation aims to mitigate the loss of biodiversity, lack of natural resources, and the erosion that occurs due to deforestation. Armenia is a landlocked country, leading it to be heavily reliant on its internal surface and ground waters. However, it has experienced water misuse, particularly involving Lake Sevan, leading to water depletion within the country (Kirakosyan, 2011). Water scarcity presents a threat to both ecosystems and human communities, and the trends of water depletion and increased pollution lead to conditions like eutrophication and algal bloom. The high level of nutrients associated with these water conditions can pose health issues for wildlife and humans alike. The concurrent issue of deforestation aggravates this crisis, disrupting water cycles and further diminishing available water sources. This lack of easily accessible water limits many communities in their agricultural and reforestation efforts. Addressing issues such as water scarcity, deforestation, and sustainability has become a necessity. In undertaking this project with ATP, the aim was to mitigate the water scarcity that Armenian communities face. ATP is a nonprofit organization that tackles a variety of environmental issues within Armenia while aiding vulnerable communities, such as refugees and isolated individuals, among others. ATP empowers them by employing them in backyard nurseries and reforestation efforts, thereby helping them pursue economic independence. The organization addresses issues such as reforestation, biodiversity, environmental awareness, and sustainability. This project involved evaluating the physical characteristics of the nursery, designing a cost-effective automatic rainwater distribution system, identifying suitable materials for implementation in the local context, and developing construction and maintenance manuals for the employees of the Karin Nursery. By doing so, the aim was to reduce their reliance on their current water system, lower operational costs in the nursery, and demonstrate commitment to sustainable and responsible practices with natural resources. Through collaborative efforts with ATP, it is hoped to contribute to the broader goal of reforestation in Armenia.

2. Background

The Armenia Tree Project is tackling a variety of environmental problems within Armenia. In this section, the issues surrounding deforestation and water scarcity that affect the communities that ATP works with are discussed. Then, the sponsor is introduced, Armenia Tree Project, and explain their mission, in addition to describing their past work with WPI. Lastly, some key concepts regarding rainwater collection and storage are covered to provide important scope to the project.

2.1 Deforestation in Armenia

Deforestation is a problem that has been affecting Armenia for hundreds of years and in a variety of manners. The climate and location of the Republic of Armenia present a unique set of environmental challenges. Highlighted by mountainous terrain and large plains, Armenia is very arid and has trouble planting and preserving forests and nurseries (Opala-Owczarek et al., 2021 and United Nations Developer Programme, n.d). These difficulties with geography are compounded by controversial survey-taking and reforestation efforts conducted by the Soviet Union during its early years (1920-1950), and over-exertion of natural resources on a local and national scale (Sayadyan & Moreno-Sanchez, 2006). The combination of all these factors, among others, has led to drastically lower forest coverage in Armenia than ever before (Sayadyan & Moreno-Sanchez, 2006). The lack of forest coverage affects more than just the environment and conservation efforts. The livelihoods and safety of the Armenian people are put in jeopardy without the benefits that forest coverage provides.

Industrialization has long been the culprit in the deforestation of Armenia, starting as far back as the late 18th century. At this time copper mining and processing started to pick up in the region. The process of refining copper takes a lot of charcoal (Sayadyan & Moreno-Sanchez, 2006), which is made from wood. This resulted in a lot of trees being chopped down and used during the production of copper. The exact damage that copper processing did cannot be confirmed, as there is very little climate data on the region (Opala-Owczarek et al., 2021) and the exact tree coverage at the time can only be estimated. According to experts in the early to mid-20th century, the forest coverage at that time was probably around 18% (Sayadyan & Moreno-Sanchez, 2006). The forest coverage estimate at the end of the peak copper production was just slightly above 9% (Sayadyan & Moreno-Sanchez, 2006); as seen, the forest coverage was halved. Armenia has not yet recovered from this dramatic loss of forest coverage.

Another source of deforestation in the region is the increase in population throughout time (Sayadyan & Moreno-Sanchez, 2006). The most impactful of these population spikes occurred between 1920 and 1960, which were the first 40 years that the Soviet Union had control of Armenia. This period saw the population increase by almost 1.5 million people (Sayadyan & Moreno-Sanchez, 2006), and due to the mountainous terrain (Opala-Owczarek et al., 2021), people were forced to cut down forests to make room for roads, cities, villages, and livestock fields. All of these factors led to a significant decrease in the forest coverage. The issue has persisted throughout most of the history of the country, but the spike during this period stands out as the most significant with the longest-lasting effects.

The third major contributor to deforestation in Armenia was the Soviet Union’s survey and reforestation techniques, which created a long-lasting legacy in the country. For the first 30 years of the Soviet Union's time in Armenia, the surveys conducted were haphazard and insufficient. Their methods relied heavily on visual observations by their experts, often unfamiliar with the area being surveyed (Sayadyan & Moreno-Sanchez, 2006). Since the visual survey method was extremely subjective, the overall coverage, health, and age of the forests were being massively underestimated. This issue was also compounded by the lack of statistical grouping, meaning that every forest was observed and no extrapolation or grouping was done to better understand a region of forest (Sayadyan & Moreno-Sanchez, 2006). Both of these factors led to the early Soviet Union overestimating their ability to sustainably take from the forests, leading to an estimated 8.1% forest coverage in 1956 as compared to 18% just a century earlier. This was alarming to the Soviets, so efforts were made to increase the forest coverage, and by 1986, 11.2% of the country was forested, the highest it had been under the Soviets (Sayadyan & Moreno-Sanchez, 2006).

Finally, a fuel crisis caused by a war with Azerbaijan compounded the issue of deforestation. During the fuel crisis the natural gas lines to Armenia were shut down, forcing people to turn to wood as a necessary alternative source of heat and fuel. Since the winters in Armenia are extremely cold, reaching at least 0°C in Yerevan and colder in the mountains (Sayadyan & Moreno-Sanchez, 2006), fuel for heat is required to survive. The reliance on wood as a fuel source led to a significant drop in forest coverage, the most conservative estimates present a decline of 3-4% from the 11.2% of the 1986 survey (Sayadyan & Moreno-Sanchez, 2006).

The effects of this drop in forest cover are significant and still felt today. They appear as two main issues: the safety and health of the land (Vardanyan et al., 2017), and the accessibility to firewood that many Armenians rely on (Perge, 2020). Forest cover and trees are essential for the safety of roads and control of runoff and rainwater in a less mountainous region, but are especially important due to Armenia's mountainous terrain. Trees strengthen the upper layer of topsoil (Vardanyan et al., 2017), both by adding their roots to the overall structure of the soil and by encouraging the decomposition that keeps the solid healthy and strong. Because of the mountainous topography of the region, landslides and avalanches are already a threat, but without trees adding their root strength and support, the chances of these events occurring and their severity increase. Additionally, without trees, the rich top layer of soil is not enriched, and the regions that rely on agriculture to survive and make a living need healthy soil to do so.

The other major concern with diminishing forest coverage is the need for more wood for fuel. Many Armenians, primarily those who live in rural communities, rely on wood for at least heating, if not cooking. A World Bank study found that nearly 60% of Armenians who live in rural communities use wood for heat (Perge, 2020). This has put a strain on the forests of the country, as a significant amount of people utilize its resources. This usage also demonstrates how important maintaining the forests is, seeing as 60% of people in rural communities rely on them for heat. There have been efforts made to increase access to natural gas in these rural communities to reduce the reliance on wood, but the efforts have yet to replace wood as a staple heat source. The usage of natural gas for heat sits at just under 40% (Perge, 2020). For this reason, and many others, the forests of Armenia are important to the land and the people living there, and their continued growth and existence are crucial to many people's daily lives.

2.2 Water Scarcity

The availability of water has a direct effect on the condition of trees, indicating the importance of the connection between water and reforestation efforts. Trees are more than 50% water and require a consistent supply to grow and thrive. A healthy 30-meter (100-foot) tall tree may extract 42,000 liters (11,000 gallons) of water from the soil and return it to the atmosphere as oxygen and water vapor in a single growth season (Somvichian-Clausen, 2016).

Due to the landlocked nature of Armenia, the country is heavily reliant on its lakes, rivers, and groundwater. Being home to more than 100 small lakes, around 9480 rivers, and at least 80 reservoirs and underground springs, Armenia continues to face the problems of irrigation (Hetq.am, 2014). After the fall of the Soviet Union in 1991, the resulting rapid urbanization, mass consumption, water misuse, and increased water pollution contributed to the existing water scarcity in Armenia (Abrahamyan, 2021). The effects of the change in government and population boom led Armenians to overuse and misuse these internal waters, worsening the issue of water scarcity in the country. However, the biggest challenges have been brought on by climate change. This is evident through a 9% average annual precipitation decline between 1935 and 2016, as well as more frequent and intense hydrometeorological disasters such as extreme temperatures and flash floods (Arakelyan, 2023).

The quality of water resources has been impacted by a variety of anthropogenic activities, particularly climate change, leading to the total destruction of water reserves and ecosystems (Arakelyan, 2023). The atmospheric precipitation is projected to decline by up to 8.3% by 2100 in Armenia. The examination of climate change scenarios also suggests an adverse impact on Lake Sevan's ecology; under the pessimistic scenario, the total river inflow into the lake is anticipated to decline by 34% (265 million m^3) by 2100 (Ministry of Environment of the Republic of Armenia, 2020). Climate change is going to increasingly negatively impact the country's water resources, energy, agriculture, and ecosystems, among other vulnerable areas. (Ministry of Environment of the Republic of Armenia, 2020).

Sevan is Armenia's most significant lake, and one of the world's largest high-mountain freshwater lakes. It is known for its distinct ecosystem, but changes in water levels, which have become more frequent in recent years, have caused ecosystem disruption. This has been exacerbated by the entry of harmful chemicals and organic materials into the lake, which has negatively impacted its rich biodiversity (*Freshwater*, n.d.). While Armenia supposedly utilizes about 7.3 billion cubic meters of inflowing water per year (from rivers and underground sources), some analysts claim that Armenia can only take advantage of between 2 and 2.3 billion cubic meters of this water.

2.3 Armenia Tree Project

The sponsor, the Armenia Tree Project (ATP), has aided in planting more than 6.6 million trees in Armenia, fueled by their mission to "assist the Armenian people in using trees to improve their standard of living and protect the global environment" (Armenia Tree Project, n.d.). Not only have they developed tree-planting programs, but ATP has expanded to provide educational content throughout programs in both Armenia and Massachusetts, where Armenia Tree Project was created and is now based (Armenia Tree Project, n.d.).

Witnessing the deforestation that resulted from the "Dark Years" after the dissolution of the USSR, Mrs. Carolyn Mugar founded the Armenia Tree Project in 1994 (Armenia Tree Project, n.d.). The Armenian restoration efforts truly began at the Mirak Family Reforestation Nursery in 2005, located in the Margahovit Village. This has since expanded to include the Karin Nursery in Aragotsotn, the Khachpar Nursery in Ararat, and The Betty Nursery in Vayotz Dzor (Armenia Tree Project, n.d.). Not only do these nurseries contribute to reforestation efforts, but they also work to plant productive fruit trees in varying communities. This not only brings back greenery to communities that have utilized logging for survival but also aids in alleviating food insecurity throughout the whole country.

Before beginning the current project, ATP has partnered with many Inter-Qualifying Project (IQP) groups from WPI to complete impactful work within Armenia. Most recently, the 2023 team worked with them to address greenhouse heating sources within the Nagorno-Karabakh region. Before this, ATP worked with groups in 2021 and 2022 to address reforestation strategies through backyard nurseries and hydroponic systems, respectively. But it is first important to understand the environment and history of the project location, the Karin Nursery.

2.4 Karin Nursery

The Karin Nursery was established in 1996 located in the Karin refugee village in Aragatsotn province. The nursery grows more than 100 species of trees and shrubs producing more than 20000 fruit and decorative tree seedlings. There are 11 full-time employees in the nursery, two modernly equipped greenhouses, and an outdoor area for plants in containers (Armenia Tree Project. n.d.). The nursery has two irrigation systems, one for the greenhouses and the other for the outdoor areas. The nursery is in a very arid region of the country (Hydrometeorology and Monitoring Center, 2024), hence the need for additional water to supplement their current use.

2.5 Rainwater Collection Systems

Rainwater Collection Systems are an increasingly popular way to collect and utilize otherwise barely used precipitation. Typically, rainwater is not thought of as a feasible source of water due to the multitude of health concerns it can pose, specifically when used as drinking water (Center for Disease Control, 2021). However, rainwater is much more feasible in the context of this project, since it will never be directly consumed. Therefore, most of the filtering aimed to reduce organic contaminants that can damage the system, as opposed to filtering bacteria or chemicals that make water non-potable. Although the collection of rainwater would likely help to address the water scarcity that Armenian citizens face, the inconsistent and unpredictable precipitation patterns make it difficult to utilize rainwater effectively (World Bank Group, 2021). This is because it can be difficult to treat and store rainwater, especially during infrequent seasons of precipitation. Improper maintenance can lead to algal bloom and other conditions that are destructive to the system and quality of the water. This is especially felt by communities that are unfamiliar with the required maintenance and processes.

The most common rainwater collection systems use rainwater from building roofs, and then store it in containers for later use (Federal Energy Management Program, n.d.). The stored water can then be used for varying tasks in everyday life, including agriculture, sanitation, and if properly filtered, drinking and cooking (Federal Energy Management Program, n.d.). In this report, the agricultural and irrigation applications of rainwater collection was primarily addressed, since the collected water only reaches the orchards and greenhouses of the Karin Nursery. Additionally, the presence of heavy metals in rainwater was examined, since they can affect the fruit that the trees bare, making it unsafe for consumption.

Typical RWHs come with many technical components. Before storage, the system contains a form of collection, as well as a filter and diverter that remove larger organic debris from the water. These feed to the chosen form of water storage, which tends to have varying monitors, meters, and pumps that control the water's characteristics and path (Federal Energy Management Program, n.d.). These include overflow monitors, flow meters, and pumps, all of which are automatically electrically operated (Federal Energy Management Program, n.d.). A standard RWH is shown below in Figure 1**.** While this is not the exact one currently in place at the Karin Nursery, it sufficiently explains the basic operations.

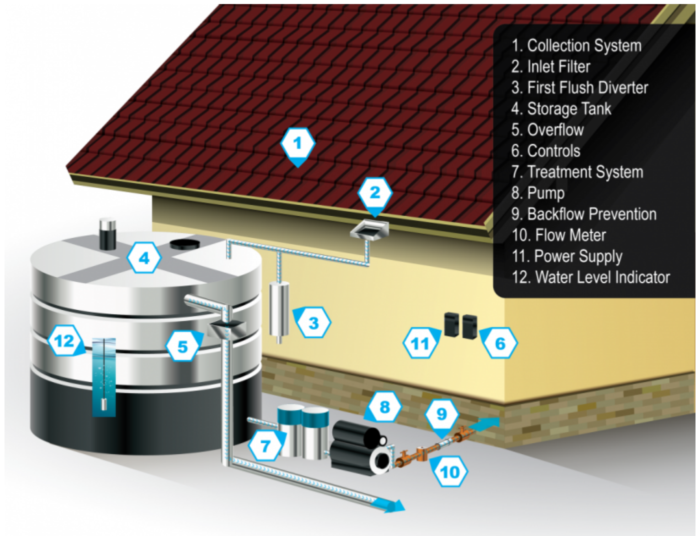

Figure 1: Components of an RWH (Federal Energy Management Program, n.d.).

As shown, rainwater is diverted from the roof through pipes and gutters. It is then filtered (Step #2) and enters the storage component. It is here that sensors and meters are employed to monitor the water quantity and quality. From the storage system, users can then transport the water to its destination. ATP has requested the use of float switches, which automatically turn the pump on and off based on the water level in the tanks. In suggesting this system design, ATP was looking for the system to operate independently. Apart from the necessary maintenance, the system would automatically collect and transport all water. Also, because of the float switch in each tank, it can adjust to the varying precipitation patterns in the arid desert where the nursery is located.

2.6 Summary

Deforestation is an issue that has been affecting Armenia for hundreds of years, and one the country is still contending with today. However, there is progress being made. Organizations like Armenia Tree Project are working to restore forests and biodiversity in Armenia. Focusing on sustainable and lasting change, the lost forest coverage is slowly being replaced. With the addition of the water distribution system that the group designed, the community members employed at the Karin Nursery will be able to continue their reforestation efforts despite the water scarcity in the area.

3. Methodology

The community members in the Karin Nursery have been using water from Lake Sevan to irrigate their orchards and greenhouses. To reduce the amount of water used, and therefore the associated costs, this project sought to automate the rainwater collection and storage system in the Karin Nursery. The automation of this system presents benefits to the employees of the Karin Nursery because it limits the amount of manual maintenance that they would have to perform, thus increasing efficiency. After the implementation of this system and a technical monitoring period of its performance, construction and maintenance manuals will be created to ensure that the nursery employees are able to construct and maintain the system. In order to achieve these goals, the following objectives were pursued:

Objective 1: Evaluate design characteristics for the Karin Nursery and the project feasibility

Objective 2: Prototype the electrical components of an automated rainwater transportation system in the Karin Nursery, then turn it over to ATP for deployment.

Objective 3: Create construction and maintenance manuals for employee and general use

3.1 Objective 1: Evaluate design characteristics for the Karin Nursery and the project feasibility.

The immediate goal was to assess the nursery's existing rainwater collection, storage, and distribution systems to ensure the project's success. Automating a rainwater collection, storage, and distribution system that exactly met the needs of the nursery required meticulously analyzing elements in order to guarantee project success and usefulness. The analysis methods included collecting statistics on environmental factors such as precipitation and temperature trends in the area, evaluating the nursery layout, and calculating irrigation requirements. Potential risks were also evaluated by communicating with the sponsors and experts in the field` to understand what preventative measures needed to include in the design.

A comprehensive site evaluation was carried out to understand the existing water collection and storage system. The evaluation consisted of reviewing the different collection points, storage tanks, their connections, electrical connections, and the seasonal fluctuation in irrigation needs.

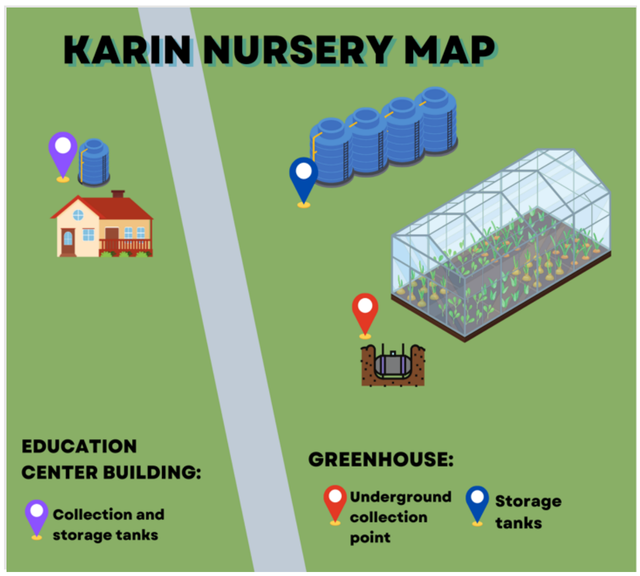

Figure 2: Map of landmarks at the Karin Nursery relevant to the project.

These observations included the distance and height difference between the collection and storage points in the different sections of the nursery, and the capacity of each collection and storage tank. In addition to the observations made, the feasibility of the project was discussed with ATP's lead engineer, Mr. Sahakyan, taking into consideration published precipitation trends in the area and the capabilities of the different collection points in the nursery. These factors, as well as analysis of current water use trends at the nursery, formed the foundation of the feasibility of the project.

Finally, potential threats to the system were considered to best mitigate potential issues. These included the risk of bacteria growth, the accumulation of algae and heavy metals in the storage tanks, and evaporation due to high temperatures. The history of algal accumulation at the Karin Nursery was discussed with Mr. Sahakyan, as well as ATP's approach to and concerns about heavy metals in the water. Additionally, Professor Garabet Kazanjian from the American University of Armenia was consulted to discuss material selection, algae in rainwater distribution systems, and loss of collected water due to evaporation. As a limnologist, his expertise on surface water helped addressing potential future risks in the automated system.

3.2 Objective 2: Prototype the electrical components of an automated rainwater distribution system in the Karin Nursery, then turn it over to ATP for deployment.

The sponsors' main request was that the water in the existing collection tanks was pumped automatically from the rainwater collection tanks to the long-term storage tanks. The first step of this objective was to design a system that met these requirements and prototype it to test all the electrical connections by researching and communicating with experts and the sponsors. By testing this first, the system working properly is ensured prior to implementing it, so as not to damage pumps, tanks, or other materials due to improper wiring.

To meet the request for automation, it was decided to use float switches to recognize the amount of water in a storage tank and trigger a pump to transfer water to it from the collection tank. The float switches are relatively low-cost and reliable, and they can be operated intuitively. This system reduced the chances of overflow in the rainwater collection tanks, since at a certain level of collection, the float switch triggers the system to be ready to distribute. It also made certain that water is only pumped when the storage tanks are empty *and* the collection tanks have a sufficient water level. This "double-trigger" system helps avoid dry-running (pumping without water), which quickly damages the lifespan of the pump and can lead to cavitation. The float switch operation is described in Appendix A.

3.3 Objective 3: Create construction and maintenance manuals for employee and general use.

To facilitate the implementation and long-term operation of the automated rainwater collection and storage system, comprehensive construction and maintenance manuals were developed for the ATP personnel and potential adopters. The creation of these manuals involved the following steps:

1. **Identification of components:** The manuals were structured to address and the construction and maintenance of essential components, including electrical system wiring and tank connections.
2. **Integration and practical experience:** Based on the implementation at the Karin Nursery, the manuals included specific details and insights gained from the field. This ensured practical relevance and ease of replication regardless of the user's expertise level.
3. **Generalization:** While tailored examples and visuals from the Karin Nursery were included for ATP's personnel, the manuals were also designed with adaptability in mind. Generalized instructions allow for easy customization to suit different environments and user demographics.
4. **Longevity and minimal maintenance:** The maintenance manual was made to contain routine tasks such as filter clearing and seal checks, and operational instructions. Emphasis was placed on minimal maintenance requirements due to the system's efficiency and reliability. The manual also included a section of common problems related to the essential components of the system and how to fix them.

4. Results

The completion of our objectives resulted in prototyping an automatic rainwater collection and storage system for the Karin Nursery. It was recommended to ATP to deploy the prototype during the Spring and Fall months to supplement their current water source. This recommendation was done based on precipitation trends in the Ashtarak region and water consumption in the nursery. In addition to turning over the prototype to ATP, construction, maintenance and troubleshoot instructions were compiled into a manual handed to ATP.

4.1 Objective 1: Evaluate design characteristics for the Karin Nursery and project feasibility.

During the term of preparation prior to arriving in Armenia, the team met with ATP over Zoom in order to understand their project request. Based on the initial diagrams the sponsor provided and early conversations, see Appendix C, the understanding was that there were no rainwater collection or storage systems in place at the Karin Nursery. Therefore, the original design before arriving in Armenia was centered around constructing an automated rainwater collection, storage, and distribution system for the nursery, pictured in Figure 2.

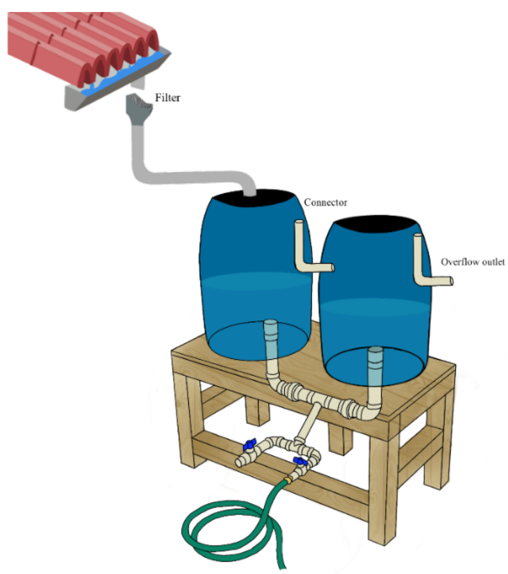

Figure 3: Rainwater collection, storage, and distribution system for Karin Nursery.

The above diagram depicts a variable series of rainwater collection tanks, connected to the roof of the predetermined building. The rainwater would move from the roof of the building, through the gutters and shown filters, into the collection tanks. The connections between the tanks ensured that the system would be able to support any amount of precipitation in the area, without overflowing and losing water. It was planned to examine precipitation data once in Armenia, which would determine if there was a need for a larger storage tank in addition to the series of collection tanks. In the initial planning stages for this design, it was decided to use 200 L collection tanks made of polyethylene, as food grade polyethylene tanks are easy to find and low-cost.

While Figure 3 represents the initial understanding of the sponsor's project request, it was not until the arrival in Armenia and the ability to meet with ATP employees in person that it was clear that the scope and objective of the project changed. During the first meeting with the lead engineer Mr. Sahakyan, the team were informed that storage tanks existed already at the Karin Nursery. He also was able to clarify that they were requesting the use of a float switch or a similar technology to automate water transportation in the system, instead of a float valve to measure the water level in a tank. These clarifications and the visit to the Karin Nursery were helpful, as they appeared to narrow the scope of the project.

The permit to conduct the first visit to the Karin Nursery was emitted during the second week of the time in Armenia. The team was led by Mr. Sahakyan and accompanied by one of the IQP advisors, Professor Hrachya Kocharyan. The team first visited the building that the designs were planned around. It was at this time the team saw that there is already a metal rainwater collection tank of about 1000 L, as well as a storage tank of 5000 L directly next to it. The team was also shown a group of 4 storage tanks located further from the building, which Mr. Sahakyan explained would eventually be connected to the 5000 L storage tank next to the building.

Next, Mr. Sahakyan introduced their large greenhouse of 1000 m^2, at which point it was not part of the project. The greenhouse's method of rainwater collection was presented, which includes gutters at the base of either side that lead to an underground storage tank of about 3000 L in the ground. To the left of this greenhouse, there are 10 storage tanks of 5000 L each that operate in parallel. He also displayed a below-ground tank behind the greenhouse, which is not utilized for irrigation of the greenhouse, but helps control the climate inside of it.

At this point in the tour, the team decided to have a conversation in a conference room about the feasibility of the project. This was crucial because the initial estimates of rainwater collection for the area pointed to a low project feasibility and usefulness. Prior to the arrival in Armenia, the team had different discussions with ATP about the Karin Nursery and its characteristics. The team learned that the nursery consumes about 14000 L of water per day, and gained some insights about the area where the rainwater collection system is located. The surface area of the roof that collects rainwater is about 140 square meters (1507 square feet). This information and precipitation trend data from the Ashtarak region were used to estimate the amount of collected rainwater throughout the year. The project feasibility was determined by comparing the estimated collection to the nursery's daily consumption, as seen in Appendix B.

Based on the initial calculations referenced in Appendix B, Table B.2, installing a rainwater harvesting system was not going to be beneficial because the nursery was not going to collect a significant amount of rainwater. To put it into perspective, in a year of collection, initial estimates only pointed towards about four to five days of viable water use, without factoring in evaporation. After discussing these concerns with the engineer in charge of the project Mr.

Sahakyan, it was determined that the rainwater was most useful in the spring (March, April, and May) and fall (September, October, and November). These six months see the most rain out of the year, as well as temperatures that very rarely drop below freezing, making collecting rainwater during these months worthwhile and realistic. The summer months see negligible amounts of rain, but the system does not interfere with the normal operation of any tanks and will remain active. The winter months in the region are not constantly below freezing, but it does fall below freezing meaning that having the system active is likely to damage it. There are methods in place to remove the risk of damage during these freezes. While most of the tanks will be emptied as part of already existing procedures, redundancy will be added by making sure that the float switches and pumps are able to be easily removed so there is no risk of those components being damaged by low temperatures. Additionally, due to the low temperatures in the winter, the irrigation system is not used. Taking this information into account, it was made clear that having the system is worth having to collect water during the spring and fall months. The amount of water that could be supplemented by the rainwater collection was estimated using the new conditions, as seen in Appendix B, Table B.3.

4.2 Objective 2: Prototype the electrical components of an automated rainwater distribution system in the Karin Nursery, then turn it over to ATP for deployment.

After achieving the first objective, the goal of the project became more clearly defined, at which point the group was able to begin designing and prototyping the automated system. Through research and personal communication with Mr. Sahakyan it was ultimately decided to utilize the float switch system that was originally proposed. Based on the number of locations that rainwater would be collected from, and the ease of automation, the goal became implementing two float switch systems: one connecting the metal collection tank and the 5000 L storage tank that are attached to the roof of the community building, and the second connecting the underground collection point at the greenhouse to the 10 parallel tanks of 5000 L.

In the design process for this automated system, there were many technical factors that were taken into account. One was the positioning of the collection and storage tanks, and how to move water from a lower point to a higher one against the force of gravity. To move water an upwards vertical distance, a certain amount of pressure needs to be applied to overcome the force of gravity on the water. To achieve this, a combination of pipes and pumps were used. Pipes were used to transfer the water, and pumps were used to push the water through the pipes and overcome the vertical distances between the collection and storage tanks.

The most important goal in undertaking this project, and the primary ask, was to automate the transportation of water from the collection points to the storage tanks. As previously mentioned, it was determined the best solution to this to be using a float switch. Float switches were placed in both the collection point and the storage tank. These both were electrically connected to existing electrical boxes on the community building and the greenhouse, as well as a pump. Float switches located in the collection points (1000 L metal tank and 3000 L underground tank) were set to trigger to “ready to pump” once the collection points were filled with rainwater to a predetermined height, 750 L and 2300 L for the metal and underground tank, respectively. Float switches located in the storage tanks were set to trigger as “ready to receive” once the water level decreased to a predetermined level, about 60 cm (2 ft) from the rim. In designing the system like this, the main aim was to ensure that the system would not be dry-running due to a lack of water in a collection point, or overflowing the storage tanks and losing water due to over-pumping. The following figures depict the designs at the community building and the greenhouse, respectively.

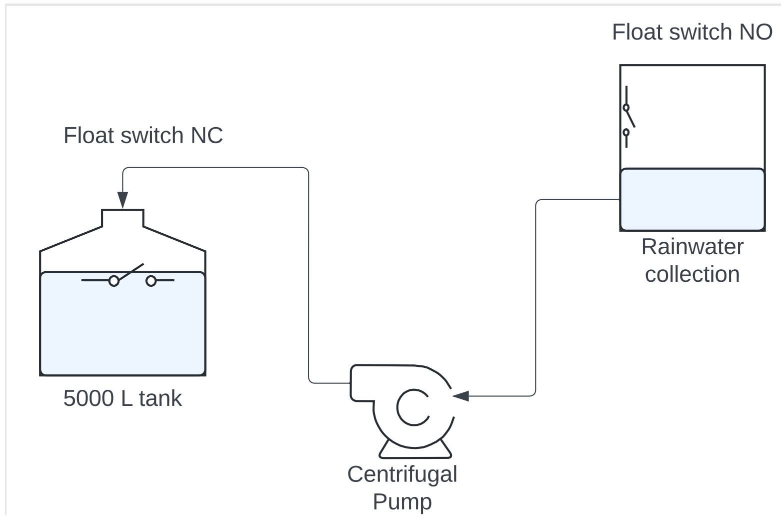

Figure 4: Automation design for the education building.

As seen in Figure 4, the 1000 L metal rainwater collection tank at the community building falls slightly lower than the ideal entry point to the storage system (top of the 5000 L tank). In order to keep the capacity of the storage tank at 5000 L, water from the rainwater collection tank was fed in through the top. This thereby eliminated the possibility of letting gravity transport the water, since the entrance to the storage tank is higher than the outlet of the collection tank. Therefore, the float switch system with a pump was used for this location of the nursery. The float switch system consists of two float switches, one in each tank, the one in the collection point set to normally open (NO), and the one in the storage tank normally close (NC). When both are active, the pump is triggered, and the water is stored.

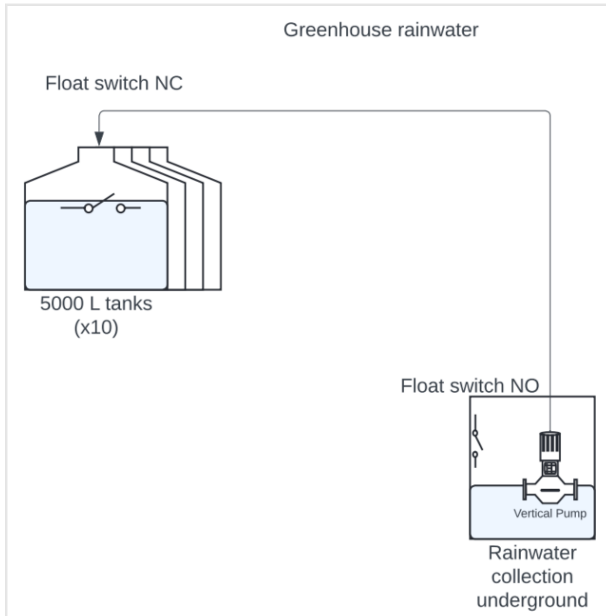

Figure 5: Automation design for the greenhouse.

As seen in Figure 5, the underground rainwater collection is located at a level that is significantly lower than the storage tanks at the greenhouse. This created a need for a pump to transport the water. Since the 10 storage tanks operate in parallel, they each fill at an equal rate simultaneously. This eliminated the need for every tank to have a float switch, since the water level in one tank will always be equal to the water level in the others.

In order to effectively implement this system, it was necessary to create a circuit diagram to ensure that the electrical components were properly wired. If done improperly, there could have been damage done to the existing infrastructure. This diagram is pictured below in Figure 6.

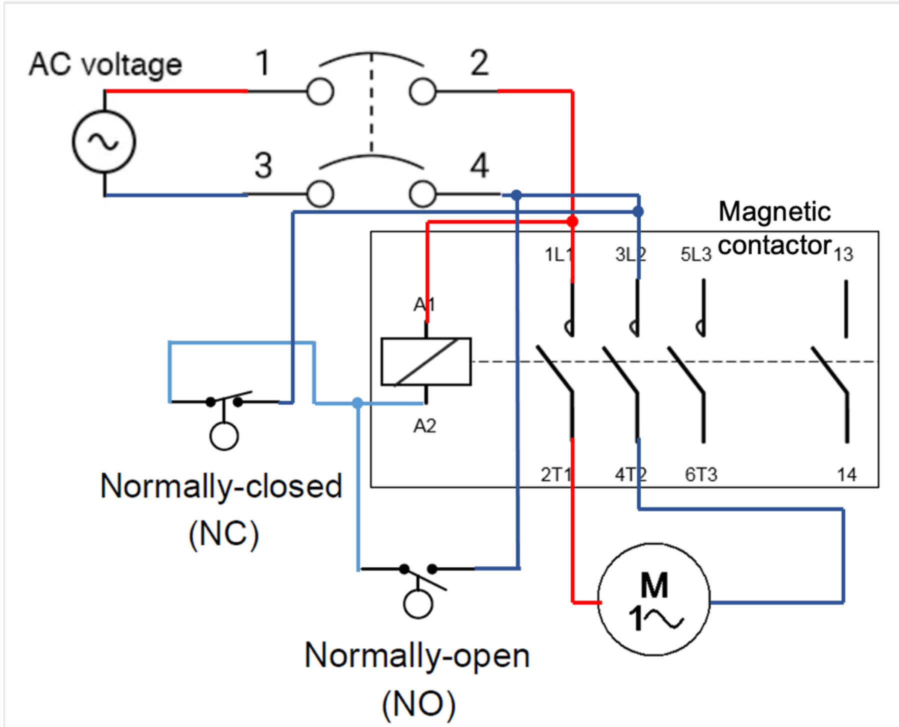

Figure 6: Circuit diagram for the automation of rainwater transportation using two float switches.

The circuit is made of four major components, the miniature circuit breaker (MCB), a magnetic contactor with 3 points of contact, float switches, and a single-phase pump. The MCB works the same as a regular circuit breaker, but it meant for less connections. This is a safety measure for damage caused by short circuits or any other failure of wiring. The magnetic contactor is a type of relay that works by connecting the two sides using an electromagnet. This is useful for high amperage applications like the pump and is more reliable than a regular relay. The float switches are used to detect once the water level in the tank reaches a certain height, their function is expanded on in Appendix A. Finally, the single-phase pump is used to move the water. A single-phase pump was chosen due to them being able to handle turning on and off multiple times a day, which could be required during periods with high rainfall.

The final factor in the design was the implementation of filtration methods. Originally, the team was considering a variety of contaminants for filtration. It was determined highly necessary to filter for large organic contaminants, since they are most destructive to the integrity of the pipes and pumps. If large organic particles, such as leaves or animal debris were to get inside the system, they could damage the pumps and possibly require replacing parts. In order to accomplish this filtration, multiple wire mesh sheets of different gauges were installed at the inlet to the rainwater collection system, to ensure that the contaminants would not enter and damage the piping system.

Heavy metal filtration was also considered. Heavy metals are known to pose health concerns when consuming fruit from trees irrigated by water containing large amounts of these contaminants. To understand the components of rainwater and gauge if there were any reasons for concern, the team met with Professor Kazanjian, a professor at AUA and expert in groundwater, who informed the team that heavy metals are not prevalent in rainwater in Armenia. The team were also reassured by Mr. Sahakyan that they should not present any issues, and that the orchards already receive rainwater directly. Therefore, while it was made clear that there are not high levels of these metals in the rainwater, it would not be necessary to filter them either way since the plants already come into direct contact with this water.

The last component that was considered for filtration was algae. Algae is formed when there is a high level of nitrogen and phosphorus in water. This leads to increased levels of photosynthesis under the right conditions, forming algae. Professor Kazanjian mentioned that while algae likely would not affect the health of the plants, it may pose issues similar to organic contaminants in that it can be physically destructive to pipes and pumps. The team spoke with Mr. Sahakyan about this possibility, and he clarified that the Karin Nursery has experienced algal growth already and employees have developed their own methods of cleaning it. Therefore, there was no need to account for this during the filtration designs.

Once all of these design factors were considered and a budget was created, permission was granted from ATP's director to purchase the necessary materials. After ATP employees accompanied the team to purchase the system components, the automation system was prototyped to ensure that it was functioning properly prior to installation. In doing this, the aim was to avoid implementing an improperly wired system at the Karin Nursery, since this may have damaged system components.

To prototype the electrical components of the system, a miniature circuit breaker (MCB) and magnetic contactor were wired together to a float valve and a power source. These were each measured by a voltmeter to ensure that voltage was passing through each component correctly. In order to test the functionality of these components together, the float switch was placed in a vertical position prior to connecting the components to the power source. Once the system was powered, the float switch was lowered to a horizontal position, at which point its internal mechanisms triggered the system. These components are shown in Figure 7 below.

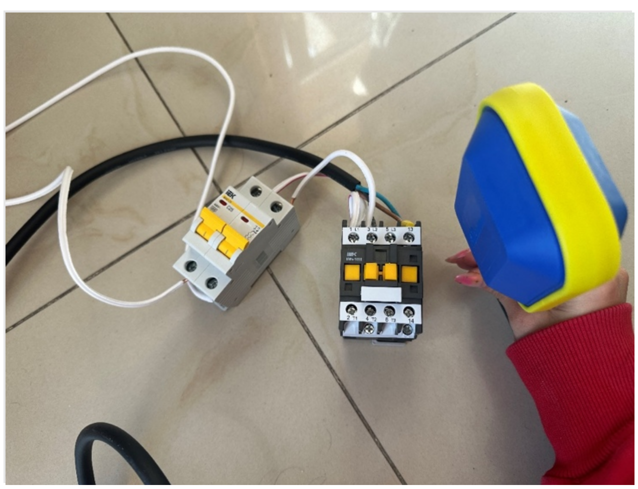

Figure 7: Components used to prototype the automated system. Pictured from left to right are the miniature circuit breaker (MCB), magnetic contactor, and the float switch.

The automation system was proven to be functional when the switch (movable contact) on the magnetic contactor was immediately pushed into position at the turning of the float switch. This proved that the voltage was properly running through the entire system, it was wired correctly, and that each component was functional.

Once the electrical components were proven to work properly and safely, the team was confident turning over the components to ATP for its deployment in the Karin Nursery. The complete implementation occurred on April 17, 2024. Both designs were installed by Mr. Sahakyan, one at the education center, the other at the greenhouse across the street. After installation, each system was tested to ensure functionality and safety. Each system functioned properly. To guarantee that the system continues to work as it did during the implementation, Karin Nursery employees were provided with maintenance manuals.

4.3 Objective 3: Create construction and maintenance manuals for employee and general use

Once the conditions of the nursery were assessed, and at the same time as the distribution system was being implemented, a set of manuals were being developed that outlined the operation and installation of the various components. The manuals were meant for two audiences, the employees at the Karin Nursery and people with already existing collection systems that were looking to implement a similar system. The manual for Karin nursery employees was specific to the location's characteristics. This includes information such as dimensions, water patterns, and maintenance that are only relevant to the Karin nursery. The general use manual includes information behind the system, why someone would want it and basic information on how to install it. Both manuals included the components that were used, the amount, and the estimated price for such a system.

One of the major hurdles for designing the manuals was presenting the information in a way that makes sense to anyone. The manual for the Karin nursery included a variety of technical documentation, including piping and circuit diagrams, which are not always intuitive to understand. This led to finding ways to effectively communicate these designs without relying on the diagrams. There were several methods proposed, including explaining the diagram in text, including a version of the diagram that was simpler and omitted most of the images used to represent electrical components, and including pictures of the installed system. For the final version, the team used a combination of all three of these ideas. This decision was based on several factors, the first being the idea that having the widest range of options will be better. To ensure everyone got the necessary information out of the manuals, presenting it in a wide range of options was deemed best. There were downsides to this design decision, namely the increase in the length of the manual. To accommodate all these options, extra steps had to be taken when redesigning the circuit diagrams to make the diagram still convey what it needed to.

Another factor that led to the decision to combine these methods was feedback from other members of the cohort who did not know anything about how the system worked. While most of these individuals are familiar with reading various types of technical diagrams and terms, their feedback was still considered, and was especially helpful with the extended written portion of the manuals. By responding to the feedback received from these tests the team adapted the manuals to best fit an audience unfamiliar with the design and the components used to make it.

The final factor for the design considered was the manual's layout. This step was foundation that the rest of the manual will be built on and determine how the information will be presented. Based on the requests of ATP, the manual will be primarily presented in a digital format and will be printed sometime in the future. Because of this, making sure the manual flowed well in both formats was also important. For manual, see Appendix D.

5. Discussion

Throughout the project, the team has outlined the limitations experienced, the recommendations for further expansion and care, and key takeaways. The team finds it relevant to highlight the limitations of the project and the prototype. They are important to understanding the context for decisions and to manage expectations of the prototype moving forward. The recommendations are actions the team strongly recommends pursuing moving forward, ranging from expansion of the water collecting capabilities to the continued maintenance of the prototype and attached systems. The conclusion summarizes the project's main points and cements the team's recommendations.

5.1 Limitations

Throughout the completion of this project, there were a multitude of limitations presented. These are important to consider, not only to gain a better understanding of the design process, but also to ensure that there are realistic expectations for the long-term outcomes of this project.

The most significant limitation during this project was the unclear communication about project objectives from ATP. During the preparatory period prior to arrival in Armenia, the team was presented with the goal of implementing an automated rainwater collection, storage, and distribution system at the Karin Nursery. The mechanical aspects of the design were planned out prior to arriving in Armenia, at which point the automation was to be discussed. However, after meeting with ATP for the first time in-country, they explained that there were already rainwater storage tanks behind the target building. This piece of information was inconsistent with answers to previous questions about existing infrastructure but did not pose any major design changes. However, after visiting the Karin Nursery in-person at the end of the second week in Armenia, the previous designs were essentially discarded. The target building already had an entire rainwater collection, storage, and distribution system installed, with plans to expand to additional storage tanks in the future. ATP then requested that an automation system was installed at the greenhouse across the street, despite multiple conversations about the project and location, during which requests for greenhouse automation were never mentioned. Similar to the education center, the greenhouse had existing rainwater collection, storage, and distribution infrastructure in place. Due to these major differences, the goal of the project shifted, and had to be understood prior to implementation of any technology. This took a significant amount of time away from the design process, since it was weeks into our time in Armenia that this information was received. Consequently, this lack of time for designing and prototyping meant that not all possibilities were able to be researched and considered.

Another significant limitation that influenced the final project design was the request for a low-cost automated system. Despite requests for clarification on ATP's definition of low-cost, a budget was never presented. The lack of cost constricts led to delays in understanding the scope of the project and designing a solution. The final system design could have used various types of technology ranging in complexity, but the team was never provided with a monetary cap to gauge the appropriate level of complexity. During the research stage, it was determined that computerization would be the most reliable and efficient form of automating these rainwater collection and storage systems. This technology also would have improved overall user experience since the required maintenance would have been minimal. However, in an attempt to be as low-cost as possible without compromising the integrity of the system, more advanced forms of automation like computerization were not considered in the final design. Instead, mechanical systems like float switches were ultimately prioritized during the design process.

Karin Nursery employees may experience some challenges presented by the precipitation levels in the region. Since the function of the automated system is dependent on water levels in collection and storage tanks, the frequency of use, and therefore system wear, is going to be impacted by the amount of precipitation in the region. To best mitigate this, precipitation data going back over a decade was analyzed to determine estimates of water collection versus nursery water use. While these calculations proved that there has been sufficient water collection for the technology to be useful, these models do not predict what future precipitation and collection will look like. There may be periods of time in which the system does not serve any use for employees, since it will not be triggered until the exact water level requirements are met. The precipitation in the winter also requires the system to be disassembled and stored away, since freezing temperatures and heavy precipitation will damage the components. This leaves the technology more susceptible to being misassembled, which could shorten its lifespan.

Since any technological system is subject to a variety of failures, the construction and maintenance manuals provided to ATP and Karin Nursery employees aim to provide best practices to avoid the possibility of failure. These include safety practices, required maintenance, detailed diagrams, etc. For the implemented systems to function properly and safely, it is absolutely critical that anyone maintaining or recreating them utilize the provided manuals. This itself creates a limitation, since nonadherence to the manuals may lead to incorrect wiring, placement of components, etc. Since the automated system is automated, and carries high levels of voltage, any nonadherence to the manuals could endanger people. It also could lead to the destruction of system components, at which point ATP would need to find funding. This can be made more difficult and dangerous if the individual(s) constructing or maintaining a system have no electrical experience. The manuals detail these processes in a clear, understandable manner, but if inexperienced individuals do not adhere to the instructions, they can endanger themselves and others. Therefore, there is a heavy reliance on those maintaining or recreating these systems to follow the manuals exactly.

Lastly, the periods of collection were limited by the weather patterns around the Karin Nursery. The Ashtarak region experiences sub-freezing temperatures during their winter months, along with precipitation like snow and ice. This renders the winter months unusable for rainwater collection. If those winter months were viable for collection, the amount of water the nursery could use during their off seasons would increase. In addition to the lack of collection, the weather patterns during this time require that certain technologies are placed inside. This is something that the Karin Nursery has already experienced, and they take action to protect their existing infrastructure. However, the addition of an electrical system is going to increase the required manpower at the end of the fall and beginning of the spring. These are the times of the year when the automated system will be disassembled and reassembled, respectively. However, every time the system is disassembled or reassembled, there is a higher chance for improper construction, which can lead to further issues.

5.2 Recommendations

The following recommendations are made to ATP in consideration of the technology that was installed and their plans for expansion in the future. These include suggestions about the maintenance of the system, the quality of the existing system, the plans for expanding the system, and other options to increase water levels during the off seasons.

5.2.1 System maintenance and component replacement

We cannot stress the importance of proper maintenance and construction enough. It is the most crucial recommendation to follow to guarantee personnel safety and longevity of the automated system.

Regarding the construction of the system, it is highly recommended that a licensed engineer is present during the construction of the system. While the manuals are simple to follow, the construction of the system does involve the use of wires and high voltage. It is critical that someone familiar with these concepts is present, even if they are not the ones to physically construct it. In doing so, electrical accidents such as short-circuiting, and electrocution become more easily avoided. This could not only save the integrity of purchased components, but this practice could save lives.

It is also highly recommended that all practices detailed in the maintenance manual are followed. Thorough and consistent cleaning and careful attention to component conditions will help ensure that the system continues to run smoothly. Additionally, it is important that any other maintenance procedure, such as the algae cleaning performed at the Karin Nursery, are also consistently completed. High levels of algae could damage the pumps if not frequently removed. While this system does automate the transportation of water from the collection points to storage tanks, the upkeep of the system conditions is not automatic, and must be attended to. If this does not occur, there is the possibility of individual system components being damaged, and if it runs unmaintained, the entire system could be rendered unusable.

In consideration of the maintenance conditions required, it is also suggested that the system is disassembled prior to freezing temperature reaching the area, and reassembled only after weather conditions are consistently above freezing. It is expected that this suggestion will be well followed, since the Karin Nursery does not utilize their rainwater collection seasons in the winter months. However, freezing temperature could damage the integrity of the electrical components, making them useless during reassembly.

5.2.2 Replace the metal collection tank at the education center

Prior to arriving in Armenia, the original design for this project included the use of polyethylene tanks. This research was conducted to ensure that environmental factors, like sun exposure and erosion, would not affect the quality of water stored inside the collection or storage tanks. However, after observing the existing infrastructure at the Karin Nursery, it was noted that the rainwater collection tank at the education center is made of metal. This is significant because metal tanks tend to be more susceptible to algal and bacterial growth due to the sun. They also can rust over time, which can lead to physical damage, and sometimes an accumulation of metals in the water being stored. This metal tank was very rusted and elevated approximately 2.56 m (8.4 ft) off the ground. Due to the corroded nature of the tank, it is recommended that this tank is replaced by a nonmetallic one in the near future. Not only would this lengthen the lifespan of the tank, but it would ensure that rust from the tank is not affecting the quality of water inside. The Karin Nursery has also experienced algal bloom, and replacing the tank might help lower the levels of algae.

5.2.3 Connect additional storage tanks to the education center automated system

The lead engineer explained that they are looking to connect the rainwater collection and storage system at the education center to four additional storage tanks that are further back in the orchards. While this was not to be achieved during this project, there are some recommendations alongside the final design that can make this connection easier. It is recommended that the float switch technology is used to connect the primary 5000 L storage tank to the farther storage tanks.

At the education center, a float switch was not used to automate the transportation of water. Instead, an automatic pump was used, and it functions in the same manner. However, using this pump instead of the float switch system for this location means that the primary storage tank is not occupied by large devices at the moment. This would allow for the installation of a float switch system here. This should be connected to a powerful pump, at least 2 hp since there is so much horizontal distance between the primary and secondary storage tanks. The piping should then be run underground to the secondary storage tanks since the area is very public and social. Running the piping underground will help mitigate damage by visitors, and will also ensure that the aesthetic value of the area is not ruined by unsightly PVC piping.

5.2.4 Add a second gutter system to the education center building to increase water collection

Since one of the limiting factors of the usefulness of the automated system is the level of precipitation in the region, it is recommended that a second gutter is added to the education center to maximize rainwater collection. The Ashtarak region is very arid and gets little precipitation. This means that in order to optimally utilize rainwater collection systems, it is important to also optimize the area used for collection. Only half of the area of the education center roof is being used at the moment. There are already some gutter components in place on the second half of the building, so they would only need to be connected to the collection tank on the opposite side. This is strongly recommended to occur alongside Recommendation 6.2. While this would not lead to a significant increase in collection, it would lead to a slight increase. Any increase in collected water relieves some of the reliance on other water sources.

5.3 Conclusion

In this project, the team aimed to design and prototype an automatic rainwater collection and storage system to supplement the existing water source in ATP's Karin Nursery. The project was guided by three primary objectives:

Evaluating design characteristics and project feasibility: The process consisted of thorough planning and on-site assessment to gain valuable insights into the layout and water consumption patterns of the Karin Nursery. Using precipitation data from the area and understanding the nursery's needs, the feasibility of the project was assessed by estimating the potential rainwater yield.

Prototyping the electrical components of the system: A working prototype was tailored to meet ATP and the Karin Nursery's needs. Seamless integration and efficiency were ensured by prioritizing safety and selecting suitable components. The prototype was turned over to ATP for a guided installation.

Creating construction and maintenance manuals for user guidance: A comprehensive construction and maintenance manual was developed to facilitate the implementation, upkeep, and replication of the automatic system. These manuals include text instructions, simplified diagrams, and visual aids to serve to users of diverse backgrounds. The manual will be handed over to Ani Melkonyan and Hovhannes Sahakyan.

Based on our research and outcomes, several recommendations were proposed to ATP for the successful deployment and maintenance of the automatic rainwater collection and storage system:

Continued maintenance: ATP is advised to prioritize monitoring and regular maintenance of the prototype to ensure its longevity and safe operation. Routine checkups on component integrity and staff awareness of safety protocols are crucial.

Upgrading infrastructure It is recommended that ATP upgrades different features of the education center such as adding a rain gutter to a section of the roof that currently does not collect water, and upgrading the metal collection tank to mitigate potential risks associated with rust and leakage. Addressing these issues could prevent future complications.

Future expansions: ATP is advised to expand the collection and storage capacity of the nursery. Changes such as adding more collection points, and connecting more storage tanks could further improve the water management practices and increase the amount of water supplemented using rainwater at the Karin Nursery.

In conclusion, the successful completion of this project represents a milestone in promoting sustainable water management practices by addressing water scarcity challenges. Through innovative and safe design practices, a prototype that holds the potential to make a positive impact on water conservation efforts was developed. Moving forward, continued monitoring and maintenance will be essential to ensure the long-term effectiveness and safety of the rainwater collection system at the Karin Nursery.

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Appendix A: Float switch explanation

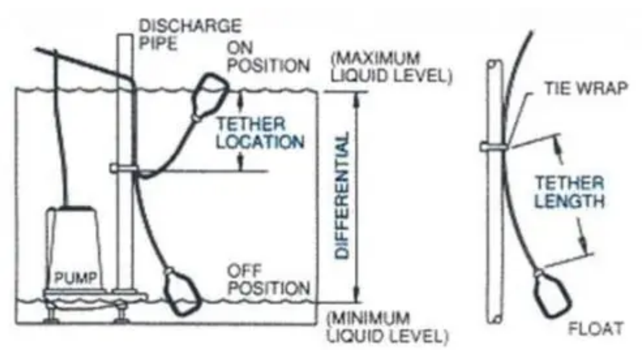


Figure A.1: Diagram of the function of an anchored float switch, which is the one used in the design (PASLR, 2021).

The diagram shows how the float switch works, with the on and off positions referring to when the float switch allows an electrical current to flow or not. By utilizing the float switch's ability to react to different water levels, the water level in a tank was ensured to not get low enough to damage the pumps and that the tank did not overfill. There are three types of float switches, normally open, normally closed, and interchangeable. This refers to how the circuit inside the float switch works, with the current off by default, on by default, or able to be chosen. The different types are useful for different purposes, such as having a normally open switch closed when the water gets high enough and activating a pump. The on and off positions for a float switch are determined by where the anchor for the switch is placed, each float switch has an angle from the anchor that it will change its state, determined on length of the cable and the specification of the switch itself.

Appendix B: Project feasibility calculations

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
2012	12.4	66.6	13.7	43.6	41.1	24.9	33.1	0.1	14.7	34.5	10.3	47	28.5
2013	38.1	25.1	37.1	29.5	70.4	12.9	10	3.6	10.6	7.9	14.8	21.5	23.5
2014	28.9	0.6	44	25.3	64.5	42.1	13.3	5.9	10	18.5	46.9	15.5	26.3
2015	13.9	16.1	39.2	30.7	54	15.6	0	25.9	1.5	117.9	7.6	29.5	29.3
2016	47.4	25.8	23.1	30.2	41.2	58.2	34.9	9.6	28.3	45.2	39	35.7	34.9
2017	34.7	21.9	30.2	23.1	48.8	30.2	10.9	17.9	2.3	42.4	66.1	28.6	29.8
2018	20.7	23.6	33.3	29.4	87	58.8	9.5	6.7	4	47.6	37.8	48.3	33.9
2019	6.8	39	65.8	27.2	37.7	26.7	3.9	6.6	27.9	2.9	19.2	37.4	25.1
2020	14.9	33.2	37.7	126.5	56.4	12	43.7	34.8	10.3	20.1	9.9	59.7	38.3
2021	18.4	30.6	77.3	20.7	40.3	0.6	16.6	17.4	9.9	23	21.2	23.4	25
2022	22.2	12.1	52.1	24.9	71.6	26.7	0	0.6	3.6	18.2	18	8.3	21.5
2023	8.4	14.5	41.9	52	17	30.3	8.7	15	9.6	32.9	19.9	20.4	22.6

Table B.1: Precipitation trends in the Ashtarak region for 2012 to 2023 in millimeters (Hydrometeorology and Monitoring Center, 2024).

Rainwater collection estimations

$$V = A \times h \tag{1}$$

Equation (1) is the estimate of rainwater collected; V is the volume of water collected in liters, A is the collecting area in square meters, and h is the amount of rainfall in millimeters per meter squared. Initially, the amount of water that could collected per square meter during the Spring and Fall seasons was estimated, and then adapted the data to each collecting area in the Karin Nursery. The data corresponding to the amount of rainfall (h) is the data from the precipitation trends in the Ashtarak region. The average collection capacity for each building was calculated separately and then added to estimate the nursery's total collection capacity. This value was then compared to the water consumption in the nursery to evaluate the project's feasibility.

month/year	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	Total
2012	14	44	41	25	33	0	15	35	10	216
2013	37	30	70	13	10	4	11	8	15	197
2014	44	25	65	42	13	6	10	19	47	271
2015	39	31	54	16	0	26	2	118	8	292
2016	23	30	41	58	35	10	28	45	39	310
2017	30	23	49	30	11	18	2	42	66	272
2018	33	29	87	59	10	7	4	48	38	314
2019	66	27	38	27	4	7	28	3	19	218
2020	38	127	56	12	44	35	10	20	10	351
2021	77	21	40	1	17	17	10	23	21	227
2022	52	25	72	27	0	1	4	18	18	216
2023	42	52	17	30	9	15	10	33	20	227
Average	47	38	44	29	4	8	7	26	19	259
Roof	6577	5381	6199	3988	609	1092	924	3575	2652	36276
Greenhouse	47000	38450	44300	28500	4350	7800	6600	25550	18950	259225
Both	53577	43831	50499	32488	4959	8892	7524	29125	21602	295501

Table B.2: Rainwater collection estimation in liters for the Karin Nursery based on precipitation trends in the Ashtarak region. Equation 1 was used to estimate the volume of water collected per square meter each month, year. These values were averaged and then used to estimate the volume of water collected in each area of the Karin Nursery.

Project feasibility evaluation

The nursery consumes about 14000 L per day if all the irrigation systems are active. The greenhouse consumes 6000 L of the total amount, and the rest of the nursery consumes 8000 L. However, the irrigation system is not activated every day. For the spring, the use of the system for 45 days during the season was considered. For the fall, the use of the system for 54 days during the season was considered.

	Greenhouse	Estimated supplement	Roof	Estimated supplement	Total	Estimated supplement
Spring	129750	48.1%	18157	5.0%	147907	23.5%
Fall	51100	15.8%	7151	1.7%	58251	7.7%
Total	180850		25308		206158	14.9%

Table B.3: Supplement capacity estimation in liters for the Spring and Fall seasons in the Karin Nursery.

Appendix C: ATP Initial Design Requests

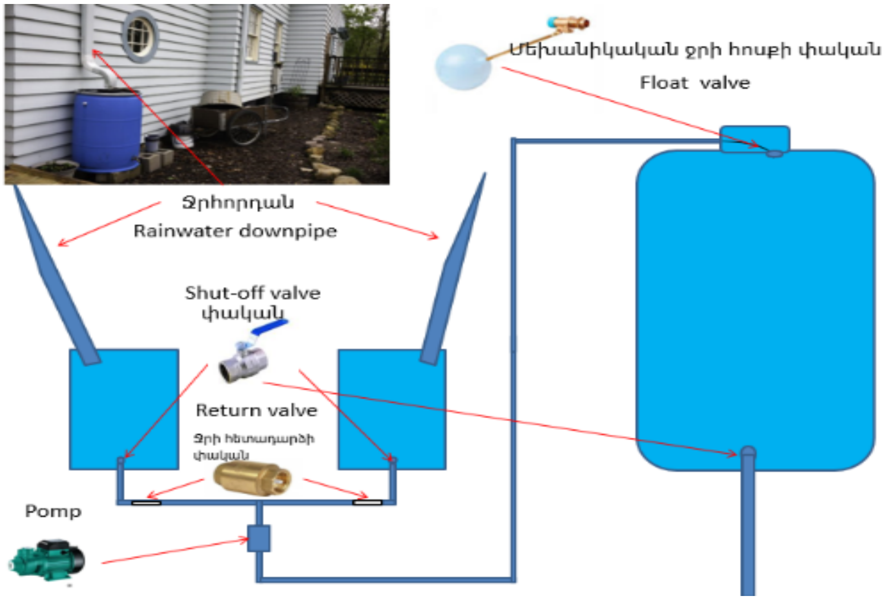


Figure C.1: ATP's original design request for an automated rainwater collection, storage, and distribution system.

The diagram shows two collection tanks with downpipes connected to the roof, from which a pump transports water to a larger storage tank. There was some translation difficulty prior to arriving in Armenia, and the pictured "float valve" was actually intended to be labeled as a "float switch". This is important to note because a float valve and float switch are different types of technology: a float valve merely indicates the water level in a tank (through observation or computerization), while a float switch is electrically controlled to trigger the pump once at a predetermined water level. This led to confusion in the initial design process but was later clarified through in-person conversations with ATP employees.

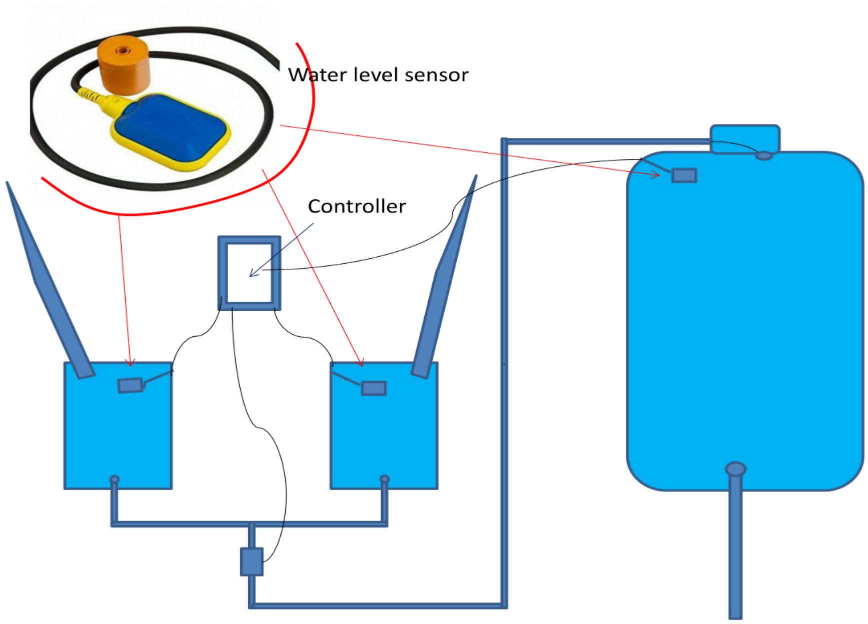


Figure C.2: Second design request that ATP provided with C.1.

This diagram represents the request for automation and is very similar to the final implementation design. The water level sensor shown depicts the aforementioned float switch, which is connected to an electrical box. However, the juxtaposition between the two initial diagrams (C.1 and C.2) caused some misunderstandings in the early design process, and the focus was primarily on implementing the tanks for this system. However, after the visit to the Karin Nursery, it was understood that these collection and storage tanks are already in place, and the request for automation became the main goal of the project.

Appendix D: "Automated rainwater collection and storage: design and maintenance manual"

Automated rainwater collection and storage: design and maintenance manual

ARMENIA TREE PROJECT

WPI

AUA American University of Armenia

INDEX

Table of Content

Overview of the manual

Rainwater collection systems are an effective way to combat the effects of inconsistent rainfall and dry conditions, as well as reducing the amount of water consumed from Lake Sevan and other sources. Rain water can supplement, or even replace, water needs for households, gardens, or even tree nurseries. The collection of rainwater can come in many forms, however, the prototype outlined in this manual is automatic and facilitates the storage of larger quantities of rainwater by storing the water in a separate tank from the tank that it was collected in. It also has the benefit of being automatic, not requiring any human interference other than maintenance to work.

This prototype reacts to the water level in the collection and storage tanks, and once there is enough water to move to the storage tanks, and there is enough room in the tanks to receive the water, a pump will activate and move the water from one tank to another. A combination of float switches allows this to happen. How to install these component will be shown later in the manual.

Components

Necessary

Items per system

Item	Quantity
Float Switch	2
2 Pole Miniature Circuit Breaker - Type C25	1
AC Magnetic Contactor	1
Electrical box	1

Custom

All items here should be purchased depending on the infrastructure of the installation site.

Item	Quantity	Customization*
Single Phase Pump	1	0.5 HP, 0.22371 KW
Submersible Pump	1	1 HP, 0.7457 KW
12 Gauge (2.05 mm) wire	X m	
Return valve	4	
Pipes	X m	

*Customization made for the Karin Nursery

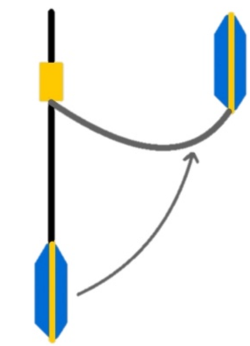
Optional

Item	Quantity
Wire nuts	Approx. 10
Automatic Pump Controller	1
Pin crimps	Approx. 20

Float Switch

A float switch detects the level of a liquid in a container. It floats on the liquid surface and acts a mechanical switch as the level goes up or down.

Installation



1) Fix the counterweight on the electrical cable to control the height of the water level.

2) Adjust the length of the cable inside your container.

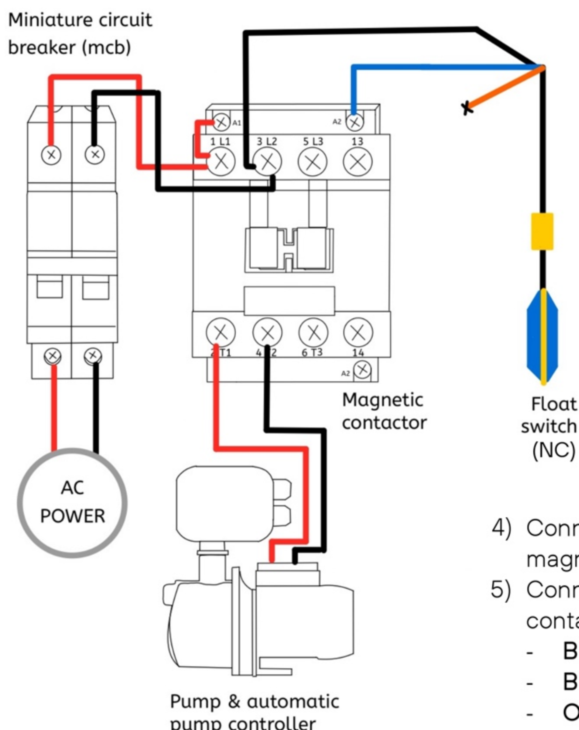
3) Move the counterweight to the desired height. When the container is full at the desired height, the counterweight will downforce the float switch to the up position.

Usage

Depending on the mode selected, a float switch can either turn the circuit on or off at its up position. This is called normally open and normally closed, respectively.

Construction guide

Instructions for auto-filling a tank



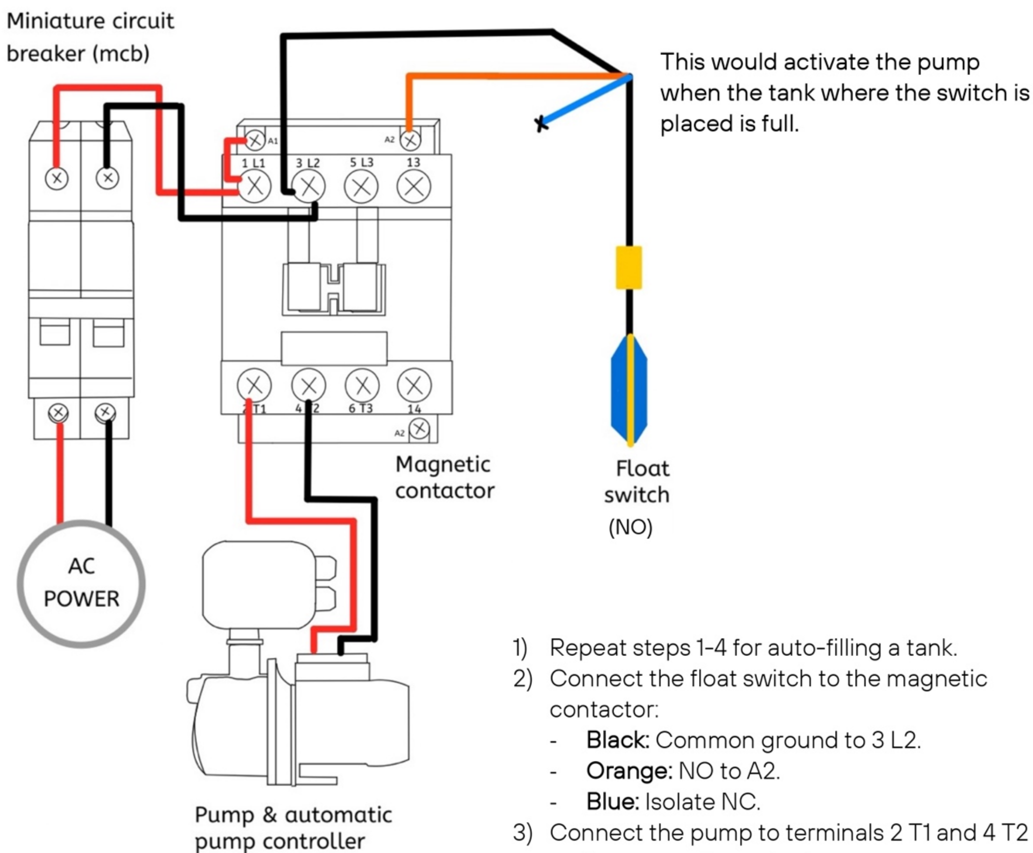
This would activate the pump when the tank where the switch is placed is empty.

1) Install the float switch as desired in the container that is getting filled.
2) Connect one pole of the MCB to terminal 1 L1 on the magnetic contactor.
3) Connect 1 L1 to A1 on the magnetic contactor.
4) Connect the other pole of the MCB to 3 L2 on the magnetic contactor.
5) Connect the float switch to the magnetic contactor:
   - **Black:** Common ground to 3 L2.
   - **Blue:** NC to A2.
   - **Orange:** Isolate NO.
6) Connect the pump to terminals 2 T1 and 4 T2 on the magnetic contactor.
7) Finally connect your MCB to power.

⚠️ WARNING ⚠️

Do not work on the system if connected to power.
The wires should not be in contact with water.

Instructions for auto-emptying a tank

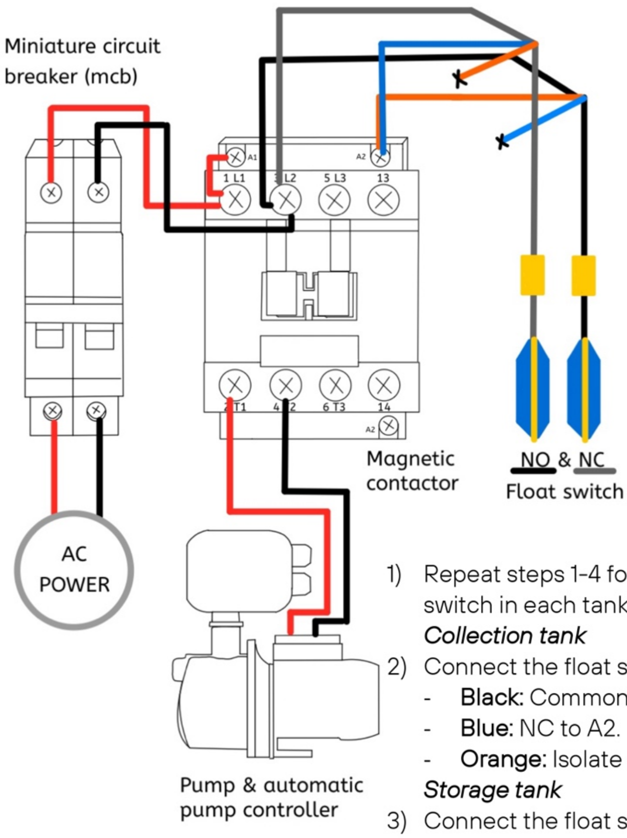


1) Repeat steps 1-4 for auto-filling a tank.
2) Connect the float switch to the magnetic contactor:
   - **Black:** Common ground to 3 L2.
   - **Orange:** NO to A2.
   - **Blue:** Isolate NC.
3) Connect the pump to terminals 2 T1 and 4 T2 on the magnetic contactor.
4) Finally connect your MCB to power.

⚠️ WARNING ⚠️

Do not work on the system if connected to power.
The wires should not be in contact with water.

Instructions for auto-emptying and auto-filling tanks



This would activate the pump when the collection tank is full AND the storage tank is empty.

1) Repeat steps 1-4 for auto filling a tank, placing one float switch in each tank.

Collection tank

2) Connect the float switch to the magnetic contactor:
   - **Black:** Common ground to 3 L2.
   - **Blue:** NC to A2.
   - **Orange:** Isolate NO.

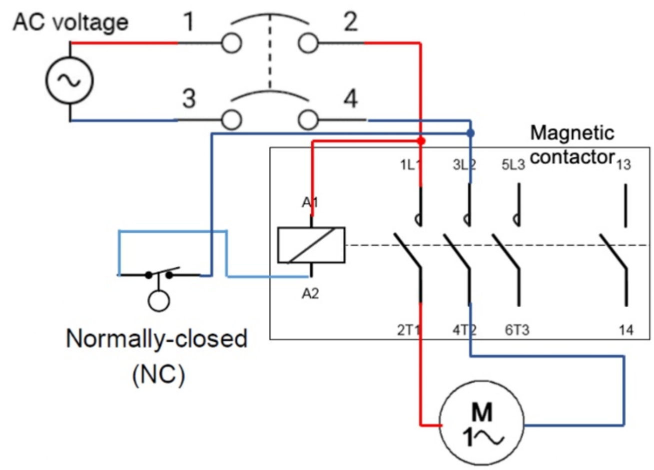
Storage tank

3) Connect the float switch to the magnetic contactor:
   - **Black:** Common ground to 3 L2.
   - **Orange:** NO to A2.
   - **Blue:** Isolate NC.
4) Connect the pump to terminals 2 T1 and 4 T2 on the magnetic contactor.
5) Finally connect your MCB to power.

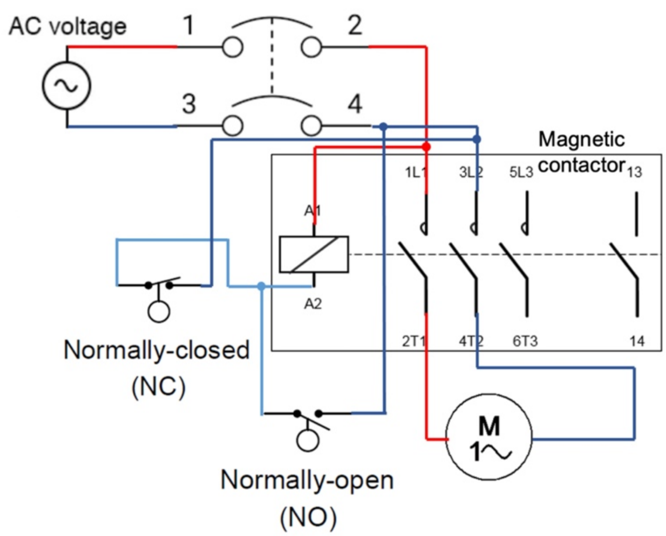
⚠️ WARNING ⚠️

Do not work on the system if connected to power.
The wires should not be in contact with water.

Electrical diagram for auto-filling a tank



Electrical diagram for auto-emptying and auto-filling a tank



Troubleshooting & Maintenance

This section of the manual goes over troubleshooting methods that would be most useful for the prototype. As well as the maintenance and expected regular care that is anticipated for this prototype.

Troubleshooting

The pump is not turning on or off even when I move the float switches.

This is likely caused by the one of two issues:

- The wires are not properly connected to components (MCB, contactor, etc). Check all connections and make sure there is full contact.
- The system may not be wired correctly, most likely the float switch is not wired properly. Check all connections and make sure they line up with the diagram.

The MCB keeps tripping and not letting the prototype turn on

This can be most commonly caused by one of two issues:

- A short circuit: if two live wires were to touch, it would short the circuit and trip the breaker. This should be noticeable, as this will likely cause insulation on a wire to melt, which has a distinct smell. It can also cause visible damage to wires. If this were to happen, find the two wires that are touching and ensure that they no longer touch at all.
- An excess of voltage or current. This can be caused by a variety of things, most notably lighting strikes or drawing more power from the circuit than it can handle.

Maintenance

While this prototype is designed to work autonomously, there is still some regular maintenance and checks that should be done to ensure everything still works as intended

- ***Wire condition should be checked regularly***
    - While all outside wires should be wrapped in a weatherproof tubing, it is still possible for this tubing to fail. Periodically check the condition of this tubing.
    - Poor tubing conditions can lead to the wires being damaged, either their insulation being worn away, making them unsafe or allowing animals to have access and chew through the wires.
    - While none of these are guaranteed if the tubing is broken, they are possible. A malfunction can be prevented by keeping an eye on the condition of the tubing.

- ***During long periods where rain is not expected, the power should be turned off***
    - While the prototype is designed not to let an electricity past the MCB if it is not activated, taking this extra step removes the chances of any accidents happening with the prototype itself.

- ***Be mindful of pipe seals***
    - Overtime, the pipes can develop leaks, oftentimes at the places where two pipes or hoses are joined. These leaks can be noticeable, but it is still recommended that these connections are inspected every so often to try to prevent these leaks from starting.

Operation checklist

Steps to follow for a monitoring or maintenance session of the prototype:

☐ Turn off the MCB.

☐ Disconnect the prototype from power.

☐ Make sure all wired connections are in place.

☐ Inspect the state of each wire.

☐ Examine the condition of the pump.

☐ Ensure all pipe connections are in good condition.

☐ Inspect float switch condition.

☐ Connect the prototype back to power.

☐ Turn on the MCB.

☐ Test each component is functioning.

Karin Nursery

General Information

Two prototypes were installed at the nursery by Mr. Hovhannes Sahakyan, and any questions about the details of the installation should be directed to him. Each prototype operates on 220 V to 240 V, and approximately 4-5 amps. This is a lethal amount of electricity, and while the electrical conditions are approved and/or installed by Mr. Hovhannes Sahakyan, caution should be taken whenever interacting with the prototype in any way. If there are any doubts or concerns about the safety or operation of the system, unplug it immediately and seek aid.

No amount of water is worth risking your life for.

Education Building

As previously stated, the installation was approved and/or done by Mr. Hovhannes Sahakyan, so things should be up to standards and working safely, however there are things to note that are not related to electricity:

- When walking behind the education building, be mindful of the cables between the electrical box and the tanks, as they are at head height
- Likewise, be aware of the plumbing connections between the tanks and pumps.
- The electrical box is locked with a key to make sure it doesn't accidentally open, the key is located in the lock.

Greenhouse

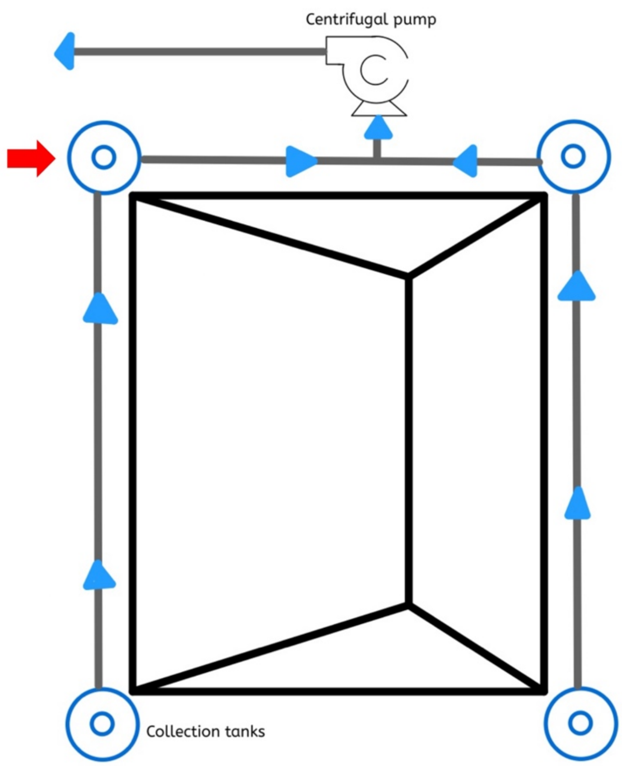
- The cables that connect the pump and the float switch run under the ground, and while they are several inches deep and the soil is hard and dry, caution should still be exercise after extremely heavy rain in case any of the cables are now exposed.
    - Immediately disconnect the electrical box from the main power, which is located in the outlet on top of the box.
    - Be aware of any puddles surrounding the greenhouse that are near the buried cables. If any wires were torn or exposed, then you will be electrocuted if you were to have contact with the water.
    - In order for the puddles to be charged, several things would have to go very wrong, but it is always worth exercising extreme caution when dealing with the voltages present in the prototype.

- The electrical box is located on the second post on the right once you enter the building. It is locked with a key to prevent the box from accidentally opening

- During normal operation of the greenhouse, refrain from spraying the electrical box directly with water, as water directly sprayed on it can cause issues with the wiring and lifespan of the box

Grafting Building Expansion

Here is the proposed design for the water collection at the grafting building and buildings like it.



The connecting pipes in each tank should be placed at the bottom of the tanks with return valves to avoid the water from flowing back.

This system would consist of 4 tanks, one under each rain gutter. Since the building is on an incline, the tanks on the top will gravity-feed the ones on the bottom (closer to the pump). Using the instructions for auto-emptying and auto-filling tanks (See page 9), place a float switch in the tank marked with a red arrow (this one will fill up faster) and one in the desired storage tank. This system will fill up the storage when it is empty, and there is sufficient water in the collection area.

Glossary

Rainwater Collection System: system designed to collect and store rainwater.
Prototype: preliminary model or version of a product or system used for testing and evaluation.
Float Switch: device that detects the level of a liquid in a container and acts as a mechanical switch as the level changes.
Counterweight: weight used to balance or offset another weight; it adjusts the height of a float switch.
Electrical Wiring: system of wires and components used to transmit electrical power within a structure.
Miniature Circuit Breaker (MCB): safety device that automatically interrupts electrical flow in a circuit in the event of an overload or short circuit.
Magnetic Contactor: electrical device used to remotely switch power circuits to control electromechanical devices.
Automatic Pump Controller: device that automatically controls the operation of a pump.
Single Phase Pump: type of pump that operates using a single-phase electrical supply.
Submersible Pump: pump designed to be fully submerged in liquid.
Gauge: unit of measurement for the diameter of wire, with lower gauge numbers indicating thicker wire.
Return Valve: valve used to control the flow of fluid in a pipe, allowing it to flow in only one direction.
Pipes: tubes used to convey fluids from one location to another.
Wire Nuts: connectors used to join or splice electrical wires together.

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