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Repurposing 275-Gallon Intermediate Bulk Containers from Tropical Storm Helene: Prototyping Design of Rain Catchment System for Emergency Water Supply

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Abstract

Rainwater catchment has been a common practice in many areas of the world for hundreds of thousands of years. This practice remains prominent in our modern age, and can prove useful when dealing with an unreliable infrastructure. During Helene, damage to the main water transmission lines caused high turbidity in the North Fork Reservoir, leaving over 70% of Asheville residents without potable water for 53 days. Simple rainwater catchment and filtration systems can provide immediate access to potable water for small residential communities, without the need for power in emergency situations. For this project, a design for a simple rainwater harvesting and filtration system was developed using Autodesk Fusion 360 modeling software, incorporating 275-gallon water totes that were distributed during Hurricane Helene relief efforts and subsequently abandoned. Two

prototype systems were built at UNC Asheville's STEAM studio and installed in two communities. One utilizing the roof of a community member's mobile home and the other installed at a Swannanoa community center. Both systems use preexisting gutter systems to collect surface water, as well as an initial filtration system for large particulate matter, before being deposited into a covered recycled tote to prevent algae growth and a raised foundation for accessibility. A second filtration system for potable water is integrated separately and only used when necessary. Both systems are undergoing testing for potability and irrigation purposes. All parts of the system can be purchased from a hardware store, and STL files for 3-D printers will be available. Once testing is complete and improvements have been made to the prototype's design, a building manual with care instructions will be provided for additional communities.

Problem Statement

Tropical Storm Helene caused $59.6 billion in damages across Western North Carolina (*Labor Market Impacts of Hurricane Helene*, 2025). This brought to light how ill-equipped both rural and urban Western North Carolina (WNC) was when faced with the effects of a rising number of extreme weather events (*Extreme Weather Events Have Increased Significantly in the Last 20 Years*, n.d.).

The subsequent damage to the infrastructure of Asheville, NC left 70% of residents without clean city water access for 52 days (*Hurricane Helene's Water Crisis Leaves Lingering Doubts for Asheville Residents - EHN*, n.d.). Many nonprofits, educational institutions, and the general public were widely responsive in attempting relief efforts, but the population lacked access to basic materials(Phillis et al., 2024). Water was distributed to residents from 275-gallon Intermediate Bulk Containers (IBCs) until city water services were restored (Peterson & Press, 2024). After water services were restored, however, many IBCs were abandoned.

The purpose of this project is to repurpose IBCs for home rainwater collection by providing detailed instructions on outfitting the containers with products available at most major hardware stores. These tanks can be used in the event of an emergency as a source of water or means of sustainable collection for irrigation use. Feasibility of affordable water catchment systems for vulnerable populations is a main focus within this project. The creation of a simple design is a priority for the general public to be able to assemble the kit themselves without need for professional intervention.

Research and Analysis

When entering the design process, several problems that would arise needed to be addressed to the best of our ability along with the time constraints of the project period.

Survivalist and "off-grid" guides (Alexander, 2011) were taken into consideration when deliberating different ways of storing rainwater and the needed precautions and maintenance, as well as professional guide-lines (*ARCSA/ASPE/ANSI 63-2020: Rainwater Catchment Systems*, n.d.).

Below freezing temperatures in the winter time is an area of concern when considering water storage. Several possible solutions were presented, such as insulation and heated covers, however both solutions were foregone for the option of reducing the water in the tank to ¾ the tanks volume to allow the water to freeze without cracking the IBC bottle. Freeze resistant spigots were also considered, however due to the inner mechanism of the spigot allowing for freeze, the spigots were unreasonably long, and the inner mechanism significantly reduced the water pressure from the IBC tank from 2.02 psi to a slow trickle. The psi was calculated using the equation:

$$P = \rho g h$$

Where P is pressure in Pascals, ρ the density of water, g the acceleration due to gravity, and h the depth of the water.

$$P = (1000 kg/m^3)(9.81\ m/s^2)(1.42\ m)$$

$$P = 13930.2\ Pa$$

Or 2.02 psi

A separate heated cover or placing the IBC underground could be a viable option for future attempts. For the scope of this project, any solutions that required electrical amenities were foregone, as were any solutions that required significant displacement of site terrain.

Water storage solutions which are left in direct sunlight are subject to the effects of increased growth of certain types of algae (Li et al., 2011). Water collected via rainwater collection is regarded as surface water due to organic matter making its way into the tank regularly (Palmer, 1964). Because of this, a solution to block sunlight from entering the bottle is desired to circumvent the need for chemical water treatment. Initially black paint and white primer were considered, however this erases the ability to appraise the semi-opaque bottle while practicing routine maintenance and reduces the ability to find any growth or unwanted particulate matter when cleaning the tank. Another option explored was wrapping the tank in a black plastic material which would block sunlight from entering into the IBC and could be removed depending on future needs. This solution was foregone due to the possible prolonged use of single-use material creating greater volumes of waste. Ultimately, a reusable reflective cover with a cord cinch at the base was purchased for the role. This allows for other uses for the IBC to be considered in the future as well as being a straightforward attachment for the public to install.

The issue of water collection was uncomplicated when taking into consideration the pre-installed gutter systems at both prototype testing sites. Copper pipe was considered for the inlet due to its antibacterial abilities (Konieczny & Rdzawski, 2012), however due to cost and tendency to tarnish this option was unused. The rate of flow was taken into consideration when determining the size of PVC pipes to incorporate into the design and a 3" pipe was determined acceptable. The outlet size of the large particulate filter selected at the beginning of the design process has the dimensions to fit the 3" PVC attachments as well.

Figure 1. Leaf litter downspout filter purchased and used during testing.

To create a more accessible design for common water containers, a cradle was designed to elevate the IBC off the ground with a minimum clearance of 12 inches, this decision was made with common 5-gallon buckets in mind. When designing the cradle, drainage was considered as a secondary purpose for the cradle. Renderings of the cradle included a raised gravel bed, a timber-framed wooden frame featuring half-lap joints, and cinderblocks.

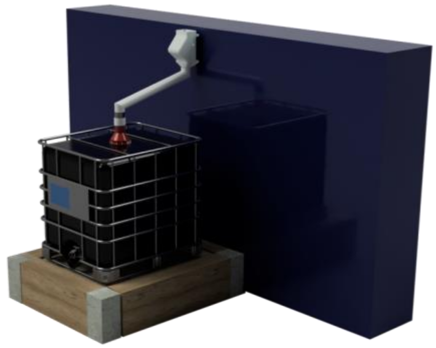

Figure 2. Concept model for retrofitted IBC tank design.

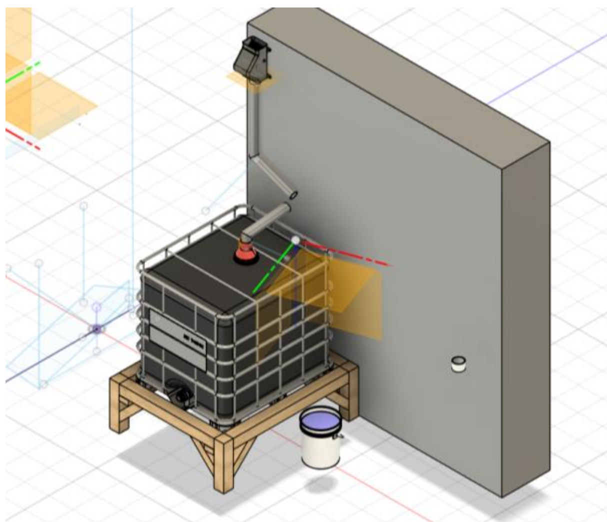

Figure 3. 3D render of IBC placement and construction initial concepts. Shows initial design for the wooden cradle and overflow.

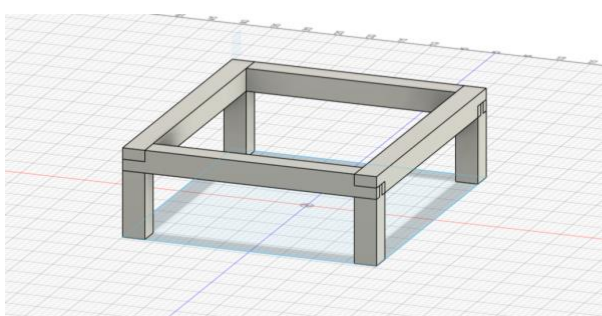

Figure 4. 3D render of frame design.

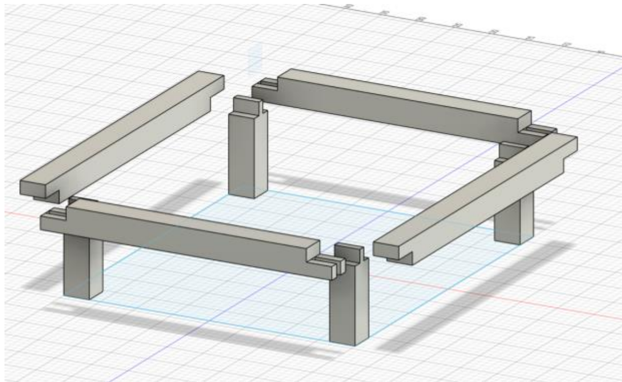

Figure 5. Disassembled 3D cradle design.

Figure 6. Joint design of side pieces for cradle prototype.

Figure 7. Fully assembled first frame prototype.

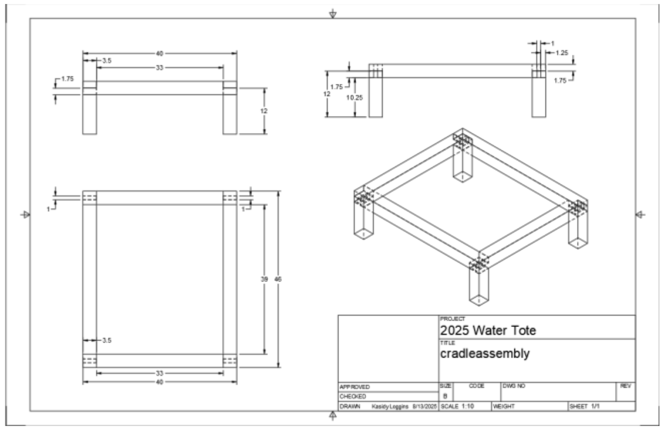

Figure 8. Blueprint for cradle assembly.

Design

Two IBCs were sourced for the purpose of outfitting and prototyping for this project by a community initiative named Semmilla de Vida along with Elevate AVL (Edwards, 2025), who purchased all prototyping items needed during testing as well. The bars surrounding the inner bottle of the IBC are made of galvanized steel, with a high-density polyethylene (HDPE) pellet material used for manufacturing the inner containers. The valve located on the front of the container also includes HDPE and polypropylene, with fluorine rubber gaskets for sealing (HUAN Machinery, n.d.).

The cradle was built using 4-inch x 4-inch x 6-ft pressure treated wooden posts. 2 posts were required for the base leaving post leftover. Using timber-framing techniques for the half-lap joints, the frame was assembled to be the exact dimensions of the base of the IBC tank with 46-inch cross members slotting into 12-inch base posts for height, and 38-inch posts resting on top, assembled using 12 timberlock 4-inch screws. The IBC tank is meant to rest on the cradle and is anchored using steel pipe anchors screwed directly into the posts.

Manufactured spigot adapters for IBC tanks are available online and in hardware stores, these prebuilt couplings are recommended in place of the PVC adapter that was tested. The prebuilt spigot housed within the tank is incompatible with most PVC attachments, therefore a cam-lever male to female coupling was purchased. This adapter allows for 2-inch PVC attachments to be used with the spigot. A second adapter was created using PVC primer and cement, 2-inch PVC female slip adapter, and a ½ inch PEXA x ¾ inch attachment used to attach a spigot, all components of this secondary adapter are commonly available from a hardware store.

The cover used was prepurchased for its reflective outer layer, lid inlet access cutout, and cinch cord for stability. The cover was pre-made for use with IBC tanks.

The lid adapter was designed in Fusion 360 3D modeling software using a premade IBC lid (creator unlisted) and modified to match the size of 3-inch schedule 40 PVC pipe attached to the PVC inlet using either a 90 degree elbow or sanitary tee depending on if overflow drainage is desired. The lid was 3D printed using polyethylene terephthalate glycol modified (PETG) filament for its weather resistant and heat resistant nature in comparison to other common 3D filament such as Polylactic Acid (PLA).

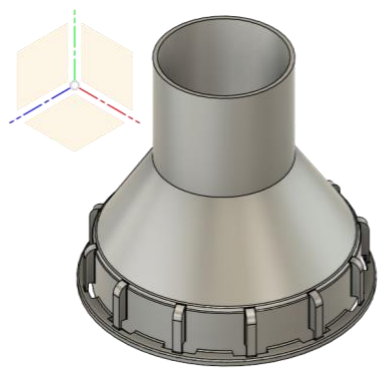

Figure 9. 3D render of modified lid adapter printed for prototyping.

The PVC inlet connecting the large particulate filter to the IBC access is made of 3 inch schedule 40 pipe as well as 3 inch PVC 90 degree elbow connectors and one 3 inch straight connector attaching the filter to the PVC piping. PVC cement and primer was used in the joints of the attachments as well. Primer and cement were not used in the connection below the leaf litter filter or the connection between the 3D printed lid adapter and the PVC piping system to allow for future sanitation of the tank and the entering water collecting system.

The large particulate filter positioned directly below the outlet of the gutter system was purchased online, and is used to flush out the leaf litter from the surface of the roof before it makes it into the tote. The item is listed as "Rain Harvesting Pty Original Leaf Eater Downspout Filter" and features a screen with a 7/32" aperture and is set at an angle of 45°. This product was installed using the gutter downspout anchors previously installed at the prototype locations.

Figure 10. PVC inlet connecting leaf particulate filter and 3D printed lid adapter attached to home using preinstalled gutter fastenings.

Finally a 1.5 gallon carbon filter system was purchased and tested for base filtration of Allura Red AC, also known as FD&C Red 40 or E129, particulates. Further testing is needed to determine the reliability of this potable water system. Chlorine treatments were considered when approaching the issue of algae growth, however, this solution required an individual to be trained in administering chlorine per unit-volume within the tote, rendering this option outside of the scope of the project (Environmental Protection Agency (EPA), 2002).

Requirements for long term potable water service centers are managed by NC DEQ, however because this is an emergency circumstance only system, serving under 60 days, these standards do not legally apply. To ensure safety to those who wish to use the potable water system, the tests required for long term service will be conducted nonetheless (DEQ, n.d.). Tests include a presence-absence indicator test for total coliform, E.coli, giardia, and cryptosparidium (Certad et al., 2017).

Prototyping

The pieces of the prototype that were purchased were secondary mesh filters (which did not enter the second prototype), a 1/2 HP High Capacity Cast Iron Transfer Pump, an

Automatic Yard Watering System, a Woodford 19CP-12 Model 19 Wall Faucet, a LeafEater downspout filter, a semi-reflective IBC tote cover, a 3/8 in. Dia x 100 ft. 20-Piece Garden Soaker Hose Kit, and a 1.5 gallon Berkey travel filter kit.

The first part to be fabricated was the lid adapter created in Fusion 360. The initial print was made of a filament called TPU (thermoplastic polyurethane) and has a rubber-like consistency. TPU was selected because of its waterproofing and sealing capabilities replacing the originally needed rubber gasket on the inner wall of the lid. While the material properties were ideal, it proved to be extremely difficult to remove the supports and a rather expensive option.

The material was switched to PETG because of its semi-common use in hobby prints serving outdoor purposes, its higher resistance to increased temperatures, and reduced cost in comparison to TPU. Several other modified prints would be fabricated while prototyping was ongoing. The second iteration of the lid included a drainage outlet at the top of the incline leading to the attachment section which was ⅜ inch in diameter for use with a garden hose. However the wall of this print was too thin to withstand the attachments required to install the hose. Plastic soldering was attempted to salvage the print, however the print was foregone for the second prototype due to the volume of waterflow possible during heavy rainfall, and therefore replaced by a 3-inch PVC sanitary tee instead.

Figure 11. 3D printed IBC lid adapter first iteration.

Several iterations of the cradle were designed, however the edition selected was the wooden frame cradle to accommodate the height of common water vessels such as 5 gallon buckets as well as handle up to 2,290lbs of rainfall. The first prototype of the half lap joints were less-than optimal due to inexperience and measurement errors made during the building process, however this cradle was used nonetheless as these errors were not detrimental to the overall structural integrity of the frame. The tools used for this frame were a bandsaw, tablesaw, chisels, timberlock screws, and an impact driver.

Installation and Testing

Two installation dates were scheduled for each prototype to be transported to both locations, however further modifications would be made later on when needed. Two locations with differing terrain required different solutions for the separate prototypes, one location being the residence of a Semilla de Vida Community Initiative member, and the second being Swannanoa Communities Together community center. Concrete blocks with dimensions 2 x 8 x 16 inches were placed below the cradle posts to mitigate settling earth while the tank filled.

During the installation of the first prototype, non-schedule 40 gutter downspout PVC was used and led to fitting issues due to differences in diameter and thickness. Schedule-40 PVC was purchased instead and the issue was resolved. The tank was positioned under existing gutter outlets, using the preinstalled gutter pipe fasteners to attach the leaf litter filter to the house siding along with 13 inches of pipe before reaching an elbow joint. The tarp, the faucet, and inlet piping were installed without issue. The adapter lid did not seal properly due to the diameter of the attachment being slightly smaller than the PVC 3-inch schedule 40 used. This was corrected in the second prototype.

Figure 12. First prototype installed under a home gutter system using the cradle system.

The installation of prototype two was completed two weeks after the first, following the building of a second cradle with increased quality joint construction.
The site of the second prototype is a sloped asphalt parking lot behind the Swannanoa Communities Together community center. Instead of concrete supports for fear of settling earth, wooden shims were needed to correct the uneven asphalt terrain, however it did not require a redesign. The drainage outlet designed into the adapter lid for location 1 was replaced with a PVC sanitary tee, allowing the overflow into the pipe to flow over the side of the tank towards the embankment. Otherwise the design for the PVC inlet remained the same, save for the community center being taller than the initial residence requiring longer PVC sections.

Product Analysis and Improvement

The overall cost of this kit depends on the needs of the individual seeking to add a water catchment system to their home. The IBC tanks lacking ownership are in the process of being located by Semilla de Vida and Elevate AVL, aiding in the ability to assemble this system economically. Products required for base level operation of a raincatchment system are piping, a modified IBC lid, and initial leaf litter filtration. Without purchasing the IBC this leads to a cost of $124.95 including the leaf litter filter, PVC pipe and connectors, and PVC cement. This price does not include the IBC or the lid adapter designed and 3D printed at Steam Studio of UNCA, however an .STL file will be made available for anyone with access to a 3D printer. If desired, the cradle, reflective cover, Timberlok screws, and spigot adapter can be purchased leading to a final price of $215.69. Finally if a possible solution for potable water is desired, purchase of a Berkey filtration system will be $327, bringing the total cost to $542.69.

All products but the spigot adapter, leaf litter filter, carbon filter, and lid adapter were either directly available for purchase from 2 major hardware suppliers, or ordered from an online storefront. Possible solutions to reduce overall price could include substituting PVC piping for Copolymer FLEX Drainpipe, although a solution for fastening was not explored. Replacing cradles with elevated preexisting terrain or cinderblocks could also be an option to consider depending on individual resources and location.

Irrigation systems should also be considered when further benefits are desired from the rainwater harvesting system. A pressurized water pump, soaker hose, and irrigation splitter could also be purchased for this purpose, costing $54.99 for the irrigation splitter, $34.99 for the soaker hose, and $179.99 for the irrigation pump. Listed products were purchased from a major hardware store for community use, however it is possible to find everything needed for a lower price.

If attempting to assemble this system, it's recommended that the specifications of the location are taken into consideration. There is a possibility that much of what was purchased for these prototypes can be foregone in different situations, the opposite is also true. Going forward it is recommended that an attempt should be made to find a premade lid adapter, as none were located until the prototyping stage began, as well as a premade spigot adapter. Both of these options can prove economical in comparison to the created adapters tested during this process. A collapsible copolymer drain pipe is recommended for overflow drainage if there is a safe runoff location farther from the IBC location as well.

Conclusion

The abandoned IBCs scattered throughout Asheville, NC could prove useful by recycling them into rainwater catchment systems for the public to assemble for both personal and emergency use. Existing rainwater catchment systems can be inaccessible to some due to economic hardship, therefore an economical solution using these tanks was considered. The tanks can be used for basic water catchment on any building with a preinstalled gutter system using PVC piping or Flex drain pipe. If other uses are desired, options are available for higher costs, however these designs and attachments are not required. Potable solutions are currently undergoing testing using the carbon filter system. If found to be successful in proper filtration and reliable as an emergency alternative, these systems could be considered in an individual's emergency kit.

Acknowledgments

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