ENGINEERING DESIGN

SOLUTION TO THE DRC WATER CRISIS

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Identification and Definition of the Problem

The Democratic Republic of Congo, also known as the DRC, has been entangled in a complex crisis that has lasted over the span of several generations. This Central African country, the second largest on the continent, has been locked in political turmoil for years, and in turn has suffered devastating declines in its economy, public health, public safety, infrastructure, and overall well-being (*Globalwaters*). Evidently, the lack of infrastructure in the country is the primary root of the DRC's largest and most pressing matter: the water crisis (Shore). Currently, approximately fifty-eight percent of the DRC's population has been left without clean water ("In Water-Rich") ("Overview"). Many of these people, approximately sixty percent, are from rural or tribal communities, which are the areas most profoundly affected by the water crisis (Thelwell). This is primarily due to the fact that most rural area populations live under the poverty line and do not have the ability to purchase clean water (Thelwell). Regardless, even urban areas have suffered, as clean water only reaches about sixty-nine percent of them (Shore). Clearly, the water crisis in the DRC has affected countless, making it a nationwide issue that must be solved before it worsens any further.

Water is a basic human need and is considered to be the second most essential substance needed for human life, coming just behind oxygen (Fritz). Considering the average human being can only survive three days without water, the lack of drinkable water in the DRC is extremely concerning, especially for families (Johnson). Even in a country with terrible violence and volcanic eruptions, the number one concern for families in the DRC is finding safe water for their children and loved ones ("How Much"). 25-year-old Justine, a resident of the DRC, states that "... water is life... there is nothing we can do without water" ("How Much"). Getting water is no easy task however, with many citing it as their most difficult responsibility ("How Much"). Justine explains, "I had to search for water for many kilometers and spent all my time just to find water…" ("How Much"). Many of the women and children in the DRC are forced to search for water every day and carry it home in large yellow jerry cans ("How Much"). This problem stems from not only a lack of clean water in every community, but also from the lack of water piping and infrastructure (Shore). This means that even if a large water spring or other alternative source is found, there is no way to get that water to other communities that are struggling. Additionally, since the gathering process may take hours, most women are unable to work, and most children are unable to attend school ("How Much"). This reality is a major contributor to the DRC's current poverty rates, with most families living on $1.25 a day, as well as the country's illiteracy (Thelwell). The DRC's water crisis and its consequences have had many dramatic and damaging effects on the lives of the Congolese.

The water crisis in the DRC does not originate from a lack of water like many would assume. In fact, the DRC holds fifty percent of Africa's total water reserves (*UNICEF*). Unfortunately, most of this water is highly contaminated, which has limited the DRC's water supply to springs and groundwater ("The Congo"). Even these sources offer minimal safety, but they are presently the best option that the citizens of the DRC have. The solution to this country's water crisis can be found right next door, or more literally running right through it. The Congo River borders the DRC on one side and continues through the center of the country ("Congo River"). The amount of water in the Congo River is substantial enough to provide for the entire country, as it is the deepest river in the world, and the ninth longest (Secon). The DRC is unfortunately unequipped to treat the variety of contaminants in the Congo River, and thus is unable to safely harness it ("In Water-Rich"). In a way, the lack of water infrastructure has made the Congo River less safe to use because the country does not have proper restroom facilities ("In Water-Rich"). This has led people to use poor locations that lead to rivers and streams, like the Congo ("In Water-Rich"). Now, the list of the Congo's pollutants has skyrocketed to include biological waste, sediments, heavy metals, bacteria, and diseases (Mata et al.). The most common metals found in the Congo River are copper, chromium, zinc, cadmium, palladium, and mercury (Mata et al.). Diseases, on the other hand, include diarrhea, dysentery, bilharzia, typhoid fever, cholera, and ebola ("The Congo"). The river may also contain parasites, such as Schistosoma Mansoni ("Schistosomiasis") (*IAMAT*). Therefore, the DRC has millions of gallons of untapped potential that they are unable to harness due to mass contamination and inability to treat said contamination.

Many citizens of the DRC have been forced to live without clean water. Instead, they – mostly women and children – travel for hours just to obtain water that is not fit for consumption because of its high percentage of dangerous and often deadly contaminants. Even further, the lack of water has caused devastating blows to the DRC's economy and educational success. If this chain of inadequate water continues, the DRC and its citizens will inevitably continue to suffer and even die. Fortunately, the DRC has the Congo River. If harnessed and properly treated, the Congo River could evidently supply thousands of people with water. Currently, there is only one major issue preventing this from happening; the DRC lacks the infrastructure to filter the Congo River. Regardless, if given the proper tools, the DRC would be able to free itself from its generations-long water crisis.

Importance of Solution & How It Would Impact Lives

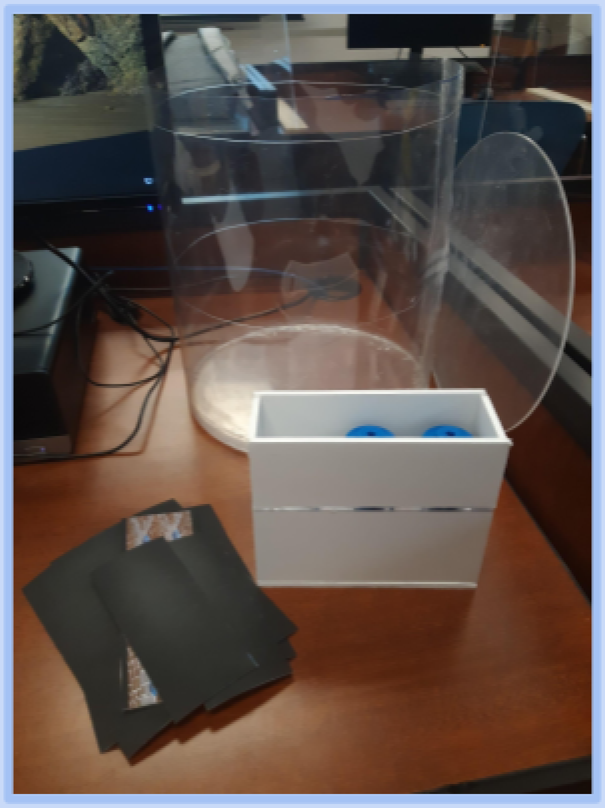
A solution for the water crisis in the Democratic Republic of Congo must be enacted to prevent a further decline in the country's industries, health, and overall condition. Currently, the DRC is classified as a Level Three Emergency Priority by the United Nations (Thelwell). For reference, Level Three is the highest the emergency scale used by the UN goes, and there are only three other countries within this bracket; Iraq, Syria, and Yemen. (*ReliefWeb*). Resolving the DRC water crisis would improve various aspects of the country, but would be most beneficial in three categories; economic, education, and public health/ quality of life.

The DRC's economy has declined drastically in the last few decades due to a multitude of reasons, including the water crisis. The water crisis is currently limiting certain industries within the DRC and it is preventing a large portion of the population from working, and thus preventing them from making money ("The Facts"). Since disease travels quickly in the DRC, due to the contaminated water, many workers must miss work to rest and recover. During this time their position is left vacant, slowing the work process and ultimately slowing the economic flow of the country ("Overview"). This is especially evident in the trading industry, which is a large sector of the DRC's economy ("Country Risk"). Most of the DRC's industries are dependent on exporting goods ("Democratic Republic"). Mining, consumer products, timber, and more, all of which are main industries in the DRC, rely on the cultivation of goods ("The People"). Without healthy workers, there is not an adequate cultivation rate (Remes et al.). By fixing the water crisis, the export industry will no longer suffer losses due to absences because the water would no longer be making workers ill. Other economic effects of the water crisis pertain to the agricultural industry ("Water Issues"). Agriculture in the DRC is primarily for subsistence, meaning for consumption, not exportation, so it is needed for the citizens of the DRC to have food (*WFP*). Consequently, it has become difficult to supply food to the people of the DRC because of the water crisis (*WFP*). The shortage caused by the crisis is also taking away the portion of income farmers do make from exporting surplus, though it is far less than the loss caused by not being able to sell crops within the country (*WFP*). The agriculture industry is also the DRC's main employer, so it is vital for it to stay active; otherwise, millions of people will lose the already little income they have ("Country Profile"). If the water crisis is not resolved, the agricultural industry and other industries will inevitably continue to suffer and may potentially begin to fail, which would leave the people of the DRC without water and without pay.

The DRC's water crisis is also contributing to the educational declines in the country. Children and their families are often too impoverished to support the materials needed for school (Brown). With the water crisis resolved, there will be an economic improvement, thus leading to more schooling availability and support ("Water Issues"). Additionally, children would no longer have to participate in long scavenging trips for water, as the resource would become significantly more accessible without the current infrastructure issues ("How Much"). More education will provide more economic potential as well ("Education"). Therefore, resolving the water crisis will allow for more education in the DRC, which will improve the lives of the citizens through the opportunities it unlocks.

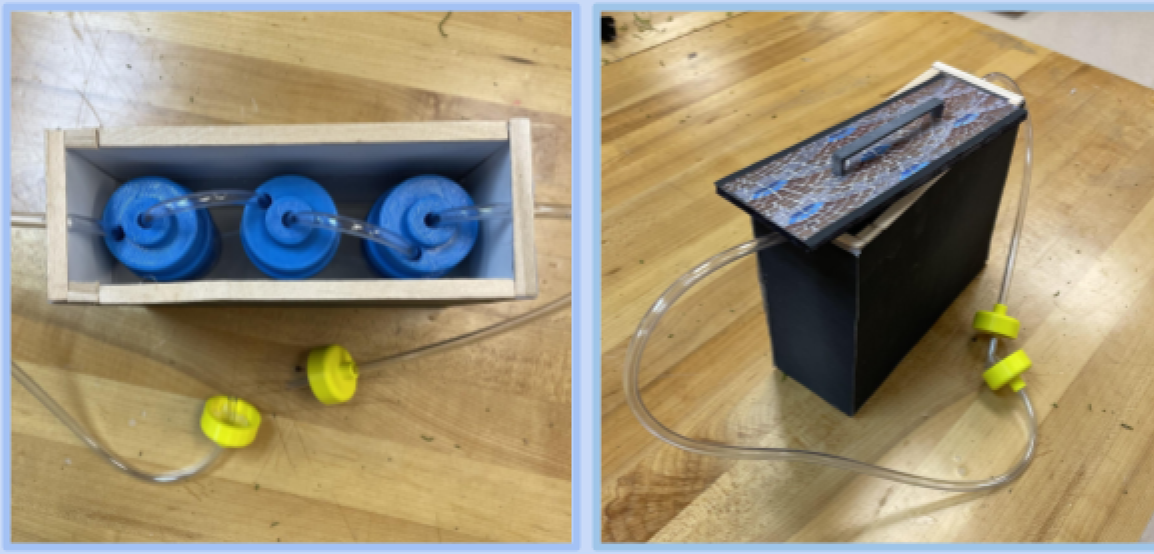
Providing a solution to the water crisis in the DRC will save thousands and improve the overall public health of the country. Currently, water sources are the root of large disease outbreaks because of a lack of sanitation and filtering ("DRC"). Many of these diseases are not minor conditions, but instead more rampant and dangerous illnesses, like cholera ("DRC"). With the lack of medical facilities in the DRC, many are lucky to even survive ("Congo"). Moreover, even if a person survives a bout with cholera, or another one of the diseases, they are likely to suffer with long-lasting disabilities and consequences, which cripple a person's life and drastically decrease the quality of their life (Ogasawara and Inoue). Not to mention, many can not afford to take time away from their many duties. There are also substantial traces of heavy metals and other dangerous contaminants, such as human excrement, which can also inflict bodily harm (Mata et al.). The outbreaks and mass contamination have claimed millions, many of which were children ("Ebola"). With a solution, the DRC would no longer have to suffer such terrible and impactful loss. Children and adults alike will no longer have to struggle to survive and will be able to enjoy some spoils of what is considered to be modern life. All and all, eliminating the water crisis will evidently improve the general health of the DRC as disease and other health complications will not spread as quickly or at all.

In today's modern world, water is considered to be a given resource, one that everyone has access to. Unfortunately, this is not the reality, and many places, like the DRC, have been left to rely on dangerously contaminated water. This unclean water has sparked economic decline, educational decline, and health decline under the DRC, which has caused the country to enter a spiral of failure and disarray. A solution to the DRC's water crisis must be found before the country reaches an even greater state of peril. With a solution, the people of the DRC will no longer struggle to grow; they will finally be able to live.



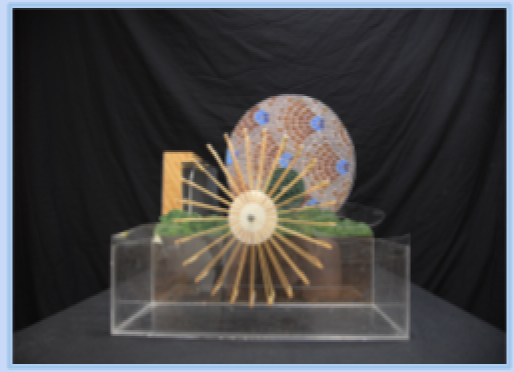
Images of beginning stages of model construction.

Tank before finishing details and rotation arm implant.



The Reverse Osmosis device was assembled as such before being placed on the final model.

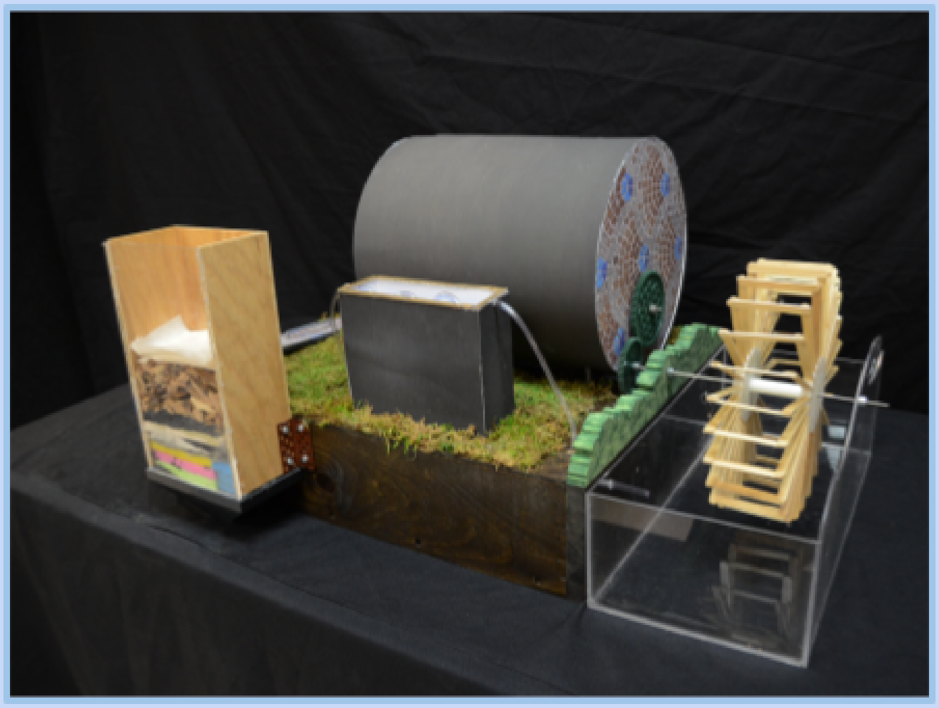
After the canisters were designed, they were 3D-printed and fit with custom sewn filter implants that mimic the replaceable filters of the design.



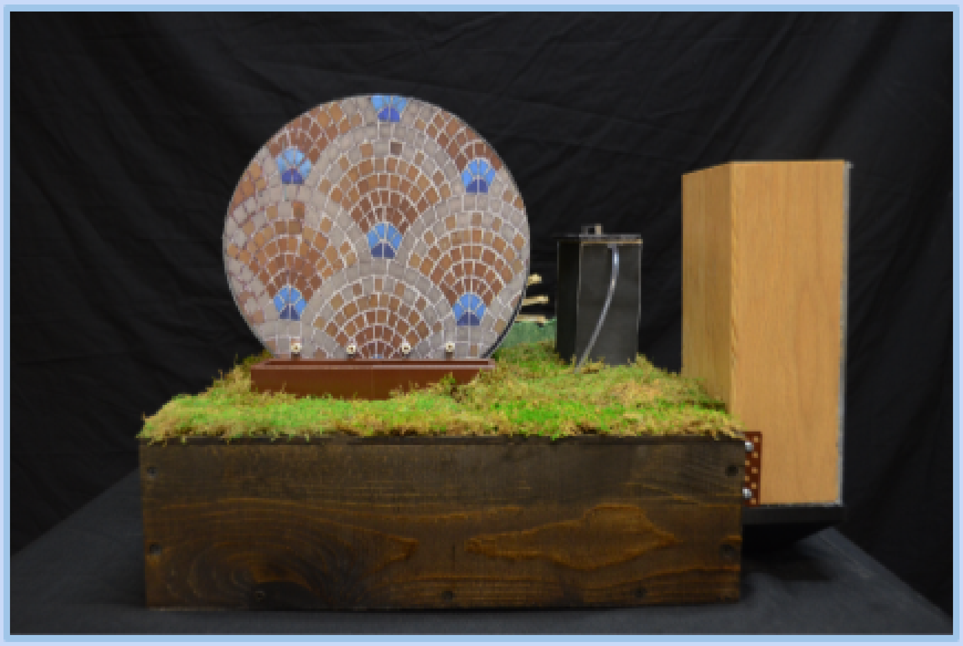
Enlarged view of water wheel mechanism on model.

Enlarged view of assembled canisters placed on the scale model.

Enlarged view of faucet setup located at the rear of the water tank.

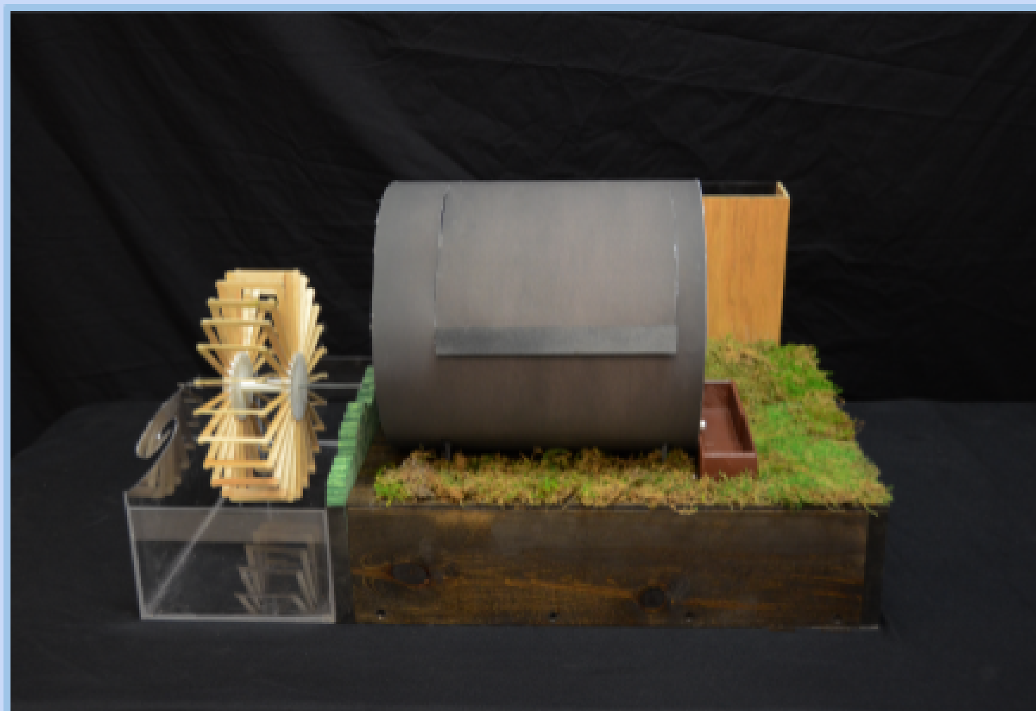


Diagonal of scaled model that showcases the RO device, storage tank, and water wheel. **Scale: 1/8**

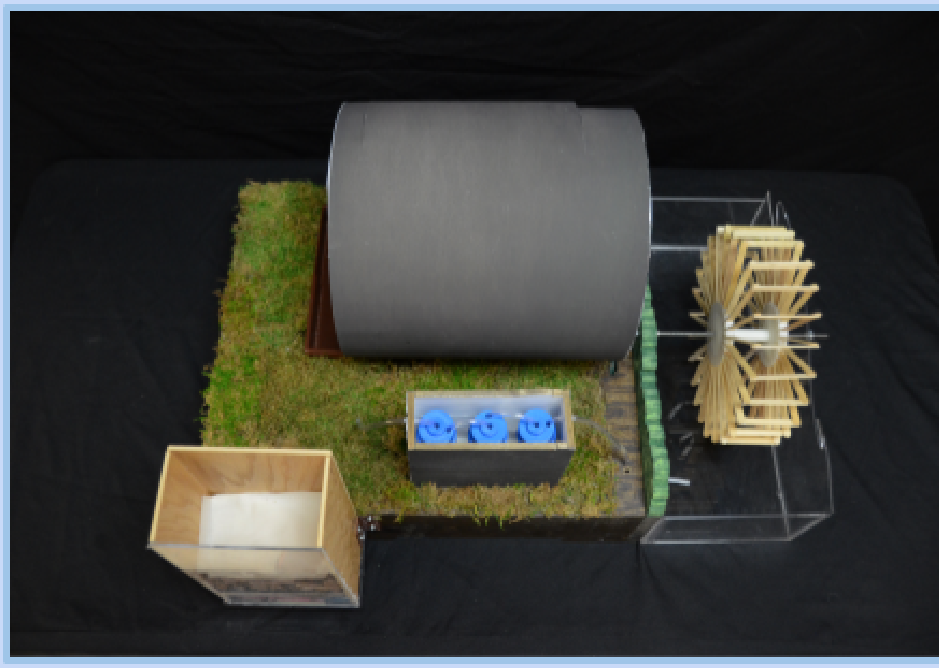


View of the inland facing side of the RORD filtration system and tank.

Right-hand lateral view of the scale model.



Left-hand lateral view of the scale model.



Overhead view of the scale model.

Enlarged view of the filter tower.

Enlarged view of the rotating arm in the water tank.

Explanation of Three Possible Solutions:

-Solution One-

Distillation is a highly effective method used to decontaminate water, and it is used in the majority of purification facilities in the US. In order to grasp this process, one may refer to the hydrologic cycle as a reference. The cycle begins with evaporation, during which water rises from the earth, leaving behind all foreign matter, and entering its purest form — water vapor (*Waterwise*). Distillation uses this same process by heating the contaminated water to its point of evaporation. As the vapor rises, it is funneled towards several cooling rods. These rods cause the temperature of the water vapor to drop drastically, making it condense into newly purified water ("How Does"). Distillation is able to effectively remove bacteria, parasites, herbicides, pesticides, and other wastes from water, which makes it well suited for purifying the Congo River (*Waterwise*). Biological contaminant levels also drop significantly through the use of this method as the process frees water from 98% of its impurities ("How Does"). All in all, this method could ultimately offer a highly effective solution for the Congo water crisis.

Using the concept of distillation, the team designed a filtration system that would provide clean water by filtering the currently infected Congo River. Water from the river would run through a grate and into an extraction pipe. This pipe would carry the water to a large boiler where it would be heated, causing evaporation to occur. The steam would then rise to the sloped roof of the tank, which is angled to direct the vapor toward the cooling rod section of the system. As the vapor passes over the rods, it is cooled and condensed into water droplets, which fall onto another sloped surface to guide them into a new section of the tank where only clean water is gathered. Finally, the water is channeled into a pipe leading it to a 3000-gallon storage tank. People may use the faucets on the outside of the tank to extract the purified water for use.

This intricate system requires three accessory mechanisms to function properly. The first accessory is required to control overflow. The pipes in this system are sized to ensure an appropriate flow rate of forty-five gallons of water per minute into the system ("Steel Pipes"). At this rate, however, the boiler portion of the system would be swiftly overwhelmed if left untamed, creating an occurrence of overflow into the clean side of the tank. To avoid this, the team engineered a unique mechanism to stop overflow from occurring. In the boiler portion of the tank lies a separate but still heated chamber. Eight inches into this chamber one will find a pressure plate that is held in place by springs that attach to the bottom of the chamber itself. The pressure plate is connected via a rod to the overflow stop barrier, which is situated above the water's entranceway. As the water rises within the boiler, water will begin to overflow into the chamber at a certain point. The weight of the incoming water will force the pressure plate downward which in turn causes the barrier to drop as well. This halts the intake of water, and gives the system time to properly process the water inside.

The team considered multiple options when determining a method of boiling the water within the boiling tank that would work well in the Congo region and be inexpensive. The team determined that using off-the-grid reflective boiler technology would be most fitting. The DRC has a very warm climate since it lies on the equator where the sun is most powerful (Lemarchand). The tank is surrounded by heliostats — metal poles with an array of mirrors attached — that absorb the sun's thermal energy and reflect it onto the tank to heat the water inside (Kanellos). To help speed up the process, the exterior of the boiler would be made of aluminum as it is both a good conductor of heat and a non-toxic element ("Aluminum"). The system also needs a way to convert this vapor back into water through the use of a cooling rod. The operation is simple in that the rod reduces the temperature of the steam, and it is condensed back into water, but the rods do need power ("How Does"). To obtain this there will be an electricity box powered by solar panels on top of the tank. Finally, the inside 3000-gallon storage tank would be lined with a dark interior, while the exterior of the tank remains light in color. Algae can thrive in any form of sunshine or light, so using this lining to essentially black out the inside ultimately prevents algae growth (*Americover*). Meanwhile, the tank's light exterior will reduce heat absorption. The distillation design does have its faults. First, it takes a long time to fully filter the water. Second, this system can not function at night. Between its boiling rate and the inability to work at night, the unit would not work as efficiently as other options.

The distillation mechanism shows much promise because it significantly reduces the levels of sediment, metals, and biological contaminants in the water ("How Does"). It has proven to be extremely self-sufficient, and if the machine were to need any sort of repair, going about doing so would be simple and easy for those who rely on it. The design requires no direct hands-on labor to function accurately and is not a particularly bulky insertion to the riverside. Overall, the distillation water filtration system serves its main purpose of eliminating contaminants and has many other advantages, but is not the selected design due to its hindering shortcomings.

-Solution Two-

Another possible method that can be used to solve the DRC's staggering water crisis is purification through the use of chemicals, specifically chlorine. Chlorination is the use of chlorine to kill parasites, bacteria, and viruses in water, and is one of the most familiar ways of purifying water ("Types of"). Unalloyed chlorine is rarely used for this but is instead combined with other chemicals to form chlorine gas, sodium hypochlorite, or calcium hypochlorite, all of which are used for water decontamination ("Types of"). Chlorine gas has an extremely high toxicity which makes it a quality water disinfectant, however, the substance can provide fatal risks for humans ("Types of"). Sodium Hypochlorite is a yellowish liquid very similar to household bleach ("Types of"). The substance does assist in purifying the liquid but, in the full analysis, would be a messy and difficult substance to utilize. The final form of chlorine is Calcium Hypochlorite ("Types of"). It increases the pH of the water being treated and successfully decontaminates it. It is often used in pellet form which would work best in this environment ("Types of").

Once again, the team was able to design a separate solution incorporating the use of Calcium Hypochlorite. The water begins by passing through a grate in the Congo River and entering the pipe system. The water is run through the piping and eventually is showered into a container of sand through the use of a rain nozzle. As it falls through the sand, larger particles like dirt or pebbles are caught and removed from the water. From there, the water is gathered into a small tank until it is directed back into the piping system. The water is taken up through the pipes where it will be disinfected when it passes over pellets of Calcium Hypochlorite. These pellets are held in a row in a cartridge above the pipe. Once the beginning pellet is disintegrated, due to use, a new one from the cartridge will fall into place. This limits the number of maintenance stops as the cartridge replaces pellets automatically until empty. Next, the water enters the carbon filter. Molecules are absorbed by pores in the charcoal as the water passes through it which ensures that the water has been cleansed of particles and brought to a guaranteed safe level of chemical ("The Science"). At last, the now cleansed water is taken through more pipes to a final storage tank, sized at 3000 gallons, where it will stay until extracted by a DRC's citizen via a faucet.

The system, though it fulfills its function, cannot do it on its own. Multiple additions were made to the idea to successfully patch the several flaws it had. The sand filter works when the debris in the water is caught in the particles of sand as the water passes through it; however, this debris eventually builds up contaminants which can cause problems in the drinking water (Lillenberg). Solving this problem would require manual maintenance. A manually operated water control globe valve, located on the pipe running from the river, can start and stop the flow of the water. The globe valve would be closed by hand giving the user a chance to remove the sand filter catch basin from its place in the tank. This can be done from the outside of the tank since the basin is inserted like a drawer, having the ability to slide out of its runway and then be snapped back into place. The dish would be dumped to get rid of the sand and debris, cleansed, and filled again with fresh sand. Once the job is complete, the sand basin is returned to its position, and the control valve is opened, allowing the process to continue. It became apparent that very similar maintenance would be needed for the chlorine cartridge and the carbon filter as well. Once again, the water valve would need to be closed to shut off the water. Then one can remove the chlorine cartridge or carbon filter canister from the device, and restore it with a replacement insert. The chlorine vessel will be restored with pellets; the carbon vessel will have its charcoal filter renewed.

Despite the first solution's flaws, there were several concepts that the team decided would be beneficial to carry into this design. Basic ideas for insertions like piping and tank material were subsumed into this new plan. Piping was also sized to allow for an adequate flow rate. The last implementation reproduced from the distillation design was the use of dark acrylic paint on the 3000-gallon storage tank to avoid algae growth. A new idea that the team included in this design stems from the basis of a toilet water fill valve. A common mechanism consists of a float attached to an arm. In toilets, water flows into the tank, and the float rises with the rising water level ("Easy Fixes"). The float's arm eventually reaches a point where the water fill valve is closed and water no longer fills the tank ("Easy Fixes"). In the filter's design, a float will once again be attached to an arm and, as this arm is raised, a fill valve is rotated and the pipe entrance is closed, preventing overflow.

This machine has many advantages compared to the first option. The machine is fed purely by pressure and force and requires no power in any area. It also requires very simple maintenance. There are just three materials needed — sand, charcoal, and chlorine pellets — that are all cheap and acquired very easily. This design is also much faster and more efficient than the previously introduced idea. Additionally, it can run all day and night. Compared to the first idea, however, the design could be seen as unappealing in terms of hazard. Locals would have to handle a foreign chemical that is flammable when in contact with certain materials, but the handling process is quite simple nonetheless ("Types of"). Despite this flaw, this device has great potential to provide safe and purified water for the citizens of the DRC.

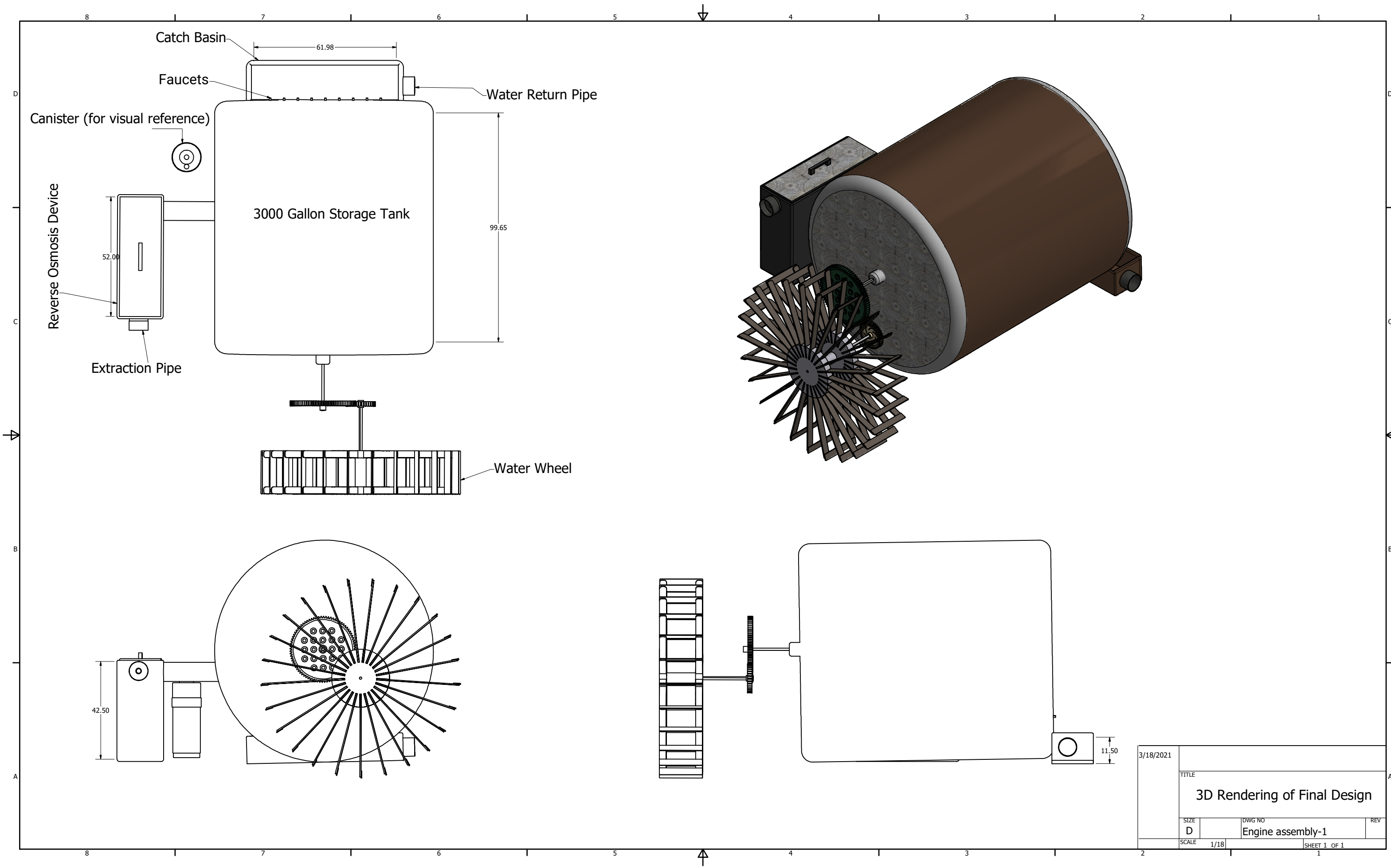
-Solution Three-

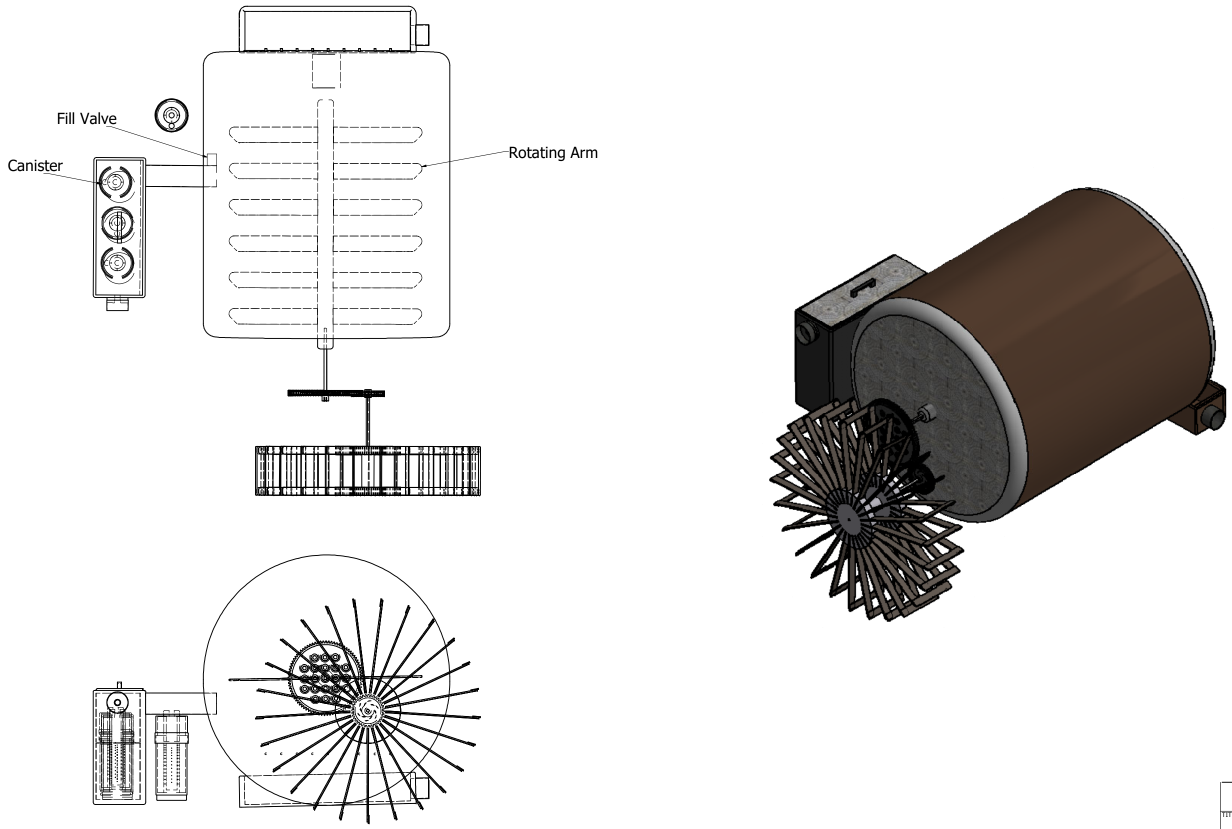
Distillation and calcium hypochlorite pellets are both effective purification methods that present realistic and practical solutions for the Democratic Republic of Congo's water crisis, but both methods present flaws that make them minorly challenging to maintain in a country like the DRC. Thus, the team continued to research potential treatment methods in attempts to procure a better system that would present fewer complications and yield equally, if not greater, results. After conducting extensive research, the team determined that the process of reverse osmosis (commonly referred to as RO) would be an excellent method of filtration that can, with adjustments, provide a viable solution to the DRC's crisis. The RO method is proven to remove protozoa, bacteria, viruses, chemical contaminants, metal ions, aqueous salts, dissolved sediment, and much more ("Technical") (Woodard). In fact, it removes 99% of all contaminants (Woodard). RO filtration systems are composed of several different elements. The primary filtration element in this system is the RO membrane. This semipermeable membrane facilitates filtration using the natural sequence of osmosis, or the moving of water from high concentration to low concentration, as an initiator (Woodard). Essentially, as polluted water, called feed water, is introduced on one side of the membrane osmosis compels it to move to the other side of the membrane that lacks water forcing it to travel through the RO membrane (Woodard). The RO membrane itself contains microscopic pores that prevent all particles, other than water, from passing, hence filtering and purifying the contaminated water (Woodard). The purified water is known as permeate, while the discarded contaminants are called brine (Woodard). In order to dispose of brine, most osmosis systems, including the team's design, have drainage pipes that are responsible for flushing the waste away (Woodard).

RO systems often include several accessory filters as well. The team tailored the type and quantity of these filters to best suit the Congo River's current needs. The first of these support filters is a sediment pre-filter. This filter uses a unique compound of materials to reduce the number of large particles traveling in the water, which avoids clogging in the RO membrane (Woodard). Typically, this filter would use a blend of sand, pebbles, and wood chips since these three materials are effective at absorbing and catching dirt, oils, grease, some bacterias, and other large particles ("Natural Materials"). The second pre-filter in the team's system is a carbon filter. For the purpose of this system, the carbon filter is used to effectively remove volatile organic compounds, but their purpose in standard systems is primarily focused on reducing chemical levels as chlorine deteriorates the RO membrane (Woodard). Most systems also include post-filters that function in improving the water's flavor, but such additions were deemed unnecessary and would ultimately hinder the community they were meant to help due to cost and additional maintenance (Woodard). Overall, the team engineered an extremely effective solution for the DRC's water crisis by enhancing and altering RO filtration technology.

After graduating from the filtration segment of the team's device, the permeate will travel to a ceramic storage tank through a transport pipe. The team has chosen to use a ceramic tank in this scenario because the purified water from the system has been stripped of all minerals, which gives it the ability to deteriorate standard water tanks. In addition, this design also implements the use of support mechanisms, the first is a water fill valve. This valve is used in the previous design and it works when the water flows into the tank and raises a float, lifting the arm and cranking the ball valve into off position ("Easy Fixes"). The mechanism stops the disproportional movement of water throughout the system, but the possibility of algae growth was still readily present. To alleviate such a threat, the team designed and implemented a rotating arm that would keep the water from becoming stagnant, thus preventing algae growth ("How Aeration"). This rotating arm would, however, need to be powered in some manner, but not necessarily by electrical power. The team chose to use mechanical power instead by introducing a water wheel as a mechanical generator. This water wheel, located in the nearby Congo River, turns a small gear that is connected to it by an axle. This smaller gear spins a second, larger gear which in turn rotates the turbine inside of the tank. These support additions are all integral to the overall function of the RO design.

Other implementations were also designed for the system to enhance its overall function and suitability for the region. Since this mechanism is designed to function in communities along the Congo River, it would need to be sustainable, easy to maintain, cost-efficient, and safe. The device itself is slightly expensive, but it has a sufficiently longer lifespan than the previous two options. Still, to aid in reducing the cost, the team designed replaceable filter canisters. The canisters themselves are reused, but the filtering components, all of which are cost-friendly and have many alternatives, are replaced. This may be done by simply disconnecting the canister, unscrewing the lid, and then removing the pouch of filter material. Once the sleeve of material is removed, the user may either empty the pouch and replace the material within it or use an entirely new sleeve; this aspect would be solely dependent on the region. It is important to note that there is a manual control valve that should be used to halt the system, as it avoids mass leakage from the disconnected pipe. Overall, the RO design provides the best and most effective solution to the DRC's crisis.


Catch Basin
61.98
Faucets
Water Return Pipe
Canister (for visual reference)
Reverse Osmosis Device
3000 Gallon Storage Tank
99.65
52.00
Extraction Pipe
Water Wheel
42.50
11.50
3/18/2021
TITLE
3D Rendering of Final Design
SIZE
D
DWG NO
Engine assembly-1
REV
SCALE
1/18
SHEET 1 OF 1

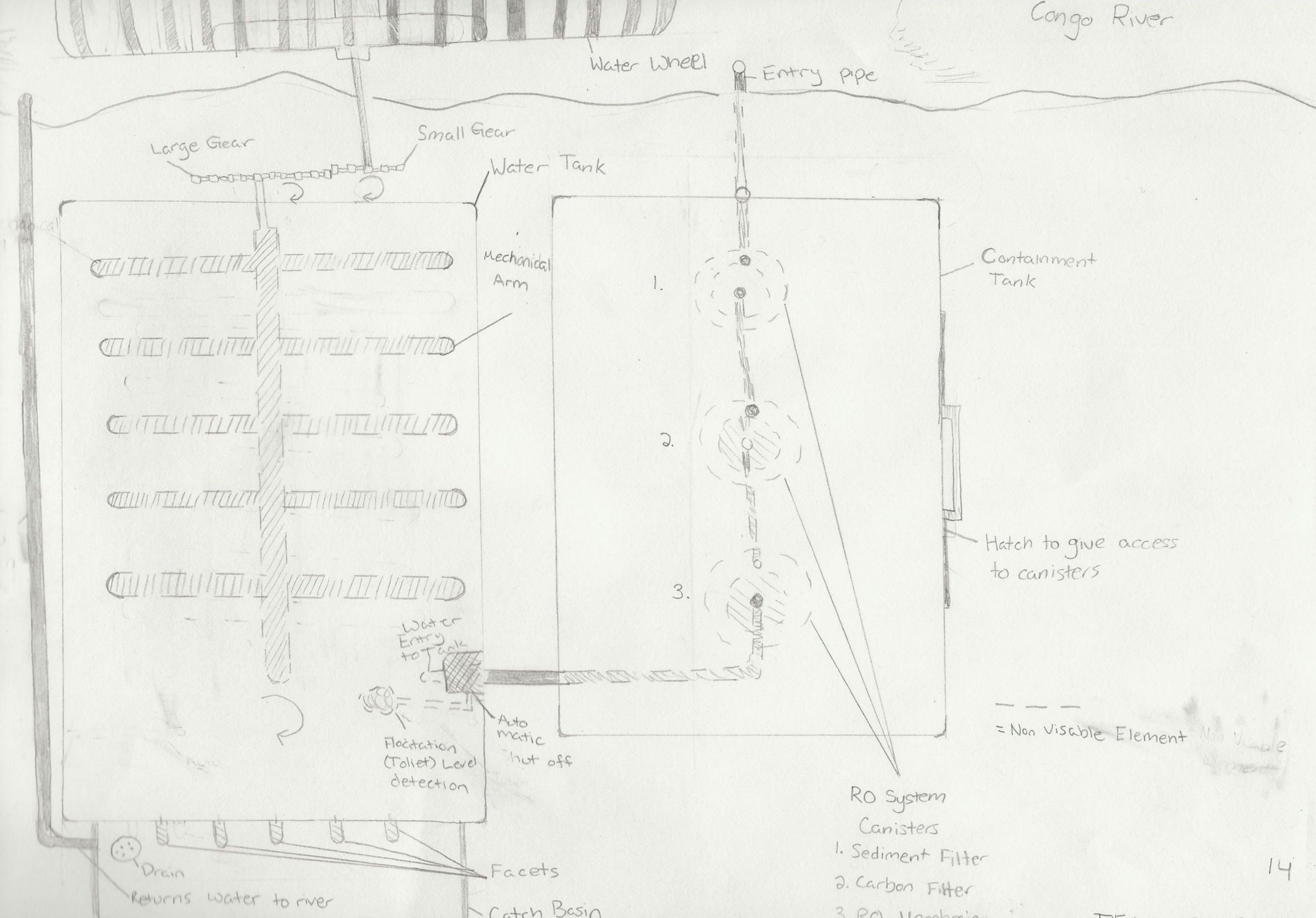


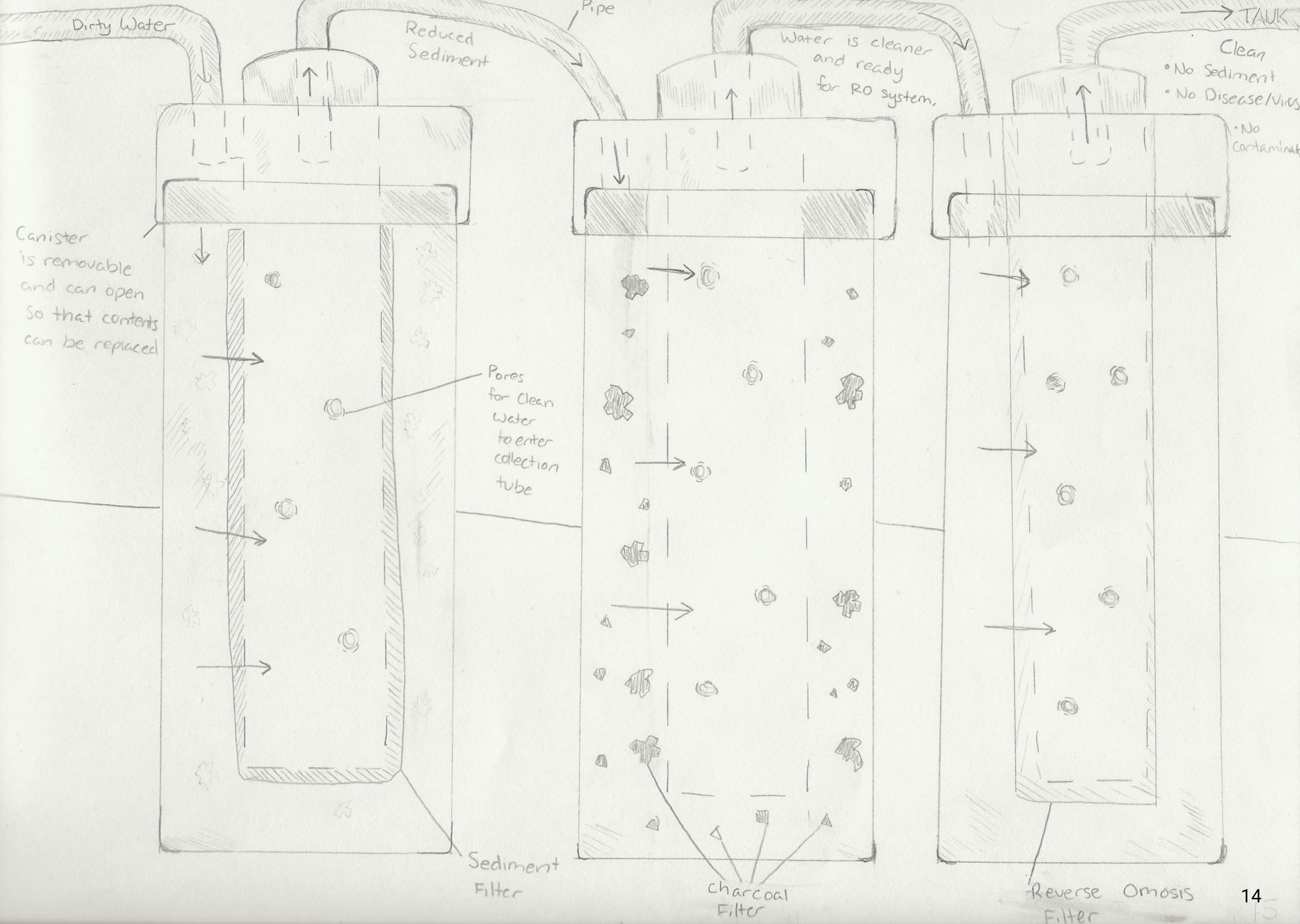
TITLE

View of Inside Components

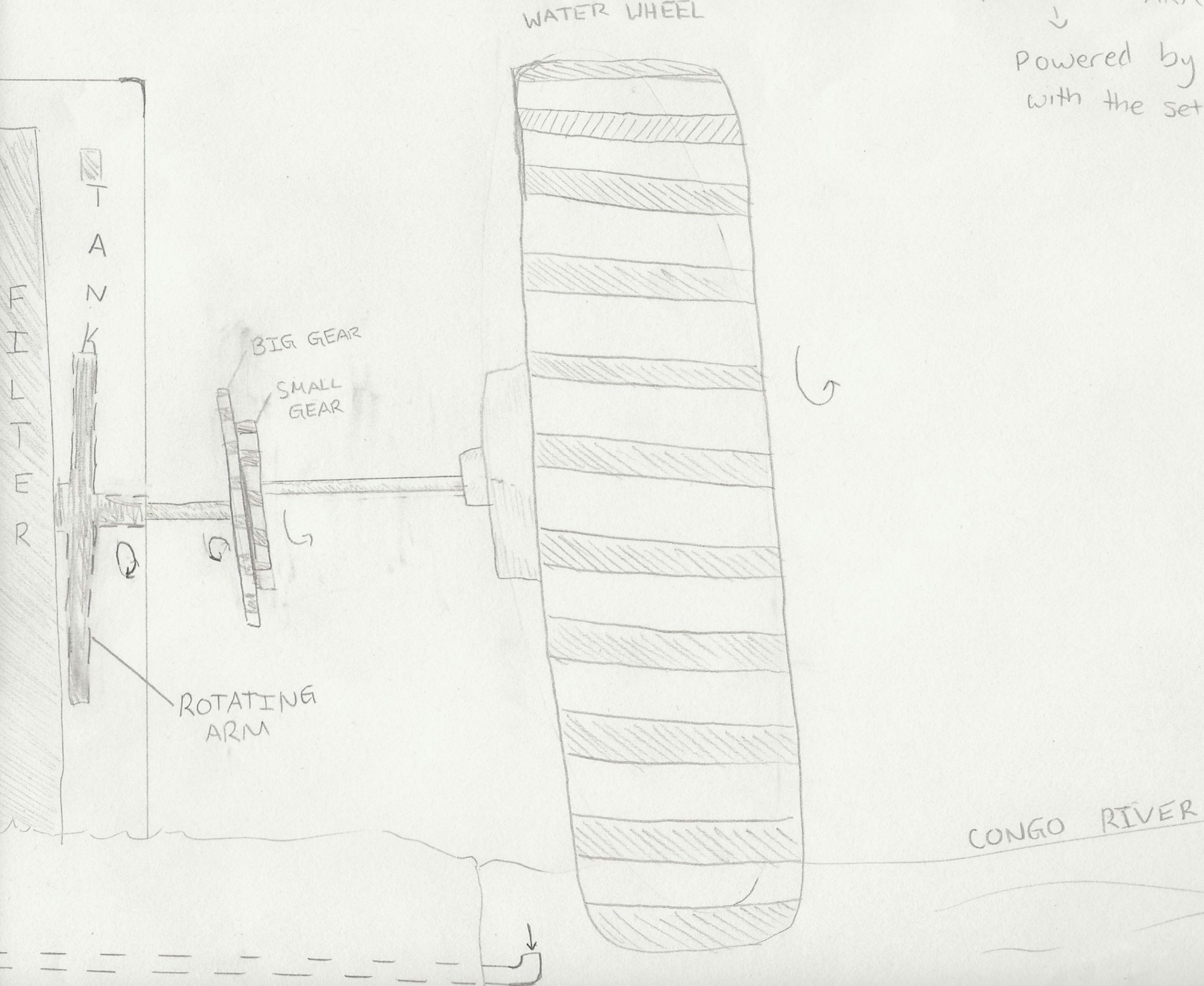
SIZE	DWG NO	REV
D	Engine assembly 2	

SCALE 1/18 SHEET 1 OF 1


Congo River
Water Wheel
Entry pipe
Small Gear
Large Gear
Water Tank
Mechanical Arm
Containment Tank
1.
2.
3.
Hatch to give access to canisters
Water Entry to Tank
Automatic shut off
Flotation (Toilet) Level detection
= Non Visable Element
RO System Canisters
1. Sediment Filter
2. Carbon Filter
3. RO Membraine
Drain
Returns water to river
Facets
Catch Basin


Dirty Water
Pipe
Reduced Sediment
Water is cleaner and ready for RO system,
→ TANK
Clean
• No Sediment
• No Disease/Virus
• No Contaminants
Canister is removable and can open so that contents can be replaced
Pores for Clean water to enter collection tube
Sediment Filter
Charcoal Filter
Reverse Omosis Filter

ROTATING ARM prevents algea.
↓
Powered by mechanialpower
with the set up below...



Summary of Iteration Process in Design of the Prototype & Results of Each Test

~Narrative of Testing~

The team has selected Solution Three, now titled the Reverse Osmosis Water Crisis Relief Device (RORD), as the most viable option for eliminating the Democratic Republic of Congo's decades-long water crisis because of its unique utilization of reverse osmosis technology and a multitude of other specially designed mechanisms that provided the most potential and promise. Despite this design's on-paper excellence, it still required extensive testing and analysis to guarantee its effectiveness. In order to obtain accurate and substantial results, the team used past outsourced tests and conducted their own analysis of the system as a means of evaluation.

The first analysis tested the effectiveness of different sediment filters since said filters can be constructed using a variety of different materials. The team needed to select a specific compound of materials that would ensure prime effectiveness and filtrations per the needs of the Congo River. In one study, water was run through a mixture of sand, pebbles, and wood chips before commencing through the other separate filtering material. The team tested this mixture themselves and analyzed changes in pH, chlorine, nitrate, iron, hardness, and copper levels ("Natural Minerals"). The compound proved to be extremely successful, but the team continued tests. The next test used corn cob in addition to the previously listed materials. Though chlorine, nitrate, magnesium, and calcium levels all were diminished, a dangerous amount of iron remained within the water after filtration; leaving the water undrinkable ("Natural Minerals"). Based on this, the team disregarded the addition of corn cob to the sediment filter compound. The third test added ungerminated seeds to the original combination of sediments. This test showed greater results than that of using corn cobs since this combination completely eliminated chlorine, copper, nitrate, and iron, but it was still unsuccessful as it caused an increase in the water's pH, making it far too acidic for human consumption ("Natural Minerals"). Our test suggests that one-hundred and fifty two grams of each component, a total of four hundred and fifty six grams per gallon, will suffice, but the amount can be altered per region. Overall, the original compound listed above provided the best results and in turn, was chosen for use in the team's device.

A combination of sediments that would provide sufficient prefiltering results has yet to be found, so we used a carbon filter as well. The carbon filter functions as a "clean-up" filter; removing unwanted tastes, odors, chemicals, detergents, pesticides, and other manmade and or organic chemicals ("Drinking Water"). The reverse osmosis system relies on the carbon filter to stop specific contaminants that can cause damage to the RO membrane (Ebnesajjad). Charcoal, a type of carbon, produced excellent results as chemical properties, pH levels, and hardness levels all came to appropriate values ("Natural Minerals"). Essentially, the unwanted molecules were absorbed into the pores of the activated carbon, thus the results. The team also evaluated carbon's absorbent abilities and effectiveness with their own tests. The durability of the carbon was tested by tracking how many milligrams of iodine can be absorbed into a single gram of carbon; the higher the number of milligrams of iodine absorbed, the more absorbent the carbon is ("Drinking Water"). Due to the inability to use pure iodine, the team used numbers from previous tests. The carbon used in our design should be well within the 0.008–0.04 non-absorb iodine range, so the team moved on to effectiveness testing. To test the effectiveness of the carbon, one must analyze how much phenol can be absorbed by the carbon. The lesser number recorded of phenol in the carbon, the more effective the activated carbon is ("Drinking Water"). These numbers would be taken into account and cross-reference with absorption rate results in order to be sure the best type of carbon would be used for the conditions of the Congo river. The team, with the tools they had available to them, tested different grains of carbon. Applying carbon with varying pore sizes to the filter gave a range of results, and in the end, provided that a mixture of large and small pore sizes would be optimal. The specifics of the charcoal can vary to fit the different regions in the Congo, especially in regards to cheaper options. The base amount of charcoal, per the model scale, is eighty grams per gallon. Overall, the team determined that a mix of small and large charcoal grains would provide the best filtration.

Osmosis is a phenomenon when water passes through a semipermeable membrane and becomes a more concentrated solution (Ebnesajjad). Reverse osmosis, per its name, takes this process and reverses it. The concentration solution is forced through a semipermeable membrane into a simpler substance (Ebnesajjad). RO membranes are commonly composed of three layers. The top layer is a thin aromatic polyamide film. Directly under this layer lies a polysulfone layer, and under this is a non-woven fabric that provides strength for the entire membrane (Ebnesajjad). This combination of layers all works to eliminate a long list of contaminants. Past tests show that filtered ions and metals include arsenic, aluminum, barium, cadmium, calcium, chloride, chlorine, chromium, copper, fluoride, iron, lead, magnesium, manganese, mercury, nitrate, potassium, radium, radon, selenium, silver, sodium, sulfate, and zinc (Oram). These tests also prove that organic chemicals like benzene, carbon tetrachloride, dichlorobenzene, toluene, trichloroethylene, and total trihalomethanes are also removed in the RO filtration process (Oram). Most importantly, tests for residual diseases and viruses left in the water returned clean (Oram). A final test the team analysis, inclusive of particles and pesticides, shows that asbestos, protozoan cysts, cryptosporidium, atrazine, endrin, heptachlor, lindane, pentachlorophenol, and other dangerous contaminants are all filtered as well (Oram). Due to supply restrictions, the team modeled the RO membrane with sponge. Varying amounts of the RO membrane may be used, but per the model scale the filter will contain a base membrane that weighs sixty four grams per gallon. When water from a local stream was run through the model's functional filter tower, all contamination results came back negative and the water's chemical values were all within safe standards. Overall, the RORD system reduces many contaminants.

The final branch of the RORD machine is the tank at the end of the system. In the DRC, the population of a community tends to range from one-hundred-fifty to five-hundred people, each consuming an average of 1849 gallons of water a year, or approximately five gallons of water a day (Lemarchand) (“Issue In”). With this information in mind, the team determined that a 3000-gallon storage tank, when filled, would sufficiently supply each person in a community of five-hundred with five gallons of water a day, plus surplus. This tank contains a massive rotating agitator arm that keeps any algae growth to an absolute minimum. Algae tends to thrive in warm, sunlit water bodies that are stagnant and have little surface movement (West). In the DRC’s climate, the team understood that keeping the water cool and dark was very far from reach, so instead, they designed a rotating agitator arm that would use the mechanical power from a water wheel in the Congo River to turn it. The team created a functioning water wheel and gear system so that they could test to see the power of the rotating agitator arm. According to plan, as the water wheel was spun, the gears spun and the axle of the stirring agitator arm was spun.

When it came to designing the agitator arm itself, the team tested several distinct arm shapes. The first shape resembled a whisk. It was hypothesized that the shape’s effectiveness in the water tank would correspond to its effectiveness in the kitchen, however, this was not the case. The design worked poorly compared to what was expected. The team inferred that this related to the difference in rotation since the axle remains rotating in one place instead of moving in the back and forth motion that is typically used with a whisk. An alternative design would hopefully show better results. The next structure can be imagined as a “T” shape, however, along the center pole, there are additional rods that intersect parallel to the top of the "T". This design worked significantly better as it was able to stir the water through the entire length and width of the tank. The team also tested the agitator arm's ability to repel algae using the scale model. A small motor was programmed to rotate the water wheel continuously, simulating the current of the Congo River, which caused the model agitator arm to rotate the water within the model tank. This water was taken from a local stream and filtered through the model's functional filter, replicating the anticipated conditions of the Congo River. The entire arrangement was also placed under a heat lamp to simulate the temperature of the DRC and prompt algae growth. After a week no algae was present in the water and all tested quality levels remained consistent. Hence, the team determined that the mechanics behind the rotational agitator arm are effective and that the arm itself needs to be constructed per the specification of the "T" design.

These tests were used to help better understand the complicated reverse osmosis filtration system. They have shown the successes and failures of each filter and exemplified how the filters rely on one another to function at their fullest intent. The specific tests researched and conducted showed the team what changes need to be taken into consideration and what needed to remain unaltered. With the results in mind, the team began to plot out this device's greatest and most effective form.

~Expected Problems and Their Solutions~

The team expected the RORD system to have multiple complications, and test results only affirmed our suspicions. Based on testing and previously conducted research, the team predicted that the filters would need to be replaced far more often than previously desired. The Congo River has terrible water conditions, carrying a large combination of bacteria, viruses, and other particles, which contributes to this system's need for a high filtration change rate. In most instances, these filters would need to be replaced around every six months, but it is estimated that the filters would actually need to be replaced at least every three weeks instead. Fortunately, the team was able to predict this issue and had already implemented a reusable filter canister as a solution. Within these reusable canisters is a sleeve of filtering material, which may simply be removed, emptied, refilled, and then reinserted. Each filter, excluding the RO membrane, contains materials that are readily available in most regions of the DRC making it easy for locals to obtain the supplies they need in order to refill the sleeves. Overall, implementing the reusable filter design makes this system more sustainable, affordable, and combats the concerns revolving around the high filtrater change rate.

The team also discovered the potential for sediment accumulation within the entrance and inside of the piping system due to the Congo River's environment. In the original design of the machine, water entered the system through a collection pipe embedded in the riverside. The team has since realized that there is a high probability of large objects like sticks, rocks, and other large particles clogging this pipe or blocking it entirely. To combat this design flaw, we designed a cover for the entrance of the pipe. The cover would take the shape of a triangular prism, sitting before the grate, and would be hit first by the water's current. Any larger objects heading in the direction of the grate would hit this cover and slide away from the system's entrance, while water would still be able to flow through the cover and into the pipes. Although the water is able to continually enter the system with a much lower risk of the entrance being clogged, there was still the chance of build-up in the flush pipe, which is responsible for carrying brine back to the river. Because this pipe is being flooded with contaminants, its walls may become encrusted with sediment deposits. This can lead to more severe problems in the future, like system backflow and pipe breakage. Thus the team connected a small vertical tube to the flushing pipe that would allow the citizens of the DRC to flush a cleaning solution through the pipe when needed. There was the concern that cleaning solutions would not be available, but after some research, it was determined that a lemon juice mixture — which has shown to be an excellent natural cleaning product and is available in the DRC— can erode away a majority of obstruction (Aguirre).

The team also incorporated several mechanisms, all in attempts to improve the invention. All of them succeeded in doing so, however, with these came a few worrisome risks that the team wished to resolve. The design includes a manual control valve before the filtration system and a water fill valve. The general concern about these valves is that they could simply fail in a time of need. Now, the manual control valve is paired with an additional emergency stop valve, while the solution for the water fill valve is slightly more complex. The possible risks with this mechanism mostly occur with the float or the valve itself. Perhaps the float would break off of the rod, leaving the valve with no way of turning off, or the ball valve would break and not be able to turn, never closing the chamber to halt water intake. Both scenarios lead to excessive amounts of pressure and overflow, so it was essential for there to be a pressure relief mechanism within the tank. The team decided to implement an idea from the distillation filter, where there was a spring mechanism used to close a barrier and keep the tank from filling too much during this operation. The water would rise to the top of the tank and eventually reach the plate. The plate would be pushed against the springs and the rod connected to the plate would lift open a part of the tank's wall, therefore emptying some of the extra water and relieving pressure. This keeps the system from rupturing, while the spilling water alerts the citizens that there is a problem within the system that needs to be addressed.

As to be expected, there were a few other problems within this complex creation, most of which involved possible breakages or failures from overuse. The more vulnerable parts of the system include the water wheel, its gear system, and exposed pipes. The gear system specifically will have supports for the axles to reduce any chance of the rods bending out of place. Meanwhile, the water wheel exists in a very chaotic environment and has a high chance of receiving damage, whether it be from falling tree branches or large objects floating down the Congo River. The team understood the grave importance of the water wheel so it was constructed of extremely durable and inflexible material, making it resistant to damage. The final addition was for visual purposes, not functional. At first, the device was aesthetically displeasing, but the team didn't want the people of the DRC to have an unpleasant addition to their community, so the team colored the device in neutral organic colors and added tile mosaic as an expressive decoration. All and all, the additions, both functional and otherwise, were necessary for the overall success of the RORD filtration system.

The Overall Success of Design

Each section of the Reverse Osmosis Water Crisis Relief system was analyzed and reworked several times in order to unlock the device's fullest capabilities. Overall, testing the device was extremely successful. The tests helped determine what materials would be needed for the filtration units, proved the system's effectiveness, and revealed the underlying issue within the system. Based on the errors found during testing, the team engineered a variety of alterations, most of which were used to prevent malfunctions and improve the effectiveness of the system. The additional valves helped make the RORD system safer in case of an emergency, while the replaceable filters made the system far more manageable and sustainable. Moreover, the alterations to the piping system will help prevent long-term blockage issues that would ultimately render the system inoperable. The final alteration was made in consideration for the people living in the DRC, as they help improve the device's outward appearance without hindering its effectiveness. Clearly, testing and alterations have helped this device reach a new level, making it even more suited for eliminating the DRC's water crisis.

The citizens of the Democratic Republic of Congo's everyday lives can ultimately improve with the help of this water filter design. The Congo River has reached unacceptable conditions; it is relied on as a waste system more than a reliable water source (Mata et al.). The river is infected with human waste and deadly bacteria, especially cholera ("The Congo"). In fact, the river is the primary reason why cholera has spread to the extent that it has in the DRC ("The Congo"). Moreover, the Congo also houses mass amounts of heavy metal waste, and a variety of inorganic and organic chemicals ("In Water-Rich"). In the current world, Congolese people have reached a point where they are digging through the ground with any hope that one day they will find water that can keep them hydrated and healthy ("How Much"). Placing these filtration systems along the Congo river could change the lives of thousands in the DRC and rid it of the water crisis that has hindered its growth for generations.

TECHNOLOGY STUDENT ASSOCIATION PLAN OF WORK LOG

Date	Task	Time involved	Team member responsible (student initials)	Comments
November 2nd, 2020 1.	-Determined Issue and Began Research. -Began Brainstorming Solutions.	2 weeks	MO, EM, LC	The team determined that water crisis in the DRC is an approprite issue for this event after uncovering an article on it from the UN and considering this year's theme.
November 18th, 2020 2.	-Developed Solutions	2 weeks	MO, LC, EM	The team finished researching the DRC and its water crisis, as well as potental solutions. Additionally, the team determined the basis of the three engineering solutions and began making refinements for the final three.
December 2nd, 2020 3.	-Began Paperwork -Determined Final Design -Began Developing Prototype	1 month	EM and LC	The team began to draft and write the portfolio. The final design was also determined based on an evulation of the benifits and flaws of each solution. Additionally, the team began drafting the set u of the prototype and finding supplies.
January 3th, 2021 4.	-Drafted Paperwork -Completed Prototype -Began Figuring Testing	2 weeks	MO and LC	Writing portions, except for testing report, and work cited were completed. Design of portfolio cover and other small responsablities remained.
January 18th, 2021 5.	-Finished Testing -Finished Paperwork -Began Display -Entered Editting Phase	2 weeks	EM and LC	Portfolio was offically finalized and the virtual display was completed. All testing and evaluation methods were fulfilled. The project then entered the editting phase, while the virtual display entered its final steps of developement.
February 1st, 2021 6.	-Finished Final Detials -Added Remaining Detials to Display and other Elements	1 week	EM, LC, MO	Cover of portfolio was completed, all paperwork was finalized, display was finalized, and model was completed. Projected was prepared and submitted for review.

Advisor signature ______________________

TECHNOLOGY STUDENT ASSOCIATION PLAN OF WORK LOG

Date	Task	Time involved	Team member responsible (student initials)	Comments
1. February 23rd, 2021	-Discussed Alteration For States -Brainstormed Improvements	2 Days	EM, LC, MO	After recieving feedback and results from the regional confrence we began accessing the alterations that need to be made in order to bring our project to a new level. We also began brainstorming additions and other various ideas.
2. February 25th, 2021	-Began Making Alterations To Model -Brainstorming for Video Format Digital Display	3 Days	EM, LC, MO	The team set out to create a accuratly scaled and functional model of the final design invention. To do so, team members altered the wall sizes and saught for better materials to use for walls, piping, and other structures in the design.
3. February 28th, 2021	- Finished dimentional aspects of model and continued improving accuracy to function -Began video display	2 Days	EM, LC, MO	The basic structure of the model was assembled and adjustments were made in order to make it as comparable to the real life final design. The team also began the digital video display by creating a script and graphics. After this was completed, the team began working on the composion of the video.
4. March 1th, 2021	-Finished making model fully functional -Began composing video display -Made needed alteration to porfolio	2 weeks	EM, LC, MO	The team successfully completed making the model of the device fully functional. This allowed the final testing process to begin. Additionally team members completed composing the digital display video. With the alterations made to the model, it was necessary to update the CAD drawing of the device and add additional explainion and info to the paperwork.
5. March 14rd, 2021	-Finished Video Display -Tested Model -Added Results of improved device to the paperwork	2 weeks	EM, LC, MO	The team made the final edits to the video display and was reviewed by advisors. Testing of the device was comleted and results were insurted into the paperwork. With the results inserted, the team made further edits to the paperwork for general improvement.
6. March 26th, 2021	-Completed All Aspects of Project -Made Final Revisions and Alterations	1 Day	EM, LC, MO	The team's paperwork. display, and model were all entirely completed. Projected was prepared and submitted for review.

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TECHNOLOGY STUDENT ASSOCIATION PLAN OF WORK LOG

Date	Task	Time involved	Team member responsible (student initials)	Comments
April 19th, 2021 1.	-Discussed Alterations for Nationals -Brainstormed Furthur Improvements	1 Day	EM, MO, LC	After the state confrence, the team evaluted the project once again to determine the areas that needed improvement. Once these areas were defined, the team began constructing a general idea of what improvement were to be made.
April 20th, 2021 2.	-Began making alterations to model -Started developing new additions to the display	2 Weeks	MO, EM, LC	With brainstorming complete, the team began to work on the necessary elements of the project. Most notably, members worked to improve the functionality of the model and started creating more appealing and descriptive components for the new website display.
May 4th, 2021 3.	-Completed new elements to model -Began filming process of new model	5 Days	MO, EM	All new portions of the model were completed and retested by the team. Additionally, the team began gathering video footage of the model and its new components.
May 9th, 2021 4.	-Finished all elements of video display -Began composing display and entered editting phase	3 Days	MO, EM, LC	The graphics and video clips for the website display were all completed. With this complete, the team was able to begin composing the wedite by placing the components in the proper order and applying various design principles.
May 11th, 2021 5.	-Made minor changes to documentation - Finished editting display	2 Days	LC, MO	The team completed the website display and inserted minor changes to fomat, layout, and transitional elements. Moreover, members began making small changes to documentation to ensure optimal quality for the national conference.
May 13th, 2021 6.	-All elements of the project were checked and final alterations were made	1 Day	EM, LC	All changes to the model, display, and documentation were completed, and the project was entirely finished. All emlements were given one final evaluation before being submitted for the judges to score.

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STUDENT COPYRIGHT CHECKLIST *(for students to complete and advisors to verify)*

STUDENT: Answer question 1 below.

1) Does your solution to the competitive event integrate any type of music and/or sound? [X] YES [ ] NO

If NO, go to question 2.

If YES, is the music and/or sound copyrighted? [ ] YES [X] NO

If YES, move to question 1A. If NO, move to question 1B.

1A) Have you asked for author permission to use the music and/or sound in your solution and included that permission (letter/form) in your documentation? If YES, move to question 2. If NO, ask for permission and if permission is granted, include the permission in your documentation.

1B) Is the music/sound royalty free, or did you create the music/sound yourself? If YES, cite the royalty free music/sound OR your original music/sound properly in your documentation.

CHAPTER ADVISOR: Sign below regarding your student's answer(s) to the use of music/sound in his/her competitive event solution. Even if your student answers "NO" to question 1, please sign below noting that you have evaluated the competitive event solution and the student answered the question(s) accurately.

I, ______________________ (chapter advisor), have checked my student's solution and confirm that any use of music/sound is done so with proper permission and is cited correctly in the student's documentation and/or the solution has been found to have no music/sound included.

STUDENT: Answer question 2 below.

2) Does your solution to the competitive event integrate any graphics/videos? [X] YES [ ] NO

If NO, go to question 3.

If YES, is(are) the graphics/videos copyrighted, registered and/or trademarked? [ ] YES [X] NO

If YES, move to question 2A. If NO, move to question 2B.

2A) Have you asked for author permission to use the graphics and/or videos in your solution and included a permission (letter/form) in your documentation for graphic/video used? If YES, move to question 3. If NO, ask for permission and if permission is granted, include the permission in your documentation.

2B) Is(are) the graphics/videos royalty free, or did you create your own graphic? If YES, cite the royalty free graphics/videos OR your own original graphics/videos properly in your documentation.

CHAPTER ADVISOR: Sign below regarding your student's answer(s) to the use of graphics/videos in his/her competitive event solution. Even if your student answers "NO" to question 2, please sign below noting that you have evaluated the competitive event solution and the student answered the question(s) accurately.

I, ______________________ (chapter advisor), have checked my student's solution and confirm that the use of graphics/videos with proper permission and is cited correctly in the student's documentation and/or the solution has been found to have no graphics/videos included.

STUDENT: Answer question 3 below.

3) Does your solution to the competitive event use another's thoughts or research? [X] YES [ ] NO

If NO, this is the end of the checklist.

If YES, have you properly cited other's thoughts or research in your documentation? [X] YES [ ] NO

CHAPTER ADVISOR: Sign below regarding your student's answer(s) to having integrated any thoughts/research of others in his/her competitive event solution. Even if your student answers "NO" to question 3, please sign below noting that you have evaluated the competitive event solution and the student answered the question(s) accurately.

I, ______________________ (chapter advisor), have checked my student's solution and confirm that the use of the thoughts/research of others is done so with proper permission and is cited correctly in the student's documentation and/or the solution has been found to have all original thought with no use of other's thoughts/research.