AquaCleanse Solutions

Abigail Parnell

Brandy Parks

Cole Niblett

Olivia Broussard

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Introduction

Garver Engineering is a consulting firm headquartered out of North Little Rock, AR that provides services to clients in several different markets. One market where Garver excels is water resources; the company is known for conducting quality work in wastewater, distribution, and environmental assessments, among others. Garver has presented AquaCleanse Solutions with the opportunity to design an interactive, educational exhibit that displays a wastewater treatment process. The exhibit will serve to inform the public of the necessary steps to purify wastewater and preserve the environment. The exhibit is desired to be trailer or skid mounted and would be utilized in science fairs, elementary classrooms, and other educational environments.

Problem Statement

Garver Engineering has tasked AquaCleanse Solutions with designing a trailer-mounted interactive wastewater treatment display. This display needs to be as hydraulically and mechanically similar to a functioning wastewater treatment plant as possible. In addition, the components and treatment process should be easily understandable and explainable to grade school-aged children.

Mission Statement

AquaCleanse solutions will strive to promote awareness for wastewater treatment by exhibiting the latest treatment techniques in a unique wastewater treatment display trailer. This trailer will be used for elementary education in order to increase their appreciation for the wastewater treatment process, and will further reinforce the importance of water quality and conservation.

Customer Requirements

Mary Elizabeth Mach, a Project Manager from Garver, specified the customer requirements at a meeting that took place on September 17, 2015 at the Norman Garver Office. The customer gave a broad overview of the wastewater treatment process and possible routes the group could take to designing a functional wastewater treatment system. Some general requirements and guidelines are listed as follows:

- Target audience is elementary and middle school aged students
- Engaging the younger generation to "get excited about water"
- Walk up and see something they can identify and use daily, such as a modified toilet.
- Audience can see process work
- Cross sectional view with clear materials
- Imperative that it is an interactive display
- Components to consider: Start with something identifiable to younger children, perhaps a toilet or sink. Then, gravity flow from this waste source to the plant. For preliminary and primary treatment, consider rotating bar screens, grit removal chamber, and primary clarifier. For primary and tertiary treatment, typical components include clarifiers, aeration basins with air diffusion, Chlorine disinfection units, and Ultraviolet (UV) disinfection basins.
- Pumping and component layout: It is typical for Waste Water Treatment Plants (WWTP) to utilize gravity flow for many of their piping systems. Therefore, a good concept that would be good to show is a lift station that would elevate the water to a high point in the plant, and then from that point on employ gravity flow through all systems.
- Include some component of wastewater reuse, such as irrigation or direct/indirect potable reuse.
- For an irrigation display, perhaps employ a sprinkler on the ground that would be hydraulically powered from the system and easy for children to enjoy.

- Trailer mounted display
- Flowing water with electricity (Single phase, 120V, outlet hookup)
- Aesthetics and functionality are very important
- To show unit operation effects, may use colored tubing or dyes to signify water quality changes.
- Generate hydraulic profile for water flowing through system

From the meeting with Garver and the aforementioned guidelines, a thorough set of customer requirements was established. It is our plan to make the wastewater treatment trailer an interactive and engaging trailer to get younger generations excited about the processes involved with wastewater treatment and water resources. This trailer will be user-friendly, hydraulically functional, and aesthetically pleasing. With these requirements recognized, a comprehensive statement of work was drafted, and is presented in the following pages.

Statement of Work

Abstract

Garver Engineering in Norman, OK requests an interactive wastewater treatment display that can be used for the education of children around the fourth and fifth grade age. This trailer will primarily show what processes water goes through before it is clean enough to be reused or put back into the environment. The overall process must be easily understood by children in order to explain and convey the concepts effectively, and the trailer will serve to raise awareness to these topics wherever it is being displayed.

Scope of Work

Neither the senior design team nor Garver expects to have a complete trailer-mounted system built at the conclusion of this fiscal year. The trailer will be thoroughly designed, including design plans in CAD, all associated hydraulic models, complete technical specifications, and the cost of constructing such a unit will be estimated. In the spring semester, the senior design team will construct a “tabletop” model that will be a direct representation of what would be mounted on the final exhibit.

Location of Work

The conceptual designs of the trailer during the fall and spring semesters will primarily take place in the OSU Biosystems and Agricultural Engineering computer lab. In the spring semester, all of the work related to the construction of the “tabletop” model will take place in the Biosystems and Agricultural Engineering Laboratory and machine shop.

Fall Performance of Work

The main body of work in the fall semester will be focused on generating conceptual designs for the wastewater treatment process that will be shown on the trailer. The scale model drawings of each component will be drawn using a 3D CAD program. Pipe sizing, pump selection, system head and pump curve generation, pump selection, and hydraulic profile generation will be completed along with any other appropriate hydraulic modeling. The unit operations will be scaled so that the components fit spatially within a confined space and that the processes will be easily identifiable and the components are big enough that the process can be seen working with educational purposes in mind.

Deliverables Schedule

To ensure steady progress towards the project completion and group cooperation, a weekly agenda was delivered to Dr. Weckler that included an outline of what tasks the team would undertake, and what team members would be working on different tasks. At the end of each week, a weekly summary describing progress from said agenda was also sent to Dr. Weckler. By the end of the fall semester, the following will be delivered to Mary Elizabeth Mach and Dr. Weckler:

- Thorough conceptual designs, with at least two trailer "style" alternatives
- Rough Draft of Final Report to Dr. Weckler
- Final Technical Report
    - Final design
    - Fall task list/preliminary schedule
    - Estimated cost
- End of Semester Presentation.

By the end of the spring semester, the following should be delivered to Mary Elizabeth Mach and Dr. Weckler:

- Final Design(s) that include the specifications given in the technical requirements

- A tabletop model of wastewater treatment system
- Rough Draft of Project Report to Dr. Weckler
- Final Draft of Project Report
- End of year presentation

Acceptance Criteria

In order for our design proposals to be acceptable, all designed components need to be spatially compatible for a tabletop model or trailer mounted exhibit. The hydraulics of the proposed system should be sound, and should allow for an easy use and presentation of the trailer. All required electrical and safety specifications should also be in the design considerations

Along with the above requirements, the wastewater treatment display needs to be educational and aesthetically pleasing to catch the attention of younger students. This display should serve as a learning environment for all involved and an accurate representation of wastewater treatment technologies.

The tabletop model will serve as a direct representation of what would be mounted on a trailer, and will allow the senior design team to better understand how the system will operate hydraulically, and will also give the team a better idea on how to design the system spatially and aesthetically.

Key Assumptions

The assumptions that are made for the design of the scale model of the wastewater treatment plant include:

- Wastewater Treatment
    - The display is not expected to be able to actually treat wastewater
    - Based on client meeting with Garver
        - Practicality
        - Ease of Use
- Solid Waste Treatment

    - The display is not required to model the sludge portion of wastewater treatment
    - Based on client meeting with Garver
- Activated Sludge vs. Trickling Filter
    - The designs will implement activated sludge instead of trickling filter
    - Based on meeting with Mary Elizabeth on 10/23/15

Funding

Garver is not anticipated to bear any of the financial load in the construction of the tabletop model. The purchase of materials and assembly of the model will be made through funding available to the Senior Design class through the University.

Technical Analysis

The technical analysis includes comparable patents of model educational devices. This interactive wastewater treatment display trailer will primarily attempt to show what processes the water goes through when wastewater treatment is performed. The overall process must be understood in order to explain and demonstrate it effectively to others. There are several books and patents that are relevant to this project. Also, since one of the project's main goals is for the education of others on wastewater treatment, other education tools and methods were considered.

The overall process of wastewater treatment (see Figure 1) is broken up into several different stages, primary, secondary, and tertiary treatment. Based on the request of the client, this project is also concerned with a fourth stage, which is the reuse of the wastewater. This requires a certain level of cleanness, which the project should keep in mind when deciding which components should be included in the display. There are different levels of reuse, and each level has a different requirement for the level of treatment required before it can be reused. These regulations can be found in the EPA's Guidelines for Water Reuse, available online.

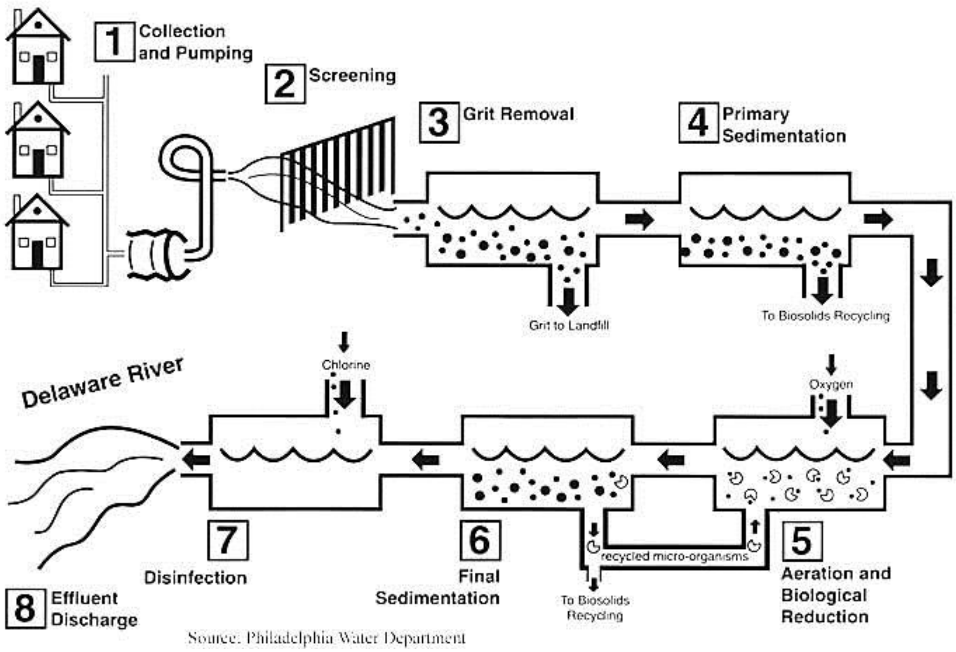


Figure 1: Overall wastewater treatment diagram, available online at http://www.phillyh2o.org/backpages/MSB_DRAINAGE2/MSB_DRAINAGE.htm

The primary treatment deals with the inorganic solids removal and is made up of preliminary treatments and sedimentation. Preliminary treatments includes the addition of screens and a grit removal chamber. The Screens are designed to catch objects as large as tree limbs and other pieces of debris. The screens are typically made up of both course (6-24 mm) and fine (2-6 mm) screens, with the velocity being 0.7 m/s on average.

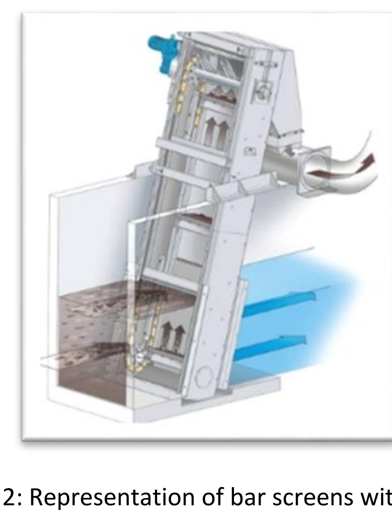


Figure 2: Representation of bar screens with chains.

The grit removal chamber, with velocity of flow at around 0.3m/s, is supposed to get 95% of all particles greater than 0.2mm in diameter (*Industrial Microbiology*, 231). After the initial processes have removed the larger debris and sand, primary sedimentation occurs in clarifiers. The clarifiers have a hydraulic retention time of 1-6 hrs, according to *Industrial Microbiology*, and should reduce the Biological Oxygen Demand, BOD loading on the subsequent steps of the process (*Industrial Microbiology*, 232).

Secondary treatment is where the majority of the BOD removal is performed, either biologically or chemically. There are many different processes implemented in this stage and the one actually displayed in this project should be chosen carefully based on the needs of the client and the audience in mind. Secondary treatment options can be broken into either aerobic or anaerobic biological processes, which use microbial growth to remove pollutants. According to *Industrial Microbiology*, the most common anaerobic options include stirred tank reactors and some forms of trickling filters. The most common Aerobic options include activated sludge (which requires an aeration tank and a secondary clarifier), and trickling filters.

According to *Industrial Microbiology*, "A major problem with these anaerobic treatments is that their efficient and stable operation requires the balanced interaction between all three groups of microorganisms" that live in the reactors. "Changes to factors that influence the activity of any one of these groups can result in system failure" (*Industrial Microbiology, pg 237).* According to *Environmental Biotechnology*, "the energy needed for mixing in the anaerobic processes is much less than the energy required for the aeration of aerobic processes. However, the slower rate of reduction in anaerobic processes makes it necessary to use treatment plants of larger sizes" (*Environmental Biotechnology,* 242). Size is a serious consideration for real world operations, but also for this project with the scale models needing to fit on a trailer.

Considering aerobic trickle filters, *Environmental Biotechnology* gives several pros and cons of its industrial uses. These can be helpful in deciding whether to display an aerobic trickle filters or an activated sludge process. According to *Environmental Biotechnology*, a few of the pros of using an aerobic trickle filter in an industrial setting include the following:

- Appropriate for small- to medium-sized communities
- Reliable results, appropriate for secondary discharge

Figure 3: An aeration basin, this picture was taken at the Stillwater Wastewater Treatment Plant

These pros have implications for the display of this kind of process in this project. First, because it is an appropriate process for smaller communities, it may be better to include the process, which is more common for larger communities (activated sludge). Second, because the resulting effluent is appropriate for secondary recharge, further treatment must be performed if the water is to be reused.

Table 1: Similarities and differences in the trickling filter and activated sludge processes.

Similarities	Differences
Biological treatment of wastewater	Sludge recycled to activated sludge process while clarified effluent recycled to trickling filters
Wastewater treated through an aerobic process	Microbial growth is in suspension in activated sludge process and adhered to a surface in trickling
Level of treatment that can be achieved is similar	Oxygen supplied by mechanical or diffused air aeration to activated sludge process, but supplied by convection currents in trickling filter
	Activated sludge used in larger communities and trickling filter used in smaller communities

This is important since one of the goals in this project is to display a process that will end with reusable water. Comparatively, the activated sludge process is more widely used and is the process used at the Stillwater Wastewater Treatment Plant. The activated sludge process requires both an aeration basin and a clarifier.

Figure 4: An empty clarifier, this picture was taken at the Stillwater Wastewater Treatment Plant.

The final treatment process is called tertiary, and is necessary if the water is going to be reused. According to FAO, "Disinfection normally involves the injection of a chlorine solution at the head end of a chlorine contact basin. The chlorine dosage depends upon the strength of the wastewater and other factors, but dosages of 5 to 15 mg/l are common. Ozone and ultra violet (UV) irradiation can also be used for disinfection but these methods of disinfection are not in common use. Chlorine contact basins are usually rectangular channels, with baffles to prevent short-circuiting, designed to provide a contact time of about 30 minutes. However, to meet advanced wastewater treatment requirements, a chlorine contact time of as long as 120 minutes is sometimes required for specific irrigation uses of reclaimed wastewater. The bactericidal effects of chlorine and other disinfectants are dependent upon pH, contact time, organic content, and effluent temperature" (FAO,). Even though FAO says the usage of UV light is not very common, it is the method used in Stillwater. Another good thing about the usage of UV instead of chemical disinfection is that there is no process required to remove the chemical after disinfection.

Reuse of wastewater as potable water supply can be broken down into two main categories: direct and indirect potable water reuse. An example of indirect reuse would be treated wastewater being released into a surface or groundwater reservoir with the intent of being utilized for drinking water down the line. Direct reuse would be taking treated wastewater and then immediately integrating that water into the municipal system. Aside from drinking water, treated wastewater can be reused as irrigation or other uses. We will be striving to display at least one type of reuse in our final display.

Some patents are useful in terms of this project in that they demonstrate some of the small-scale hydrology that goes into wastewater treatment. For example, we examined Michael R. Hoffmann's patented ***Self-contained, pv-powered domestic toilet and wastewater treatment system*** (U.S. Patent No. 20140209479A1). This project is not concerned with actually creating a working system, but this patent at least shows that a small-scale system can be built. The system utilizes an electrochemical cell to disinfect the wastewater. The cost of the electrodes is one reason why this system is not commercially available, and not a viable option for this project. A diagram from said patent showing the conceptual process can be seen below.

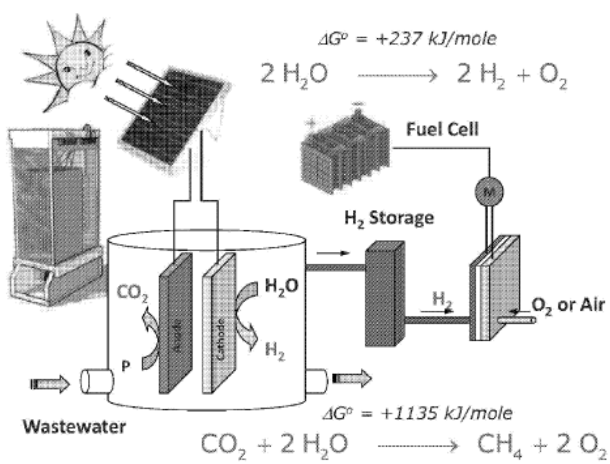


Figure 5: Process diagram from Patent No. 20140209479A1

There were several patents that were designed with a similar motivation as this project: the education of others in wastewater treatment. Patents CN2650270Y, CN202075901U, CN2904175Y, and US20080020360A1 all concern prototype systems that would serve as educational models to some extent. Patent CN2650270Y is a municipal wastewater treatment demonstration model. The model includes a wastewater intake pipe, storage tank, flowmeter, grille tank, de-silting basin, anaerobic tank, anoxic tank, aeration basin, after settling tank, sludge scraper and discharging pipe, chemical and disinfecting tank, mixer, filter, water pump, mud collecting tank, and exhaust pipe. All pipes are made of transparent acrylic material for the ease of observance. The models educational uses are to demonstrate sewage treatment and water reuse methods. It is a little unclear what the scale is of this model was, or whether it was ever built and tested.

Patent CN202075901U is another teaching tool, a water supply and drainage system that models the physical aspects of a drainage system. This device was built as a base class for the application of building a functioning water supply and drainage for college education. The drainage system includes basins, storage water tank, drainage pumps, sewage treatment, washbasin, and sewage disposal units. This drainage system is model to scale for the physical education of real structure drainage, drainage equipment and water supply. This patent is less applicable to this project since the target audiences are different.

Patent CN2904175Y is another model of sewage treatment with the goal of public education. The model consists of an urban area model, grate, detritus pit, oxidation channel, scraping bridge, and a storage pool. The model is interactive, allowing the viewers to control each process separately. Because the original patent is in Chinese, some translations and diagrams are hard to decipher. Still, there are a few concepts present in this patent that we considered in our initial designs.

Patent US20080020360A1 is a portable model for simulating a wastewater treatment process. The model includes a body of untreated drinking water, simulated sources of wastewater and simulated drinking water and wastewater treatment plants. In the wastewater treatment plant simulation, wastewater is filtered, clarified, disinfected, and discharged. The water is moved through a simulated pipeline network. The solid waste is either stored or applied to land. This model can also be used to simulate storm drain system. The materials used in this model are non-toxic, non-poisonous, and biodegradable to facilitate use with children and clean up. A conceptual diagram of that process can be seen below.

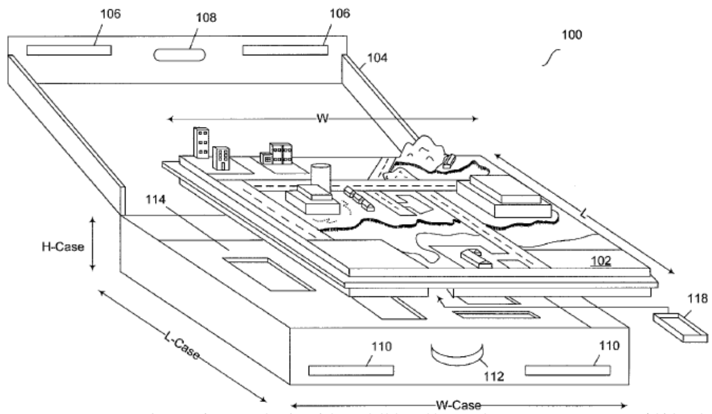


Figure 6: Diagram from Patent No. 20080020360A1

A large reason that creating an actual small-scale wastewater treatment unit would be impractical, and perhaps the reason there are few designs present, is because of the amount of time needed to activate the biological side of the water treatment. Bacteria would need to be inoculated and, even at our prototype scale, would take hours or days before they would be efficiently treating water. This is why treatment plants are run continuously, except for occasional maintenance and unexpected shutdowns. With that being said, the maintenance needs of an “operational” display trailer would also be much greater than for a simple display with only water running through it. The display would need to be cleaned out after every use to prevent unwelcome bacterial growth while the trailer was in storage.

The education aspect of our project must also be taken into account. While the technical design of the trailer must be sound, it must also be engaging and interesting for young children. Some programs and exhibits do exist for teaching students about topics similar to wastewater treatment. For example, students can be taken on tours of wastewater treatment plants, and some states have educational programs, like Florida’s Water. Along with tours and educational programs, some educational models are produced for purchase. For example, enVision Environmental Education manufactures Groundwater Flow Models. These models include infiltrating water, wells, springs, artesian wells, lakes, malfunctioning septic systems and leaking underground storage tanks to display groundwater flow processes. Figure 7 shows an example of one such model.

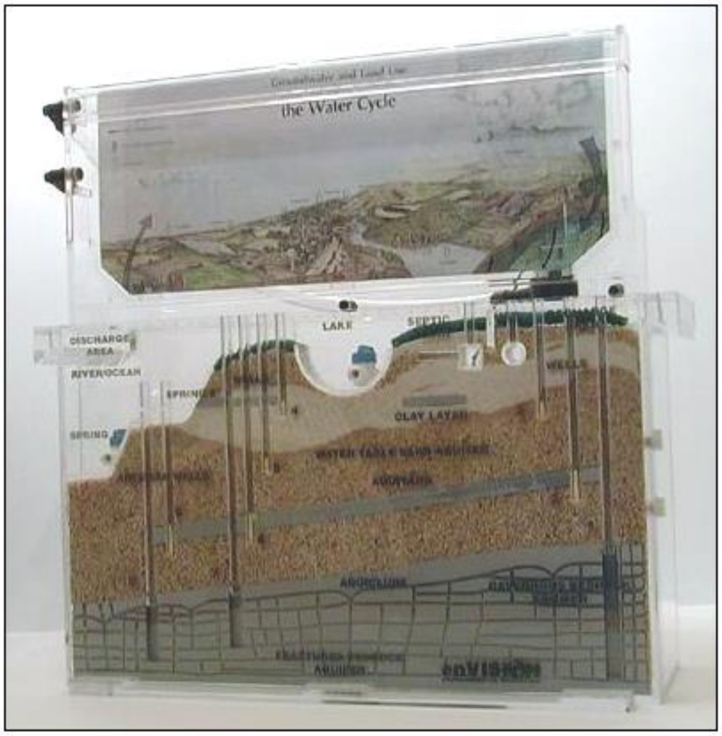


Figure 7: Photo of enVision 3000 Groundwater Model

Also, the enVision system utilizes dyes to show how contaminants can move within a groundwater system, and this is a concept that could be useful in our trailer display. Dyes to show how solids are removed from the wastewater would be a great idea to implement in our design. However, we are unsure how these dyes would be removed from the water aside from dilution.

Children's museums and other interactive venues were also considered for inspiration in generating design concepts. While there were no museums that were found with wastewater treatment exhibits, there was one recurring theme with every popular museum: a plethora of hands-on, interactive exhibits. It's no surprise that the best way to get and hold children's attention is to give them the opportunity to be involved somehow and not present them with continuous lecturing. Therefore, it seems that once technical designs are well on their way, a large objective will be to make our display as interactive and as hands-on as possible. Characteristics for our project that are not existing in other researched methods are designing a system that is a side view display (possibly with Plexiglas), with the starting point of the wastewater system to be a representative toilet or sink with an inlet for water flow. Although some of the discussed patents were meant to be educational in nature, none of them showed specifically bar screens, grit chambers, clarifiers, aeration basins, or any tertiary treatment as we are planning to do. Therefore, we will most likely not be restricted in that regard.

The largest inconsistency between our project and other patents is the fact that our final display will be trailer-mounted. This will present several different design considerations for us, however the largest concern will probably be the fact that we will have a considerable amount of water on this trailer. The storage tank is not expected to be filled while driving, it is expected to be filled on site. Thus, some research into trailer axle loading and payload was conducted, and some typical values for trailer loading were recorded. For a tandem axle utility trailer, the max load can be expected to be around 7,000 lbs. For a single axle utility trailer of the same size, this value can be expected to drop to approximately 3,500 lbs. For our "side view" concept and perhaps implementing side-opening windows for the display, custom tailgate trailers were considered. These trailers ranged from 8-12 feet in length, and axle payloads were rated from 3,500-5,200 lbs. More than likely, axle payload will not be a limiting factor in our designs, but it is definitely something that must be taken into account.

Design Concepts

The finalized system will be thoroughly designed as a “tabletop” model, which will be a direct representation of what would be mounted on the final exhibit. The scale model process will display an identifiable starting point, gravity flow from this starting point through the first two unit operations, to a lift station where the water will be pumped to an elevated point at the next unit operation, and then once again gravity flow throughout the remainder of the system. Figure 8, which can be seen below, shows a summary of the unit operations that were selected for the system.

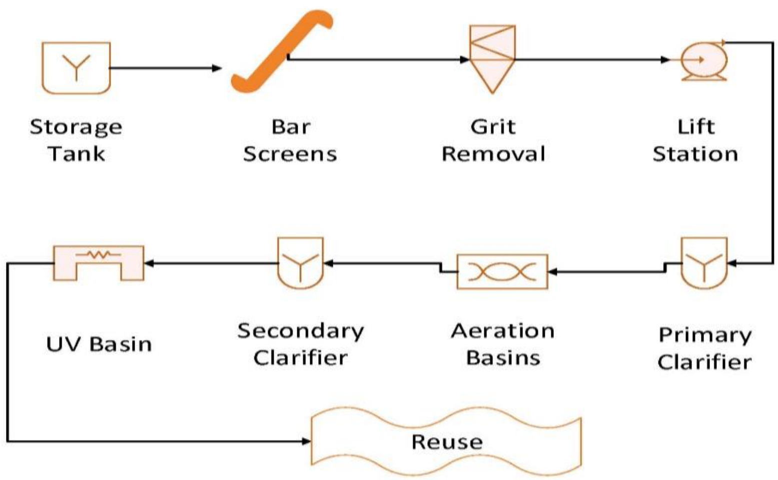


Figure 8: Design components for the prototype.

Components

From the above diagram, it can be seen that the system will start with a storage tank. This tank will serve as a reservoir where water can be recirculated back towards, and also as an initial source of hydraulic head from where gravity flow can be utilized in the first few unit operations. Next, the system will display mechanical bar screens and a grit removal chamber. From there, a pump will send the water to a primary clarifier, and from this point the system will be gravity flow again and will flow through aeration basins, a secondary clarifier, and a UV basin. From these selected components, CAD models were generated of what the team expects them to look like in the trailer mounted system.

The mechanical bar screens (Figure 9) are used for the removal of larger objects that could obstruct flow within the process. They also keep larger things out of the system that allow the system to function properly.

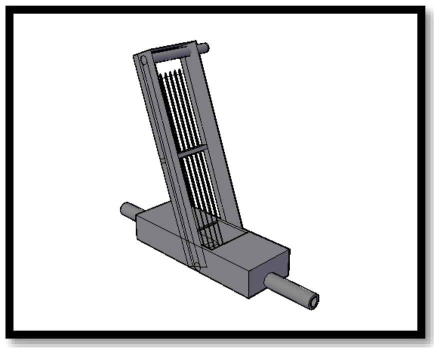


Figure 9: CAD model of the mechanical bar screens.

The grit removal station (Figure 10) removes the largest sand particles through centrifugal flow.

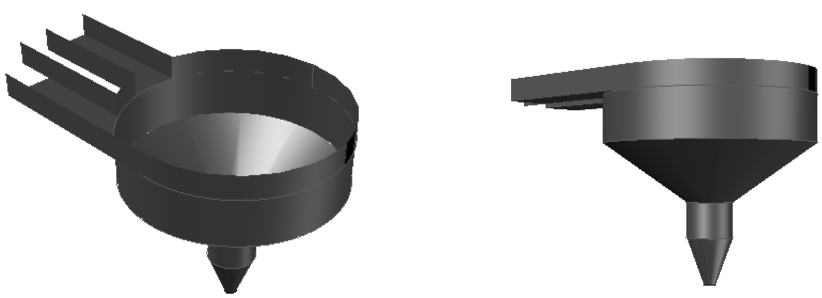


Figure 10: CAD model of the top and side view of the grit chamber.

The lift station as seen below in Figure 11 is used to move and elevate water through piping systems. The float switches are used to turn the pump on at certain speeds depending on how much water is flowing into the lift station chamber.

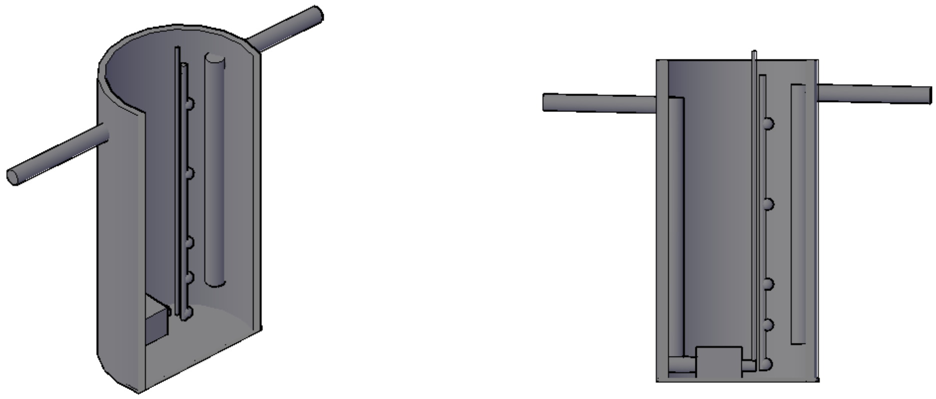


Figure 11: CAD model of the top and side view of the lift station.

The aeration basins shown below in Figure 12 are used to provide air to the microbes so that the biological processes needed to reduce the Biological Oxygen Demand (BOD) can be performed.

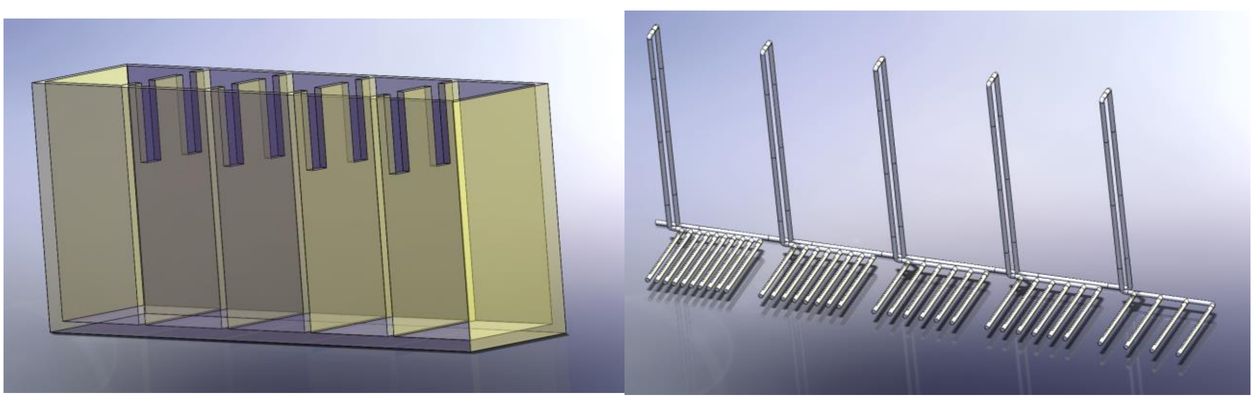


Figure 12: SolidWorks model of the side view of an aeration basin on the left, and the aeration tubes on the right. From freshman design team.

The primary and secondary clarifiers shown in Figure 13 are used to remove the flocculated solids from the water.

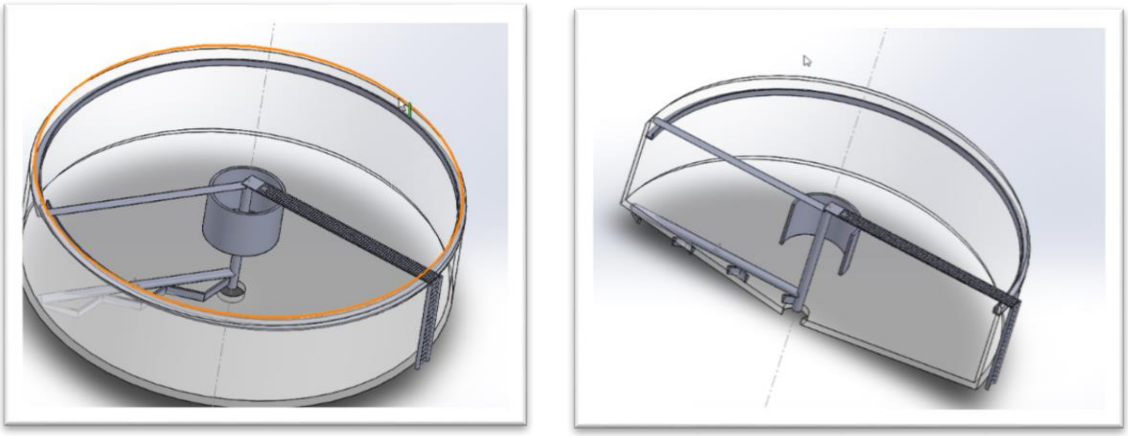


Figure 13: Solidworks drawing of a Clarifier model.

The final stage of wastewater treatment that the model will include is disinfection via UV light exposure, shown in Figure 14.

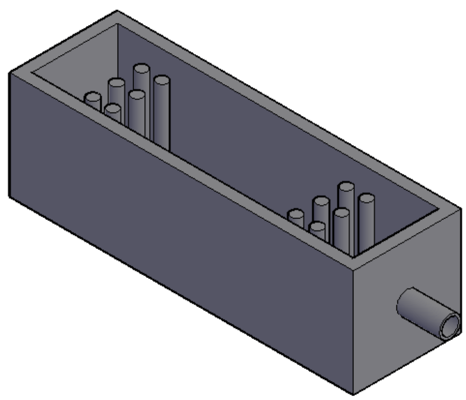


Figure 14: AutoCAD model of disinfection basin

There will be a display of the water discharging out of the system to a stream or river that will recirculate back into the storage tank. The reuse of the system will be displayed as an interactive irrigation sprinkler. The combined layout can be seen in Figure 15, with all the CAD models displayed functioning together within a system.

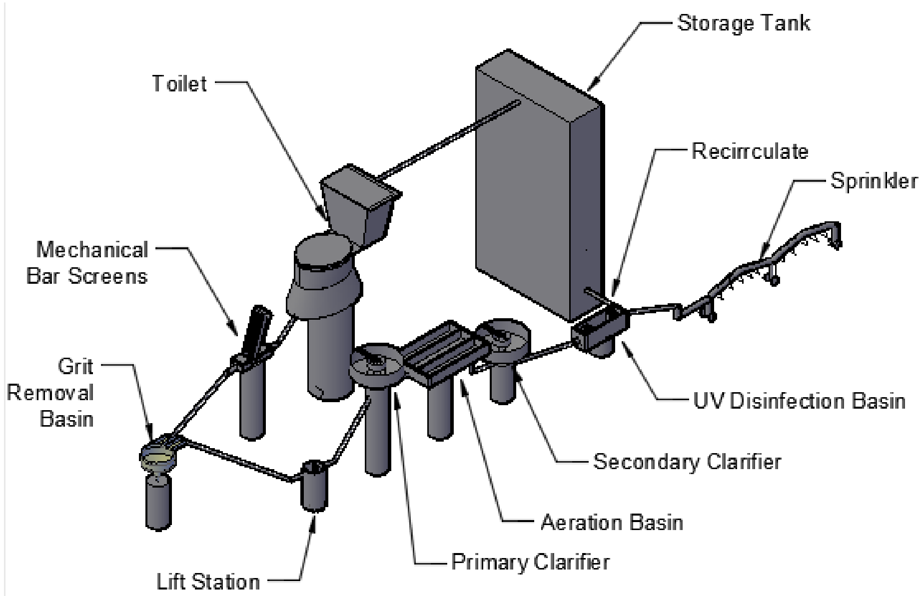


Figure 15: Final layout of the system.

Trailer Layouts

The trailer layouts have been examined for design purposes and cost breakdown. The following trailer designs have been considered for the trailer layout product.

The "walk around" trailer style, which is shown in Figure 16, is based off of custom tailgate trailers and certain concession stand trailers. This trailer would have a 10'x4' opening window on either side of the trailer. The unit operations would be mounted on a wall in the center of the trailer, and viewers would see different parts of the system on either side.

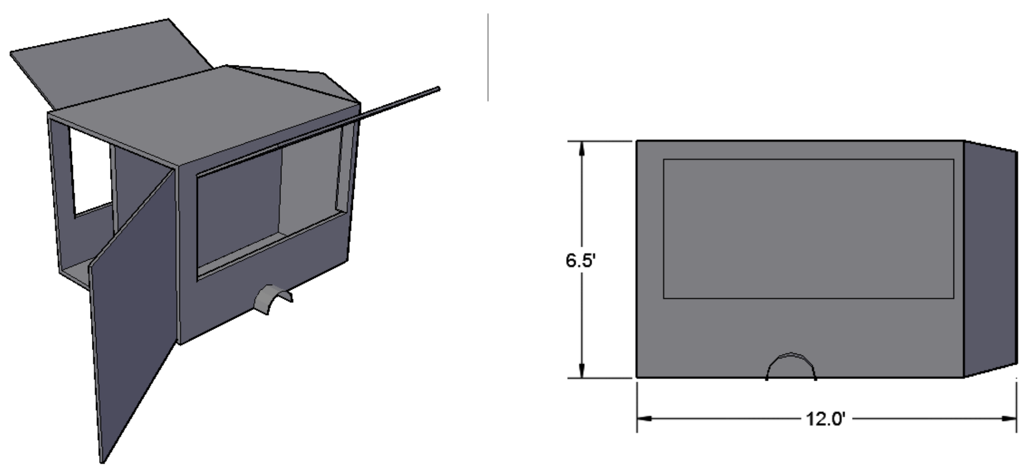


Figure 16: CAD model of top and side view of the "Walk-around" trailer.

The “Stream Erosion” style trailer (Figure 17) would be an interactive display that would utilize the top of the trailer for unit operation placement. This trailer is based off of the OSU Stream Erosion Trailer program, and was considered based off of past success with educational events and cost estimates.

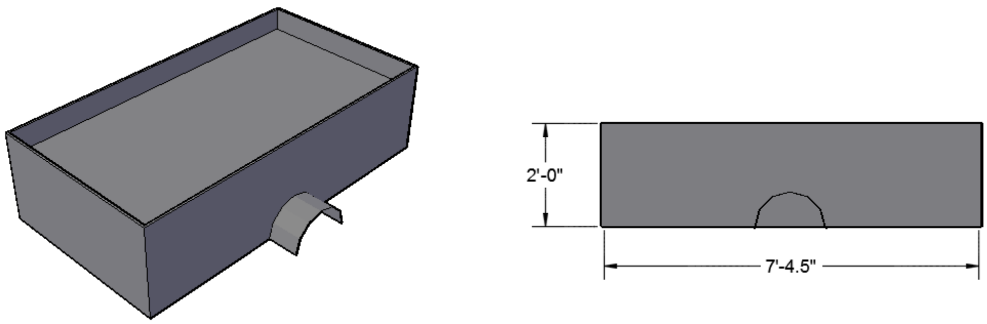


Figure 17: CAD model of top and side view of Stream trailer.

The “Pull-out” style trailer (Figure 18) is again based off of custom tailgate trailers, however would utilize a “pull-out” platform with which the unit operations would be mounted. This display would allow the viewers to be very much up close with the system.

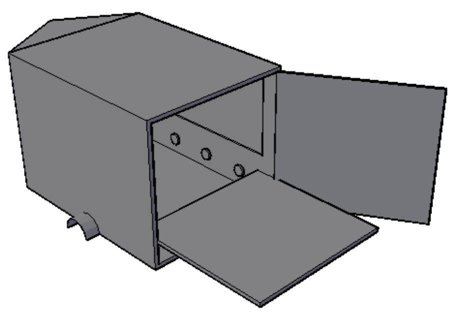


Figure 18: CAD model of the top view of the pullout trailer.

The “Open Sides” trailer (Figure 19) would have opening windows on the rear and one side of the trailer. This trailer would allow for wall mounting of the unit operations, and would still allow for viewers to come up into the trailer and view the system up close.

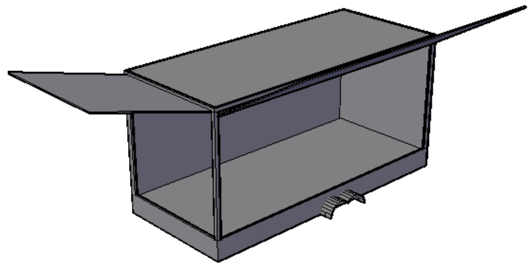


Figure 19: CAD model of the top view of the open trailer.

Scaling

Scaling the components from example wastewater treatment plants were important to the design process to ensure that the unit operations were accurately represented. Among the parameters considered when scaling were geometric similarity, dynamic similarity, nominal scaling, and space availability on the trailer. Obviously, the team needed the components to look as close to the real thing as possible, so making sure that geometric similarity was upheld was imperative. Before the Stillwater WWTP was toured, dynamic similarity was considered to examine how hydraulically similar the system could be made to operational systems, and this was mainly done by comparing Froude and Reynolds numbers between model and prototype systems. Problems do arise with this approach, however, based off of the amount of flow some plants handle and the extremely high retention times in certain components. Nevertheless, Froude and Reynolds number scaling did give the team a better idea of what range of sizes to expect in the prototype system. When the Stillwater WWTP was toured, the staff was kind enough to allow access to their plans and construction drawings. From this, a thorough set of dimensions and measurements could be used to scale the plant at a nominal scale. The Stillwater plant was scaled down by a factor of 100, and for some components this worked very well, however some sizes needed to be adjusted up to ensure that aesthetics and proportionality were upheld. Table 2 shows a summary of how the sizes of the prototype system are estimated compared with the Stillwater WWTP.

Table 2: Scaling of different components from Stillwater WWTP to prototype system.

Stillwater WWTP		Prototype System	
Unit	Characteristic Length	Unit	Characteristic Length
Bar Screens	28 FT	Bar Screens	12 IN
Grit Chamber	17 FT	Grit Chamber	9 IN
Clarifiers (Secondary)	125 FT	Clarifiers (Secondary)	15 IN
Aeration Basins	191 FT	Aeration Basins	23 IN
UV Basin	50 FT	UV Basin	16 IN

Hydraulic Calculations

Hydraulic modeling for the system was imperative to ensure that the system is operational and carrying too much or too small of a flow. Bentley WaterCAD was used to generate pump curves, system head curves, and the hydraulic grade line. For aesthetic purposes, pipe materials are expected to be clear plastic pipe with ¾" diameter. Because the system is not pressurized, and the friction losses from small plastic pipe can be expected to be small, the system head curve for this system is mainly a function of elevation change. Although there are many pumps that could meet the requirements of this project, two small centrifugal pumps were considered, and their specifications can be seen below in Table 3.

Table 3: Pump specifications for considered pumps

	Dayton Utility Pump	Little Giant Pump
Motor (HP)	1/10	1/10
Power Source	115V or 12VDC	115V
Shutoff Head (ft.)	37	48
Price	$103.95	$141.20

With the given pump specifications, pump curves were generated for both pumps and compared with our system head curve. As shown in Figures 20 and 21, both pumps will operate at approximately 6 GPM. Because of the power source being available in 115V or 12VDC and cost, the Dayton pump was then used as the recommended pump and for all further calculations.

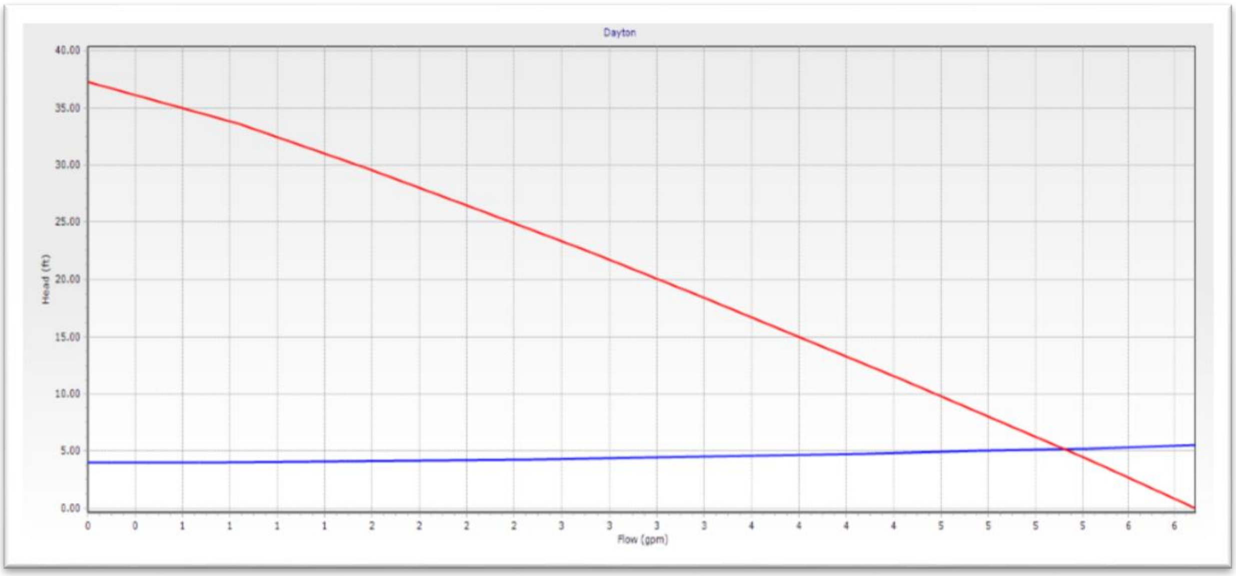


Figure 20: Pump and system curve for Dayton Pump.

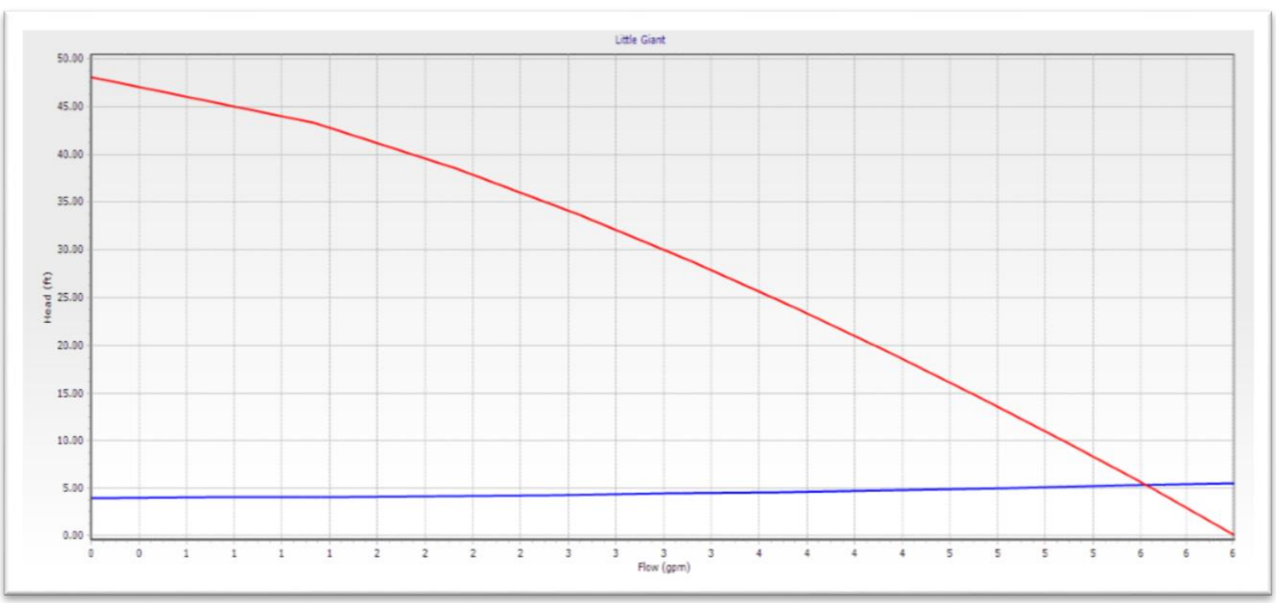


Figure 21: Pump and system curve for Little Giant Pump.

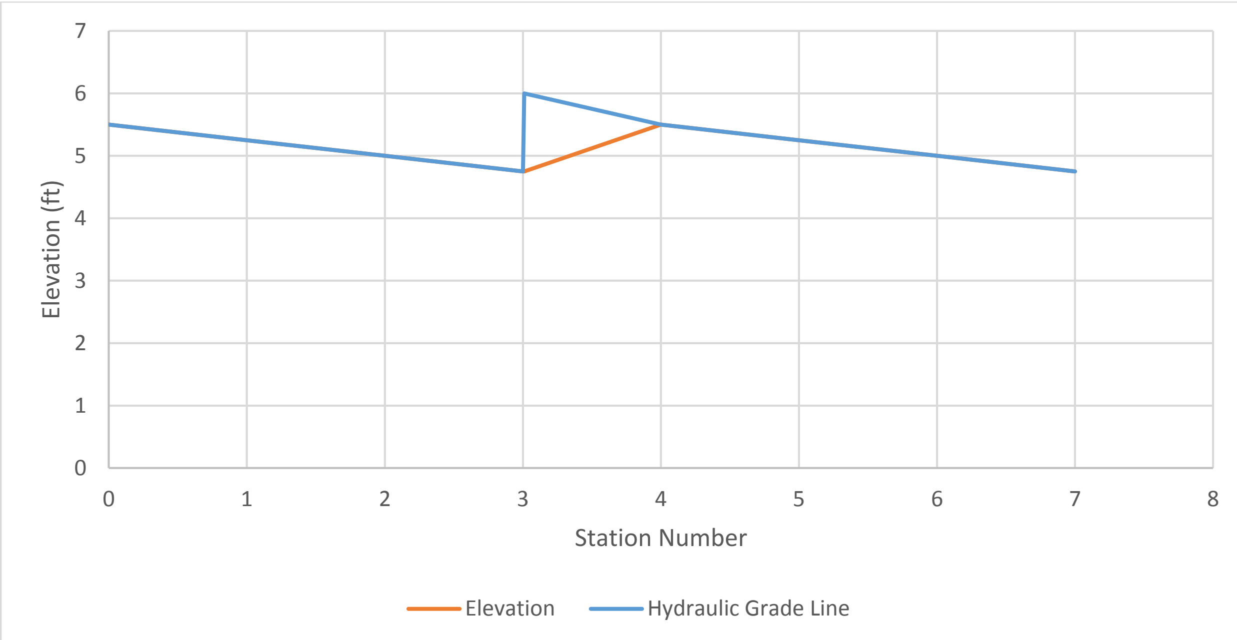


Figure 22: Hydraulic Profile for system design.

To ensure that the gravity flow sections could handle the 6 GPM provided from the pump, Manning's Equation was used to determine the slope needed to carry that amount of flow. As shown in Table 4, the parameters and outputs for Manning's equation that allow for 6 GPM of flow in ¾" pipes are displayed. Based off of these values, as long as the gravity flow sections are kept at a slope of 0.25 ft/ft, then the system will carry the same amount of flow throughout.

Table 4: Manning's Equation parameters and ouputs

Parameter	**Value**	**Output**	**Value**
Pipe Diameter (in.)	0.75	Wetted Perimeter (in.)	2.36
Manning's Roughness, n	0.01	Flow Area (in.^{2})	0.442
Slope (ft/ft)	0.25	Hydraulic Radius (in.)	0.1875
Percent of Full Depth Flow	100%	Flow (GPM)	6.0

Finally, a hydraulic grade line was generated for the system. As shown in Figure 22, the hydraulic grade line begins at around 5.5 feet, which is representative of the elevated tank of water. From there, the system will be gravity flow until it reaches the pump inlet at Station 3.

The pump spikes the hydraulic grade line to a max at the pump outlet, and from there the system will again be gravity flow through the remainder of the unit operations.

Interactivity

One of the main goals the display is that it will be interactive and engaging to children in fourth and fifth grade. The team has considered several possibilities for how to complete this goal. One of the ideas has been to incorporate moving parts in the design, to better illustrate how the different components function. Another possibility being considered is making the components detachable from their mountings and allowing the students a chance to rearrange the system. Since the target audience is the fourth and fifth grade, the students should be old enough to be able to constructively think about the abstract process of wastewater treatment. The display could also include some kind of response system to tell the students whether the water is actually being cleaned in the order that they have chosen. This would allow the students to interact with the display and to give them a chance to actively think about what steps have to be taken before wastewater can be reused.

Cost

The following tables are the cost estimates for the materials for the table top model and trailer.

Table 5: Cost of materials for the table top model.

Material	Unit Cost	Quantity	Cost
Pipe	$4.45/ft	15	$67
Valve (BF)	$10/unit	3	$30
Plexiglas	$13/ft^2	25	$75
Sprinkler	$15	1	$15
Misc.	-	-	$63
Total	-	-	$250

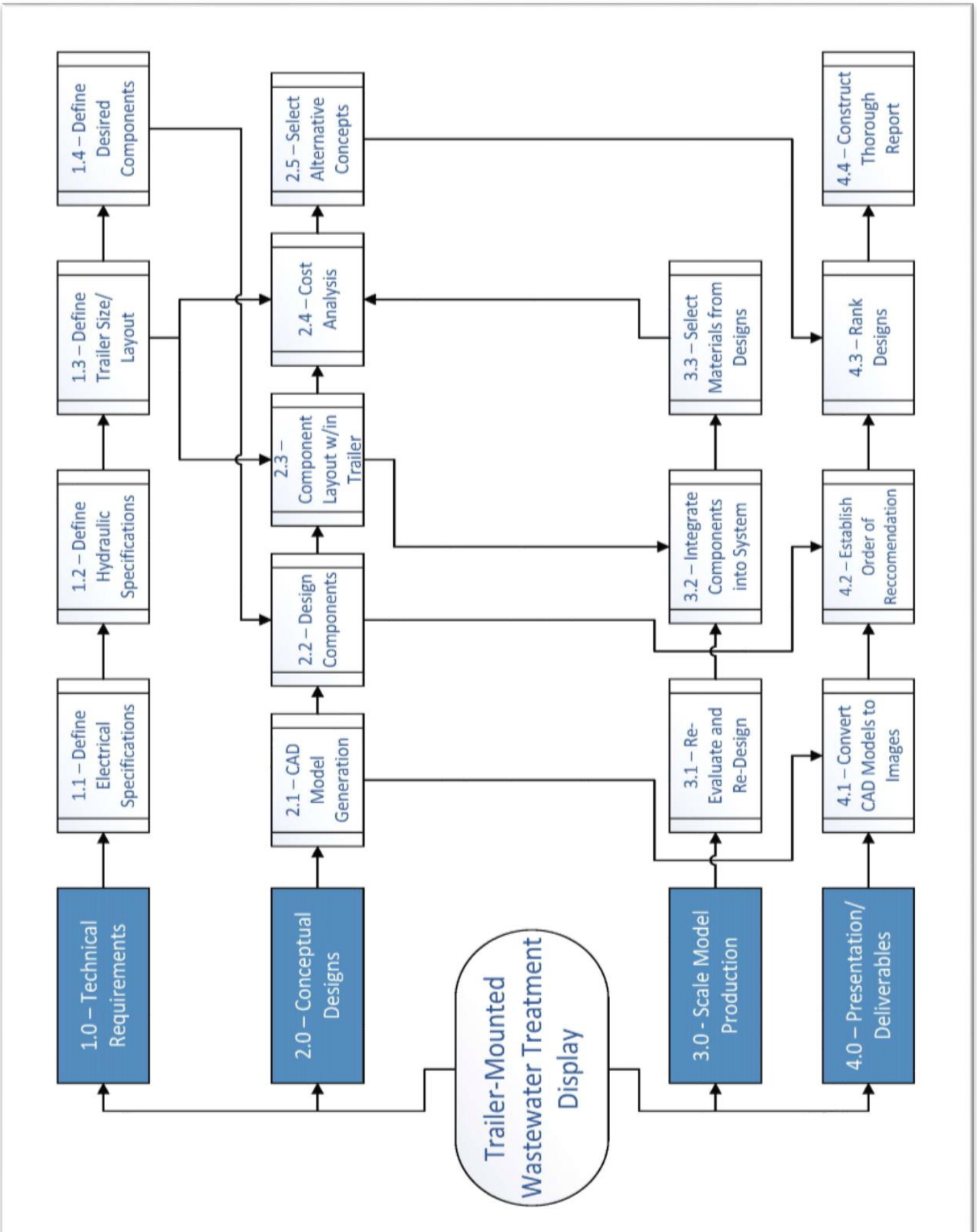
Table 6: Cost estimates for trailer and trailer materials.

Alternatives				
	"Open Sides" Trailer	"Walk around" Trailer	"Pull-Out" Trailer	Stream Trailer
Bare Trailer	$22,500	$15,000	$15,000	$10,000
Pump (Dayton)	$104	$104	$104	$104
Materials	$700	$600	$600	$500
Total Cost	$23,304	$15,704	$15,704	$10,604

Discussion

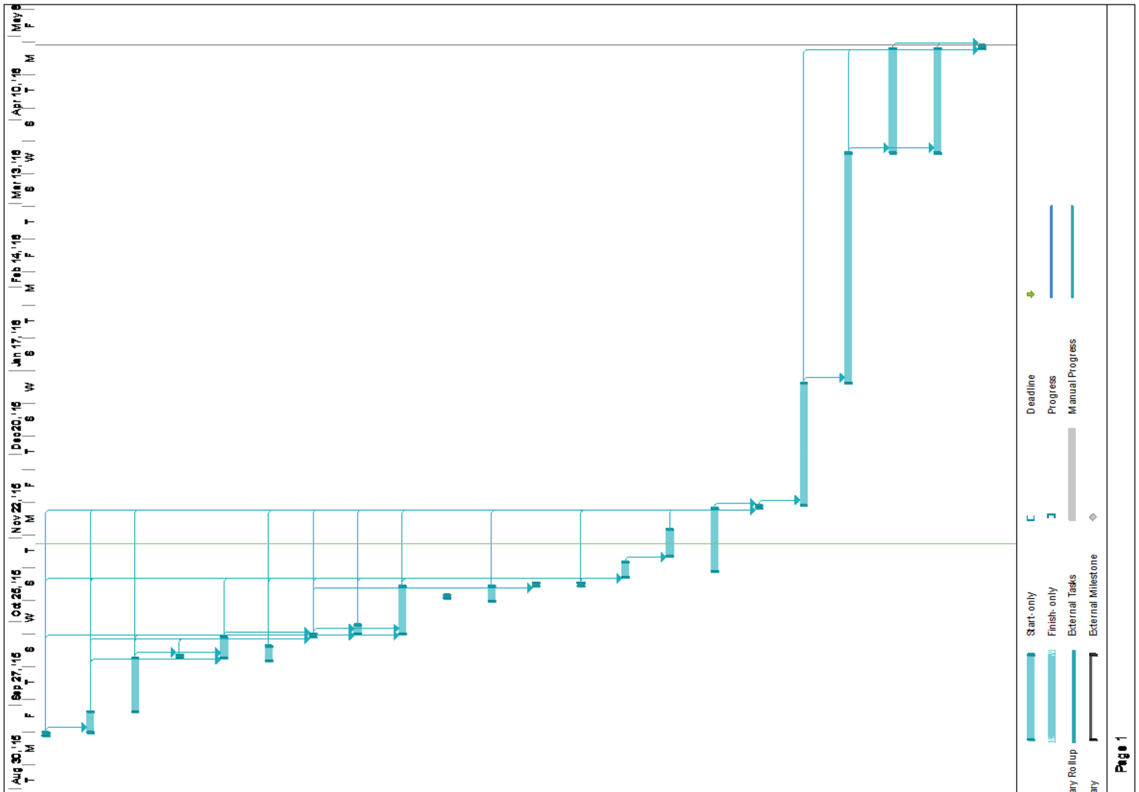
These practical treatments of wastewater will be an educational opportunity for the young generation, so the trailer will be as interactive as possible. Our final display will be trailer-mounted, this will present several different design considerations, however the largest concern will probably be the fact that we will have a considerable amount of water on this trailer. Research into design concepts have led to different layouts of the interactive trailer.

Fall 2015 Work Breakdown Structure



Gantt Chart

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Meeting with Garver	1 day	Thu 9/17/15	Thu 9/17/15	
2		Literature Review	5 days	Fri 9/18/15	Thu 9/24/15	1
3		Initial Designs	12 days	Fri 9/25/15	Mon 10/12/15	
4		Meeting with Freshmen	1 day	Tue 10/13/15	Tue 10/13/15	3
5		Short Report	5 days	Tue 10/13/15	Mon 10/19/15	2,3
6		Technical Analysis	5 days	Mon 10/12/15	Fri 10/16/15	
7		Meeting with Garver at OSU	1 day	Tue 10/20/15	Tue 10/20/15	2,3,4,5
8		Statement of Work	3 days	Wed 10/21/15	Fri 10/23/15	1,7
9		Pre-liminary Design	12 days	Wed 10/21/15	Thu 11/5/15	3,7
10		Meet with Freshmen	1 day	Mon 11/2/15	Mon 11/2/15	
11		Prepare Powerpoint Presentation	5 days	Sun 11/1/15	Thu 11/5/15	
12		Final Presentation Date	1 day	Fri 11/6/15	Fri 11/6/15	7
13		Work Breakdown Structure	1 day	Fri 11/6/15	Fri 11/6/15	
14		Fall Report Draft	5 days	Mon 11/9/15	Fri 11/13/15	1,2,5,6,7,8,9,13
15		Final Fall Report	7 days	Mon 11/16/15	Tue 11/24/15	14
16		Fall Powerpoint Presentation	15 days	Wed 11/11/15	Tue 12/1/15	
17		Fall Presentation to Garver	1 day	Wed 12/2/15	Wed 12/2/15	1,2,3,6,7,8,9,11,13,15,16
18		Select Design and Research	29 days	Thu 12/3/15	Tue 1/12/16	17
19		Build and Test Design	55 days	Wed 1/13/16	Tue 3/29/16	18
20		Create Final Report	25 days	Wed 3/30/16	Tue 5/3/16	19
21		Create Final Presentation	25 days	Wed 3/30/16	Tue 5/3/16	19
22		Present Final Prodcut to Garver	1 day	Wed 5/4/16	Wed 5/4/16	18,19,20,21



Project: AquaCleanse Solutions
Date: Fri 11/20/15

Page 1

Engineering Specifications

A few broad specifications that will be key to the design process are known. One of these is trailer axle payload. From what we have seen, most trailers around the size that we are looking at will have either a 3,500 or 5,200-pound axle payload. Dual axle trailers are an option as well. Regardless, we will need to keep the weight of our trailer in mind, especially if we expect to carry any water within the system while traveling.

Another specification that the design team is considering is the electrical power consumption of our display. Most definitely, the trailer should be functional off a single 120 Volt plug in power source. However, we are also considering the practicality of running our system off one or two 12 Volt car batteries. This would allow the trailer to be displayed in any environment, regardless of the presence of electrical outlets. This would provide less power to the display, and is unclear at this point if it would be a sufficient power supply or not.

At this point, we expect the flow through our system to be around 3 gallons per minute. This will allow the system to run on a small centrifugal pump, and will provide enough flow that moving water will be visible within the unit operations.

The trailer size is expected to be a maximum of 12 feet long. From an economic standpoint, a 12-foot trailer would be the least desirable choice; however, it would provide plenty of space and payload requirements. As our design begins to come to fruition, trailer size will most likely be moderated down to the 8-10 foot long range.

BAE 1012 Team Projects

Every year, the BAE senior design class is paired with the freshmen-level BAE 1012 class, and senior design teams are expected to give two freshman teams design projects which will help with the senior design teams own project. AquaCleanse Solutions had the opportunity to work with two freshman design teams, and posed them with the task of generating CAD models for the Clarifiers and Aeration Basins that would be used in the system display. Below are the problem statements that were given to the freshman teams.

Project 1: Design of a scale model primary clarifier

The senior design team would like one BAE 1012 design team to design a scale model primary clarifier. This functional model will be used on the final display and would serve to give an accurate representation of how a clarifier works. Some of the requirements are as follows:

- The model would need to be hydraulically similar to a normal clarifier. For instance, with a design flow rate, the clarifier would have some amount of hydraulic retention time.
- Model needs to be mechanically similar. For example, sludge scraper blades and skimmer arms must be present and have the potential to be driven by an electric motor.
- Finally, the model must be visually accurate. Same scraper blades and rake arms as mentioned before, but other clarifier components such as sludge discharge pit, walkway, scum baffle, etc. should be included in the design. In addition, since this is for an educational display, it would be great if even the submerged parts of the model were visible to observers. Therefore, the structure of the model should be designed with clear materials, such as Plexiglas.

Project 2: Design of a Scale Model Aeration Basin

The senior design team would like the other BAE 1012 design team to design a scale model aeration basin. This functional model would be used on the final display and would serve to give an accurate representation of how an aeration basin works. Some of the requirements are as follows:

- The model would need to be hydraulically similar to a normal aeration basin. This means that with a design flow rate, the basin would exhibit some amount of hydraulic retention time.
- Model needs to be mechanically similar. For example, most aeration basins have a grid of air diffusers at the bottom of the reservoir to support bacterial growth with added oxygen. This model would need to have the potential to diffuse air into the water with the addition of a compressor or other air supply.
- Finally, the model must be visually accurate. Tank dimensions, air diffusers, multiple reservoirs, and clear materials will be in the design process.

Appendices

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INTERACTIVE WASTEWATER TREATMENT DISPLAY

GROUP PICTURE

Abigail Parnell - Brandy Parks - Olivia Broussard - Cole Niblett

AGENDA

- Project Introduction
- Wastewater Treatment Overview
- Objectives and Project Scope
- Conceptual Designs
- Cost Analysis
- Discussion

PROJECT SPONSOR

- Garver Engineering
- Multi-disciplined firm
- Headquarters: Little Rock, AR
- Point of contact: Mary Elizabeth Mach, PE
  - Norman, OK office
  - 2006 OSU BAE Graduate

PROJECT INTRODUCTION

- Design a wastewater treatment educational display
  - 4th and 5th grade students
  - Trailer-mounted
  - Hydraulically similar to a WWTP
    - Vertical
  - Aesthetically pleasing
  - Interactive
  - Venues: Classrooms, fairs, conventions
- Build table top model

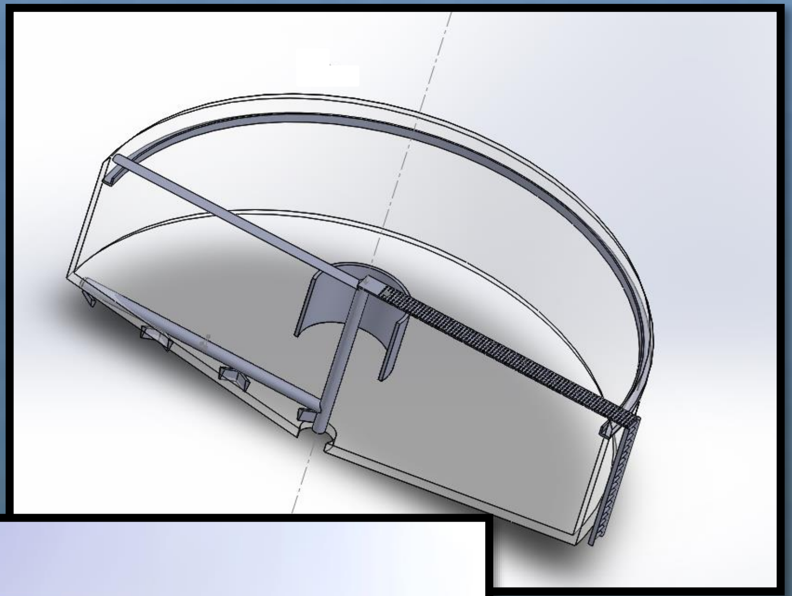
WASTEWATER TREATMENT OVERVIEW

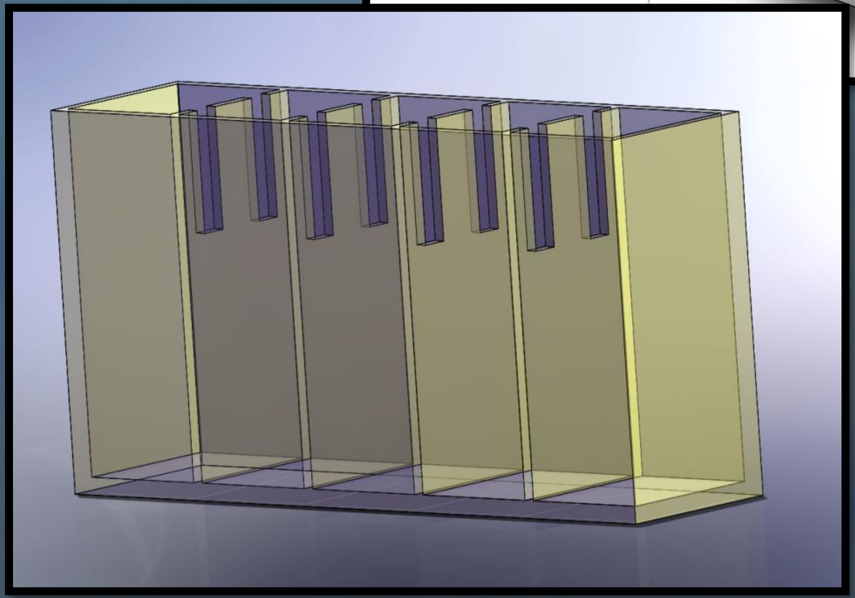
- Pretreatment
  - Inorganic solids
  - Bar screens, grit removal
- Primary Treatment
  - Sedimentation
- Secondary Treatment
  - Biological
- Tertiary Treatment
  - Chemical/UV disinfection
- Reuse/Discharge




FALL SEMESTER OVERVIEW

- Initial concepts and designs
  - Research wastewater treatment theory
  - Stillwater WWTP Tour
- Component selection/sizing
- Technical specs
- Cost estimates
- Freshman Design Teams





SPRING SEMESTER SCOPE & OBJECTIVES

- Revise conceptual designs
  - Examine hydraulic accuracy
- Technical/Electrical specs
- Materials/Fabrication Estimate
- Deliverables
  - "Table-top" model

SELECTION OF UNIT OPERATIONS

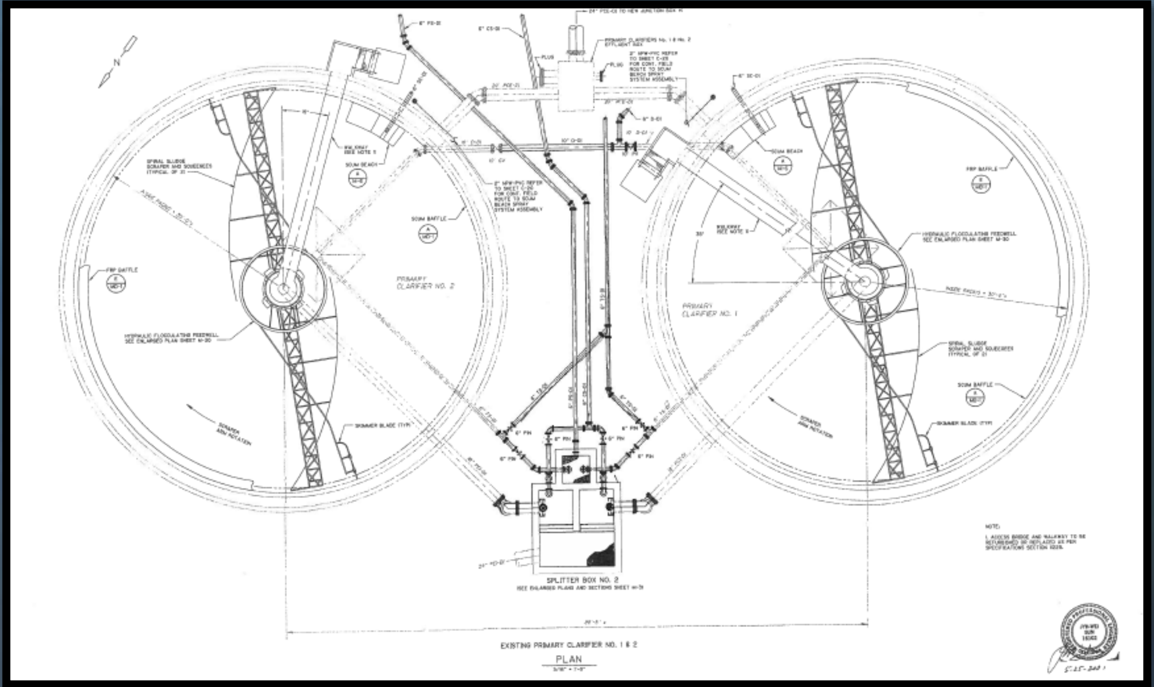
- From Fall Semester:
  - Mechanical bar screens
  - Grit removal basin
  - Primary clarifier
  - Aeration Basin
  - Secondary clarifier
  - UV disinfection
  - Reuse

SIZING OF UNIT OPERATIONS

- Geometric Similarity
- Dynamic Similarity
  - Reynolds/Froude Numbers
- Scaled Stillwater WWTP
  - λ=1:100
- Space Availability

$$Re = \frac{\rho v D}{\mu}$$

$$Fr = \frac{\upsilon}{\sqrt{gD}}$$



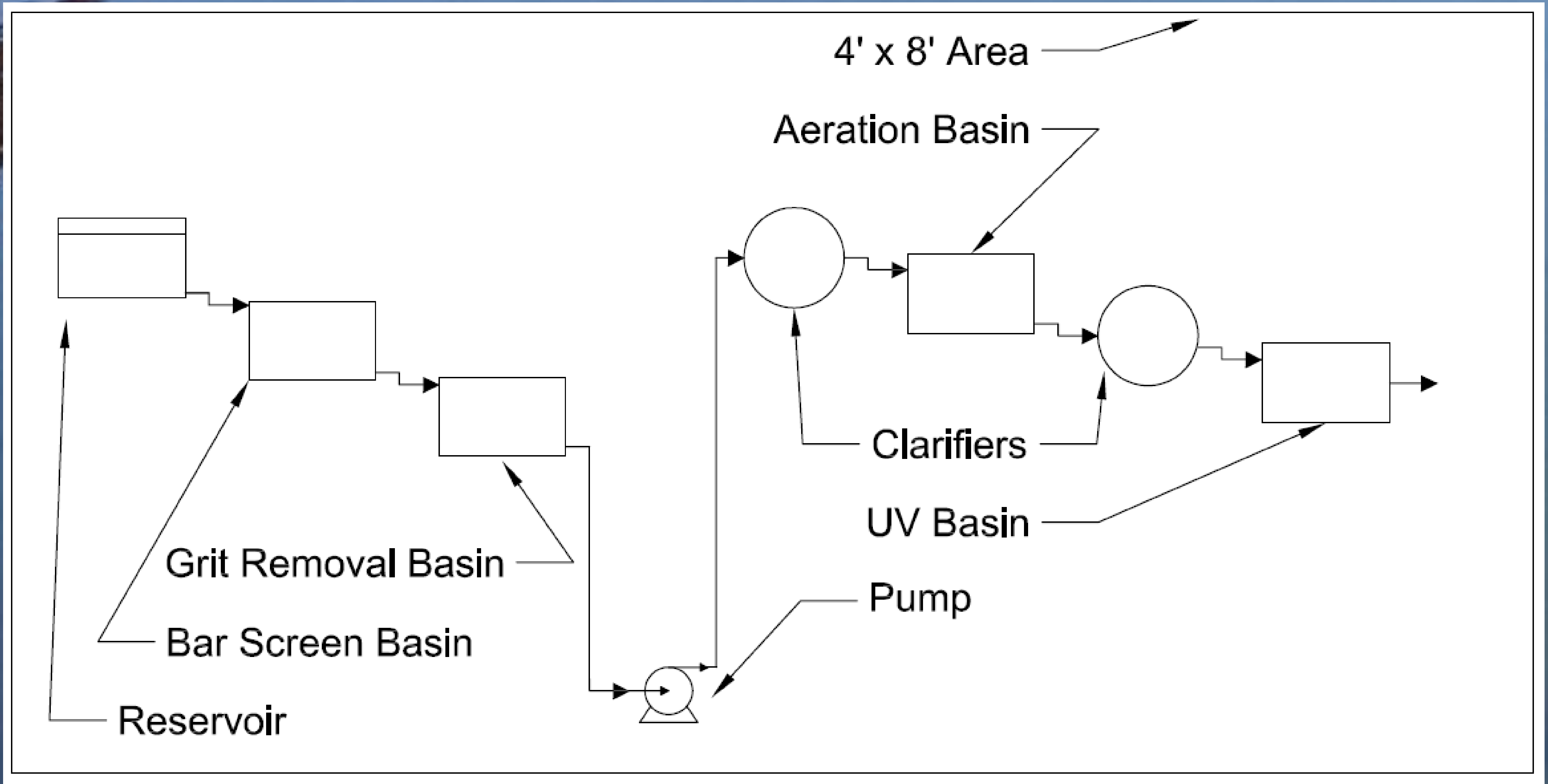
SIZING OF UNIT OPERATIONS

Stillwater WWTP		1:100 Scale	
Unit	Characteristic Length	Unit	Characteristic Length
Bar Screens	28’	Bar Screens	3”
Grit Chamber	17’	Grit Chamber	2”
Clarifiers (Secondary)	125’	Clarifiers	15”
Aeration Basins	191’	Aeration Basins	23”
UV Basin	50’	UV Basin	6”

SIZING OF UNIT OPERATIONS

Stillwater WWTP		Prototype System	
Unit	Characteristic Length	Unit	Characteristic Length
Bar Screens	28’	Bar Screens	12”
Grit Chamber	17’	Grit Chamber	9”
Clarifiers (Secondary)	125’	Clarifiers	15”
Aeration Basins	191’	Aeration Basins	23”
UV Basin	50’	UV Basin	16”

HYDRAULIC MODEL FLOW DIAGRAM



HYDRAULIC CALCULATIONS

- Pump operates at ~4-6 GPM
  - Gravity veins must carry same flow
- Manning's Equation

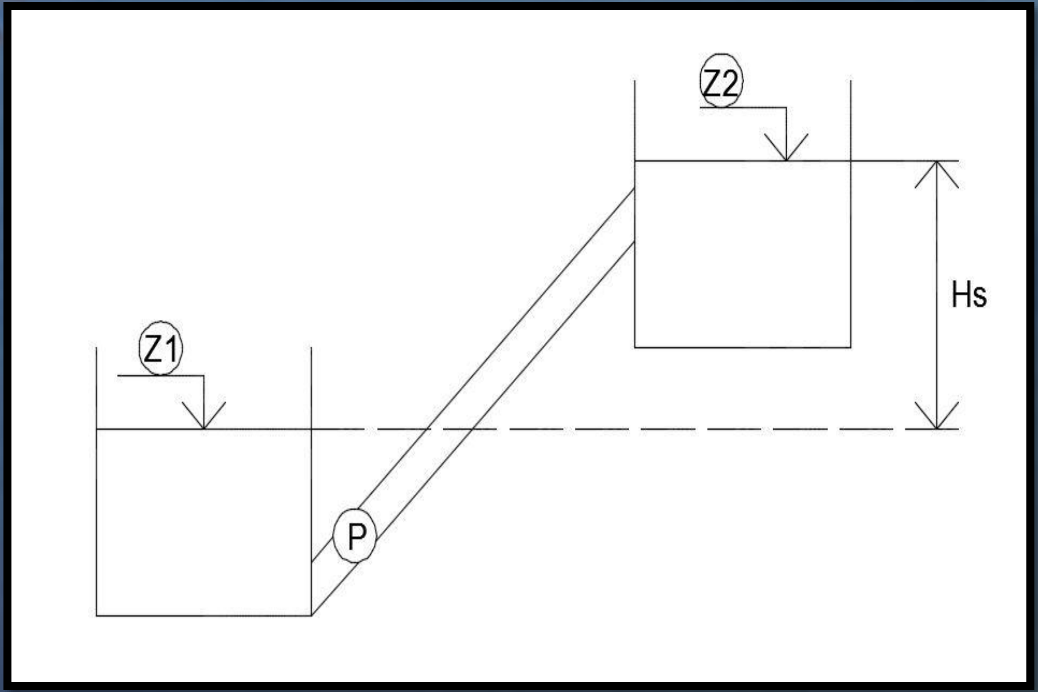
$$V = \frac{1.49}{n} R_h^{2/3} S^{1/2}$$

Parameter	Value
Pipe Diameter (in.)	0.75
Manning's Roughness, n	0.01
Slope (ft/ft)	0.25
Percent of Full Depth Flow	100%

Output	Value
Wetted Perimeter (in.)	2.36
Flow Area (in^2)	0.442
Hydraulic Radius (in.)	0.1875
Velocity (ft/s)	4.4
Flow (GPM)	6.0

HYDRAULIC CALCULATIONS

$$z_{grit} + \frac{p_{grit}}{\gamma} + \frac{V^2}{2g} + h_p = z_{clarifier} + \frac{p_{clarifier}}{\gamma} + \frac{V^2}{2g} + h_f$$



$$h_p = \left(z_{clarifier} - z_{grit}\right) + h_f$$

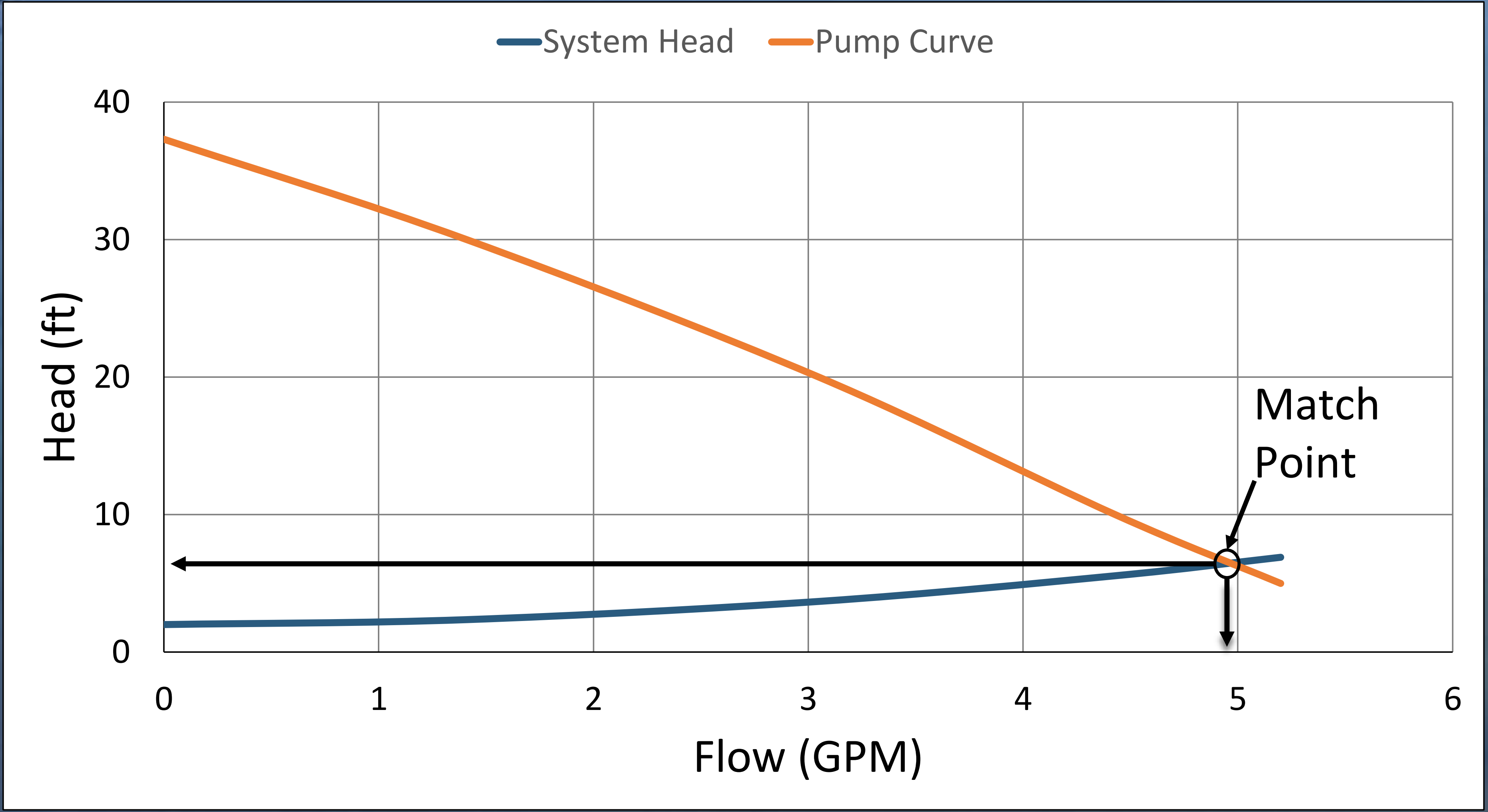
$$h_f = f\frac{L}{D}\frac{V^2}{2g} + K_{valve}\frac{V^2}{2g}$$

$$f = .025 \quad K_{valve} \sim 20$$

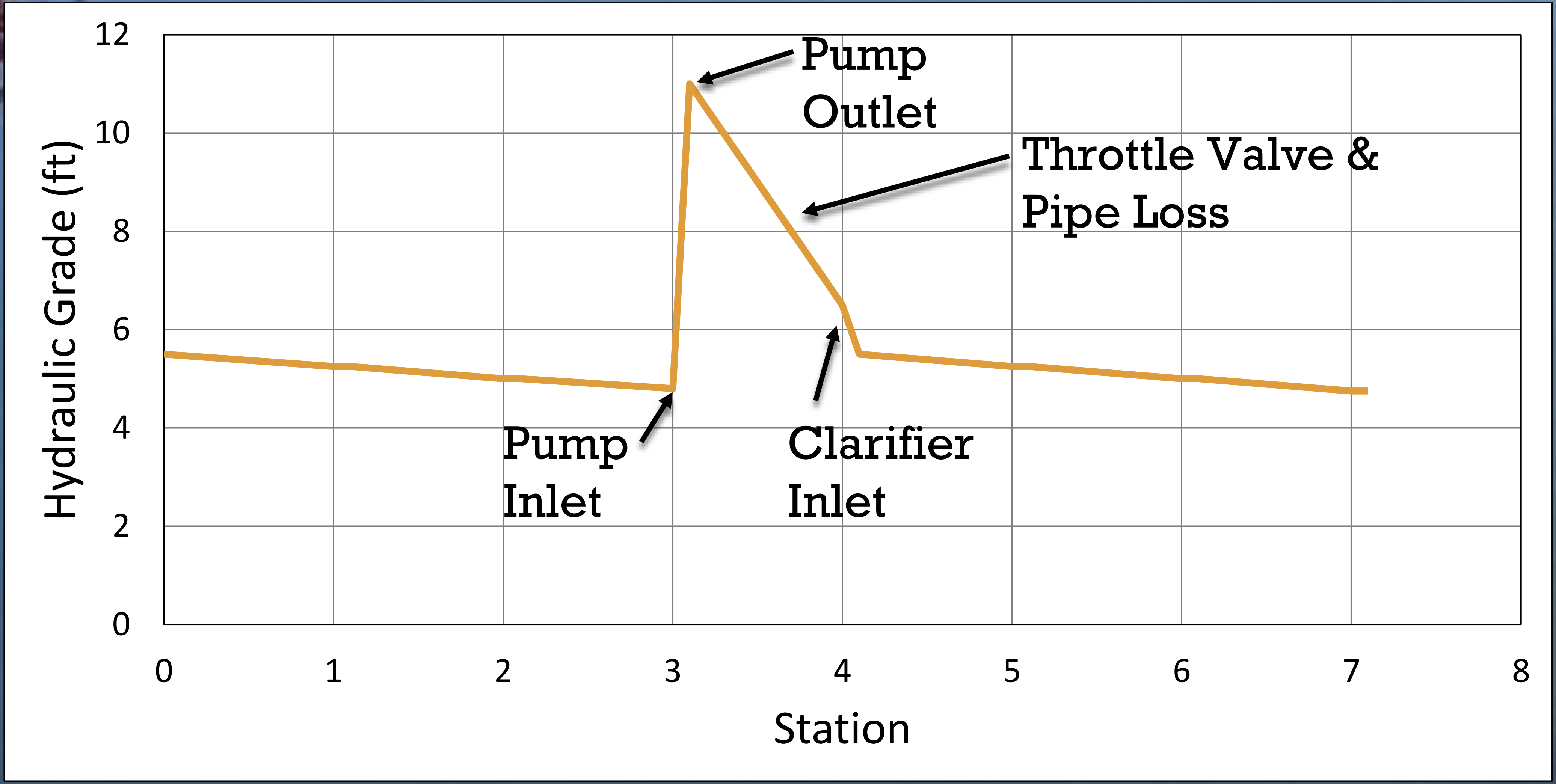
HYDRAULIC CALCULATIONS

Pump Curve			System Curve		
Flow (GPM)	Velocity (ft/s)	Head (ft)	Friction Loss (ft)	H_s (ft)	H_{system} (ft)
5.2	3.8	5	4.89	2	6.89
4.43	3.2	10	3.55	2	5.55
3.05	2.2	20	1.68	2	3.68
1.41	1.0	30	0.36	2	2.36
0	0.0	37.3	0.00	2	2.00

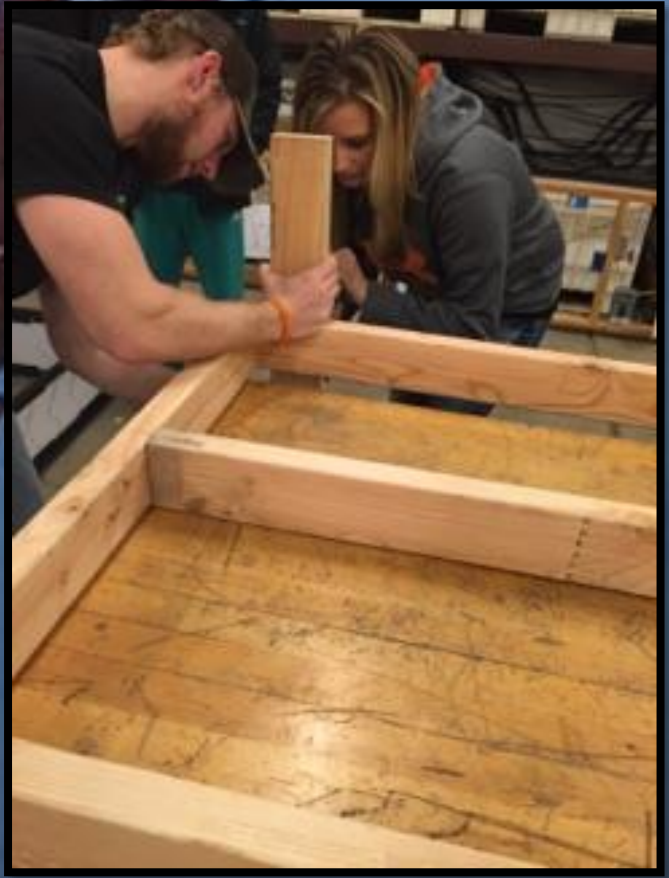
HYDRAULIC CALCULATIONS

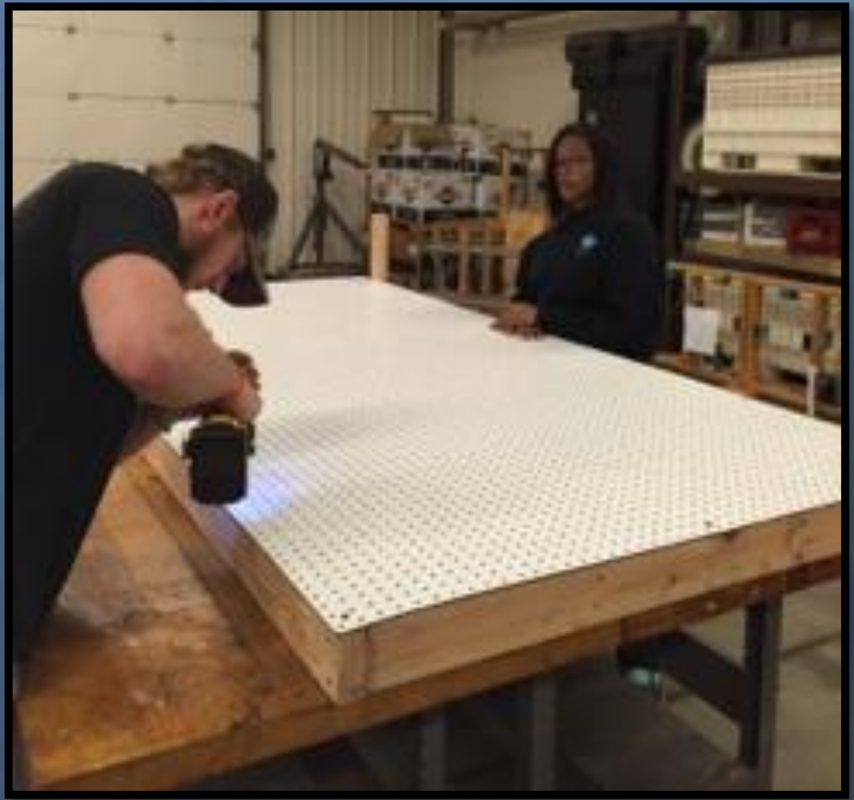


HYDRAULIC GRADE LINE



HYDRAULIC MODEL FABRICATION





HYDRAULIC MODEL FABRICATION

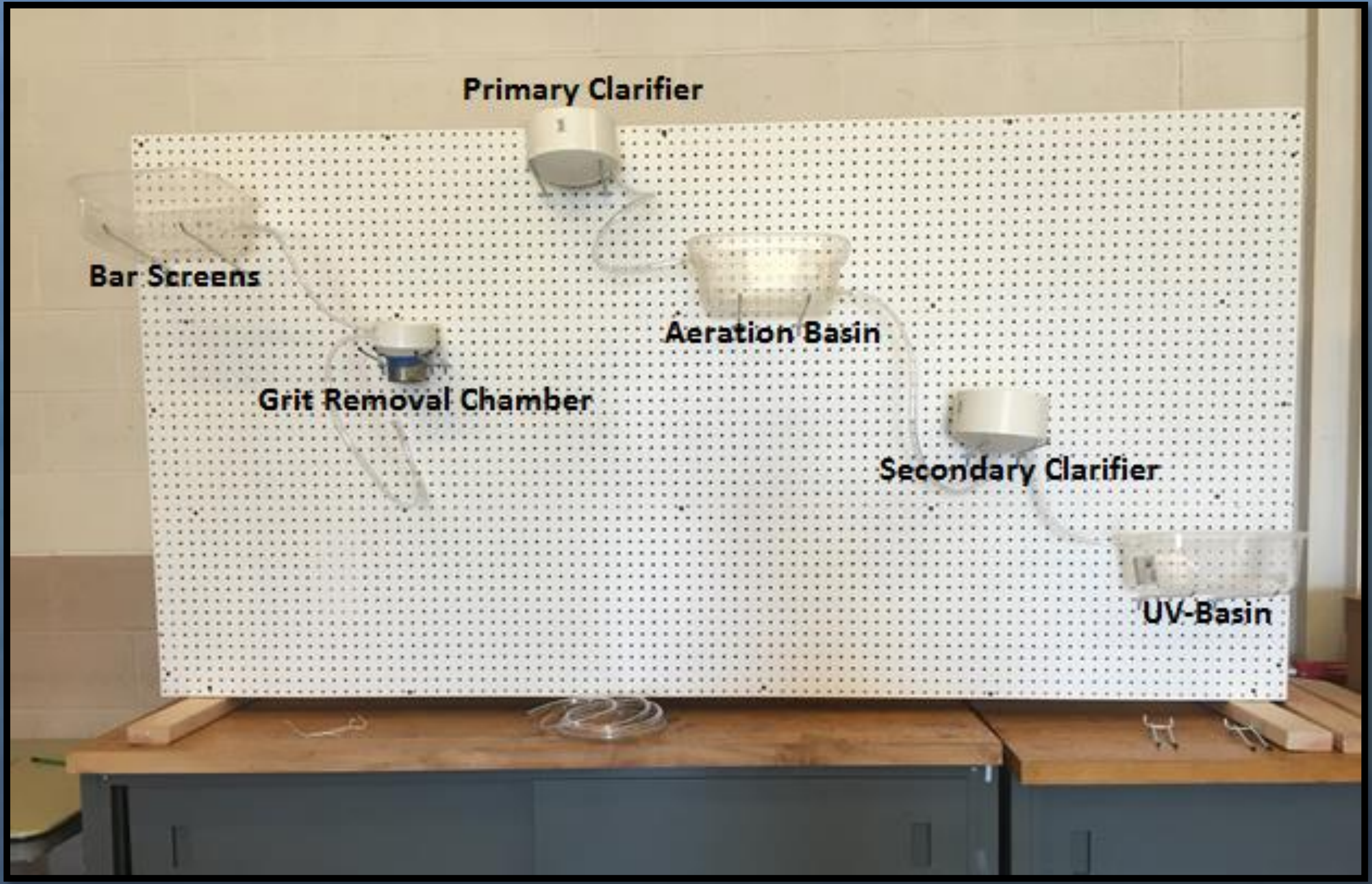
- Clarifiers:

- Dayton Centrifugal Pump

HYDRAULIC MODEL FABRICATION

- Basins
- Grit removal chamber

HYDRAULIC MODEL FABRICATION



HYDRAULIC MODEL TESTING

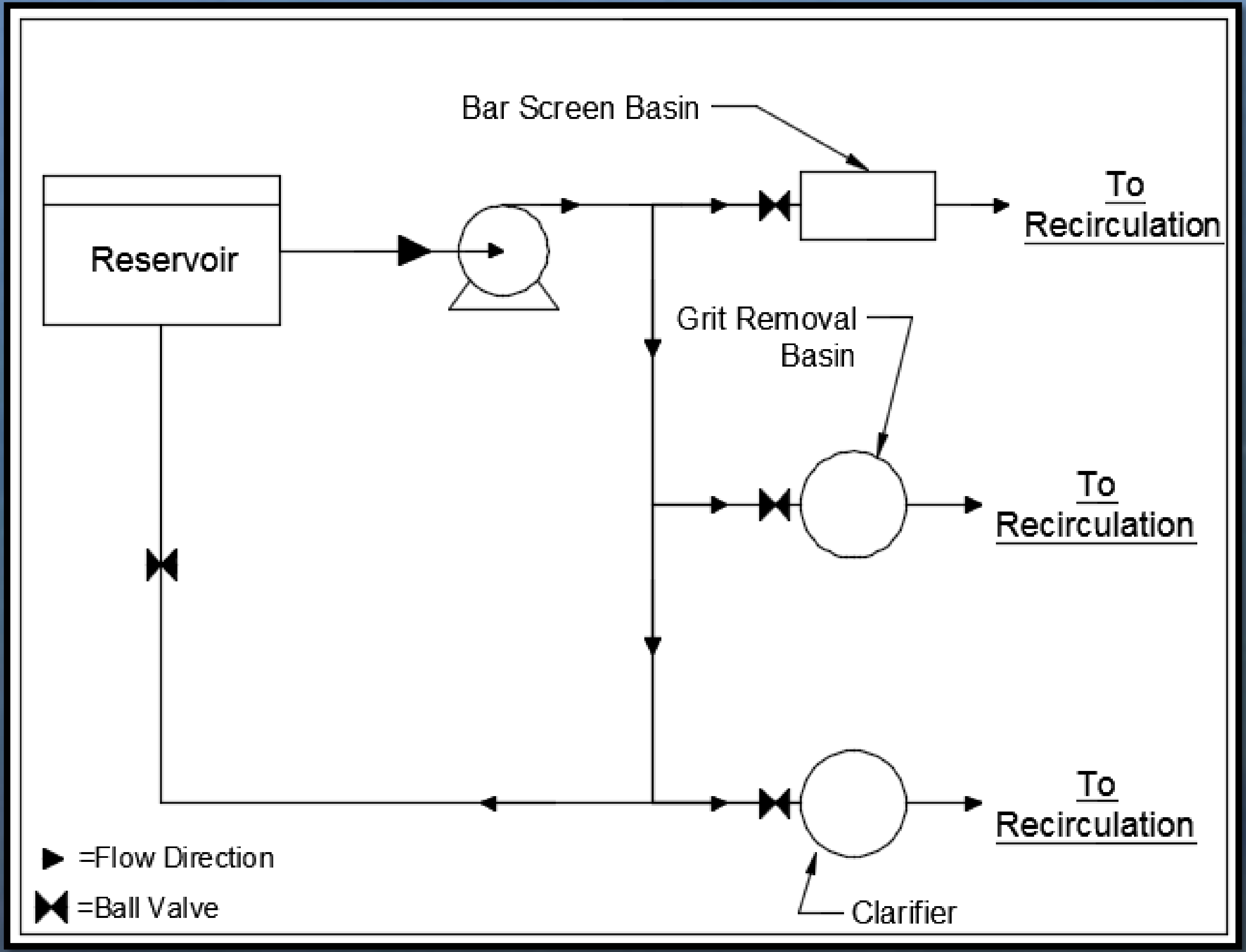
CONCLUSIONS FROM HYDRAULIC MODEL

- Dynamic similarity not reasonable
- Flow-through system is inconvenient
  - Operation & maintenance
- Keep target audience in mind

DESIGN REVISIONS

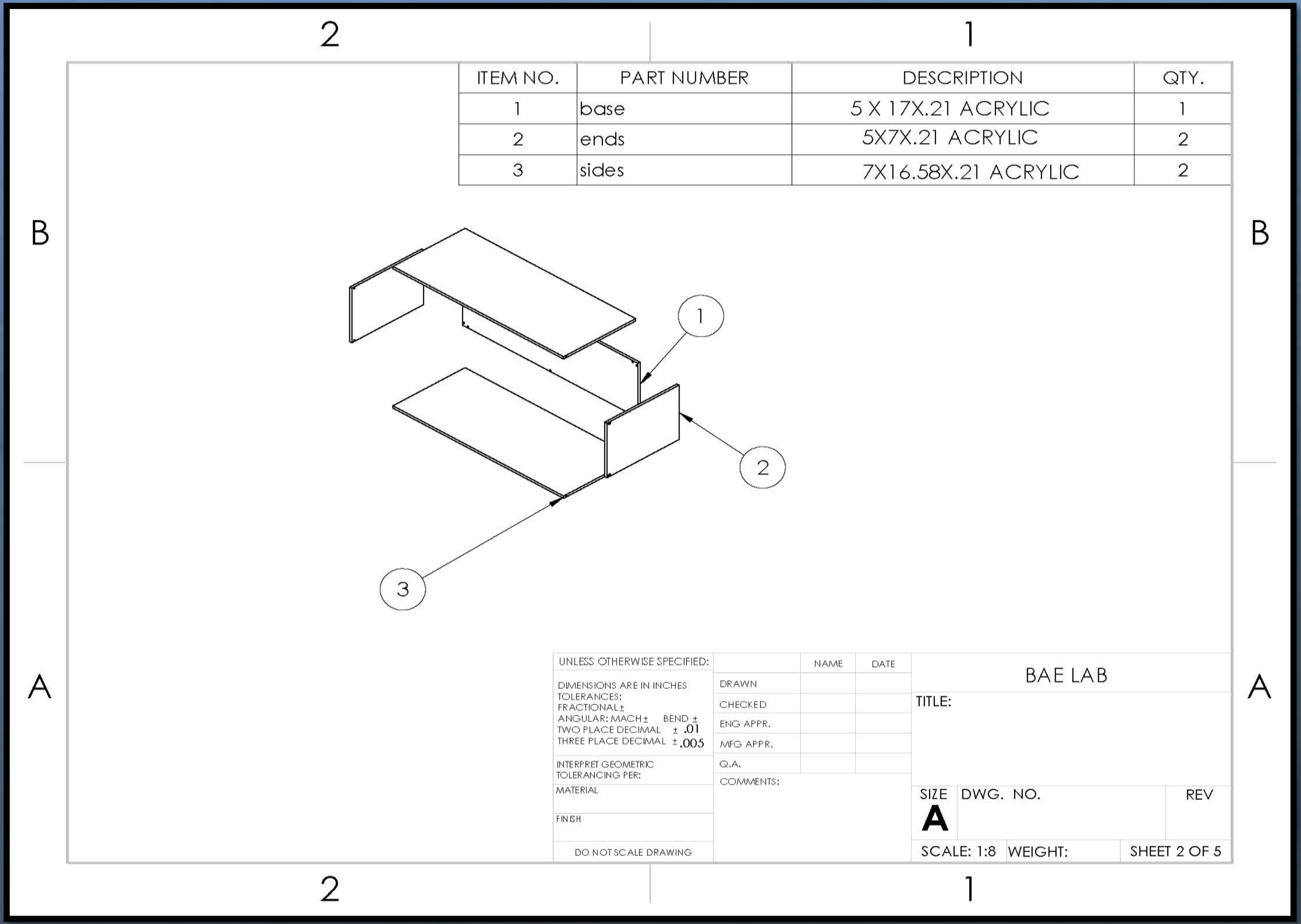
- Needed more flow control→ "Flow Loop"
  - "Compartmentalized" units
  - Simplifies drainage, storage, operation
- Some units don't even need flow
  - UV and aeration basin
- Move toward educational product

FINAL DESIGNS

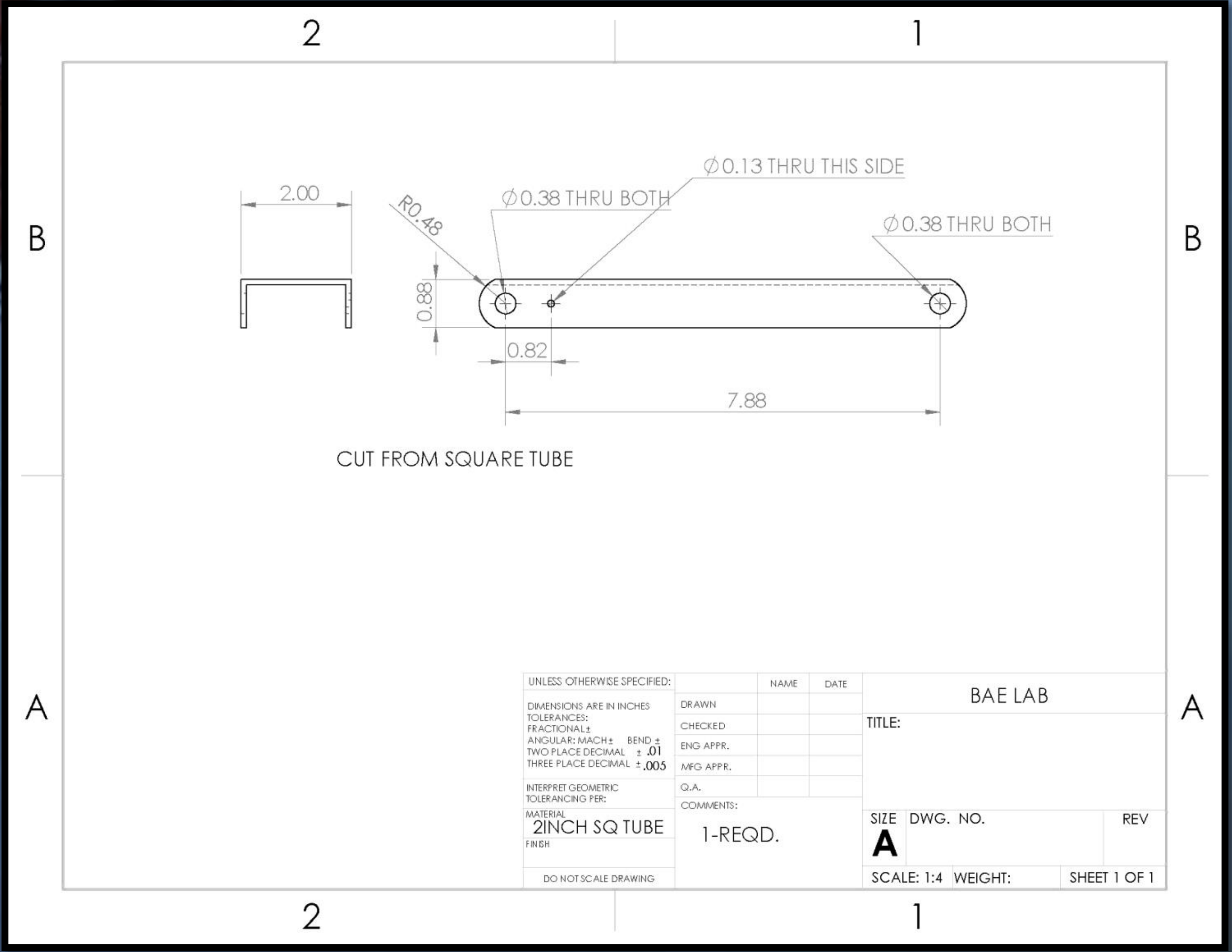


FINAL DESIGNS

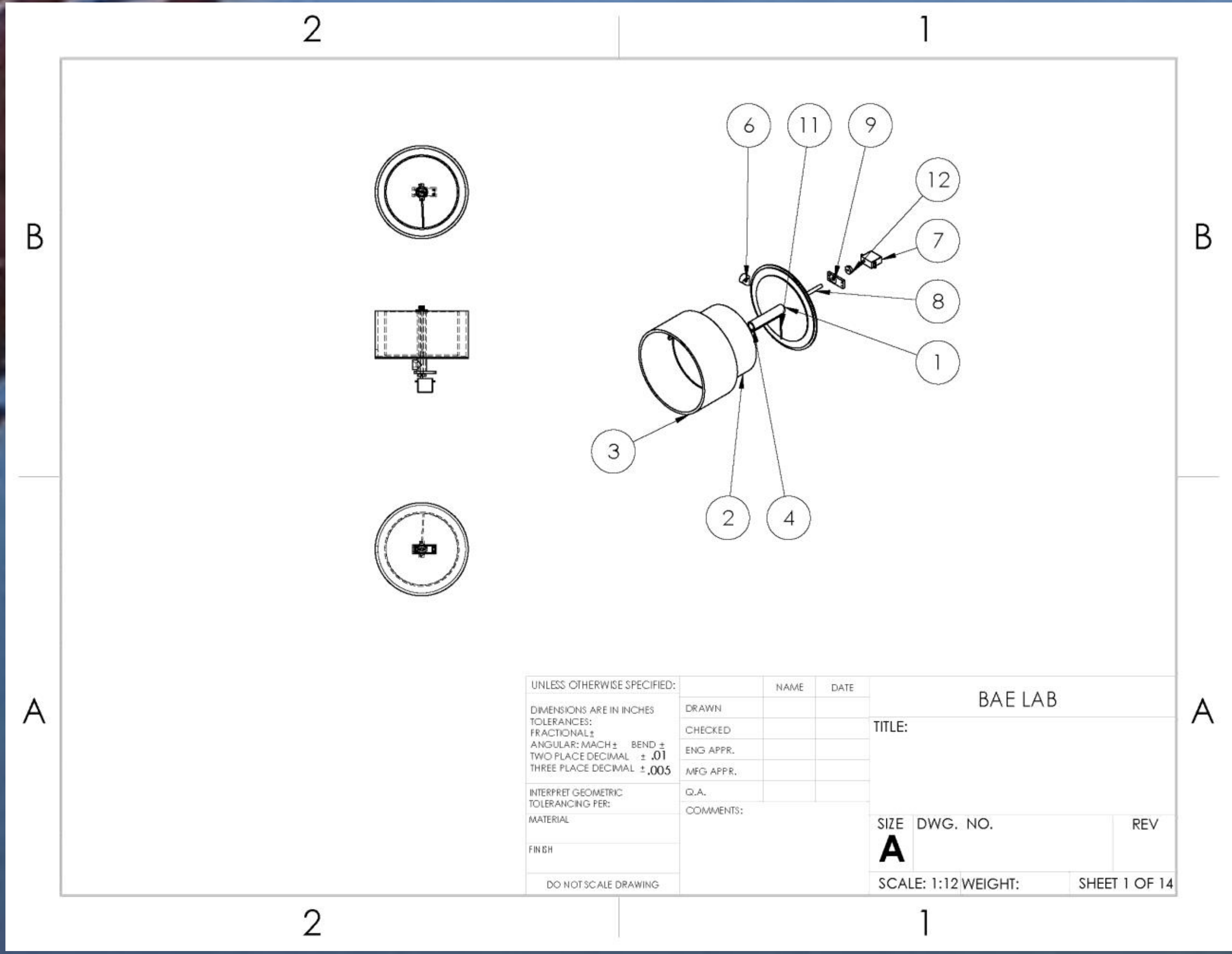
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	base	5 X 17X.21 ACRYLIC	1
2	ends	5X7X.21 ACRYLIC	2
3	sides	7X16.58X.21 ACRYLIC	2

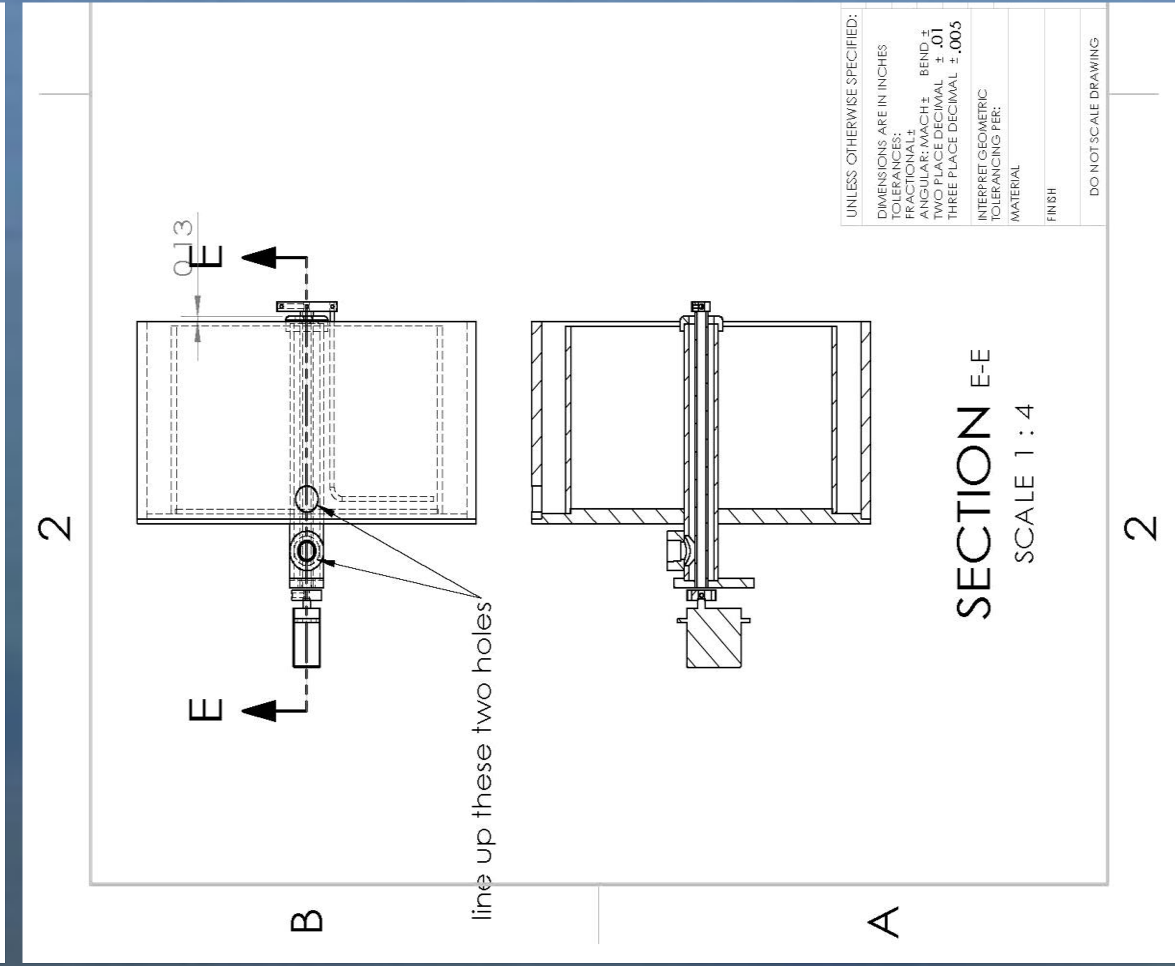


FINAL DESIGNS

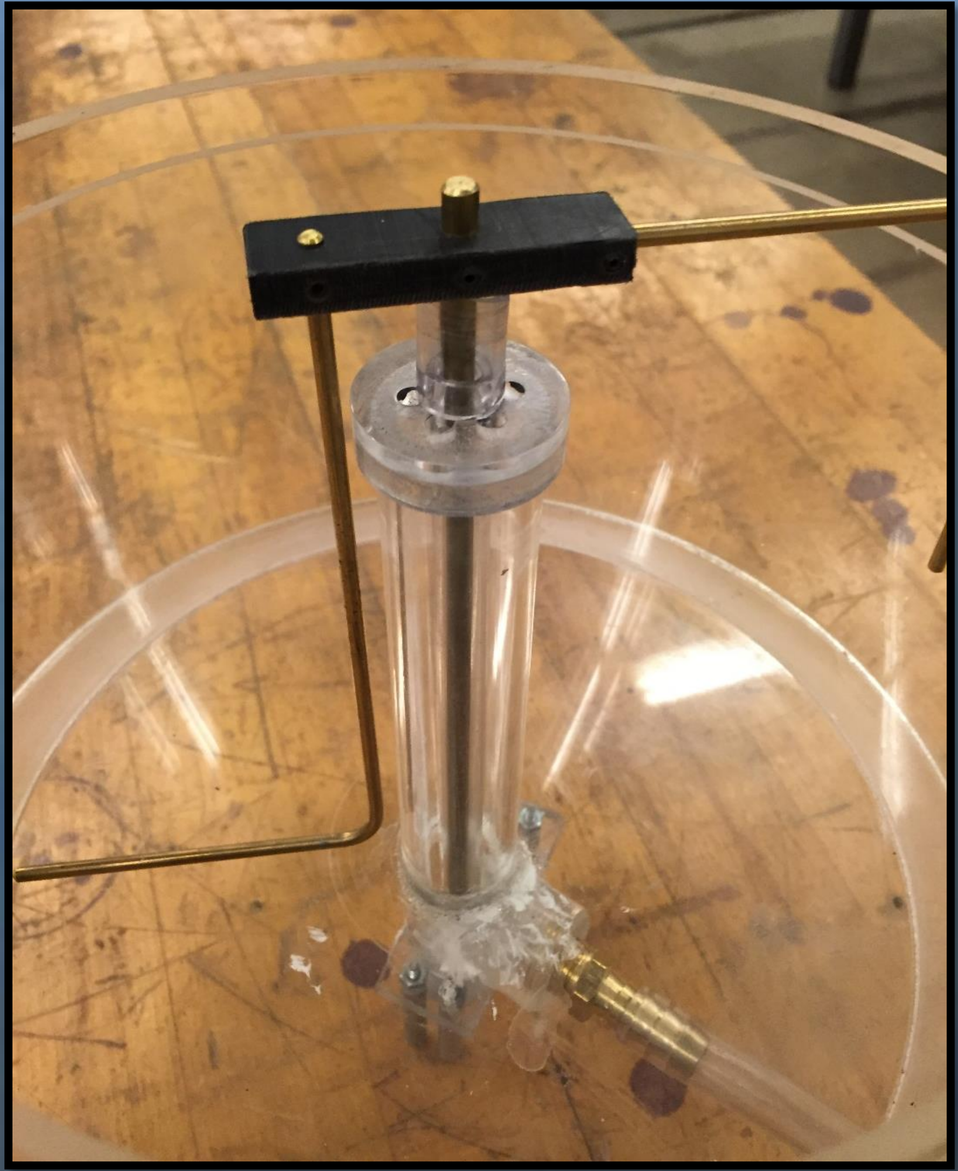


FINAL DESIGNS

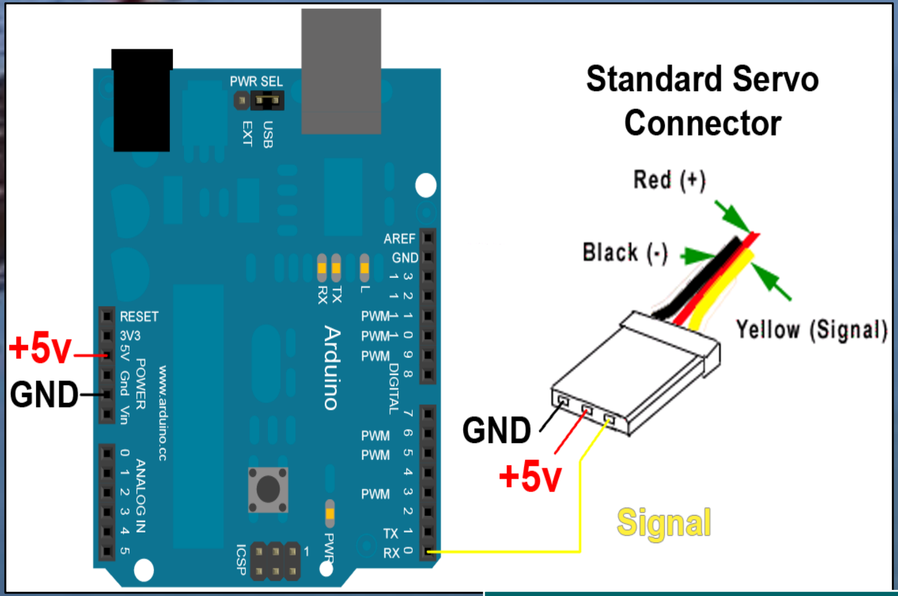




FINAL DESIGNS



FINAL DESIGNS




```
Clarifier_Code
#include "Servo.h"
Servo myservo; //create servo object to control a servo

int pos=0;  //variable to store the servo position

void setup() {
myservo.attach(3); //attaches the servo on pin 9 to the servo object
}

void loop()  {
  for(pos=0; pos<180; pos+=0.1) //goes from 0 degrees to 180 degrees in steps of 1 degree
  {
  myservo.write(pos);  //tell servo to go to position in variable 'pos'
  delay(3000);  //waits 15ms for the servo to reach the position
}
delay(3000);
for(pos=180; pos>=1; pos+=0.1)  //goes from 180 degrees to 0 degreees
{
  myservo.write(pos);  //tell servo to go to position in varaible 'pos'
  delay(3000);
}
}
```

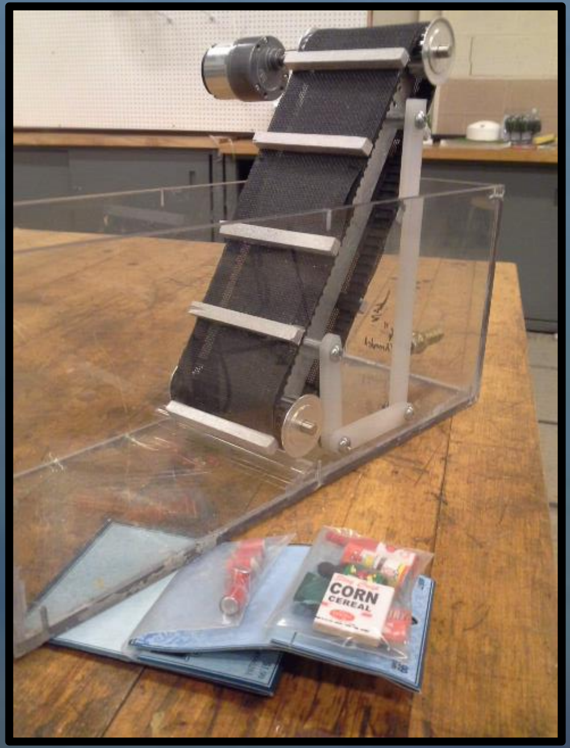
Hextronik Servomotor Specifications	
Weight (g)	39
Torque (kg)	6.5
Speed(Sec/60deg)	0.16

BENEFITS OF REVISED DESIGNS

- Simplifies drainage, storage, operation, maintenance
- Flexibility in display arrangement
- All units receive flow from one pump
- Flow control at every point
- Electronics functional with one standard wall plugin

INTERACTIVITY/EDUCATIONAL ASPECTS

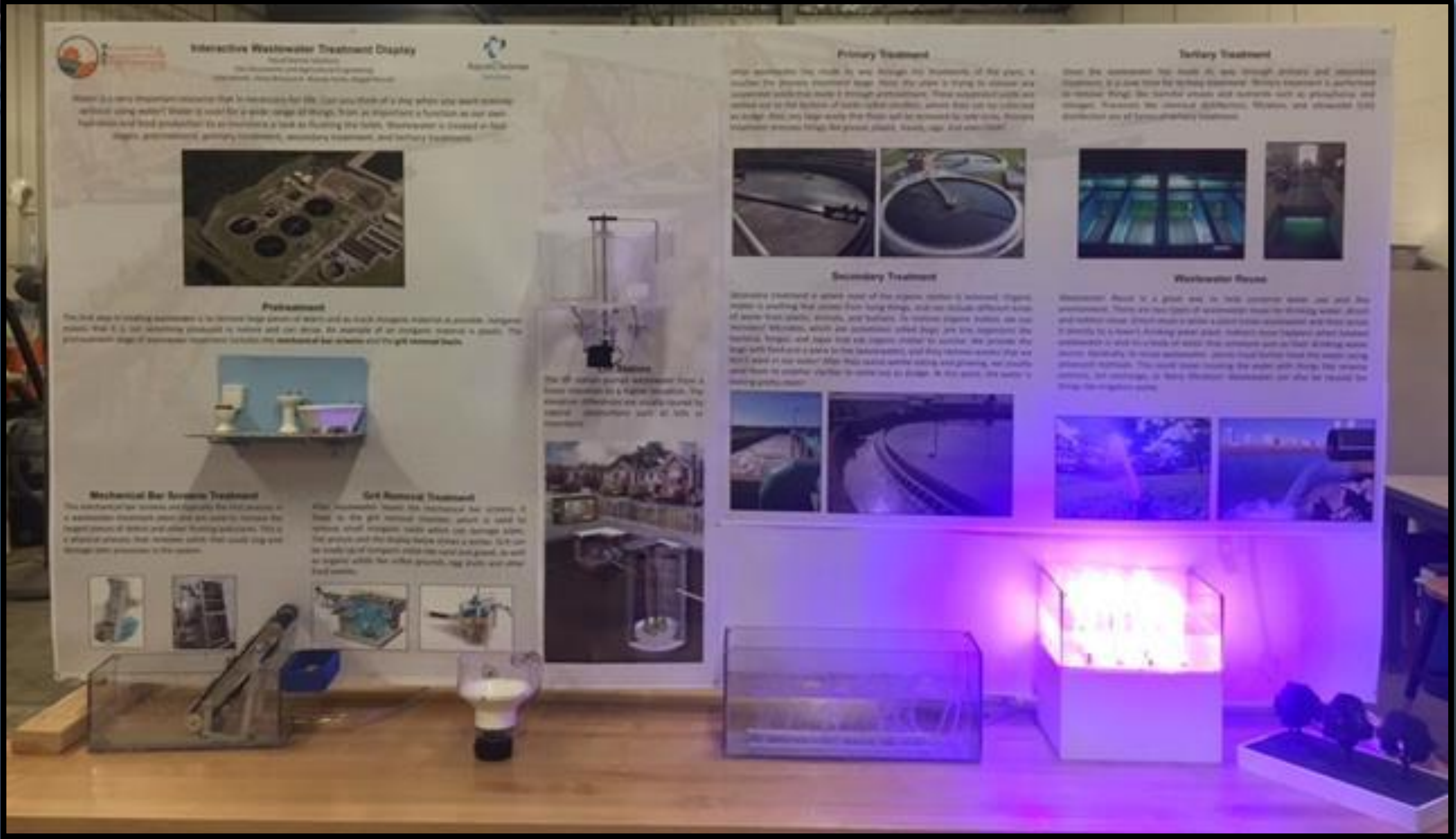
- Relatable beginning for target audience
- Lights and moving parts used
- Able to interact with bar screen portion



INTERACTIVITY/EDUCATIONAL ASPECTS

- Usage of posters with relevant information and component functions
- Wastewater treatment scavenger hunt
- Educational Value

FINAL DISPLAY



COST OF HYDRAULIC MODEL

DESCRIPTION	MATERIAL	UNIT COST	QTY	COST
Clarifier and Grit Removal	PVC Pipe	$10	5	$50
Basins	Plastic containers	$5	3	$15
Pipe Fittings	Plastic/Brass	$5	10	$50
Pipe	PVC Clear Vinyl	$1.79/ft	40	$72
Pump	-	$105	1	$105
Misc.	-	-	-	$200
Total				$492

COST OF FINAL MODEL

DESCRIPTION	MATERIAL	QTY	COST
Component Fabrication	Polycarbonate (4'X4' Sheet)	4	$120
Pipe	Plastic tubing	2	$12
Pipe Fitting	Brass fittings	10	$8
Pump	1/10 HP	1	$105
Misc.	-	-	$200
BAE Shop Labor	-	-	$360
Total			$1,249

- Shop staff labor will be approximately 3 to 4 times more for fabrication for others besides BAE senior design students.

COST OF FABRICATION FOR GARVER

DESCRIPTION	UNIT COST	QTY	COST
Trailer	$10,00-$15,000	1	$15,000
Component Fabrication	-	-	$2,800
Shop Labor	~$100 per hour	-	$3,000
Misc. Materials	-	-	$3,000
Total			$23,800

- These cost estimates are projections of what it would cost Garver to build a similar system with a commercial machine shop.

FUTURE RECOMMENDATIONS

- Component Mounting
  - Drawers
  - Keymod mounts
- Reuse
  - Irrigation
  - Golf Course
- Educational
  - Teacher Evaluation
  - Keywords

ACKNOWLEDGEMENTS

- Mary Elizabeth Mach, PE
- Stillwater WWTP
- Drs. Garey Fox, Paul Weckler, Ning Wang
- Wayne Kiner and BAE shop staff
- Freshman design teams
- We greatly appreciate your support!

DISCUSSION

INTERACTIVE WASTEWATER TREATMENT DISPLAY

Cole Niblett Olivia Broussard Brandy Parks Abigail Parnell

GARVER

AquaCleanse Solutions

GROUP PICTURE

AGENDA

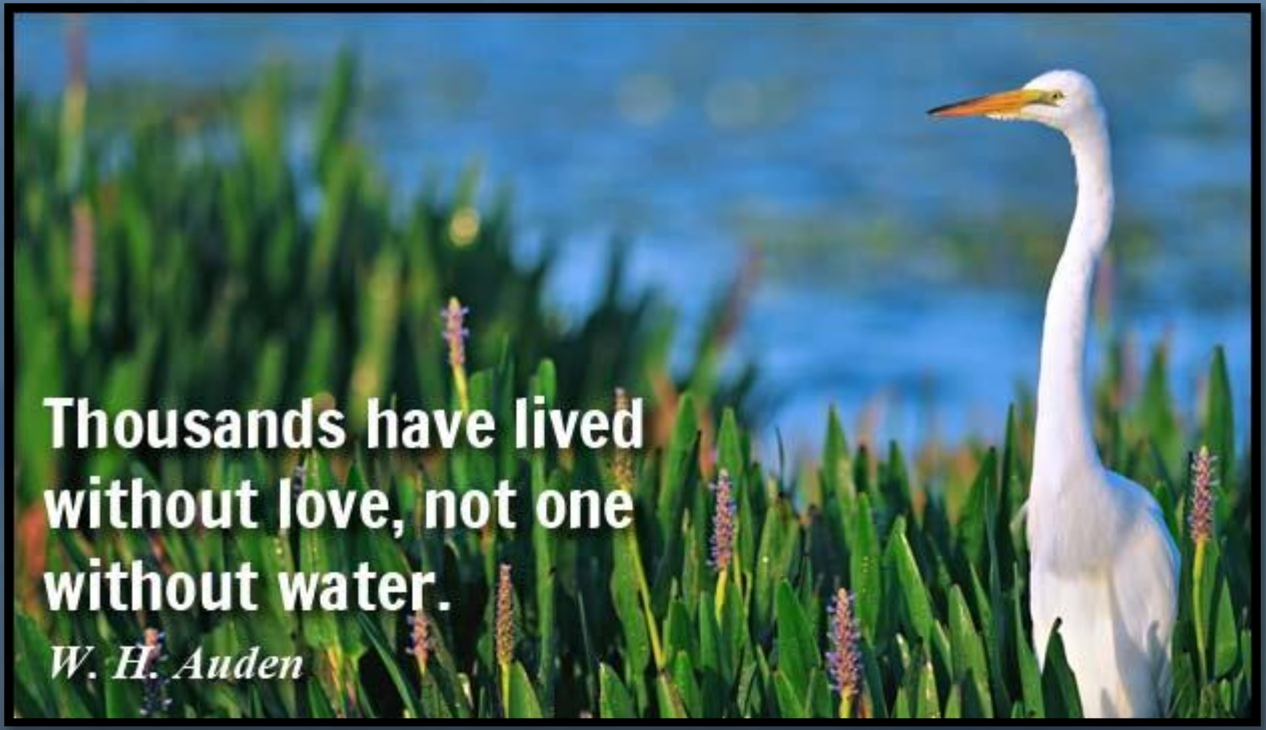
- Problem Statement and Background
- Objectives and Project Scope
- Conceptual Designs
- Economic Analysis
- Project Schedule
- Discussion

PROJECT SPONSOR

- Garver Engineering
- Multi-disciplined firm
- Headquarters: Little Rock, AR
- Person of contact: Mary Elizabeth Mach, PE
  - Norman, OK office
  - 2006 graduate of OSU Biosystems Department

PROBLEM STATEMENT

- Desired Product: Wastewater Treatment Display
  - Interactive
  - Educational
  - Mobile
- Why?
  - Raise awareness
  - Everyone drinks water
  - Limited education

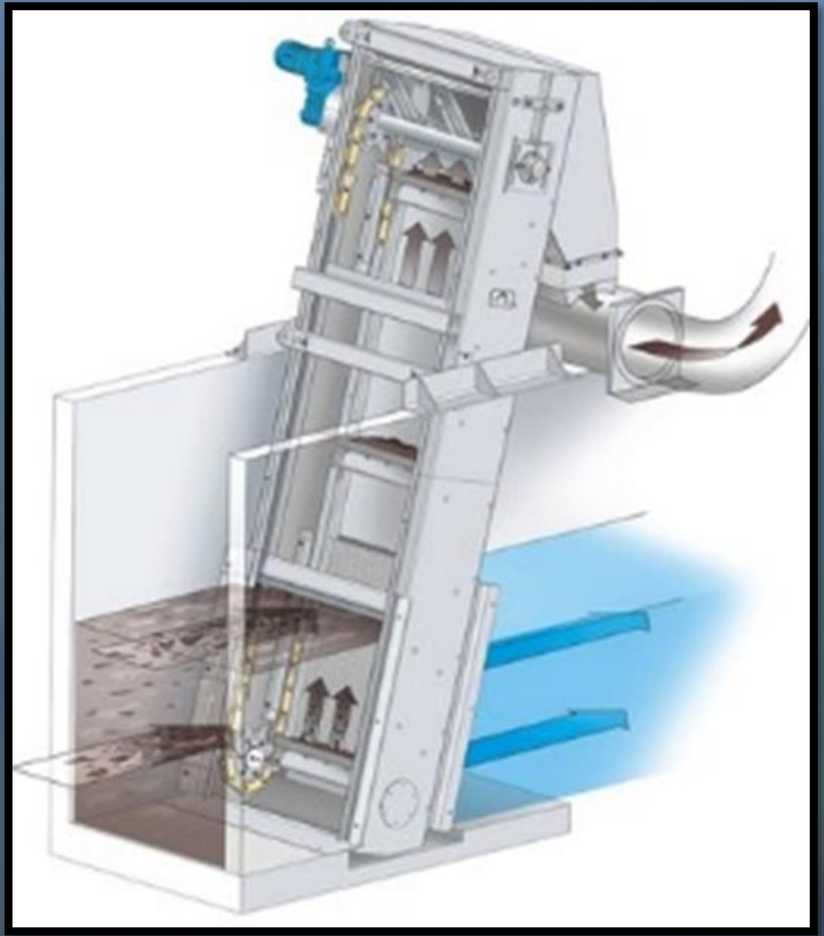


WASTEWATER TREATMENT OVERVIEW

- Wastewater Treatment
  - Incorporate most relevant technologies
  - Scale/Modify to serve our purpose
- Four main sectors were analyzed:
  - Primary – Secondary – Tertiary
  - Reuse

WASTEWATER TREATMENT OVERVIEW

- Primary Treatment
  - Inorganic Solids Removal
  - Grit Removal and Sedimentation
- Secondary Treatment
  - Aerobic vs. Anaerobic
  - Activated Sludge vs. Trickling Filter

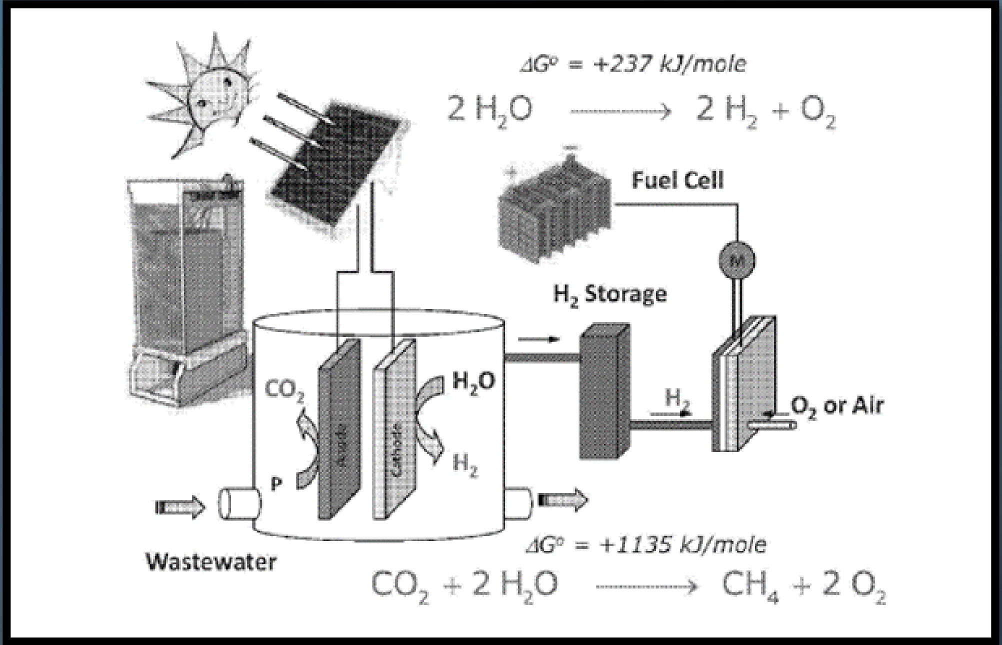


WASTEWATER TREATMENT OVERVIEW

- Tertiary Treatment
  - Chemical Feed
  - UV Disinfection
- Reuse
  - Direct/Indirect Potable
  - Irrigation

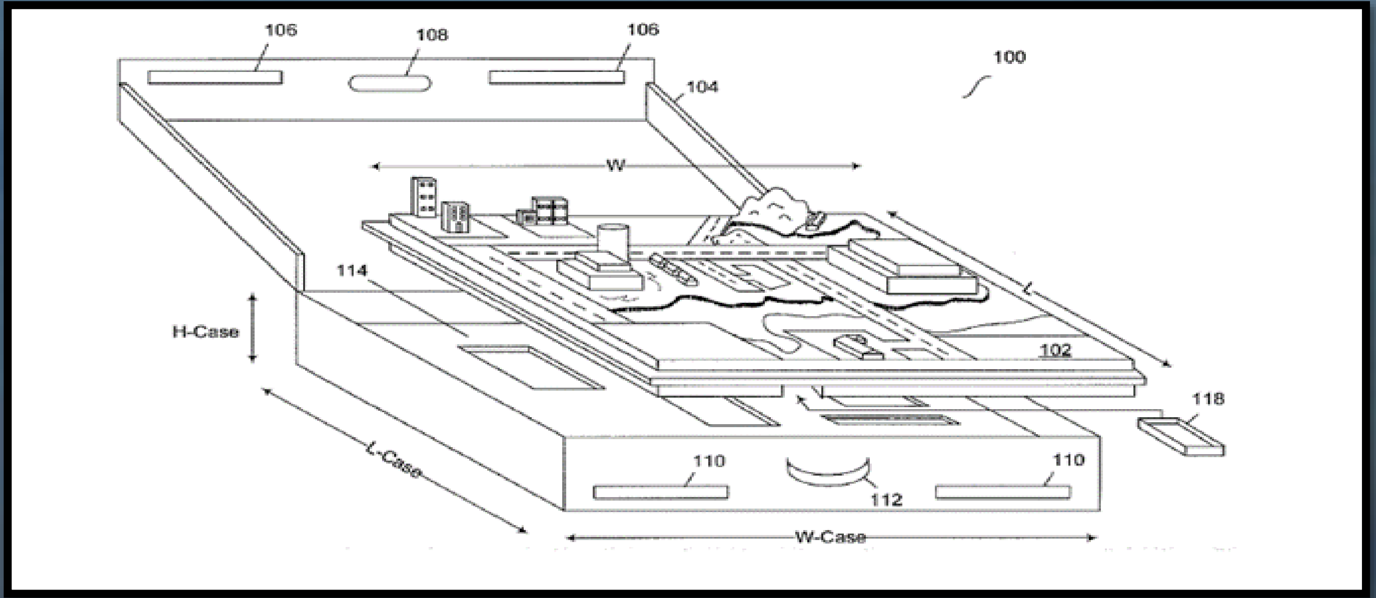
TECHNICAL ANALYSIS

- Patent Search – Small Scale Treatment
  - Patent #20140209479A1
    - Electrochemical disinfection
  - Unfavorable qualities in small scale treatment:
    - High maintenance
    - Sludge handling
    - Low efficiency



TECHNICAL ANALYSIS

- Patent Search – Wastewater Education
  - Patent #US20080020360
    - WWTP model
    - Simulated wastewater treatment
  - Patent #CN202075901U
    - Teaching tool
    - Drainage model



TECHNICAL ANALYSIS

- Patent Search – Educational Exhibits
  - How do we make wastewater interesting?
  - Science Museums
    - Interactivity
    - Moving Components
    - Movable Components
  - OSU Stream Trailer

PROJECT SCOPE & OBJECTIVES

- Conceptual Designs
  - Educational Tool - No wastewater treatment abilities
    - Not biologically active
- Technical Specifications
- Cost/Materials Estimate
- Deliverables
  - Table top model
  - Design of trailer exhibit

TECHNICAL REQUIREMENTS

- Highway-legal
- Ease of storage
- Hydraulically Functional
  - Low flow and pressure
- Power Requirements
  - Standard 120V outlet
  - 12V batteries
- Safety Regulations
  - National Electrical Safety Code (NESC)
  - Federal Motor Carrier Safety Administration (FMCSA)

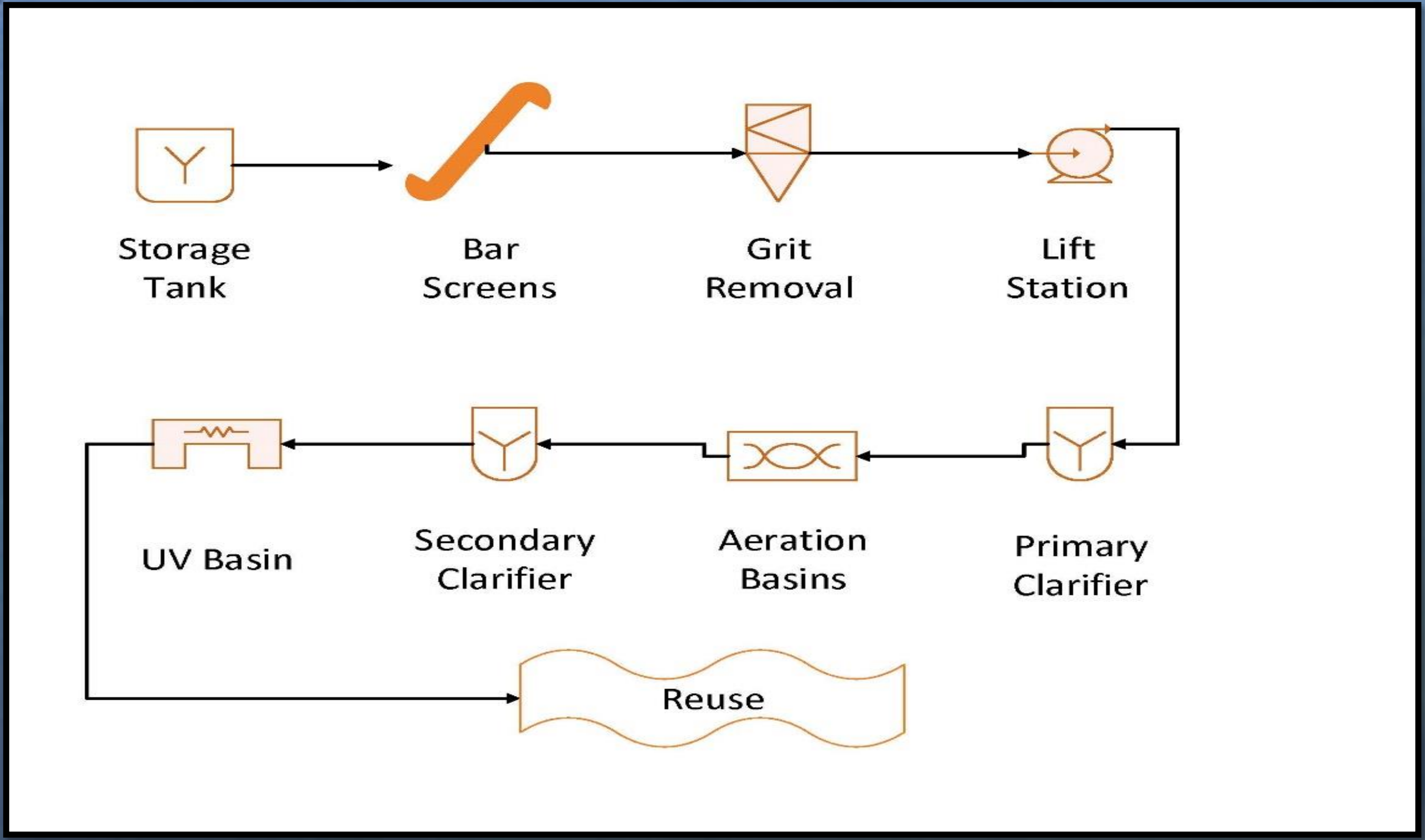
SELECTION OF UNIT OPERATIONS

- Headworks/Pre-Treatment
  - Mechanical bar screens
  - Lift station
- Primary Treatment
  - Grit removal basin
  - Primary Clarifier
- Secondary Treatment
  - Aeration Basin
  - Secondary Clarifier

SELECTION OF UNIT OPERATIONS

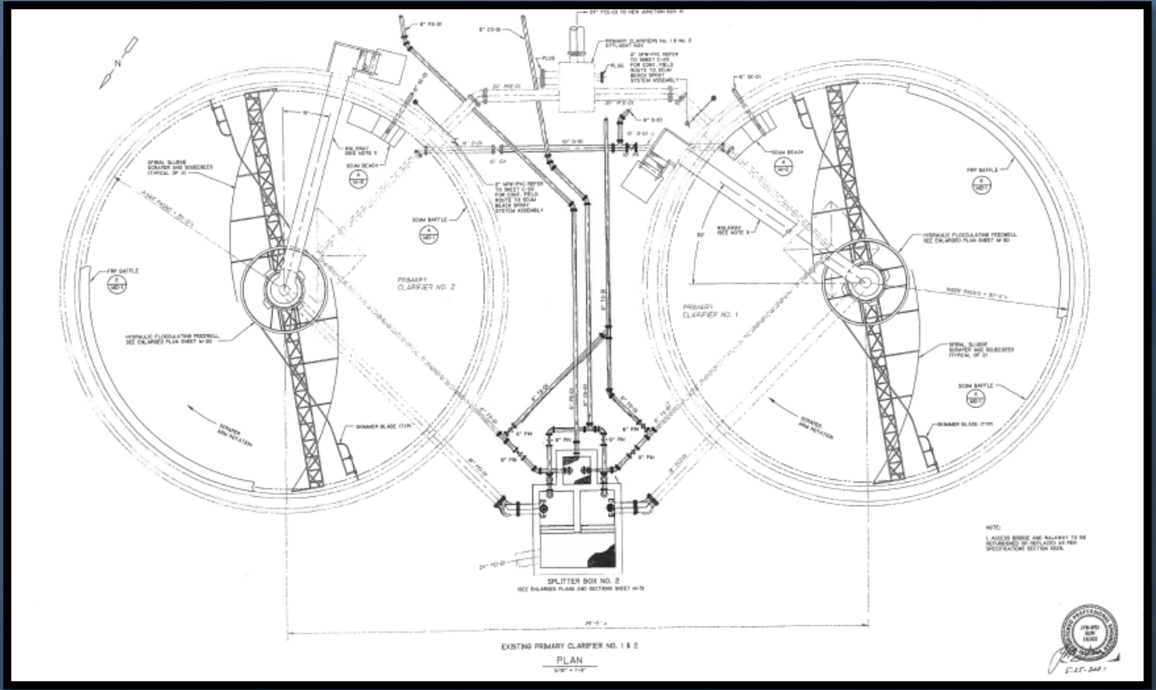
- Tertiary Treatment
  - UV Disinfection Basin
  - Aesthetically pleasing
- Reuse
  - Display discharge to river
  - Irrigation

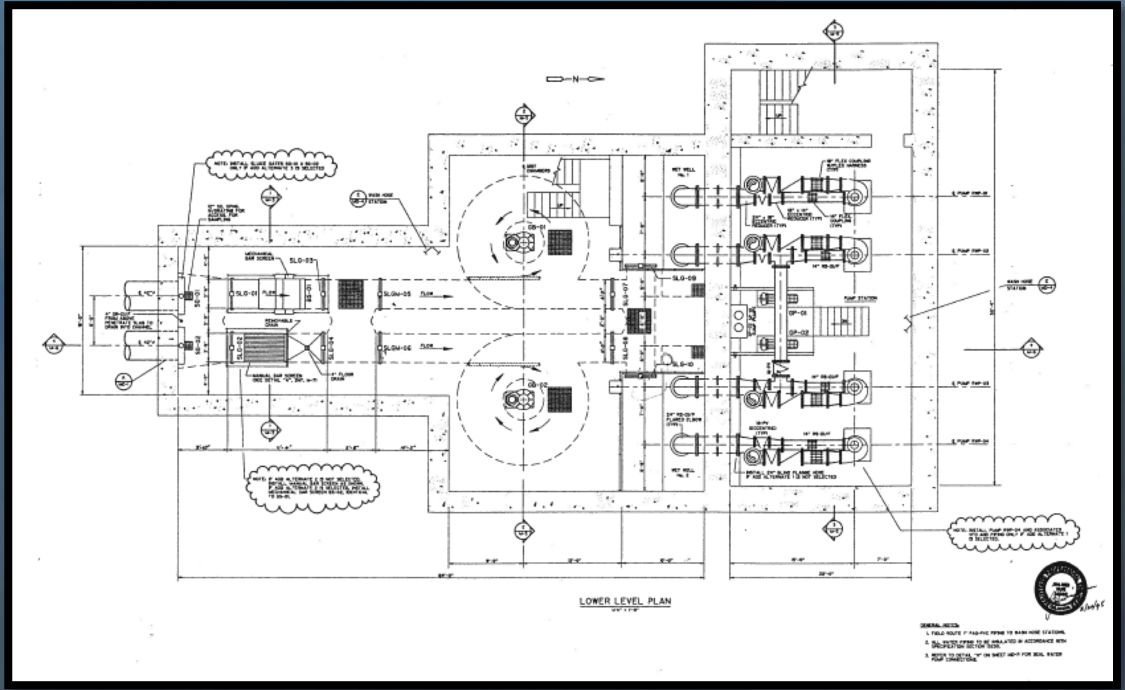
PROCESS FLOW DIAGRAM



SIZING OF UNIT OPERATIONS

- Geometric Similarity
- Dynamic Similarity
- Reynolds/Froude Numbers
- Stillwater WWTP as "model"
- Space Availability





SIZING OF UNIT OPERATIONS - PROCEDURE

- Used Froude/Reynold numbers to get in ballpark
- Scaled Stillwater plant at factor of $\lambda = 1:100$
- Based on above steps, geometry, space, adjusted to our needs

$$Re = \frac{\rho V D}{\mu}$$

$$Fr = \frac{\upsilon}{\sqrt{gD}}$$

SIZING OF UNIT OPERATIONS

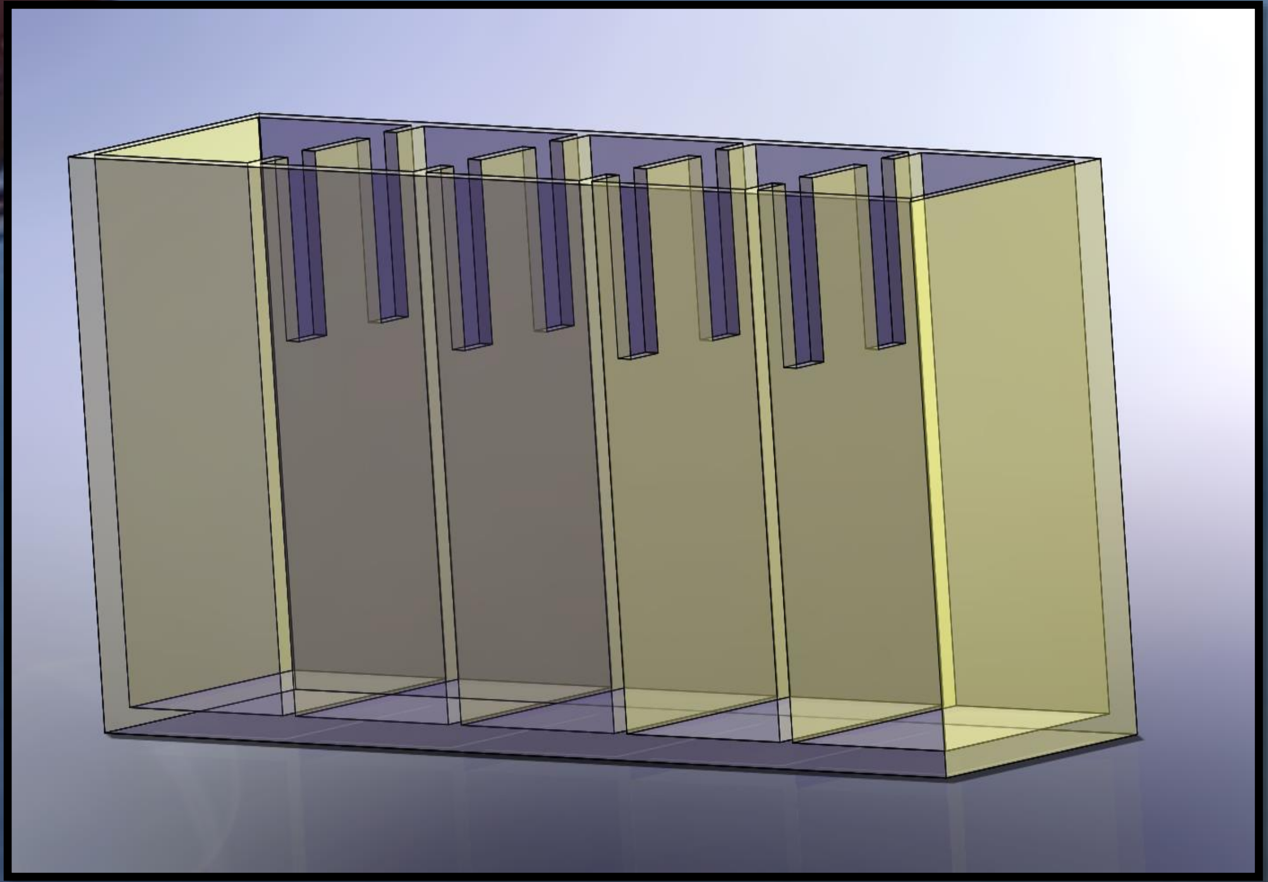
Stillwater WWTP		Prototype System	
Unit	Characteristic Length	Unit	Characteristic Length
Bar Screens	28’	Bar Screens	12”
Grit Chamber	17’	Grit Chamber	9”
Clarifiers (Secondary)	125’	Clarifiers	15”
Aeration Basins	191’	Aeration Basins	23”
UV Basin	50’	UV Basin	16”

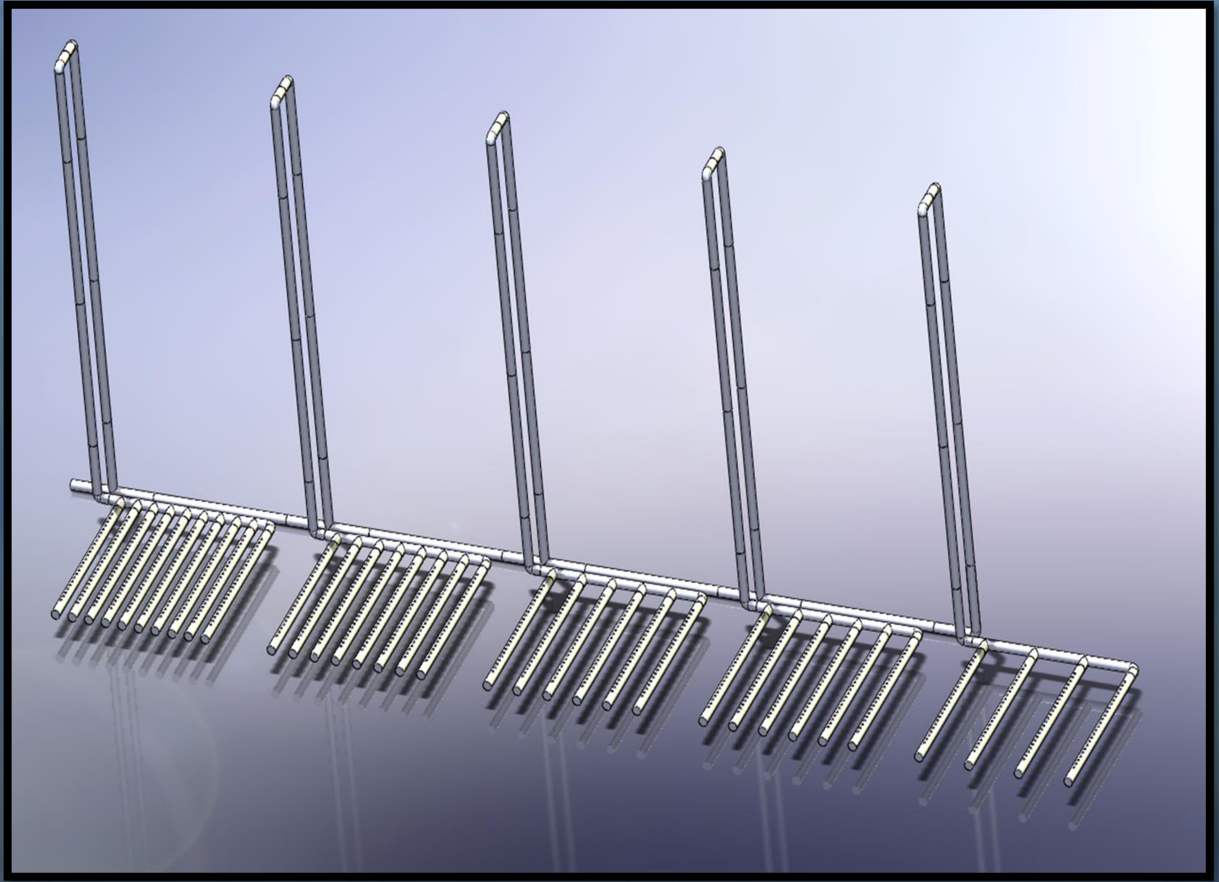
BAE 1012 PROJECTS

- Scale model design and CAD drawings for
  - Primary/secondary clarifiers
  - Aeration basins
- Requirements:
  - Hydraulically similar
  - Mechanically functional
  - Aesthetically pleasing

CAD MODELS

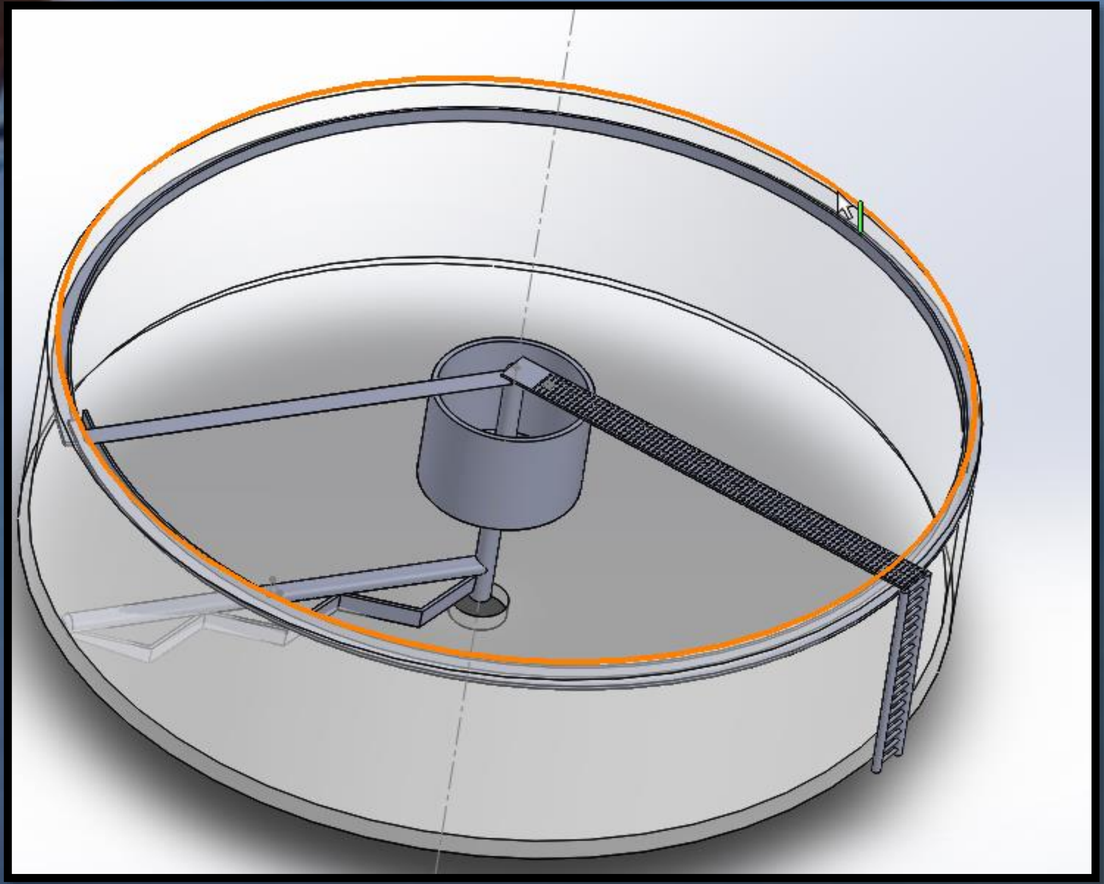
- BAE 1012 – Aeration Basins

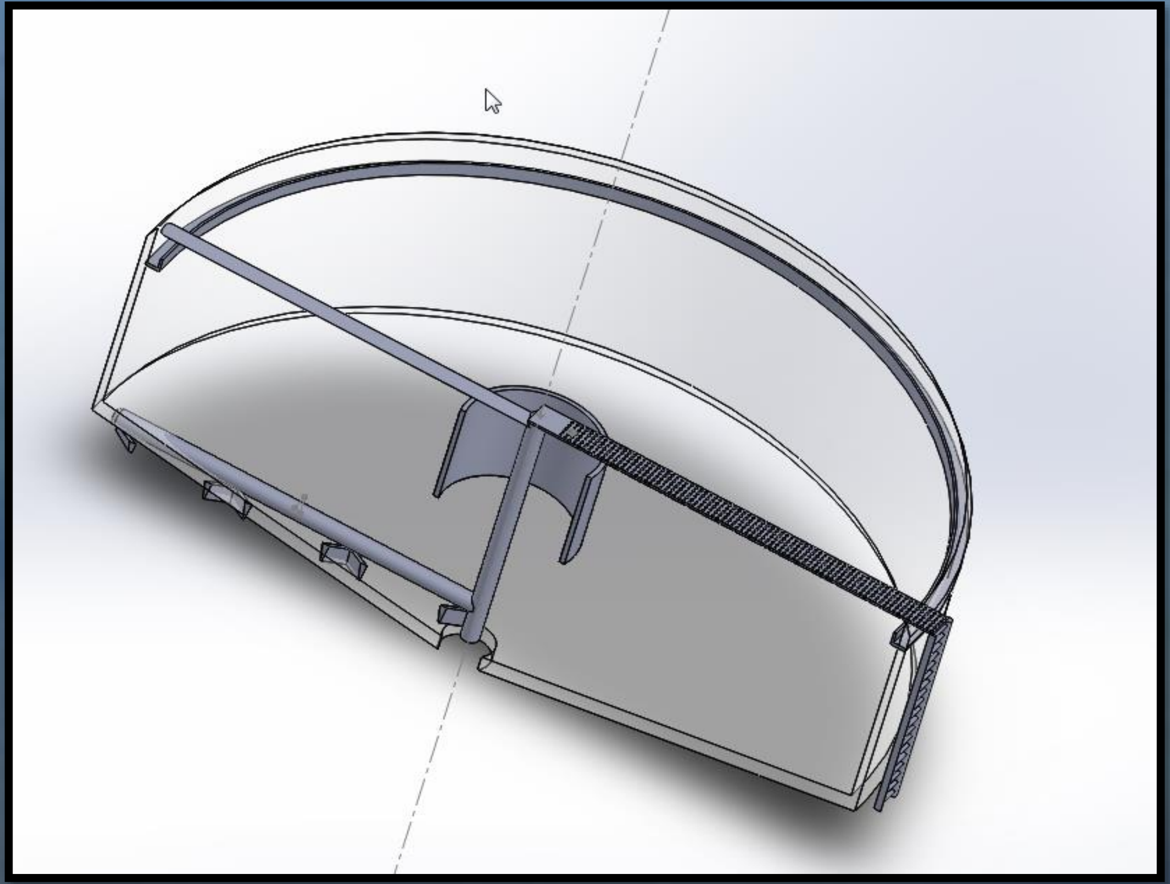




CAD MODELS

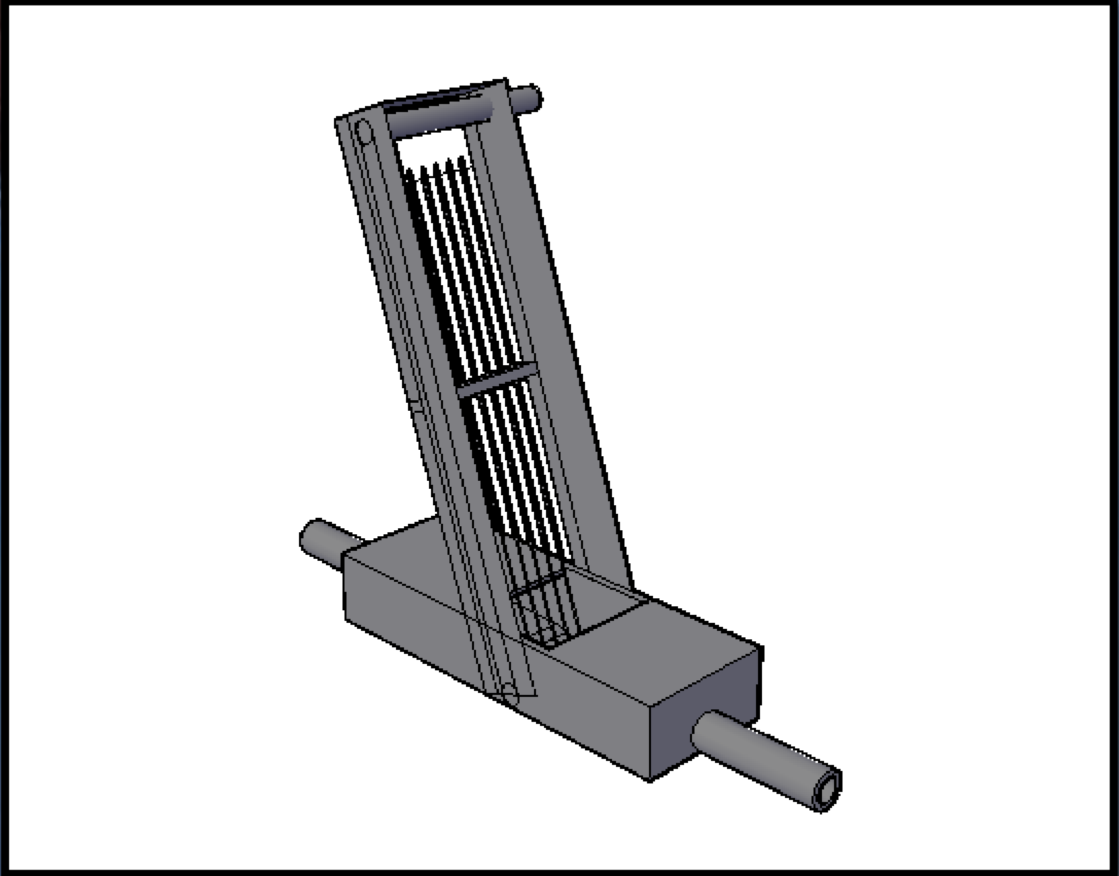
- BAE 1012 – Primary and Secondary Clarifier



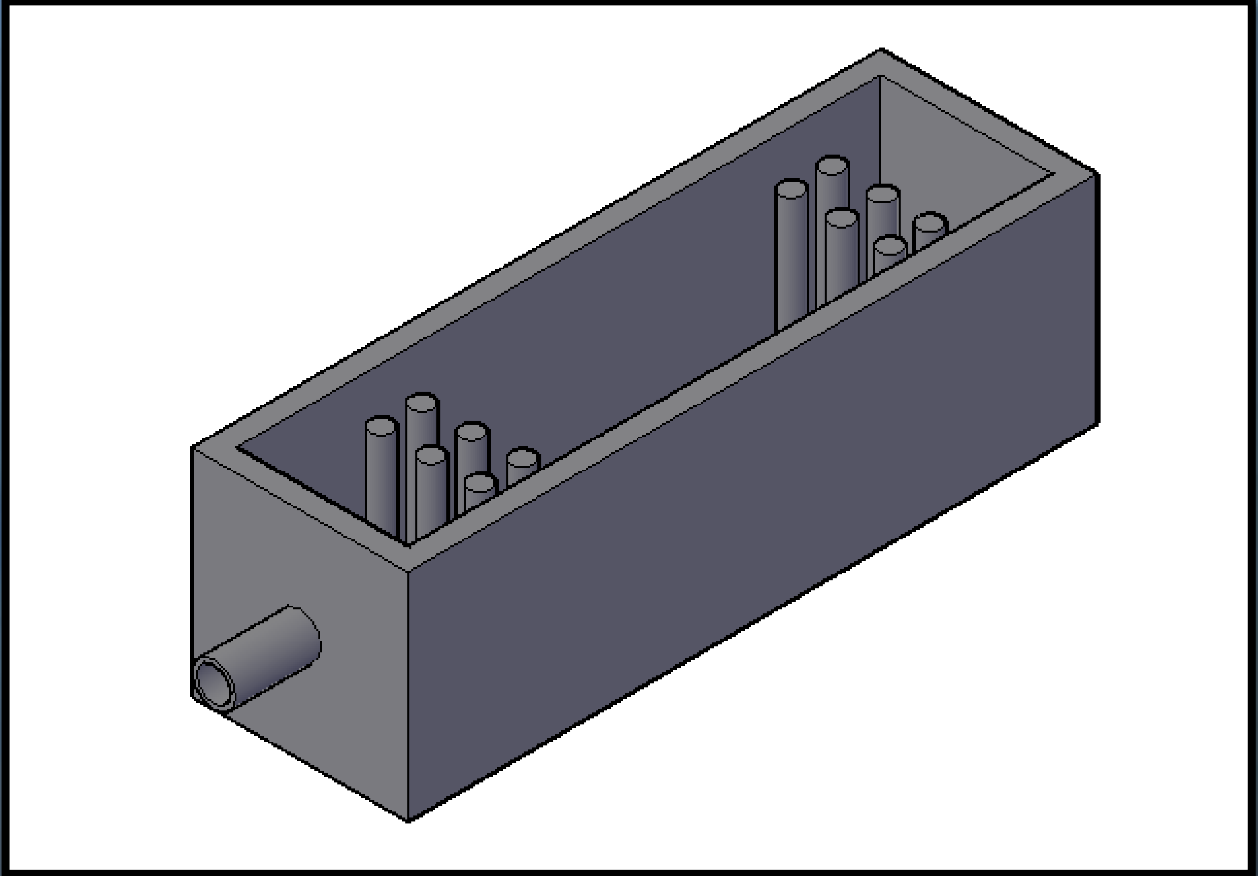


CAD MODELS

- Mechanical Bar Screens

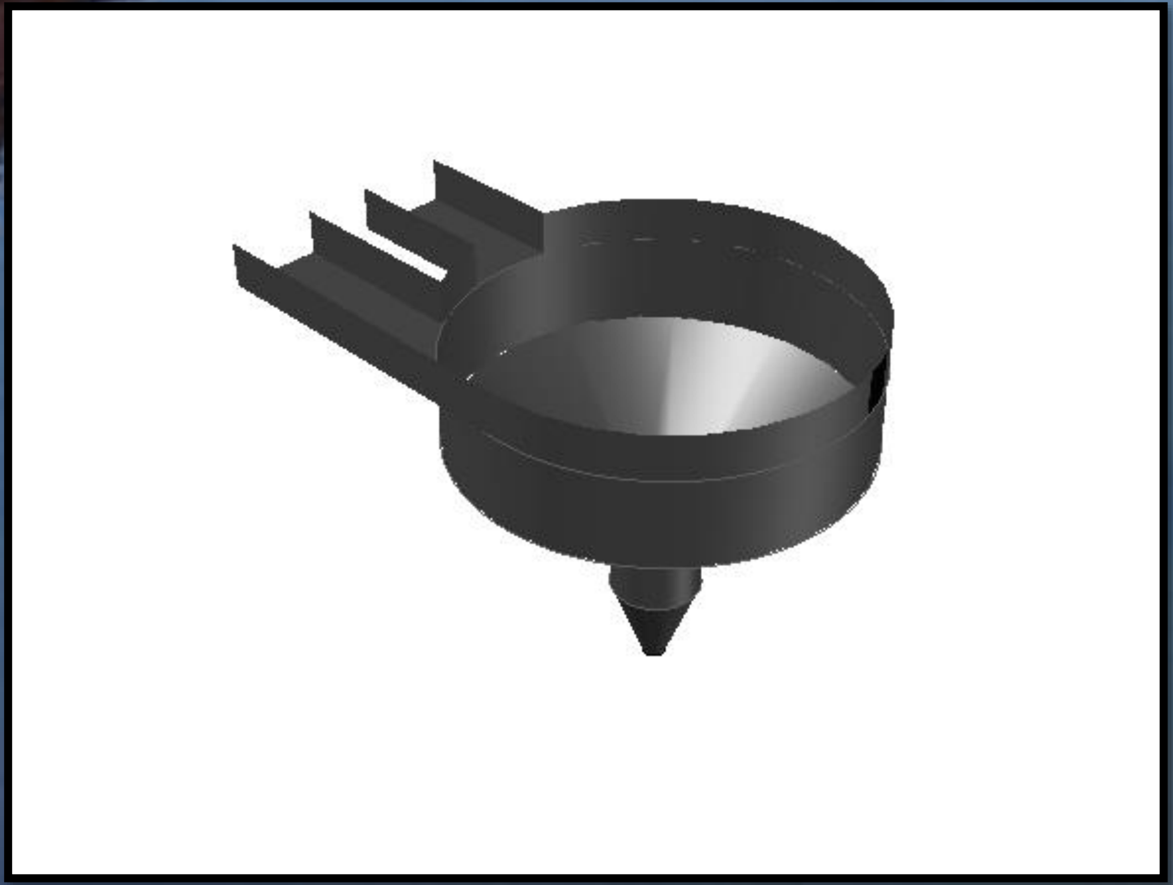


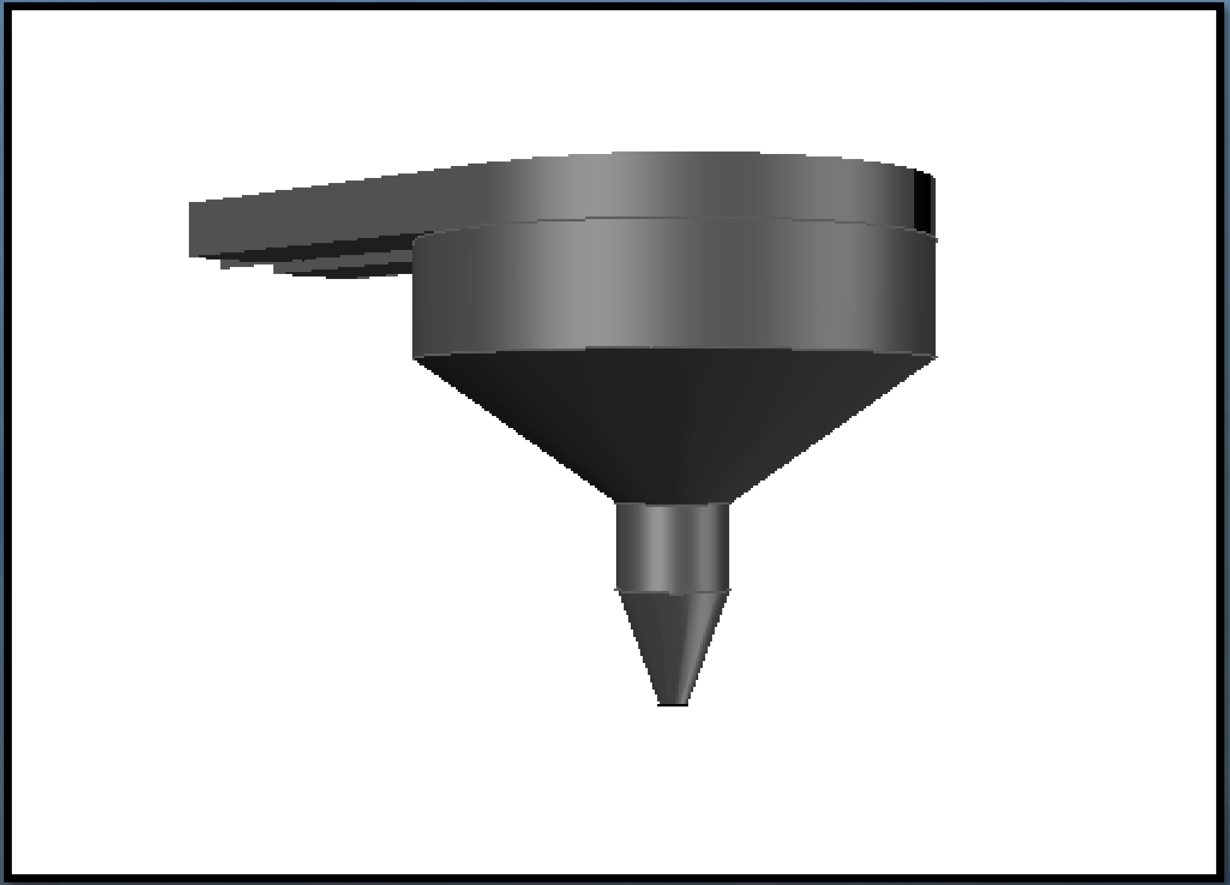
- UV Disinfection Basin



CAD MODELS

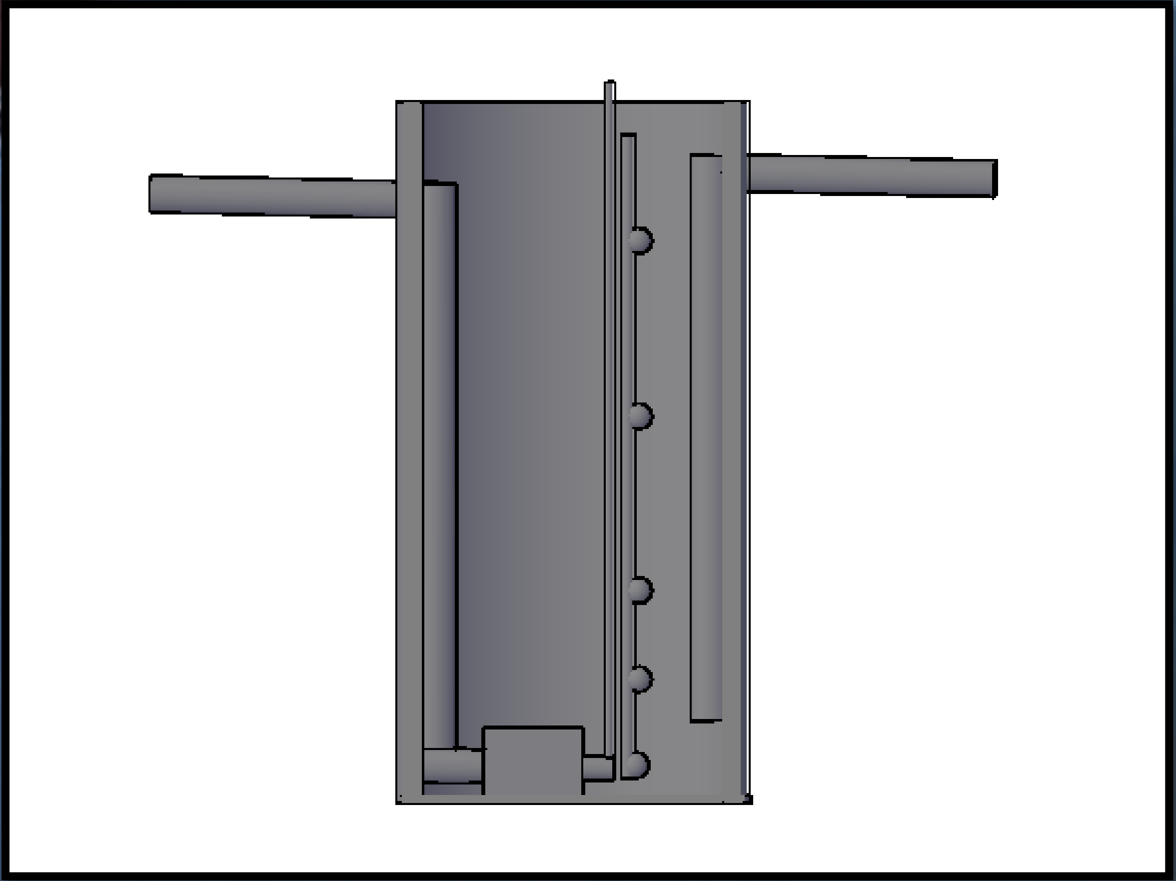
- Grit Removal Chamber

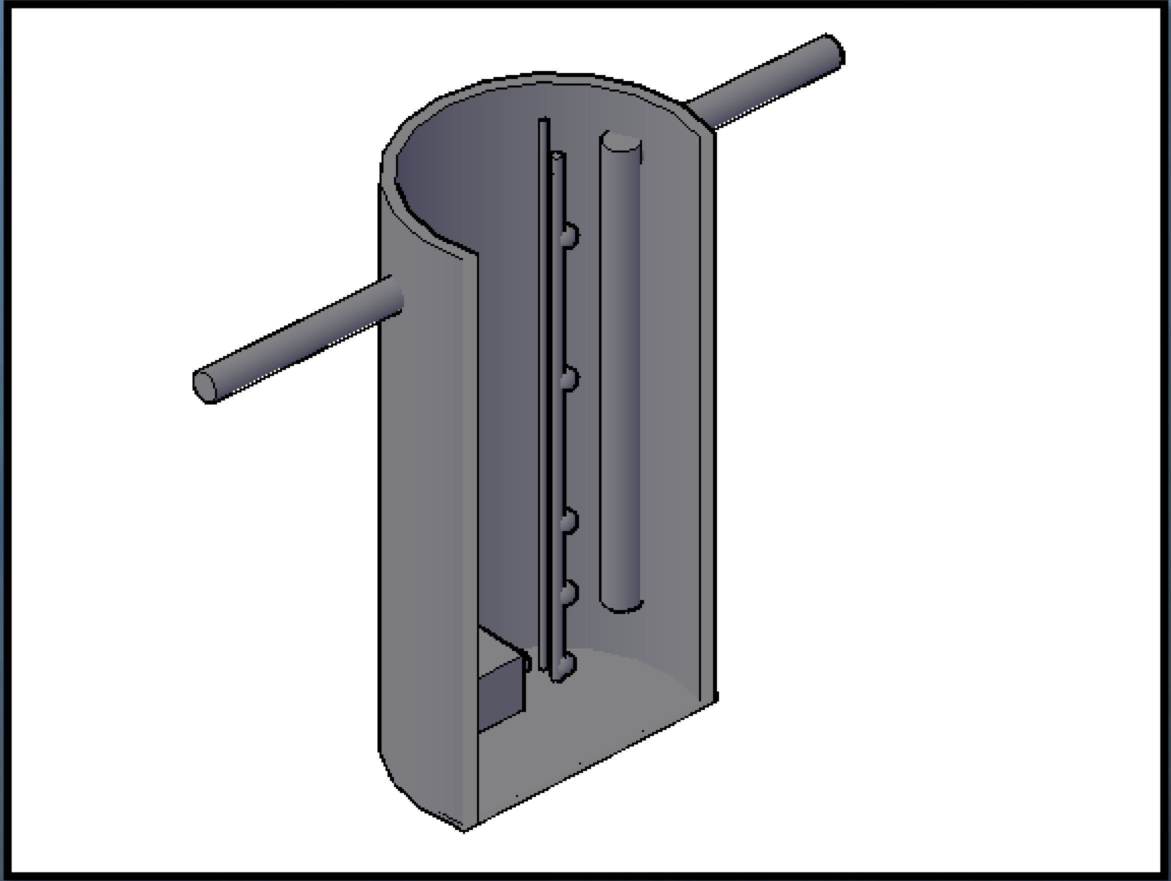




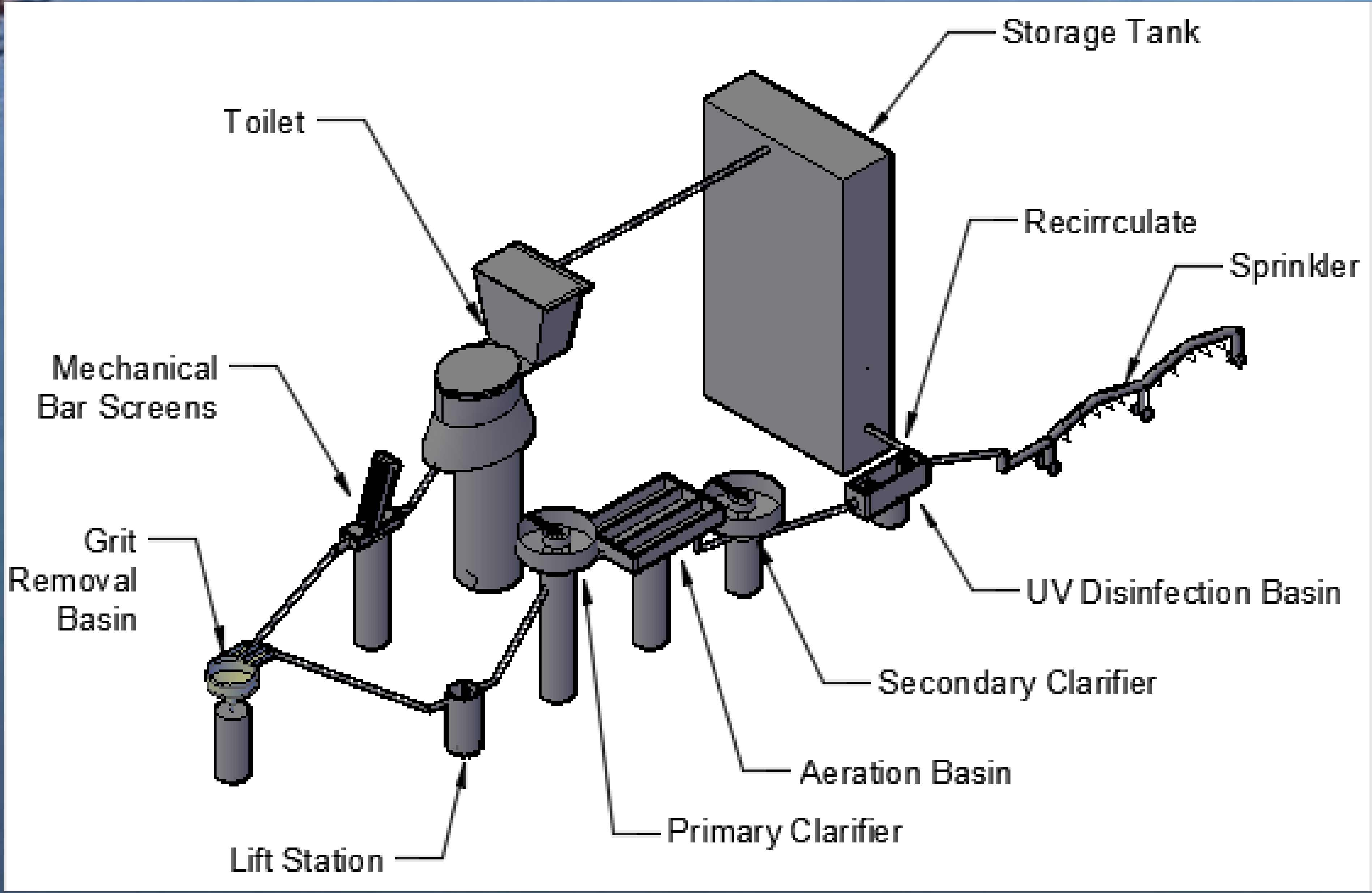
CAD MODELS

- Lift Station





OVERALL LAYOUT

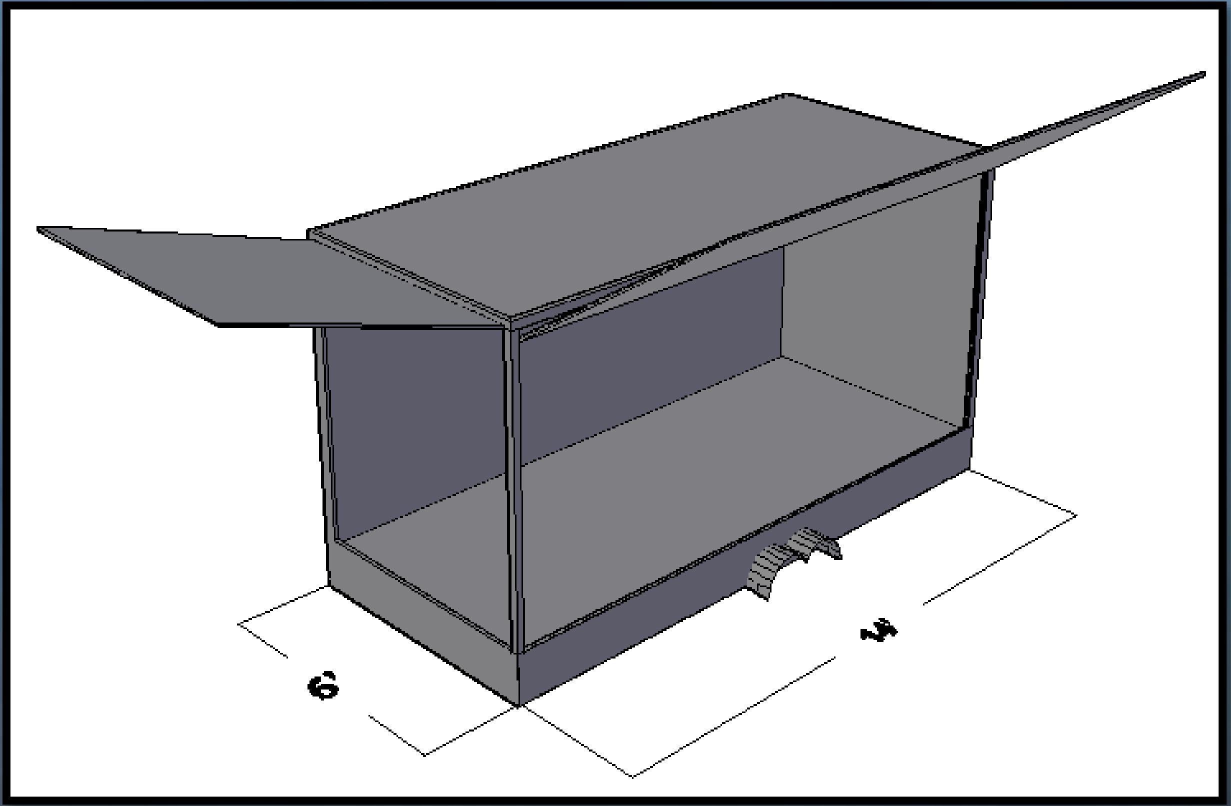


TRAILER STYLE SELECTION

- Things that were kept in mind
  - Size and ease of travel
  - Storage
  - Cost
- Narrowed down to four styles
  - "Open Sides"
  - Tailgate "Walk around"
  - Tailgate "Pull-Out"
  - Stream Trailer

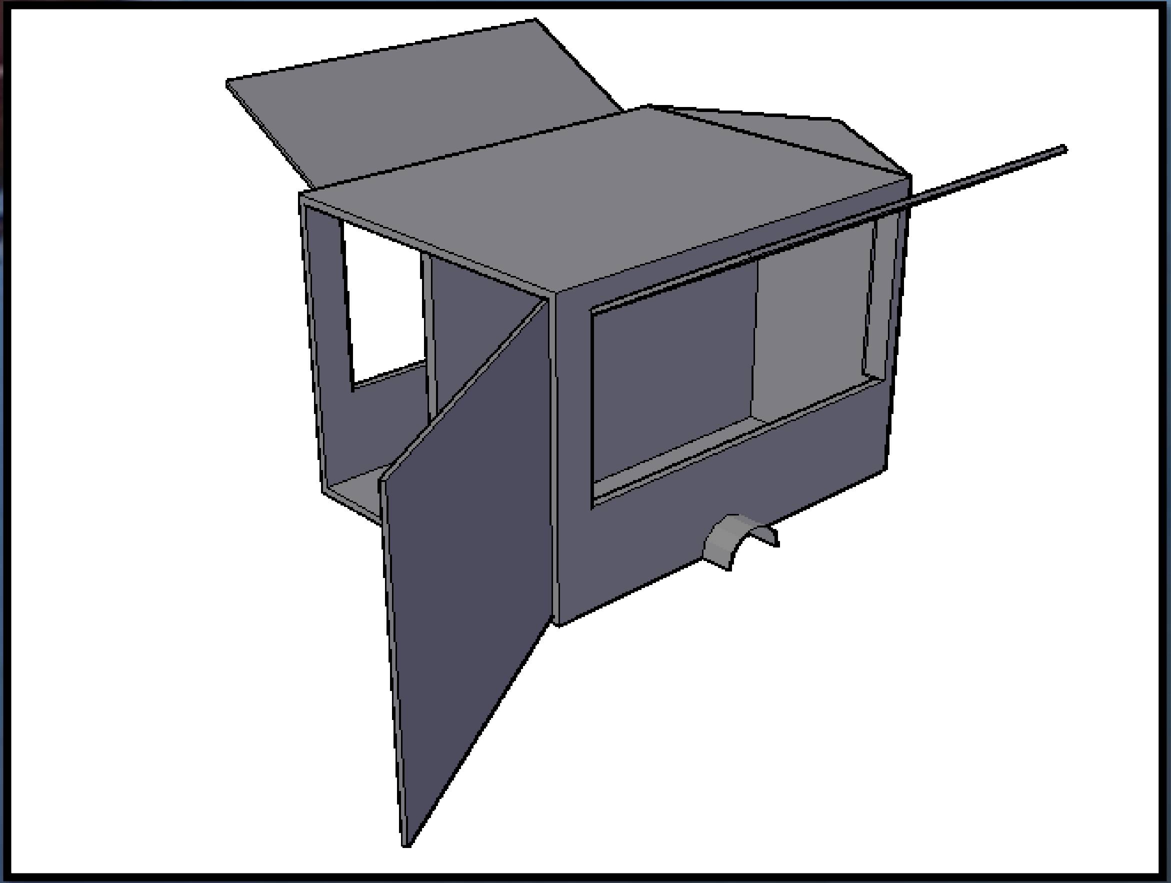
TRAILER STYLE SELECTION

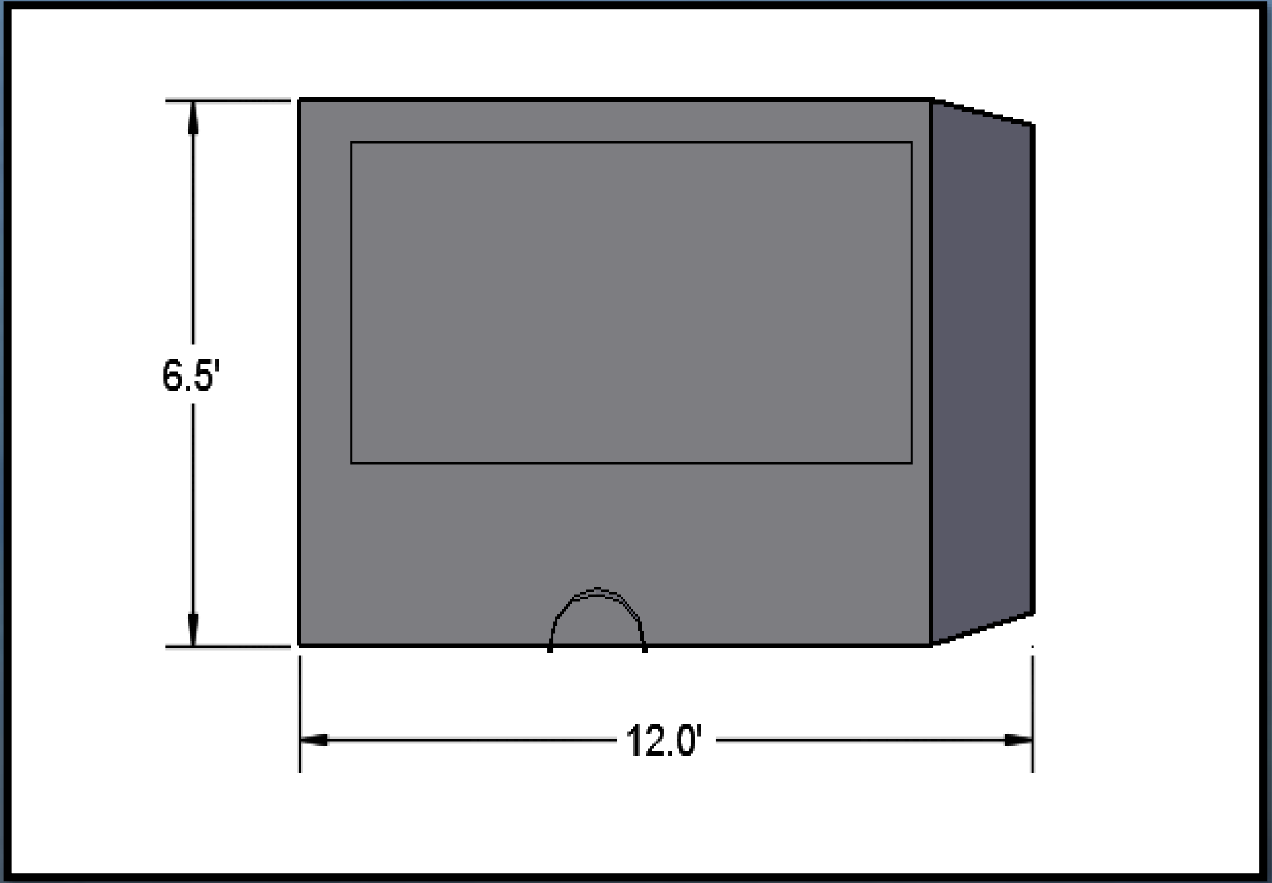
- "Open Sides" Trailer



TRAILER STYLE SELECTION

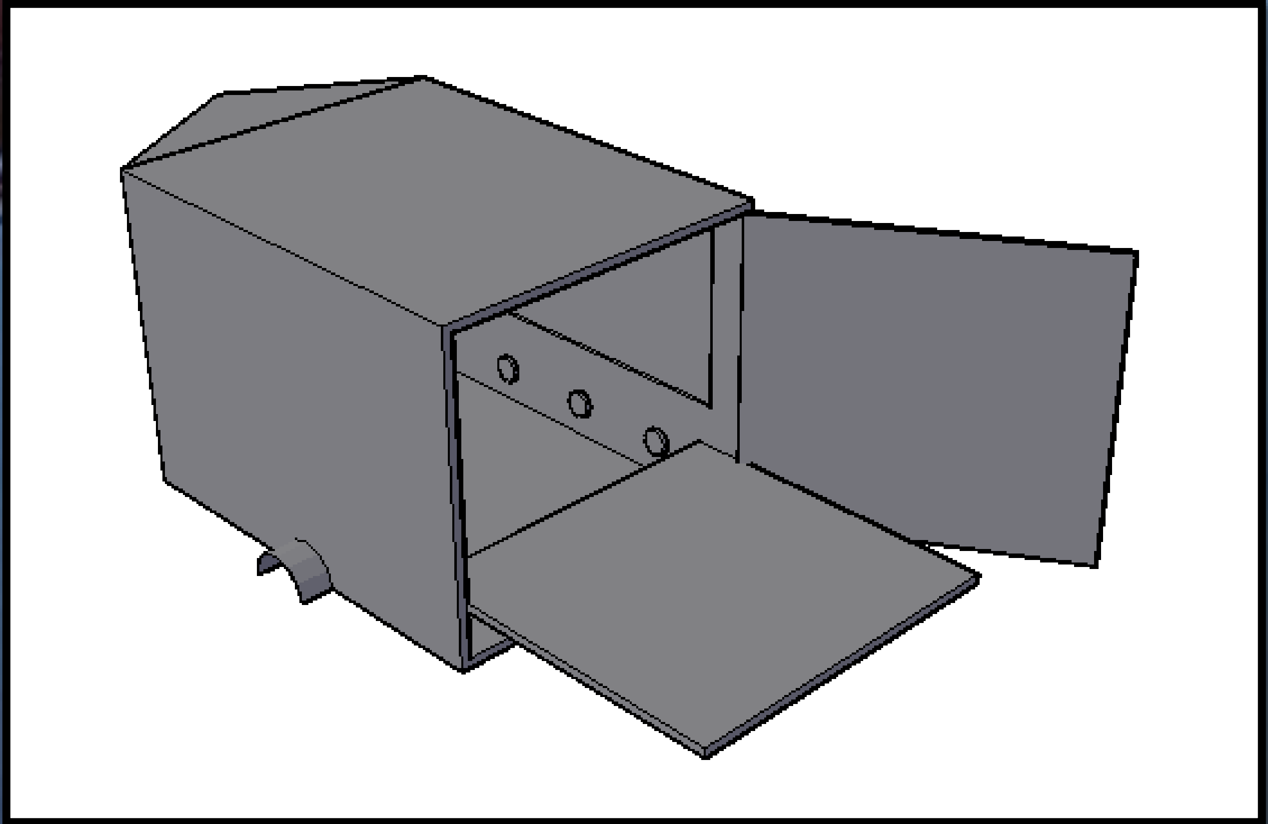
- Tailgate "Walk around" Trailer

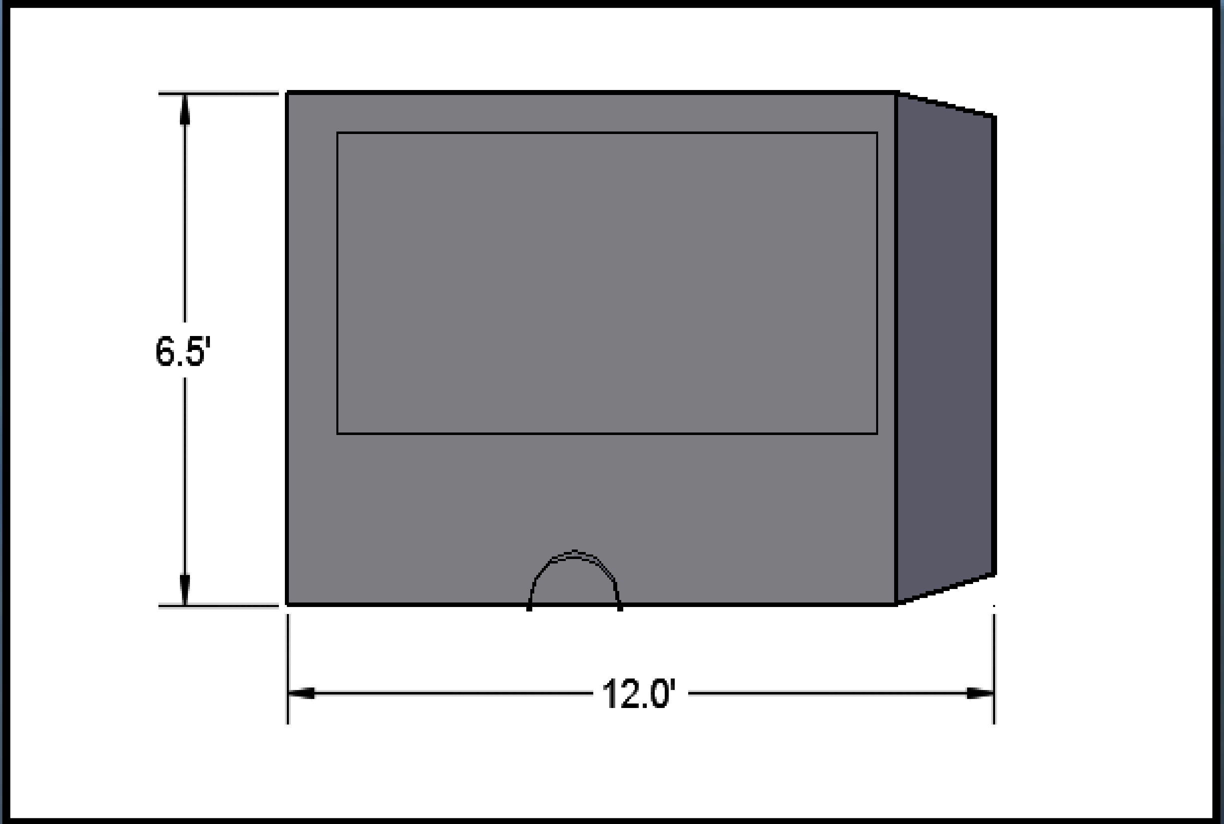




TRAILER STYLE SELECTION

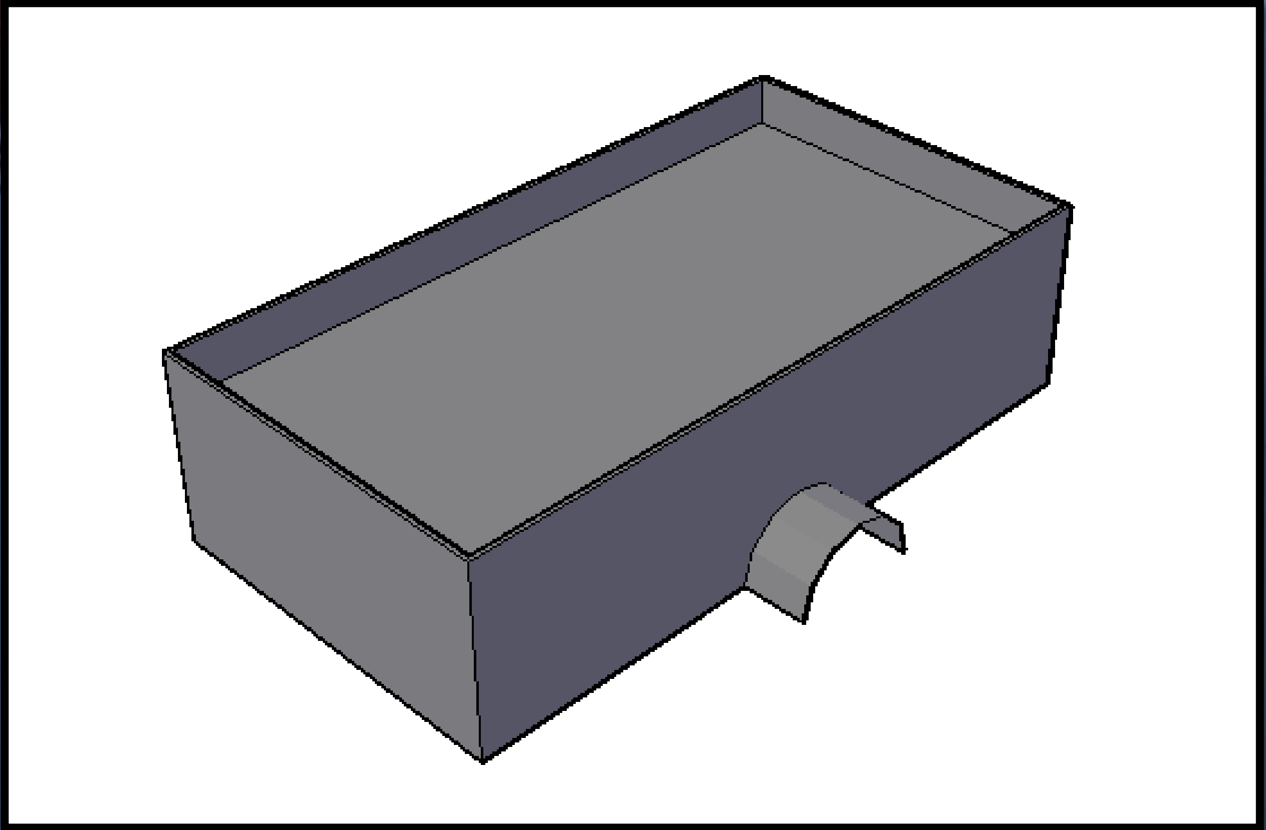
- "Pull-Out" Trailer

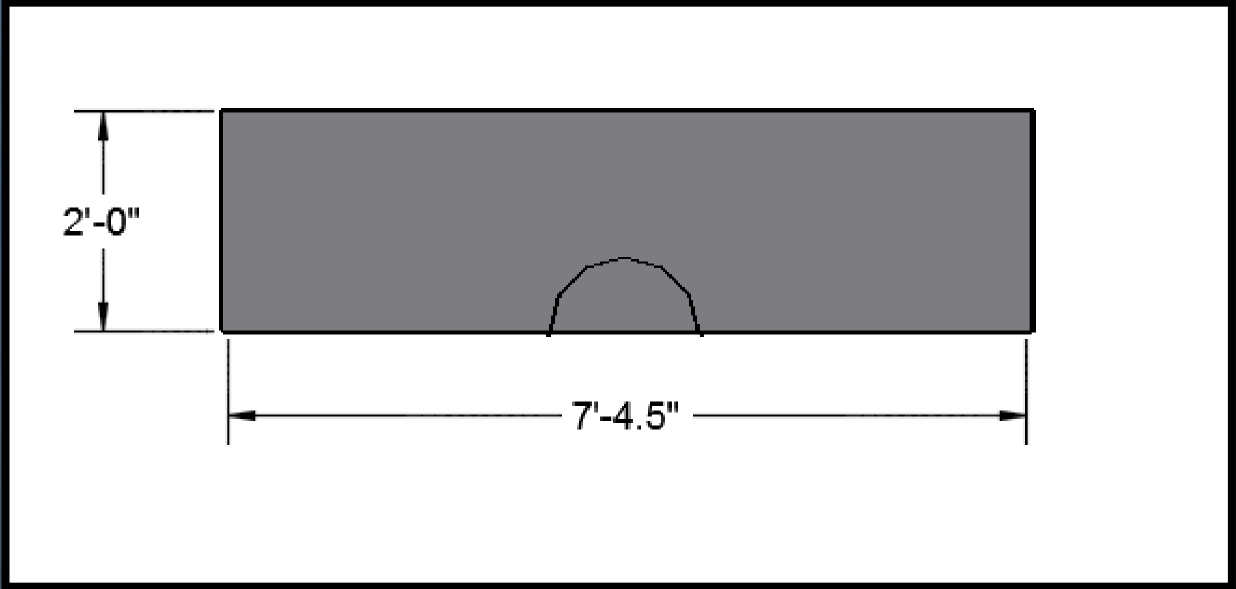




TRAILER STYLE SELECTION

- Stream Trailer Style



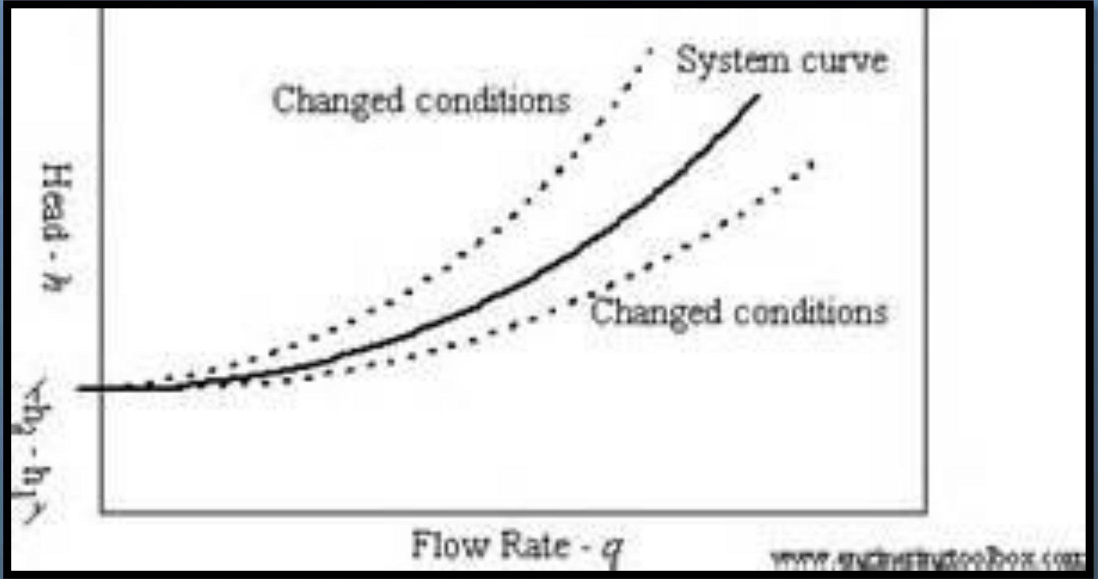


HYDRAULIC MODELING

- Two small centrifugal pumps considered
- Bentley WaterCAD used to generate hydraulic profile
- Modeling parameters:
  - Pipe diameter= ¾ "
  - Pipe material – Acrylic/Plastic/PVC
  - Unit operations modeled as "reservoirs"

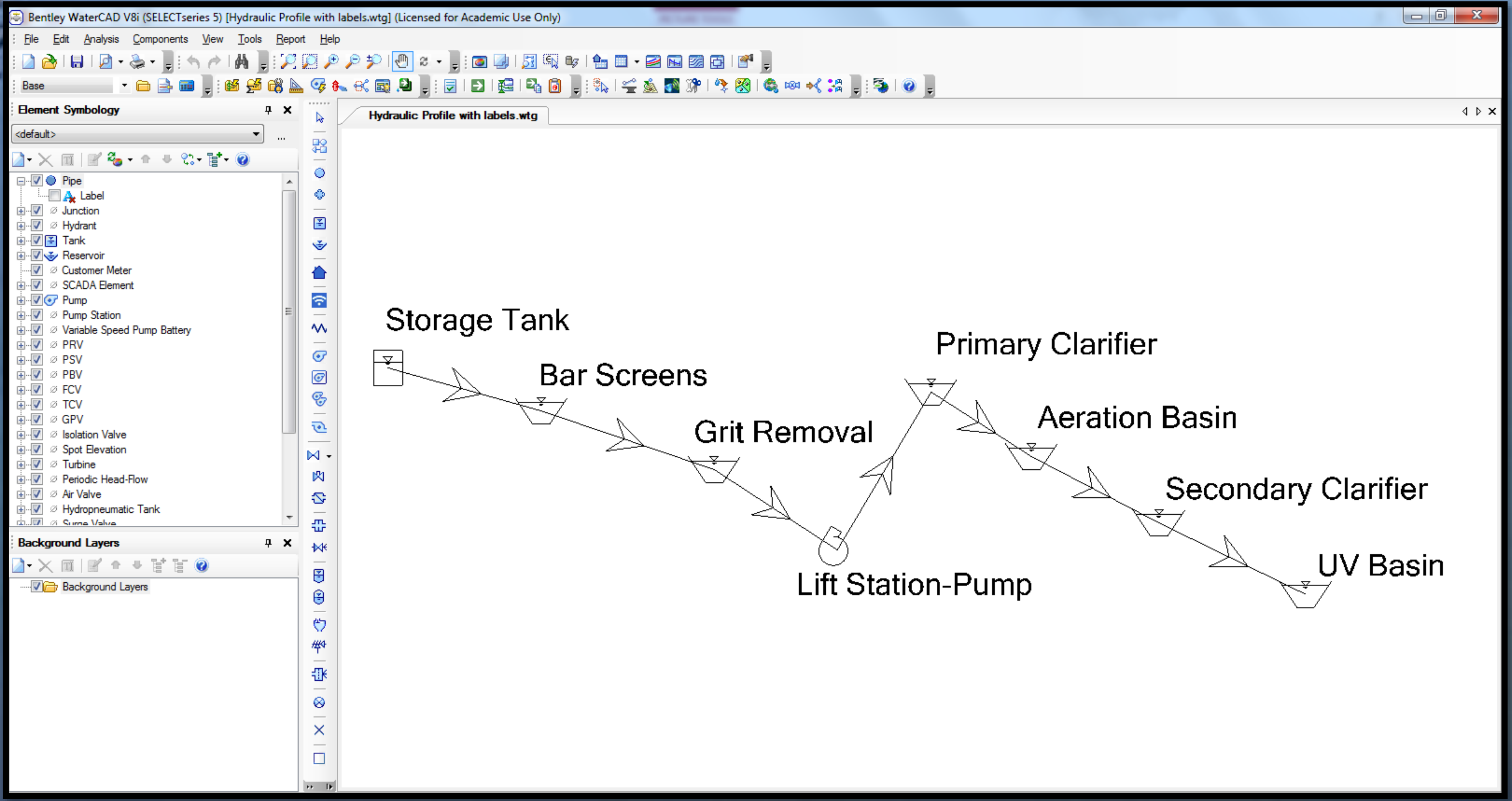
HYDRAULIC MODELING

- System head curve generation
  - Function of elevation, static head, major/minor losses
- Friction loss is minor, but still present
  - Straight line losses
  - Tank entry/exit losses
  - Valves



$$h_f = \frac{fLV^2}{2gD}$$

HYDRAULIC MODELING

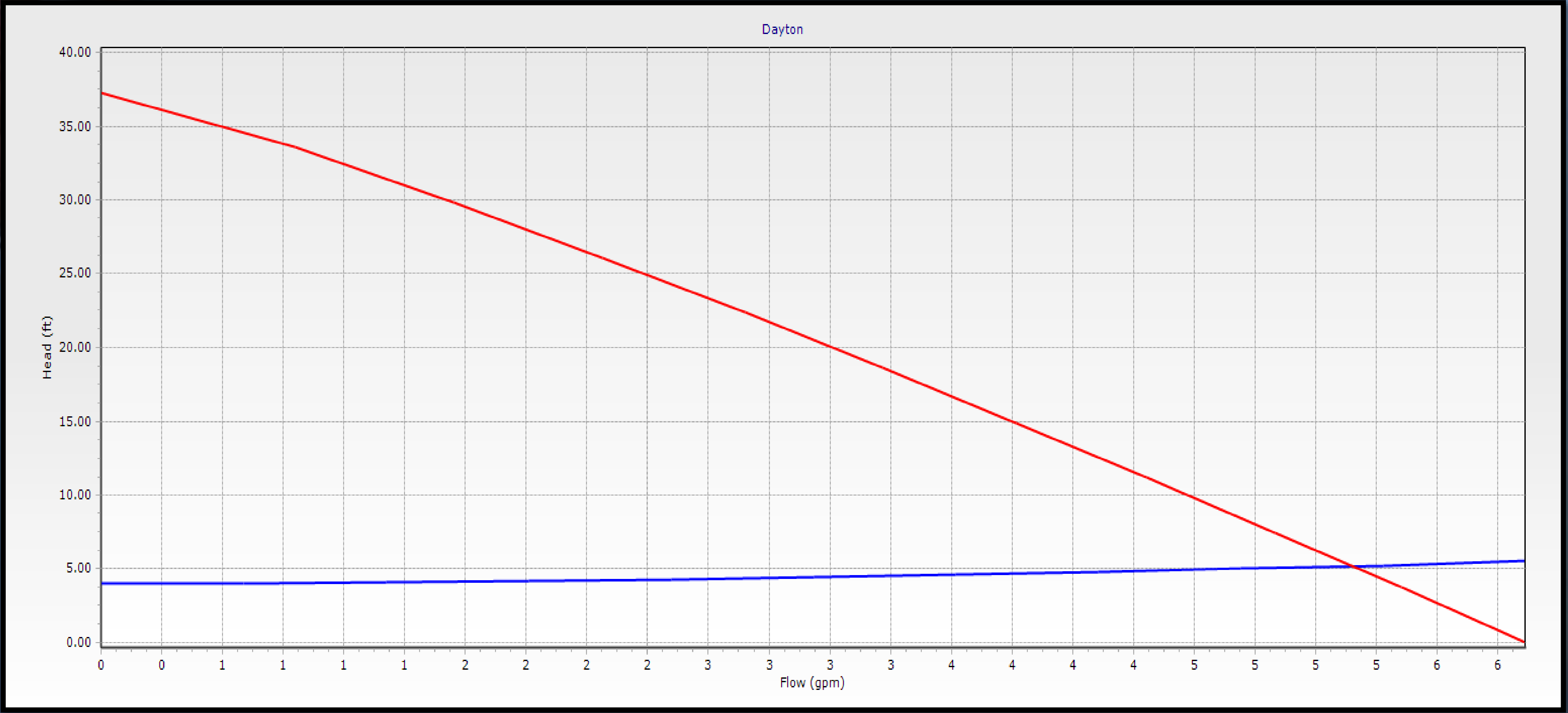


PUMP SELECTION

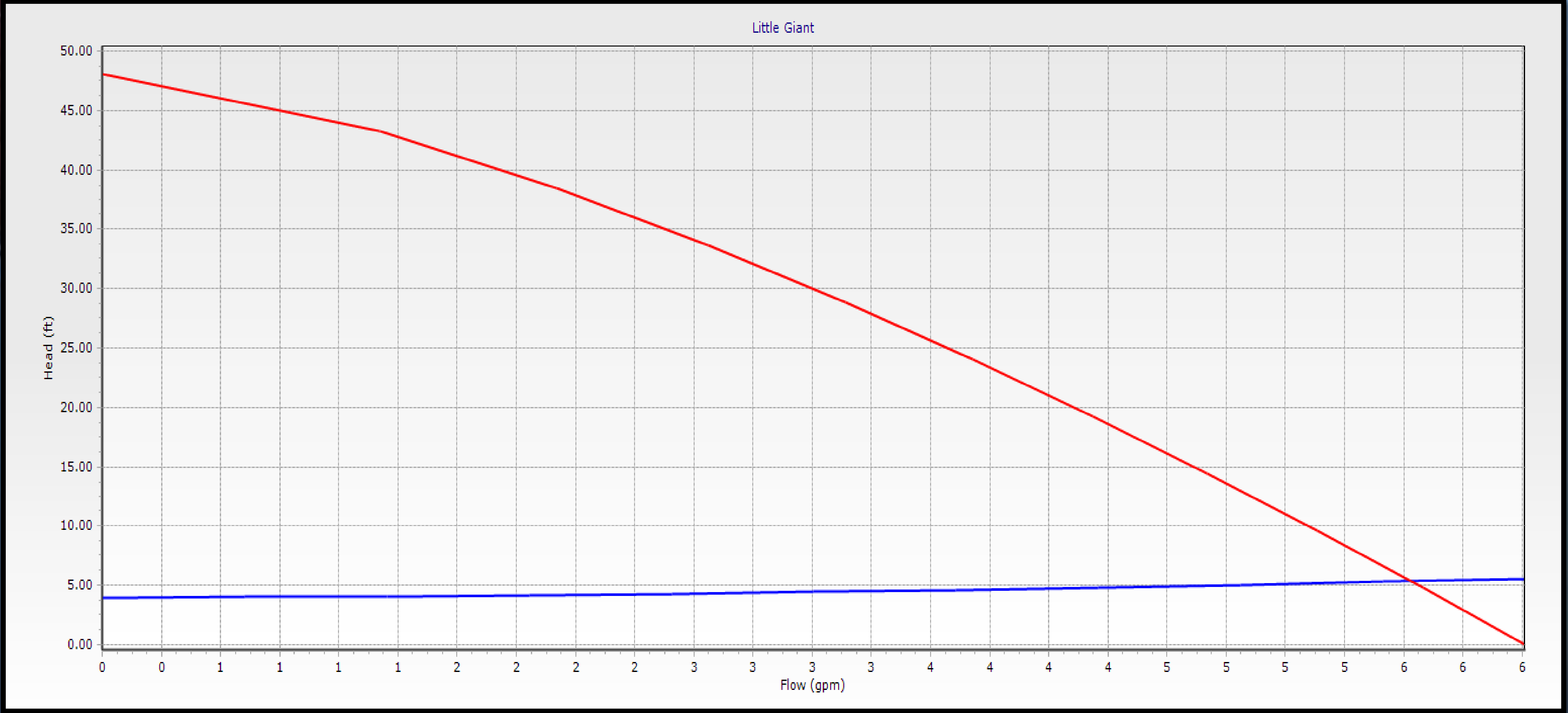
- Dayton Utility Pump
  - Motor – 1/10 HP
  - 115V or 12VDC
  - Shutoff Head=37’
  - $103.95

- Little Giant Pump
  - Motor – 1/10 HP
  - 115V
  - Shutoff Head=48’
  - $141.20

PUMP AND SYSTEM CURVE - DAYTON



PUMP AND SYSTEM CURVE – LITTLE GIANT



GRAVITY FLOW

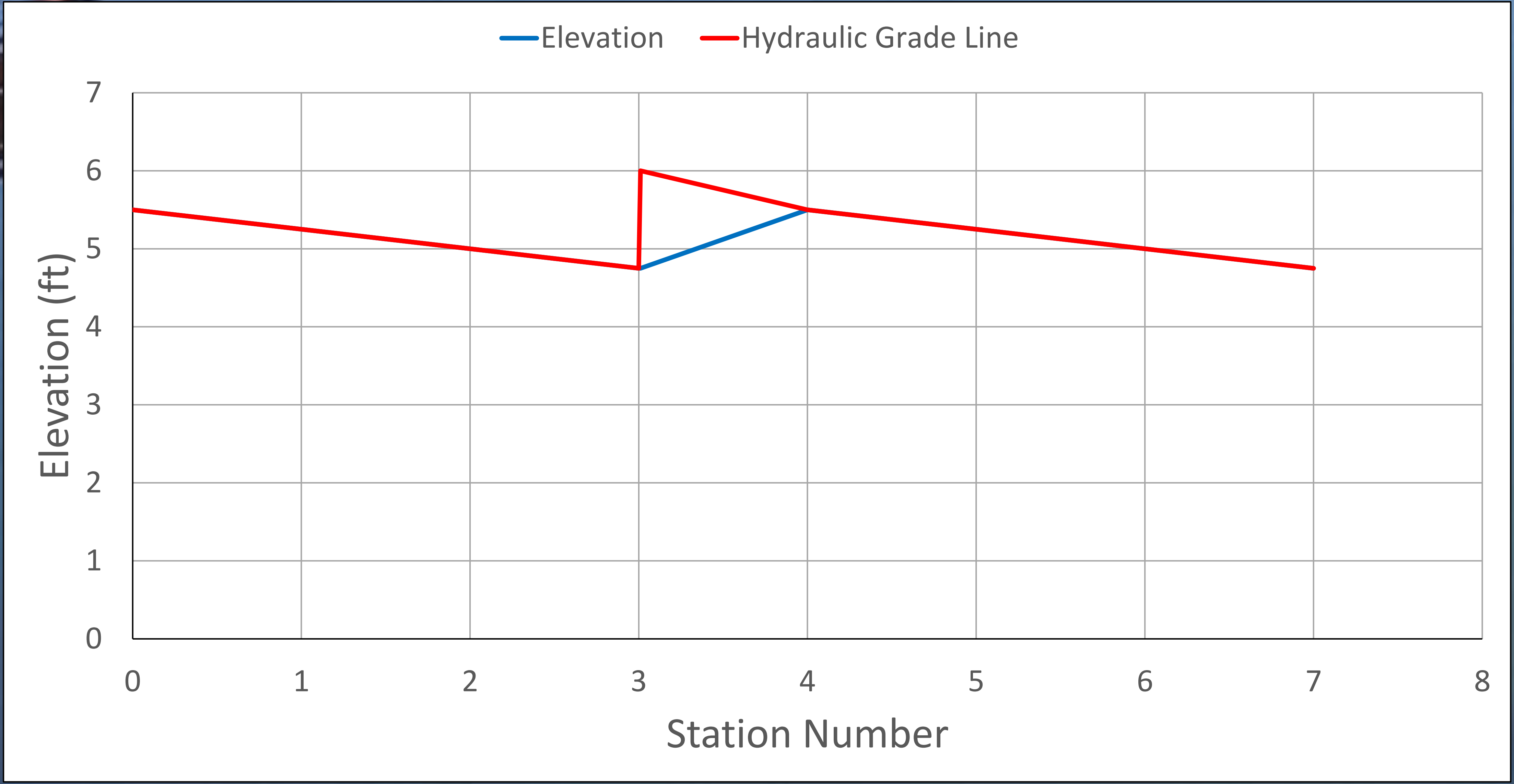
- Both pumps operate at ~6 GPM
  - Must ensure that gravity veins carry same flowrate
- Manning's Equation

$$V = \frac{1.49}{n} R_h^{2/3} S^{1/2}$$

Parameter	Value
Pipe Diameter (in.)	0.75
Manning's Roughness, n	0.01
Slope (ft/ft)	0.25
Percent of Full Depth Flow	100%

Output	Value
Wetted Perimeter (in.)	2.36
Flow Area (in^2)	0.442
Hydraulic Radius (in.)	0.1875
Velocity (ft/s)	4.4
Flow (GPM)	6.0

HYDRAULIC PROFILE



ECONOMIC ANALYSIS

Material	Unit Cost	Quantity	Cost
Pipe	$4.45/ft	15	$67
Valve (BF)	$10/unit	3	$30
Plexiglas	$13/ft^2	25	$75
Sprinkler	$15	1	$15
Misc.	-	-	$63
Total	-	-	$250

ECONOMIC ANALYSIS

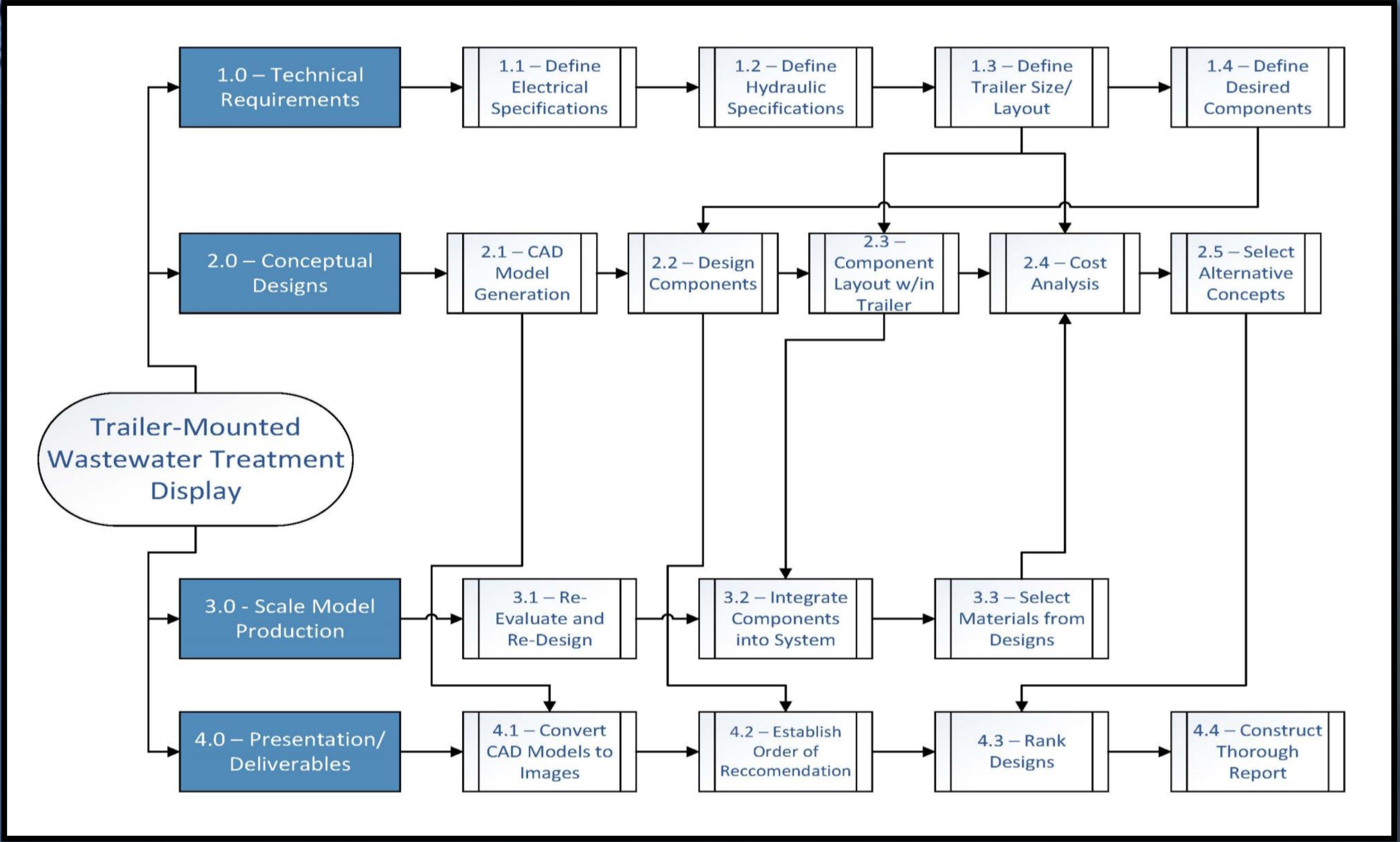
Alternatives				
	"Open Sides" Trailer	"Walk around" Trailer	"Pull-Out" Trailer	Stream Trailer
Bare Trailer	$22,500	$15,000	$15,000	$10,000
Pump (Dayton)	$104	$104	$104	$104
Materials	$700	$600	$600	$500
Total Cost	**$23,304**	**$15,704**	**$15,704**	**$10,604**

ALTERNATIVE EVALUATION

- Criteria judged on 1-10 scale

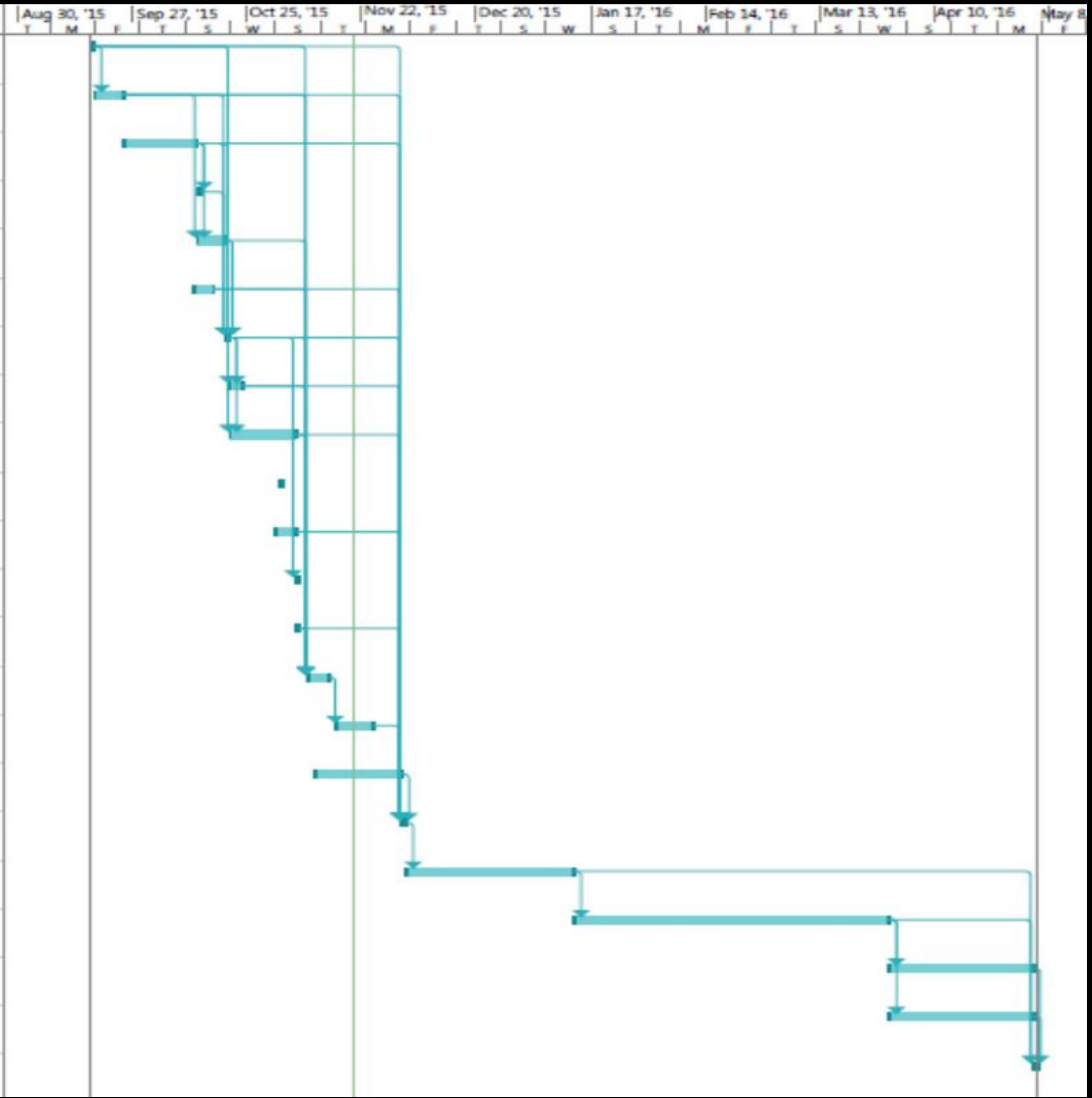
Alternative	"Open Sides" Trailer	"Walk around" Trailer	"Pull-Out" Trailer	Stream Trailer
Capacity	10	9	8	5
Storage	10	10	10	5
Style	10	7	7	5
Cost	3	5	5	10
Overall Score	33	31	30	25

WORK BREAKDOWN STRUCTURE



GANTT CHART

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Meeting with Garver	1 day	Thu 9/17/15	Thu 9/17/15	
2		Literature Review	5 days	Fri 9/18/15	Thu 9/24/15	1
3		Initial Designs	12 days	Fri 9/25/15	Mon 10/12/15	
4		Meeting with Freshmen	1 day	Tue 10/13/15	Tue 10/13/15	3
5		Short Report	5 days	Tue 10/13/15	Mon 10/19/15	2,3
6		Technical Analysis	5 days	Mon 10/12/15	Fri 10/16/15	
7		Meeting with Garver at OSU	1 day	Tue 10/20/15	Tue 10/20/15	2,3,4,5
8		Statement of Work	3 days	Wed 10/21/15	Fri 10/23/15	1,7
9		Pre-liminary Design	12 days	Wed 10/21/15	Thu 11/5/15	3,7
10		Meet with Freshmen	1 day	Mon 11/2/15	Mon 11/2/15	
11		Prepare Presentation	5 days	Sun 11/1/15	Thu 11/5/15	
12		Final Presentation Date	1 day	Fri 11/6/15	Fri 11/6/15	7
13		Work Breakdown Structure	1 day	Fri 11/6/15	Fri 11/6/15	
14		Fall Report Draft	5 days	Mon 11/9/15	Fri 11/13/15	1,2,5,6,7,8,9,13
15		Final Fall Report	7 days	Mon 11/16/15	Tue 11/24/15	14
16		Fall Powerpoint Presentation	15 days	Wed 11/11/15	Tue 12/1/15	
17		Fall Presentation to Garver	1 day	Wed 12/2/15	Wed 12/2/15	1,2,3,6,7,8,9,11,13,15,16
18		Select Design and Research	29 days	Thu 12/3/15	Tue 1/12/16	17
19		Build and Test Design	55 days	Wed 1/13/16	Tue 3/29/16	18
20		Create Final Report	25 days	Wed 3/30/16	Tue 5/3/16	19
21		Create Final Presentation	25 days	Wed 3/30/16	Tue 5/3/16	19
22		Present Final Design-Garver	1 day	Wed 5/4/16	Wed 5/4/16	18,19,20,21



MOVING FORWARD…

- Determine trailer style/layout
- Next semester:
  - Final CAD drawings of trailer plus components
  - Table top model
    - Determine materials
    - Build and test

ACKNOWLEDGEMENTS

- Mary Elizabeth Mach, PE
- Stillwater WWTP
  - Lou Ann Fisher, Superintendent
  - Elton Moore, Plant Manager
- Dr. Garey Fox & Dr. Glenn Brown
- Dr. Paul Weckler
- Freshman design teams
- We greatly appreciate your support!


DISCUSSION
GARVER
AquaCleanse
Solutions