



AquaCleanse Solutions

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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.

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 an educational wastewater treatment system. Some general requirements and guidelines are listed as follows:

- Target audience is elementary and middle school aged students

- See something they can identify and use daily, such as a modified toilet
- Audience can see process work
- Cross sectional view with clear materials
- Interactivity, aesthetics, and functionality are imperative
- Components to consider: Bar Screens, Grit Removal, Clarifiers, Aeration Basins, Disinfection Basins
- Consider showing in some way gravity flow and lift station hydraulics
- Include some component of wastewater reuse
- Electronics powered by standard 120V outlet

From the meeting with Garver and the given guidelines, a thorough set of customer requirements was established. It is our plan to make the wastewater treatment display an interactive and engaging exhibit 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. A comprehensive statement of work from these requirements have been drafted, and is presented in the following pages.

Statement of Work

Abstract

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



Scope of Work

Neither the senior design team nor Garver Engineering expects to have a complete trailer-mounted system at the conclusion of this fiscal year. At the end of the year, the senior design team constructed a “tabletop” model that represents what is to be mounted on the final exhibit.

Location of Work

In the fall semester, conceptual designs of the trailer primarily took place in the OSU Biosystems and Agricultural Engineering computer lab. In the spring semester, the construction of the “tabletop” model took place in the Biosystems and Agricultural Engineering Laboratory and machine shop.

Fall Performance of Work

The main body of work in the fall semester was focused on generating conceptual designs for the wastewater treatment process to be displayed. The scale model drawings of each component was drawn using a 3D CAD program. Pipe sizing, pump selection, system head and pump curve generation, pump selection, and hydraulic profile generation were all completed. The unit operations were scaled so that the components could fit within a confined space and be easily identified.

Spring Performance of Work

After spending the fall semester drafting conceptual designs, the goal of the spring semester was to finalize these designs and start working toward the fabrication of a tabletop model. All of the building and testing of the subsequent models took place in the BAE lab. The

senior design team completed the component designs and fabrication was completed by Wayne Kiner and the BAE shop staff.

Deliverables Schedule

To ensure steady progress towards project completion and group cooperation, throughout the project a weekly agenda was emailed 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 was delivered to Mary Elizabeth Mach and Dr. Weckler:

- Conceptual designs of trailer-mounted system, with four trailer “style” alternatives
- Final Technical Report
 - Final designs
 - Fall task list/preliminary schedule
 - Estimated cost chart
- End of Semester Presentation.

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

- Final component design(s) that include the specifications given in the technical requirements
 - Cost estimate
 - Interactivity designs/display
 - Electrical
 - Storage and maintenance plans
- Constructed “tabletop” model of system
- Final draft of project report

Acceptance Criteria

In order for our design proposal 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 reasonable 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 served as a representation of what would be mounted on a trailer, allowed the senior design team to better understand how the system will operate hydraulically, and gave the team a better idea on how to design the system spatially and aesthetically.

Key Assumptions

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

- No physical wastewater treatment in the system
 - Based on client meeting with Garver
 - Practicality
 - Ease of Use
- Display will focus on the “water” treatment processes; will not deal with sludge handling
 - Based on client meeting with Garver
- Display will exhibit activated sludge processes as opposed to trickling filter
 - More relevant to Garver client base
 - Based on client meeting with Garver

Funding

Garver was not responsible for any of the financial load in the construction of the tabletop model. The purchase of materials and assembly of the model were made through funding available to the senior design class through Oklahoma State University.

Design Concepts

In the spring semester, design efforts were directed toward fabricating a tabletop model that was presented at the summation of the semester. The first model that was constructed primarily served as a hydraulic model that allowed the team to better understand how each unit operation functioned. This model also helped the team get a feel for issues that might arise with operation, such as leaks and proper flow through the components. Once this model was thoroughly tested, a second model was produced. With the second model, a greater focus was placed on aesthetics and interactivity to reinforce the project's educational objectives. Figure 1 shows a process flow diagram of the first model.

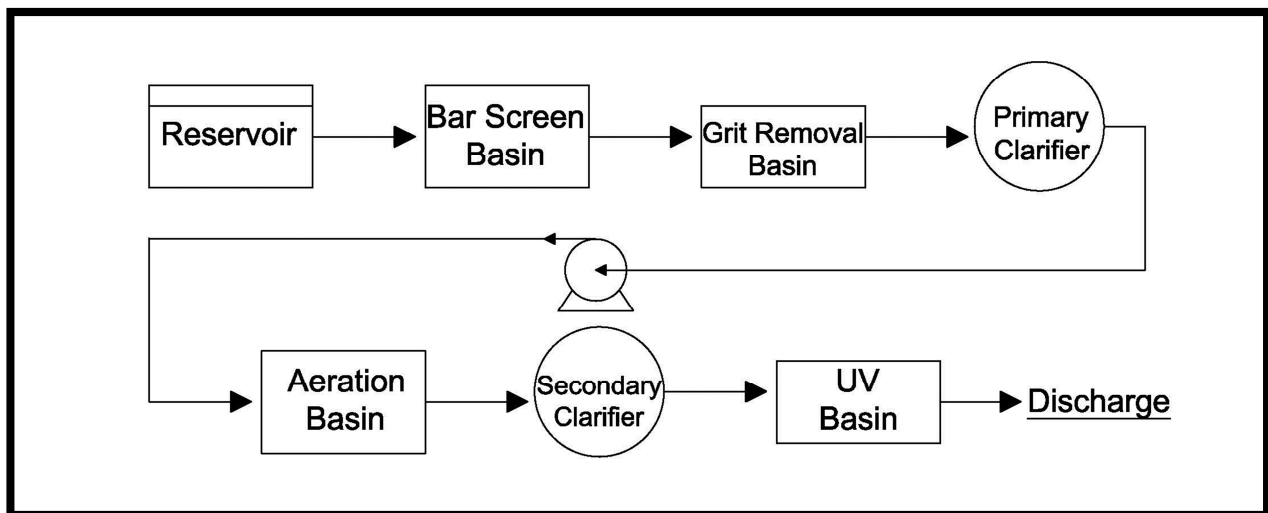


Figure 1: Process Flow Diagram for hydraulic model

Scaling

The components in both models needed to be geometrically similar to unit operations in a wastewater treatment facility. Before the tour at Stillwater Wastewater Treatment Plant

(WWTP), 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 the Stillwater WWTP and a “prototype”. Problems did arise with this approach, however, based on 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. The Stillwater plant was scaled down by a factor of 100, and for some components this worked very well (see table 1), 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 an “ideal” prototype system are estimated compared with the Stillwater WWTP.

Table 1: Nominal 1:100 Scale of Stillwater WWTP.

Stillwater WWTP		1:100 Scaling	
Unit	Characteristic Length	Unit	Characteristic Length
Bar Screens	28'	Bar Screens	3.4"
Grit Chamber	17'	Grit Chamber	2"
Clarifiers (Secondary)	125'	Clarifiers (Secondary)	15"
Aeration Basins	191'	Aeration Basins	23"
UV Basin	50'	UV Basin	6"

Table 2: Summary of "ideal" prototype system

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 (Secondary)	15"
Aeration Basins	191'	Aeration Basins	23"
UV Basin	50'	UV Basin	16"

Components Used for the Hydraulic Model

To save time and money, off-the-shelf materials that were as appropriately sized as possible were used to fabricate the hydraulic model. While this is not as accurate of a representation as individually machining and constructing parts, it allowed for sufficient hydraulic testing of the model that could then be used to better design the final components for display. Most of the materials were purchased from Lowe's in Stillwater. First, a wooden frame with pegboard attached to either face was constructed to allow for easy mounting and adjustment of unit operations. Pictures of the construction process can be seen in Figure 2.

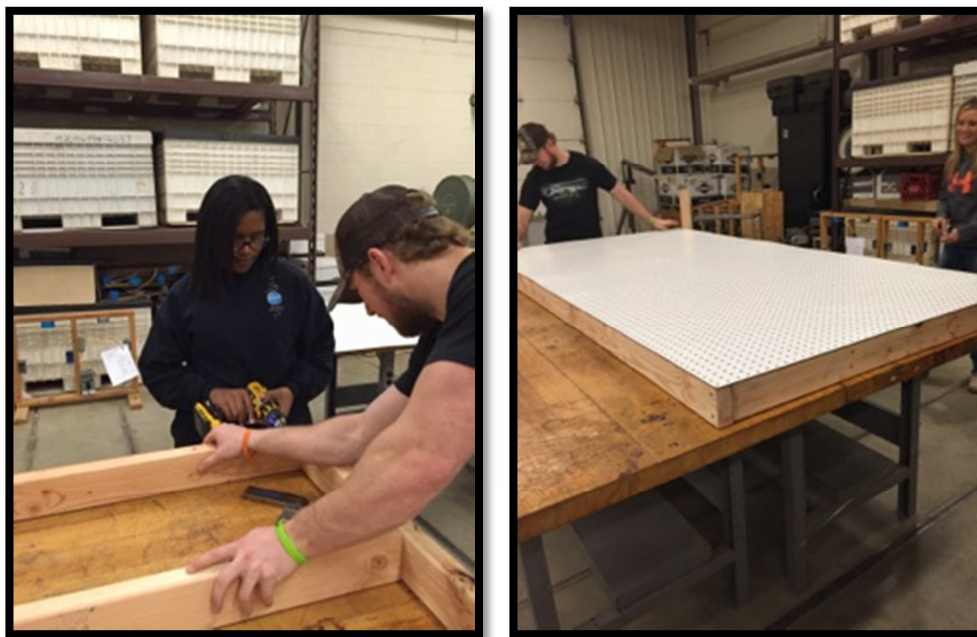


Figure 2: Photos of building the wooden frame for the hydraulic model

Next, the selected unit operations were purchased and assembled. The mechanical bar screens, UV basin, and aeration basin were all modeled with small plastic containers that mimicked a basin or trough geometry. Holes were drilled into either end and plastic fittings with both hose barbs and threaded ends were sealed in to create usable inlet and outlets. The grit removal basin was constructed by drilling holes into a 4"-3" PVC reducing coupler and fashioning a makeshift waterproof bottom. The inlet and outlet holes were placed fairly close together so that the water was forced to take a rough "vortex" path before exiting the basin.

The clarifiers were modeled by attaching the same style PVC coupler used in the grit basin to a larger 6" PVC end cap. This allowed an inlet to be drilled into the bottom of the end cap, and from there water would fill the coupler until it overflowed into the end cap and subsequently into the outlet. Photographs of all of these components, along with an image of the system mounted onto the frame, are shown in Figures 3 through 6.

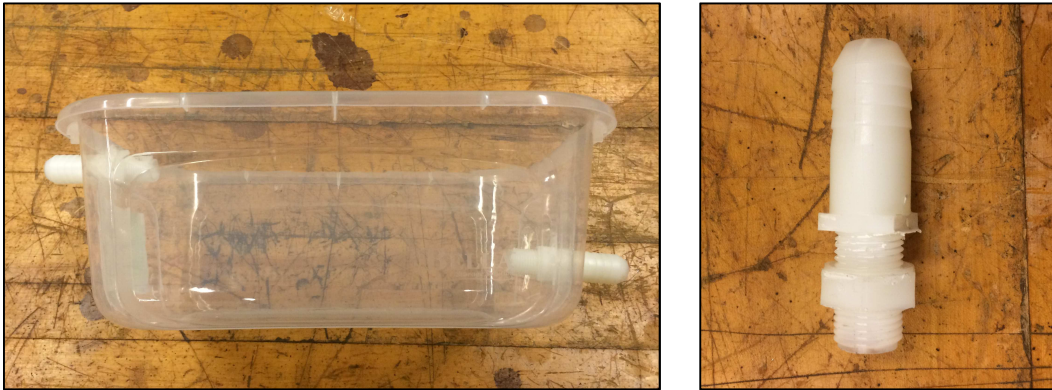


Figure 3: Profile view of "basin" (Left). Close-up of the fittings used to create the inlet and outlets (Right). This style was used to model the bar screens, aeration basin, and UV basin.



Figure 4: Top (Left) and bottom (Right) view of clarifier model. The inner chamber is a PVC reducer that was attached and sealed to the wall of the PVC end cap. Inlet (center) and outlet (rim) holes can be seen.



Figure 5: Profile (Left) and plan (Right) view of grit removal basin model. As shown, the water flows in through the higher inlet and, after traveling around the circumference of the basin, exits through the lower outlet.

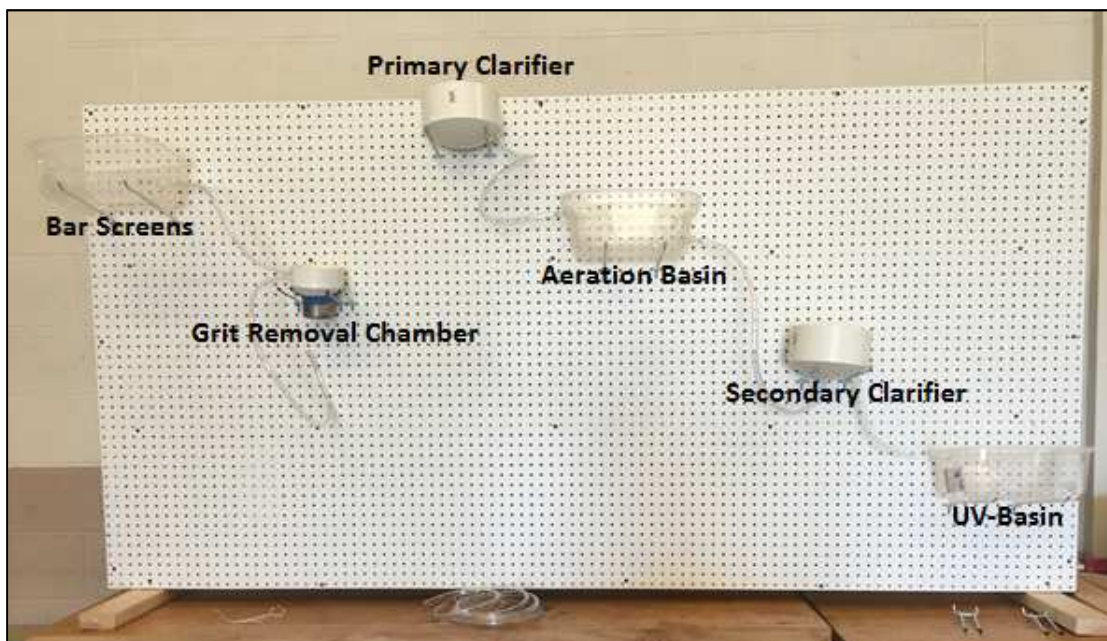


Figure 6: Labeled image of the hydraulic model mounted onto the frame. The pump (not shown) was placed below the grit removal chamber and pumped directly up to the primary clarifier.

Hydraulic Calculations

Hydraulic calculations were pivotal in sizing the pipes, inlets/outlets, and establishing elevations of the various components in the hydraulic model. First, calculations completed in the fall 2015 semester were used to establish a starting point for some of the parameters. For example, as established in the fall semester, with the selected Dayton 5UXL7 centrifugal pump and the estimated size of the unit operations, the projected flow through the entire system would sit around 5-6 gallons per minute (GPM). With this, the team used Manning's equation

(shown below) to size the pipe needed to carry that capacity of gravity flow. As shown in Table 3, to deliver the desired flow of 6 GPM and a convenient slope of 0.25 ft/ft , a ¾” pipe diameter is required for PVC/plastic pipe.

$$\text{Manning's Equation: } V = \frac{1.49}{n} R_H^{2/3} S^{1/2}$$

Where: V=Flow Velocity (ft/s)

N=Manning's Roughness

R_H=Hydraulic Radius, Flow Area/Wetted Perimeter (ft)

S=Slope (ft/ft)

Table 3: Parameters and calculated values for gravity flow sections

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

With the pipes for the hydraulic model sized, a system head curve and pump curve were examined to determine at what rate the pump would deliver water from the grit basin to the primary clarifier. A pump curve was acquired from Dayton for the 5UXL7 and a system head curve for where the pump would be operating was calculated. This was done by performing an energy balance between the grit removal basin and primary clarifier. Setting up the energy balance between the two reservoirs yielded the following:

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

Where: z_x= Elevation of respective component (ft)

$\frac{p_x}{\gamma}$ = Pressure head at respective component (ft)

$\frac{V^2}{2g}$ = Velocity head at respective component (ft)

h_p = Pump head (ft)

h_f = Friction head loss (ft)

In the setup of the hydraulic model, the grit removal basin was around two feet below the primary clarifier, so the respective elevations are known. Because both reservoirs are open to air and not pressurized (see figure 7), they are at atmospheric pressure and the pressure head at each location are zero. Furthermore, the velocity heads at either reservoir can be assumed to be negligible. Consequently, the pump head and friction losses are related by the following equation:

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

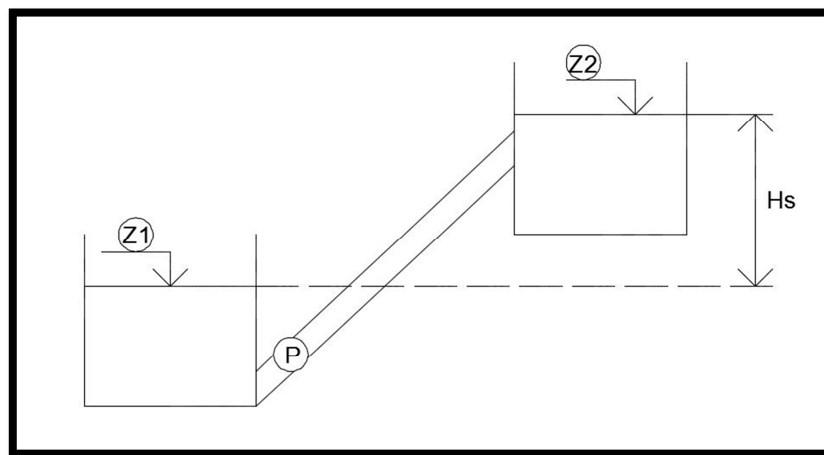


Figure 7: Visual representation of the single pump and pipeline system

Furthermore, the friction head loss can be further defined as the straight pipe losses along with any minor losses. For convenience and to allow throttling, a PVC ball valve was placed in line after the pump outlet, and since tank exit/entry losses were considered minimal, was the only

source of minor friction losses. Therefore, the h_f term was equated with the Darcy-Weisbach equation for friction loss:

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

Where: f = Darcy-Weisbach friction factor

L =Length of straight pipe (ft)

D =Diameter of pipe (ft)

K_{valve} =Valve loss coefficient

The Darcy-Weisbach friction factor is specific to the material of pipe, diameter of pipe, and the Reynolds Number. The valve loss coefficient for a ball valve has a wide range of accepted values. For a totally open valve, it is typically accepted to be 0.05. However, 1/3 closed and 2/3 closed ball valve coefficient values have been reported as 5.5 and 200, respectively. Based on the amount of flow the pump was producing and the amount that the valve was throttled during hydraulic testing, it was estimated that the coefficient for this particular valve setting was approximately 20.0. With the friction losses defined and static head known, the pump curve flowrates could then be used to generate a system curve and determine where the Dayton pump would perform. Using the equation for h_p , the following were produced. The pump and system curve calculations yielded the values seen in Table 4 and graphed in Figure 8. From this, it can be seen that the pump and system head curve intersect at a point that corresponds to around 4.9 GPM of flow and 6.4 feet of head, and therefore those are the performance values of the Dayton pump in this system. Ideally, the pump-system match point should be closer to the interior of the pump curve to provide higher efficiencies; however, for this hydraulic model it is sufficient.

Table 4: Tabulated pump and system head curve parameters

Pump Curve 5UXL7					
Flow (GPM)	Velocity (ft/s)	Head (ft)	Friction Loss, h_f (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

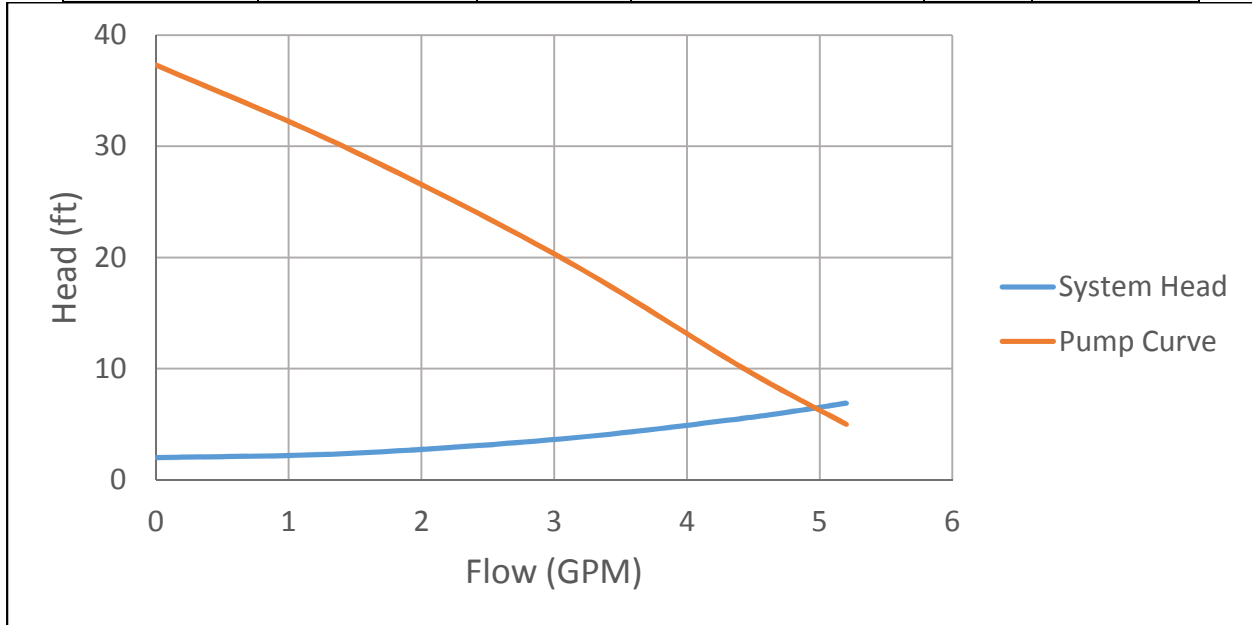


Figure 8: System Head curve and Pump head plotted versus flow

Conclusions from Hydraulic Model

Several conclusions were made at the completion of hydraulic testing. First, although it would be technically enriching and interesting to have a continuous flow-through system that was dynamically and geometrically similar to a functional WWTP, for the purposes of education and ease of use this is not a requirement. Furthermore, the target audience for the original project must be considered. As fascinating as practicing engineers may find a hydraulically accurate model, grade school students will not appreciate or understand all of the calculations that goes into selecting proper pipes, slopes, and flow rates. Consequently, there is no need to

go through the headache of operating and maintaining a flow-through system that has the potential for leaks, overflows, and other issues when the same educational objectives can be achieved with easier-to-handle processes.

With that being said, design efforts were then directed to producing “compartmentalized” unit operations. In simpler terms, the team decided to propose components that were not hydraulically connected to each other and could operate independently. Moreover, it was determined that some components did not even need to have water flowing through them at all. For instance, the aeration basins were one such process where this is true. In practice, the flow-through velocity through these basins is extremely small, with hydraulic retention times lasting at the least several hours. So, an educational display aeration basin could simply be a tank of water with no flowing water and some sort of bubbling apparatus that adequately displayed the aeration process.

Grouping the unit operations in this way simplifies several aspects of the display. First, it reduces cost by decreasing pumping performance requirements and energy costs. It eases the display operation by eliminating risks such as leaks, misaligning pipe slopes, and overflows. Finally, it greatly simplifies maintenance issues such as component drainage, storage, and installation. From the standpoint of presenting and preserving the display, it quickly became evident that this approach was much more efficient.

Final Unit Operation Designs

After the conclusion of hydraulic modeling, designs for the final display model were produced. Full construction drawings with complete specifications can be seen in the appendices/attachments, but brief overviews of these results are presented in this section. As shown in Figure 9, the flow diagram was modified from the original series configuration of the hydraulic model to a more convenient configuration.

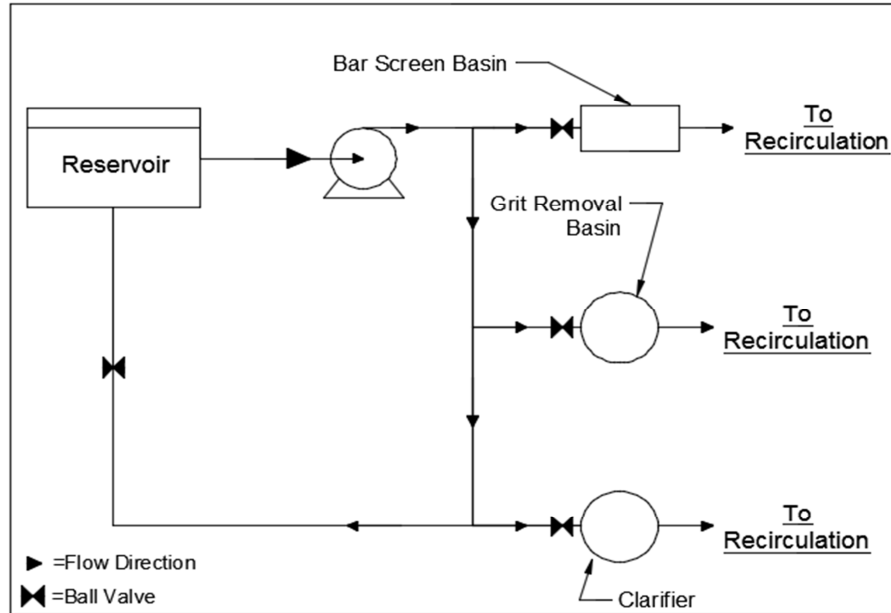


Figure 9: Process flow diagram of final design

The idea behind this modification is that a single pump could provide flow to each unit operation, and valves could be placed before each unit operation to allow the user to throttle the flow in each component to a desirable level. In addition, a ball valve was placed after the last flow splitter in the loop to allow pressure to be built in the preceding pipes. Therefore, a pump could draw water from a tank and send the flow to a loop with pipe splitters at each junction, and both the water from the unit operations and the original loop could be recirculated back to the main tank. With this in mind, the final unit operations were fabricated.

First, simple, clear-sided tanks were constructed to represent the aeration and UV disinfection basins. They were designed with the same materials and wall thicknesses, however, they were sized slightly different to mimic the sizes of the basins at the Stillwater WWTP.

The clarifier design evolved from the basic plan of the hydraulic model clarifier to include a rotating rake arm apparatus and a more uniform tank and weir configuration. As shown in Figure 10, the clear tank walls allow for easy view into the clarifier, and the servo motor mounts on the bottom center axis of the inlet tube. Water enters a hole set into the side of the inlet tube above the servo mounting. This allows for easy motor control of the rake arms

and still displays the bottom-up inlet model of functional clarifiers. As shown in Figure 11, water is pumped in through the lower inlet and then upflows through the inflow vein and to the main tank of the clarifier. Then, it overflows the weir and exits the outlet. A splash guard was installed to ensure that water would not spill into the rake arm tube and down onto the Servo motor.

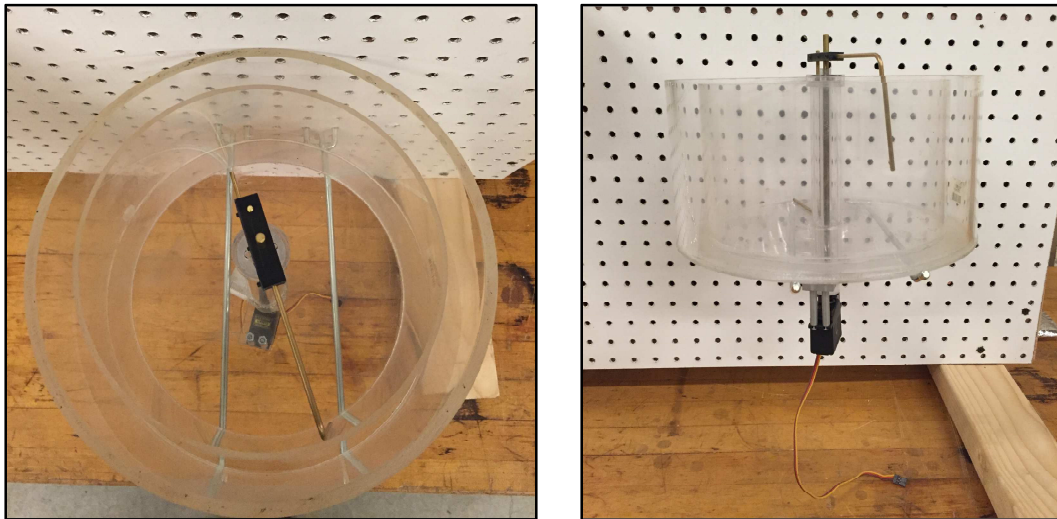


Figure 10: Top and side views of fabricated clarifier

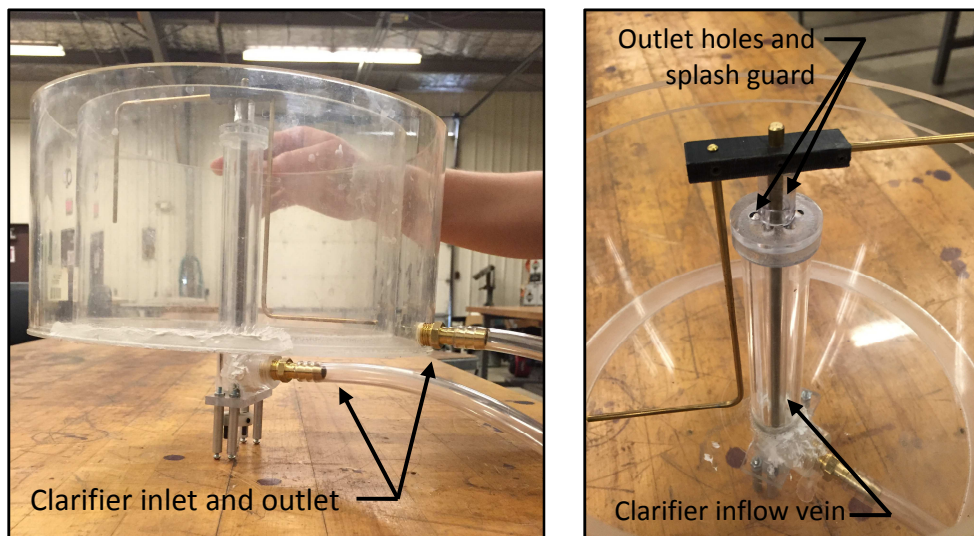


Figure 11: Clarifier inlet/outlet (Left) and inflow vein (Right)

The mechanical bar screen design essentially resulted in a small conveyor-type device that could be mounted inside a basin with flowing water to mimic the in-line removal of solids by the screens. The conveyor frame was made from two-inch steel tubing that was cut in half and with filleted edges. The rest of the conveyor consisted of two 19" timing belts, four 6mm pinion pulleys, 6mm steel shafting, and a 12VDC-10RPM motor. Figure 12 shows the bar screen conveyor belt assembly.

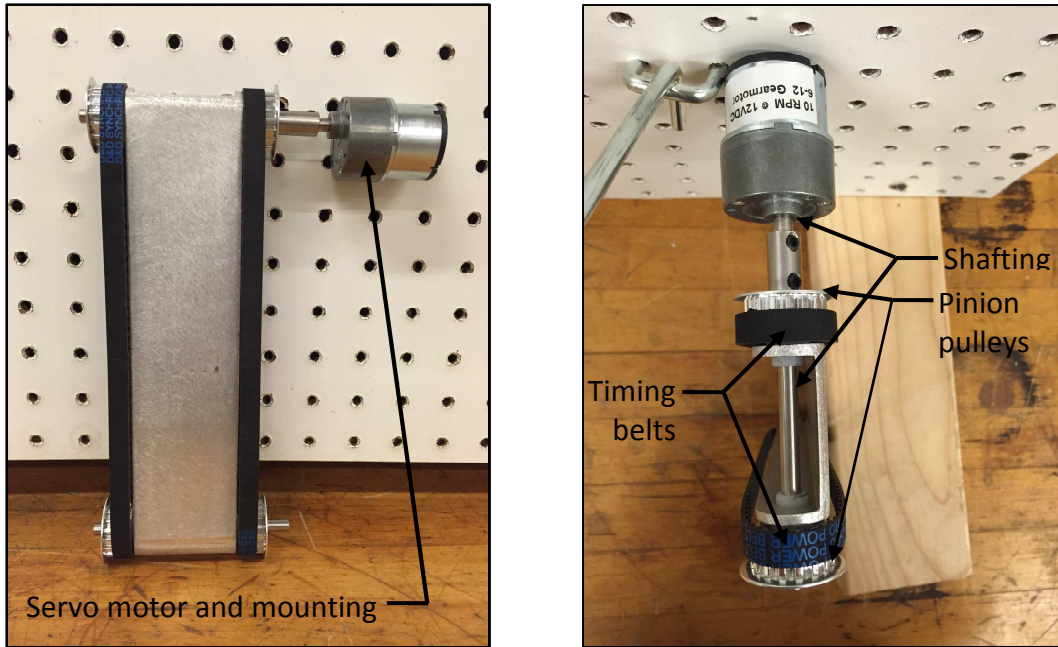


Figure 12: Top and side views of the fabricated bar screens

Fiberglass screening and small wooden “bars” were attached to the timing belts shown in Figure 12 to give the bar screens the ability to pick up small objects from a stream of water flowing through the frame as the motor turned the shafting attached to the pinion pulleys. The finished bar screens can be seen in Figure 13.

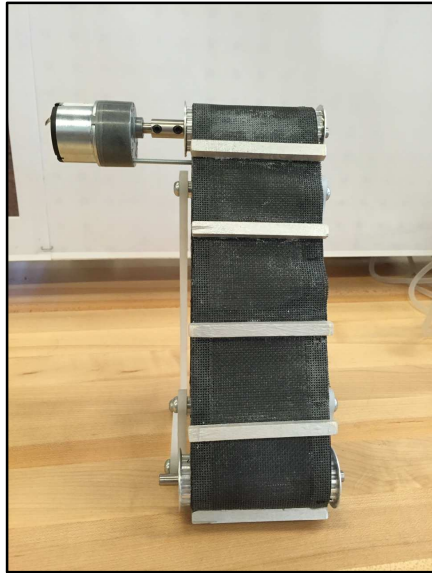


Figure 13: Top and side views of the finished bar screens

The final layout of both the components and posters can be seen in Figure 14.

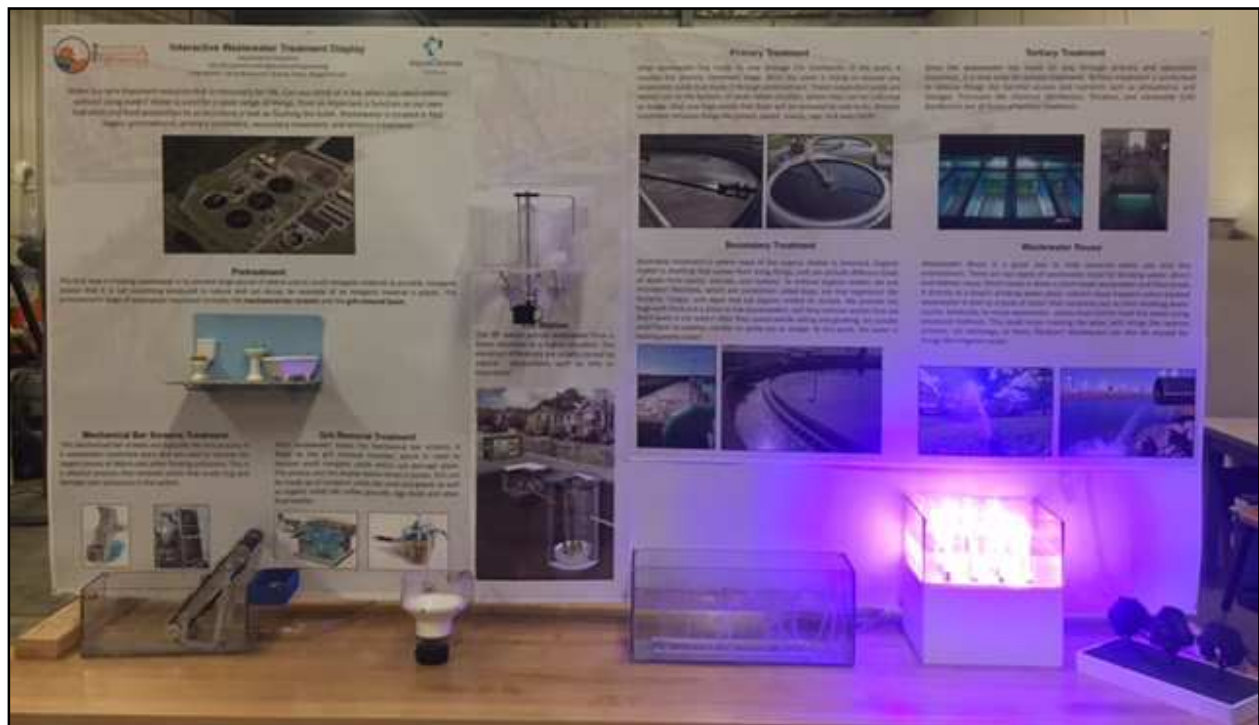


Figure 14: The final display including all posters and unit operations.

Electrical Configurations

The bar screens were powered by a small, 12 VDC, 10 RPM gear motor. The clarifier's rake arms were rotated using a Hextronik twin bearing digital servomotor and Arduino microcontroller configuration. Also, the UV and aeration basins contained 12V LED strips and air bubbler rods, respectively, for aesthetics purposes. To power the LEDs of the UV basin and the bar screen motors, 120V-12VDC power switching units were used to deliver the required power from standard plug-ins. For simplicity of use, all of the electronics were wired in a way that allowed the entire system to be ran off the same standard wall plug in and power strip. Complete wiring diagrams and motor specifications can be seen in the Appendices.

The clarifier configuration was a simple setup on the Arduino microcontroller. As shown in Figure 14, the servomotor circuit consisted of a 5V power wire, a digital signal wire, and connection to ground. With these connections, a short Arduino program was drafted to give the motor the signal required to turn the clarifier rake arms. Figure 15 shows this code in the Arduino program window, and this program can also be seen in the Appendices.

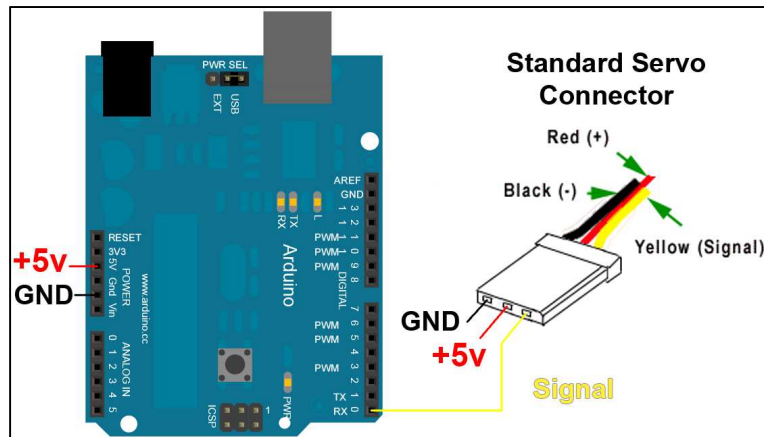


Figure 155: Servo connection diagram

```
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 degrees
  {
    myservo.write(pos); //tell servo to go to position in variable 'pos'
    delay(3000);
  }
}
```

Figure 166: Arduino code used to operate servomotor

Interactivity

One of the main goals outlined in the fall semester was that the display should be interactive. In each unit operation, the team endeavored to provide at least some degree of interaction. The display is designed to be used in conjunction with a guided tour, each unit operation and its functions will then be more fully described.

In order to demonstrate the importance and relatability of wastewater treatment to 4th and 5th graders, a model home bathroom was included in the display (Figure 16). Though a laundry room or kitchen would also work to illustrate the need for wastewater treatment.



Figure 177: Mini bathroom using ceramic sink, toilet, and bathtub

The audience can directly interact with the mechanical bar screens, which will help solidify and illustrate the actual process. The design allows for “debris” to be dropped into the

flow of water and for the bar screens to show how this debris would be removed and disposed of from a waste stream. The bar screen design and the “debris” can be seen in Figure 17. Mini pop cans and other food items made from wood and plastic were chosen to illustrate some of the common items that can be found in a waste stream. These will float and be easily picked up by the bar screens. A single motor turns the bar screens which were constructed like a conveyor belt. Wooden bars were glued to the screen which move together as the timing belts rotates. This gives the appearance of the rake arms in actual mechanical bar screens as they move up the screen.



Figure 188: The “debris” used (Left) and the completed mechanical bar screens (Right)

The grit removal basin has water flowing through it, as well as a small mixer on the bottom, which can be seen in figure 18. The mixer is battery operated and the audience can push a button to turn it on. Using a mixer ensures that a vortex is formed and helps illustrate the flow of water through the grit removal chamber.



Figure 199: The grit removal chamber (Left) and the mixer impeller (Right)

The clarifier designs have rotating rake arms to represent how sludge is removed from the clarifier. The UV basin has purple LED lights to represent the UV light. The LED strips are

inside plastic tubes and are mounted in a way that is very similar to actual UV basin design (see Figure 19).

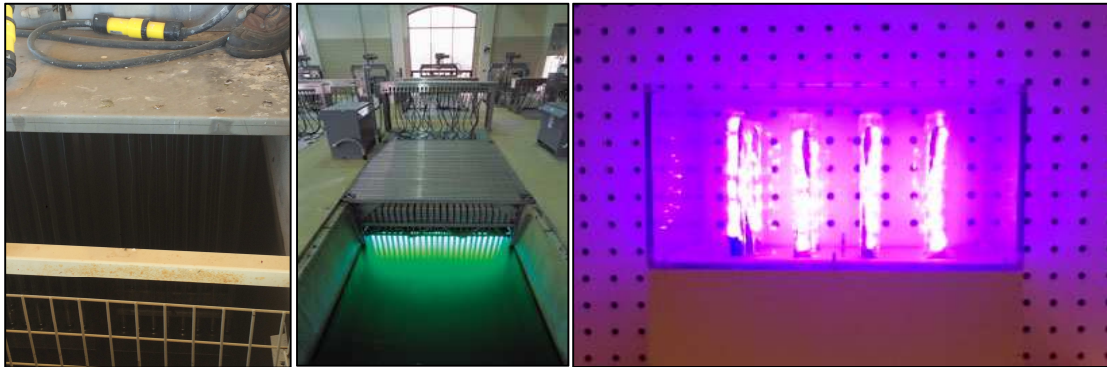


Figure 20: A UV disinfection basin at the Stillwater WWTP (Left), a lit basin (middle), and the table top UV basin (Right)

The final component of the display is concerned the reuse of wastewater. For this component, something such as agricultural irrigation would be easy to show. Also, a fun idea that could be easily integrated is having a miniature putting green that the audience could play with while at the same time showing that reclaimed wastewater can be used to irrigate areas such as golf courses. Wastewater reuse is an important topic which brings the water cycle back to a very relatable subject. Wastewater reuse is a practice that brings the health of the world to mind and reminds the students that properly using our resources is important for all of life.

Another interactive activity is a scavenger hunt worksheet. The students have to find the answers in the display. This gives the students a chance to interact with the display in a way that will help them remember the main points. This activity could also be a helpful tool in a classroom setting, providing an activity which the teachers can use as a review of the topic of wastewater treatment.

The display utilizes posters to provide information and facts about each component and process. These posters were designed with the target audience in mind and can be used in conjunction with the scavenger hunt. The display focused on the water treatment, though solids treatment could very easily be covered in either the guided tour or added into the posters. The posters can be found in the Appendix.

Each operation in the display is presented in a way that highlights each component’s individual function and importance. The worksheet provided will reinforce the main points of wastewater treatment. The interactive wastewater treatment display provides an opportunity for 4th and 5th graders to learn about the importance of wastewater cleaning and reuse. Overall, students will be encouraged to think about the importance of protecting the life-sustaining resource of water.

Cost

The following tables are the cost estimates for the construction of the team’s tabletop model and for construction of a fully completed, trailer-mounted system. Since the goal of the hydraulic model was to test the approximate sizes of the components and how they performed hydraulically, building the hydraulic model (Table 5) was significantly less expensive.

Table 5: Cost of materials for 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

The cost to fabricate and build the final tabletop model can be seen in Table 6. The cost to fabricate the tabletop would be 3 to 4 times greater from any other shop and there would be an added cost for materials. The team was also able to save money on the cost of materials in constructing the tabletop model, since some of the material was readily available at the shop. It

should also be noted that the pump mentioned in table 6 is the same pump as the one in table 5. The team did not have to buy two separate pumps.

Table 6: Cost Estimates for final tabletop 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

For Garver to construct a fully operational, trailer mounted display, the estimated cost can be found in Table 7. These assessments were based on estimates given by Wayne Kiner from the BAE shop and are projections of what it would cost Garver to fabricate using a commercial machine shop. The trailer cost was based on research done in the fall on custom trailer costs. The tabletop model is representative of what Garver would mount on their trailer of choice.

Table 7: Cost estimate for total construction of trailer-mounted system

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

Discussion of Component Fabrication

The fabrications of the components were done using the construction drawings in the Appendix, though some of the components did require a few additions. There were also several small pieces of electronics which the team borrowed from one of the BAE professors, Dr. Wang, and cannot be taken with the tabletop model. These include a small bread board, an Arduino mini, the servo motor for the clarifier, and a SyQuest Switching Power Supply (Model No. DSA-0302-01).

The grit removal chamber was constructed using a 4 to 2 inch coupler. The 4 inch section was taken off and replaced with a clear plastic ring and a small motor with an impeller was inserted into the bottom.

All of the basins were constructed using the same design and wall thickness, but with different lengths, widths, and depths. These dimensions are given in Table 8. It should be noted that these measurements are of the finished basins, and take into account the wall thickness.

Table 8: Basin dimensions

Component	Length (in)	Width (in)	Depth (in)
Bar Screen Basin	12.5	4.5	5.25
Aeration Basin	17	5	7.25
UV Basin	10.5	7	5.25

For the aeration basin, aquarium bubblers were glued to the bottom of the basin and a hole was cut for the air supply tubes. The UV basin was constructed and then holes were drilled in the bottom for the LED wires to be run through. The holes were placed such that there would be three rows of four looking at the UV basin from its longest side. Acrylic tubes with caps were used to represent the glass rods and were caulked into the wholes. The LED strips were then placed inside each tube and were wired in series. Finally, a mounting box was made to cover up all of the wiring.

The clarifier required one addition, which was a small piece of plastic tubing (3/8"), placed over the intersection between the pipe that leads to the motor and the pipe that leads to the outflow for the basin. The piece of tubing, seen in Figure 19, was used as a splashguard and protected the inner pipe from the water coming from the outlet of the outer pipe. The inner pipe connects the motor to the rotating scraper arm, so it was important to keep water from getting to it.

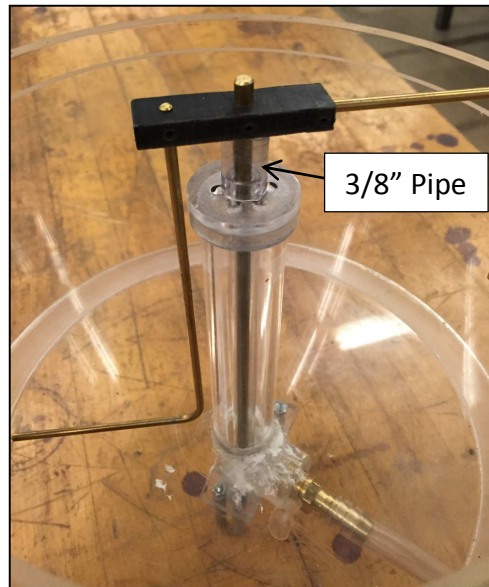


Figure 20: 3/8" pipe used to insulate pipe for motor and rotating scraper arm

The reuse section was constructed using a wooden box with a foam pad placed in it to soak up any water from a sprinkler or any demonstration of water reuse. A grass liner was placed on the foam and then trees were placed on top of the grass liner to illustrate the use of wastewater for irrigation.

Recommendations

Based on the work and testing done on the tabletop model, the senior design team has several suggestions for Garver's future manufacturing of the trailer-mounted display.

The trailer-mounted display should be properly mounted to ensure that the components are secure during travel. With the tabletop model, the pegboard slat shelves used

were adequate since securing the components was not a big concern and the layout of the components needed to be as flexible as possible. In the trailer mounted system, the senior design team suggests using “keymod” mounting fixtures. These keyhole mounts, which are found in some shelving products, would be easy to implement and would still allow some flexibility in moving the components around. Simple mounting tabs with keyhole stubs would be attached to each unit operation, and then the components could be easily popped into and out of place. Another way to make the mounted system more neat would be to add hose clamps to the back of the display. This would help keep everything secure.

Another area that could be expanded upon in a trailer mounted system is the reuse portion. With the designed flow loop system, a drip irrigation display could be easily integrated into the flow scheme, using either commercial drip-hoses or a fabricated structure. Using a commercial sprinkler would require either another pump or a standard water hose hookup. Also, as before mentioned, a mini-golf putting green could be a great way to show irrigation along with a fun activity for the audience. Any of these options could be left up to the presenter’s preference. Another idea for the reuse section that the senior design team recommends would be to have a faucet and cups where kids could pour their own cup of “reused” wastewater to drink. This too could be easily integrated into the flow loop design.

To get some feedback about the quality of the display, two teachers with experience in teaching 4th and 5th grades were given the educational material and pictures of the display and how it would be used. One of the comments received back was that some of the vocabulary may be too difficult. It was also mentioned that a keyword list would be a helpful tool for teachers using the display. Another point of discussion was that the usage of a bathroom in the display may be a little too distracting for the students. A different point of relatability could easily be used instead, like a kitchen or laundry room. The teacher’s feedback and the scavenger hunt can be seen in the appendices.

It should also be noted that the posters (found in the Appendices) utilized in the senior design team’s final display were designed and printed out with the 4’ X 8’ pegboard in mind. All

of the components and posters had to fit within that space. It may be beneficial for Garver to rearrange the components and posters in a different way in the actual trailer. Since the components are compartmentalized, there is enough flexibility in the design and hydraulics of the system that they can be moved, and the posters will be provided in a form that can be edited as Garver needs.

Some notes for the improvement of the final display include adding some kind of indication of level of water cleanness. This could be done using different colored clear acrylic for the construction of the components, or in some note on the posters. At the final demonstration of the display, some helpful feedback was received, including an idea about how to better indicate the water cleanness. One of the suggestions was to use different reservoirs for each component with varying levels of dye in it. That would be simpler than trying to add dye and then try to evenly dilute it through the system. It would require each component with flowing water to have its own pump. But this also is not necessarily a bad thing. It was noted at the demo that the one motor used was a little loud, so it would be beneficial to switch out to smaller quieter pumps.

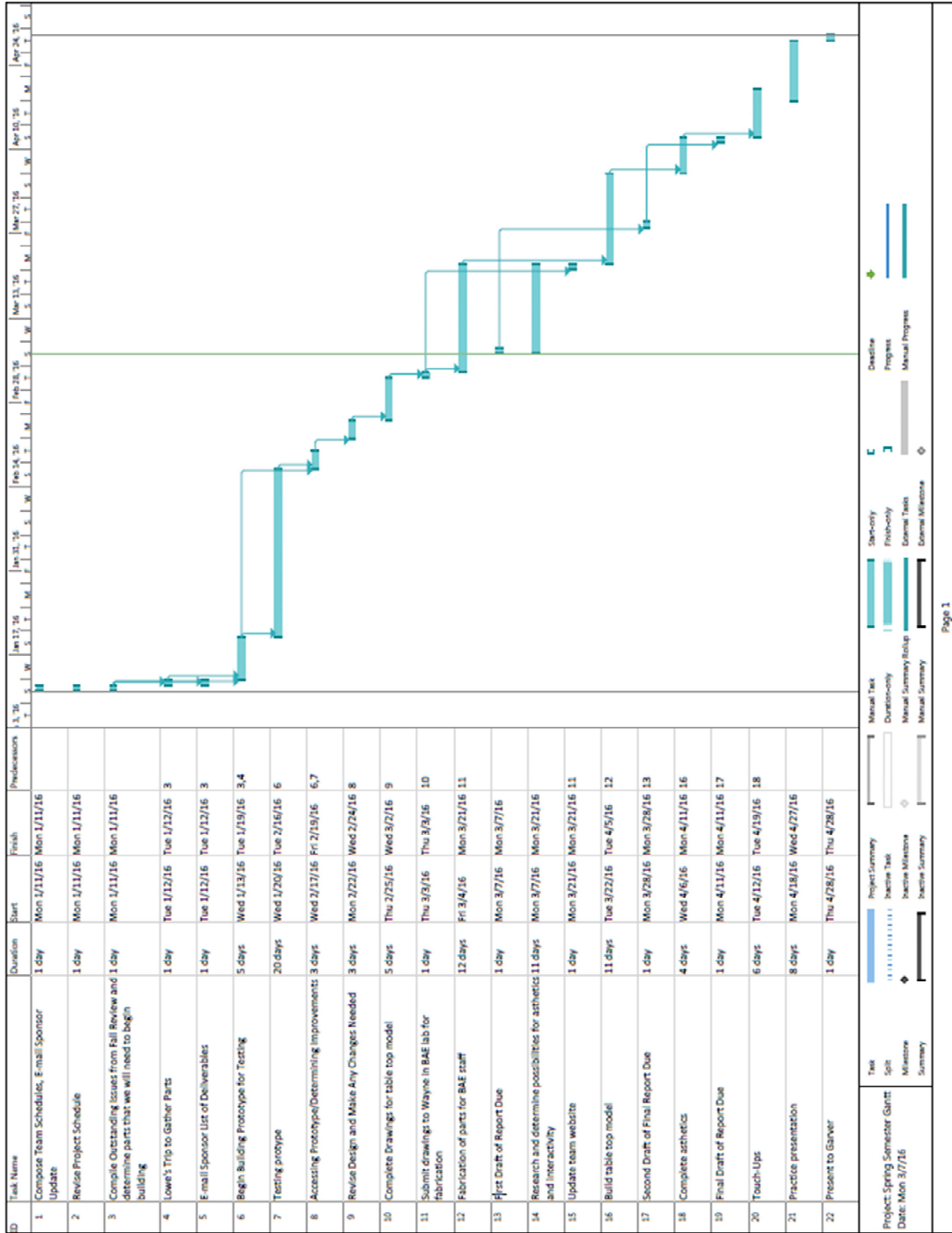
Based on some of the feedback from Garver at the final demonstration, another helpful addition to the display would be to indicate the connections between each component. With the compartmentalized design it is easier to move things around and simplifies a lot of things, but it is still necessary to have some way of representing that the components are sequential. One way to do that would be to use plastic pipes on the front side of the display that appear to be attached to the different components. The final layout of the components would first be finalized, then the posters could be mounted, and finally, the tubes could be permanently mounted showing the connection between each component.

Finally, some notes on the construction and ease of use of the display. The UV basin was a little large and so was slightly out of proportion to the other components. In future construction, it can easily be made smaller. Another small note for the construction of the aeration basins would be to add the hole for the air supply tubes closer to the top edge of the

basin. It can be difficult to move the components around when they are attached to the hoses. For the ease of use of the display, it may be beneficial to change out the barb hose fittings for something that is still water tight but is easier to take on and off.

Appendices

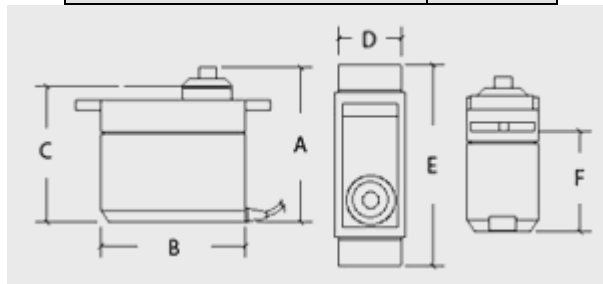
Spring Gantt Chart



Electrical Specifications

HX5010 Servomotor:

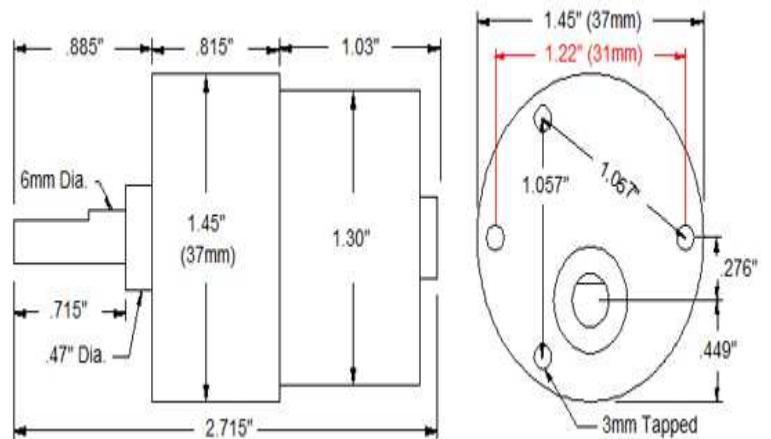
Hextronik Servomotor Specifications	
Weight (g)	39
Torque (kg)	6.5
Speed(Sec/60deg)	0.16
A(mm)	44
B(mm)	40
C(mm)	40
D(mm)	20
E(mm)	55
F(mm)	29



10 RPM Gear Motor:

Operating Range: 3-12VDC

- Torque @ Max Efficiency: **127 oz-in. @ 12VDC**
- Torque @ Stall: 368 oz-in. @ 12VDC
- Stall Current: 0.5A @ 12VDC
- **Gear train damage can occur if stalled (locked)**
- .240" (6mm) Diameter Shaft
- No load current: 45mA
- No load current @ Max Efficiency: 95mA (12V)
- No load speed: **10 RPM**
- No load speed @ Max Efficiency: 7.96 RPM
- Gear ratio: 300:1 · Motor size: 1.30"Dia. 1.015"L ·
- Gear size: 1.45"Dia. x .985"L
- Shaft size: 6mm (0.236") Dia. x 0.715"L
- Weight: 0.2813 lbs. (4.5 oz.)
- DC reversible motors
- Solder type terminal
- High torque construction



Servomotor Coding:

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

int pos=0;              //variable to store the servo position
void setup() {
myservo.attach(3);      //attaches the servo on pin 3 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 degrees
  {
    myservo.write(pos);          //tell servo to go to position in variable 'pos'
    delay(3000);
  }
}
```

Operating Instructions & Parts Manual

Models: 5UXL7 thru 5UXL9 and 5UXN0

Please read and save these instructions. Read this operating manual carefully before starting to assemble, install, operate or maintain the product. Follow all the safety information to protect yourself and others. Please make sure to comply with instructions. Any failure to follow the safety instructions could cause serious personal injury and/or property destruction. Keep these instructions for future reference.

Dayton® Utility Flexible Impeller Pumps

Description

Dayton Utility Flexible Impeller Pumps are self-priming pumps, have a wide range of applications in general commercial and industrial applications where there are non-abrasive, nonflammable liquids compatible with the pump material make-up. The pumps are designed for transferring liquids, emptying or filling tanks, sinks or basins. The pumps can be used to pump bilge water, but the pump must not be located in the bilge area. Self-priming to 7 ft, if the impeller is initially wet (primed). The maximum liquid temperature of pump is 140F, the minimum liquid temperature of pump is 40F. Carrying handle included.



Figure1

NOTE: Pump is NOT RECOMMENDED for use with soap detergents, gasoline, waste oil, fuel oil, flammable, explosive or combustible liquids or other fluids not compatible with pump component materials. Do not use pump in enclosed areas. Intermittent duty only (15 minutes per hour).

Performance

Motor HP	Model	Dimensions (inch)			GPM at Total Feed of Head						Shutoff (ft)*
		L	W	H	5	10	20	30	40	50	
1/10	5UXL7	6.75	4.00	4.50	5.20	4.43	3.05	1.41	--	--	37.3
1/10	5UXL8	6.10	4.00	4.21	3.72	3.32	2.31	1.15	--	--	36.7
1/10	5UXL9	6.75	4.00	4.50	5.20	4.43	3.05	1.41	--	--	37.3
1/10	5UXN0	6.10	4.00	4.21	3.72	3.32	2.31	1.15	--	--	36.7

(*) Shut-off, to convert to PSI, divide by 2.31

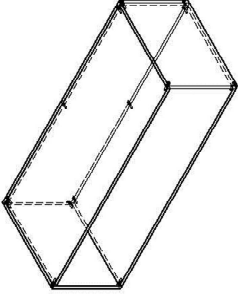
NOTE: All dimensions have a tolerance of $\pm 1/8"$.

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Construction Drawings

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B	A	A
2	1	1

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ANGULAR: MACH: BEND .1	Q.A.			
W/3 PLACE DECIMAL ± .01	COMMENTS:			
THREE PLACE DECIMAL ± .005				
INTERPRET GEOMETRIC TOLERANCING PER:				
MATERIAL				
FINISH				
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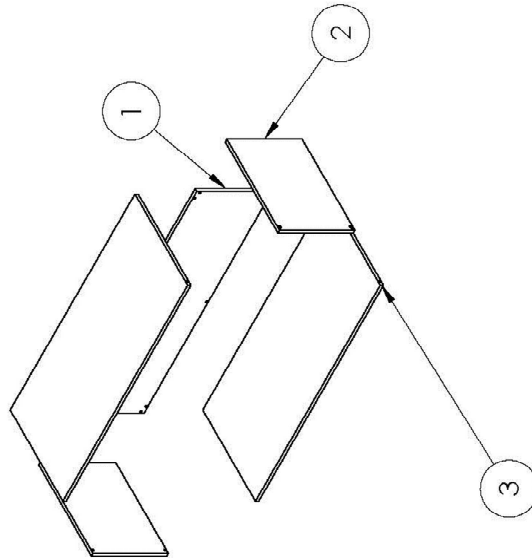
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2	ends	5X7X.21 ACRYLIC	2
3	sides	7X16.58X.21 ACRYLIC	2

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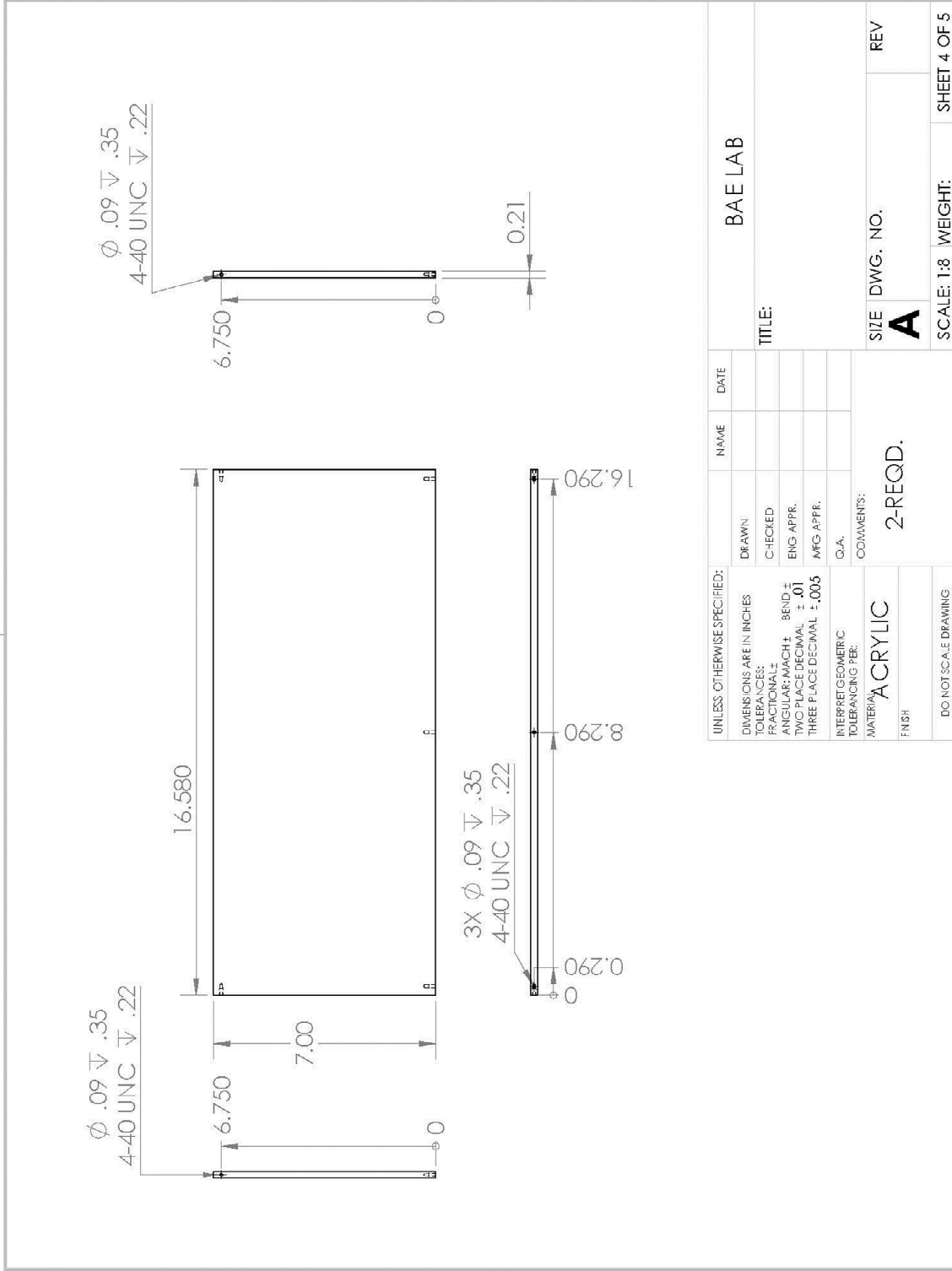
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MATERIAL			
FINISH			
DO NOT SCALE DRAWING			
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ANGULAR: MACH ±	MFG APPR.		
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THREE PLACE DECIMAL ± .005	COMMENTS:		
INTERPRET GEOMETRIC TOLERANCING PER:			
MATERIAL: ACRYLIC			
FINISH:			
DO NOT SCALE DRAWING			

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BAE LAB

TITLE:

REV

SIZE DWG. NO. **A**

SHEET 4 OF 5

SCALE: 1:8 WEIGHT:

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2X ϕ .09 ∇ .35
4-40 UNC ∇ .22

2X ϕ .13 THRU ALL
 ϕ .23 X 100°

4.750
0.250
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5.000
4.895
0.105
0
7.00
6.75
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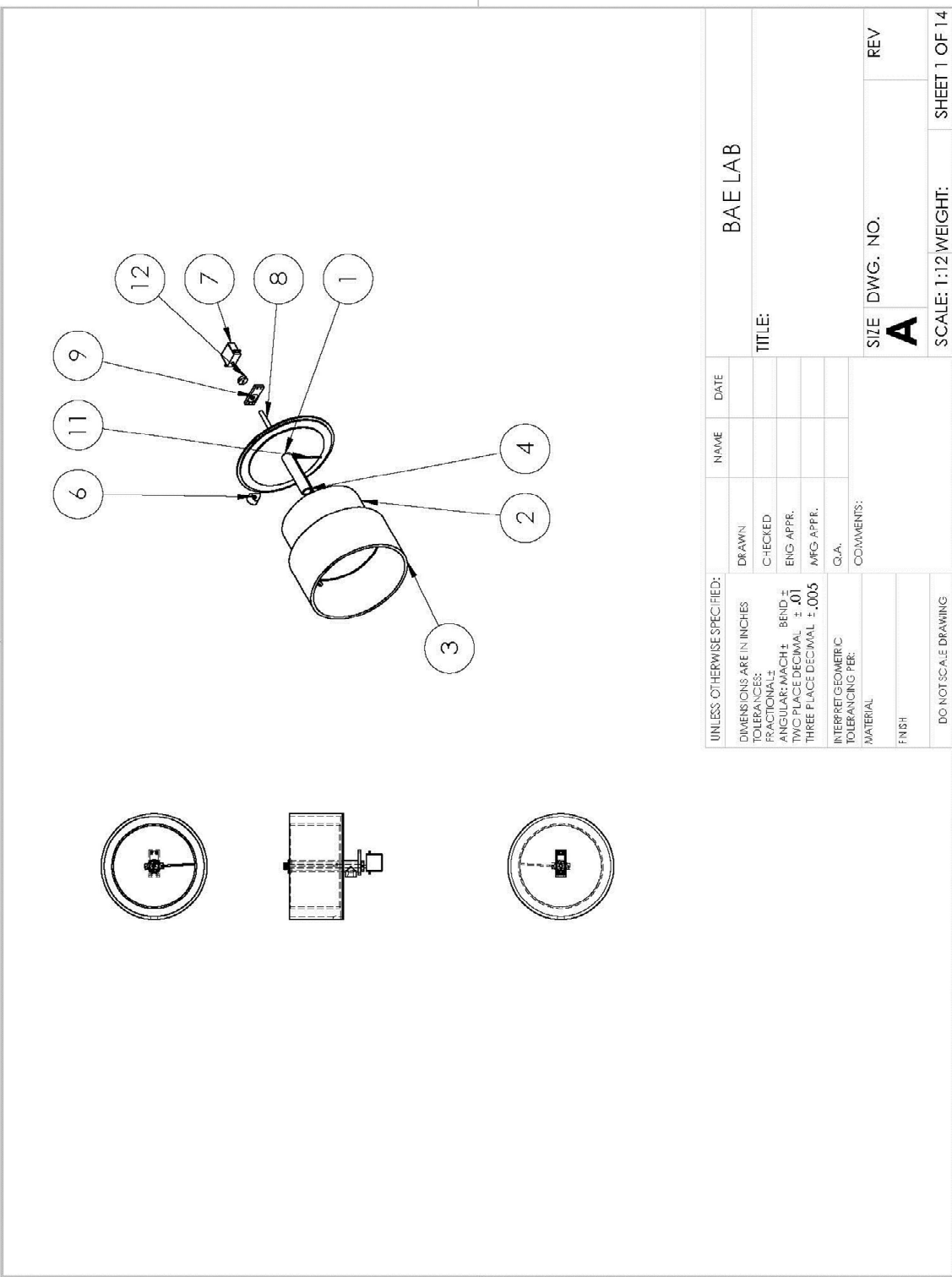
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SCALE: 1:12 WEIGHT: SHEET 1 OF 14

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1	clarifier base		1
2	inner ring		1
3	outer ring		1
4	water tube		1
5	guide		1
6	adapter		1
7	servo		1
8	guide tube		1
9	mmount		1
10	top drive		1
11	boom		1
12	coupler		1

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ANGULAR/MACH ± BEND ±		Q.I.A.	COMMENTS:
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THREE PLACE DECIMAL ± .005			
INTERPRET GEOMETRIC TOLERANCING PER:			
MATERIAL			
FINISH			
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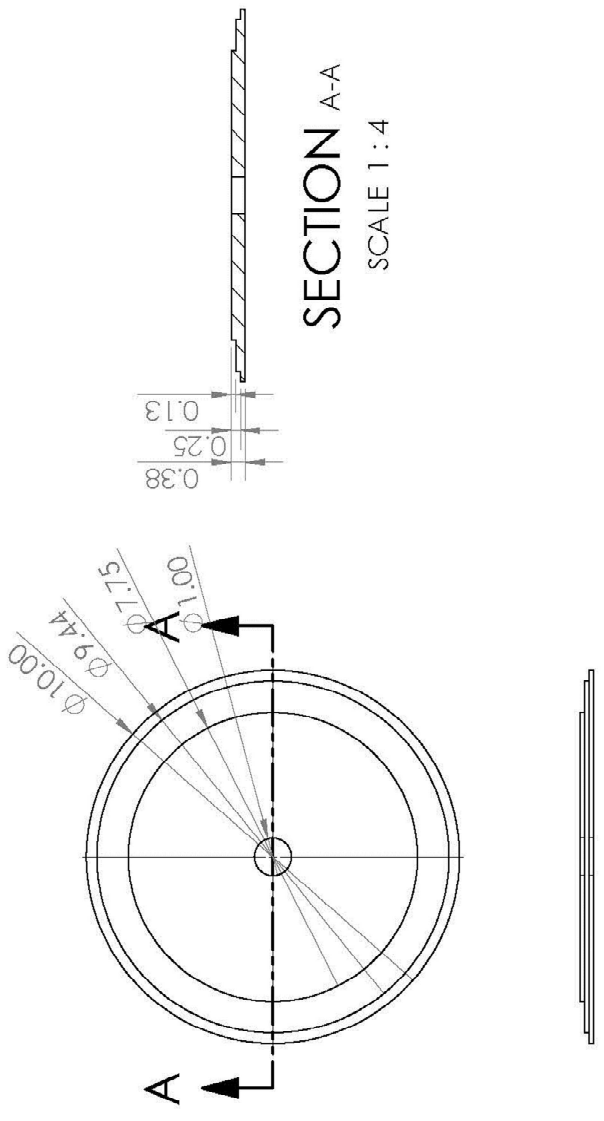
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SECTION A-A
SCALE 1:4

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ANGULAR: MACH	MFG APPR.		
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FINISH			
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BAE LAB

TITLE:

SIZE DWG. NO.

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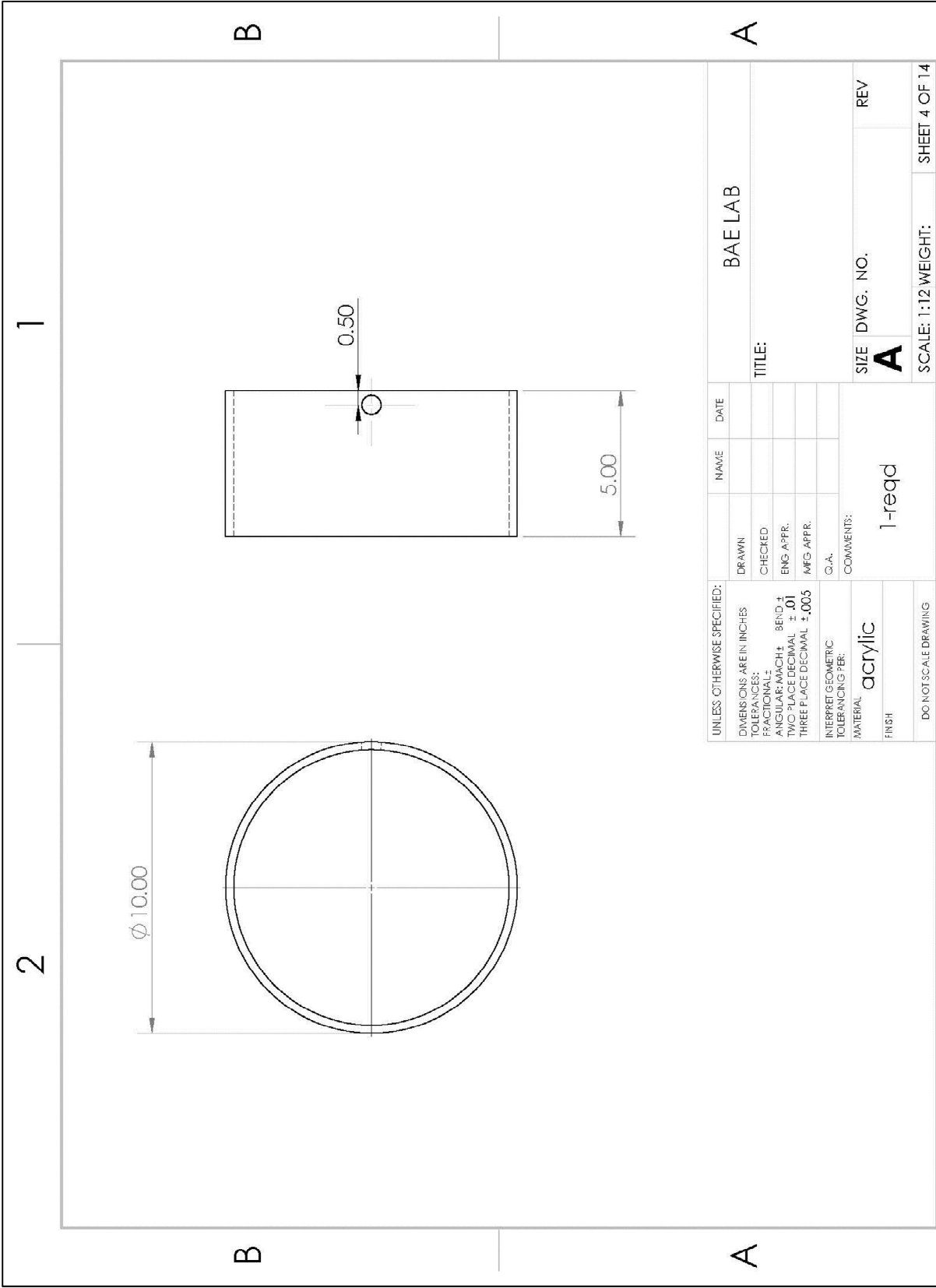
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SHEET 3 OF 14

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THREE PLACE DECIMAL $\pm .005$	COMMENTS:		
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FINISH:			
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BAE LAB

TITLE:

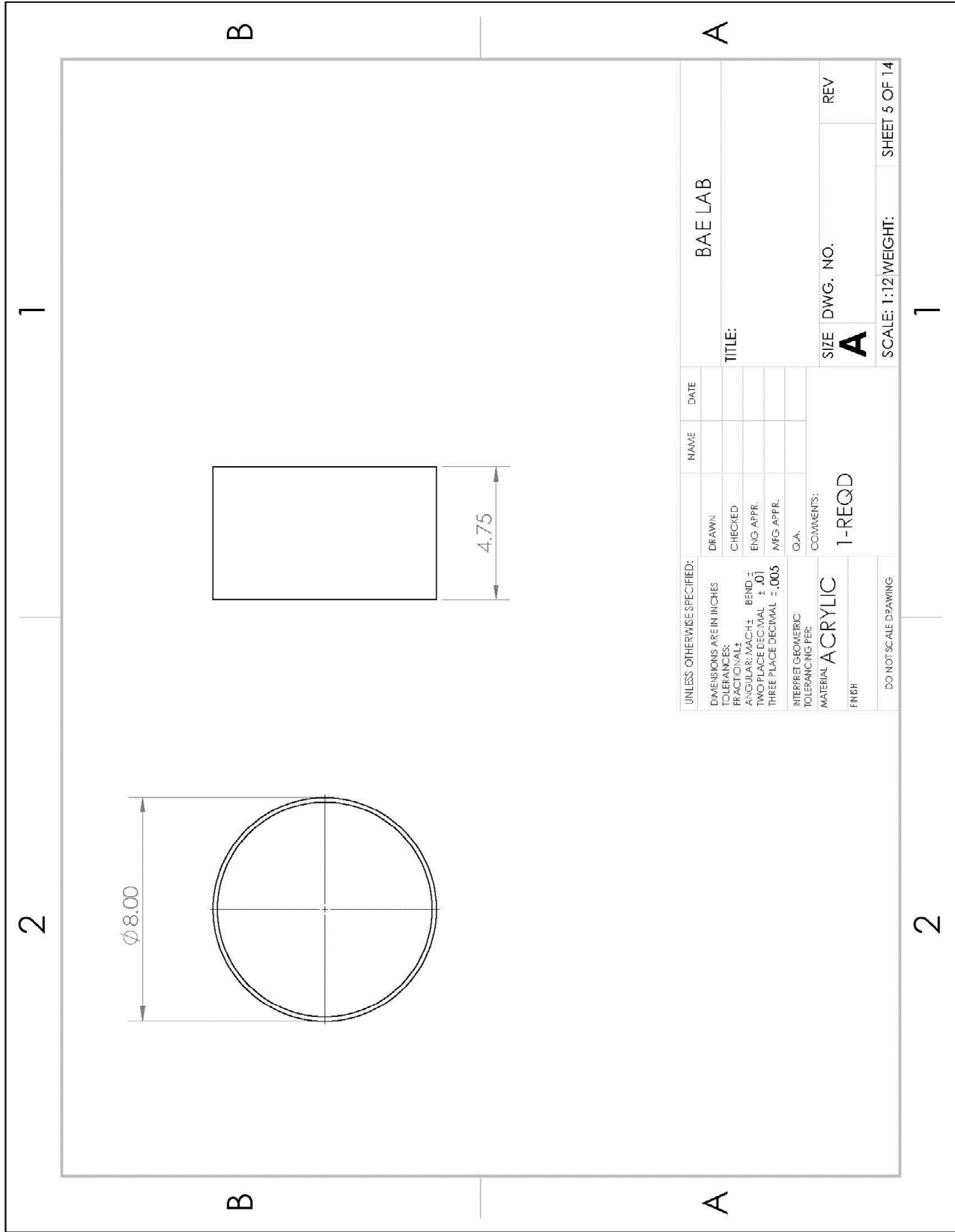
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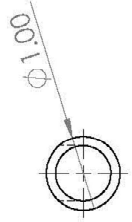
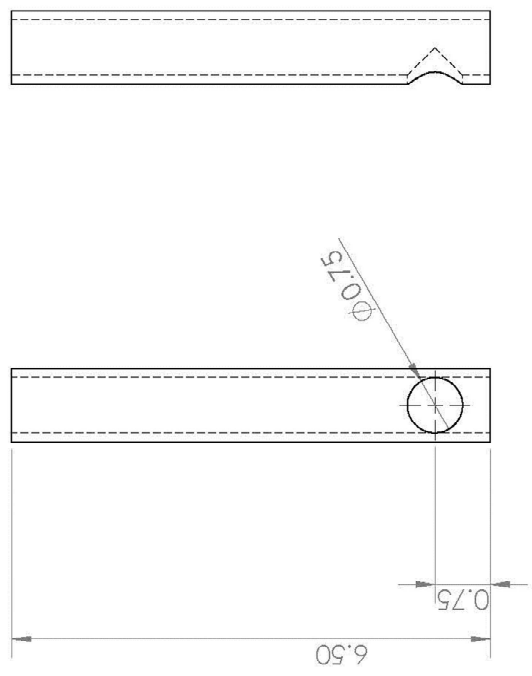
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THREE PLACE DECIMAL ± .005		1-REQD.				
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MATERIAL ACRYLIC						
FINISH						
DO NOT SCALE DRAWING						

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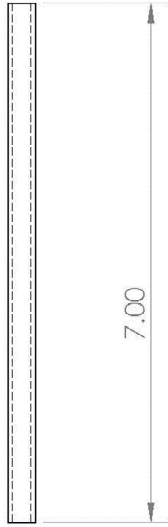
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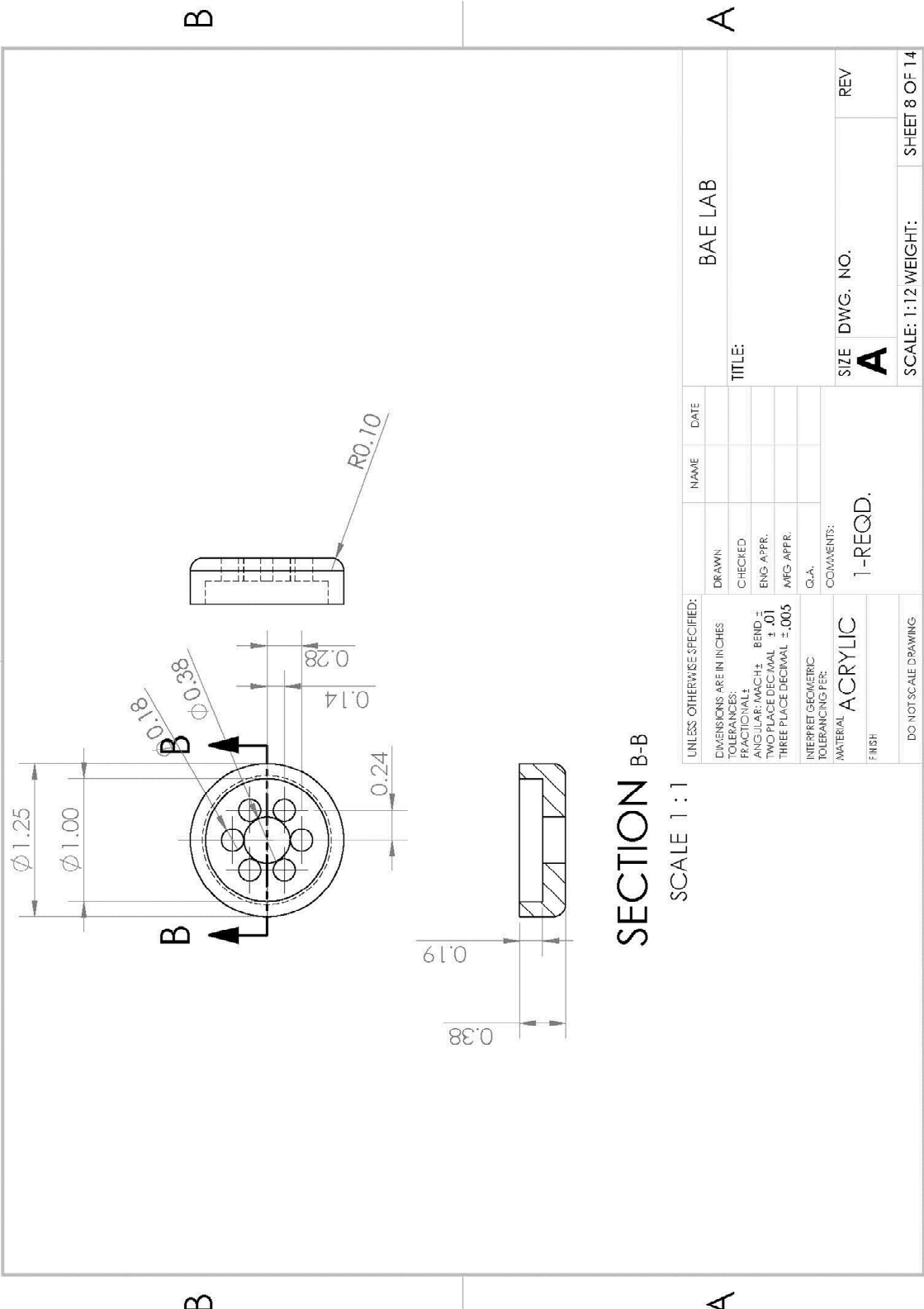
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ANGULARS: MACH ±		COMMENTS:						1-REQD	
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SECTION B-B

SCALE 1 : 1

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DIMENSIONS ARE IN INCHES	DRAWN		
TOLERANCES:	CHECKED		
FRACTIONAL:	ENG APPR.		
ANGULAR: MACH ± .01	Q.A.		
TWO PLACE DECIMAL ± .005	COMMENTS:	1-REQD.	
THREE PLACE DECIMAL ± .003	MATERIAL	ACRYLIC	
INTERPRET GEOMETRIC TOLERANCING PER:	FINISH		
	DO NOT SCALE DRAWING		
TITLE:		BAE LAB	
SIZE	DWG. NO.	REV	
A			
SCALE: 1:12		WEIGHT:	SHEET 8 OF 14

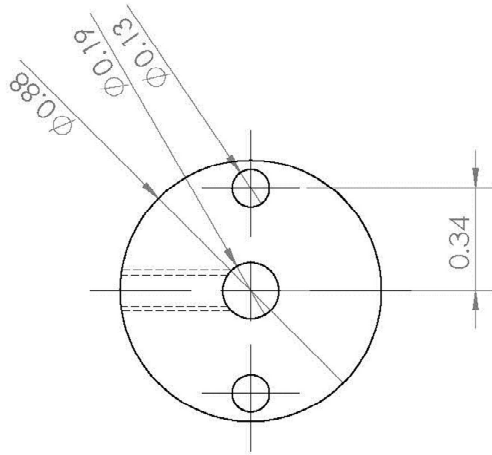
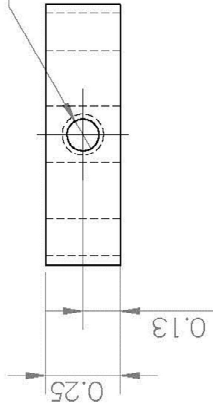
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$\phi .11$ THRU
6-32 UNC THRU



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UNLESS OTHERWISE SPECIFIED:		NAME	DATE	BAE LAB	
DIMENSIONS ARE IN INCHES	DRAWN			TITLE:	
TOLERANCES:	CHECKED				
FRACTIONAL: \pm	ENG A*PR.				
ANGULAR: MACH: \pm	MFG APPR.				
TWO PLACE DECIMAL: $\pm .01$	Q.A.				
THREE PLACE DECIMAL: $\pm .005$	COMMENTS:				
INTERPRET GEOMETRIC TOLERANCING PER:				SIZE	DWG. NO.
MATERIAL: ACETAL	1-REQD			A	REV
FINISH					
DO NOT SCALE DRAWING				SCALE: 1:12	WEIGHT: SHEET 9 OF 14

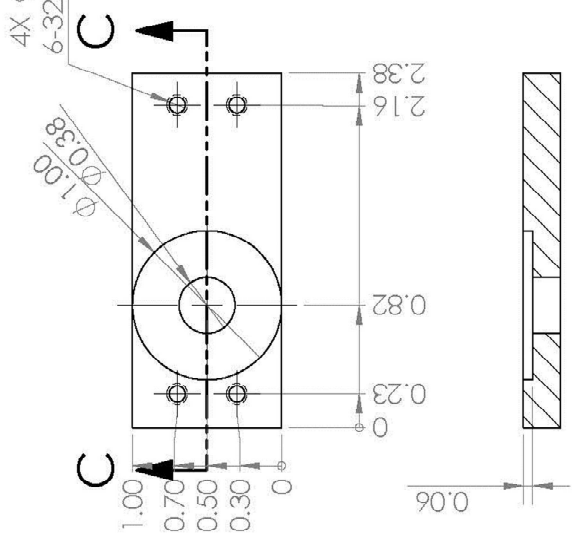
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6-32 UNC THRU ALL



SECTION C-C
SCALE 1 : 1

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES	DRAWN		
TOLERANCES:	CHECKED		
FRACTIONAL	ENG APPR.		
ANGULAR: MACH	BEND		
TWO PLACE DECIMAL \pm .01	MFG APPR.		
THREE PLACE DECIMAL \pm .005	G.A.		
INTERPRET GEOMETRIC TOLERANCING PER:	COMMENTS:		
MATERIAL	1-REQD		
FINISH			
DO NOT SCALE DRAWING			

BAE LAB

TITLE:

SIZE DWG. NO. REV

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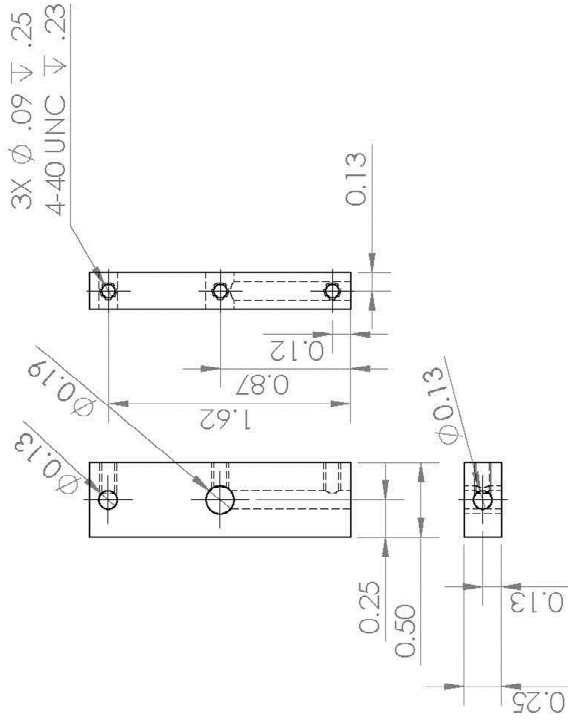
SCALE: 1:12 WEIGHT: SHEET 10 OF 14

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UNLESS OTHERWISE SPECIFIED:		NAME	DATE
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TOLERANCES:	CHECKED		
FRACTIONAL:	ENG A*PR.		
ANGULAR: MACH	MFG APPR.		
BEND: \pm			
TWO PLACE DECIMAL: $\pm .01$			
THREE PLACE DECIMAL: $\pm .005$			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL: ACETAL	COMMENTS:	1-REQD.	
FINISH			
DO NOT SCALE DRAWING			

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TITLE:

SIZE DWG. NO.

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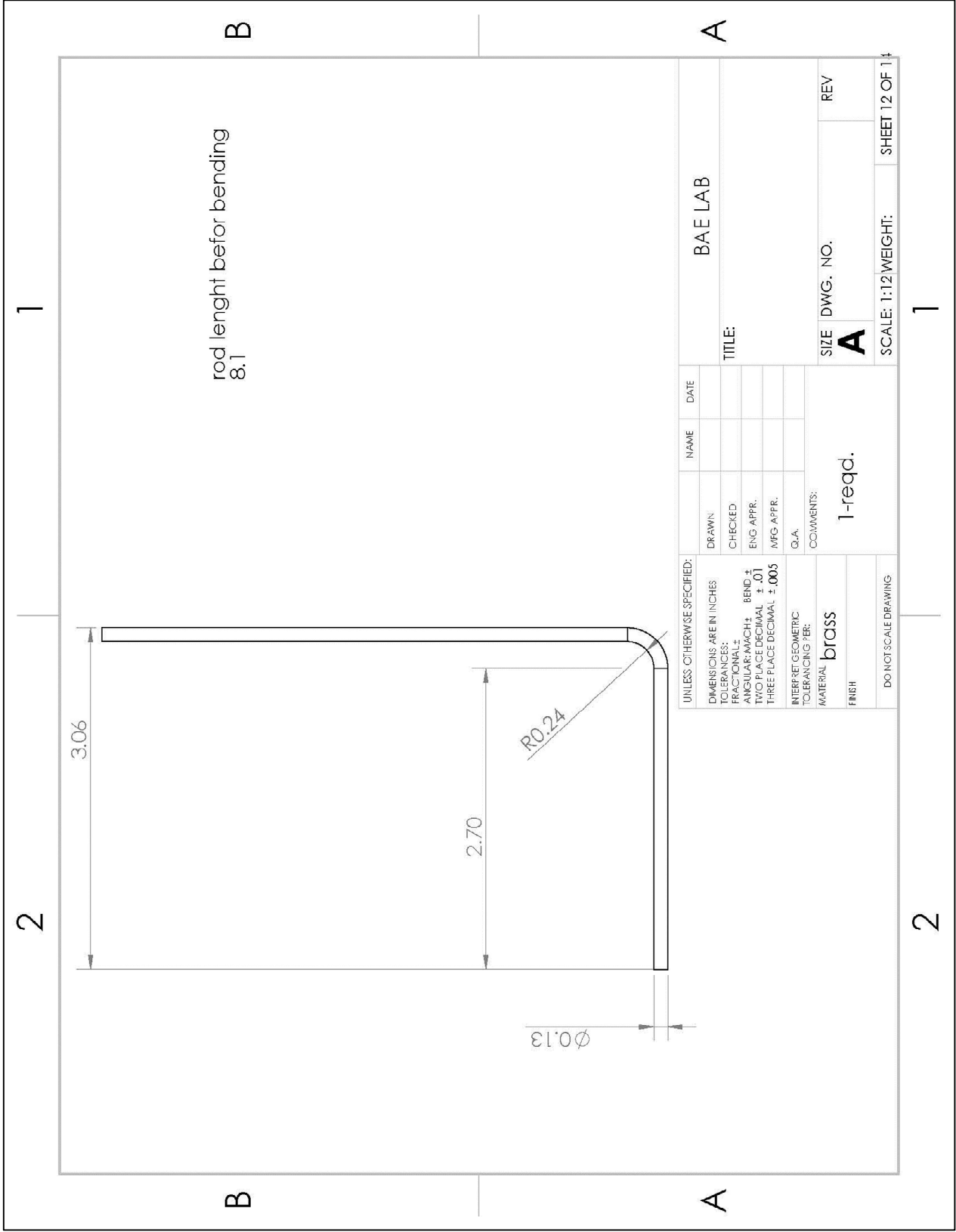
REV

SCALE: 1:12 WEIGHT:

SHEET 11 OF 14

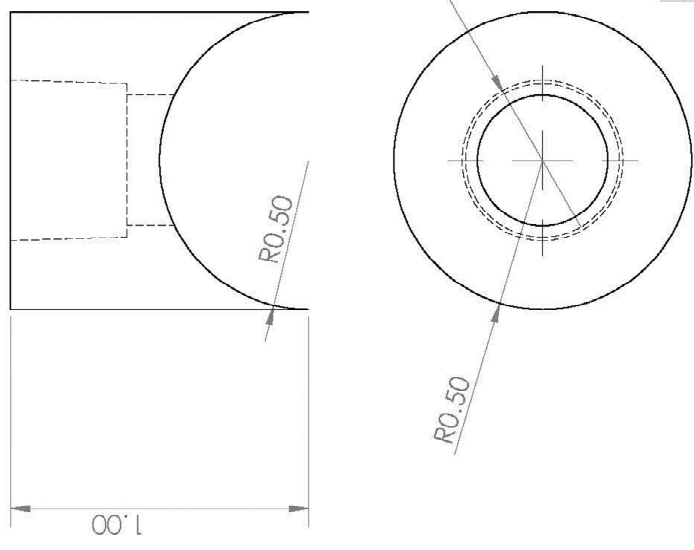
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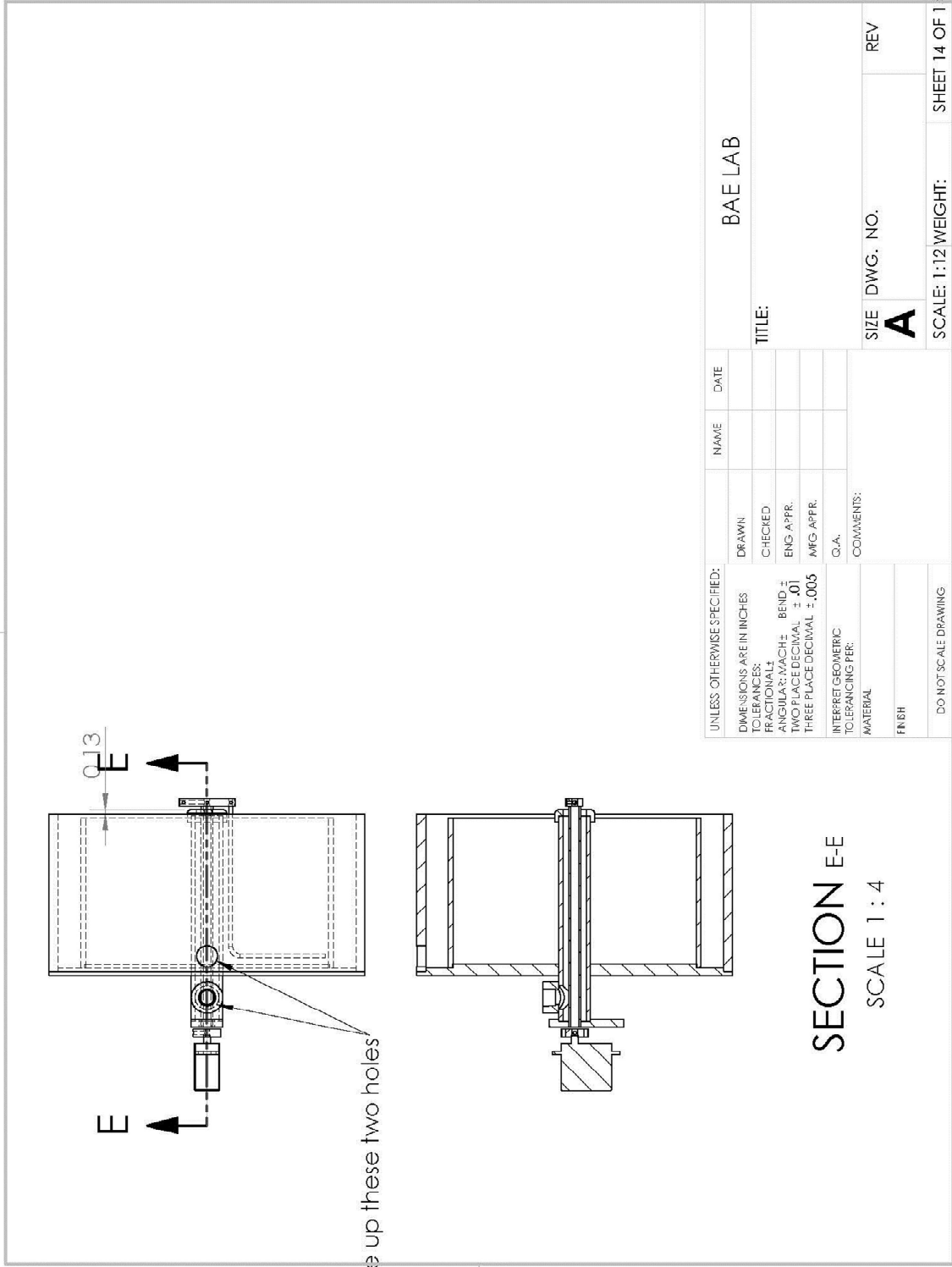
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DIMENSIONS ARE IN INCHES		DS/AVIN	
TOLERANCES:		CHECKED	
FRACTIONS: 1/16, 1/8, 1/4, 3/8, 1/2		ENG APPR.	
DECIMALS: 0.0005, 0.001, 0.002, 0.005, 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1.0		MFG APPR.	
ANGLES: 30°, 45°, 60°, 90°, 120°, 150°, 180°		Q.A.	
HOLE LOCATIONS: 0.005		COMMENTS:	
HOLE DIAMETERS: 0.005		SIZE	DWG. NO.
HOLE DEPTHS: 0.005		A	REV
HOLE TOLERANCES: 0.005		SCALE: 1:12	WEIGHT: SHEET 13 OF 14
HOLE FINISH: 0.005		DO NOT SCALE DRAWING	
HOLE MATERIAL: 0.005		FINISH	
HOLE FINISH: 0.005		DO NOT SCALE DRAWING	

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line up these two holes

SECTION E-E
SCALE 1 : 4

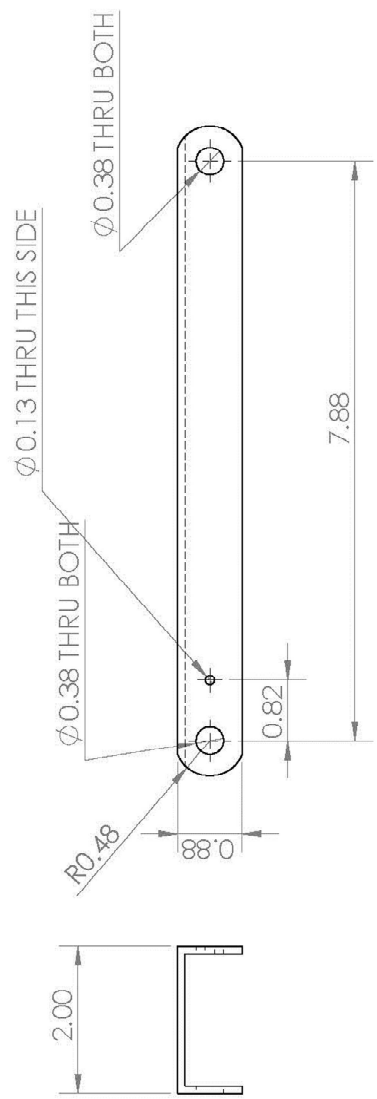
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TOLERANCES:		CHECKED			
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ANGULAR: MACH BEND ±		MFG APPR.			
TWO PLACE DECIMAL ± .01		G.A.		SIZE DWG. NO. A REV	
THREE PLACE DECIMAL ± .005		COMMENTS:		SCALE: 1:12 WEIGHT: SHEET 14 OF 14	
INTERPRET GEOMETRIC TOLERANCING PER:		MATERIAL			
FNSH		DO NOT SCALE DRAWING			

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CUT FROM SQUARE TUBE

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UNLESS OTHERWISE SPECIFIED:		DRAWN:	NAME	DATE	BAE LAB	
DIMENSIONS ARE IN INCHES		CHECKED:			TITLE:	
TOLERANCES:		ANGULAR: MACH:			SIZE DWG. NO. A	
FRACTIONAL:		BEND: ±			REV	
TWO PLACE DECIMAL ± .01		THREE PLACE DECIMAL ± .005			SCALE: 1:4 WEIGHT: SHEET 1 OF 1	
INTERPRET GEOMETRIC TOLERANCING PER:		Q.A.			1-REQD.	
MATERIAL		COMMENTS:	1-REQD.			
2 INCH SQ TUBE						
FINISH						
DO NOT SCALE DRAWING						

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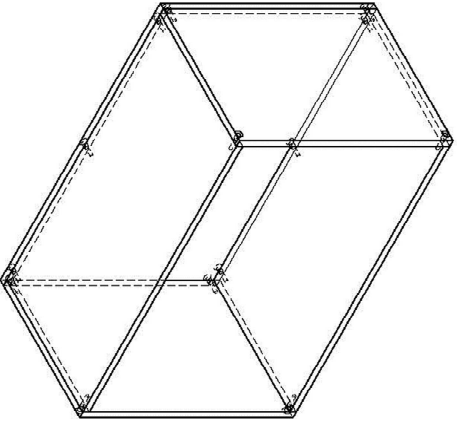
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UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES	DRAWN		
TOLERANCES:	CHECKED		
FRACTIONAL: MACH	ENG A*PR.		
ANGULAR: MACH	MFG APPR.		
TWO PLACE DECIMAL: ± .01			
THREE PLACE DECIMAL: ± .005			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

BAE LAB

TITLE:

SIZE DWG. NO.

A

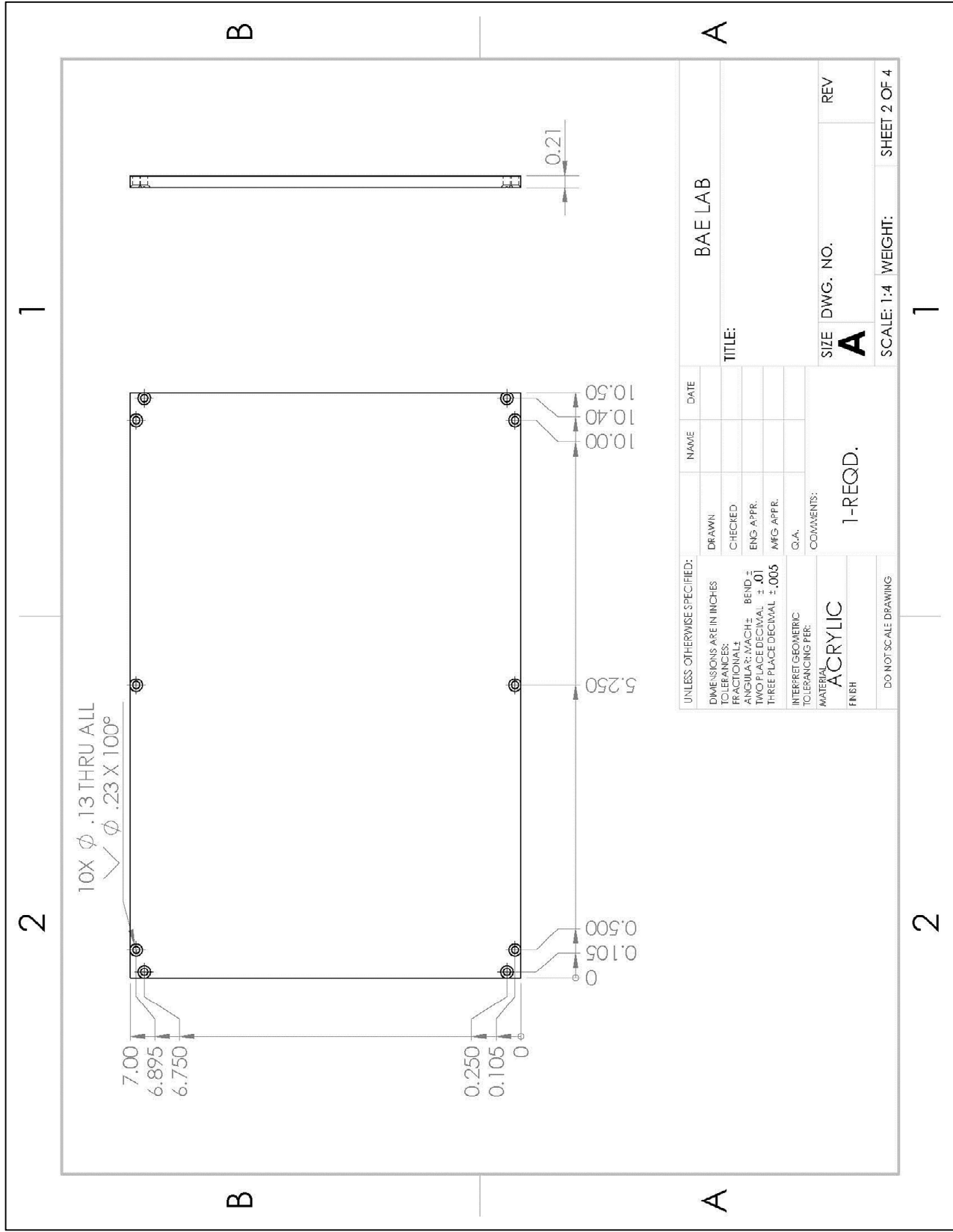
REV

SCALE: 1:4 WEIGHT:

SHEET 1 OF 4

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UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES	DRAWN		
TOLERANCES:	CHECKED		
FRACTIONAL	ENG A*PR.		
ANGULAR: MACH	MFG APPR.		
BEND \pm			
TWO PLACE DECIMAL \pm .01			
THREE PLACE DECIMAL \pm .005			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL	COMMENTS:		
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FINISH			
DO NOT SCALE DRAWING			

BAE LAB

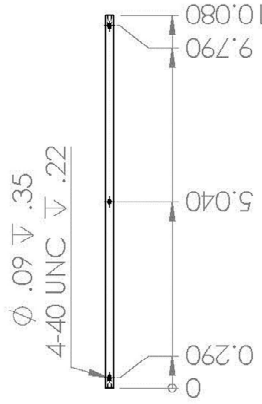
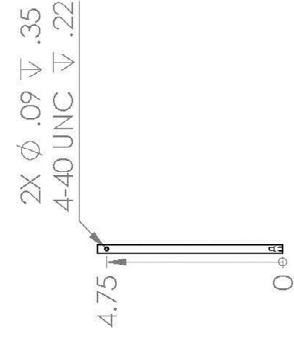
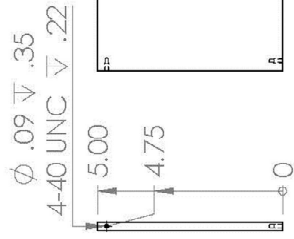
TITLE:

SIZE DWG. NO. **A** REV

SCALE: 1:4 WEIGHT: SHEET 2 OF 4

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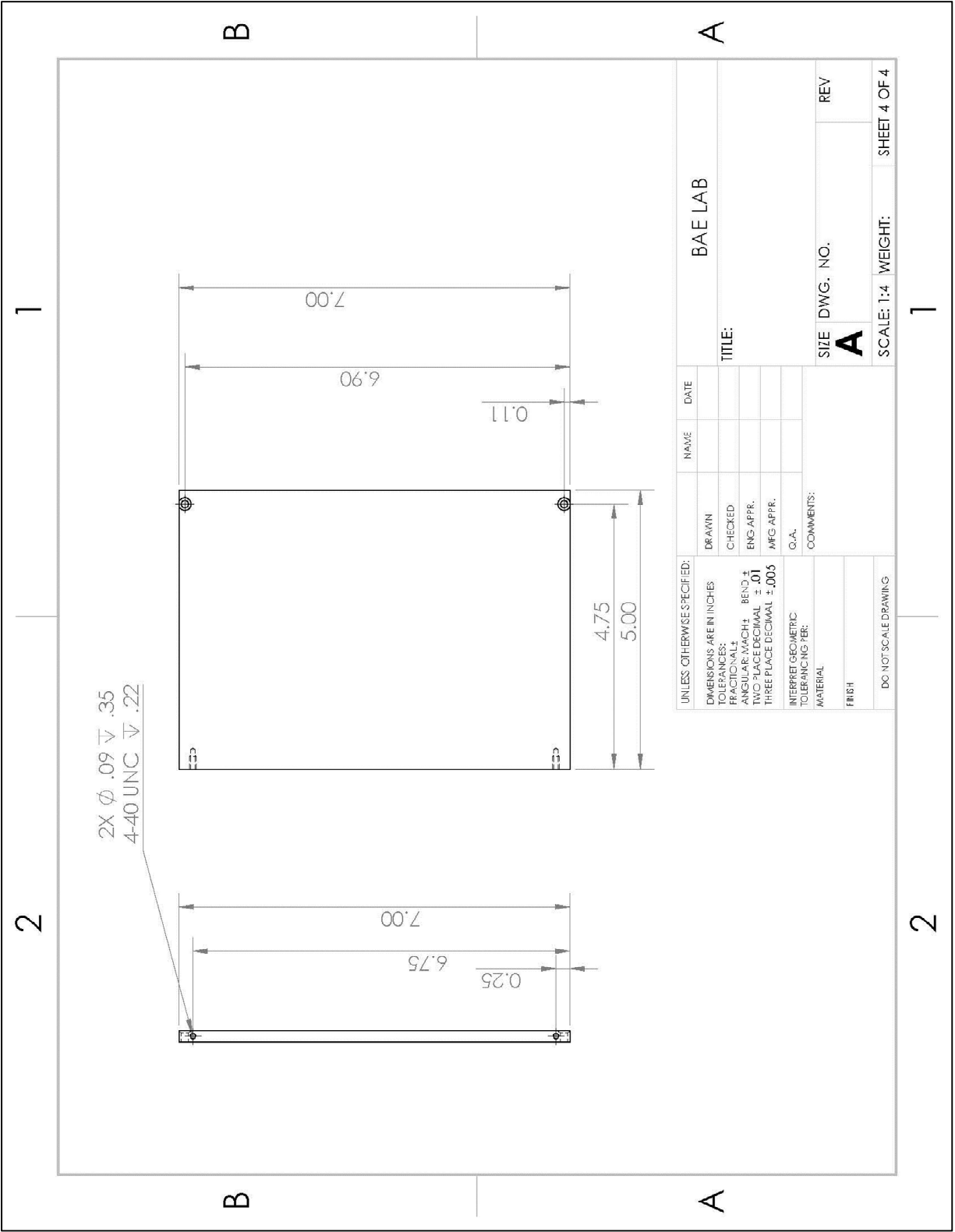
A

A

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	BAE LAB	
DIMENSIONS ARE IN INCHES		DRAWN		TITLE:	
TOLERANCES:		CHECKED		REV	
FRACTIONAL ±		ENG. APPR.		SIZE DWG. NO. A	
ANGULAR: WACH ± BEND ±		MFG APPR.		SCALE: 1:4 WEIGHT: SHEET 3 OF 4	
TWO PLACE DECIMAL ± .01		G.A.			
THREE PLACE DECIMAL ± .005		COMMENTS:			
INTERPRET GEOMETRIC TOLERANCING PER:		MATERIAL			
FINISH					
DO NOT SCALE DRAWING					

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Poster Display



Interactive Wastewater Treatment Display

AquaCleanse Solutions
OSU Biosystems and Agricultural Engineering
Cole Niblett, Olivia Broussard, Brandy Parks, Abigail Parnell



Water is a very important resource that is necessary for life. Can you think of a day when you went entirely without using water? Water is used for a wide range of things, from as important a function as our own hydration and food production to as mundane a task as flushing the toilet. Wastewater is treated in four stages: pretreatment, primary treatment, secondary treatment, and tertiary treatment.



Pretreatment

The first step in treating wastewater is to remove large pieces of debris and as much inorganic material as possible. Inorganic means that it is not something produced in nature and can decay. An example of an inorganic material is plastic. The pretreatment stage of wastewater treatment includes the **mechanical bar screens** and the **grit removal basin**.

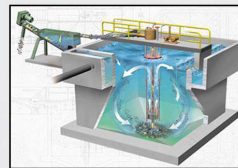
Mechanical Bar Screens Treatment

The mechanical bar screens are typically the first process in a wastewater treatment plant and are used to remove the largest pieces of debris and other floating pollutants. This is a physical process that removes solids that could clog and damage later processes in the system.



Grit Removal Treatment

After wastewater leaves the mechanical bar screens, it flows to the grit removal chamber, which is used to remove small inorganic solids which can damage pipes. The picture and the display below shows a vortex. Grit can be made up of inorganic solids like sand and gravel, as well as organic solids like coffee grounds, egg shells and other food wastes.



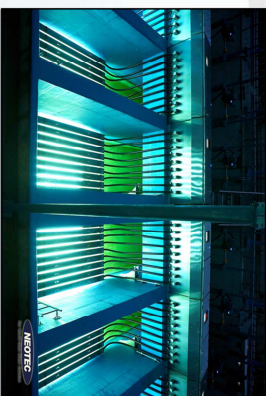
Primary Treatment

After wastewater has made its way through the headworks of the plant, it reaches the *primary treatment* stage. Here, the plant is trying to remove any suspended solids that made it through pretreatment. These suspended solids are settled out to the bottom of tanks called *clarifiers*, where they can be collected as sludge. Also, any large waste that floats will be removed by *rake arms*. Primary treatment removes things like grease, plastic, leaves, rags, and even HAIR!



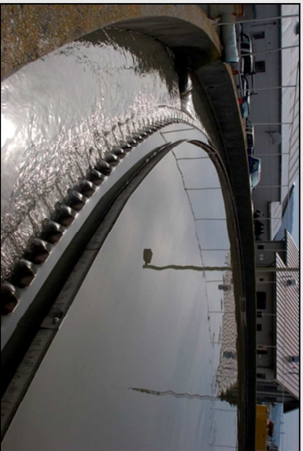
Tertiary Treatment

Since the wastewater has made its way through primary and secondary treatment, it is now time for *tertiary treatment*. Tertiary treatment is performed to remove things like harmful viruses and nutrients such as phosphorus and nitrogen. Processes like chemical disinfection, filtration, and ultraviolet (UV) disinfection are all forms of tertiary treatment.



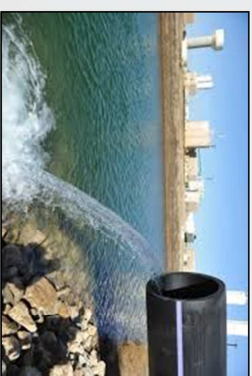
Secondary Treatment

Secondary treatment is where most of the *organic matter* is removed. Organic matter is anything that comes from living things, and can include different kinds of waste from plants, animals, and humans. To remove organic matter, we use *microbes*! Microbes, which are sometimes called *bugs*, are tiny organisms like bacteria, fungus, and algae that eat organic matter to survive. We provide the bugs with food and a place to live (wastewater), and they remove wastes that we don't want in our water! After they spend awhile eating and growing, we usually send them to another clarifier to settle out as sludge. At this point, the water is looking pretty clean!



Wastewater Reuse

Wastewater Reuse is a great way to help conserve water use and the environment. There are two types of wastewater reuse for drinking water: *direct* and *indirect reuse*. Direct reuse is when a plant treats wastewater and then sends it directly to a town's drinking water plant. Indirect reuse happens when treated wastewater is sent to a body of water that someone uses as their drinking water source. Generally, to reuse wastewater, plants must further treat the water using advanced methods. This could mean treating the water with things like reverse osmosis, ion exchange, or Nano filtration! Wastewater can also be reused for things like irrigation water.





Lift Station

The lift station pumps wastewater from a lower elevation to a higher elevation. The elevation differences are usually caused by natural obstructions such as hills or mountains.



Source: © T.T. Pumps LTD. 2011

Teacher Feedback



Wastewater Interactivity/Educational Feedback

Thank you for taking the time to evaluate AquaCleanse's Interactive Wastewater Treatment Display. Prior to filling this out, you should have received pictures of the full display and each component as well as the educational material (posters and scavenger hunt). Thank you again!

Name: Vicky Parnell

Signature: Vicky Parnell

Date: 4-26-16

Experience Teaching (What grades): All elementary grades

1. Was the display and presentation understandable? Yes

2. Was there anything that was too simple or too complex?

Some vocabulary may be too difficult for 4th/5th graders

3. Would you use the educational tools provided? (Posters + Scavenger hunt handout)

Yes. Would be good preparation before a field-trip to a water treatment plant.

4. Was there anything really bad about the presentation/display?

4th/5th graders will have a hard time being serious about toilets and "debris"

5. Was there anything really good about the presentation/display?

The mechanical display will be a good representation of the process. Kids will love it.

6. How would you rate the educational value (1 to 10, with 10 being the highest)?

-10-

7. How would you rate the interactive value (1 to 10, with 10 being the highest)?

-10-

8. Do you have any suggestions for how this presentation/display could be improved?

- More specific instructions for Scavenger Hunt -

"Scan the posters for the answers to the following questions."

- Key words defined

Second Teacher Response

Name: Margaret Carroll

Teaching Experience: Elementary School levels including 5th

"This looks good.

My only question is why was the last page called a scavenger hunt? Is this sheet used as you tour a water plant? Otherwise it just seemed like questions to answer. Scavenger hunt part all kinds of fun activities to my mind which this sheet did not live up to. If you want to make something fun for kids, turn your questions into a crossword puzzle or word search. You can still ask the questions, just use the answers in more of a game format. Kids will enjoy that!"

Scavenger Hunt

Wastewater Scavenger Hunt: Use the posters to answer the following questions

1. Name something that you use water for.
2. How does a wastewater treatment plant get water over obstacles?
3. Which operation(s) are purely physical cleaning processes?
4. Which operation(s) employ the use of microbes to clean the water?
5. In which unit operation can you find this?

Bonus: What is this part called?



6. What kind of disinfection process is displayed?
7. How is cleaned wastewater reused?



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

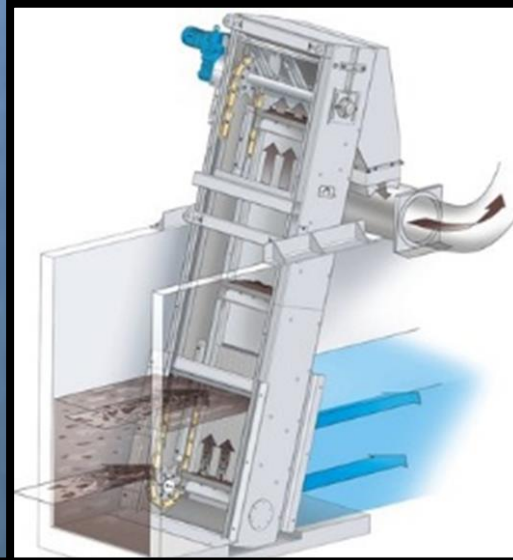
- Garver Engineering
- Multi-disciplined firm
- Headquarters: Little Rock, AR
- Point of contact: Mary Elizabeth Mach, PE
 - Norman, OK office
 - 2006 OSU BAE Graduate

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

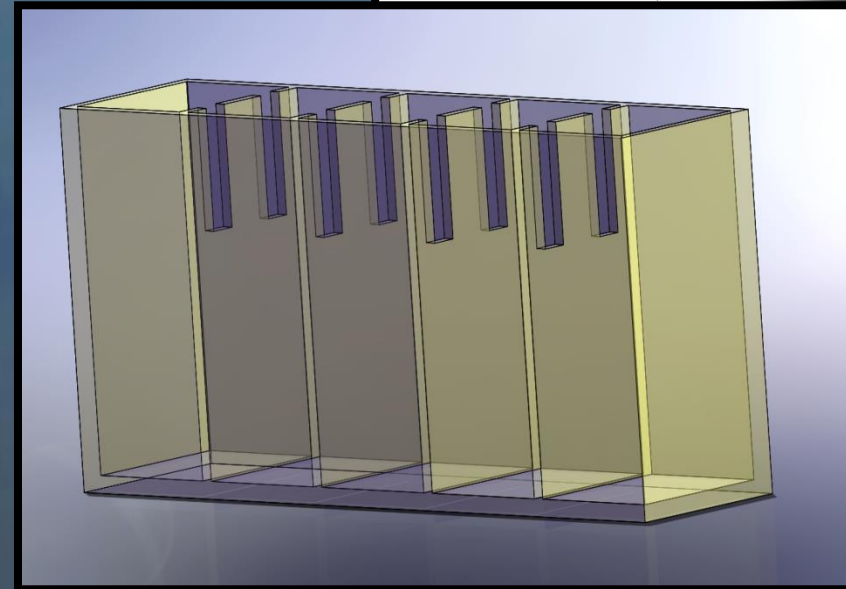
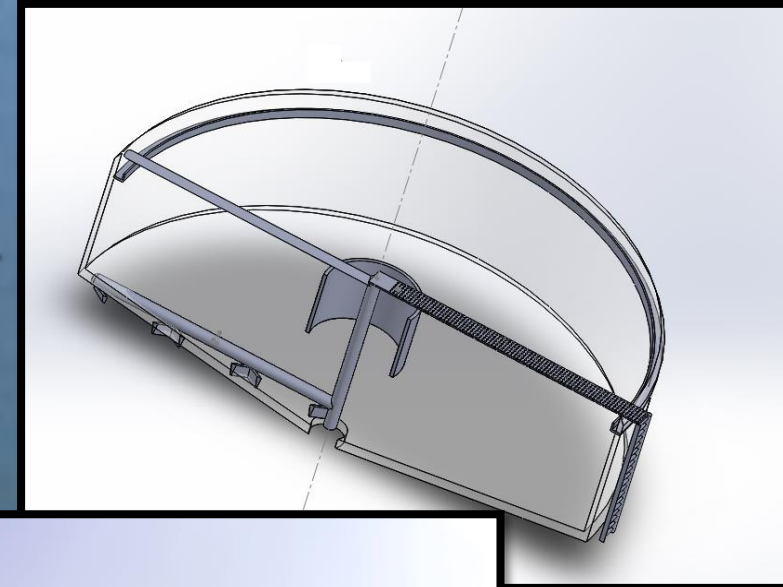
WASTEWATER TREATMENT OVERVIEW

- 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

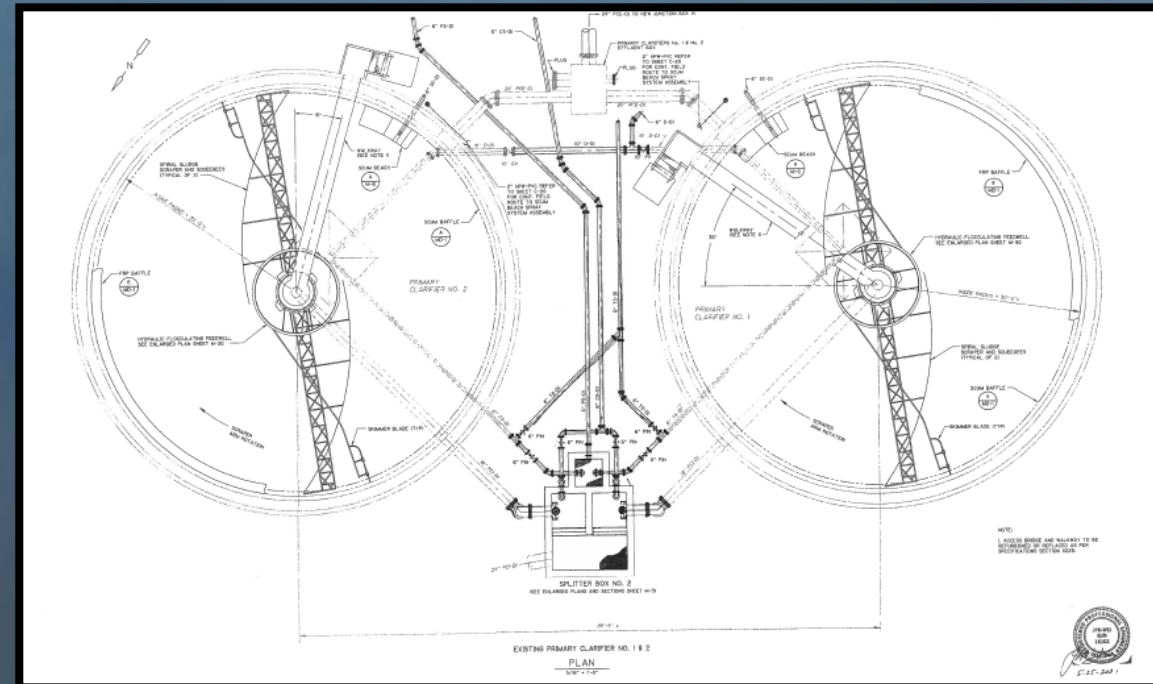


SIZING OF UNIT OPERATIONS

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

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

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



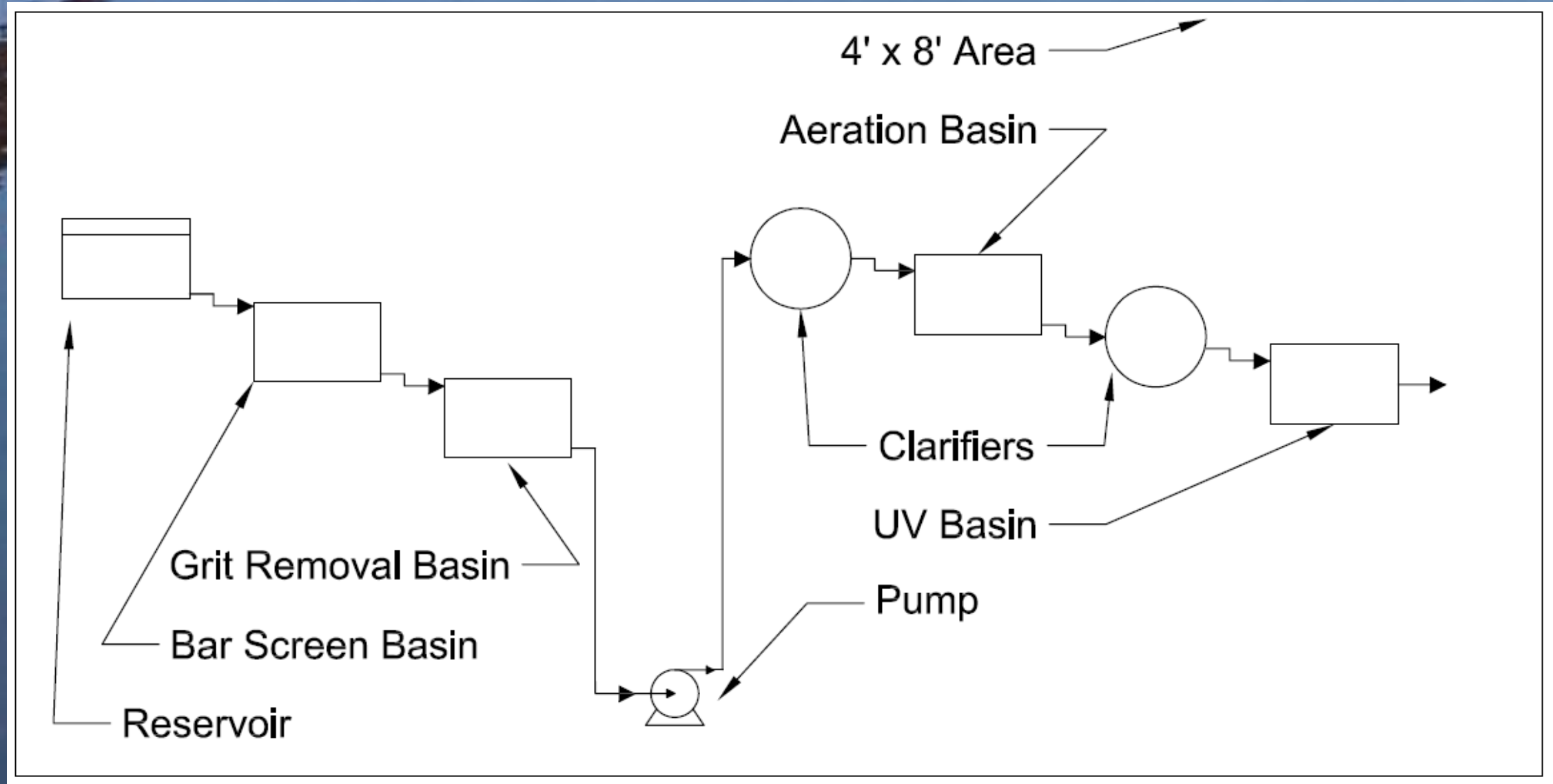
SIZING OF UNIT OPERATIONS

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

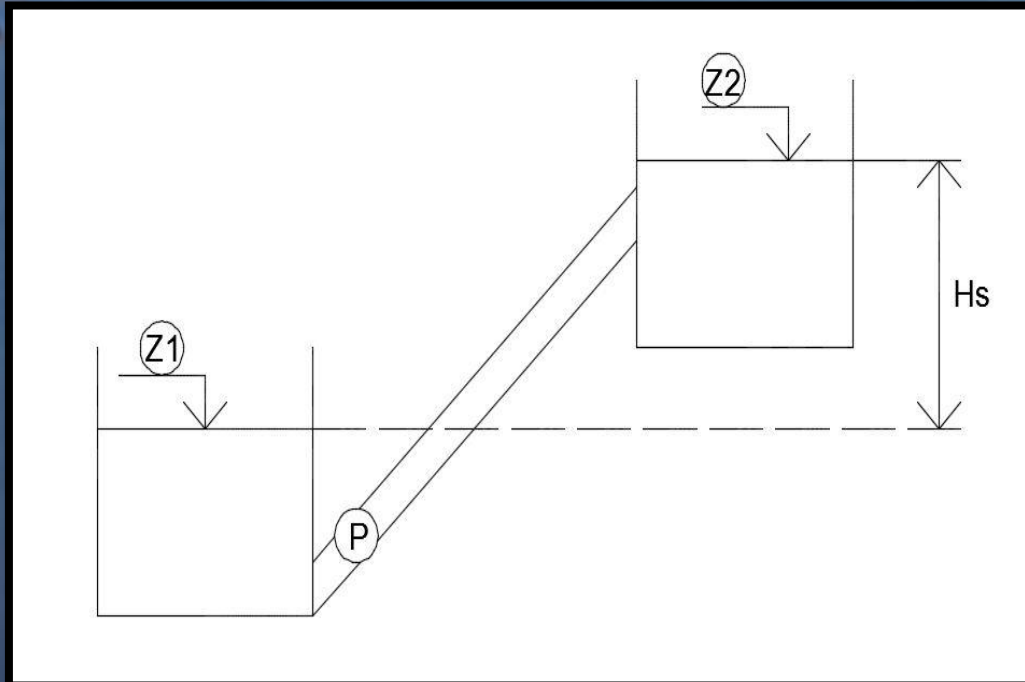
HYDRAULIC CALCULATIONS

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

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

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

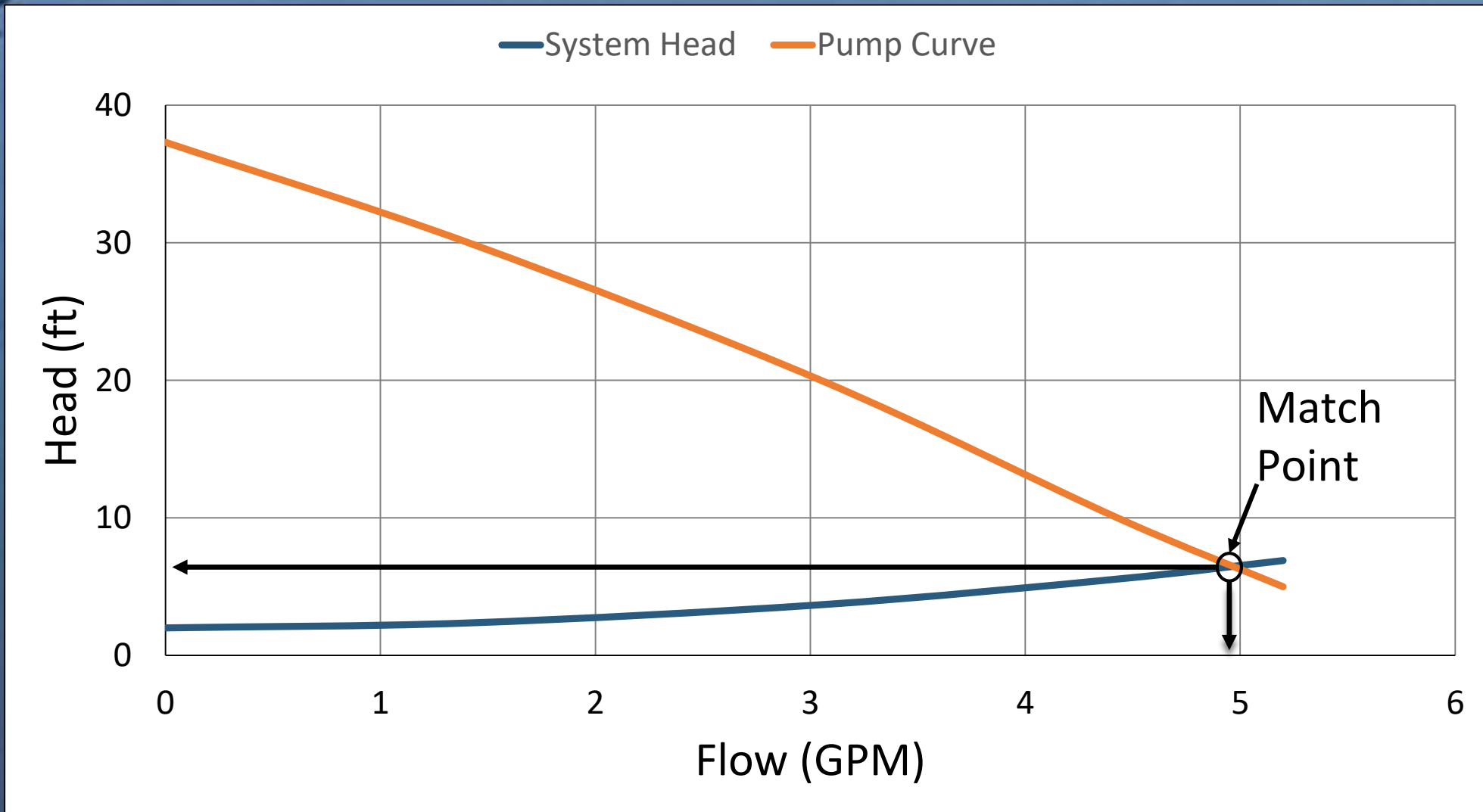
$$f = .025 \quad K_{valve} \sim 20$$



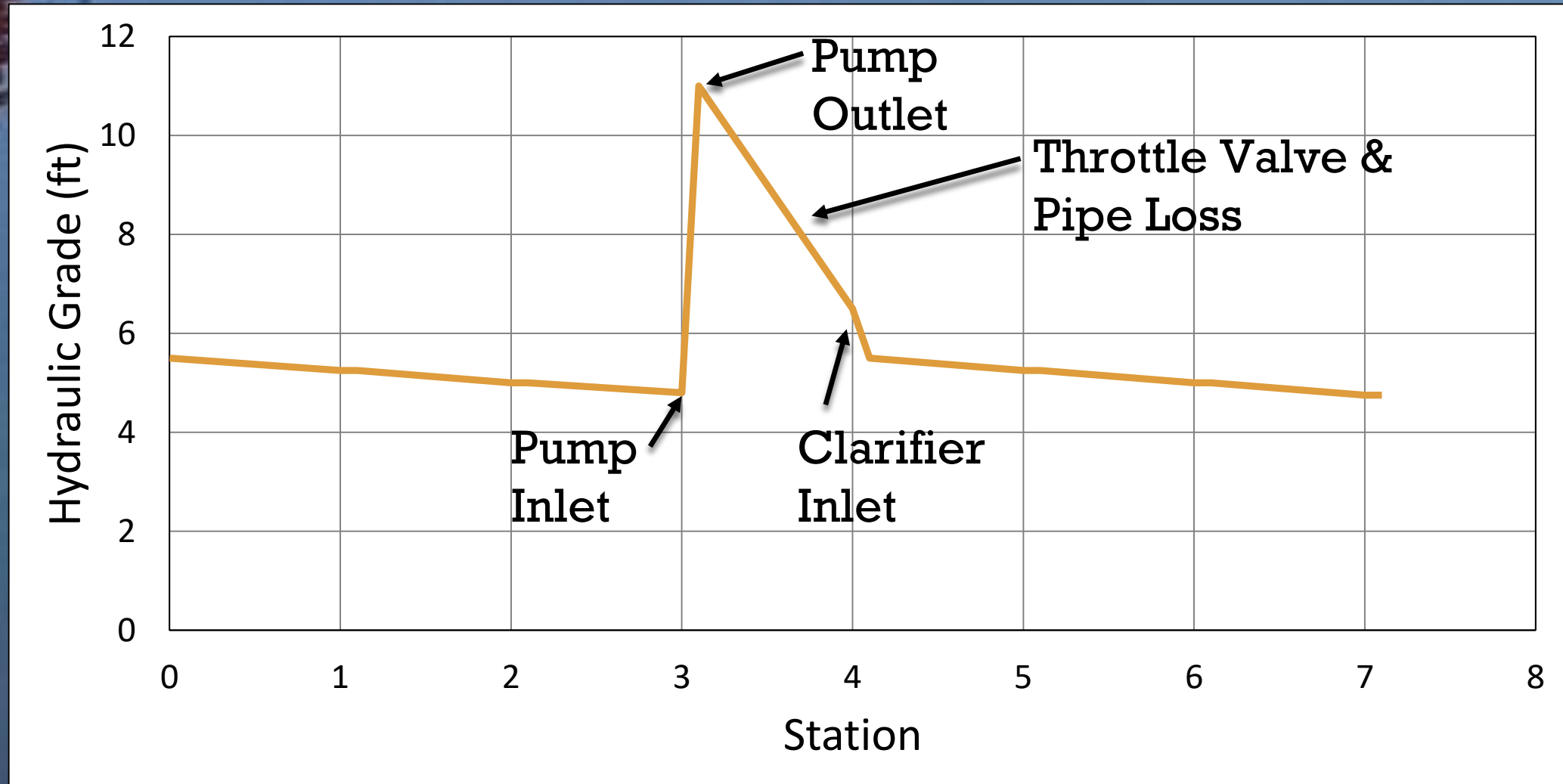
HYDRAULIC CALCULATIONS

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

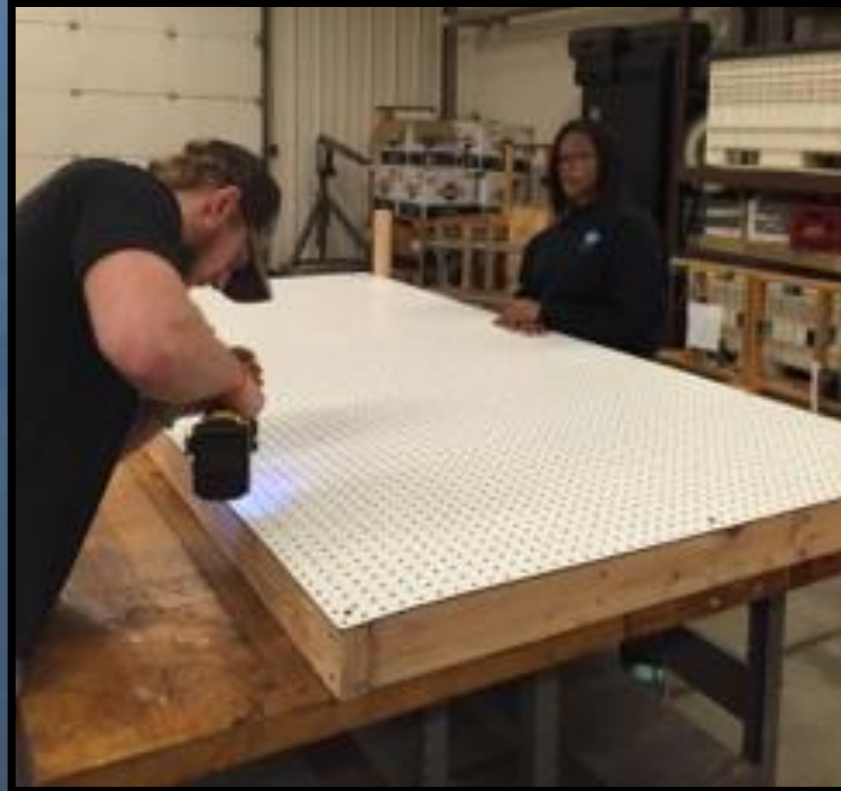
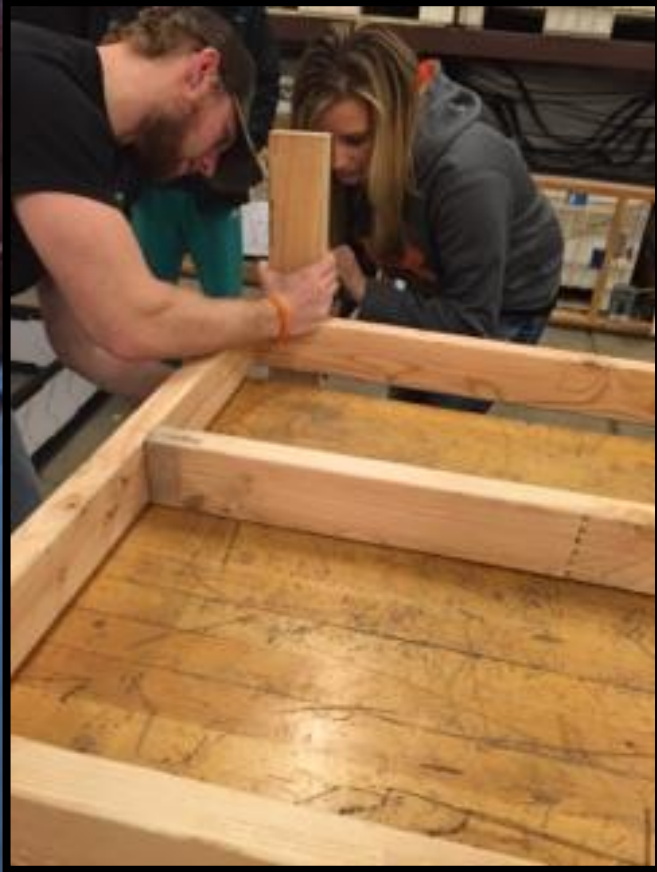
HYDRAULIC CALCULATIONS



HYDRAULIC GRADE LINE



HYDRAULIC MODEL FABRICATION



HYDRAULIC MODEL FABRICATION

- Clarifiers:



- Dayton Centrifugal Pump

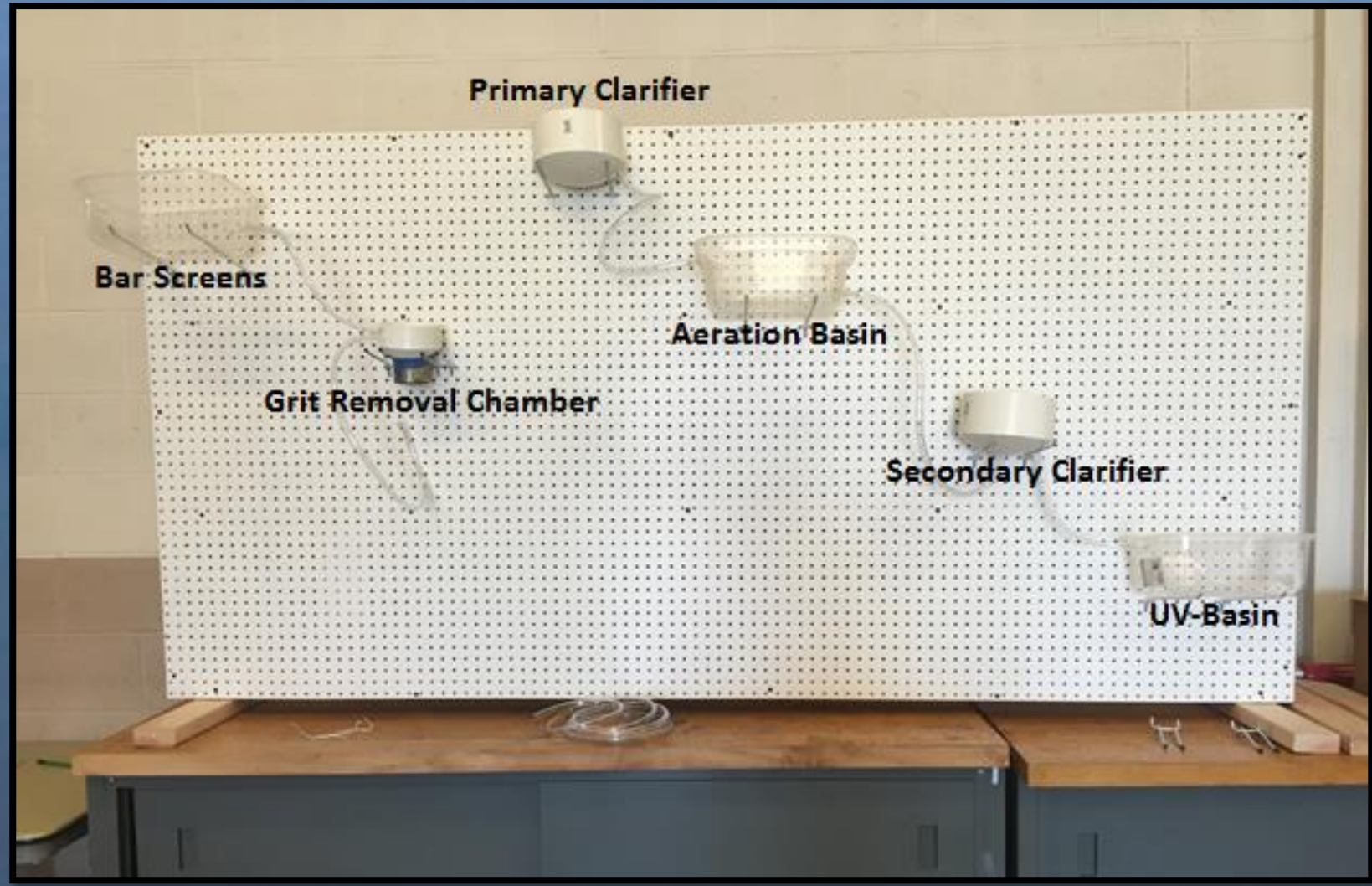


HYDRAULIC MODEL FABRICATION

- Basins
- Grit removal chamber



HYDRAULIC MODEL FABRICATION



HYDRAULIC MODEL TESTING



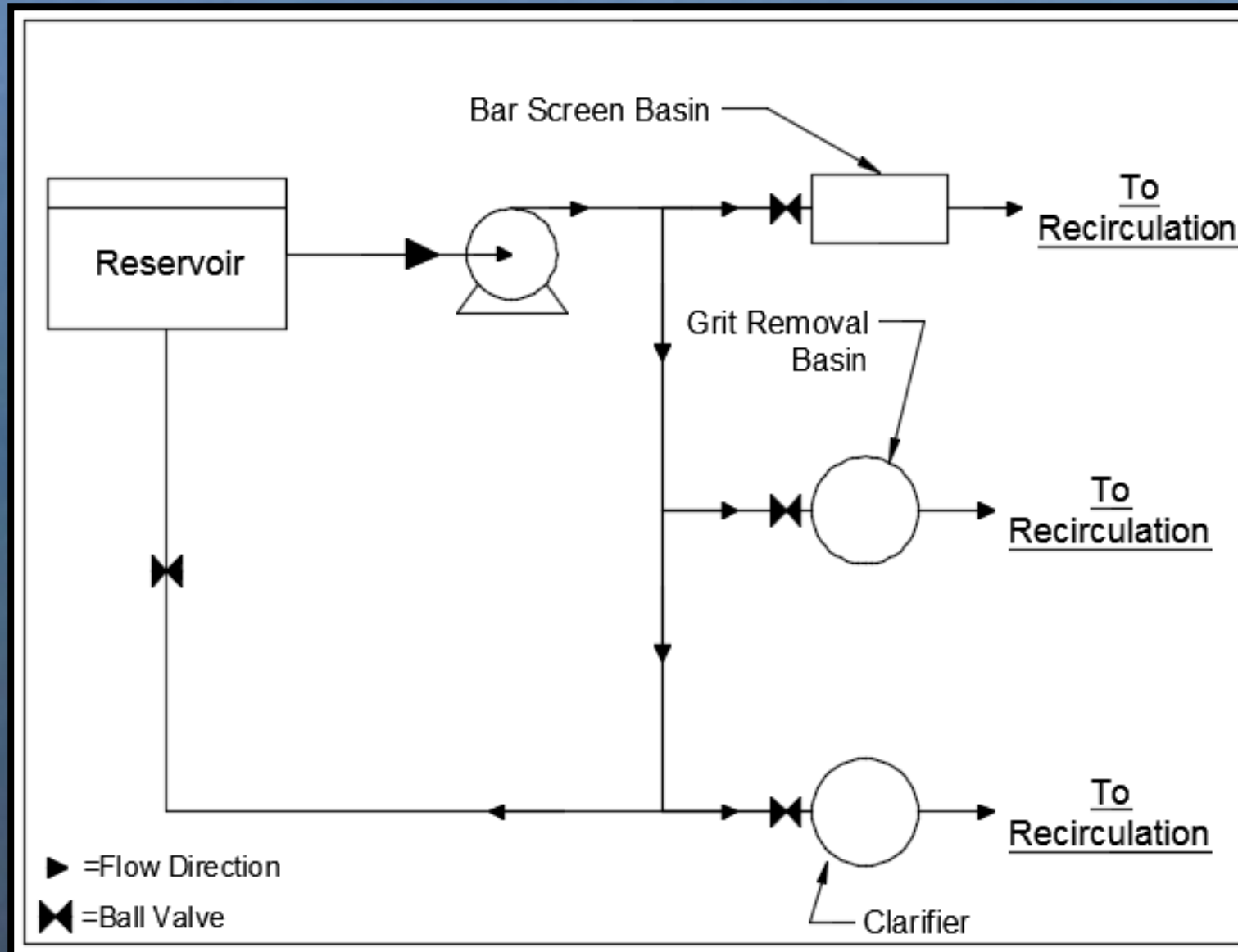
CONCLUSIONS FROM HYDRAULIC MODEL

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

DESIGN REVISIONS

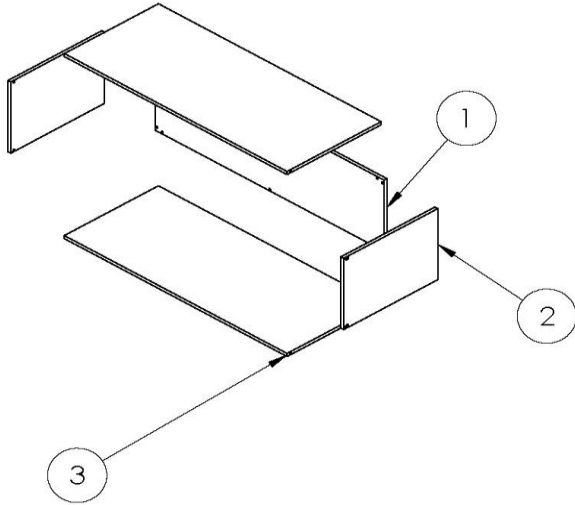
- Needed more flow control → “Flow Loop”
 - “Compartmentalized” units
 - Simplifies drainage, storage, operation
- Some units don’t even need flow
 - UV and aeration basin
- Move toward educational product

FINAL DESIGNS



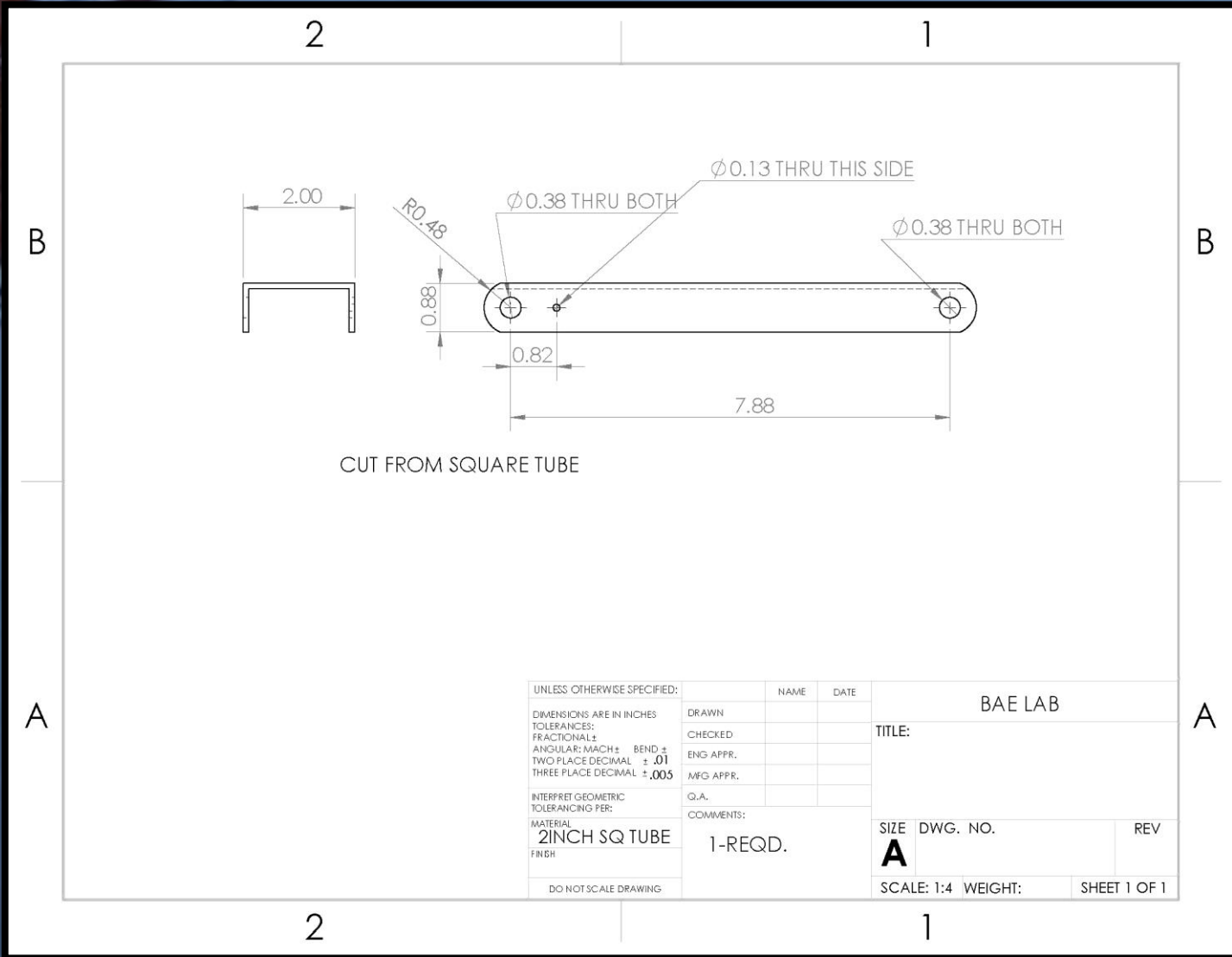
FINAL DESIGNS

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

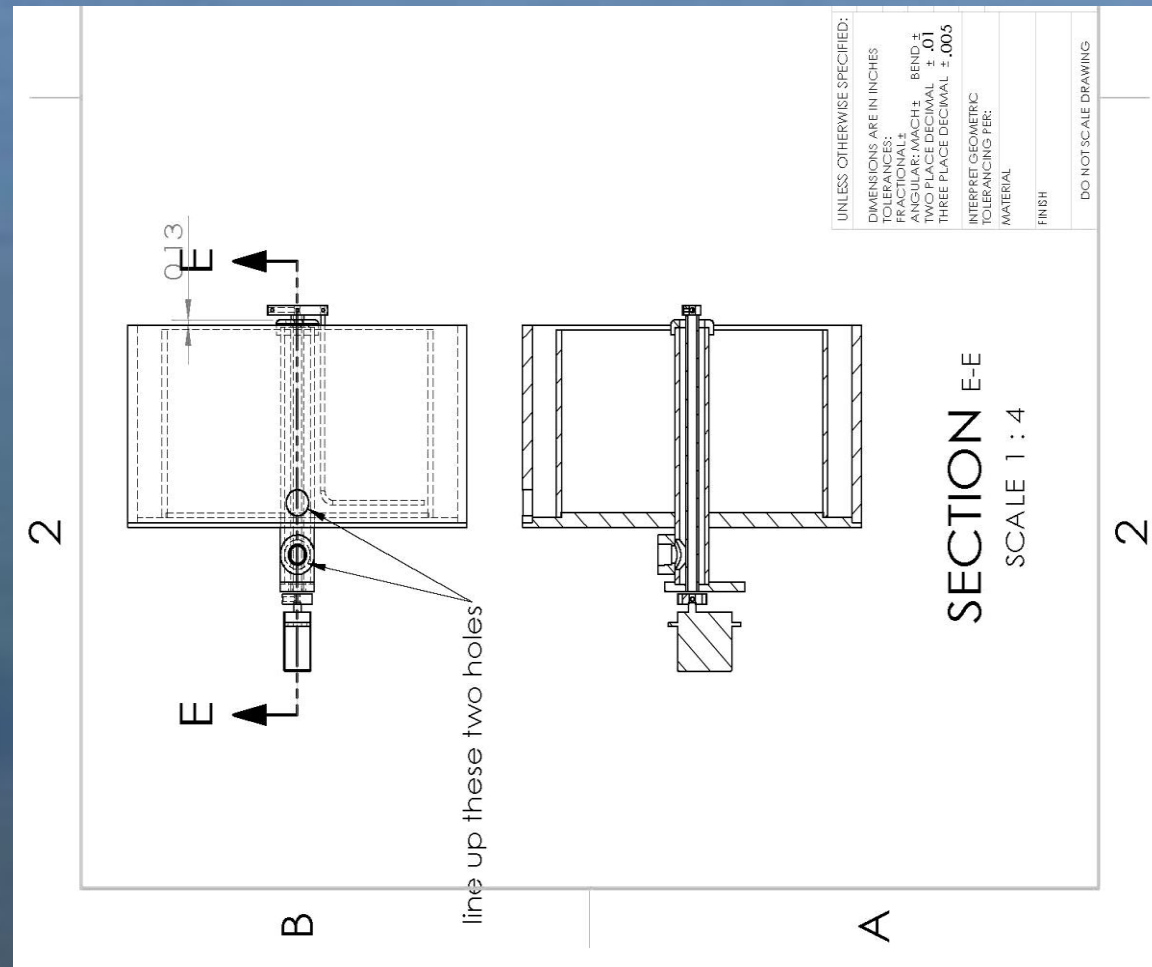
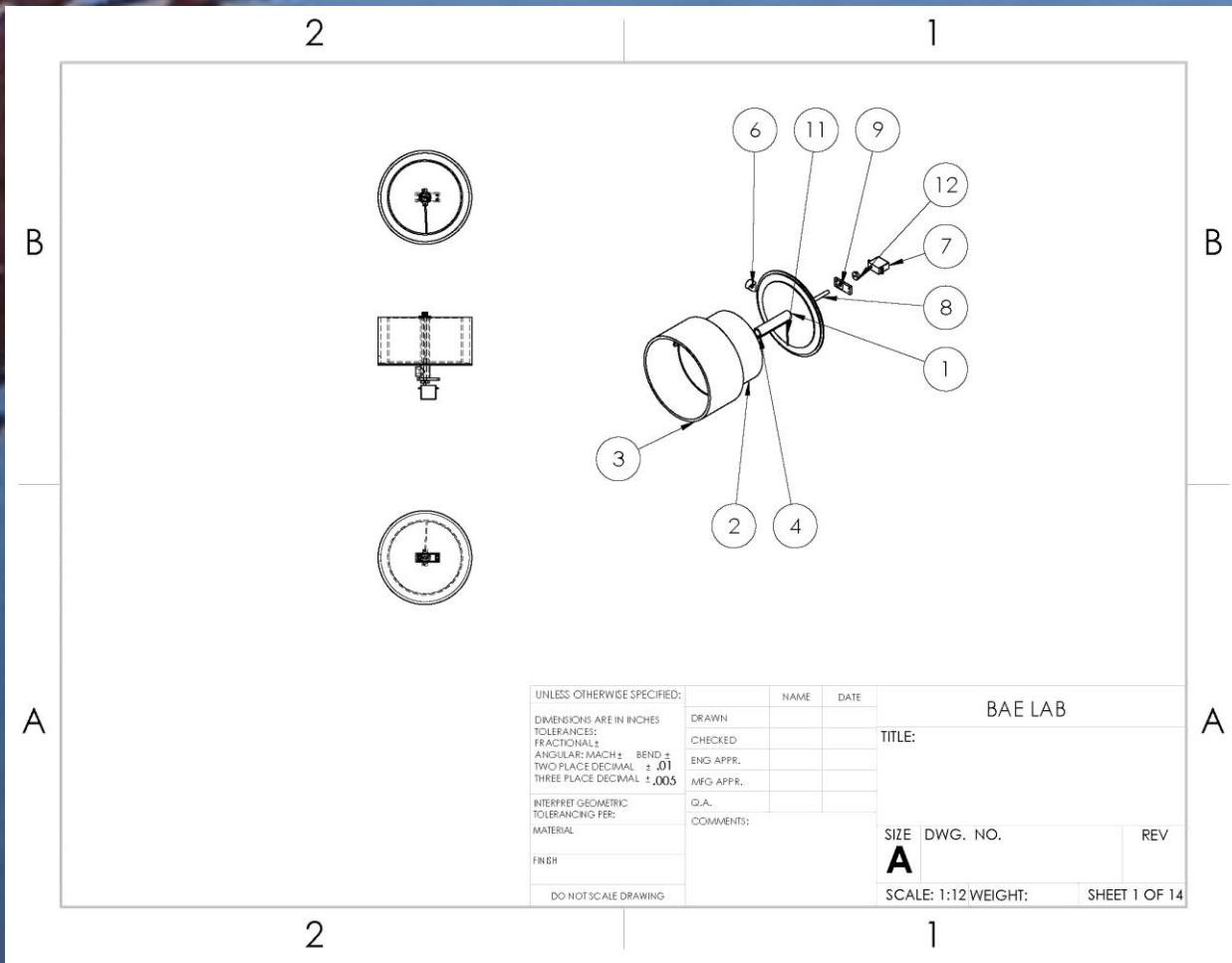


UNLESS OTHERWISE SPECIFIED:		NAME	DATE	BAE LAB		
DIMENSIONS ARE IN INCHES		DRAWN		TITLE:		
TOLERANCES:		CHECKED				
FRACTIONAL ±		ENG APPR.				
ANGULAR: MACH ± BEND ±		MFG APPR.				
TWO PLACE DECIMAL ± .01		Q.A.		SIZE	DWG. NO.	REV
THREE PLACE DECIMAL ± .005		COMMENTS:		A		
INTERPRET GEOMETRIC TOLERANCING PER:				SCALE: 1:8	WEIGHT:	SHEET 2 OF 5
MATERIAL						
FINISH						
DO NOT SCALE DRAWING						

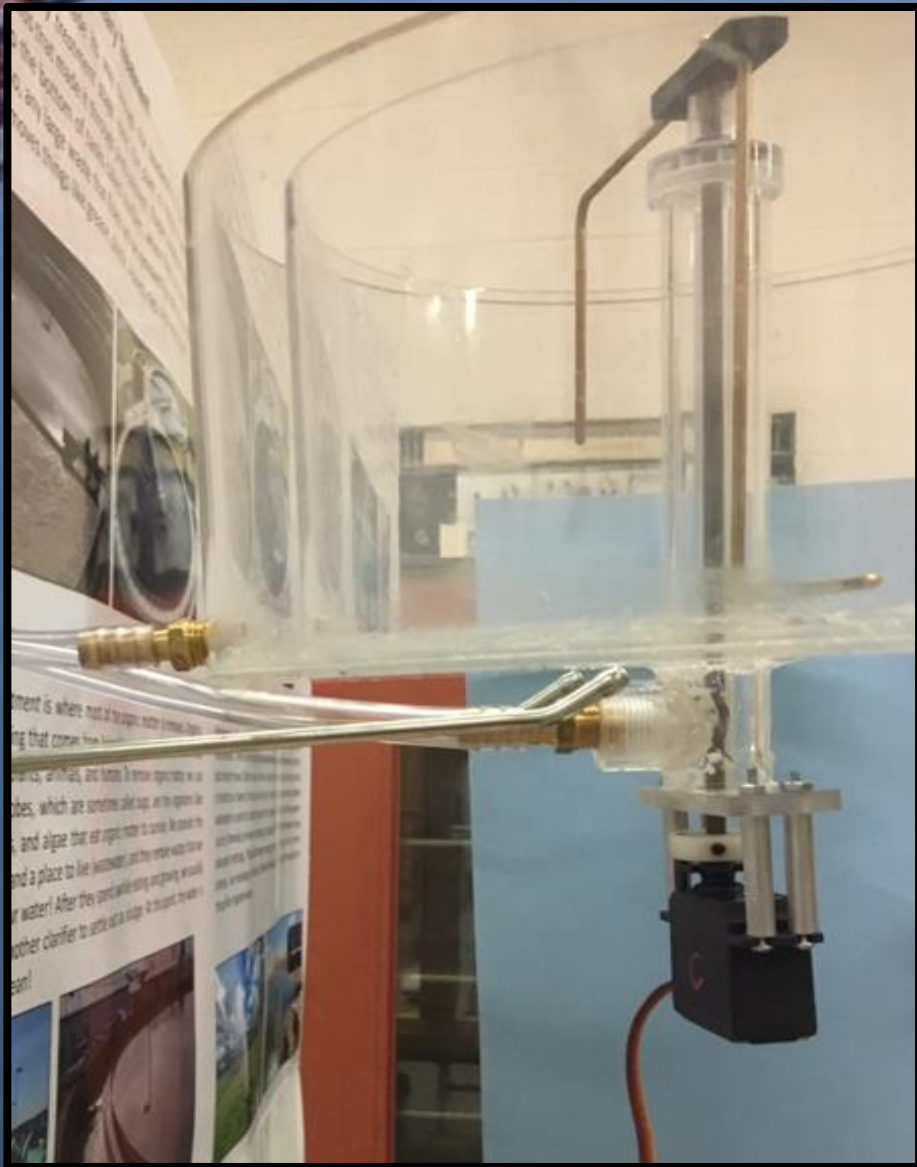
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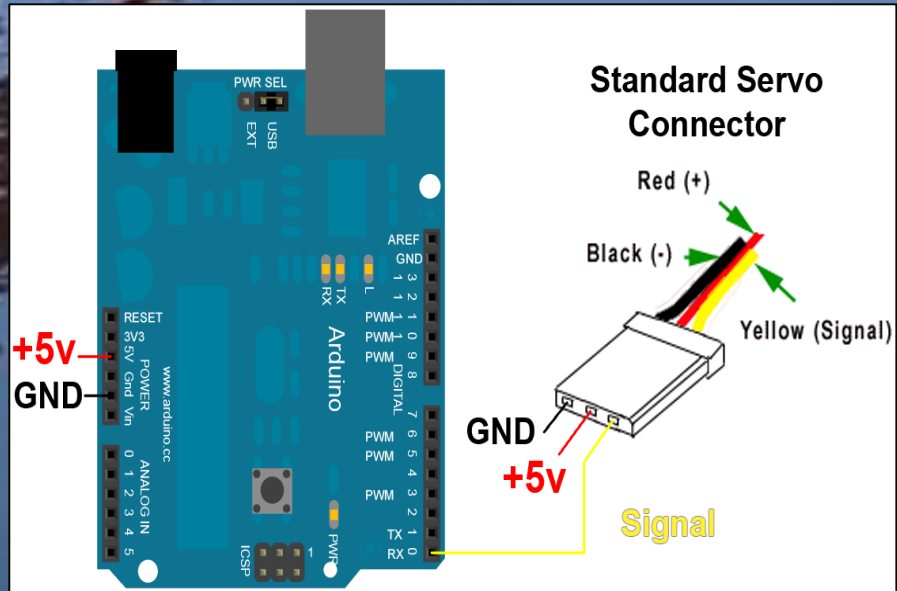
FINAL DESIGNS



FINAL DESIGNS



FINAL DESIGNS



Hextronik Servomotor Specifications

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

```

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 degrees
  {
    myservo.write(pos); //tell servo to go to position in variable 'pos'
    delay(3000);
  }
}

```

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

Interactive Wastewater Treatment Display
 West Valley Institute
 Environmental and Mechanical Engineering
 1100 West Valley Road, West Valley, IL 60158

Primary Treatment

After wastewater has made its way through the treatment of the plant, it reaches the primary treatment stage. Here, the plant is trying to remove any remaining solids that float through the system. These suspended solids are pulled out by the bottom of each tank's surface, where they can be collected as sludge. This can help reduce the flow of pollutants by up to 30%. Primary treatment removes things like grease, plastic, leaves, paper, and other debris.

Secondary Treatment

Wastewater treatment is a great way to help conserve water and protect the environment. There are two types of wastewater treatment: primary and secondary. Primary treatment is a process that uses a series of tanks to remove any remaining solids that float through the system. This can help reduce the flow of pollutants by up to 30%. Primary treatment removes things like grease, plastic, leaves, paper, and other debris.

Tertiary Treatment

After the wastewater has made its way through primary and secondary treatment, it goes through tertiary treatment. Tertiary treatment is a process that uses a series of tanks to remove any remaining solids that float through the system. This can help reduce the flow of pollutants by up to 30%. Tertiary treatment removes things like grease, plastic, leaves, paper, and other debris.

Wastewater Reuse

Wastewater reuse is a great way to help conserve water and protect the environment. There are two types of wastewater reuse: primary and secondary. Primary reuse is a process that uses a series of tanks to remove any remaining solids that float through the system. This can help reduce the flow of pollutants by up to 30%. Primary reuse removes things like grease, plastic, leaves, paper, and other debris.

Pre-treatment

The first step in treating wastewater is to remove large pieces of debris and to break down any possible dangerous materials that it is not otherwise possible to remove and can cause the example of an orange trapped in a pipe. The pre-treatment stage of wastewater treatment includes the mechanical bar screens and the grit removal tanks.

Mechanical Bar Screen Treatment

This mechanical bar screen and separates the large pieces of debris and other floating materials. This is a physical process that removes debris that could clog and damage the equipment in the system.

Grit Removal Treatment

After pre-treatment, heavy grit removal is used to remove small inorganic solids such as sand, gravel, and stones and the floating debris that is removed. This can be made up of things like sand, gravel, and stones, as well as organic solids like coffee grounds, egg shells, and other food waste.

Secondary Treatment

Wastewater treatment is a great way to help conserve water and protect the environment. There are two types of wastewater treatment: primary and secondary. Primary treatment is a process that uses a series of tanks to remove any remaining solids that float through the system. This can help reduce the flow of pollutants by up to 30%. Primary treatment removes things like grease, plastic, leaves, paper, and other debris.

Wastewater Reuse

Wastewater reuse is a great way to help conserve water and protect the environment. There are two types of wastewater reuse: primary and secondary. Primary reuse is a process that uses a series of tanks to remove any remaining solids that float through the system. This can help reduce the flow of pollutants by up to 30%. Primary reuse removes things like grease, plastic, leaves, paper, and other debris.

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.

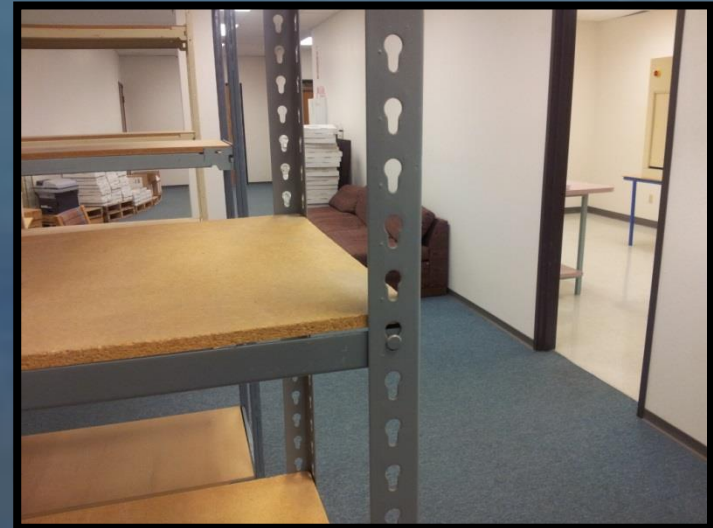
COST OF FABRICATION FOR GARVER

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





AquaCleanse Solutions

Abigail Parnell

Brandy Parks

Cole Niblett

Olivia Broussard

December 4, 2015

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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

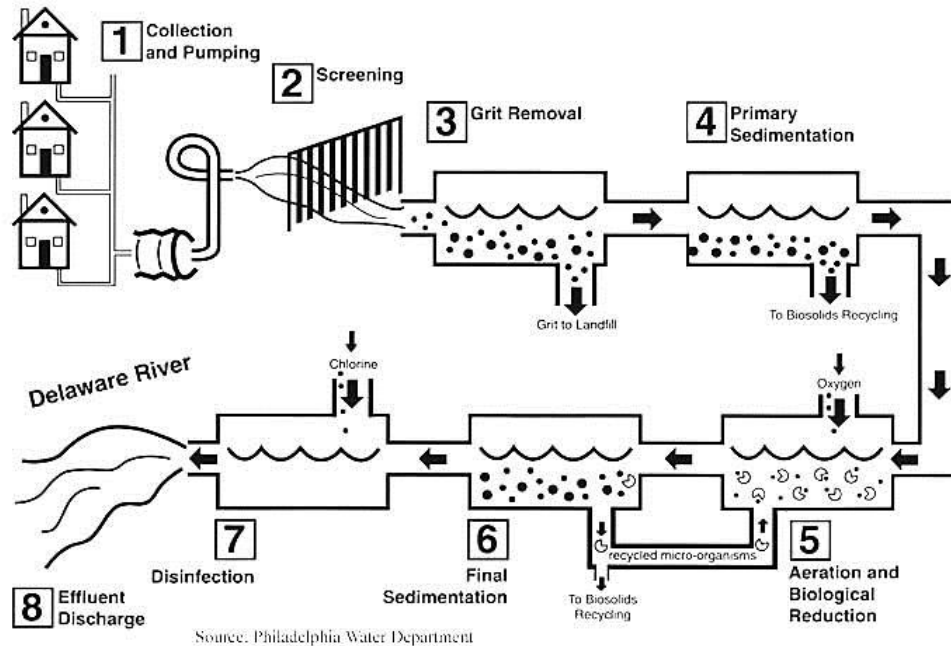
Funding

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.



Source: Philadelphia Water Department

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 coarse (6-24 mm) and fine (2-6 mm) screens, with the velocity being 0.7 m/s on average.

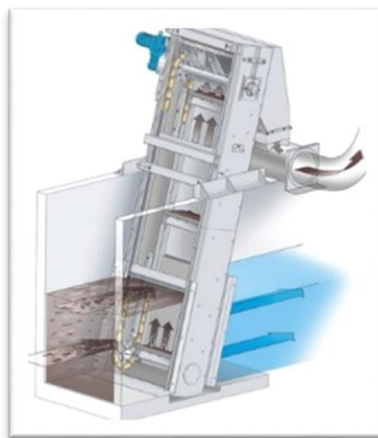


Figure 2: Representation of bar screens with chains.

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.

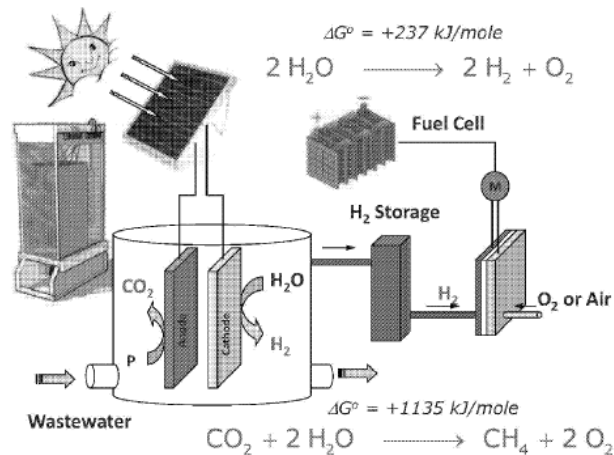


Figure 5: Process diagram from Patent No. 20140209479A1

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.

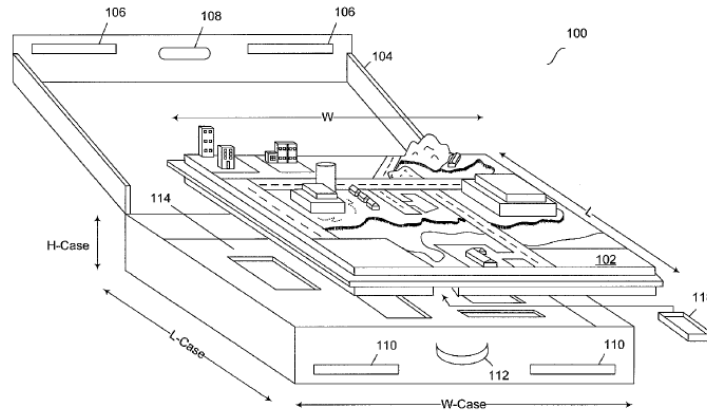


Figure 6: Diagram from Patent No. 20080020360A1

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.

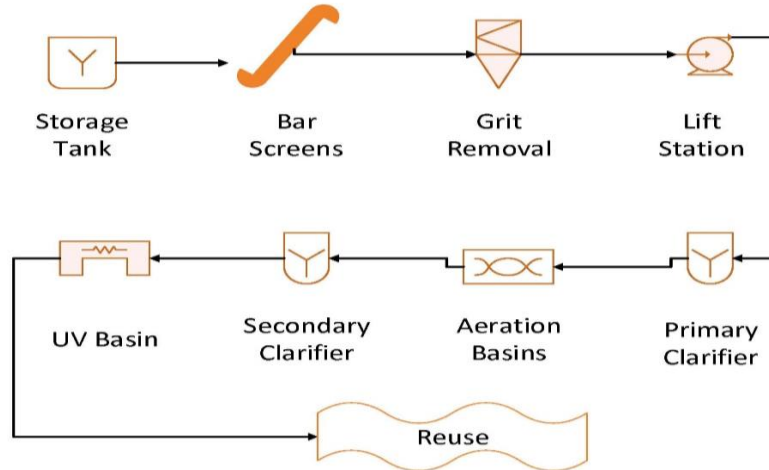


Figure 8: Design components for the prototype.

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.

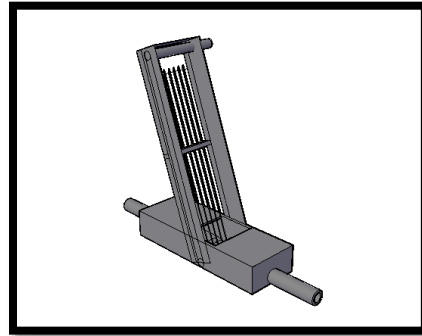


Figure 9: CAD model of the mechanical bar screens.

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

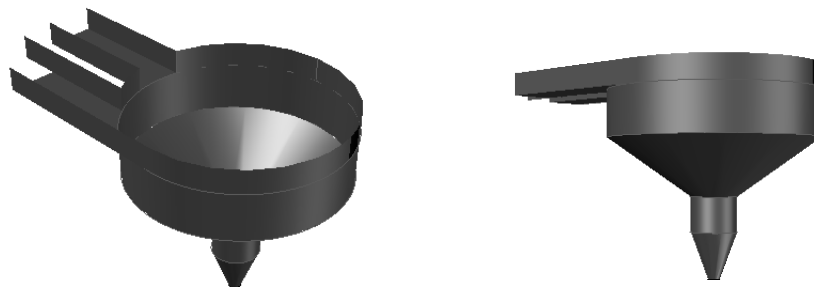


Figure 10: CAD model of the top and side view of the grit chamber.

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.

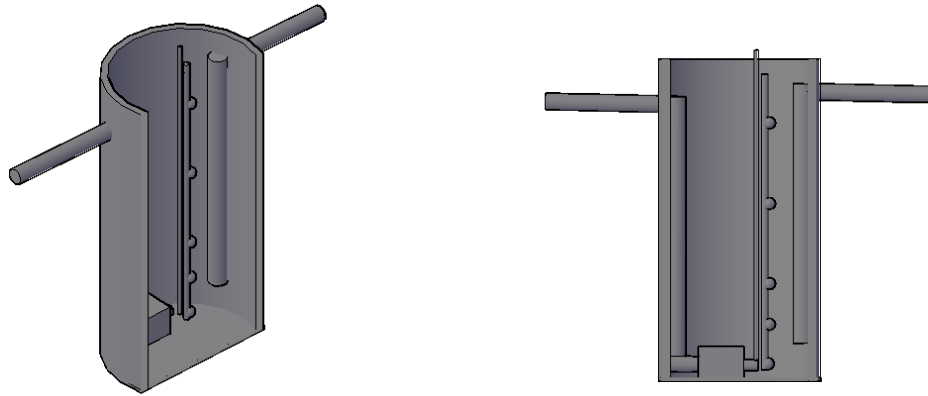


Figure 11: CAD model of the top and side view of the lift station.

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.

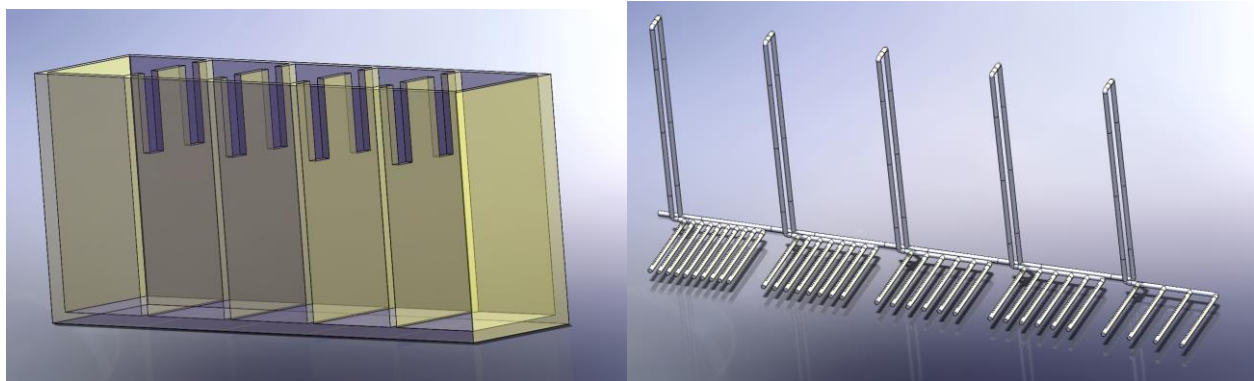


Figure 12: SolidWorks model of the side view of an aeration basin on the left, and the aeration tubes on the right.
From freshman design team.

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

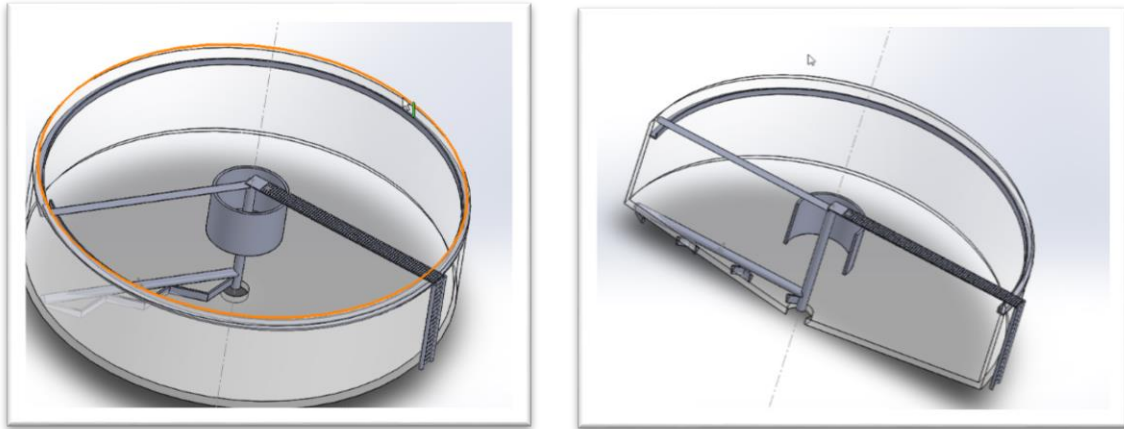


Figure 13: Solidworks drawing of a Clarifier model.

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

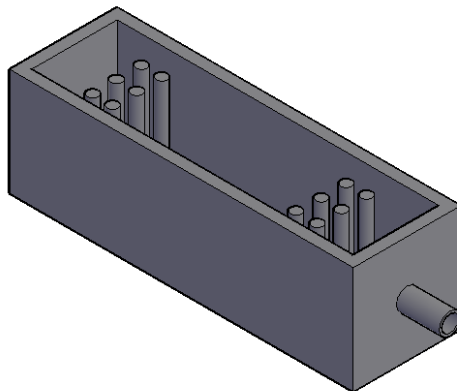


Figure 14: AutoCAD model of disinfection basin

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.

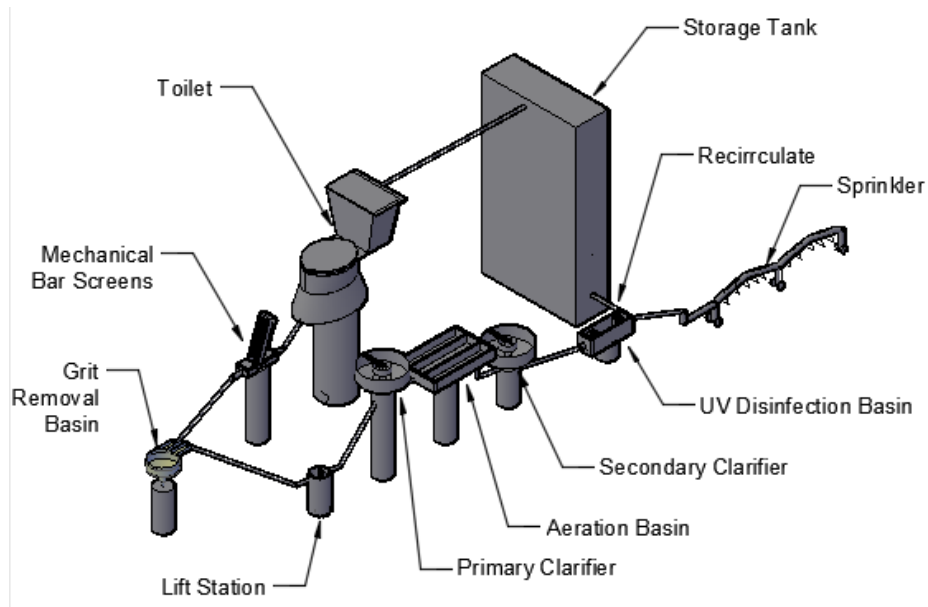


Figure 15: Final layout of the system.

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.

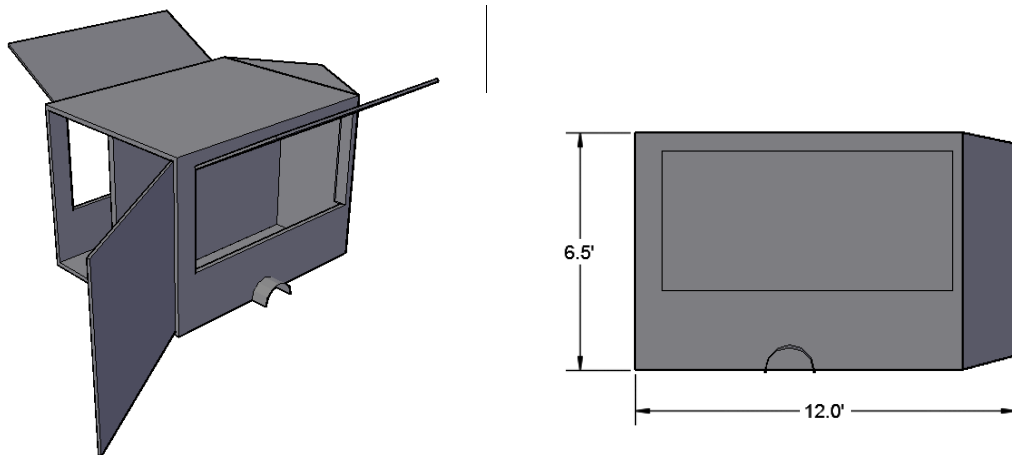


Figure 16: CAD model of top and side view of the “Walk-around” trailer.

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.

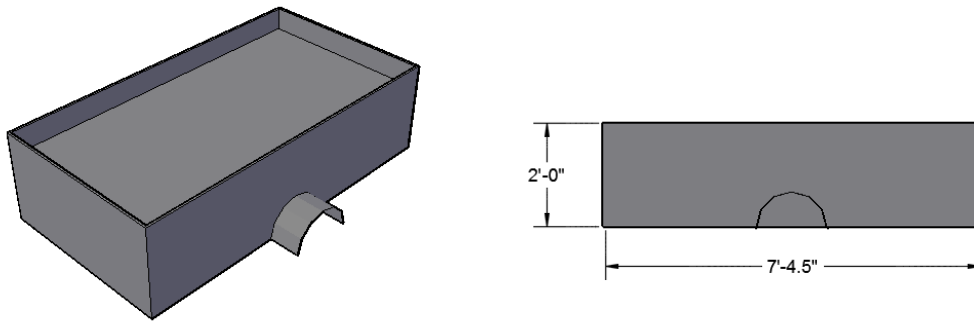


Figure 17: CAD model of top and side view of Stream trailer.

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.

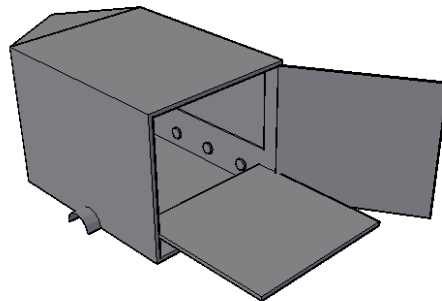


Figure 18: CAD model of the top view of the pullout trailer.

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.

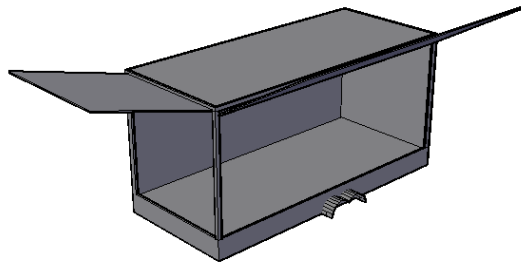


Figure 19: CAD model of the top view of the open trailer.

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 $\frac{3}{4}$ " 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.

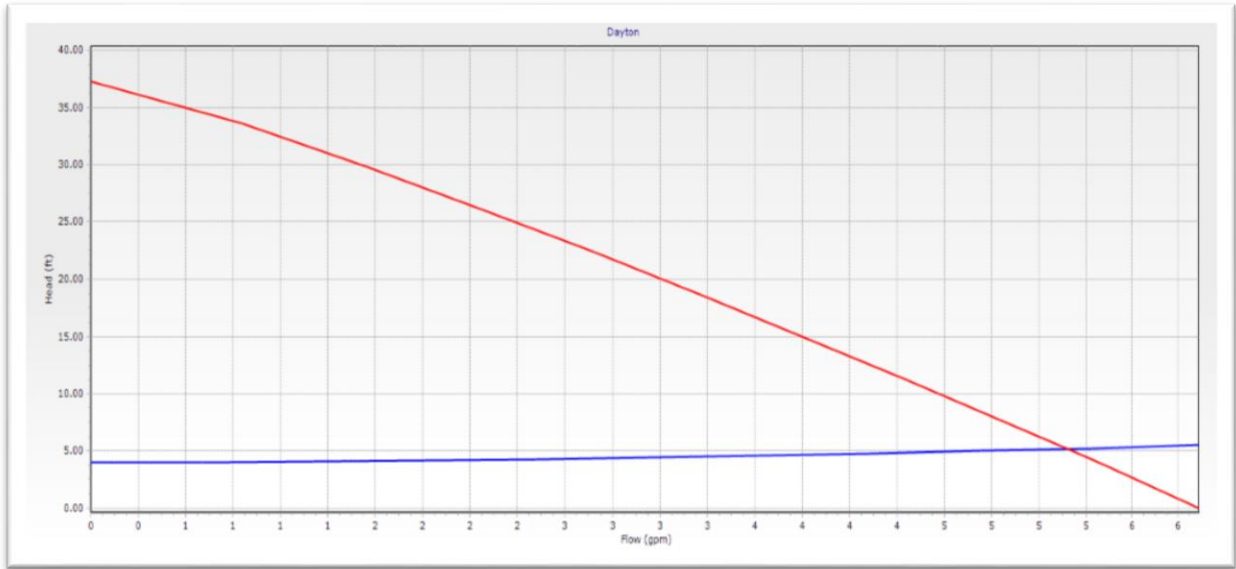


Figure 20: Pump and system curve for Dayton Pump.

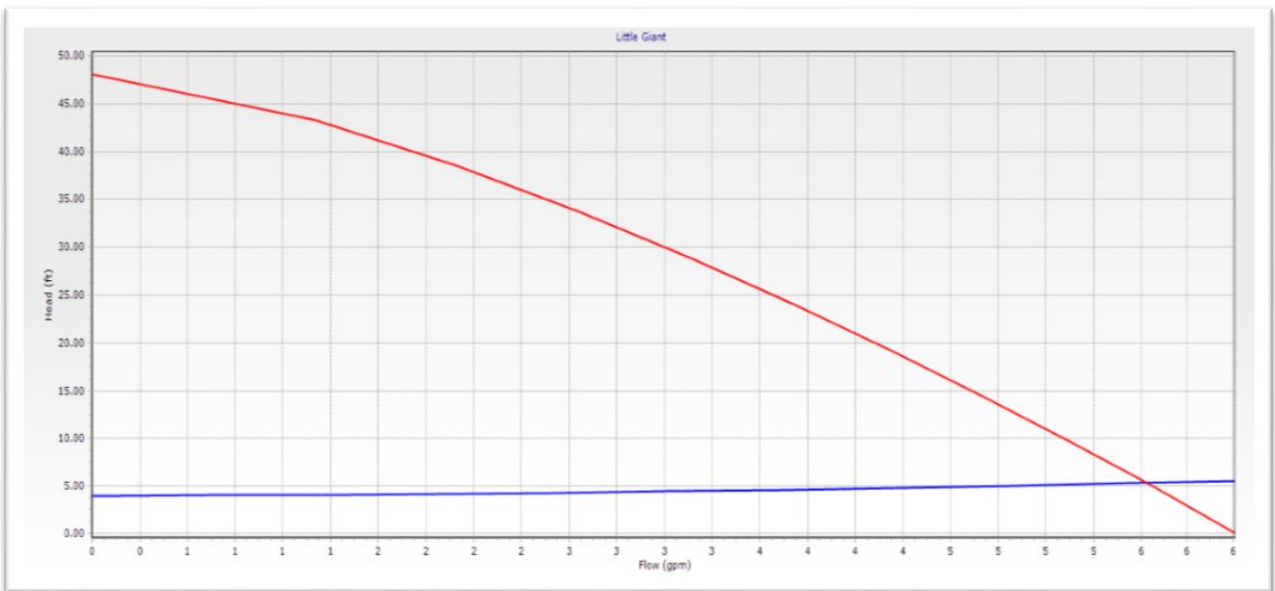


Figure 21: Pump and system curve for Little Giant Pump.

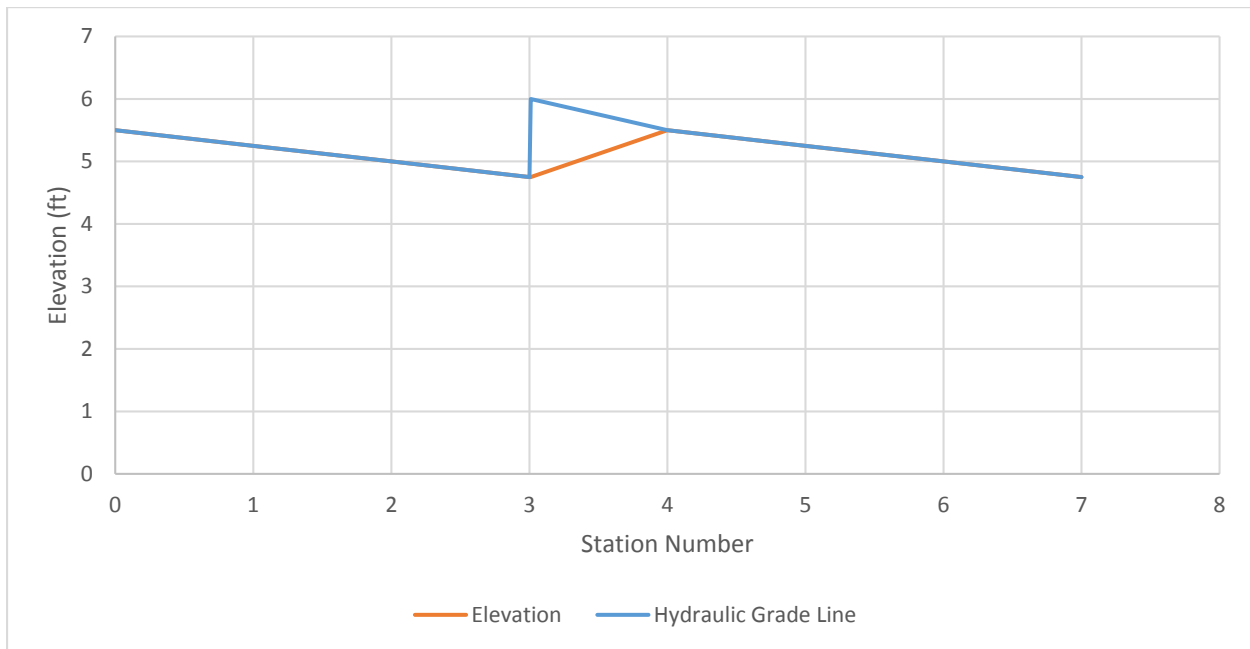


Figure 22: Hydraulic Profile for system design.

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 $\frac{3}{4}$ " 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 outputs

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.

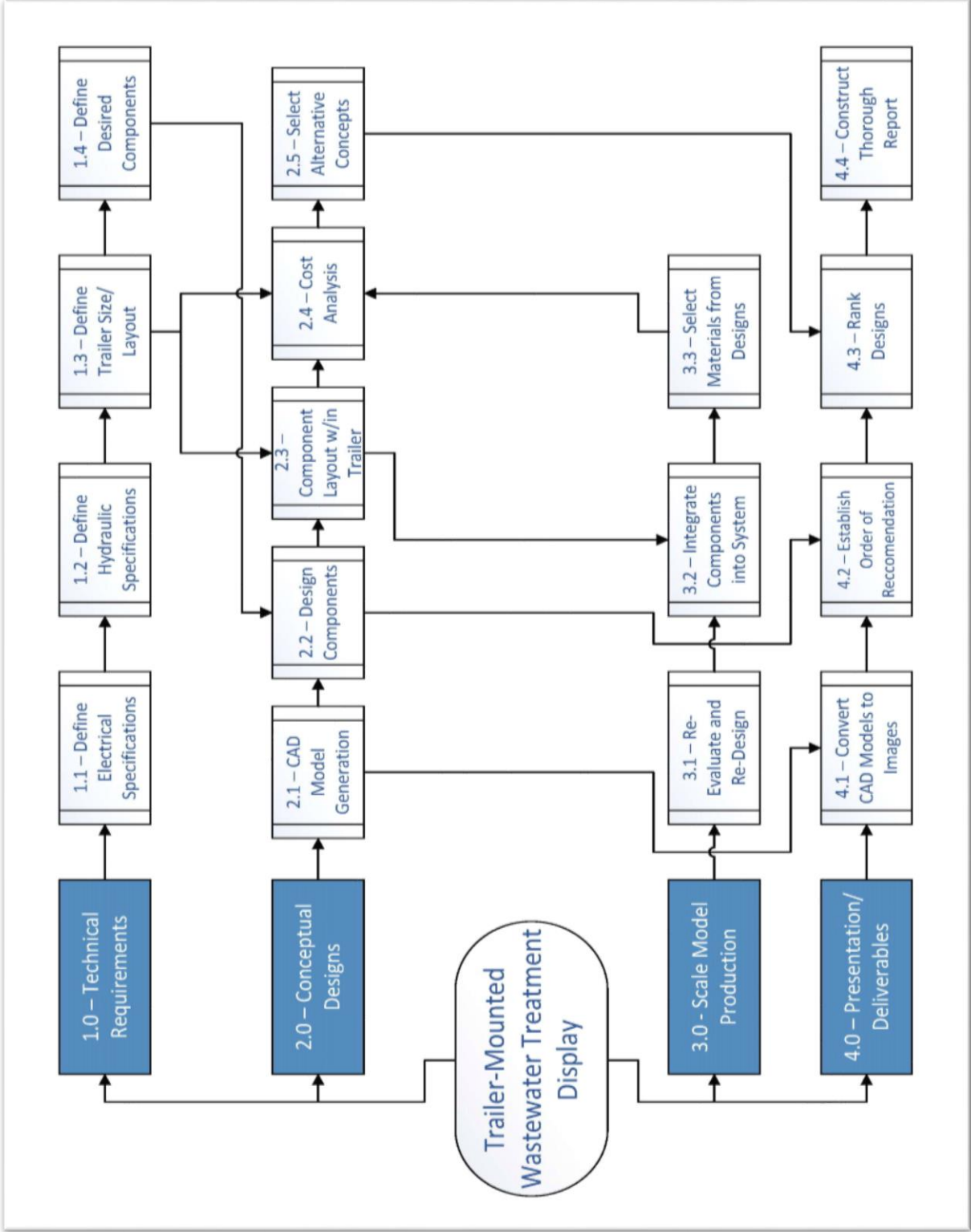
Alternatives				
	"Open Sides" Trailer	"Walk around" Trailer	"Pull-Out" Trailer	Stream Trailer
Bare Trailer	\$22,500	\$15,000	\$15,000	\$10,000
Pump (Dayton)	\$104	\$104	\$104	\$104
Materials	\$700	\$600	\$600	\$500
Total Cost	\$23,304	\$15,704	\$15,704	\$10,604

Discussion

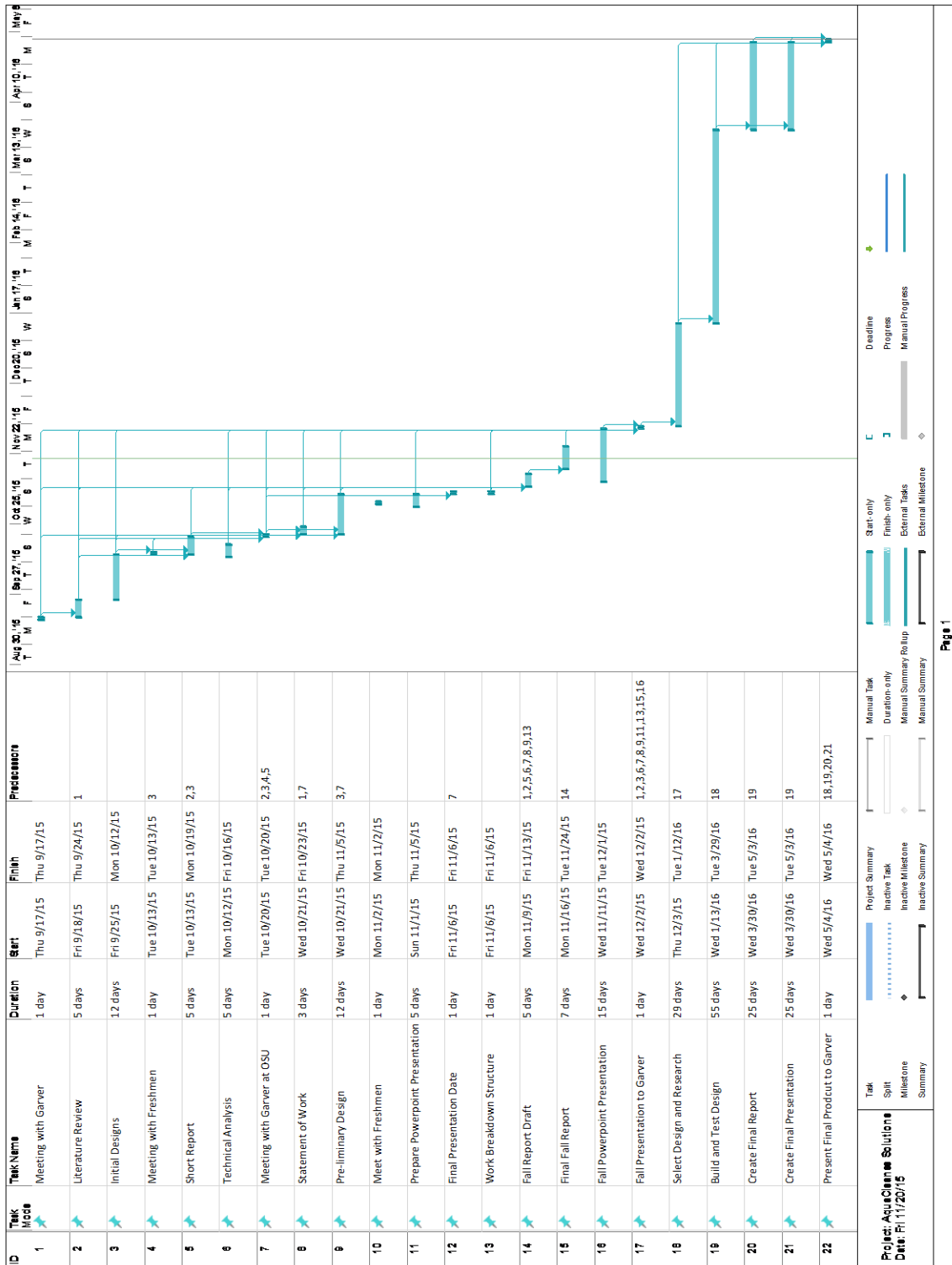
These practical treatments of wastewater will be an educational opportunity for the young generation, so the trailer will be as interactive as possible. Our final display will be trailer-mounted, this will present several different design considerations, however the largest concern will probably be the 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



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

Cole Niblett Olivia Broussard Brandy Parks Abigail Parnell



GROUP PICTURE



AGENDA

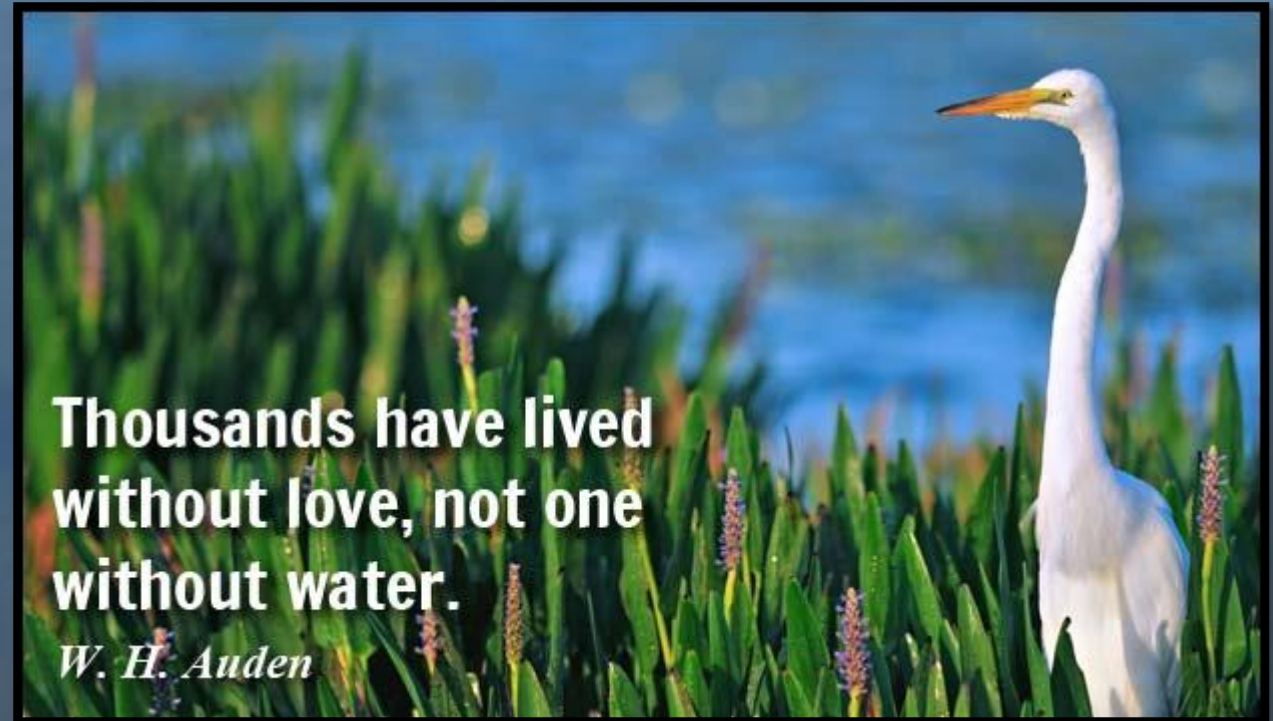
- Problem Statement and Background
- Objectives and Project Scope
- Conceptual Designs
- Economic Analysis
- Project Schedule
- Discussion

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



**Thousands have lived
without love, not one
without water.**

W. H. Auden

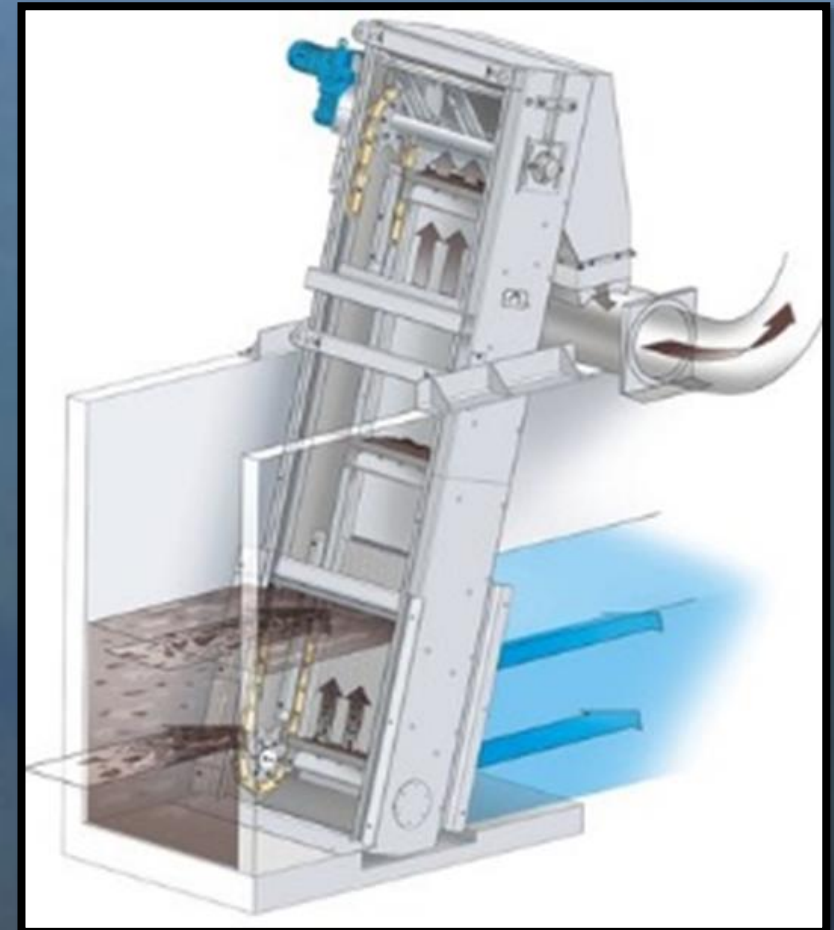
WASTEWATER TREATMENT OVERVIEW

- 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



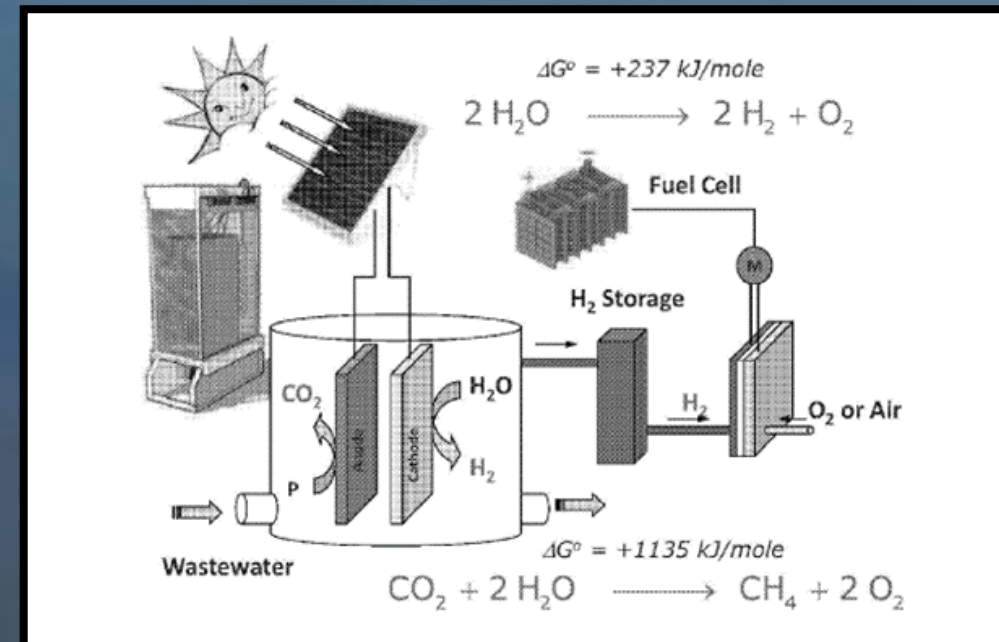
WASTEWATER TREATMENT OVERVIEW

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



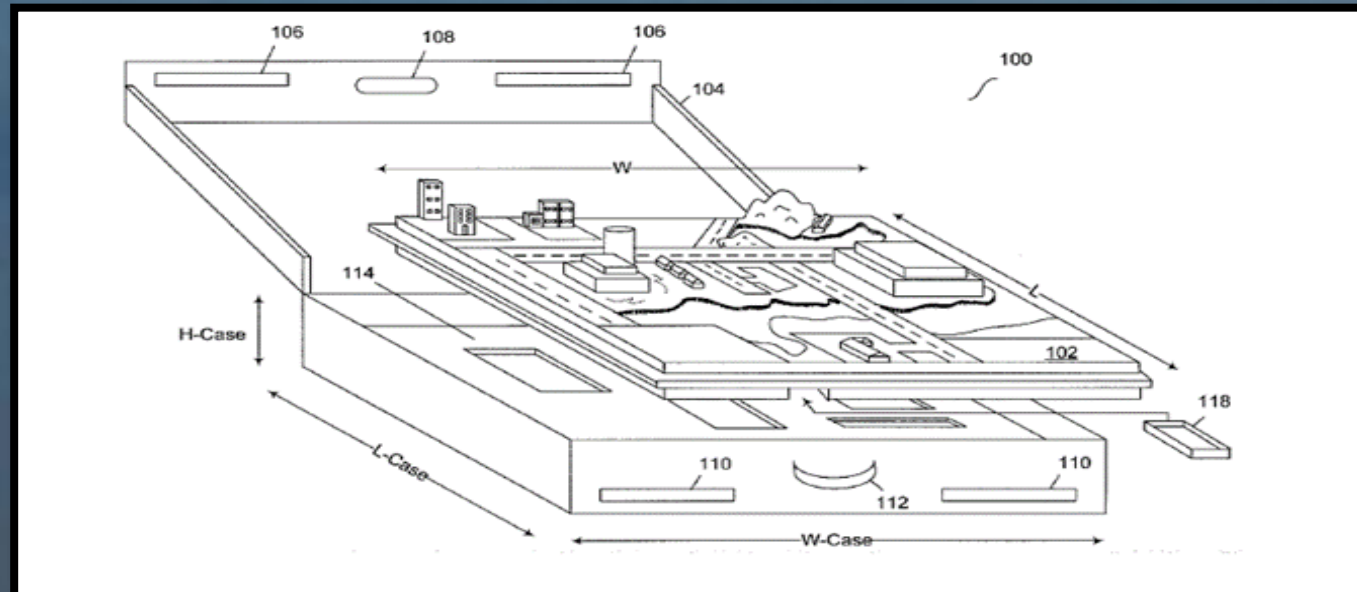
TECHNICAL ANALYSIS

- 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

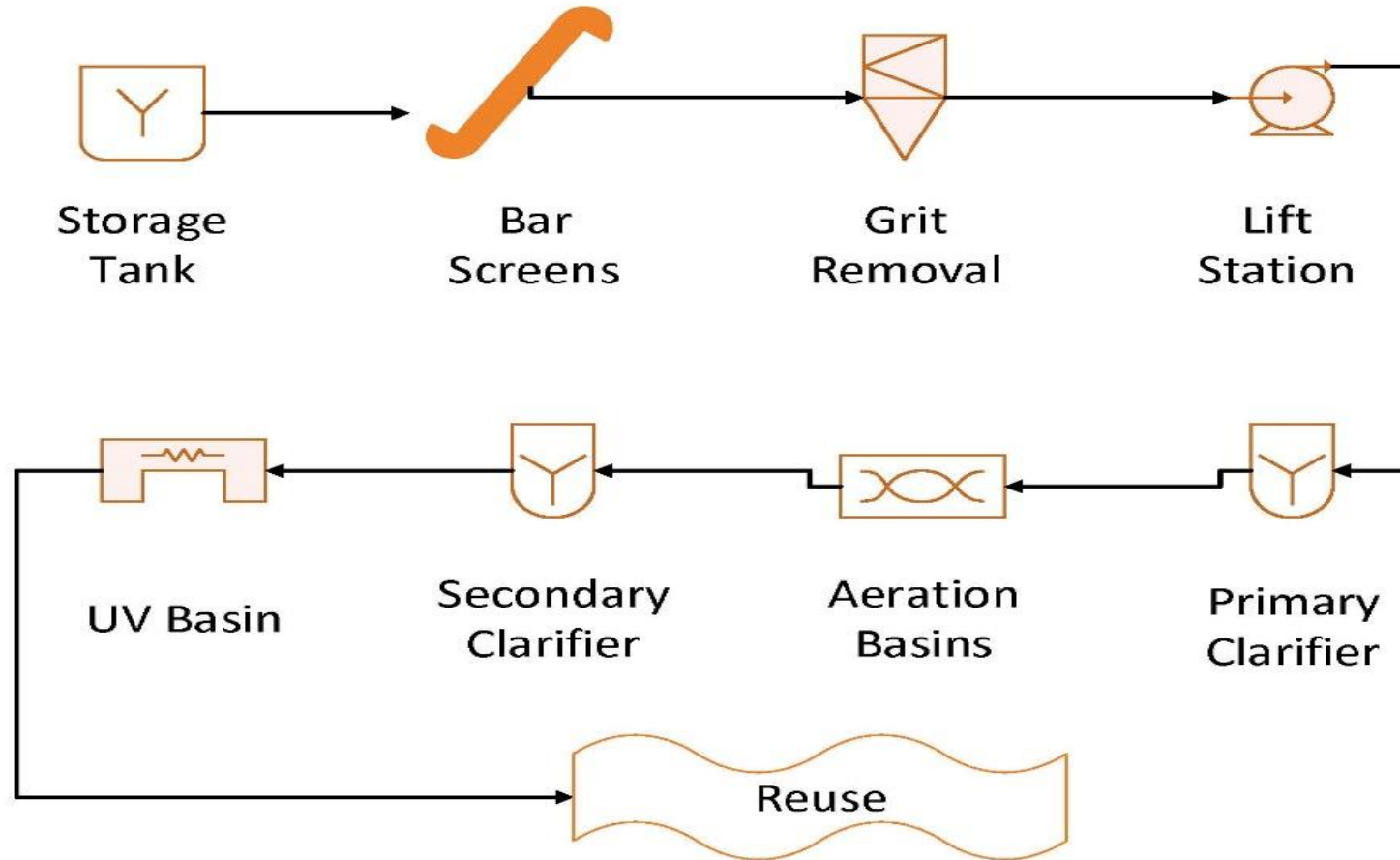


SELECTION OF UNIT OPERATIONS

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

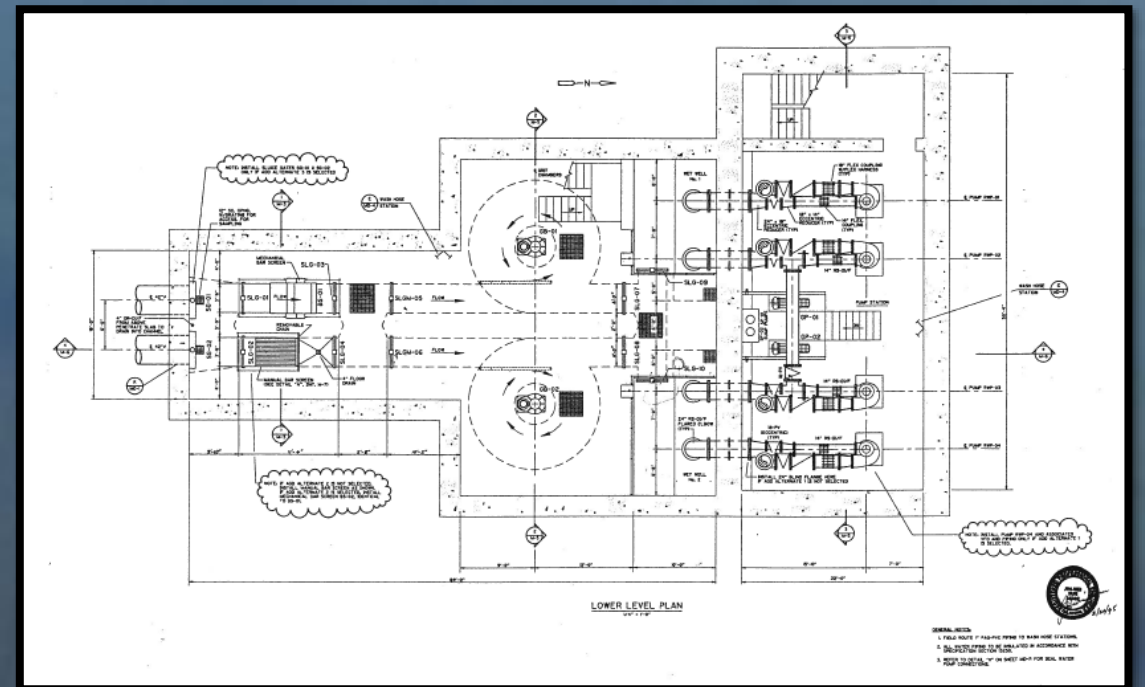
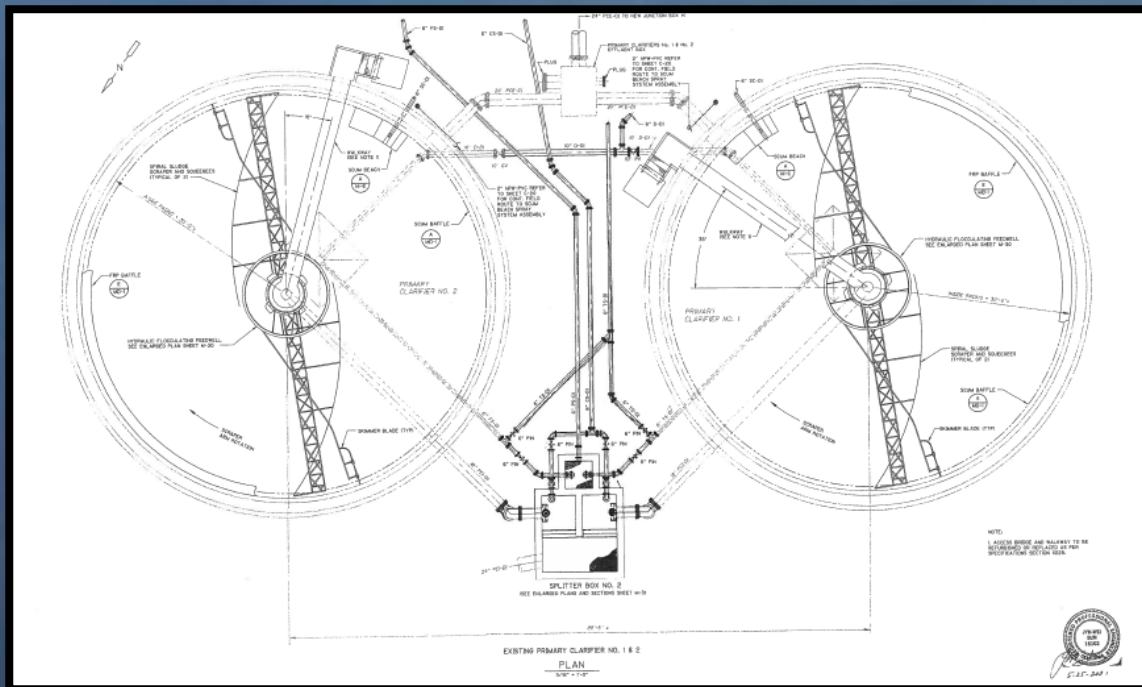


PROCESS FLOW DIAGRAM



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

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

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

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''

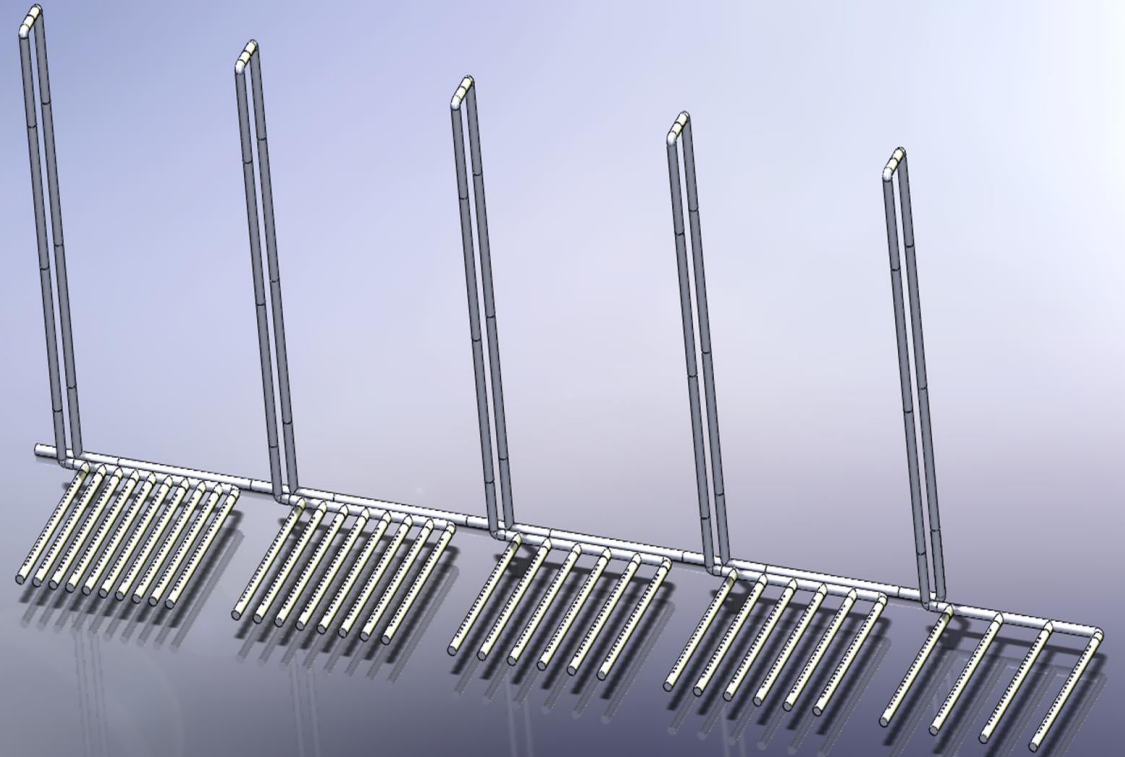
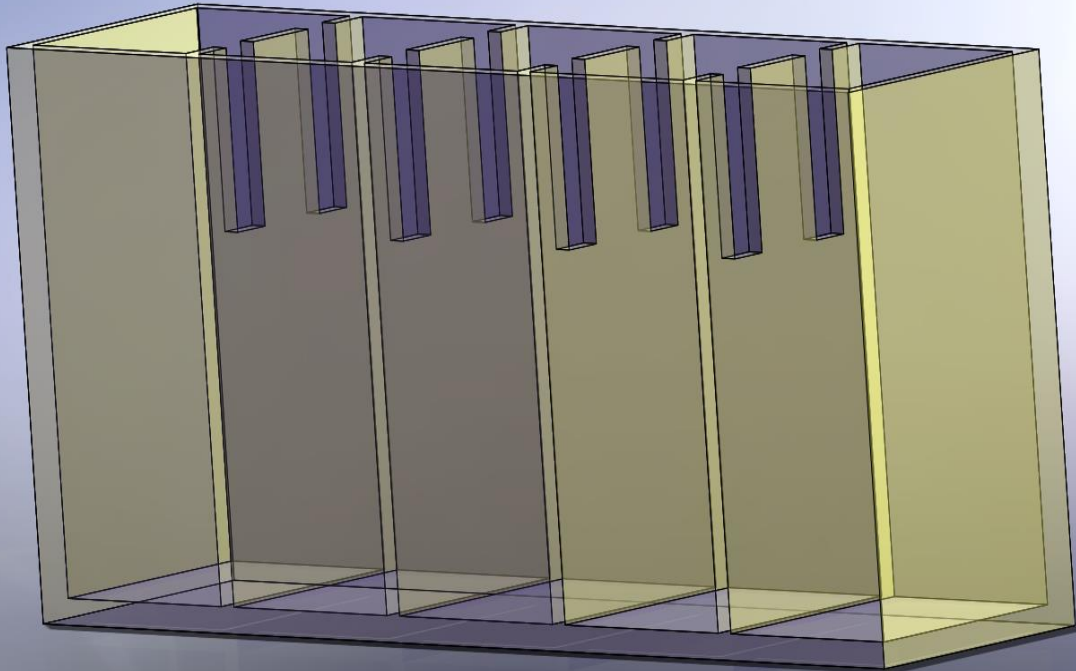
BAE 1012 PROJECTS

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



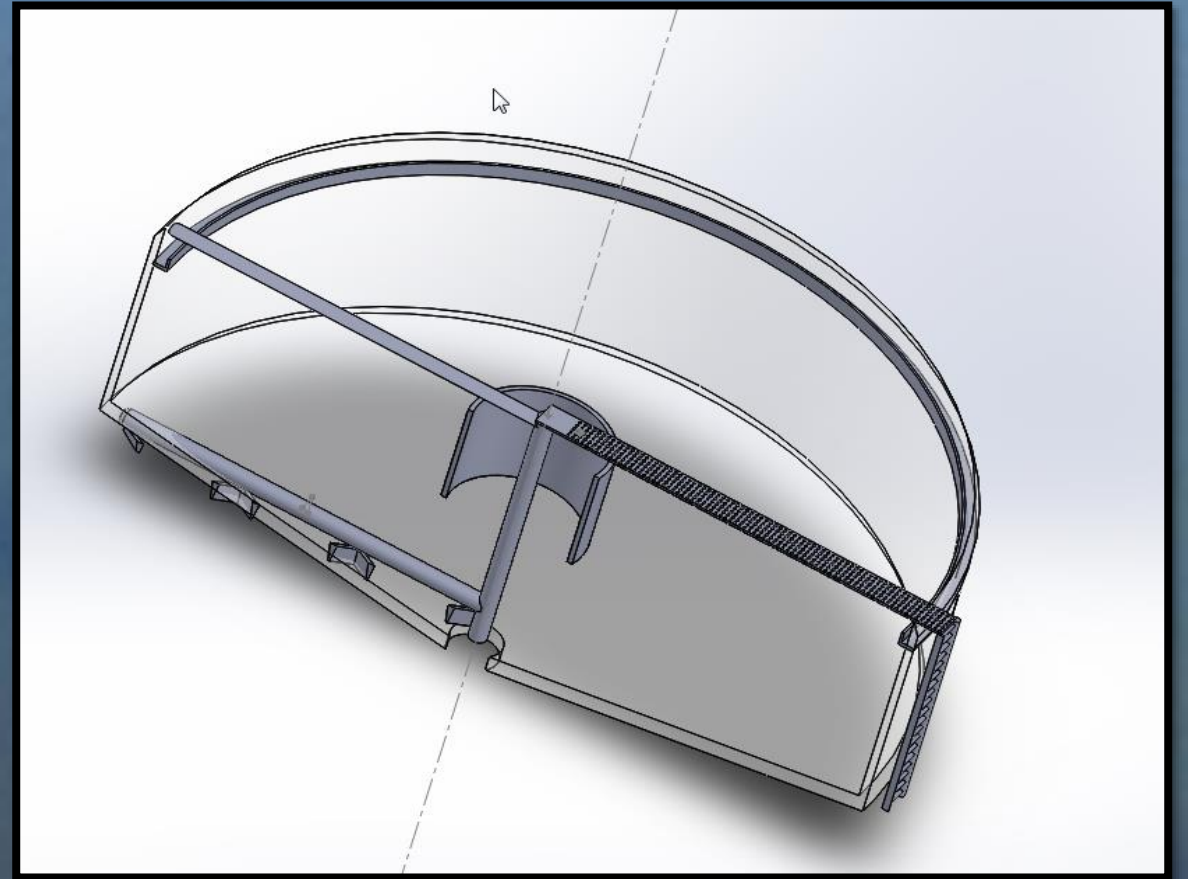
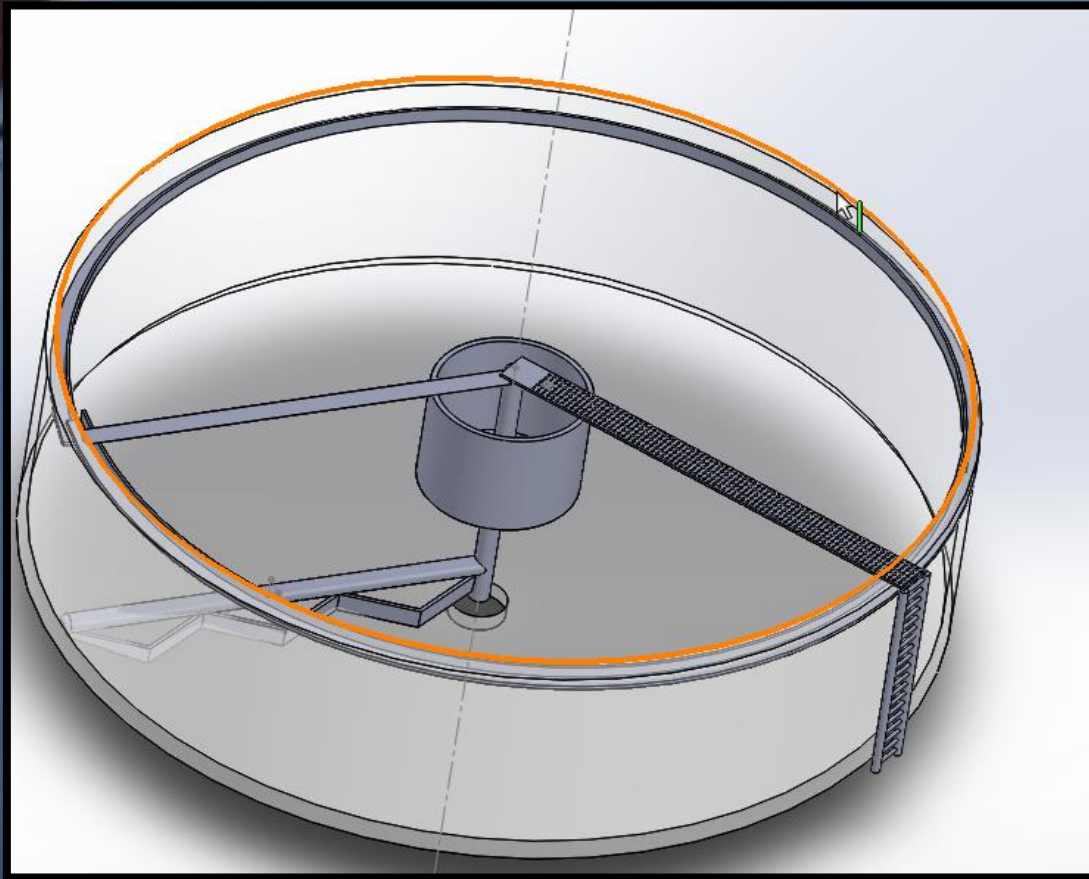
CAD MODELS

- BAE 1012 – Aeration Basins



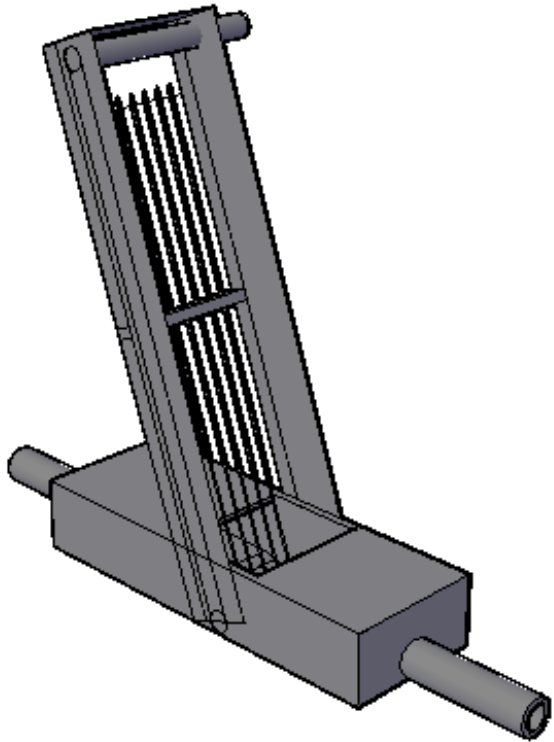
CAD MODELS

- BAE 1012 – Primary and Secondary Clarifier

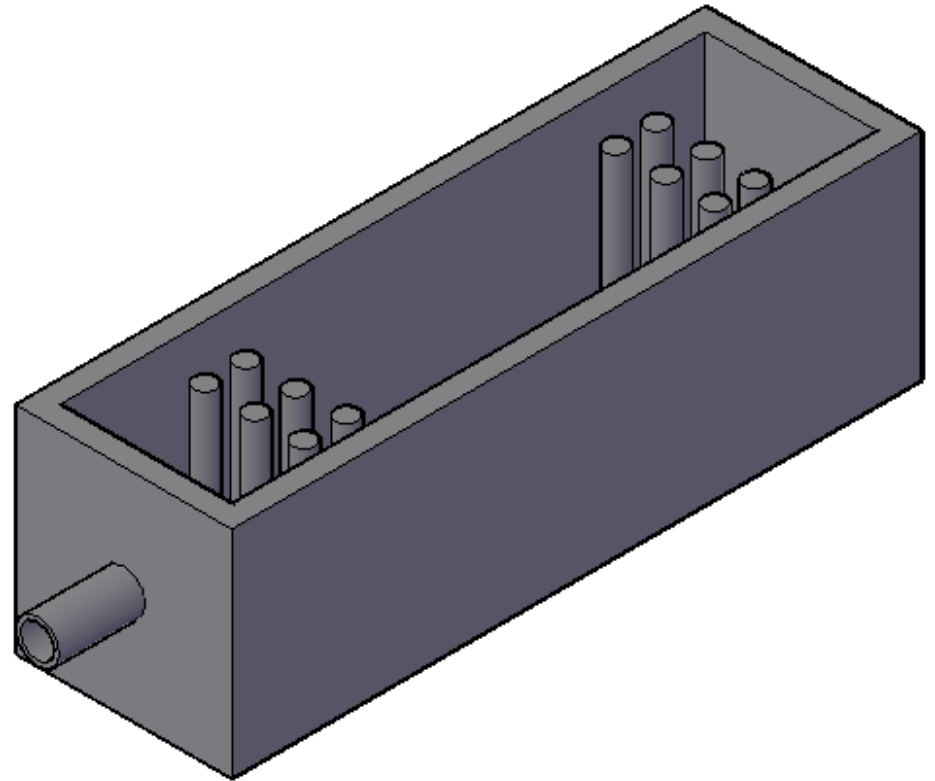


CAD MODELS

- Mechanical Bar Screens

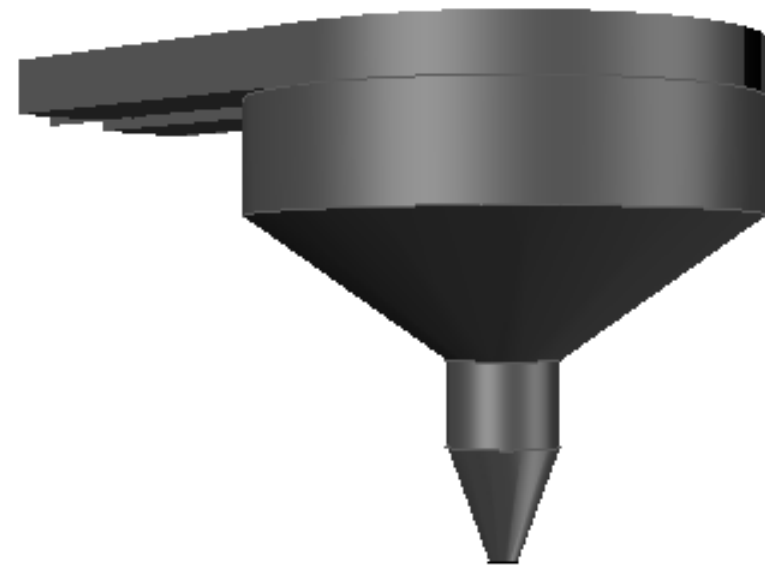
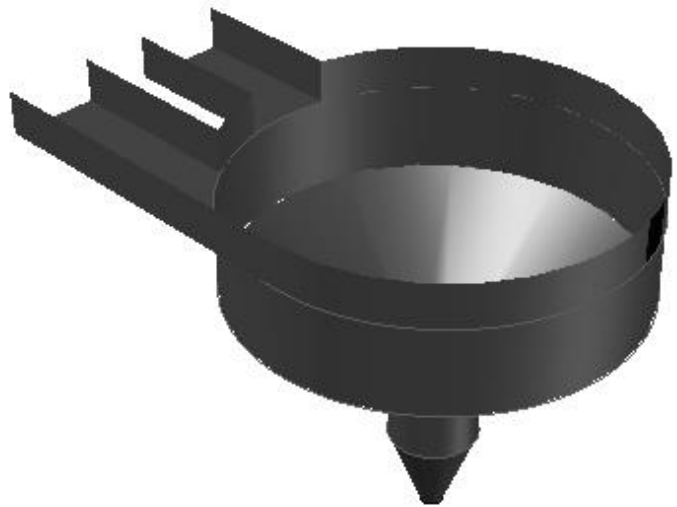


- UV Disinfection Basin



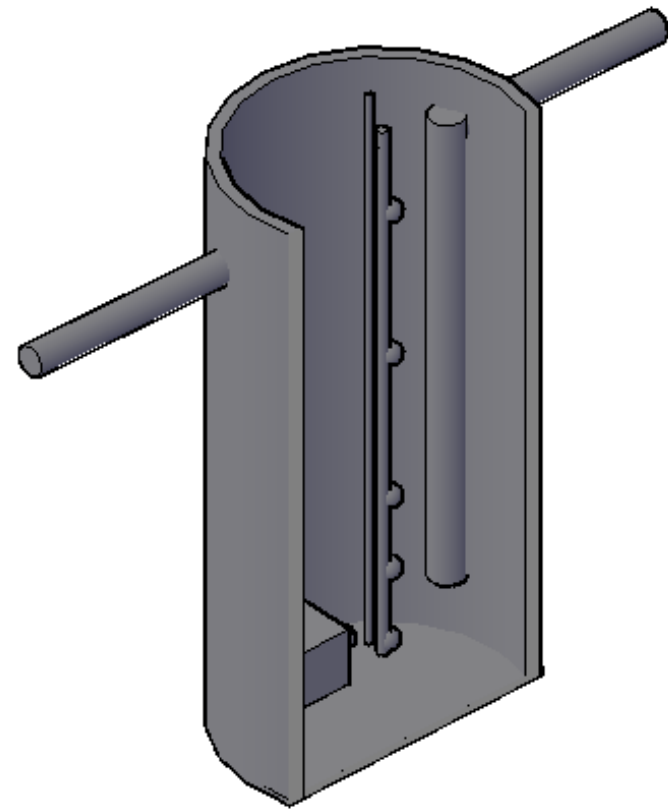
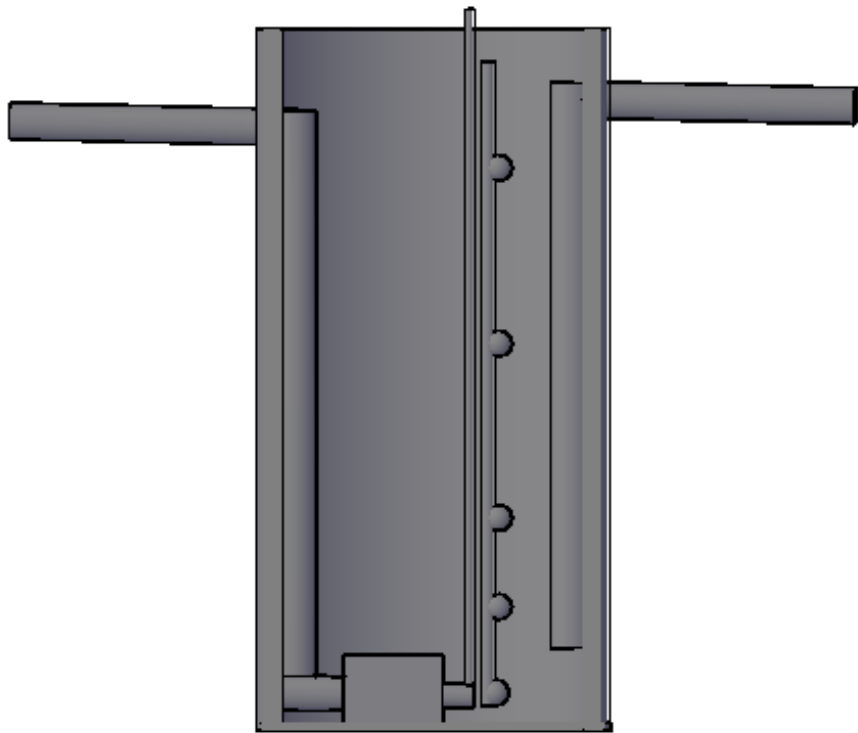
CAD MODELS

- Grit Removal Chamber

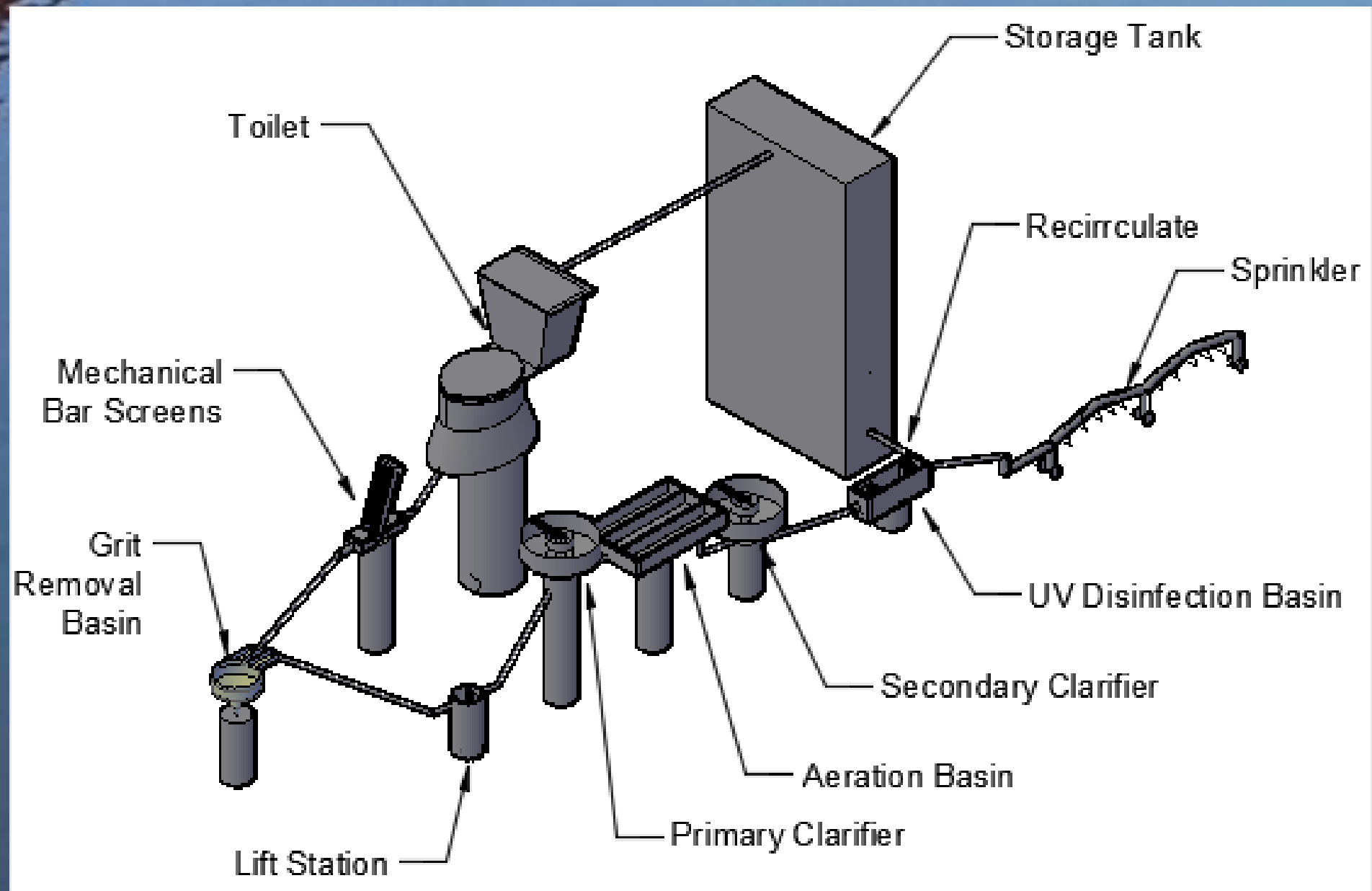


CAD MODELS

- Lift Station



OVERALL LAYOUT

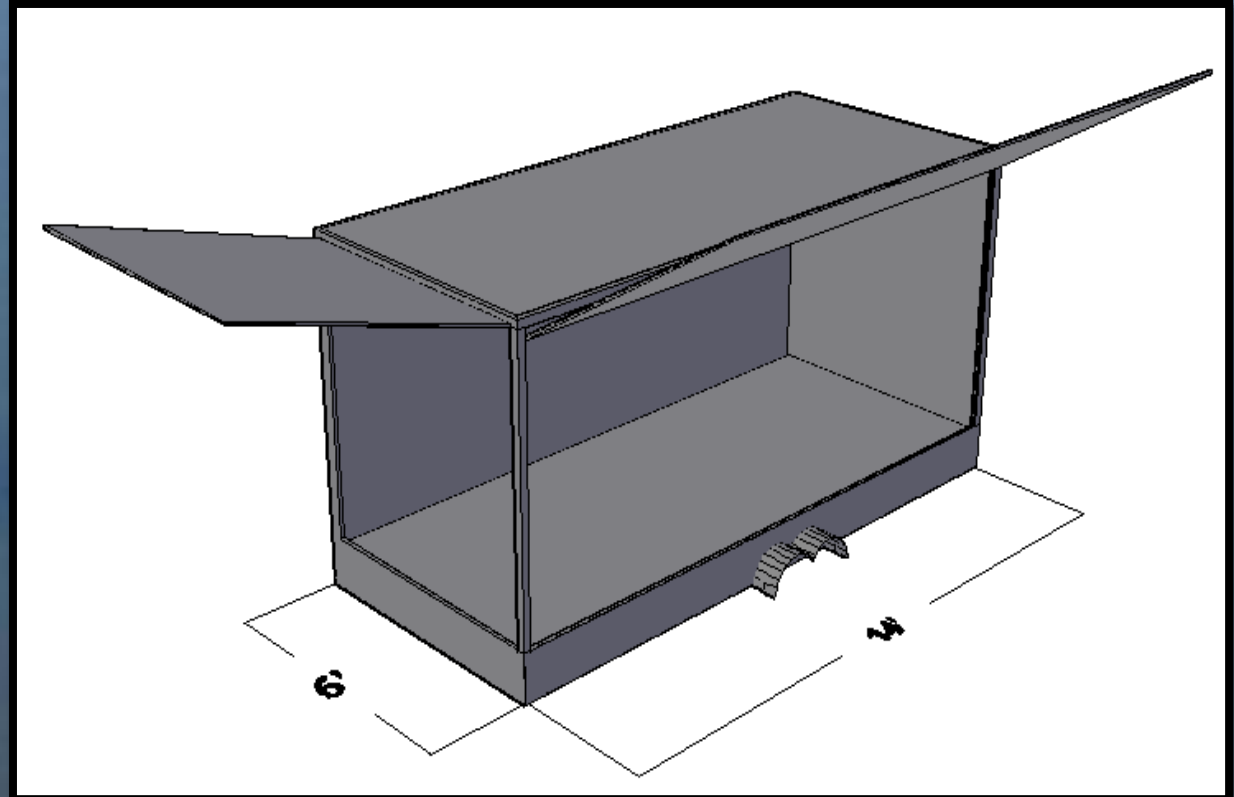


TRAILER STYLE SELECTION

- 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

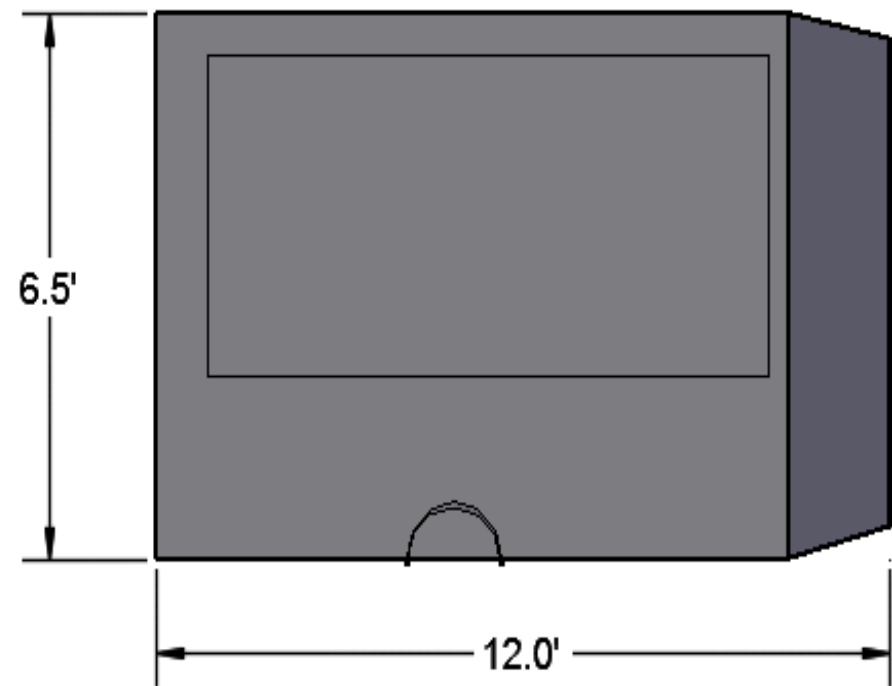
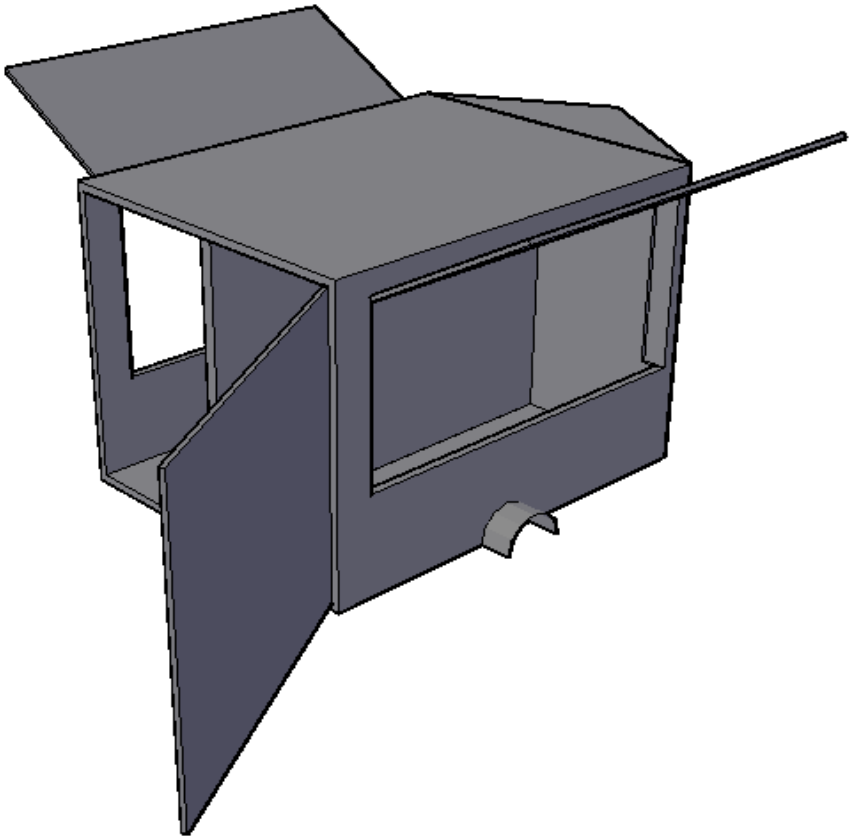
TRAILER STYLE SELECTION

- “Open Sides” Trailer



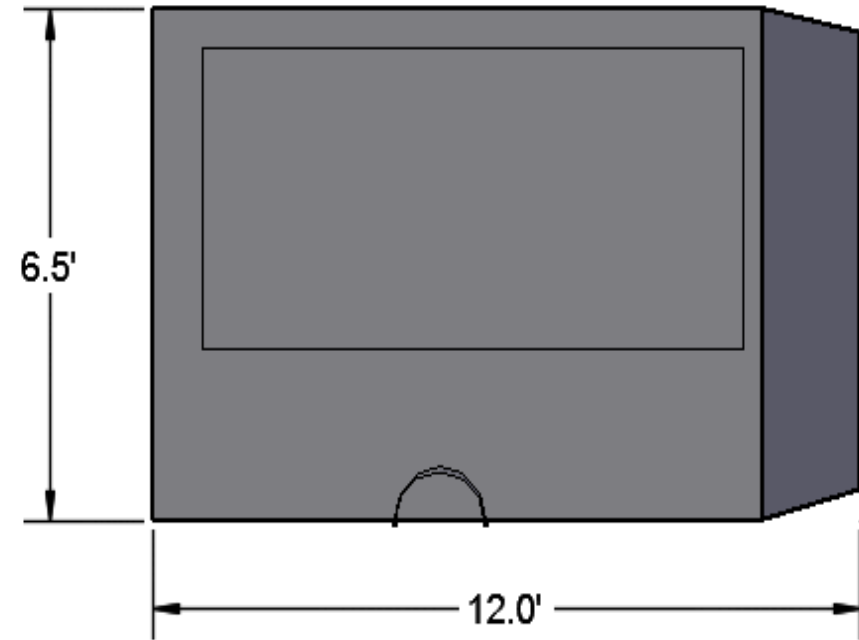
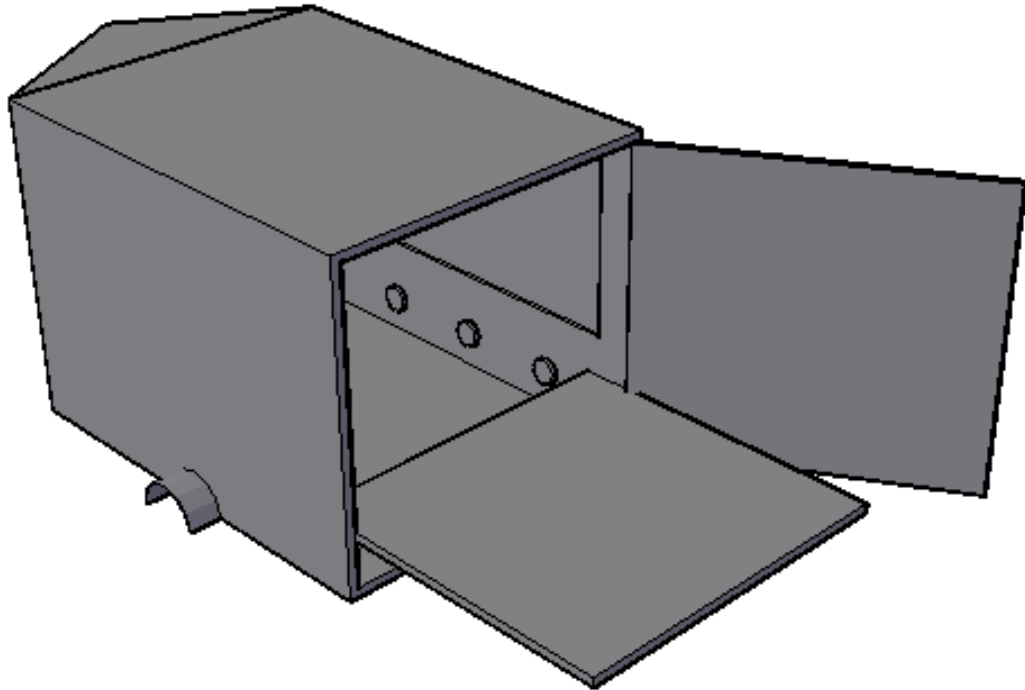
TRAILER STYLE SELECTION

- Tailgate “Walk around” Trailer



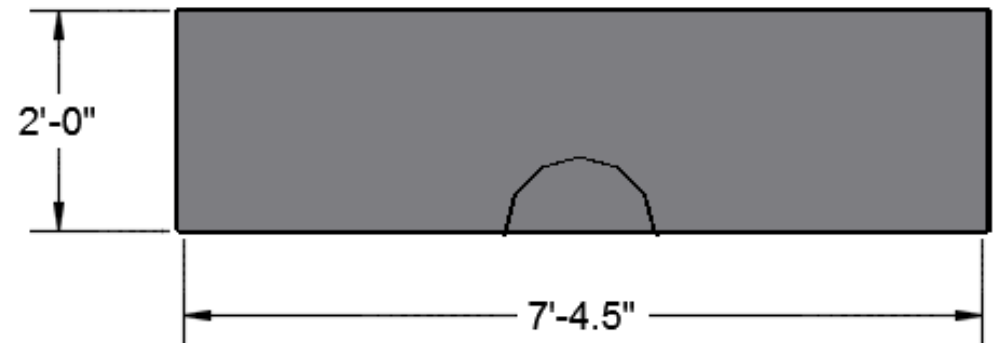
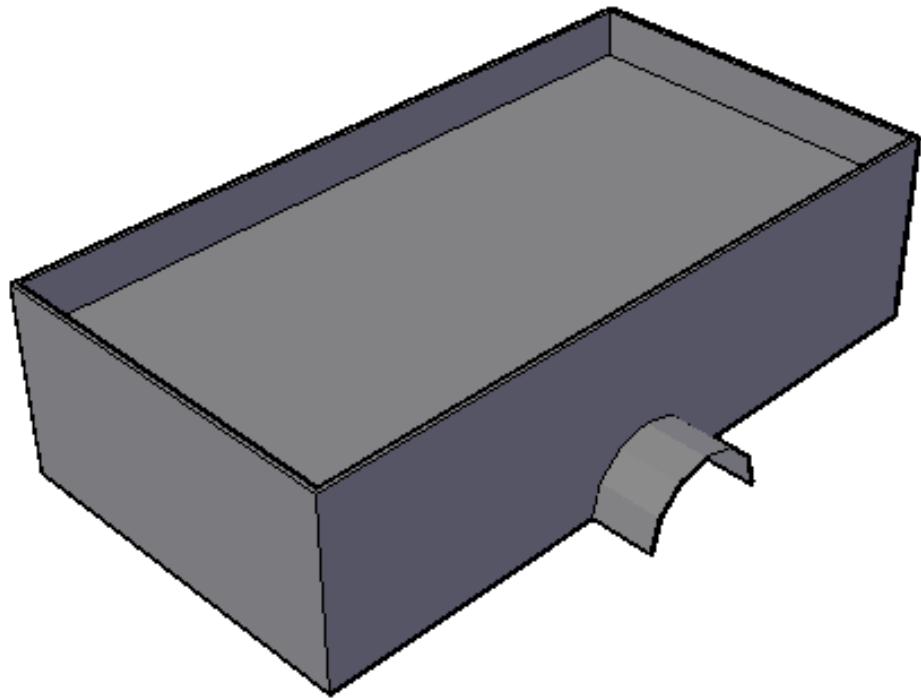
TRAILER STYLE SELECTION

- “Pull-Out” Trailer



TRAILER STYLE SELECTION

- Stream Trailer Style

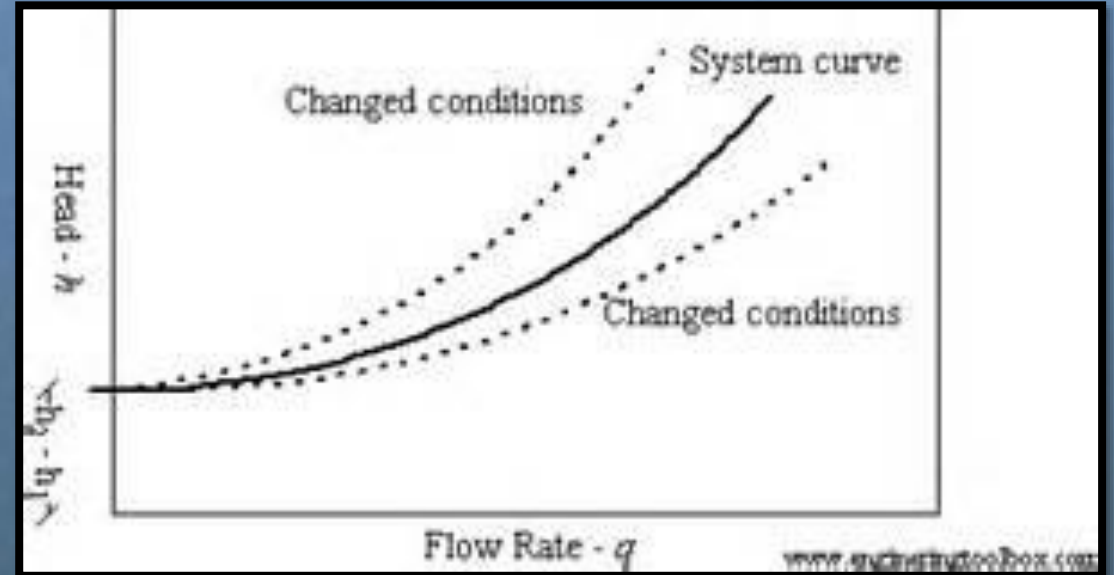


HYDRAULIC MODELING

- Two small centrifugal pumps considered
- Bentley WaterCAD used to generate hydraulic profile
- Modeling parameters:
 - Pipe diameter = $\frac{3}{4}$ "
 - Pipe material – Acrylic/Plastic/PVC
 - Unit operations modeled as “reservoirs”

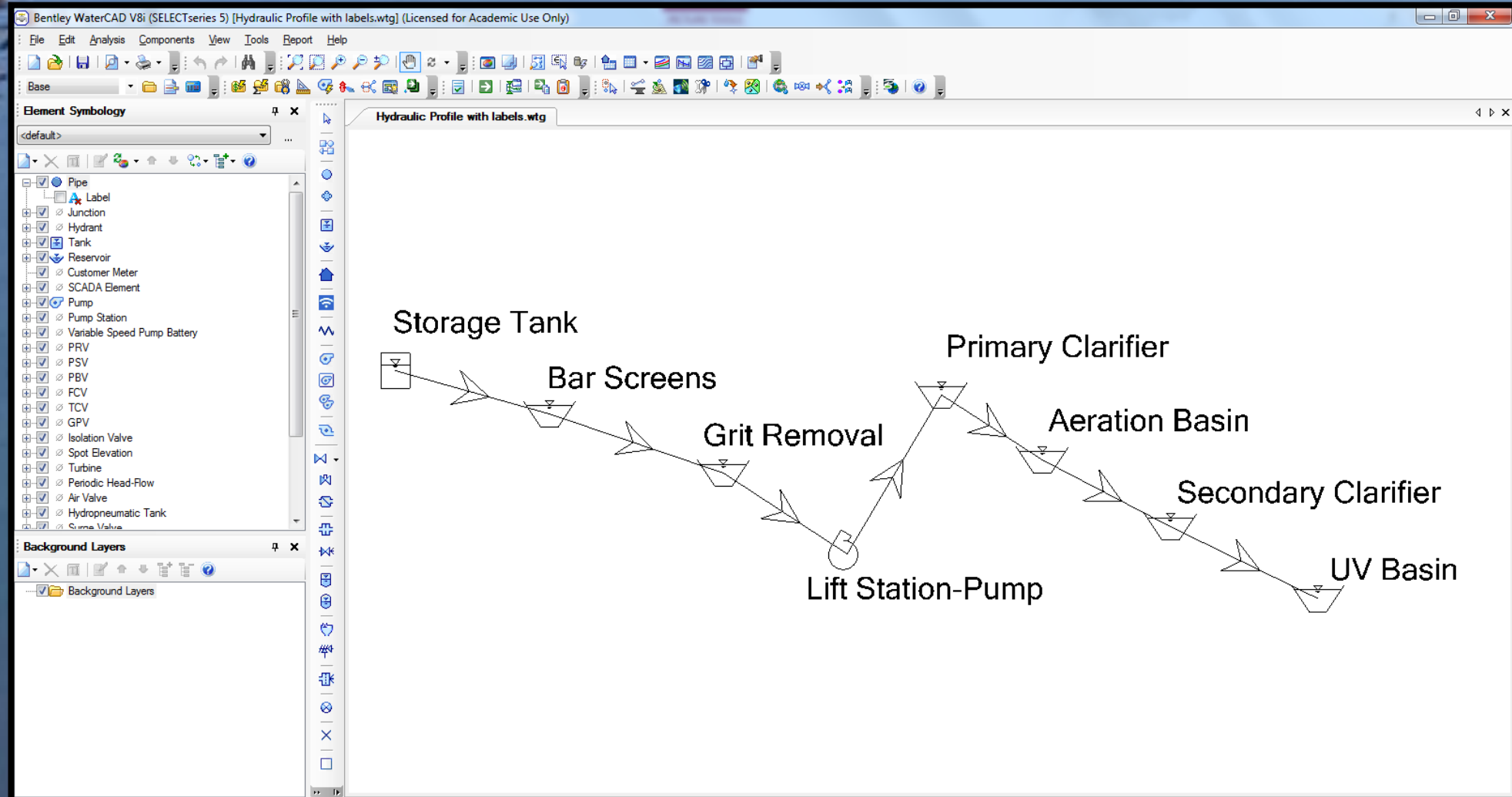
HYDRAULIC MODELING

- 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

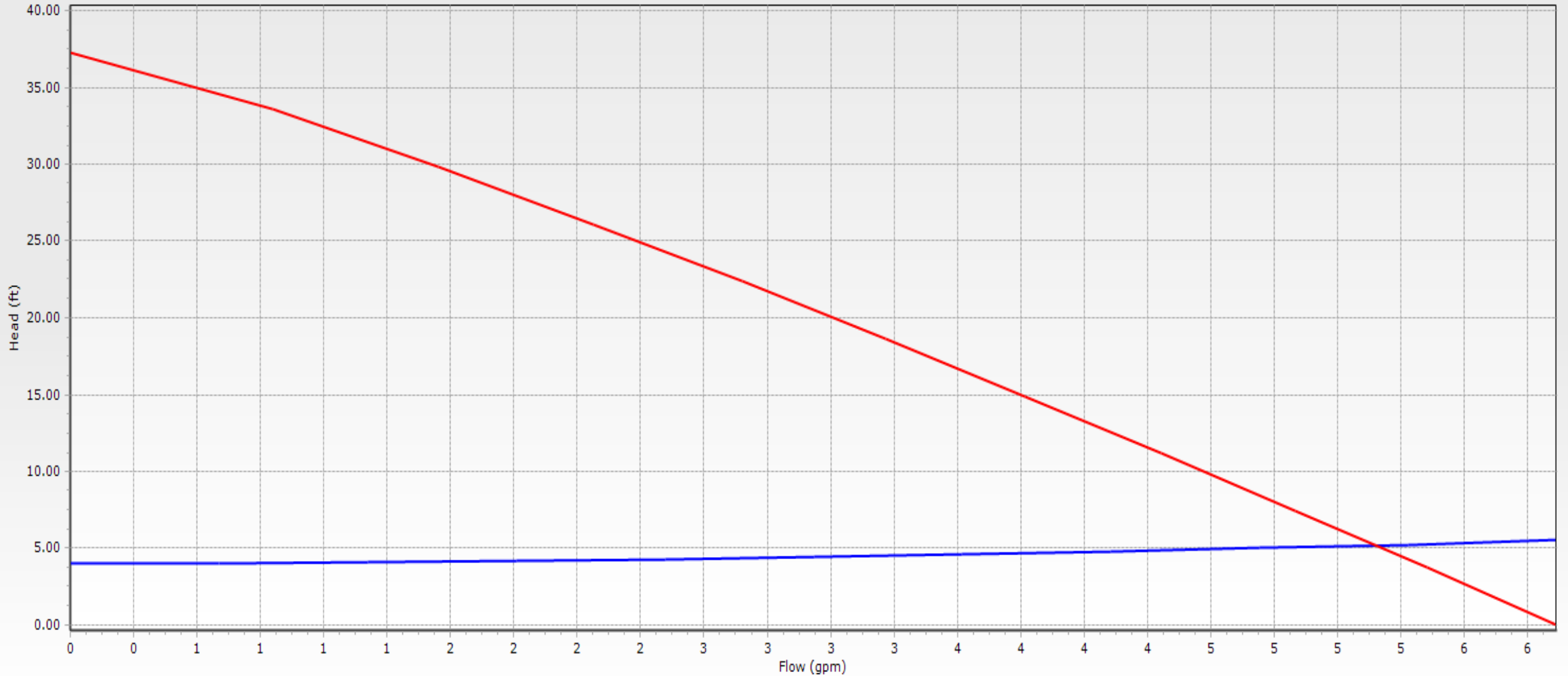
- 115V

- Shutoff Head=48'

- \$141.20

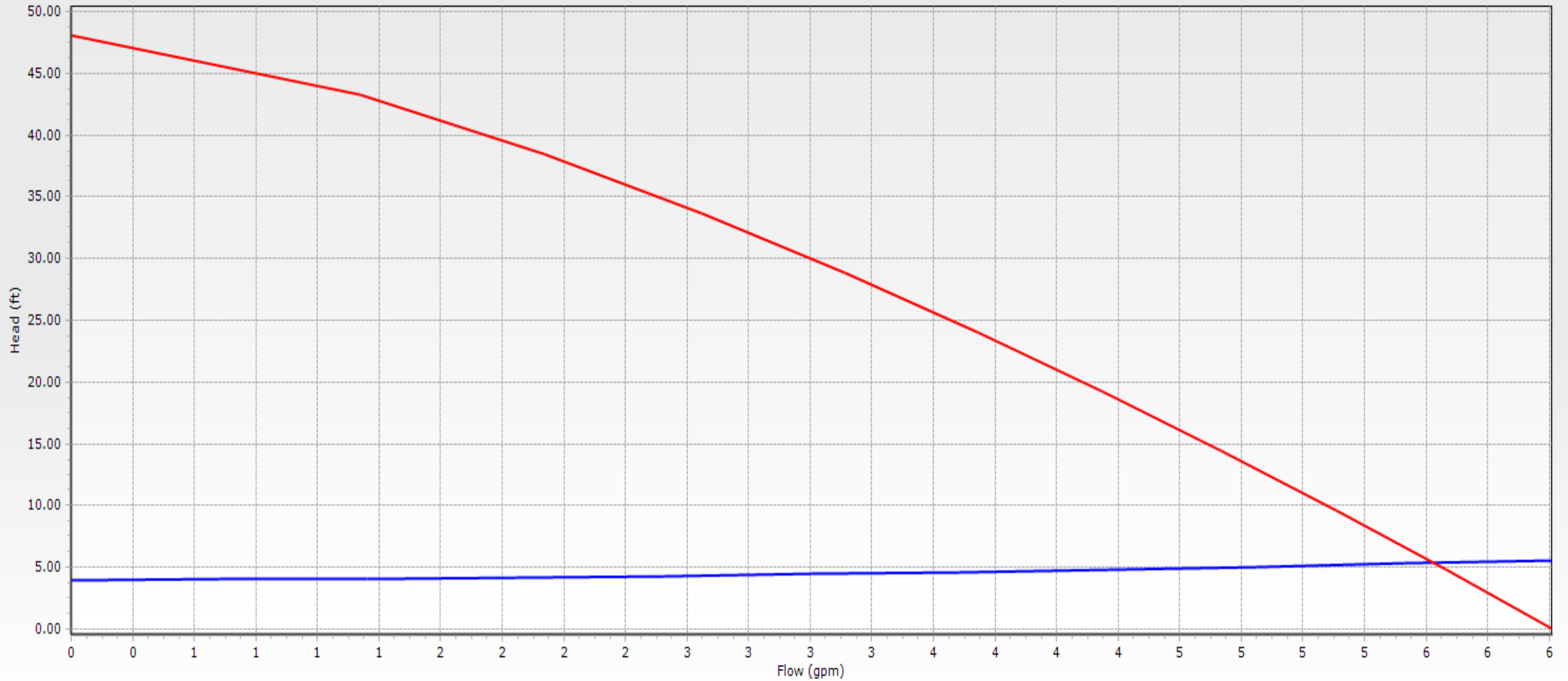
PUMP AND SYSTEM CURVE - DAYTON

Dayton



PUMP AND SYSTEM CURVE – LITTLE GIANT

Little Giant



GRAVITY FLOW

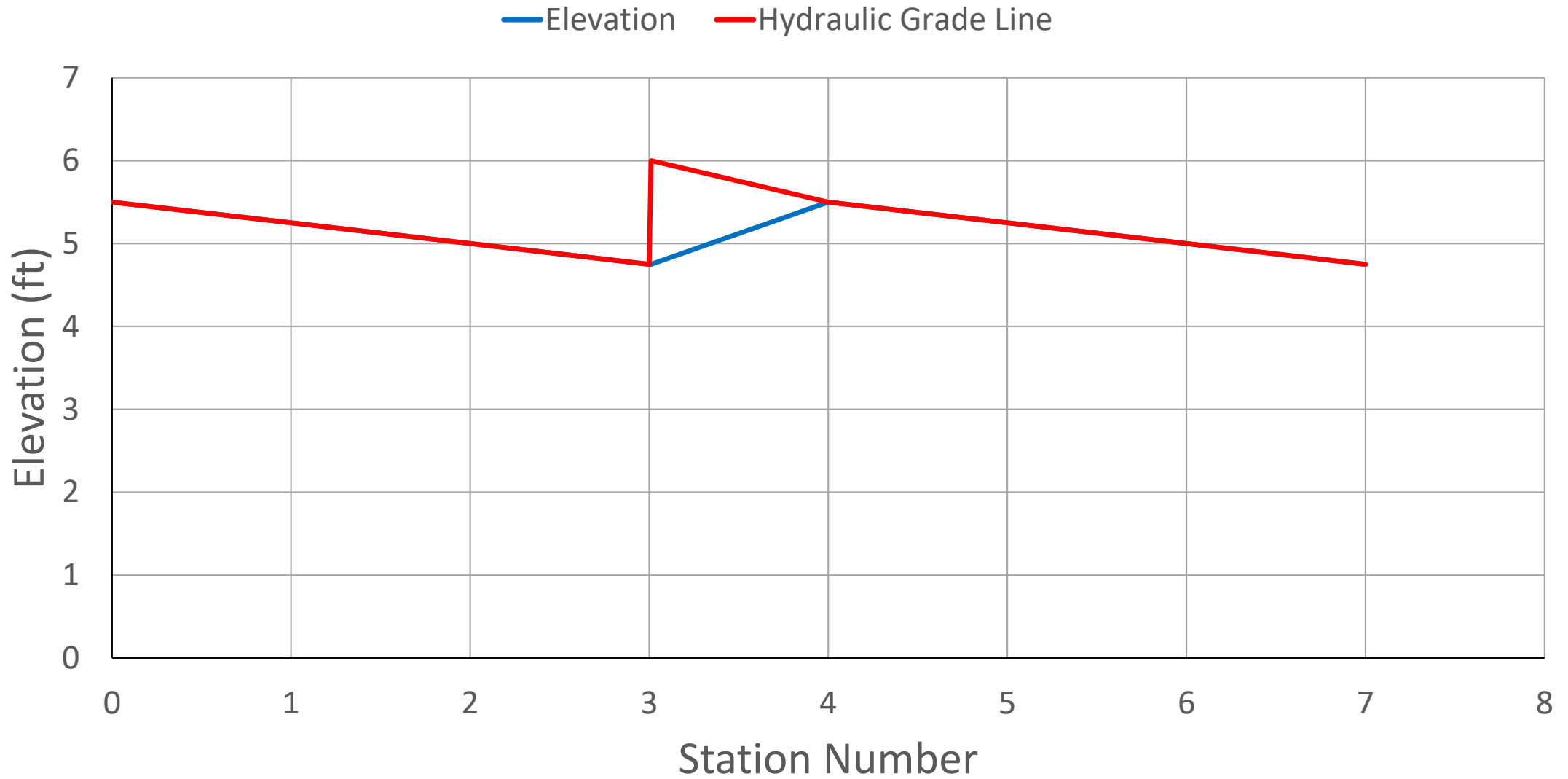
- Both pumps operate at ~6 GPM
 - Must ensure that gravity veins carry same flowrate
- Manning's Equation

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

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

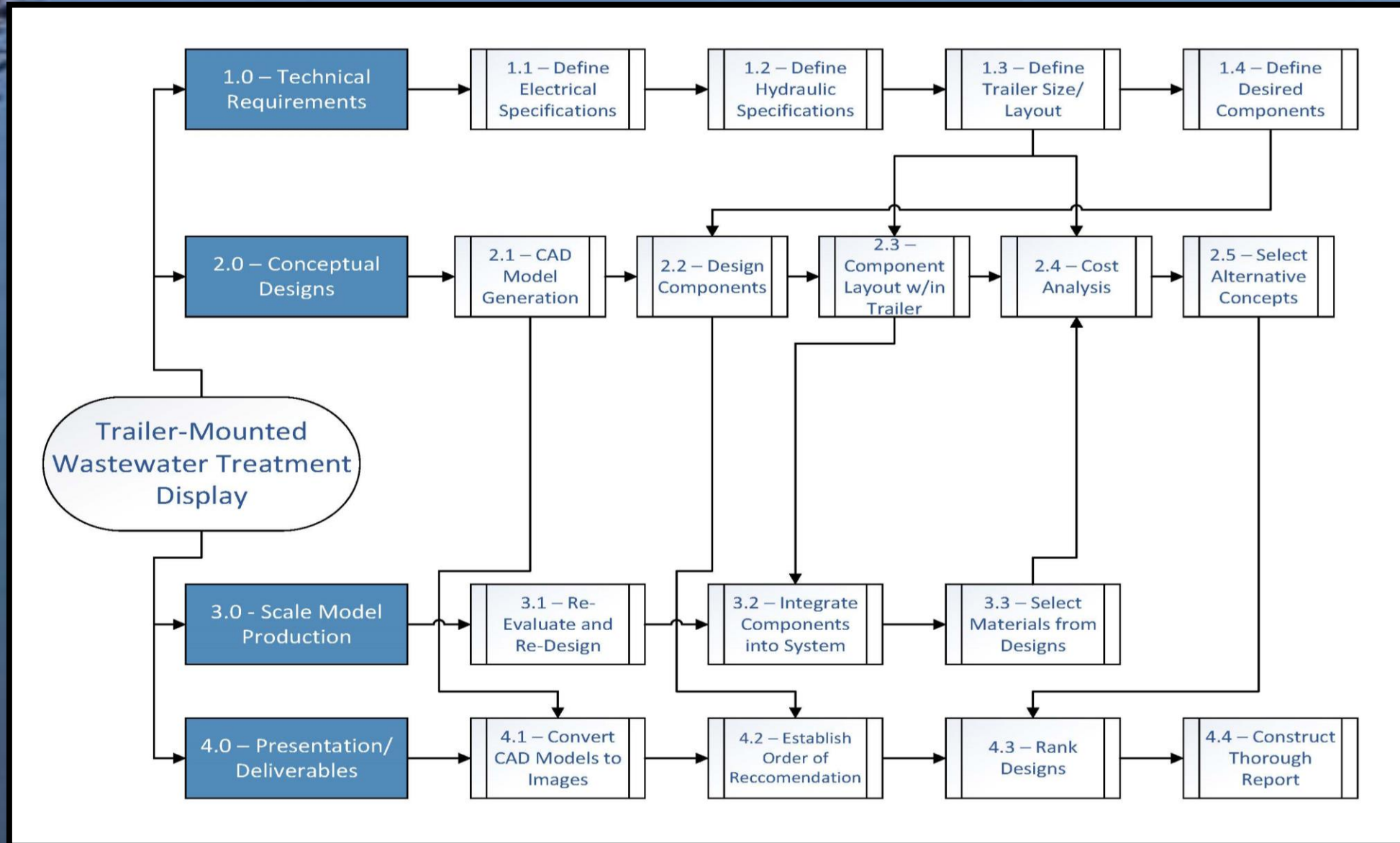
Alternatives				
	“Open Sides” Trailer	“Walk around” Trailer	“Pull-Out” Trailer	Stream Trailer
Bare Trailer	\$22,500	\$15,000	\$15,000	\$10,000
Pump (Dayton)	\$104	\$104	\$104	\$104
Materials	\$700	\$600	\$600	\$500
Total Cost	\$23,304	\$15,704	\$15,704	\$10,604

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



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