Entrance Tank Flow Control

Andrew Bales, Pei Liu

December 12, 2014

Part 1: Problem Definition

Introduction

A flow control system is necessary in AguaClara plants for two major reasons. The first is that if there is excessive raw water entering the plant it must diverted into the drain channel to avoid damaging the plant. The second is that if the water is too turbid for the plant to treat effectively, it must also be diverted into the drain channel. Current AguaClara plants use a bronze gate valve, positioned on the side of the entrance tank, to divert the water into the drain channel. A disadvantage of the current design is that it requires water to flow into the entrance tank prior to being diverted into the drain channel. In the future, plants may add coagulant in the entrance tank, and this provides a key reason to divert the water into the drain channel prior to entering the entrance tank.

Design Details

There were two designs, proposed by Paul Laurios, whose aim was to minimize cost by eliminating the bronze gate valve because bronze gate valves become prohibitively expensive at large diameters. For this reason, the first design proposed involved substituting the large gate valve for multiple smaller gate valves. The second design proposed involved the use of Fernco flexible couplings placed on the top end of the drain stopper pipes in the entrance tank. By adjusting the Fernco flexible coupling water could be diverted into the drain channel. This approach eliminated the need for valves and is cheaper than Laurios' first proposal. However, these designs require the water to first flow into the entrance tank prior to being diverted into the drain channel. For the aforementioned reasons, a third design was proposed.

This design allows water in the inlet pipe to be diverted into the drain channel without first entering the entrance tank. The design requires a gate valve to be placed on the inlet pipe. As shown in Figure 1, when the gate valve is open, water will simply travel into the entrance tank. When the gate valve is closed, water will travel up a vertical pipe, through a horizontal tee, and then back down into the drain channel. The vertical pipe will extend beyond the tee and will be unsealed. This is to ensure there is no siphoning effect when the gate is closed and then reopened. At the top of the vertical pipe a reducer fitting will connect to a pipe that will allow excess water to drain into the entrance tank. The additional pipes and fittings will all be of PVC except for the tee connected to the inlet pipe.

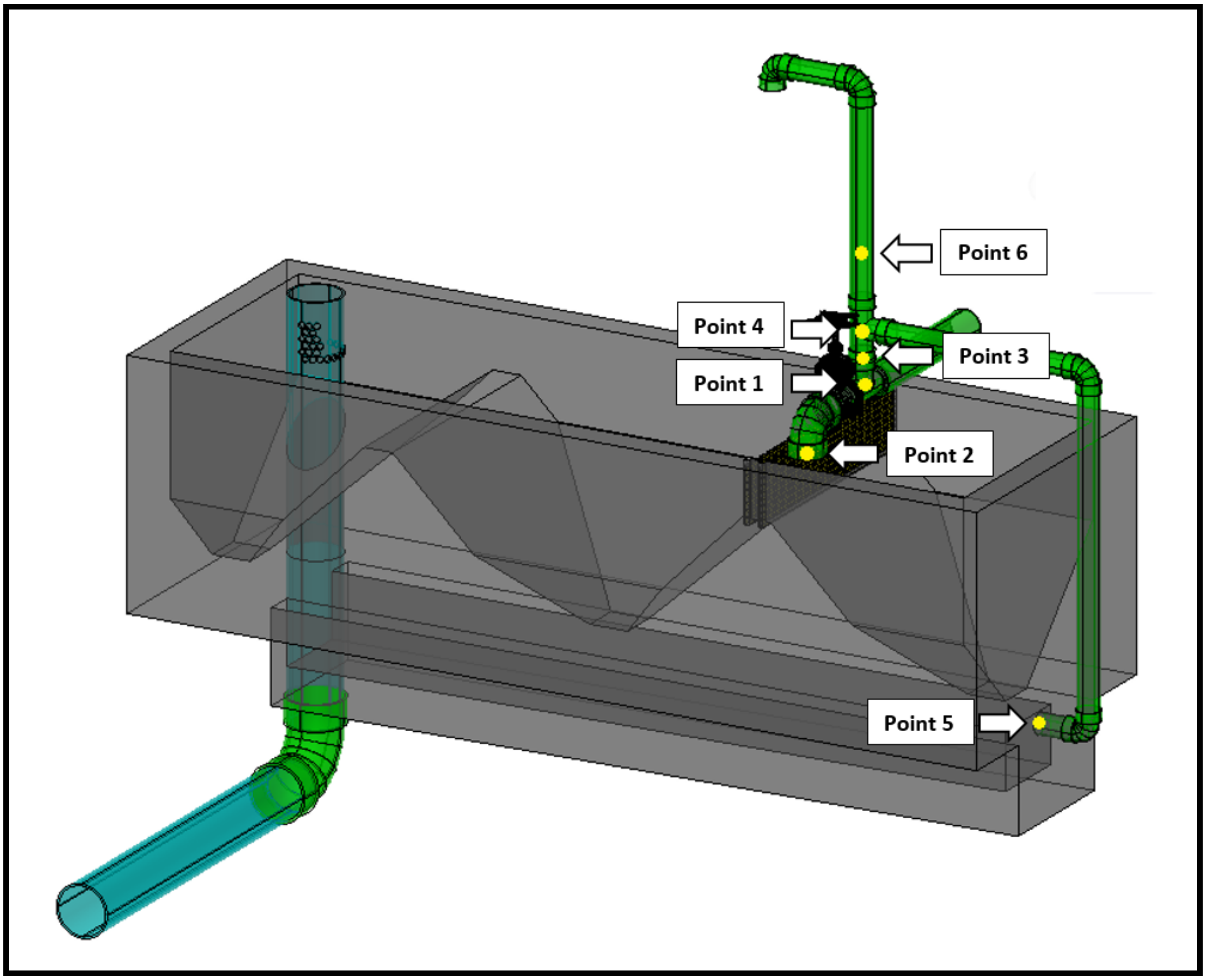


Figure 1: 3D Design Proposal

Part 2: Documented Progress

The new design required many calculations to determine the appropriate pipe dimensions. The team calculated various pressures and resulting water heights. The team considered two scenarios to calculate the water height at various points. First, the team considered when the gate valve was open. Using Equation 1, the team found the height to which water will rise above point 1 in Figure 1 at a given flow rate (given as h_{1to3}). Second, the team considered when the gate valve was closed. Using Equation 1 the team calculated the height to which water will rise above point 1 without diverting to the horizontal pipe (given as h_1). The team also calculated the height to which water will rise above point 4 (given as h_{4to6}) when water flows through the horizontal pipe.

$$p_{in} / \rho + v_{in}^2 / 2 + g\, h_{in} + w_{shaft} = p_{out} / \rho + v_{out}^2 / 2 + g\, h_{out} + w_{loss} \tag{1}$$

The goal is for the height to be as short as possible while ensuring the water does not exceed the height of the total vertical pipes. Some assumptions were made in these calculations. The team assumed the height from point 1 to 4 was 0.5m. The height from point 4 to 6 was calculated depending on this assumption. The team calculated heights that water will rise given various combinations of flow rates and PVC pipe diameters. The team used three flow rate and entrance pipe diameter combinations, which are given in Table1, to determine the design's constraint. Detailed calculations can be found in Google Drive/Design Folder/Entrance_Tank/ET_Calculations.

Q (L/s)	D (in)	D_{pvc} (in)	Water Heights	
			Valve Open	Valve Closed
16	6	4	$h_{1to3} < 0$	$h_{4to6} < 0$ $h_1 = 0.199$m
32	6	4	$h_{1to3} < 0$	$h_{4to6} = 0.387$m $h_1 = 0.794$m
		6	$h_{1to3} < 0$	$h_{4to6} < 0$ $h_1 = 0.157$m
44	6	4	$h_{1to3} = 0.083$m	$h_{4to6} = 1.502$m $h_1 = 1.906$m
		6	$h_{1to3} = 0.083$m	$h_{4to6} < 0$ $h_1 = 0.297$m

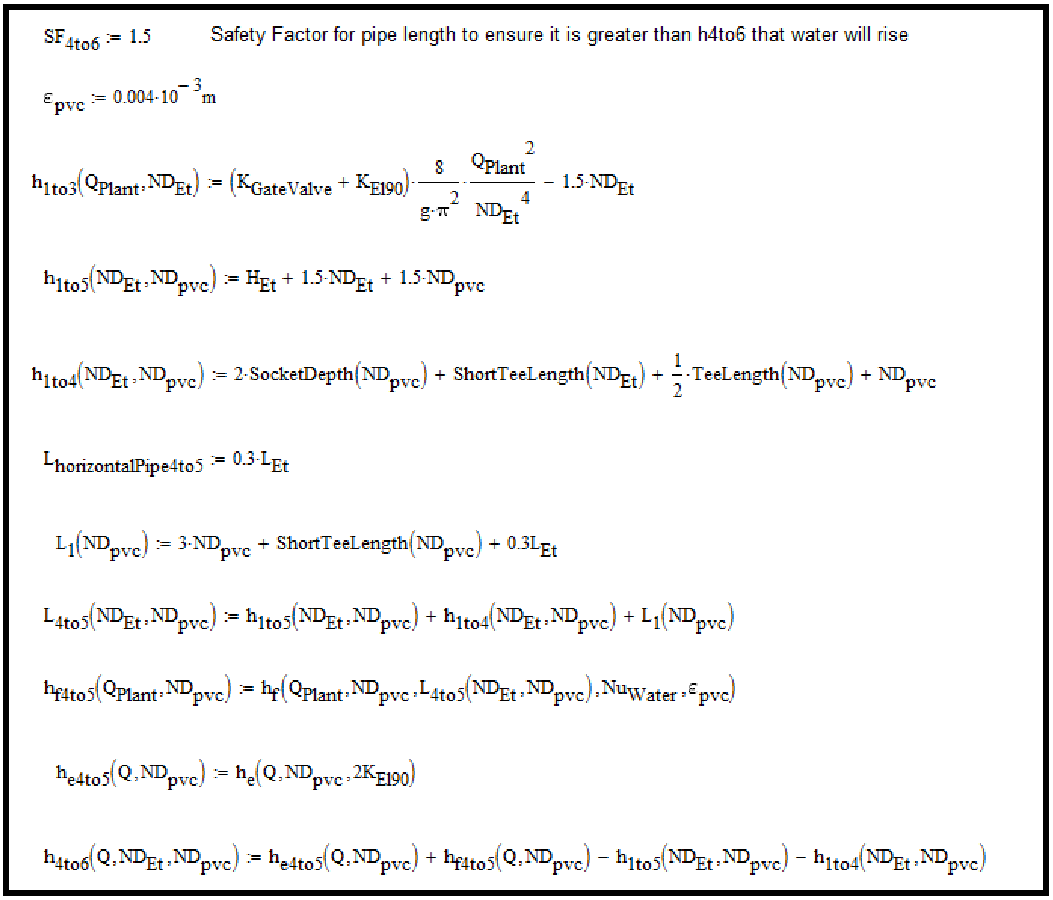
Table 1. Water Heights at Critical Points

From the results in Table 1, the team found the the team found the height to which water will rise above point 1 in Figure 1 (given as h1to3) is negligible compared to the height to which water will rise above point 4 in Figure 1 (given as h4to6) for all three plants. The design team had a discussion with Monroe where it was decided that the instantaneous height to which water will rise (given as h1), when the gate valve is closed, will not be a determining factor. This is because regardless of this figure, the water will flow horizontally and into the drainage channel, even if initially some water flows vertically and into the entrance tank.

The design team concluded that the determining factor is the height to which water will rise above point 4 when water is being diverted into the drain channel (given as h4to6). With this in mind the design team was able to write MathCAD code for the new design.

The MathCAD code requires the design tool to request a new user input: entrance pipe diameter. It outputs an optimal PVC pipe diameter. The new user input is necessary because the design tool currently outputs an entrance pipe diameter that is not adhered to in actual plant construction projects. The code sets a maximum pipe length above point 4 in Figure 1 to 0.5m. This is to ensure the height of the new pipes does not exceed the height of the plant. Since h1to4 in Figure 1 is not a design constraint this pipe length is set to the diameter of the entrance pipe. This is simply for ease of construction since it avoids two sockets being immediately connected.

The design team's code makes use of the design tools existing functions and variables. The code has an independent function that outputs h4to6, which can be seen in Figure 2. The code initially sets the diameter of the PVC pipe to the diameter of the entrance pipe. The code then utilizes a while loop that calls this function to determine if the value is less than the maximum allowed height, which is 0.5m. If h4to6 is less than 0.5m, it recalculates h4to6 with an incrementally smaller PVC pipe diameter. The code outputs the minimum allowed PVC pipe diameter, which can be seen in Figure 3. The code can be found in Final Designs/Under Development/EntranceTankapb224.



$SF_{4to6} := 1.5$ Safety Factor for pipe length to ensure it is greater than h4to6 that water will rise

$$\varepsilon_{pvc} := 0.004 \cdot 10^{-3} m$$

$$h_{1to3}(Q_{Plant}, ND_{Et}) := (K_{GateValve} + K_{El90}) \cdot \frac{8}{g \cdot \pi^2} \cdot \frac{Q_{Plant}^2}{ND_{Et}^4} - 1.5 \cdot ND_{Et}$$

$$h_{1to5}(ND_{Et}, ND_{pvc}) := H_{Et} + 1.5 \cdot ND_{Et} + 1.5 \cdot ND_{pvc}$$

$$h_{1to4}(ND_{Et}, ND_{pvc}) := 2 \cdot SocketDepth(ND_{pvc}) + ShortTeeLength(ND_{Et}) + \frac{1}{2} \cdot TeeLength(ND_{pvc}) + ND_{pvc}$$

$$L_{horizontalPipe4to5} := 0.3 \cdot L_{Et}$$

$$L_1(ND_{pvc}) := 3 \cdot ND_{pvc} + ShortTeeLength(ND_{pvc}) + 0.3L_{Et}$$

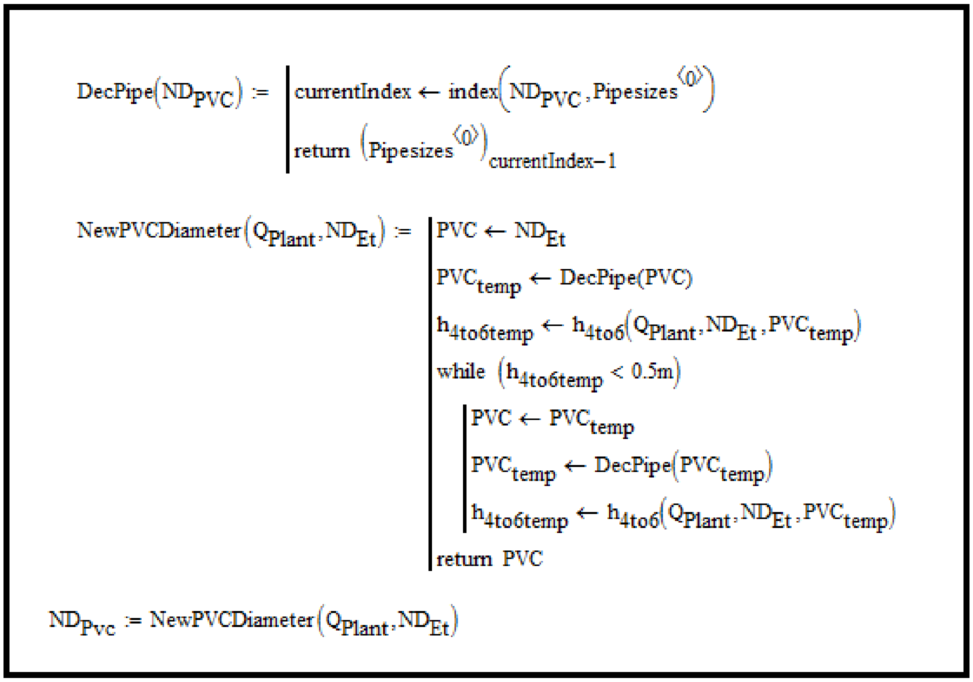
$$L_{4to5}(ND_{Et}, ND_{pvc}) := h_{1to5}(ND_{Et}, ND_{pvc}) + h_{1to4}(ND_{Et}, ND_{pvc}) + L_1(ND_{pvc})$$

$$h_{f4to5}(Q_{Plant}, ND_{pvc}) := h_f(Q_{Plant}, ND_{pvc}, L_{4to5}(ND_{Et}, ND_{pvc}), Nu_{Water}, \varepsilon_{pvc})$$

$$h_{e4to5}(Q, ND_{pvc}) := h_e(Q, ND_{pvc}, 2K_{El90})$$

$$h_{4to6}(Q, ND_{Et}, ND_{pvc}) := h_{e4to5}(Q, ND_{pvc}) + h_{f4to5}(Q, ND_{pvc}) - h_{1to5}(ND_{Et}, ND_{pvc}) - h_{1to4}(ND_{Et}, ND_{pvc})$$

Figure 2. Height Calculations



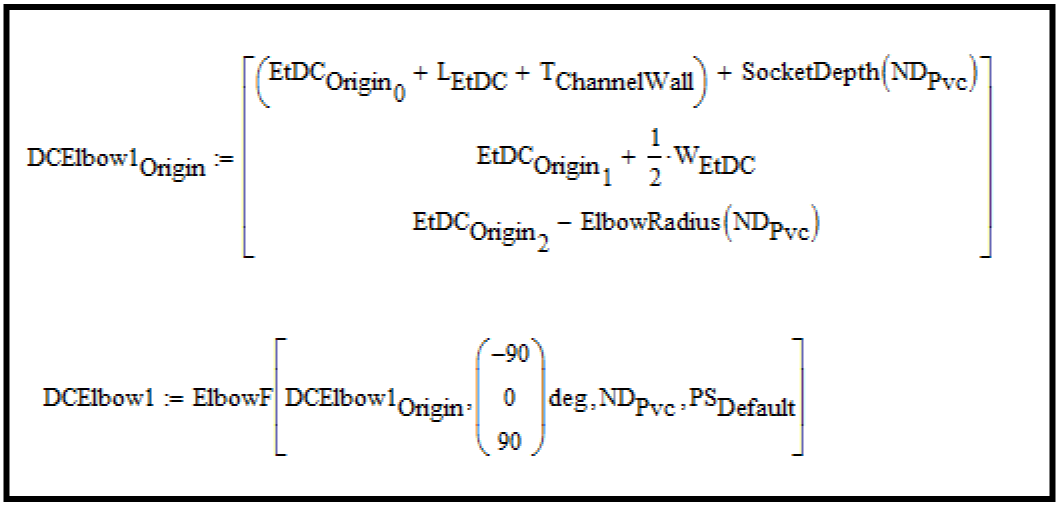
```
$DecPipe(ND_{PVC}) :=$
    $currentIndex \leftarrow index\left(ND_{PVC}, Pipesizes^{\langle 0 \rangle}\right)$
    $return \left(Pipesizes^{\langle 0 \rangle}\right)_{currentIndex-1}$

$NewPVCDiameter(Q_{Plant}, ND_{Et}) :=$
    $PVC \leftarrow ND_{Et}$
    $PVC_{temp} \leftarrow DecPipe(PVC)$
    $h_{4to6temp} \leftarrow h_{4to6}(Q_{Plant}, ND_{Et}, PVC_{temp})$
    $while\ (h_{4to6temp} < 0.5m)$
        $PVC \leftarrow PVC_{temp}$
        $PVC_{temp} \leftarrow DecPipe(PVC_{temp})$
        $h_{4to6temp} \leftarrow h_{4to6}(Q_{Plant}, ND_{Et}, PVC_{temp})$
    $return\ PVC$

$ND_{Pvc} := NewPVCDiameter(Q_{Plant}, ND_{Et})$
```

Figure 3. PVC Pipe Diameter Functions

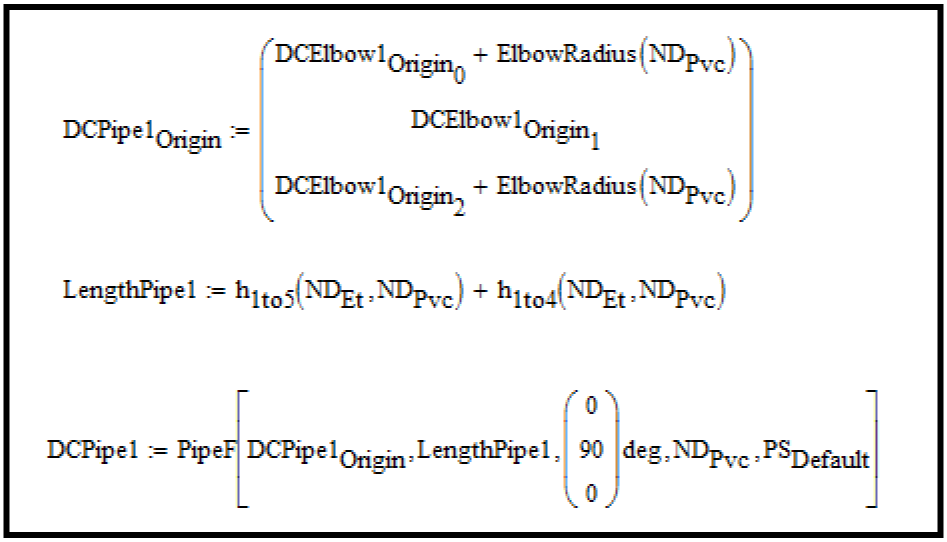
The design team generated AutoCAD drawing functions for the new design. It used 4 different Design Tool functions including ElbowF, PipeF, TeeF, and InsertThreadedValve. The method used to generate an elbow, pipe, tee, and valve can be seen in Figure 4, Figure 5, Figure 6 and Figure 7 respectively. The origin of the first elbow was based off the origin of the drain channel. Each component's origin is based off the previous component's origin.



$$DCElbow1_{Origin} := \begin{bmatrix} \left(EtDC_{Origin_0} + L_{EtDC} + T_{ChannelWall}\right) + SocketDepth\left(ND_{Pvc}\right) \\ EtDC_{Origin_1} + \frac{1}{2} \cdot W_{EtDC} \\ EtDC_{Origin_2} - ElbowRadius\left(ND_{Pvc}\right) \end{bmatrix}$$

$$DCElbow1 := ElbowF\left[DCElbow1_{Origin}, \begin{pmatrix} -90 \\ 0 \\ 90 \end{pmatrix} deg, ND_{Pvc}, PS_{Default}\right]$$

Figure 4. Elbow Drawing Example

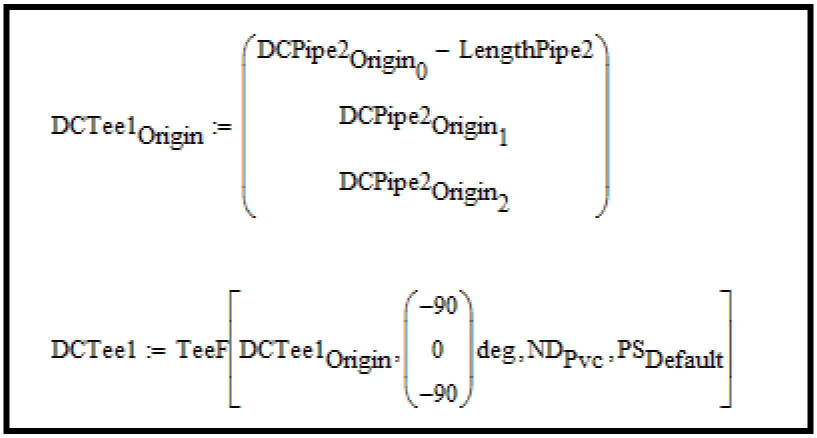


$$DCPipe1_{Origin} := \begin{pmatrix} DCElbow1_{Origin_0} + ElbowRadius\left(ND_{Pvc}\right) \\ DCElbow1_{Origin_1} \\ DCElbow1_{Origin_2} + ElbowRadius\left(ND_{Pvc}\right) \end{pmatrix}$$

$$LengthPipe1 := h_{1to5}\left(ND_{Et}, ND_{Pvc}\right) + h_{1to4}\left(ND_{Et}, ND_{Pvc}\right)$$

$$DCPipe1 := PipeF\left[DCPipe1_{Origin}, LengthPipe1, \begin{pmatrix} 0 \\ 90 \\ 0 \end{pmatrix} deg, ND_{Pvc}, PS_{Default}\right]$$

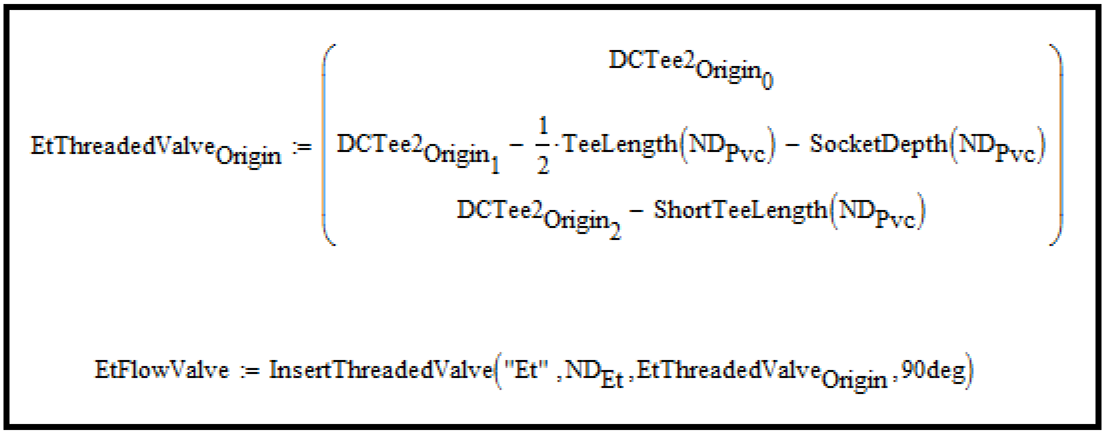
Figure 5. Pipe Drawing Example



$$\mathrm{DCTee1}_{\mathrm{Origin}} := \begin{pmatrix} \mathrm{DCPipe2}_{\mathrm{Origin}_0} - \mathrm{LengthPipe2} \\ \mathrm{DCPipe2}_{\mathrm{Origin}_1} \\ \mathrm{DCPipe2}_{\mathrm{Origin}_2} \end{pmatrix}$$

$$\mathrm{DCTee1} := \mathrm{TeeF}\left[\mathrm{DCTee1}_{\mathrm{Origin}}, \begin{pmatrix} -90 \\ 0 \\ -90 \end{pmatrix} \mathrm{deg}, \mathrm{ND}_{\mathrm{Pvc}}, \mathrm{PS}_{\mathrm{Default}}\right]$$

Figure 6. Tee Fitting Drawing Example



$$\mathrm{EtThreadedValve}_{\mathrm{Origin}} := \begin{pmatrix} \mathrm{DCTee2}_{\mathrm{Origin}_0} \\ \mathrm{DCTee2}_{\mathrm{Origin}_1} - \frac{1}{2} \cdot \mathrm{TeeLength}\left(\mathrm{ND}_{\mathrm{Pvc}}\right) - \mathrm{SocketDepth}\left(\mathrm{ND}_{\mathrm{Pvc}}\right) \\ \mathrm{DCTee2}_{\mathrm{Origin}_2} - \mathrm{ShortTeeLength}\left(\mathrm{ND}_{\mathrm{Pvc}}\right) \end{pmatrix}$$

$$\mathrm{EtFlowValve} := \mathrm{InsertThreadedValve}\left(\text{"Et"}, \mathrm{ND}_{\mathrm{Et}}, \mathrm{EtThreadedValve}_{\mathrm{Origin}}, 90\mathrm{deg}\right)$$

Figure 7. Threaded Valve Drawing Example

The resulting autoCAD drawing is shown in Figure 7.

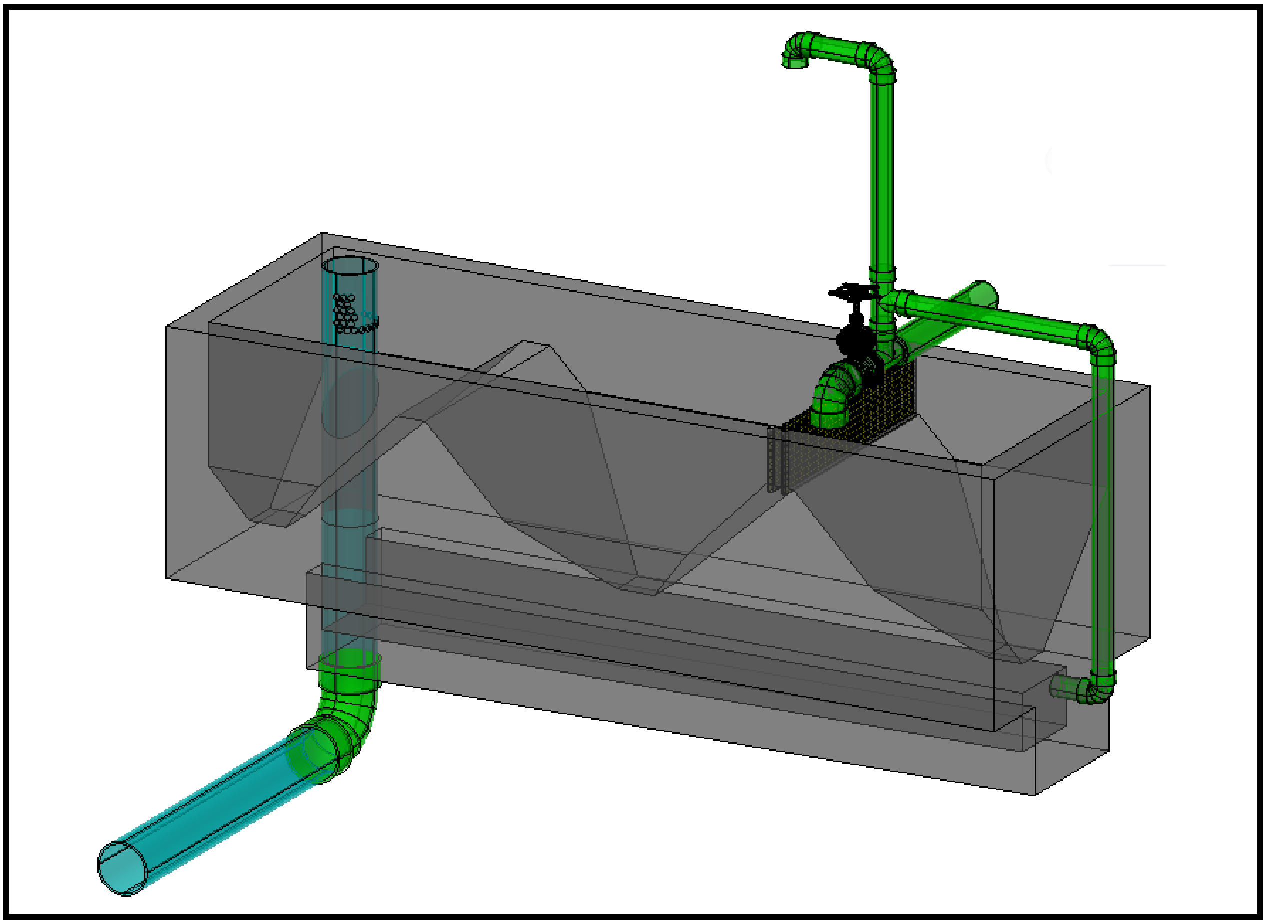


Figure 7. Design Proposal AutoCAD drawing

Part 3: Future Work

The MathCAD code that was written currently outputs a script that produces a drawing that is not entirely correct for two reasons. First, the tee fitting that connects the entrance pipe to the vertical PVC pipe will potentially have to be a reducing tee. When this occurs the drawing will be incorrect because the current design tool does not have a reducer tee function. Reducer Tee fitting values, as well as a drawing function for Reducing Tees, should be added to the design tool for use in this and any future applications.

The second reason is that currently the piping that extends the vertical PVC pipe to avoid a siphon effect and allow for excessive instantaneous drainage if necessary is drawn at the same diameter as the vertical PVC pipe. This is because the code that finds the minimum PVC pipe diameter assumes there are reducer fittings available for any combination of pipe diameters. In the design tool, however, the reducer function is limited to a set number of diameter combinations. However, this current drawing may be favored because it would reduce the number of reducer fittings and variety of pipe diameters required and may actually be a cheaper design. A cost analysis will have to be done to determine the favored option, perhaps by contacting AguaClara engineers.

Currently the piping that extends the vertical PVC pipe is being drawn to drain over the trash rack. The design team included a safety factor of 1.5 times the length of the vertical pipe to ensure water does not overflow in this manner. If, however, AguaClara engineers require that it be oriented to drain inside the trash rack, it can be modified by simply changing the rotation of an elbow.

Future groups will also have to contact AguaClara engineers to evaluate the entire design. If the design is feasible, a final cost analysis will have to be done.