

Progress Report: Design Updates

Meghan Furton mrf222

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1 Introduction

AguaClara, a student project team at Cornell University, began in 2005 to develop sustainable water treatment technology. By working with local partners and program Alumni in country, over a dozen gravity-powered surface water treatment plants have been built to serve communities in Honduras. Ground water treatment for arsenic and fluoride and energy neutral wastewater technologies are some of the new frontiers for the program, as well as the establishment of a global network of partners and beneficiaries of sustainable water technology; AguaClara LLC. Communication between student research teams on campus and engineers and communities internationally is facilitated by the design team, a subset of the student project team which publishes and updates the AguaClara Automated Design Tool and other supplementary educational materials, like graphic images to explain flow of water through the plant.

The Automated Design Tool (ADT) allows any user to request a plant with unique flow rate and other construction dimensions and receive a detailed AutoCad drawing of the plant along with a customized document describing each unit process in the design. Engineers on site must then convert this 3D drawing into useful construction documents along with structural and site design details: only the hydraulic components of the plant are provided by the ADT. The ADT uses LabVIEW to generate AutoCad and Microsoft Word files based on MathCad files which the design team students update each semester. Updates come from feedback from the field as well as research team findings. The usefulness of the tool is also being increased each semester with the addition of modular designs and more expert inputs. This report details progress in two areas of the ADT: updates to the chemical dose controller and the addition of automated section cut capability of the tool. Additional isolated bug fixes are also listed in the Miscellaneous section.

2 Chemical Dose Controller

The Chemical Dose Controller has been constructed in both standard OStARS and EStARS plants. The ADT, however, does not yet include the plumbing system between the Chemical Storage tanks and the dosing tubes. In Fall 2015, design team member Serena Takada (st587) added code to the Standard CdcAC file to draw the dosing tubes and lever arm of the CDC system. Her work is displayed by the ADT as shown in Figure 1. Figure 1 is a layout view of the CDC and Chem Stock Tanks. The components missing from this drawing are the constant head tanks, calibration columns, and plumbing connecting these components to the storage tanks and dosing tubes.

2.a Challenge Details

The first step to creating drawing scripts for the Constant Head Tanks and Calibration Columns (hereafter referred to as CdcCalCol) was to create an understandable schematic of the system based on drawings from the constructed system in San Matias. The San Matias plant is the most preferred schematic according to AguaClara Engineer Jon Christensen. Though much about the layout is either site specific or arbitrary, a few guiding principles are clear: the calibration columns should be at least as tall as the stock tanks so they do not overflow, all drainage and dosing valves should be easily and independently controlled and attached to the wall of the chemical platform or entrance tank. Some of the layout is somewhat subjective, and should be checked by other engineers after it has been drawn for correctness and simplicity. The current rough

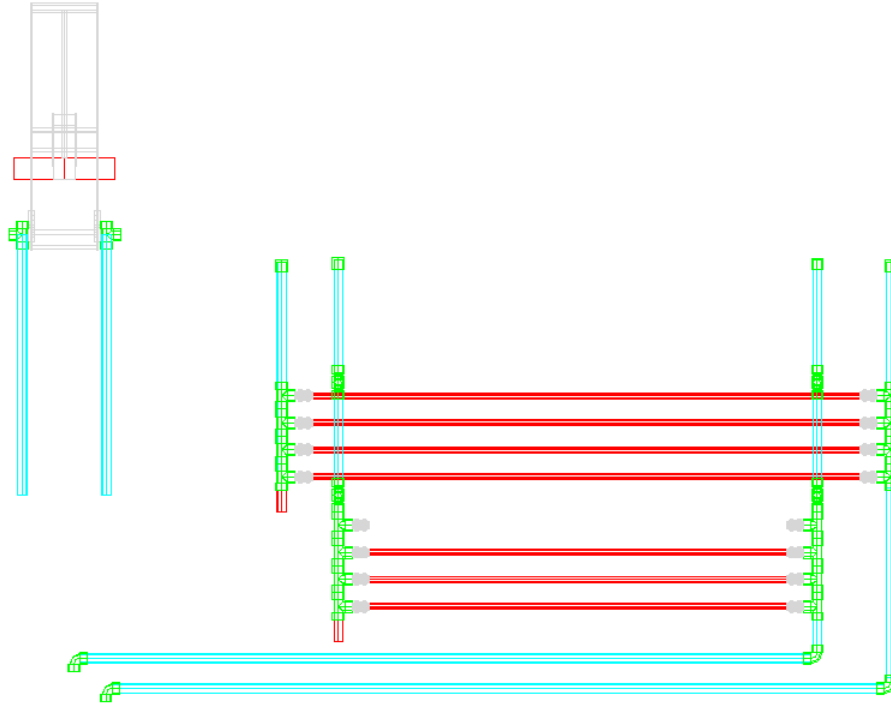


Figure 1: Server layout View of CDC for 40 Lps plant. The CDC and CHem Stock Tanks were added to the Layout file and the AI list in the method file. The Layout file is a part of the Automated Design code which automates the selection of plant component layers in AutoCad and creates unique viewports for each 'layout' which are exported from AutoCad as image files and visible on the server for each design request.

schematic is shown below in Figure 2 based on conversations with Christensen. In previous design iterations when the entrance tank was separate from the floc tank, the length of the entrance tank constrained the dosing system. Now that the entrance tank is attached seamlessly to the floc tank, there is more area available for the dosing tubes and no additional changes to this part of the system were needed.

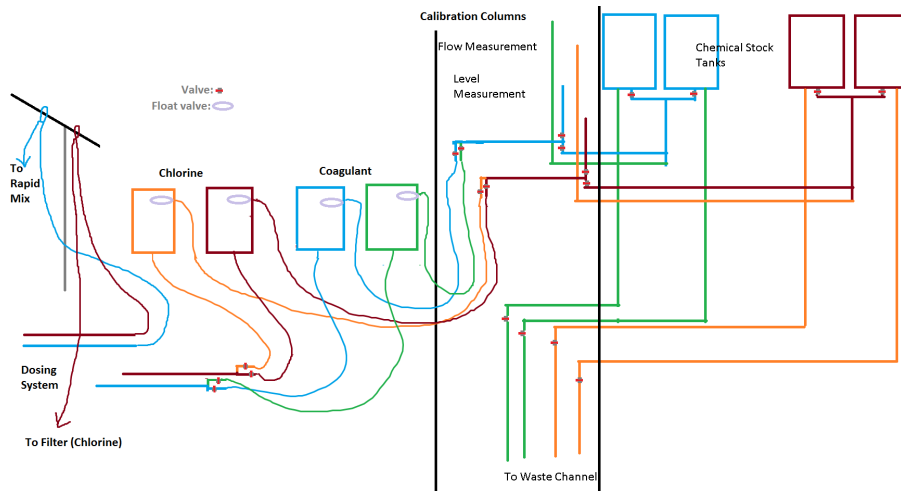


Figure 2: This is a rough drawing based on the San Matias CDC system. The colored lines are to distinguish coagulant and chlorine pathways. There are many Tees and Valves which branch from paths so that if one valve is closed, the other is open and the path is complete

The next step to adding any new piece of drawing code into the ADT is to complete the following general steps:

1. Create New, Select, Thaw, and Freeze commands for layers
2. Define origin points for new components as clearly as possible
3. Using the origin points, define the length of the pipes connecting each fitting
4. create a script for each component using drawing functions. Determining the rotation angle for each fitting or pipe is the most challenging part of this step
5. stack each script as it should be drawn, including layers and subtractions
6. Output the script into a text file to test it in AutoCad

All of these steps are in their own MathCad area to allow for ease of understanding, except for the final stacking of the scripts. Following this sequence, layers for the plumbing, fittings, Constant Head Tanks (CHTs), and a subtraction layer were made. Next, the origin points of all of the fittings were defined. The connections to the calibration columns from the stock tanks were the first to be drawn, followed by the fittings at the base of the constant head tanks, the drainage channel, and the Calibration Columns. Everything else, including the constant head tanks, was dependent on these origin points until connections to the dosing tubes. Components of the CDC drawn along with the chemical stock tanks are shown below in Figure 3.

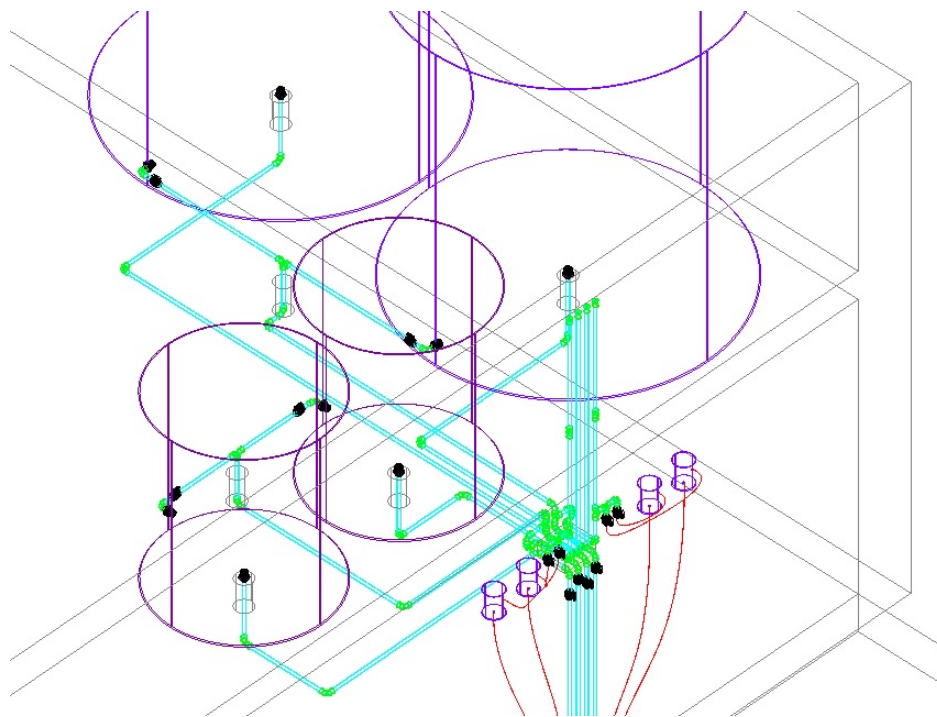


Figure 3: Complete Chemical Stock Tank drawing output including the new connections to the dosing tubes and drain channel. The smaller chlorine stock tanks are lined up along the y axis for the special case at 50 Lps and 70 Lps when the platform is not as wide as both sets of tanks. wall

Within the CdcAC drawing, the Calibration Columns, Constant Head Tanks, and connection plumbing were added. The CDC layout is shown below in Figure 4.

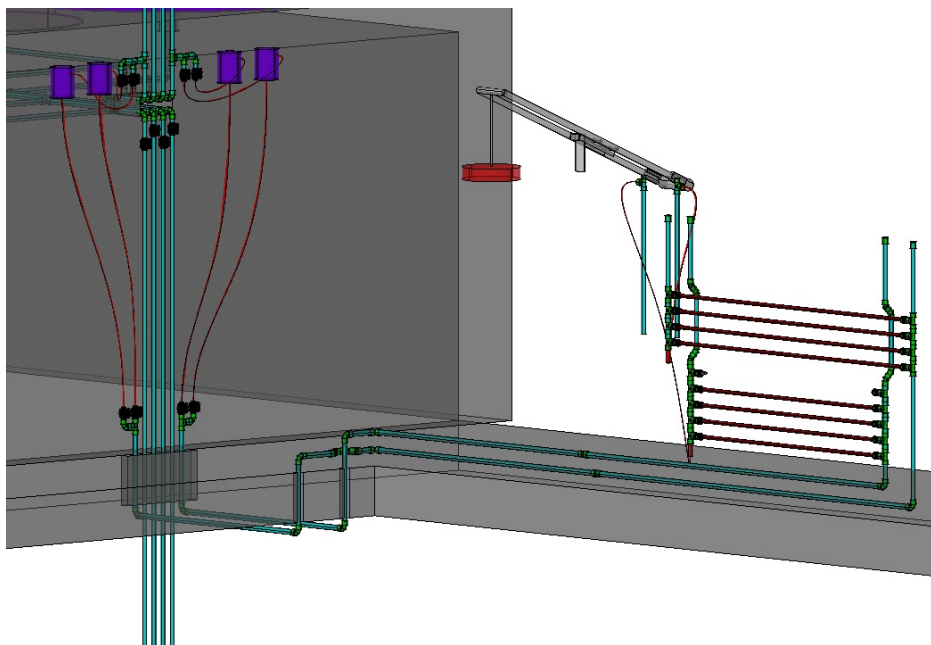


Figure 4: Complete Chemical Dosing System drawing from the Calibration Columns to the Lever Arm dosing tubes for a 50 Lps plant.

2.a.1 Elbow Bridges

In the San Matias plant, the Calibration Columns for Chlorine are nested inside those for Coagulant. In the dosing system for all plants, elbow bridges to connect pipes over the pipes are also present. Hopefully, these bridge— which add unnecessary complexity— can be reduced in future designs. One simple way to do this is to separate the coagulant and chlorine constant head tanks on either side of the calibration columns. This is also necessary because the ADT does not draw the outside walls of the plant, where CHTs are usually built. Though the tool displays the CHTs on the chemical platform wall, engineers may find it necessary to move them during construction. The consequences of this simplification should be evaluated with AguaClara engineers and plant operators. The current layout without elbow bridges is shown below in Figure 5.

One place where the elbow bridge could not be avoided was in the delivery pipes connecting the dosing tubes to the CHTs, shown in Figure 6. The use of the elbow bridge is a trade-off which allows the flexible tubing exiting the CHTs not to cross. Because the coagulant dosing system is above the chlorine system yet closest to the CHTs, the two lines had to pass over one another at one point. Consulting with Christensen led to the decision to cross the pipes prior to the start of the flexible tubing.

When AutoCAD 2013 was used to produce drawings, the following error occurred: ???. For this reason, all elbow bridges were simplified to 90 degree elbow bridges. This can be changed in the drawing files by deleting the redundant elbow and pipe definitions. In the code, the 2013 versions are highlighted in salmon and located directly below the original, 45 degree 2015 definitions.

2.a.2 Flexible Tubing

Clear plastic flexible tubing is used to connect the CHTs to the calibration columns and the dosing system. It is also used to connect the dosing system to the lever arms. These tubes vary in length depending on the convenience of the individual plant construction. Therefore, the ideal flexible tubing in AguaClara designs should have the following characteristics:

- Origin and end points for flexible tubes should be accurate
- The tube paths should not pass through concrete sections
- The tube length is not a design constraint

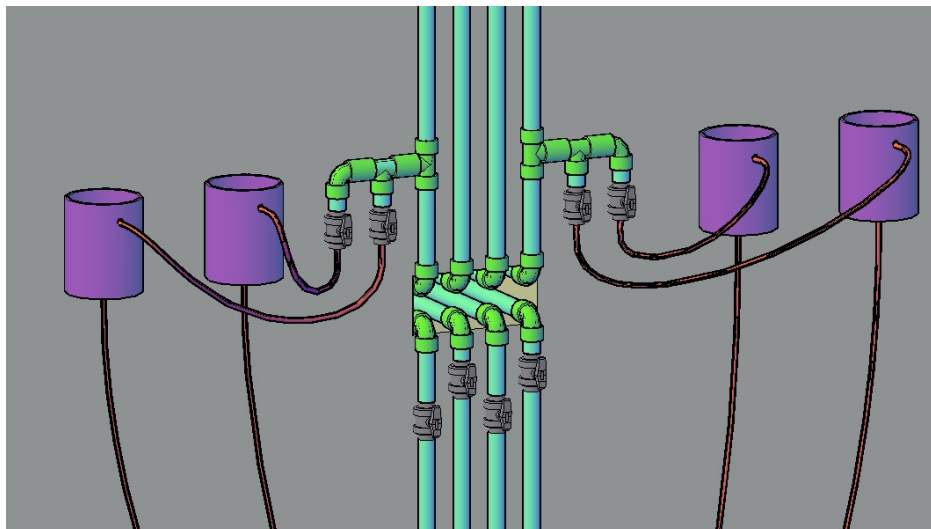


Figure 5: The layout of the CHTs along the y axis on the Chemical Platform wall is shown for a 50 Lps plant. Because the CHTs do not have to be on the same side of the calibration columns, there is no need for an elbow bridge. The CHTs are connected via flexible tubing to the flow measurement columns, which have a clear graduated cylinder component. The level columns are in the middle and do not have a connection to the dosing system.

- the tubing look 'realistic'

In the past, using the command line to create flexible tubing has challenged the design team. Initially, a hand drawn stock drawing was considered to be the best way to illustrate the flexible tubes. This semester, the team created a simple function to draw flexible tubes by sweeping a circle along a spline path. Points along the spline path are chosen by direction inputs unique to each tube. The direction inputs include whether the tube exits the origin point in the x or z direction, whether the direction is positive or negative, and how the tube enters the exit point. A 'slack' point is also chosen in the negative z direction so that the tubes look like they are influenced by gravity. The last step is to subtract the inner hollow space from the outer tube. An example of these tubes is shown in Figure 8. The MathCad code which produces the spline points for the tubes and subtracts the inner tube from the outer tube is shown below in Figure 9.

Because the design tool uses AutoCAD 2013, a few changes were needed to adapt the original sweep function to work in the older version of AutoCAD. The default setting in the sweep function for AutoCAD 2013 is no twist, which meant that sweeping the circle along the spline curve resulted in sharp 'kinks' which then prevented the subtraction function from working properly. To remedy this, the 'twist' and 'bank' options were added to the sweep function call when flexible tubes are drawn.

2.a.3 Plant Walkway Cutouts

The final Final Designs file modified in this semester's CDC update was the OperatorAccess.AC file. This is the file where the concrete plant floor is drawn along with all of the cuts in the floor. Two additional cuts were added to the floor to allow the plumbing connecting the CHTs to the dosing system to pass beneath the plant floor, and the hole beneath the lever arm was deleted. This is because the dosing system adding coagulant to the rapid mix pipe can enter the pipe directly through the LFOM and not through the plant floor. Because of this change, the L-shape in the drain channel can be eliminated.

3 Section Cuts

Currently, there is a gap between the AutoCad drawings produced by the server and the construction drawings used by engineers in the field to build the plants. Some on site engineering will likely always

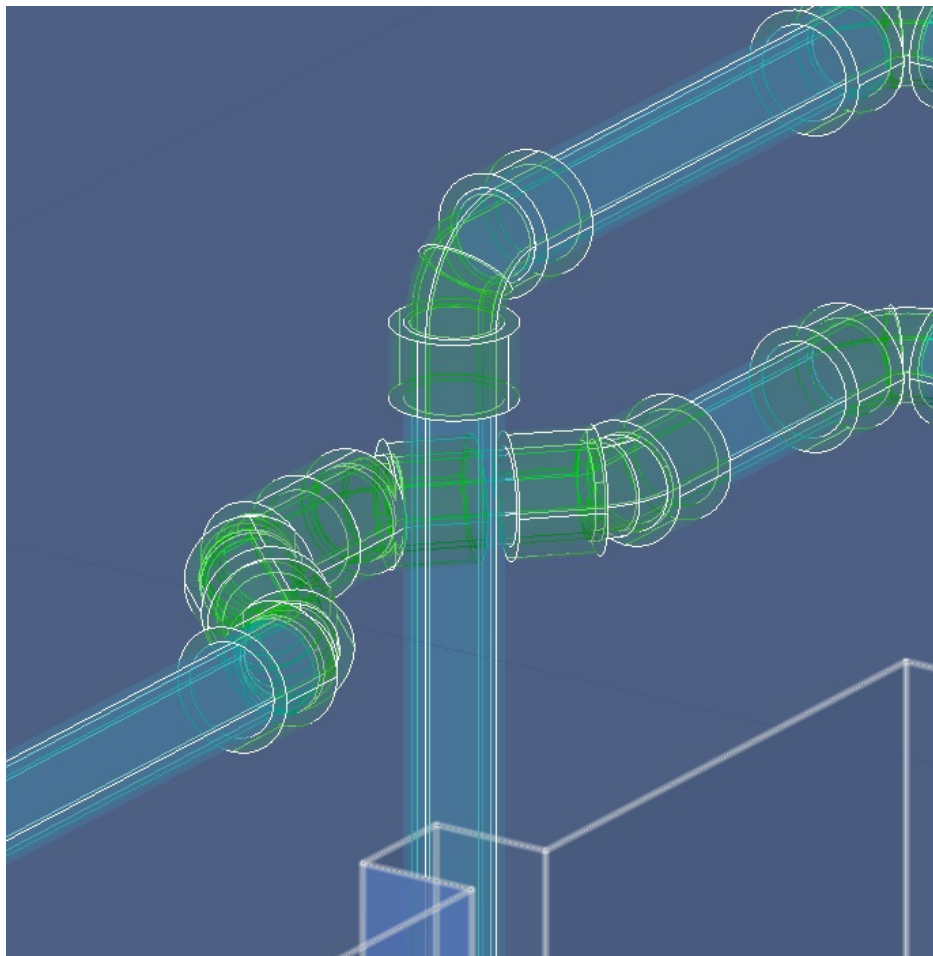


Figure 6: This elbow bride made from 45 degree elbows is part of the chlorine delivery pipe connecting the dosing tubes to the CHTs. It passes over the coagulant delivery pipe along the wall of the entrance tank.

be needed to fit a building into the landscape. This process, though, may be expedited by producing 2D section views of the hydraulic components of the plant to which the structure can be added. Though creating section cuts is simple to do by hand using the 'Section Plane to Block' command, the process is very graphics intensive and takes many expensive hours of design time. If the server could perform this simple task prior to sending drawings to the field, the time to produce construction drawings would be reduced by 2 days. Unfortunately, the process of automating section cuts is difficult and has consumed many semesters.

One of the greatest roadblocks of automated section cuts is that the AutoCad command 'Section Plant to Block' opens a dialogue box which which the user selects the plane and determines how layers and hidden lines will appear. The ADT requires that all interactions with AutoCad happen through the command line, not a dialogue box. The work of former team member, Songlin Guo (sg888) created a function to draw a section plane, convert it to a block, and create a layout view of the 2D block that would be part of the final dwg file. His work relied upon the custom ddl file 'SPTB' created by AutoDesk Employee Kean Walmsley (kean.walmsley@autodesk.com) to use the command line only to generate a block. Unfortunately, this custom file was full of errors and failed to work with multiple cuts.

In Fall 2015, an error in this custom file was identified using a dummy script and repaired. The resulting command allows for multiple cuts, but the layer colors are not preserved. The current output of the code is shown in Figure 11. Adjusting the layer color preservation and hidden line display is a difficult task. Assistance from more of the AutoDesk community will hopefully remediate these issues. In order for the automated section cut code to function as Songlin intended, these few errors must be addressed and the

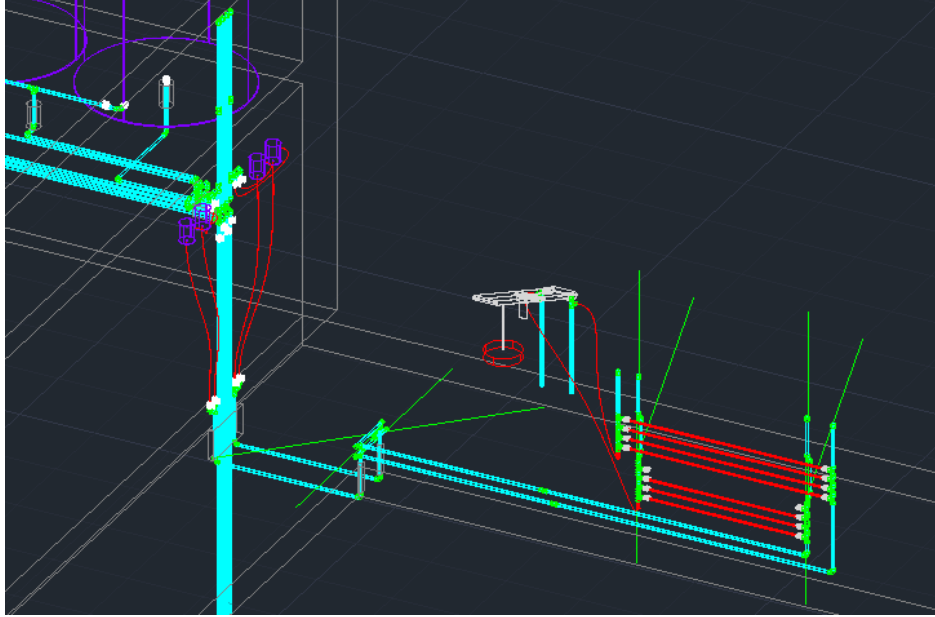


Figure 7: This image shows the error caused with drawing 45 degree elbow bridges in AutoCAD 2013.

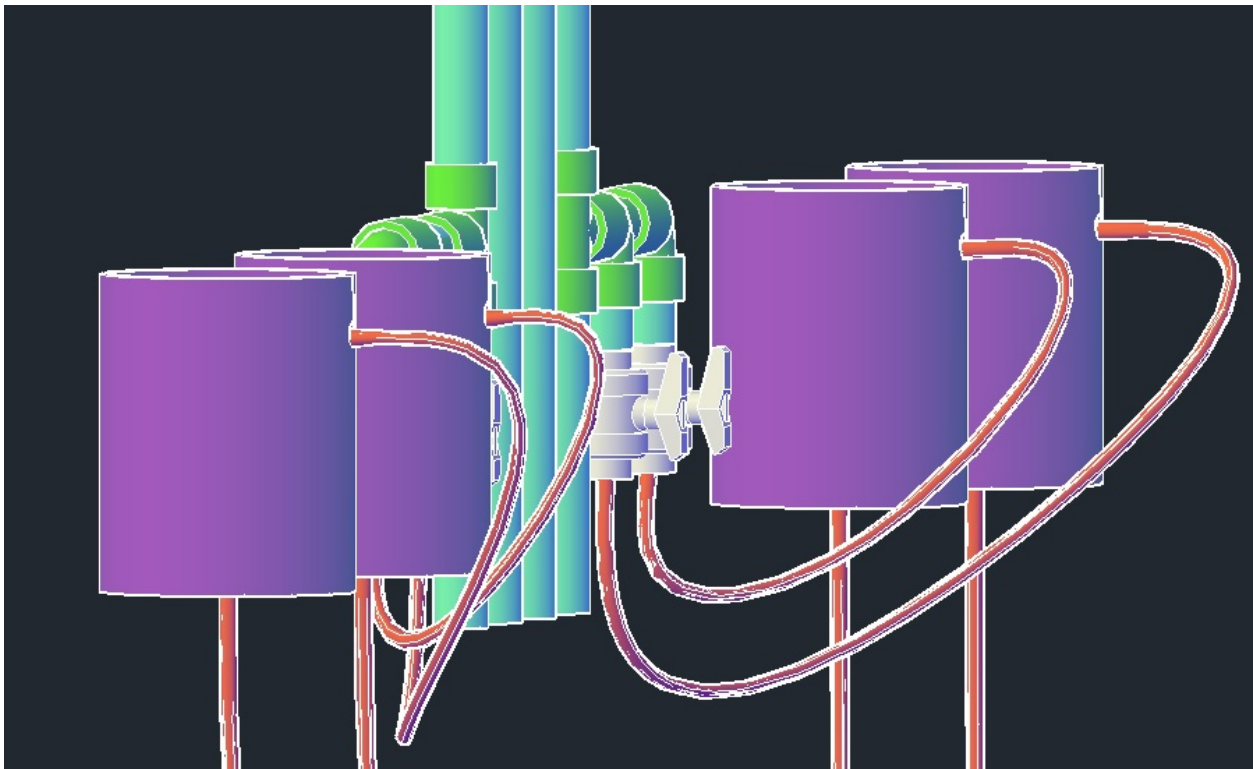


Figure 8: Flexible tubing connecting constant head tanks to calibration columns for a 30 Lps plant

updated section cut code must also produce layout views. Lastly, a key must be drawn to identify where on the 3D plant each cut is made.

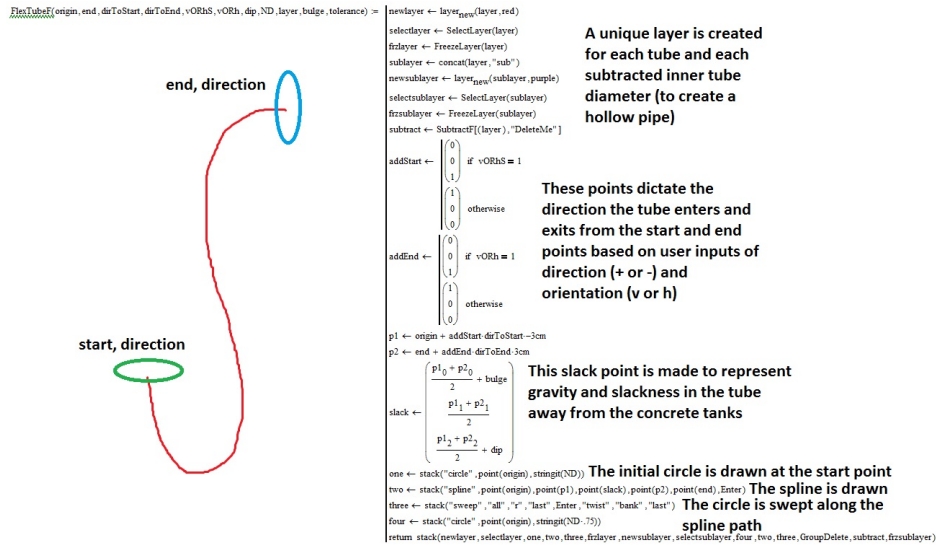


Figure 9: This MathCAD programming bar also includes notes as to how the function works because MathCAD does not support comments within the programming bar. This function is defined directly in the CdcAC code because it is not used anywhere else in the plant at present.

3.a Challenge Details

The first step in this process is to renew a dialogue with AutoDesk. Until the 'SPTB' function works as needed, it is not useful to progress in the tasks. An email correspondence with Kellan Hays (project coordinator for global and non-profit projects; kellan.hays@autodesk.com) was started in April 2015 regarding the potential for a pro-bono project between AutoDesk and AguaClara. On Wednesday, May 14th, 2016, Mrs. Hays participated in a conference call with the team to discuss the future project partnership with AguaClara concerning Section Cuts. Hays is assembling a team of employees to work with design team students in the fall. This team will be lead by Kean Walmsley, who has worked with past teams. For 10 weeks, the team will have weekly check-ins with the student team to discuss progress and the coding and design process with A360. This collaborative effort will allow students to both understand the design process for AutoDesk development and (more importantly) to finally make progress on this long-standing design challenge by working in a directed, concentrated environment. The first step will be the team introduction in August once the new design team is assembled. During this meeting, the deliverables of the project will be determined. Apart from working on this section cuts challenge, this AutoDesk partnership promises more involvement between parts of AutoDesk and Cornell in terms of support and student leadership. AutoDesk already has connections at Cornell. Other students who are involved with AutoDesk leadership programs could join AguaClara and enhance the capacity of the design team. This may be facilitated by Dan Vanach, the AutoDesk head of education for the district including Cornell.

4 Miscellaneous

Since the beginning of the design team, the ADT has been touched by many hands. The quick turnover rate of students and designs means that many features of the design tool become dated and neglected. Some errors or oversights in the code that are corrected in the field are not quickly updated, while some changes to a unit process are not checked for compatibility with all parts of the code. These small errors are reported to the design team by Alumni in the field and quickly fixed. Such instances during the Spring 2016 semester are documented below.

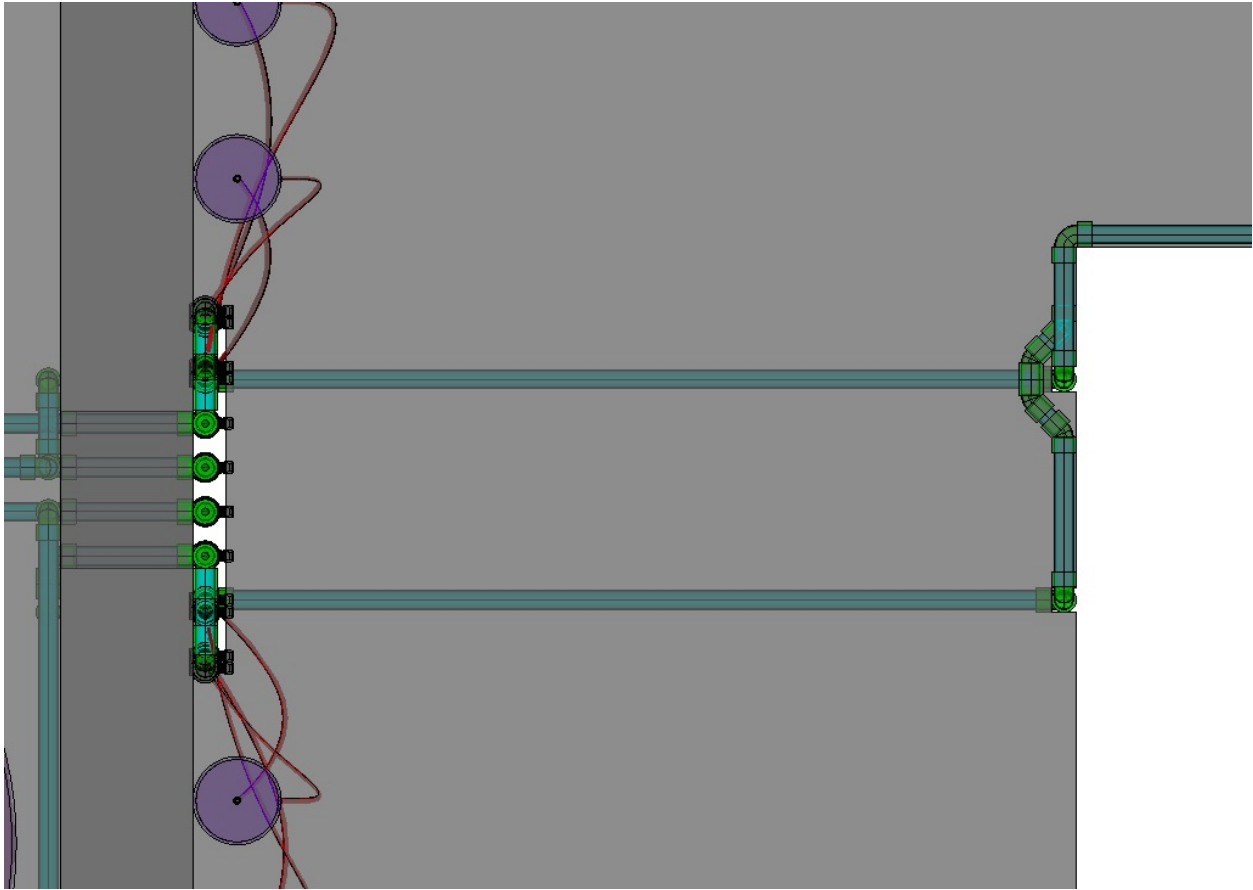


Figure 10: New holes in the plant floor added for the chemical drain pipes and the connection to the dosing tubes to pass under the plant floor.

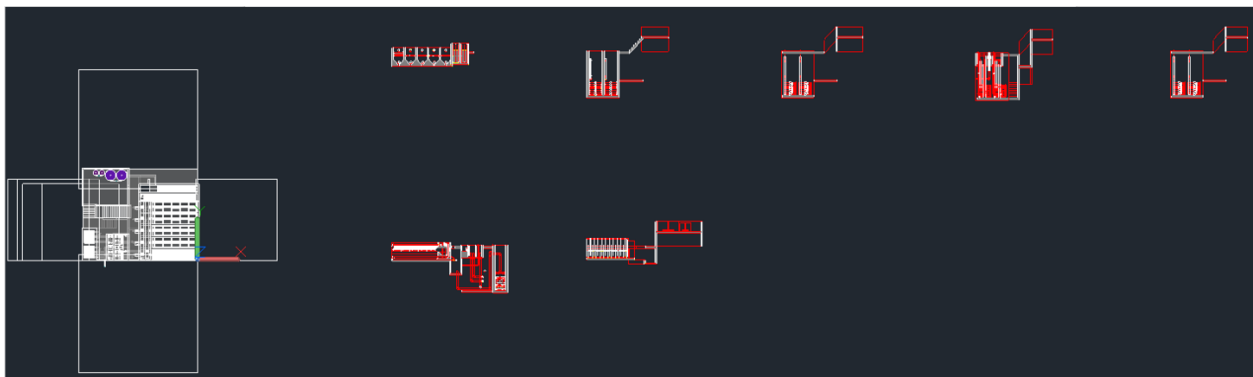


Figure 11: Current Section Cut Output for a 40 Lps Plant

4.a Chlorine Stoichiometry

In January 2016, AguaClara Alumni Jon Christensen (jonathan.s.christensen@gmail.com) notified the design team that purity of the chlorine in the stock tanks was typically 70 percent. A variable called P.Chlor was added to the expert input file. This variable was added into Chemical Dose Controller calculations as

shown below in Figure 1.

$$M_{ChlorStock} = Round\left(\frac{Vol_{ChlorStock} * C_{ChlorStockEst2}}{P_{Chlor}}, 1lb\right) \quad (1)$$

4.b Low Flow Single Filter Concrete

Prior to Spring 2016, the Low Flow (or EStARS) plants were only producing drawings of the filters for two or more filters. This was due to a 'divide by 0' error in the MathCad code when pieces of concrete were removed from the filter inlet box for inlet, overflow, and distribution weirs. Additionally, the complex system of weirs for maintaining backwash flow for multi-filter systems was not necessary for a plant with only one filter. These unnecessary weirs were removed and the necessary weirs were added separately for the case of a single filter. The correct display of the single filter is shown below in Figure 12. Whether the single filter is ever going to be produced in reality has yet to be determined. This is not advisable for OStARS filters because of difficulty backwashing a single filter. The current design team does not advise single filters for any flow rate.

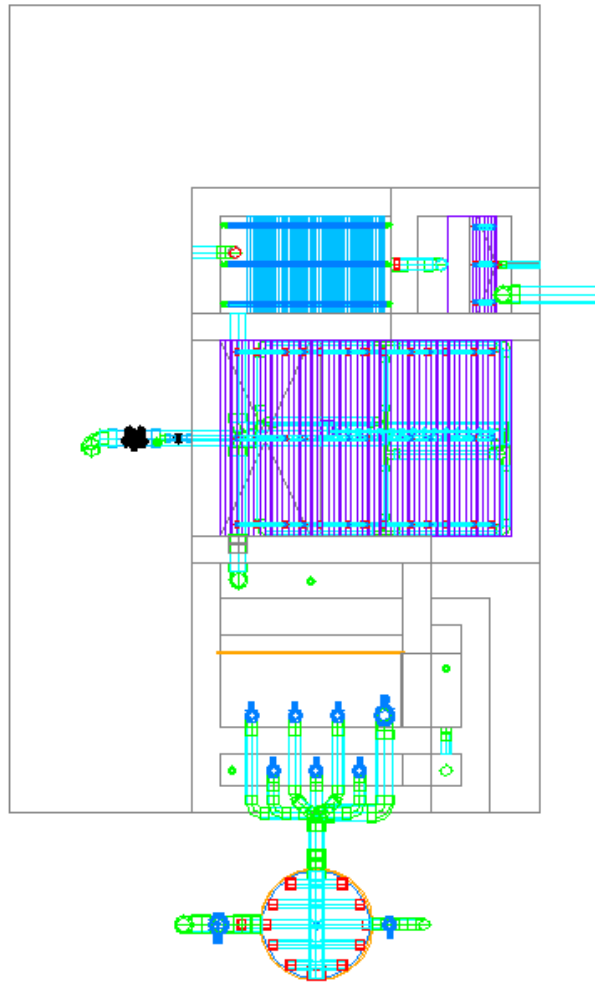


Figure 12: Beta Server Layout view of a 1.1 Lps Plant with a single filter and appropriate weirs

4.c Floc Hopper Drain Addition

In April 2016, AguaClara Engineer Jon Christensen requested an additional floc hopper drain to be added to the design tool. This new drain was to be located directly beneath the plant floor for easy operator access and regular, minute flow controls. The original drain will now be used only when the sedimentation tanks are drained for cleaning or maintenance. The completed drain addition is shown below in Figure 13.

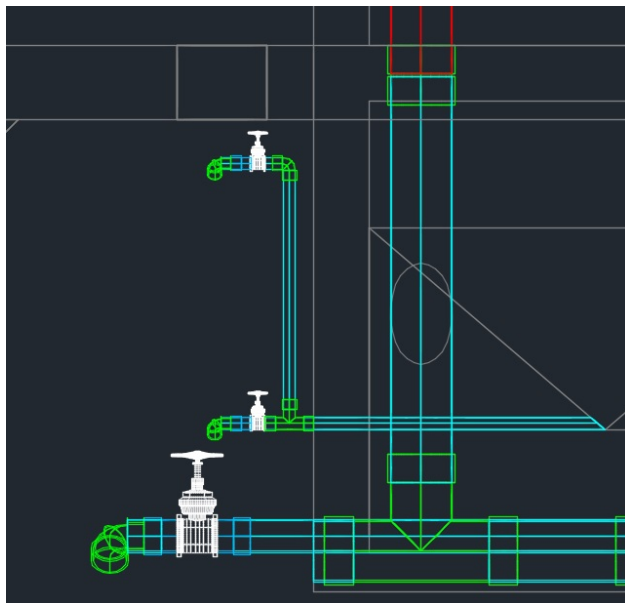


Figure 13: Additional floc hopper drain outlet for 30 Lps plant

5 Future Work

Further updates to the ADT include completing the Automated Section Cut algorithm by adding layout views and a key for each cut on the full plant drawing. This task will be carried out during the fall as indicated previously. In terms of the CDC, this script needs to be added to the low flow plant logic and correctly drawn. Also, because there are not fittings smaller than 1/2 inch, the CDC system is drawn with larger Nominal Diameters than the theory dictates. Smaller fittings should be added to the pipe database if they are useful. The last additions needed for the CDC are the updated CHTs from this year's fabrication team and connections from the lever arm to the LFOM and chlorine drip in the filter. Overall, future teams should strive for consistent, easy to read coding style and useful training files.

6 Task Map

6.a Task Map Details

- updating Chemical Dose Controller drawing files
 - Low flow rate plants need a chemical dosing system drawn
 - Normal flow rate plants (those with Ostars filters) have incomplete drawing functions for the chemical dose controller. Currently, dosing tubes and the lever arms are drawn only
 - * The parts of the system that remain to be drawn are the constant head tanks, calibration columns, and other connections to the storage tanks on the chemical platform
 - Dimensions for the float valve must be found and added as a drawing function to the design tool

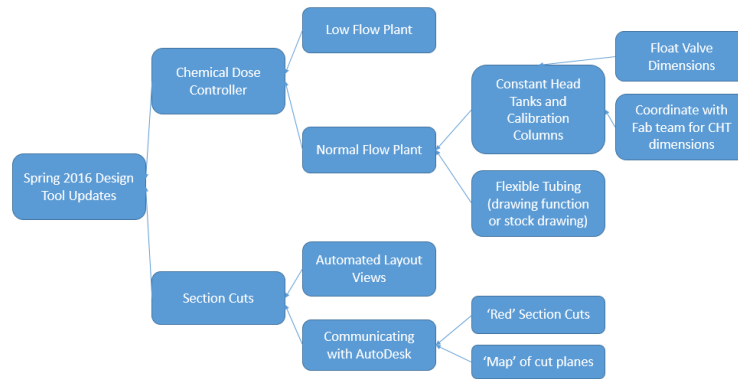


Figure 14: Task Map

- If the fabrication team creates new CHTs, this new design must be added to the code
- * Flexible tubing, an enduring challenge, has yet to be completed. Either the function must be enabled to automate 'splines' or a series of stock drawings must be created and added to the server
- Automated Section Cut Code (this project is not being worked on this semester so far; this is the status after Fall 2015)
 - * Layout views in paperspace in AutoCad must be created automatically for each cut
 - * Communication with an AutoDesk team to collaborate to solve the Section Cuts challenge
 - Currently, the section cuts are red, i.e. the layer colors are not preserved. This needs to be addressed
 - A map drawn in AutoCAD should act as a 'key' for the plane of each Section Cut on the 3D plant drawing