Small Scale Plant Model

Final Research Report Spring 2013

10 May, 2013

Abstract

The Small Scale Plant Model team seeks to construct scale models of AguaClara plants that will, through their tangibility, facilitate AguaClara's educational outreach efforts and encourage the support and sponsorship of donors. The models will be small and durable enough to travel to Honduras, and they will clarify potentially confusing features of the plants they depict. Over the past semester, the Small Scale Plant Model team has identified target audiences, selected plant features for special clarification, performed materials analysis, and created model component templates in order to meet these goals. These model component templates were then optimized and saved as drawing files ready to be laser-cut. To facilitate plant construction, the team has also compiled 3-dimensional composite shots of the plant's components. The team has finished mock-up construction of select plant components and has finalized preparations for the construction of the final plant model in the semester to come.

Literature Review

- http://aguaclara.cornell.edu/projects/

This page of the AguaClara website lists completed plants in Honduras, their design flow in L/s, and other important statistics. The average of the eight flow capacities listed here is 13.75 L/s, which, when compared with existing plant designs, is closest to the capacity of 12 L/s. Thus, 12 L/s plants may be interpreted to best represent the totality of AguaClara plants, and we plan to use 12 L/s plans in the designing of our scale model. It is the team's hope that the use of this flow rate will allow our project to be as broadly applicable as possible.

- http://designserver.cee.cornell.edu/Designs/etflocsedfi/5363/12Lps/Index.html

This page features PDFs, AutoCAD drawing files, and Word documents that depict a 12 L/s plant, including many dimensional and technical specifications. Various diagrams and figures have aided our team's spatial understanding of the plant, as they clearly illustrate plant processes. We used the drawing (.dwg) file featured on this design page to create laser-cutting templates for all flat planes in the water treatment plant. These pieces were scaled with AutoCAD and Rhinoceros, an architectural modeling software.

- References: https://confluence.cornell.edu/display/AGUACLARA/Small+Scale+Plant+Model+Referen

The Moroceli design PDF attached to this page under "References" contains the plans that are used in Honduras by construction workers. We used dimensions contained in this file to decide upon our model's scaling factor for the construction of small scale parts for the mock-up and final model plants. This PDF helped solidify our decision to scale the Small Scale Plant Model by a factor of 1:20. The dimensional information it described ensured that our model is true to life and scale.

- Component Templates: https://confluence.cornell.edu/display/AGUACLARA/Small+Scale+Plant+Mo

All Small Scale Plant Model component templates can be found in PDF form on the team's wiki page; these files were created in Rhinoceros by the team from existing AutoCAD design files. The templates are to-scale, facilitating the construction of our plant model and mock-up, with the scaling factor used indicated in in-page comments on the wiki. The team has processed and uploaded top views of the plant in both 1:20 and 1:30, which lend perspective to the size of the plant model. These PDFs can be found under the "References" heading. Finalized component templates of the totality of the plant models parts can also be found under the heading "Component Templates (1:20)." These include the entrance tank, flocculator, sedimentation tank, filter, staircase, main floor or "base" of the plant, and files separated and targeted for transparency. Again, each of these templates is scaled by a factor of 1:20. As PDFs, these files have the benefit of being easier to view than drawing files. They are also easily printed, a feature of which we have taken advantage. We have used these PDF files to cut paper templates to aid in mock-up construction.

Introduction

The Small Scale Plant Model team is a new team introduced this semester for the purpose of building a water treatment plant model that will both educate those invested in water treatment and encourage sponsors to collaborate with AguaClara. The inspiration for the creation of our team was AguaClara's 2013 trip to Honduras, where team members who had never seen a full-scale AguaClara plant expressed how useful a visual representation was for understanding the AguaClara treatment process. This treatment process can be confusing, and researchers require a complete knowledge of its components to generate further plant improvements. Completion of a model, or multiple models, will allow for better understanding of the mechanics behind AguaClara water treatment plants for those involved with the team's research at Cornell and those who benefit from it abroad. Each model is intended to highlight the plant's most significant parts and act as an informative, detailed, tactile, and easily transported education tool. This semester, the Small Scale Plant Model team has assessed materials, identified a target audience, refined the model's goals and messages, and created scaled templates of plant components in its efforts to construct a final plant model. The team also partially completed a mock-up model in chipboard, optimized plant component templates in AutoCAD for laser cutting, and obtained the sheets of Plexiglas necessary for the construction of the final model. The final model will be laser-cut in different colors and opacities of Plexiglas in order to best communicate AguaClara treatment processes.

Methods

Potential Audiences

Our first task was to decide for what audience we would design the small-scale plant model. This allowed us to assess the model's functionality and better articulate what we wanted it to convey.

We decided that one of our model's primary goals is to give team members and prospective team members who have not been to Honduras a better understanding of how the components of sub-team research come together as a whole. Visualization of the finished product manifests AguaClara's ultimate purpose and gives our research perspective. Eventually, this could motivate engineers at other universities to dedicate their time and expertise to the project. Additionally, interaction with a tangible, finished product encourages funding and informed support from the Cornell administration, organizations that support sustainable research, and donors interested in supporting plant construction. The model provides evidence that our technology, which is sophisticated yet simple, is well thought-out and effective. Such a demonstration could prove exceedingly useful to AguaClara as it applies to awards programs like Katerva and PC3.

Furthermore, the model will be a useful mode of communicating our project at ideas festivals and conferences, where it can target informed engineers, philanthropists, and organizations (like the Rotary Club) that might be interested in improving their technology or contributing to our project. Additionally, a potential secondary use for our model is outreach and elementary education within the Ithaca area. The model can be used to introduce children to global problems and demonstrate science's power to create solutions. The visual representation of the plant model increases excitement and engagement in all arenas. It will also lessen AguaClara's dependence on its audience's spatial reasoning skills: a three-dimensional model is far easier to interpret than a technical AutoCAD drawing.

The model will also be useful in Honduras, India, and any other countries in which AguaClara eventually builds plants, where it will be able to educate multiple audiences about clean water and foster their continued motivation. Understanding of technologies will encourage effective interactions with waterboards and municipal governments that already have a plant. The simplicity of the model will allow us to educate community members (including children) served by the plant. Establishment of the possibility and value of having clean water will encourage community responsibility; the community will learn the importance and benefits of clean water. Informed individuals are more likely to fight for their water, too: for instance, if the community is not receiving an adequate dosage of chlorine, understanding of its importance might support community involvement in obtaining adequate chemicals. We can also share this model with waterboards and municipal governments interested in the construction of their own plants because it makes the plant seem tangible and easy to understand. This will compel them to raise money to realize the project.

Thus, the small-scale plant model will serve two main purposes both at home and abroad: education and motivation. Education fuels the motivation to become involved with the project, through both monetary investments and investments of time and research. We need to create a model simple enough to communicate our research to audiences without significant technical knowledge, but it must also highlight the unique features of AguaClara technology to those educated in water treatment.

The Small Scale Plant Model team established these communication goals in order to help identify which plant model features should be highlighted. These features, including water flow paths through the filter and flocculator, tank geometries, and the creation of the floc blanket, were chosen so as to communicate the plant's important innovations without overwhelming its audience with information. The plant's most important features were chosen based on the evaluation of what each potential target audience would need and want to know about the water treatment plant in order to understand the processes without being overwhelmed by information. Some parts of the plant were also delegated as removable to better allow viewers to see individual functionalities within the plant.

Design Implementation

Next, we needed to decide what capacity of plant we would model. From a list of completed plants in Honduras and their capacities, we decided to model a plant flow capacity of 12 L/s, believing this to represent the average capacity of an AguaClara plant. This plant size has three sedimentation tanks, like the majority of the plants built in Honduras. It serves approximately 4,000 people. Once we decided upon this plant size, we were able to begin gathering information from relevant AutoCAD files and design files (retrieved from http://designserver.cee.cornell.edu/Designs/etflocsedfi/5363/12Lps/Index .html). In the design file EtFlocSedFi.dwg, we used the AutoCAD distance function to loosely measure the rectangular dimensions of a plant; these dimensions were approximately 11.1m x 8.1 m x 6.7 m. We then found the maximum allowed dimensions for a carry-on bag on Delta Airlines: 55.88 cm x 35.56 cm x 22.86 cm (retrieved from http://www.luggageonline.com/travel-guides/airline-weights-and-restrictions). By dividing the suitcase dimensions by the plant dimensions, we were able to estimate scaling factors for each dimension of the plant. These values, of about .05, .04, and .03, respectively, were limited by the height of the suitcase—the .03 scaling factor. We recorded this approximate value for future reference.

The next phase of the implementation of our project necessitated research into various materials. We met with architecture student Jordan Berta on February 20th to discuss the creation of our mock-up model and to learn more about the materials potentially available to us. He suggested an initial project budget of around $150. Together, we drafted a list of potential materials for plant construction:

- 99-cent plyboard (easily cut with an X-ACTO knife)
- Insulation Foam (easily cut with a heated wire)
- Medium Density Fiberboard (MDF)
- Basswood (sheets)
- Chipboard (Jordan's suggestion; a type of paperboard)
- Museum Board (can come in the same thickness as chipboard; a type of paperboard)
- Plexiglas (available through Ithaca Plastics, but expensive and difficult to attach to itself)
- For model pipes: Wood dowels, acrylic rods, small scale model tubing (Cornell Store can help in obtaining)
- No balsawood (too flimsy), no lexane or PVC (cannot be laser cut)

Jordan favored the use of clear and white Plexiglas for our final model in support of our plan to use transparent siding to make plant unit processes easier to follow. He thought chipboard or museum board would be best suited to the construction of our first mock-ups, though, because these materials are cheaper and easier to manipulate. He raised the important point that a wooden plant might be confusing to viewers, who would be unable to reconcile the plant's water treatment functions with the material with which the model was constructed; this cemented our decision to make our finished model out of some sort of acrylic. Acrylic substances, like Plexiglas, are both more durable and more clean and professional-looking than wood or paper-based alternatives.

We also consulted Jordan about the mechanics of the model construction process. He advocated the use of the programs 3ds Max and Rhinoceros, which, like AutoCAD, read .dwg files. He informed us that, with these programs, we can isolate flat planes in the plant design and use them to create templates for laser cutting. He also suggested we consider computer-navigated cutting (CNC) and the building of test model frameworks of different scales. As starting points, he suggested scales of 1:20 or 1:50, noting that it's easiest to scale along these

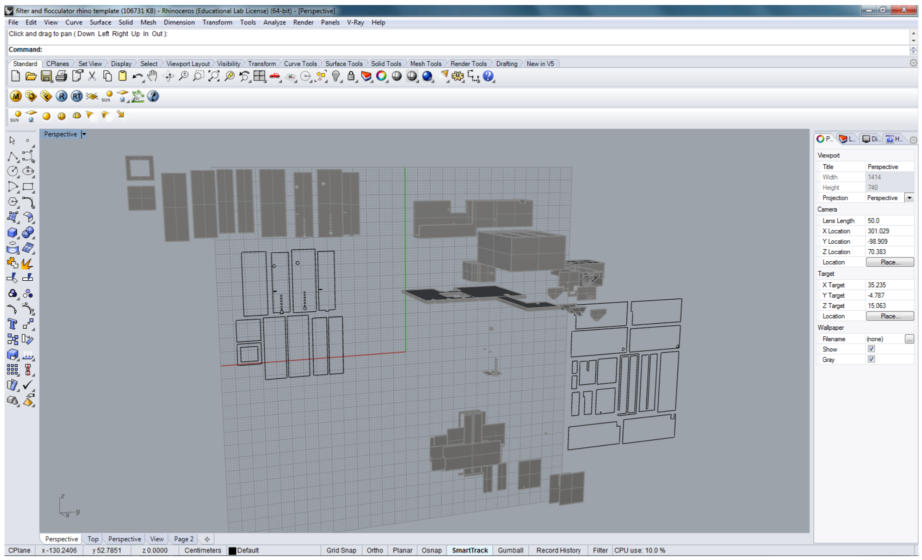

Figure 1: Screen shot of Rhinoceros
Using the program Rhinoceros, we were able to create two-dimensional template files (as seen in 1) from three-dimensional AutoCAD designs (shown above in solid gray). This progress shot includes unexploded solid objects–the aforementioned 3-dimensional shapes–as well as exploded components, which are somewhat separated from one another (top right); rotated components, which are in the bottom center and parallel to the grid of the 'c-Plane'; and finished template components, which are shown as outlines and aligned on the same plane. The filter and the flocculator templates are shown in this document (the left and right outline groupings, respectively.)

kinds of even numbers. These values are within close range of our previously estimated scaling factor of .03. Finally, Jordan seconded our commitment to document our progress so that the construction of our final scale model will be as easy as possible.

Template Creation

As per Jordan Berta's recommendation, our team began to utilize the software program Rhinoceros in order to lay out the pieces of the model for future laser cutting. We were able to access this software through the computer labs of the College of Architecture, Art, and Planning. Our AutoCAD drawing file was converted to a Rhinoceros 3DM file, and after a brief tutorial from Jordan, we were able to begin the template creation process. We created two scaled plant models, one with scaling factor 1:30 and the other 1:20. We printed the plant model's top view using both scaling factors in order to compare and comprehend each resultant plant's dimensions. Then we began to extract and rearrange plant

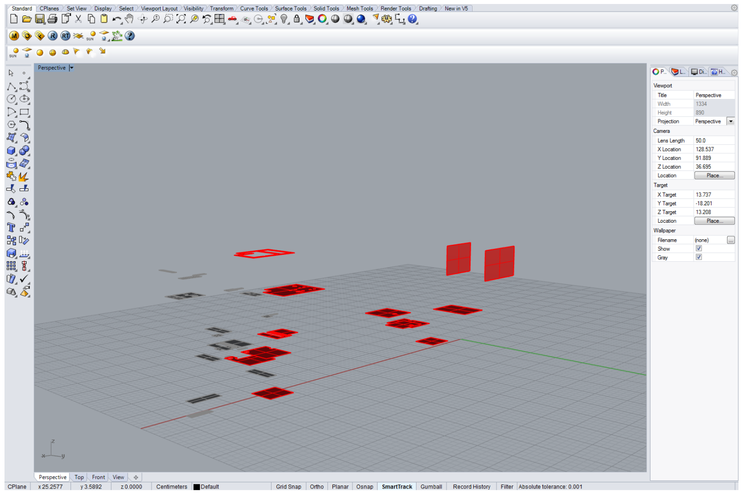

Figure 2: Exploding and Rotating Plant Components in Rhinoceros

The filter inlet (red) in the process of having its components rotated to be parallel to the c-Plane.

components in order to create cutting templates. First, the command "Explode" was used to separate an object, like a flocculator, into its smaller, fundamental components. Of these, we were primarily interested in flat planes; we ignored things like pipes and small circular fittings for now. From there, the command "Rotate3D," in combination with a held "Shift" key, enabled us to rotate objects in the 3D plane in increments of 90 degrees. This allowed us to position the components so that their flat sides were exactly parallel to the construction plane. Finally, the command "Make2D" created two-dimensional versions of the components by projecting them onto the construction plane. We saved these templates in two forms: first, in new Rhinoceros files, to be utilized in the laser cutting process, and second, as to-scale PDFs printed from the viewport window. These PDFs are portable, easily viewed on almost any computer, and clear and simple to read. Since they may be printed to-scale and used as paper templates for manual cutting, we identified them as especially useful for the creation of our mock-up model.

Creating Composite Images

Anticipating the difficulty of assembling our plant from flattened and separated components, we began to compile images depicting different views of plant sections to later facilitate plant model construction. These images clearly depict how various plant components should be put together, and they will allow us to assemble pieces of our models without needing to have Rhinoceros nearby

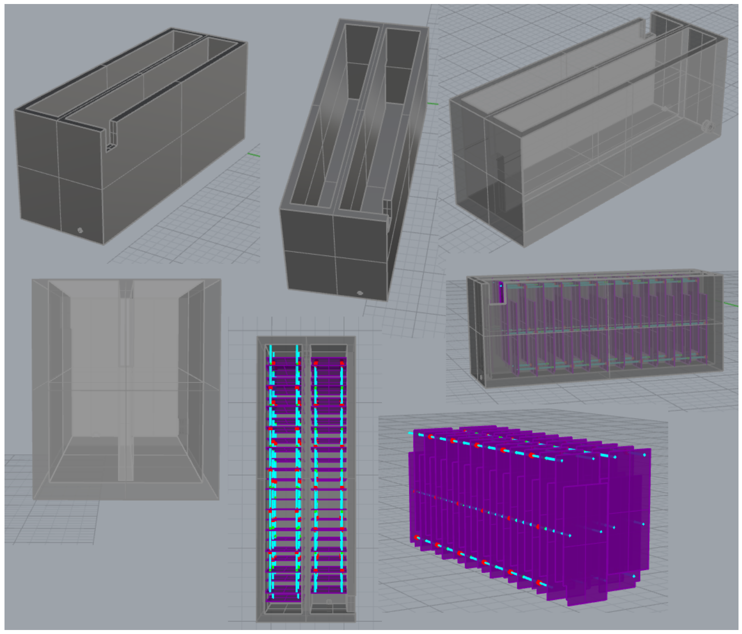

Figure 3: Composite Shot Example

Taking screenshots from Rhinoceros, we created composite shots of plant sections as seen from different angles (shown above in 3); we hope that these visual guides will help us assemble the plant model from the flattened and separated components of our templates. Here, the flocculator is shown from various viewpoints.

to access reference drawing (.dwg) files. These composite images are necessary because the plant component templates we created were designed to efficiently use space, not to group components based on their orientation in the plant. Consequently, it would be near impossible to piece the plant together without a visual guide depicting the finished product and the respective orientations of its components. Our compilations of screenshots, taken from a variety of different viewpoints of the 3-dimensional Rhinoceros model, represent our solution to this problem.

Access to Laser Cutting

After preparing templates of plant components in Rhinoceros, we began investigating laser cutting as a method for cutting our plant pieces. In order to obtain information about accessing laser cutting technology, we reached out to the Col-

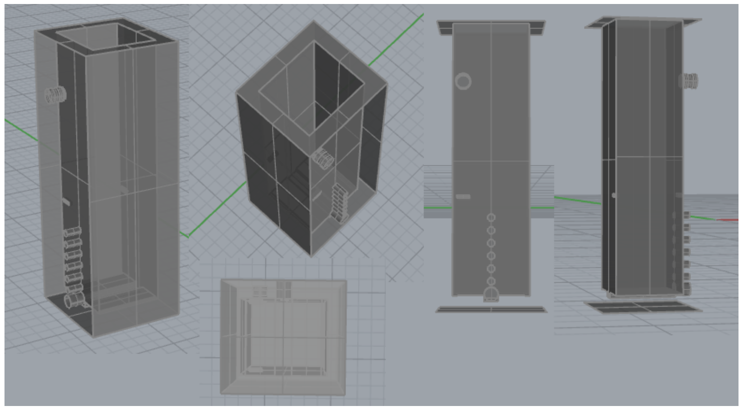

Figure 4: Filter Composite Shot
The filter, shown from various viewpoints.

leges of Engineering and Art, Architecture, and Planning. First, we spoke with Beth Rhoades, a Senior Research Associate at the Cornell NanoScale Facility (CNF). She explained the two laser cutting options available to us at CNF: we could go through safety training to use the machines ourselves or use a "Remote Project" option. Use of the machines costs roughly $17/hour, although the actual cutting process takes only a few minutes. However, especially for newcomers, setting up the machines to cut our material could take a few hours. Additionally, the safety training is close to $400 per person. This exceeds our budget, so we inquired about the Remote Project option, through which we could send our templates to Rhoades to have her cut them herself. The cost of this option includes the $17/hour lab fee as well as compensation for Rhoades' time. Because it is a busy time of year and Rhoades has deadlines coming up, she told us she would be able to complete the project within a month at the earliest. Laser cutting through CNF is still a potential option for creation of the final model, but our conversation with Rhoades reaffirmed our desire to begin mock-up assembly as soon as possible. Consequently, we decided to personally hand-cut our mock-up model pieces with an X-ACTO knife as we continued to look into other laser cutting options.

After Beth Rhoades, we contacted Frank Parish, Senior Manager of AAP's Material Practices Facilities. Our team first corresponded with Parish through email, and Theresa met with him in person on April 5th. He expressed great interest in our project and passed along important information about the logistics of using a laser cutter. He recommended a private laser cutting service, which he believed would have the shortest turn-around time, to facilitate plant construction. Noting that this laser cutter can only cut up to 12"x18", he challenged us to fit our plant model components within these dimensional constraints. The pieces we can fit in one 12"x18" AutoCAD sheet can go straight to cutting. We can also lay out pieces over several 12"x18" sheets. He gave Theresa the

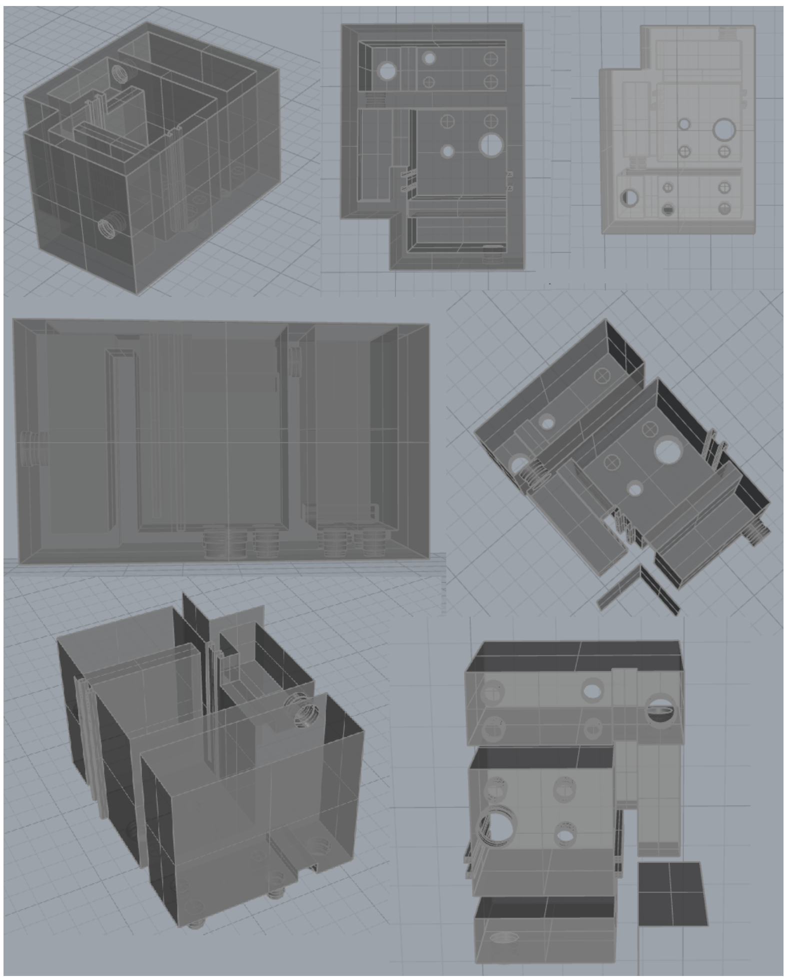

Figure 5: Filter Inlet Composite Shot
The filter inlet, shown from various viewpoints.

AutoCAD template for this size of sheet so we could work on arranging our pieces within it. He also recommended that we use dimensions in inches, not centimeters, because the laser cutter and its operators are used to U.S. standard units. He noted that if we put pieces right next to each other, this will make cutting easier and faster because only one cut will be required. If there are two pieces lined up next to each other, we must make sure there is only one line on the structure so that the thickness of the piece is not compromised. We will lose .01 of an inch for each side if we place the pieces next to each other to cut them, so we must either decide if this thickness lost is significant or figure out another way to lay out the pieces. The fact that the Plexiglas melts a little when cut may also pose a problem because we have some circles for pipes that are close to the edge of the sheet. Any cuts that are too close to the edge of the Plexiglas probably should just be scored and not cut. This also goes for laying out the Plexiglas on the template: it shouldn't be right on the edge because of melting. Furthermore, if there are pieces that need to be fit together, we will need to measure the tolerance of the hole so that whatever piece is inserted into the slot will fit. These are measurements that we can label on the AutoCAD drawing we send; any joints that go together must be measured exactly so that Parish can test whether they will fit.

It can be somewhat difficult and time-consuming to laser cut Plexiglas, so Parish maintained that we should use Plexiglas no thicker than 1⁄8". He also suggested thicknesses of 1/16" and 3/32". He also suggested using solid Plexiglass rods for holes that were too small for model tubing, and using Plexiglue to attach model components. For putting the model together, he said that we should use Plexiglue instead of caulk, which we can get through the the Cornell Store's art department. Finally, Frank informed us that actual laser cutting does not take a lot of time: it takes only minutes to cut through Plexiglas of the thicknesses we discussed.

Mock-Up Construction

We began construction of our mock-up plant model using double-thick chipboard purchased from the Cornell Store. Since laser cutting can involve weeks of turn-around time, we decided to hand-cut our model components using an X-ACTO knife and printed PDF templates that we had created from our AutoCAD drawing files. Although we had not yet optimized the formatting of these drawing files for laser cutting, they were completely adequate for the manual cutting process. We began with the filter, flocculator, and filter inlet, tracing these pattern pieces onto the chipboard for easy cutting. Although using the X-ACTO knife to cut the double-thick chipboard was somewhat cumbersome, we were quite pleased with its results overall. The cutting process is time consuming, but we are nevertheless able to cut clean, straight lines and create sturdy component pieces. One notable drawback to this approach is that the X-ACTO blades become dull very quickly, but luckily, replacement blades are comparatively inexpensive.

In its construction, the mock-up model is helping our team gain greater spa-

Figure 6: Mock-Up Construction in Various Stages
The mock-up construction process, featuring scored templates, the partially assembled flocculator, and cut component pieces.

tial understanding of our model, which will aid us tremendously in the assembly of the final plant model. We have taken great care to document the construction process, linking each cut plant component to its corresponding PDF template, which will help us keep track of construction. Notably, the mock-up model is also going to be useful in the next step of the modeling process: ordering and installing the plumbing. The mock-up plant model will ultimately help us determine what types and sizes of tubing we will need. We have finished cutting and assembling the filter, filter inlet, flocculator, and main base. We are in the process of scoring and cutting the rest of the plant components, including the entrance tank, the sedimentation tank, and the staircase. The individual pieces of each plant component have been attached with tape, and these components will then be glued together with the hot glue gun to form the whole water treatment plant.

Finalizing Templates

Once we finished exploding all of the model components and laying them out in two-dimensional templates, we were faced with the challenge of rearranging the template pieces to use space most efficiently. To do so, we used Rhinoceros's "Osnap" feature, which can join together endpoints and align components in reference to perpendicular lines. With Osnap, we could ensure two lines are perfectly colinear: this means only one cut will be needed instead of two, sav-

Figure 7: Assembled Mock-Up Filter
We assembled our mock-up filter using pieces we hand-cut from chipboard. It is held together with tape. Compare with 4, which depicts the 3D AutoCAD model of the filter.

ing us time, money, and energy. We then deleted the second of all overlapping lines to further facilitate the cutting proces. We successfully fit all of the plant components into 15 12”x18” templates, as well as a one 18"x32" template for the main base. We also measured the largest dimensions of the layout of the pieces of each plant component to see if it was possible to fit two or more different components on a single 12”x18” template. It was found that the staircase would fit with the main base on the same 18"x32" template, which saves us one template of Plexiglas. PDFs of all of these finished files may be found online under the “Component Templates (1:20)” section of the Small Scale Plant Model team wiki (https://confluence.cornell.edu/display/AGUACLARA/Small+Scale+Plant+Model).

Investigating Plant Thickness

According to the design parameters in the Moroceli report, the wall thickness of the plant is .150 m. On a 1:20 scale, this thickness translates to .0075 m or .295 in. The Plexiglas that will be cut is $^{1}/_{8}$” or .125 in, which is less than half the thickness that it would be to-scale. However, the water plant has been modeled so that there are inner and outer walls so the thickness would be doubled. This duplication brings the thickness to .250 in, which is still less than the scale thickness, but is of comparable size.

Plant Component	Dimensions of Template
Staircase	8.781 in x 6.470 in
Entrance Tank	14.853 in x 9.854 in
Flocculator 1/2	15.575 in x 10.541 in
Flocculator 2/2	17.234 in x 11.638 in
Flocculator Baffles	9.994 in x 9.646 in
Sedimentation Tank 1/4	14.962 in x 10.541 in
Sedimentation Tank 2,3,4/4	10.833 in x 9.951 in
Filter	15.254 in x 9.047 in
Filter Inlet	14.443 in x 8.184 in
Under Sedimentation Tank/Pipeport	16.797 in x 11.677 in
Main Base	21.862 in x 15.819 in
Transparent Pieces 1/3	17.339 in x 11.060 in
Transparent Pieces 2/3	17.732 in x 10.541 in
Transparent Pieces 3/3	11.878 in x 9.951 in

Table 1: Template Dimensions by Plant Component
The finalized component templates, listed with their size in inches.

Laser Templates

AutoCAD can set different curves of the same drawing in layers, which is useful for differentiating between cuts and scores. Different curves of the drawing are in different colors corresponding to the layer in which the curve is located. For example, all of the pieces on the "cut" layer are blue, while all of the pieces on the "heavy score" layer are green 8. Frank Parish gave us a laser template drawing file initialized for a 12"x18" cutting space, featuring appropriately colored layers. If a sheet of Plexiglas is smaller than 12"x18", there is also another layer for materials that identifies the dimensions of the sheet within the 12"x18" template.

We decided to score holes that were smaller than $\frac{1}{4}$" because such small cuts would take a long time for the laser cutter and as the smallest diameter of Plexiglas tubing we have found is $\frac{1}{4}$", the tubing wouldn't fit through the holes. Any piping that will be smaller than $\frac{1}{4}$" in the model will be modeled with Plexiglas rod, which can be found in smaller diameters. These scored holes will then show where to fit the rods in.

The completed laser-cutting templates for our plant components pieces can be found below in 10, 11, 12, 13, 14, and 15. These screenshots of the AutoCAD templates show the various layers detailed in 9. These two-dimensional templates were imported from Rhinoceros and placed within rectangles indicating the boundaries of their templates. For more information about template sizes, see 1.

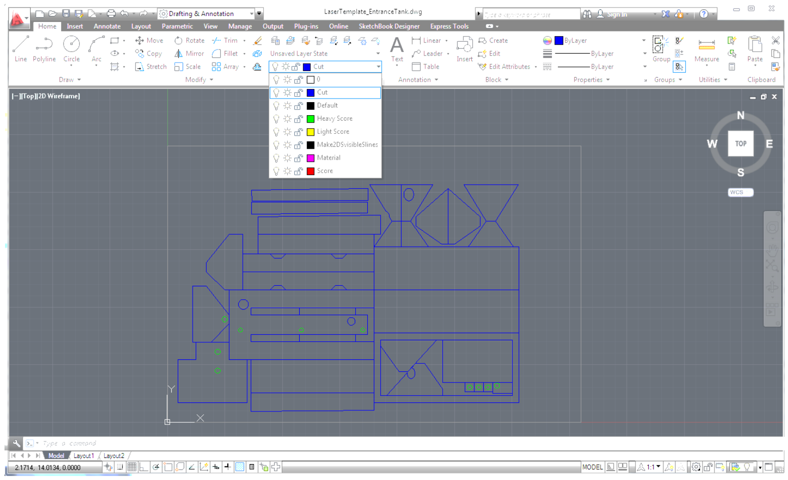

Figure 8: Laser Cutting
The above figure shows the drawing file of the laser template for the entrance tank. Curves that need to be cut are in blue, curves that need to be scored are in green.

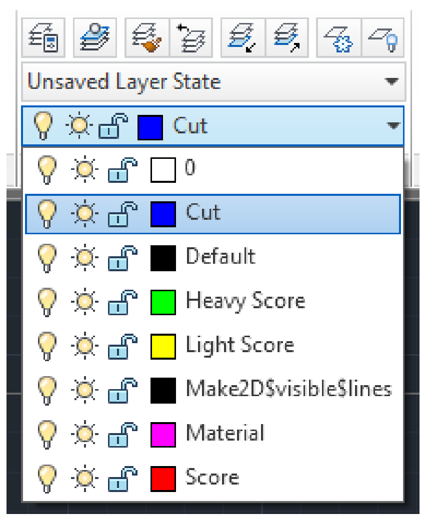

Figure 9: Template Menu
This close-up of the layer dropdown menu shows the different layers that can be used in the laser cutting template. The white layer (0) outlines the template. The cut, heavy score, and material layers in particular were utilized in this project.

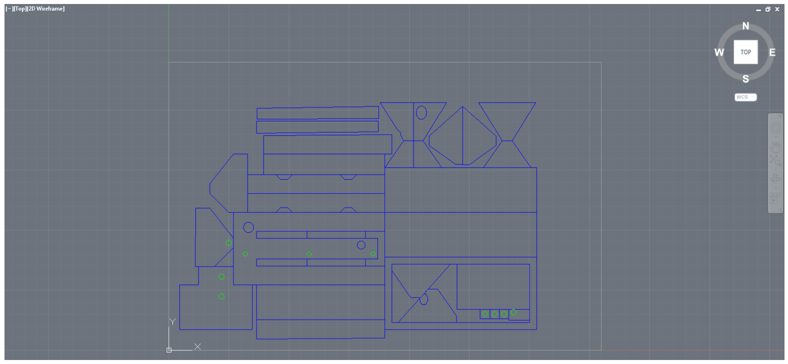

Figure 10: Entrance Tank
Laser cutting template of the Entrance Tank. Areas to be cut are shown in blue, while areas to be scored are shown in green. The boundaries of the 18" x 12" template are shown in white.

Guidance from Monroe

We met with Monroe in order to discuss what the Small Scale Plant Model team could feasibly accomplish by the end of the semester and details in creating the model. In this meeting, we decided to make our final model from Plexiglas. Plexiglue is a solvent and can only adhere Plexiglas to other Plexiglas, so attaching Plexiglas and museum board would not be practical. Plexiglas is also much stronger than museum board, which will ensure that the model will be stable and durable once it is fully built. It will also be better aesthetically to create the entire model in Plexiglas, as it will look more uniform and there will not be differences in thickness between materials. It was decided that instead of using painted Plexiglas to highlight significant plant components, we would employ colored Plexiglas, a simple and cheap alternative. For holes and pipes that were too small for the smallest tubing ($\frac{1}{4}$" outside diameter) we have found, we decided that solid Plexiglas rod would be more practical without making a significant visual difference. Monroe also raised the issue on how pieces that needed to be angled would be attached to a level piece because when the angled piece is cut out in the laser cutter, it will have a perpendicular edge only. We had to ask Frank Parish about whether angles could be cut on the Plexiglas and if not, we must look into beveling the edge of the angled piece and if that can be done in the lab. Monroe decided that melting would be insignificant for

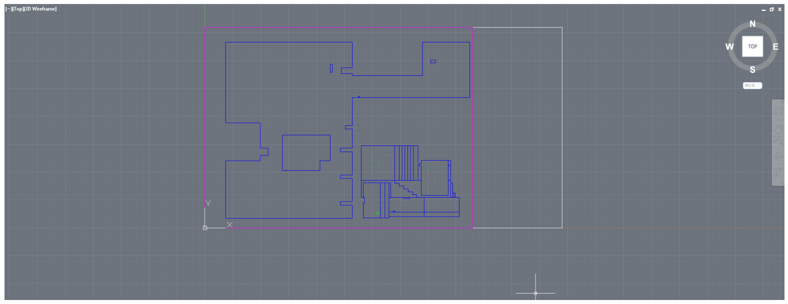

Figure 11: Main Base and Stairs
Laser cutting template of the Main Base and Staircase. Areas to be cut are shown in blue, while areas to be scored are shown in green. The boundaries of the 18" x 24" template are shown in pink.

the holes that were really close to the edge, but that we should research the tolerance of the Plexiglas as well.

Meeting with Frank Parish

After meeting with Monroe, we talked to Frank Parish about laser cutting. He informed us that Plexiglas' tolerance for holes cut very close to its edge is about 1/8". He found some small issues with the AutoCAD files we shared with him, but they were easy fixes. These files needed to be placed in the original template he sent us, rotated so that the "Top" view showed all the curves that would be cut, and reduced to a single line everywhere where two lines were colinear. These changes were all made quickly and we have since finalized the laser templates as required. Because the AAP lab is currently giving priority to AAP students who have final projects, we agreed with Parish to do our laser cutting over the summer. He then told us that the lab would be much less busy after May 7th and that if the laser cutting was done in the AAP lab, it would be free. In addition to the 12"x18" laser cutter that we originally planned to use, we would also gain access to an 18"x32" laser cutter. The main base of the model plant, which is larger than 12"x18", will now be able to be cut as a single piece on the 18"x32" cutter. Parish, furthermore, estimated that the pieces of the flocculator, spread across three 12"x18" templates, would take less than hour to cut. Although he couldn't judge the rest of the pieces of the plant model without seeing them, especially since some of them require very small and detailed cuts, he judged that it would take several hours to cut around twelve 12"x18" templates of pieces.

Materials Research

We contacted Ithaca Plastics to ask about the costs of creating our model and integrating model tubing. Although they could not give us a definitive quote

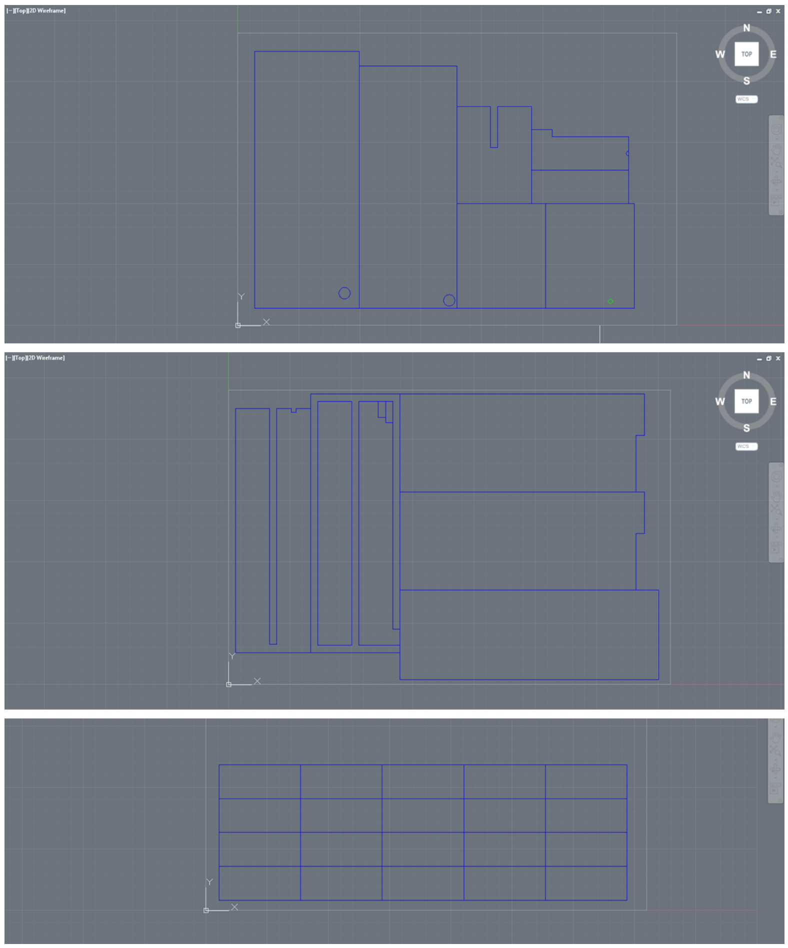

Figure 12: Flocculator
Laser cutting templates representing the Flocculator. Areas to be cut are shown in blue, while areas to be scored are shown in green. The boundaries of each 18" x 12" template are shown in white. We refer to these templates (from top) as Flocculator 1, Flocculator 2, and Baffles.

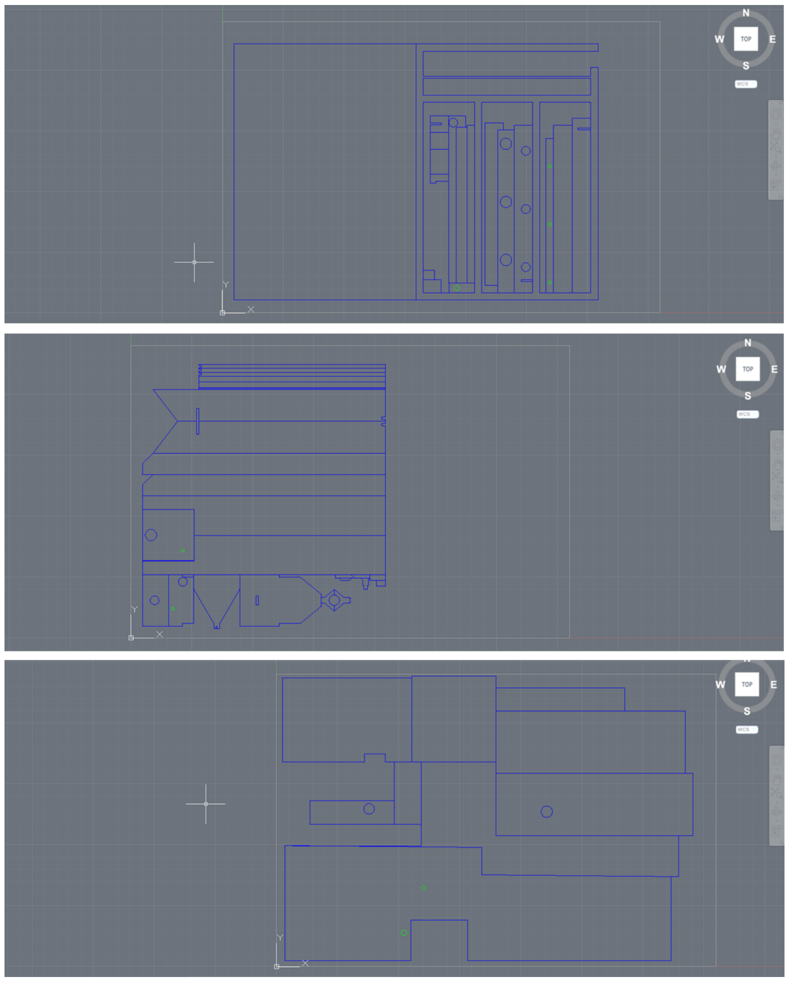

Figure 13: Sedimentation Tank

Laser cutting templates representing the Sedimentation Tank. Areas to be cut are shown in blue, while areas to be scored are shown in green. The boundaries of each 18" x 12" template are shown in white. We refer to these templates (from top) as Sedimentation Tank 1, Sedimentation Tank 2,3,4 and Under Sedimentation Tank. The second template is called Sedimentation Tank 2,3,4 because it must be cut three times in order for our plant to have the three sedimentation tanks required by its design.

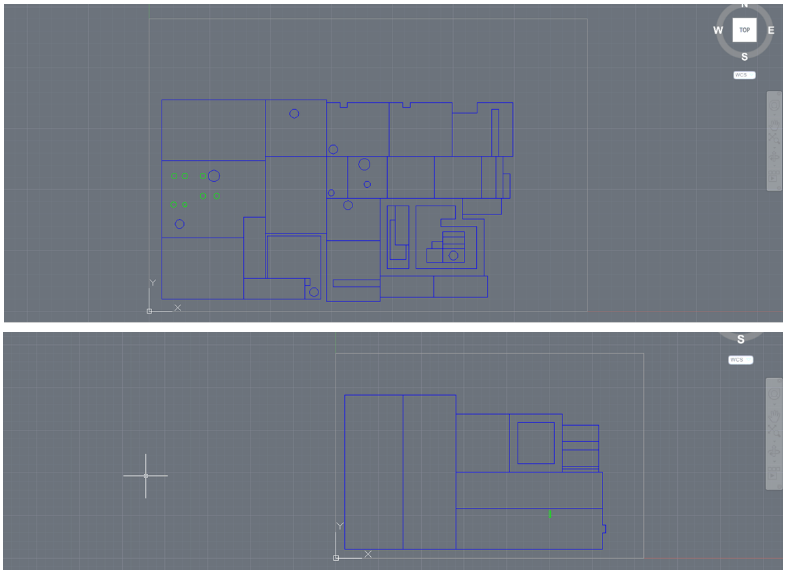

Figure 14: Filter and Filter Inlet
Laser cutting templates representing the Filter Inlet and Filter, respectively.
Areas to be cut are shown in blue, while areas to be scored are shown in green.
The boundaries of each 18" x 12" template are shown in white.

on the project without seeing all of the relevant parts, they informed us that they could work with PDF templates of the parts but would need at least a week in advance to work on the project. The smallest model tubing that Ithaca Plastics offers has a $\frac{1}{4}$" diameter on its outside and $^1/_8$" diameter on its inside. Plastruct.com also sells model plumbing pieces in both 1:20 1:30 scales, making accurate plumbing representation possible for the plant. After we investigate how much of the plumbing with be included in our model, we can create a budget for the model pieces. We will need to compare the price of ordering model plumbing to the price of using other representative pieces such as wooden dowels or plastic straws.

Gathering Materials

We have purchased all of the materials we will need for the mock-up model, including chipboard, an X-ACTO knife, replacement blades, and a hot glue gun. Other materials used in construction, such as tape, scissors, and a ruler or straight edge, have already been provided for in the lab. We have also compiled a list of materials for the final plant: Plexiglas, model tubing, paint, Plexiglue, and sand. We plan to use different colors and opacities of Plexiglas in order to highlight different parts of the plant. After a later discussion with Monroe, however, we decided on using only colored Plexiglas instead of paint

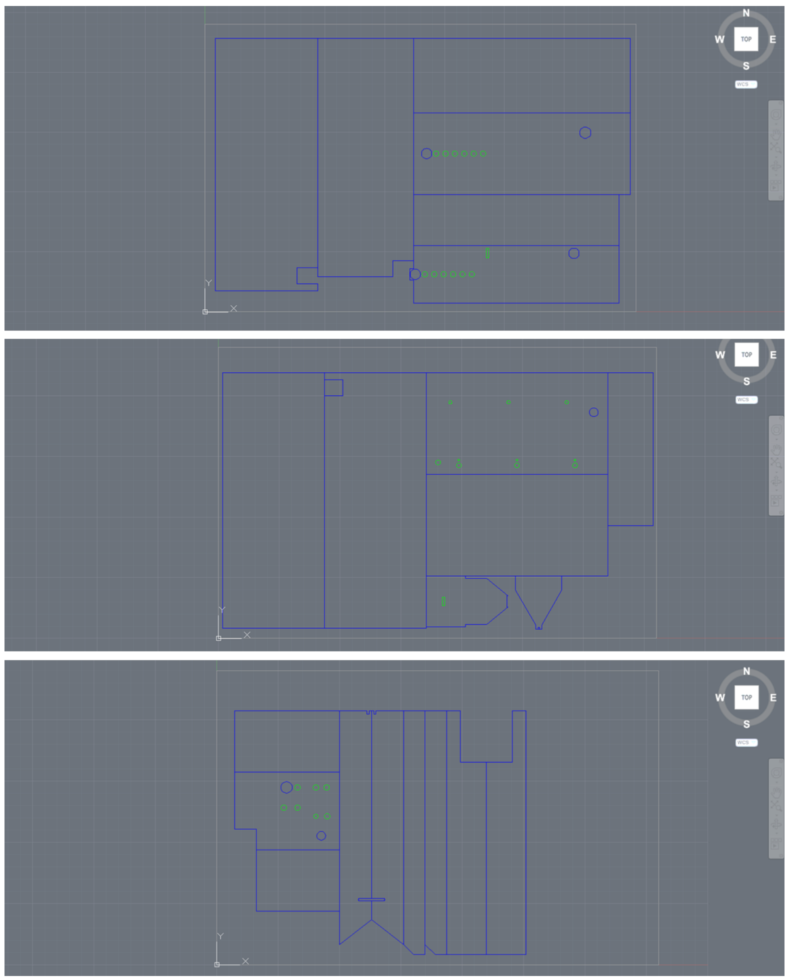

Figure 15: Transparent Templates

Laser cutting templates for the plant's transparent pieces. Areas to be cut are shown in blue, while areas to be scored are shown in green. The boundaries of each 18" x 12" template are shown in white. We refer to these templates (from top) as Transparent 1, Transparent 2, and Transparent 3.

and constructing all of the model plant structure in Plexiglas for the sake of simplicity, durability, and aesthetics.

Budget and Materials

Based on a maximum laser-cutting area of 12”x18”, we began to research ordering Plexiglas from multiple sources. We started by first calling Ithaca Plastics as recommended by Jordan Berta, but they could not give us a quote without a very specific order. After looking into other websites online, an inexpensive supplier was found: Delvie’s Plastics Inc.

Delvie’s Plastics sells custom cuts sheets of transparent Plexiglas, including sheets that are 12"x18", which cost $6.50 each. The thinnest sheets that Delvie’s Plastics sells are 1/8", which is also the greatest thickness that the laser cutter will cut. Compared to other suppliers we had previously considered, such as Professional Plastics, which charges $20 per sheet for Plexiglas of comparable thickness, Delvie’s Plastics is a much cheaper alternative. The company is based in Utah, so shipping takes five business days and costs $11.15. However, Delvie’s Plastics also gives a discount of up to 15% off of 10 sheets of Plexiglas when the sheets are bought in bulk. Delvie’s Plastics also sells Plexiglas rods, which we are still researching for tubing, but the smallest size it sold was a $\frac{1}{2}$" diameter, which is too large. Ithaca Plastics is currently the first supplier that we know which can supply small enough tubing for our purposes. Preliminary research suggested we might be able to buy four feet’s worth of model tubing for $10. In order to attach all of the pieces, Plexiglue was recommended by Frank Parish. Our initial research of ordering Plexiglue online showed that 8.9 oz of Plexiglue from Jones Tones would cost $5.43. We are still shopping around for cheaper prices on Plexiglas rods and Plexiglue, but we believe that these quantities should be sufficient for our needs.

Seeking to incorporate colored Plexiglas into our model to highlight plant features, we turned to McMaster-Carr. We purchased a 12"x12" sheet of blue Plexiglas to add contrast to our flocculator; we plan to make the baffles blue to best highlight the flow of water through this section of the plant.

After our meeting with Frank Parish, we learned that we would have access to an 18"x32" laser cutter through AAP, so we decided to consolidate our drawing files to best make use of this added space. We took our completed 12"x18" templates and arranged them side-by-side to form new 24"x18" templates. The main base was left as its own template, because it exceeds the dimensions of an 12"x18" template. We were able to fit the staircase template into empty space on the main base template, though, minimizing the materials necessary for the cutting process. However, we could not find Plexiglas of dimensions 24"x18" through our approved vendors, so we elected to buy the next biggest size of Plexiglas and have it cut down in the shop. Consequently, we ordered six 24"x24" sheets of white Plexiglas from McMaster-Carr.

We also learned from Frank that laser cutting done through AAP after May 7th would be free. When all of these costs are considered and summed, we find a total model materials cost of around $212.27 (2).

Materials Required	Cost
3 Sheets Transparent Plexiglas, 12" x 18" x 1/8", Delvie's Plastics	$18.53
Shipping from Delvie's Plastics	$13.22
Opaque Plexiglas, 24" x 24" x 1/8" (to be cut down to 18"x24")	$158.34
Colored Plexiglas, 12" x 12" x 1/8"	$6.75
Plexiglue	$5.43
Model tubing (per c. 4 ft)	$10
Laser cutting	$0
Total	$212.27

Table 2: Budget and Materials

Conclusions

Through the analysis of potential target audiences, we were able to synthesize our overall project goals as a desire to motivate and educate. We defined these categories on the basis that education creates understanding, helping realize and increase passion for AguaClara's social and technological goals, while motivation inspires groups and individuals to invest time, research, and money. This understanding helped us identify important and confusing plant features to highlight within our model. To motivate, we would need to make sure innovative AguaClara features received special attention, while to educate, we would need to make sure major unit processes were clearly explained. The Small Scale Plant Model team focused on the path of the water flow throughout the plant in order to best communicate how the water was treated. In terms of technology developed by AguaClara, highlights would include the Stacked Rapid Sand Filter (SRSF) and the dose controller. Another aspect that the plant model would emphasize is the fact that the water treatment plant is gravity-powered and thus does not need electricity, as many communities who would consider utilizing an AguaClara treatment plant are in developing countries and often do not have reliable electrical systems. Other important features include the sedimentation tank and entrance tank geometries, and these tanks will be made partially transparent so that the processes inside can be seen. Select parts of the filter inlet, filter, and flocculator will be made transparent as well. Certain smaller parts of the plant that may require more understanding but do not need to be removable are the sedimentation tank manifolds with diffusers and the SRSF and LFSRSF (Low Flow Stacked Rapid Sand Filter) manifolds.

The averaging of AguaClara plant capacities convinced us that a 12 L/s plant would be the ideal subject of our model, as it represents the most typical plant. The expert opinions of an architecture grad student compelled us to consider chipboard for the construction of our mock-up and Plexiglas for our final model. Thanks to Jordan Berta's counsel, we made plans to use 3ds Max and Rhinoceros to create laser cutting patterns for the flat planes of the frame of our design. These programs have allowed us to exactly scale our model so that it may fit in a carry-on suitcase; we first considered a scaling factor of about .03

based on preliminary calculations detailed above. Later, our team learned some basics of Rhinoceros and experimented with different scales for the plant model. Although we had previously favored a scale of 1:30, we decided that the 1:20 scale is more appropriate. The finer details of the plant may have been lost in the 1:30 scale. However, as height is still the limiting factor in the dimensions of the model, we will probably have to alter the model's height so the plant can stay within carry-on luggage dimensions. If certain parts of the plant are made removable, for example, then the 1:20 scale model should still fit within the dimension limits.

We successfully reached out to Cornell faculty members to receive access to laser cutting technology. Frank Parish, Senior Manager of AAP Material Practices Facilities, has provided our subteam with valuable information about the logistics of laser cutting, and his expertise is helping us to perfect our plans for our final Plexiglas model. With his guidance, we created 16 final plant templates of various dimensions, all optimized for laser cutting. These templates are listed in 1.

We have also made great strides in our mock-up construction. The filter, flocculator, and filter inlet have been cut out and assembled, and various other plant components have been cut or scored for future assembly.

We finalized much of our materials research and purchased, from Delvie's Plastics and McMaster-Carr, all of the Plexiglas we will need for our final model. Although incorporating model tubing seems a challenge for a later day, we are still investigating purchasing our model tubing from Ithaca Plastics.

Future Work

We have completed select parts of a mock-up model in chipboard, but some construction work still remains. The pieces for the mock-up are being hand-cut with an X-ACTO knife and assembled with a combination of tape and hot glue. The mock-up will help future teams visualize if the details are large enough and easy to understand and should confirm that 1:20 is an optimal scale for the model. In this process, teams will also have to decide what types of model tubing would be best for our plant. Assembling the mock-up will also improve spatial understanding of the plant, ensuring that the final model can be easily assembled from its components once they have been laser-cut in Plexiglas. It will be important to continue carefully numbering and labeling chipboard component pieces to better keep track of how pieces are positioned in relation to one another, and our 3D composite images will surely aid in this process as well.

The next step for the Small Scale Plant Model Team is to ensure that every piece sent to the laser cutter is to the correct scale, which will be done by checking the finished laser templates with the mock-up. To account for the thickness of the Plexiglas in the final model, it is possible that some templates will need to be resized before laser cutting actually occurs. Since our templates are already optimized, accounting for the thickness of the material can be as easy as inserting a few extra cuts along the edges of existing pieces to trim them down to size. Special attention will, furthermore, be necessary for pieces that are fitted at an angle, including parts of the entrance and sedimentation tanks. Future teams should research the possibility of beveling the sides of these angled pieces. After it has been confirmed that everything is going to be cut correctly, the Plexiglas sheets and AutoCAD drawing templates will be sent to the AAP workshop for laser cutting. Once everything is cut, construction of the final model can begin. In the process of constructing the final model, plant components (e.g., entrance tank) will be built from individual template pieces (e.g., walls of entrance tank). Plexiglas component pieces will be attached using Plexiglue, with all of the pieces coming together to form the final model. For simplicity, all of the large components will then be removable from the main base so that any part can be seen both in context to the water plant and individually.

The laser templates alone do not model the entire plant or filtration process, however. Parts of the plant that are not included in the laser templates include piping, the Linear Flow Orifice Meter (LFOM), plate settlers, diffusers, chemical storage tanks, sand in the filter, and the floc blanket. In order to model the piping of the plant, model Plexiglas tubing or Plexiglas rods must be further researched. Factors to consider are pipe length, pipe diameter, curves in pipes, cost differences between using solid rod or hollow tubing, and feasibility of using hollow tubing in smaller holes. Given the relatively small size of the LFOM in the entrance tank, we want to research 3D printing in creating a scale LFOM. The plate settlers or lamella in the sedimentation tanks will be modeled with thin sheets of plastic in order to stay to scale. The diffusers on the inlet manifold will require creativity to model the bends in the plastic. The sand in the filter can be easily added and should not be difficult to obtain. Ideally, the floc blanket will be a 3D model, but an image printed on a thin transparent plastic sheet can be used as an alternative. All of these smaller, yet significant, pieces still need to be modeled and will be looked into. Once the final model is completed, the Small Scale Plant Model team can evaluate the usefulness and viability of the model and explore making more models which can be used in different places.