Proposal for:

American Society of Civil Engineers Environmental Design Competition Final Proposal

Prepared for:

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Submitted by:

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1.0 Project Understanding

1.1 Project Purpose

Due to limited resources and technology, developing nations are faced with insufficient water treatment methods. Within the United Nations World Health Organization's (WHO) 2002 report, an estimated 1.7 million deaths per year can be attributed to the unsafe water supply and unsanitary treatment methods within developing countries. Over 90% of these deaths are reflected in diarrheal diseases in children [1]. In 2015, 29% of the human population did not have access to a managed drinking water source, meaning it is not readily available nor free from contamination [2].

The intent of this project is to design a low-technology, low-budget, unconventional water treatment device that could be used within the households of developing countries. This is done by accounting for all technical considerations within the civil and environmental engineering design process. The system will treat contaminated water simulated to replicate that of developing areas, and it will produce effluent that is in accordance with the water quality standards of the WHO [1]. This project will require water quality and filter research, filter testing, system design, system construction, and testing of the device. The culmination of this project will be the demonstration of the system at the 2018 Pacific Southwest Conference (PSWC) Environmental Design competition hosted by the American Society of Civil Engineers (ASCE).

The objectives of this project are to:

1. Provide a gravity-fed water treatment system
2. Design for an absence of advanced technology and resources
    a. The constituents of the simulated wastewater are defined by the PSWC competition
3. Verify that treated water is in accordance with the WHO potable water quality standards
    a. The parameters to be tested are defined by the PSWC competition

1.2 Project Background

Primarily due to poverty, 1.1 billion people in developing countries lack access to clean water. These low income families earn less than $2.00 per day and are consequently unable to provide clean water to their children. The exposure to waterborne illnesses increases the chance for infirmities such as diarrhea [4]. Various technologies and methods of treatment may be utilized to improve water quality in order to decrease illness within the developing countries.

The competition has outlined six parameters to be tested: total nitrate, total phosphate, turbidity, total coliforms, residual chlorine if used, and odor. These have been identified as parameters of key concern as they are a sufficient representation of the water quality. A high level of nutrients can result in human defects, including blue baby syndrome from excess nitrogen consumption. Turbidity must be treated for because it facilitates bacterial shelter and growth, and it is necessary to be removed before disinfection. Total coliforms are tested for as they are indicators of fecal contamination and pathogens which are the primary cause of diarrheal diseases. Chlorine is used as a disinfectant to kill bacteria. The residual is measured to ensure sufficient levels are achieved so that bacterial growth does not occur during water storage. Odor is a secondary standard, meaning that it does not directly impact human health; however it may indicate water pollution, such as high sulfur content.

1.2.1 Existing Treatment Technologies

Turbidity is primarily treated by filtration methods but can also be removed through sedimentation. Filtration can take place through various media. Sand filtration is common due to its high availability and efficiency. Other media that have shown to reduce turbidity and certain pathogens include activated carbon and fine cloth materials, such as the sari cloth. Sedimentation of the particles varies depending on the flow rate, the length of the tank, and the settling velocities of the particles [5].

Phosphorus is mainly treated through chemical or biological methods. Flocculants, such as aluminum or iron cations, are added to a water sample in order to react with phosphorus; this causes phosphorus to precipitate and allows the precipitate to be removed through physical processes. Microorganisms that store phosphorous can also be used within the waste activated sludge process. Waste activated sludge can then be removed by other physical processes [6].

Nitrogen is removed from water through the processes of nitrification and denitrification. Both of these biological methods are carried out by microorganisms. Ion exchange can also be used to exchange undesired nitrate ions for other ions of a similar charge by passing the water over resin beads. This exchange can be done with the chemicals described for phosphorous, but research suggests that the Moringa seed may act as a substitute where resources are limited [7].

Total coliforms are treated through the use of disinfection which may include UV disinfection, distillation, or chlorine addition. As stated previously, filtration can remove some of the bacteria, however additional treatment is necessary. Chlorine disinfection considers two parts: the amount added and the residual amount [8].

Odor can be treated by using activated carbon. The large surface area provided by the material removes the source of odors. Biological membranes can also be used to remove odors from sulfur [9].

1.2.1 Testing Methods

In order to construct an effective water treatment device, the following parameters must be tested for [10]:

1. Total P: Standard Method 4500-P Phosphorus
2. Total N: Standard Method 4500-NO3- Nitrogen (Nitrate)
3. Turbidity: Standard Method 2130 Turbidity
4. Chlorine: Standard Method 4500-Cl Chlorine (Residual)
5. Total Coliforms: Standard Method 9221 E. Fecal Coliform Procedure
6. Odor: Standard Method 2150 Odor

1.3 Technical Considerations

Designing a functional filtration system requires an understanding of the contaminants present and a respective understanding of how to remove said contaminants. The wastewater simulated will have the following constituents per each 35 liter sample [3]:

1. 1000 grams Miracle Gro All Purpose Plant Food ®
2. 1000 grams Bulk Apothecary White Clay ®
3. 30 milliliters Star Kay White Pure Lavender Extract ®
4. 20 milliliters Pre-disinfected wastewater effluent from the Tolleson Plant in Tempe, Arizona

The constraints outlined by the Environmental Design competition are as follows [3]:

1. Teams will be allotted a 3 meter by 3 meter area to construct their device. Operators nor materials may exceed the boundaries of the area.
2. Each team will be permitted to a total of thirty minutes to construct the treatment systems. Ten minutes will be allotted to poor the 35 liters of water sample into the system. After the ten minute pouring phase, operators must exit the 3 meter by 3 meter area. Twenty minutes will then be provided for the water sample to percolate through the water treatment devices.
3. Personal protection equipment (PPE) must be utilized during the construction period. The following PPE is required: closed-heeled and closed-toed shoes, long pants, long-sleeved shirt, gloves, Occupational Safety and Health Administration (OSHA) approved eyewear, OSHA approved hard hats, and lab coats.
4. The budget must not exceed $500 for the water treatment system. This includes all materials and equipment used to construct the device. Tools used to premark materials are not included in the final cost unless used within the 30 minute construction period.

1.4 Limitations and Challenges

Project limitations for this system include: construction time, filtration time, and the sizing of the treatment system. The allowed construction time for the competition is 30 minutes. If constructed in a developing country, the fabrication of the device would not be timed. The filtration process is also allotted 30 minutes. Ideally more time would be permitted for the filtration process in order to maximize treatment options. The overall design for the competition has been scaled down to meet the three meter by three meter sizing requirements as specified in the competition rules [3]. The dimensions of a municipal wastewater treatment system would have larger limits.

A specific challenge that may occur within this project is the temperature difference between Tempe and Flagstaff, Arizona. The team will be testing water samples in Flagstaff within the month of February with an average high of 7° C and an average low of -14° C [11]. Tempe has an average high of 34° C and an average low of 11° C [12]. The temperature increase in Tempe will result in a higher overall evaporation rate thus augmenting water loss during treatment. Temperature also impacts coagulation by affecting the viscosity of the water. Therefore, lower temperatures will decrease the precipitation of phosphorus and nitrogen [13].

Another challenge may be acquiring materials that are readily available in developing countries. Although this is not the responsibility of the design engineers, it may still be considered for project feasibility purposes.

1.5 Stakeholders

The primary stakeholders for the project include individuals living in developing nations. These populations will benefit from a functional water treatment device as it will reduce diarrheal diseases. Additional stakeholders in this project include: the members of the ASCE Environmental Design team, Northern Arizona University (NAU), the NAU ASCE student chapter, and the client Mark Lamer. The team will be representing the university and the local ASCE student chapter at the competition. Success in this project will provide these entities with recognition. Project failures will discredit the engineering program at NAU and the proficiency of the NAU ASCE student chapter.

2.0 Project Scope

2.1 Task 1: Literature Review

The following items need to be researched before the design of the system can be completed: treatment methods and developing country resources. These subtasks will be discussed in the following subsections.

2.1.1 Task 1.1: Treatment Methods

To better understand water treatment methods, effective mechanisms for removing contaminants will be primary areas of water quality research.

2.1.2 Task 1.2: Developing Country Resources

The main objective of the project is to provide clean water to developing nations with the design of a household water treatment system. Thus, research regarding available resources must be conducted before the system components and design are finalized.

2.2 Task 2: Unit Design

In order to design the water treatment device, a schematic must first be estimated utilizing the determined components from the prototypes. Software modeling may then be used in order to visualize the design. This step will be done iteratively. These subtasks are discussed below.

2.2.1 Tasks 2.1 - 2.6: Component Prototyping

Components that remove turbidity, total nitrogen, total phosphorus, total coliforms, odor, and chlorine will be prototyped individually making up subtasks 2.1 to 2.6. The testing will be performed within the designated lab space at NAU and modified accordingly through the application of the environmental and civil engineering design process.

2.3 Task 3: Acquisition of Materials

Materials must be obtained before the device can be constructed. Fundraising and the purchasing of materials will be completed under this task.

2.3.1 Task 3.2: Buying Necessary Materials and Parts

In order to have an effective design, various materials and parts will need to be purchased. These materials and parts may be purchased at stores such as Home Depot, Lowes, and other home improvement stores. All items purchased must have a receipt.

2.4 Task 4: Fabrication

After the materials are obtained, the system will be built. The construction phase will be divided into the following components: filters, pipes, a holding tank, and the supporting structure. This step may be done several times.

2.4.1 Component Prototype Fabrication

The fabrication of each unit or combined units will be constructed during the initial stages of the design. This may be extended into the construction period of the final design.

2.4.2 Final Design Fabrication

Once sufficient data is compiled, the final design will be constructed and tested before the start of the competition.

2.5 Task 5: Prototype Analysis

The device will be tested after it is constructed. Filters and functionality of the overall system will be reviewed. These items are discussed in the following subsections.

2.5.1 Tasks 5.1- 5.6: Data Collection

Data collection will be used to verify the treatment results for each component of the filtration system. These components include: turbidity, total nitrogen, total phosphorus, total coliforms, odor, and chlorine. Data collection will allow the team to continue to optimize the treatment methods selected.

2.6 Task 6: Final Design

After testing the system and obtaining testing results, the most effective design will be finalized for each component and compiled into the final water treatment system.

2.6.1 Task 6.1: Component Integration

The results from the prototype analysis will be compiled into the final design. This will determine which units require a certain order of progression and which units can be combined.

2.6.2 Task 6.2: Optimization

Data will be gathered concerning the final design. Based on the findings, the design will be altered to increase efficiency.

2.7 Task 7: 50% Proposal

The 50% proposal will show the progress the team has made over the first part of the 2018 spring term.

2.8 Task 8: PSWC Competition

The final design will be presented at the 2018 PSWC. This involves demonstrating the ease of construction and giving a presentation.

2.8.1 Task 8.1: Construction and Demonstration

The wastewater treatment system will be assembled in Tempe, Arizona within the specified time parameters. Once the system is constructed the wastewater treatment testing will begin by pouring the wastewater influent into the system. The system must treat the water in the designated time and the water must meet the parameters as stated in the Environmental Design competition rules, as specified in Section 1.3.

2.8.2 Task 8.2: Poster Presentation

The team will assemble a 60 centimeter by 90 centimeter poster of the process flow diagram for the system. The team will present the process flow diagram to the judges before the treatment phase begins.

2.8.3 Task 8.3: Technical Presentation

A technical presentation will be given at the 2018 PSWC after the final water treatment system device is constructed. Judges will have an opportunity to ask questions at this stage of the competition.

2.9 Task 9: Final Presentation

During the undergraduate presentation, the final results and findings will be presented to the client, thus giving the client an opportunity to clarify the results and ask questions.

2.10 Task 10: Website

A website will be developed highlighting the key aspects of the project. This will include the final proposal, results of the competition, and other relevant information.

2.11 Task 11: Final Proposal

The research, data collection and all results will be compiled in a final proposal.

2.12 Task 12: Project Coordination

Throughout the entire project, there will be team meetings in order to coordinate working schedules and communicate. There will also be meetings with the technical advisor and the client.

3.0 Project Schedule

The schedule consists of all 12 of the tasks described in Section 2.0. The total duration is 33 weeks from September 14, 2017 through May 1, 2018. However, there is no work time scheduled for the winter break, which is December 15, 2017 through January 16, 2017. The major tasks for the project consist of unit design, fabrication, prototype analysis, and the final design. Each deliverable and sub task can be seen in the Gantt Chart located in Appendix A.

3.1 Critical Path

The critical path is defined by the design tasks and deliverables dates. The dates are set by the PSWC, and the end of the spring term. The critical path is crucial as it schedule minimizes the amount of time required to complete the project. Developing a critical path allows the team to organize the tasks to be complete in the most efficient manner. To progress as scheduled, team meetings are regularly scheduled. This is to provide constant communication between the team members, the technical advisor, and the grading instructor.

4.0 Project Staffing

4.1 Staffing Positions

As all Capstone team members have the appropriate experience necessary to complete this project, all members will be taking on the various staffing positions. Depending on the task, the team members will rotate amongst or simultaneously fill the following positions:

1. Project Engineer (PE)
2. Project Manager (PM)
3. Engineer in Training (EIT)
4. Lab Technician (Tech)

4.2 Team Member Qualifications

The qualifications of the Capstone team members to fill the above positions are as follows:

Alexander Anzar has completed all coursework at NAU to this point with distinction. Additionally, he has completed a paid research internship at the Austral Center for Scientific Research in ocean water quality. Relating to the project, Anzar offers insight into the design of water treatment system. Furthermore, Anzar has worked as a lab aide for the Environmental Engineering Lab at NAU which will be advantageous when testing for the water quality parameters.

Shelby Carawan has excelled in various courses at NAU that directly relate to the concept of this project including Water/Wastewater Units Design, Unit Operations in Environmental Engineering lab, and an Environmental Engineering Lab that covered the basics of water quality testing. This experience will be necessary when undertaking the Lab Technician position. Carawan was also on NAU's ASCE PSWC Environmental Design team of 2017. This project involved the design and construction of a small-scale, low-technology water treatment system which is similar to the project at hand. The PSWC 2017 Environmental project sufficiently prepared Carawan for the successful completion of this project.

Paige Reilly is an environmental engineering senior at NAU. She has taken various courses within the engineering program that correlate to water and wastewater engineering. These courses include Environmental Engineering Lab, Wastewater and Water design, Chemistry, Computer-Aided Drafting, and various others. Obtaining knowledge relating to water quality treatment and design, she is able to successfully conduct lab procedures and conduct thorough water quality parameter analysis. As a previous participant within the ASCE Environmental Design competition of 2017, Reilly will apply her engineering skills and construct a low-tech, low-budget, and unconventional water treatment device.

Cameron Rhodes has completed the necessary course work at NAU pertaining to wastewater treatment systems. Some of the classes included are: Chemistry, Organic Chemistry, Wastewater Design, and Environmental Engineering Lab. Additionally, Cameron participated on the Environmental Design team for NAU, in 2016. This experience will allow Cameron to contribute to the technical design, report, and construction of the project.

4.3 Staffing Hours and Justification

Table 1 below estimates the required amount of hours needed by each staffing position in order to complete each task and subtask.

Table 1: Staffing Hours

Task	Subtask	STAFF (hrs)				Task Total
		PE	PM	EIT	Tech	
1. Literature Review	1.1 Treatment Methods	0	0	20	0	20
	1.2 Developing Country Resources	0	0	20	0	20
2. Unit Design	2.1 - 2.6 Component Prototyping	5	10	20	20	55
3. Acquisition of Materials		0	0	3	3	6
4. Fabrication	4.1 Component Fabrication	2	15	25	25	67
	4.2 Final Design Fabrication	2	10	25	35	72
5. Prototype Analysis	5.1 - 5.6 Data Collection	5	5	25	40	75
6. Final Design	6.1 Component Integration	15	10	10	15	50
	6.2 Optimization	15	15	15	20	65
7. 50% Proposal		10	10	15	0	35
8. PSWC Competition	8.1 Construction and Demonstration	10	20	15	10	55
	8.2 Poster Presentation	2	2	10	0	14
	8.3 Technical Presentation	2	2	10	0	14
9. Final Presentation		5	5	7	0	17
10. Website		0	5	10	0	15
11. Final Proposal		10	10	10	0	30
12. Project Coordination		10	10	10	10	40
	Total Staffing Hours	***93***	***129***	***250***	***178***	***650***

According to Table 1, the tasks that require the most amount of staffing hours include data collection, final design fabrication, component fabrication, and final design optimization. The tasks requiring the least amount of staffing hours are the acquisition of materials, presentation tasks, and building the capstone team website.

Table 2 below justifies the total hours of work that each staff position necessitates.

Table 2: Staffing Hours Justification

Positions	Total Hours	Justification
Professional Engineer (PE)	93	The PE will work the least amount of hours as they are the most experienced. It is their job to aide in component prototyping, fabrication, and the final design. The professional engineer is required to attend the PSWC competition and help compose the final proposal.
Project Manager (PM)	129	The project manager is in charge of foreseeing the project and ensuring it is completed on time within the specified budget.
Engineer in training (EIT)	250	The engineer in training is allocated the most amount of work as they are under the direct supervision of the professional engineer and project manager.
Lab technician (Tech)	178	The lab technician position will primarily be involved in prototyping and fabrication tasks, both of which require the most amount of hours.

As indicated in Table 2, the EIT position will require the most amount of work hours, followed by the lab technician, and the managing engineer. The professional engineer will work the least amount of hours for the completion of this project.

5.0 Cost of Engineering Services

The cost considerations of this project were separated into four sections: staffing, materials and equipment, and travel.

5.1 Staffing Costs

The following table displays the various costs associated with staffing dependent upon the position title, base pay per hour, benefits, and hours of work.

Table 3: Total Staffing Costs

Position Title	Base Pay Rate/Hour	Benefits % of Base Pay	Actual Pay/Hour	Total Hours Work	Total Cost
PE	$90.00	40.00%	$126.00	93	$11,718.00
Project Manager	$70.00	40.00%	$98.00	129	$12,642.00
EIT	$50.00	30.00%	$65.00	250	$16,250.00
Lab Tech	$40.00	30.00%	$52.00	178	$9,256.00
				Total Staffing Costs	***$49,866.00***

As shown in Table 3, the EIT will make the most throughout this project, followed by the project manager, PE, and the lab technician. The total staffing cost for the project rounds to $50,000.

5.2 Materials and Equipment Costs

Table 4 highlights the total material and equipment costs needed to conduct proper analysis for the wastewater treatment system. This includes the number of units, average cost of each item, and their total cost.

Table 4: Total Material and Equipment Costs

Materials and Equipment	Number of Units	Average Cost	Total Cost
Miracle Gro All Purpose Plant Food (1000 g)	1	$10.00	$10.00
Bulk Apothecary Kaolin Clay (1000 g)	2	$5.00	$10.00
Star Kay White Pure Lavender Extract (30 mL)	1	$15.00	$15.00
Wastewater Treatment Plant (WWTP) effluent (30mL)	1	$0.00	$0.00
PTFE Membrane Filters, 0.10 um, 25mm, Nonsterile (200 pack)	2	$105.00	$210.00
Homer Bucket (5 gal)	2	$10.00	$20.00
Wood Stir Stick	2	$5.00	$10.00
Presentation Board	1	$5.00	$5.00
Filter media: Pool filter sand #20 grade silica sand (50 lbs)	1	$30.00	$30.00
Filter media: Vivadoria activated charcoal (34 g)	5	$10.00	$50.00
		Total Material and Equipment Costs	***$360.00***

The total cost for materials and equipment is approximately $400.

5.3 Travel Costs

Table 5 displays travel costs for the team to attend the 2018 PSWC located at Arizona State University in Tempe, Arizona. The table outlines the costs of gas, hotel rooms, meals, and the vehicle rentals for five days and four nights.

Table 5: Total Travel Costs

Expense	Units	Quantity	Average Cost Per Unit	Total Cost
Rental Car	Days	4	$55.00	$220.00
Gasoline	Gallons	40	$5.00	$200.00
Hotel Rooms	2 Rooms Per Night (4 Nights)	8	$200.00	$1,600.00
Meals	3 Meals Per Day (5 Days)	15	$10.00	$150.00
			Total Travel Costs	***$2,190.00***

The total travel costs for the project equal $2,200.

5.4 Total Cost Summary

Table 6 displays the accumulated costs regarding staffing, materials and equipment, and travel.

Table 6: Total Costs Summary

Average Cost Per Unit	Total Cost
Staffing Costs	$50,000.00
Material and Equipment Costs	$400.00
Travel Costs	$2,200.00
Total Costs	***$52,600.00***

The total cost of the project will be about $52,600.

6.0 References

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Appendix A - Gantt Chart

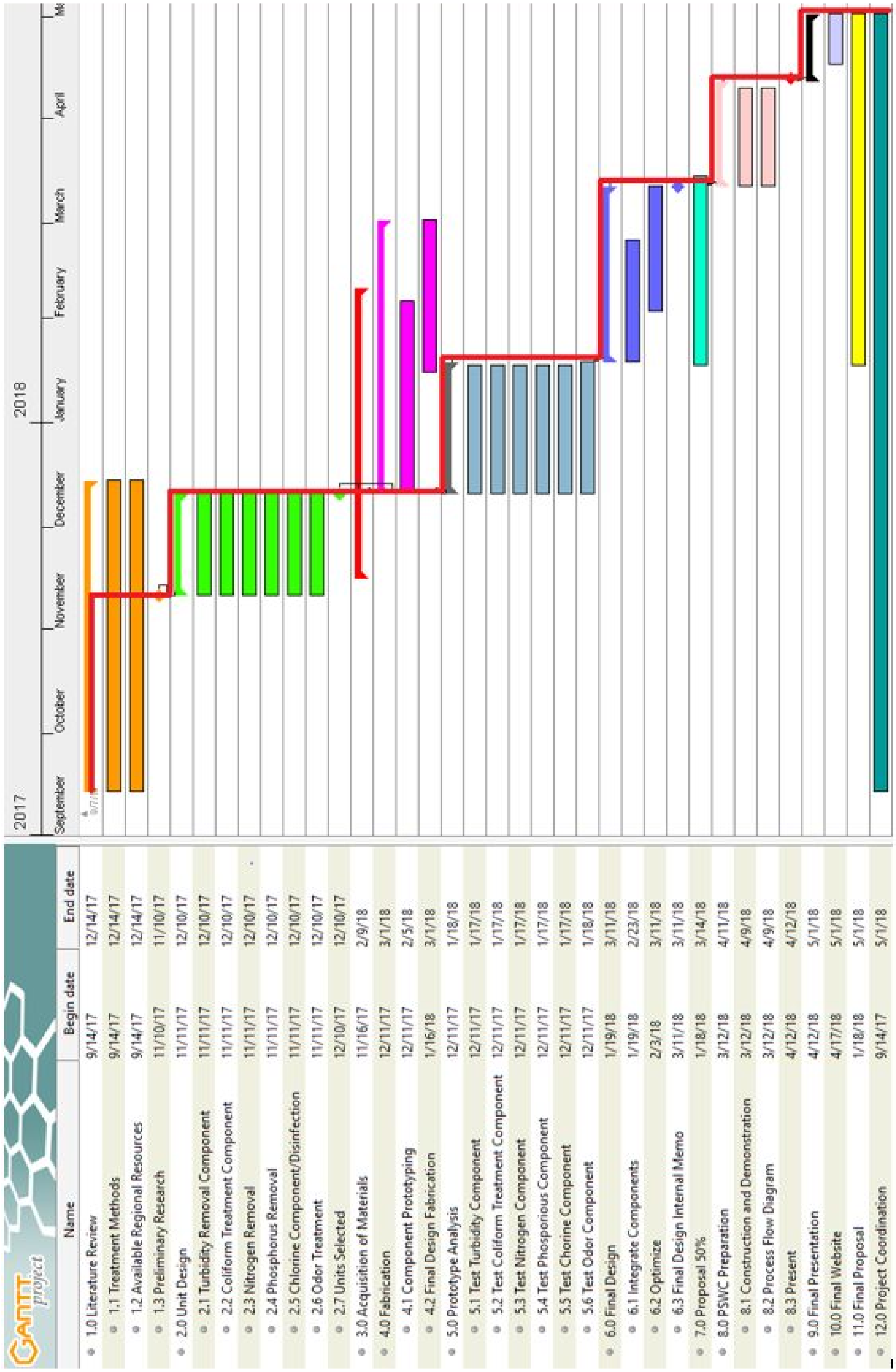

Figure 1: Gantt Chart Schedule with Critical Path in Red

Appendix B - Technical Advisor Agreement

CENE 476 / 486 Technical Advising Requirements

An essential element in the education of engineering students is their culminating senior design experience, also known as capstone. In Civil and Environmental Engineering, students work in teams of three or four with a client, usually external to the department, to develop a real-world engineered design. Each student team will work with their client and technical advisor first to develop a proposal for the project due at the end of CENE476, then to complete the full design and develop a design report and associated documents (e.g. plans, specifications, etc.), due near the end of CENE486C. This document provides a framework for the responsibilities of the student team to the technical adviser, and explanation of the technical adviser's responsibilities.

The student team agrees to:

- Interact with their technical adviser in a professional manner at all times.
- Prepare for meetings with their tech adviser so that the adviser's time is used efficiently and effectively.
- Provide meeting agendas at least three business days in advance for any meetings between the team and tech adviser.
- Keep detailed meeting minutes (date, time spent, items discussed, etc.) from meetings with their technical adviser.
- Follow all recommendations made by the tech adviser with respect to technical aspects of their design. Where a team does not adhere to their adviser's advice, they must justify and document reasons why they chose not to follow the adviser's input.
- Not request reviews of submittals for grammar, punctuation, spelling, etc.

The technical adviser agrees to:

- Interact with their student team in a professional manner at all times.
- Be available to the student team for at least one hour each week.
- Prepare for meetings with their team in advance (e.g. review documents for technical soundness, review upcoming meeting agenda, etc.)
- Provide input to the team with respect to the technical approaches used on their project. This is the PRIMARY role of the tech adviser – one of expert who can help students avoid critical mistakes (incorrect assumptions, analyses methods, etc.) that have the potential to derail the design solution.
- Provide honest yet constructive feedback to their student team on performance, professionalism, etc.
- Provide assessments of various team activities including: team preparedness for TA meetings, 50% design deliverable, and 100% design deliverable.

Signatures:

Technical Advisor: [signature] Date: 9/25/17

Print Name: TERRY E. BAXTER

Figure 2: Technical Advisor Agreement

Appendix C - Cover Letter to Client

September 21, 2017

Mark Lamer, PE
Northern Arizona University

Flagstaff AZ, 86011

Dear Mark Lamer:

Attached is the ASCE Environmental Design Competition team's understanding of the project's objectives and purpose. Comments and corrections are encouraged in order to ensure a satisfactory completion of the project.

Please respond by the end of the workday on Thursday, October 5th, 2017 with any modifications that need to be made. We will address these changes promptly and will return our revisions to you by the end of the work day on Monday, October 9th, 2017.

Thank you for working with us. We will be in contact soon.

Sincerely,

Alexander Anzar
Shelby Carawan
Paige Reilly
Cameron Rhodes