GRAND CANYON RAILWAY BOILER WASTEWATER TREATMENT AND STORAGE

Final Proposal

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Grand Canyon Railway Capstone Team

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Abstract

The goal of the Grand Canyon Railway project is to design a storage tank and develop pretreatment methods for the effluent boiler wastewater from two biodiesel-fired steam locomotives for subsequent treatment at the Williams Wastewater Treatment Plant. The wastewater to be treated is produced from a process called "Boiler Blowdown" in which water in the boiler is heated and pressurized to blow out the built-up sediment at the bottom of the boiler. The resulting wastewater has a high pH and high concentration of total dissolved solids. These parameters will be treated in order to meet minimum requirements for discharge into Williams Wastewater Treatment Plant. This proposal looks to outline the major tasks, schedule, cost, and staffing required for the completion of this project.

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Nomenclature

ADEQ	Arizona Department of Environmental Quality
CFR	Code of Federal Regulation
EPA	Environmental Protection Agency
GCR	Grand Canyon Railroad
GIS	Geographic Information Systems
NAU	Northern Arizona University
BOD	Biochemical Oxygen Demand
TDS	Total Dissolved Solids
WWTP	Wastewater Treatment Plant

1.0 Project Understanding

1.1 Project Purpose

The goal of the Grand Canyon Railway (GCR) project is to design a storage tank and develop pretreatment methods for the effluent boiler wastewater from two biodiesel-fired steam locomotives for subsequent treatment at the Williams Wastewater Treatment Plant. The GCR would like to properly dispose of wastewater at the Williams Wastewater Treatment Plant but the effluent does not meet incoming wastewater standards. The United States Environmental Protection Agency (EPA) requires wastewater entering wastewater treatment plants to adhere to specific criteria in order to maintain reclaimed water standards and ensure proper treatment. In the case that influent wastewater does not comply with these minimum standards, implementation of pretreatment is required. In the absence of pretreatment, the locomotive wastewater has the potential to leach into surrounding ecosystems, disrupting the local environment and community.

1.2 Project Background

In a steam locomotive, the inner mechanics involve firing a given fuel within a fire box to heat water in a system of pipes, located in the boiler. This water is superheated and transported from the pipe system to the cylinder of the wheel, pushing the piston and subsequently the wheel forward by one half turn. As the steam exits the system, the change in air pressure pulls the piston back and this energy creates one half turn, completing a full wheel turn. The steam that leaves the boiler is pure vapor, because when it is superheated, sediments and minerals remain condensed. Due to this phenomenon, impurities are left in the boiler water and as time goes on, the contaminations become oversaturated within the tank and precipitate. This reaction leaves the wastewater concentrated with organics and total solids.

The project site is in Williams in Northwest Arizona, surrounded by lush forests and mountainous terrain. In the past, Grand Canyon Railway has stored this water by allowing the steam to condense inside of a metal tanker railcar, then transport it to the local Williams Wastewater Treatment Plant (WWTP) that can process the waste stream. Boiler wastewater is produced during a process called "blowdown" in which the boiler is pressure washed and drained. This blows out all the built-up sediment and sludge deposited in the base of the water tank. This process results in a wastewater with a high concentration of dissolved solids. In addition to this, the most recent composition analysis of the wastewater showed a pH of 11.4 and total dissolved solids (TDS) concentration of 1540 mg/L. The Grand Canyon Railway has begun to investigate the regulations of this process internally and believes a permit is needed to continue to conduct blowouts in the traditional way. Due to cost of this permit, the company has decided that the water should be stored, pretreated, and transported to the municipal wastewater treatment plant. However, the wastewater is incapable of being accepted by the local WWTP after new influent criteria has been implemented. The GCR plans to have the pretreated wastewater transferred to the wastewater treatment facility in Williams via an on-site pressurized pipe network approximately 2.3 miles southwest of Grand Canyon Railway.

Typically, total dissolved solids, are treated by using a coagulant to settle the solids out of the water and collecting the sludge left behind for disposal. This can be done in any tank that has sufficient depth, depending on settling time and fluid viscosity, to allow the solids to completely settle. Microscopic and nanoscopic filtrations are additional options for treating dissolved solids, however this option is a more expensive and labor-intensive process. Treating pH in a wastewater stream typically requires the addition of an acidic solution to lower pH or a basic solution to raise pH. In the case of this project an acidic solution will likely be required to lower the pH.

1.3 Technical Considerations

1.3.1 Site Plan/Map

A site map of the area will be created to safely design a tank small enough to fit into the location provided by GCR. This map will also be used to provide a clear understanding between the client and the team to ensure correct placement and distances between the tank and the granger pump. Additionally, this map may include topographic and rainfall data to ensure safe and stable positioning of the tank.

1.3.2 Arizona Pretreatment Program

The wastewater from GCR will be accepted to Williams WWTP at the completion of this project. However, Williams wastewater plant treats the inflow of water to Class B+ standards and requires incoming flow to meet specified standards. City of Williams has set forth these standards and are outlined in table 1 below.

Table 1: Williams WWTP concentration standards. [1]

Parameter	Concentration
pH	5.5 to 9
BOD	300 ppm or 300 mg/L
TDS	350 ppm or 350 mg/L

These values have been approved by Arizona Department of Environmental Quality (ADEQ) and any entering wastewater must meet these requirements. Because of this, BOD will not be treated for this project because the wastewater analysis provided registered a BOD concentration of only 12 mg/L.

1.3.3 Software

The site map of the GCR facility will be generated using Geographic Information Systems (GIS). This site map will be used to provide an understanding of the area in which the storage tank and pretreatment options may be implemented. With Civil 3D, a map with the storage tank and pretreatment plan can show how they will be implemented onsite. Civil 3D shows how the project will be implemented on-site before being constructed.

1.4 Potential Challenges

1.4.1 Budget

The project budget is currently unknown and will be further developed later in the project. Budget constraints could limit the amount or quality of materials used in the storage tank. Budget constraints could also limit the potential pre-treatment methods due to expense of implementation, operation, or maintenance. To mitigate these potential challenges, instead of designing a tank for expected future growth, the tank can be designed to meet the current volumes of wastewater produced. Research into pretreatment methods noting the associated costs as well as intentional research of reduced cost methods would also be beneficial.

1.4.2 Community Response

Residents of Williams, Arizona may reject some storage tank design options due to aesthetic, environmental, or personal health concerns. The team will regularly be advised and critiqued by technical advisors and instructors on the project to ensure a safe and effective design, so as not to impact the health of the community. Signage identifying and detailing various aspects of the implementation of the storage tank could be put in place at GCR in public view to encourage an understanding of the need, safety, and beneficial effects of the tank.

1.4.3 Unexpected Contaminants

The wastewater could have contaminants that were unexpected and not considered during design. This could be avoided by the analysis of a sample of the wastewater early in the project schedule. The storage tank could leach contaminants into the wastewater during storage. This could be mitigated by researching the potential interactions of the wastewater constituents and various potential container materials, then choosing an appropriate material. The pretreatment process could create new contaminants in the wastewater. This could be mitigated by researching the potential interactions of the wastewater constituents and various potential treatment methods, then choosing an appropriate method. An analysis of a sample of the wastewater after pretreatment can confirm the removal of contaminants to acceptable levels.

1.5 Stakeholders

Table 2: Project stakeholders.

Stakeholder	Type	Primary or Secondary	Reason

Grand Canyon Railway	Social, Economic	Primary	The outcome of the project affects the operations, maintenance, income, and expense of the company. Improper design of the tank or the pretreatment method could lead to employee or customer exposure to hazardous chemical solutions, which could lead to legal action.
Grand Canyon Railway Employees	Social, Economic, Environmental	Secondary	Improper design of the tank or the pretreatment method could lead to employee exposure to hazardous chemical solutions, impacting their health. The GCR's financial success could lead to higher pay or increased benefits for employees while financial decline could lead to employee layoffs.
Grand Canyon Railway Customers	Economic, Environmental	Secondary	Improper design of the tank or the pretreatment method could lead to customer exposure to hazardous chemical solutions impacting their health. Economically, customers will save money if GCR is able to reduce operation and maintenance costs, these savings will then be passed on to their customers.
Williams Wastewater Treatment Plant	Social, Economic	Primary	If the pretreatment fails, and unacceptable wastewater enters the plant, it could cause the improper treatment of all wastewater that the plant treats, causing an image of inefficacy and inflating operational costs as emergency solutions are implemented. For a similar reason, the Williams WWTP is a social stakeholder because a water treatment emergency would result in poor public perception of the treatment plant.
City of Williams	Economic, Environmental	Primary	More GCR customers could lead to an increase in the general visitor population, and thus a larger consumer pool for all local businesses. Therefore, financial growth of GCR would provide more revenue to the city. The storage and pre-treatment solution, if poorly designed, could affect the ecology of the Williams area, including soil and water contamination.
Residents of Williams	Economic, Environmental	Secondary	The soil and water contamination, mentioned above, would directly affect their health. Financial growth of the GCR could create more job opportunities for the local community and financial decline could cause loss of employment.
Northern Arizona University	Social, Economic	Secondary	As the project team is comprised of senior NAU engineering students, success or failure in the project would reflect on the quality of the Engineering program. This could affect the reputation of NAU at large as well as the Engineering department. This, in turn, could affect the amount and quality of incoming

			students and faculty which affects the quality of the school and the amount of incoming tuition.
Technical Advisor: Wilbert Odem	Social, Economic	Secondary	Dr. Odem's reputation could be positively or negatively affected by the success or failure of the project as he guides and oversees the team in the technical aspects of the project that, as students, the team may be unfamiliar with. This, in turn, could affect his income as customers and employers prefer reputable persons.
Project Team	Social, Economic	Primary	The outcome of the project reflects on their skills and work ethic, which could affect their social standing in the engineering profession. The outcome of the project will occur at a time when the project team, as soon to be graduates, will be searching for prospective employers. A positive or negative outcome could affect their job prospects and thus income.

2.0 Scope of Services

2.1 Field Work

Field work is required to determine the ideal placement and size of the tank implemented, transport methods, and sludge processing capabilities. Field work will need to be approved by the client and capstones advisors prior to completion.

2.1.1 Site Map

A site map will be prepared to provide the client and capstone advisors with an outlook on where the work in this project will be done. Using ArcGIS, the map will have a designated location for the tank placement at the Grand Canyon Railway maintenance shop. The use of ArcGIS will allow for topographic lines, major roadways or other valuable information to be added to the site map to provide the client with complete clarity on any site-specific questions. A site survey was not necessary for the completion of our project, and as such, was excluded.

2.1.2 Sampling Plan

To sample water sources on site, ASTM D 3370-10 will be used. This is the industry standard for sampling any closed conduit water source including industrial wastewater. This standard outlines sampling procedures, handling, and storage methods. Sampling for the Grand Canyon Railway project will be confined to two major sources of water. The first being the basis of this project, the boiler blowdown water. The second being the water used during the use of the steam engines, which is rainwater captured and contained in a reservoir at the Grand Canyon Railway maintenance shop.

2.1.2.1 Boiler Blowdown Water

Because a large portion of the railway's operation take place over the summer, this sample will be taken at the end of the summer to obtain a representative sample of the water that is typically produced prior to the end of operations in early winter. Practice A of ASTM D 3370-10 will be used to obtain a representative sample of the boiler blowdown water.

2.1.2.2 Rainwater Reservoir

Because rainwater is used daily to fill the boilers, it is possible that it is responsible for the conditions of the boiler blowdown water. For this reason, the water will be sampled and analyzed to determine various parameters of the water source. To conduct the sampling of this water, practice A of ASTM D 3370-10 will be used to obtain a representative sample of the captured rainwater.

2.2 Pretreatment Alternatives

Pretreatment involves the capturing of the locomotive effluent and reducing problematic contaminant concentrations to the required standards. This treatment will involve chemical, physical, or biological processes. The current target concentrations that need addressing are TDS and pH. The wastewater will be treated on-site and pumped to the local wastewater treatment plant for further purification.

2.2.1 Wastewater Testing

Testing the wastewater will reveal what type of dissolved solids are in the wastewater. The various types of testing will bring light to the methods that will be used in order to treat the wastewater. The following lists the contaminant testing and respective ASTM method number.

2.2.1.1 pH Measurement

Standard Method ASTM D 1293-58: pH of Industrial Water and Industrial Wastewater is the method that will be used to measure the pH of the water. The sample will be procured through Standard Method ASTM D510 (see section X), then taken to the Northern Arizona University Environmental Engineering Laboratory located in the Engineering Building. The test requires the following: flask, pH meter, magnetic stirrer, magnetic stir plate, electrodes, buffer solutions, thermometer, DI water, and absorbent issues [2]. The meter, flask, and thermometer will be rinsed off three times using deionized water to ensure there will be no residue that will affect the outcome of the test. The meter will then be calibrated using the two buffer solutions, in accordance with the solution being highly basic. The wastewater solution will be placed in the flask in addition to the stirrer, thermometer, and electrodes. Start the stirrer and discontinue intensity to the point where there is no splashing or loss of solution. Insert the pH meter and electrodes to determine the preliminary pH. Record the temperature and pH of the solution once two successive portions differ by no more than ± 0.03 pH show drifts of less than ± 0.02 pH unit in 1 min [3]. The testing of the wastewater will be repeated at different temperatures in order to determine of trend of pH as a function of temperature. This will help make inferences for how the treatment processes can be adjusted based on the temperature of the effluent.

2.2.1.2 Dissolved Solids Identification

2.2.2 Treatment Options

The methods used to treat the wastewater will be determined by the results of the testing mentioned above. The complete treatment process can include biological, chemical, physical, or a combination of these.

2.3 Design Wastewater Holding Tank

2.3.1 Holding Tank Design

2.3.1.1 Choose Premade Holding Tank

A premade holding tank will be chosen that meets the minimum design parameters required.

2.3.1.1.1 Ensure Safety

The team will make sure that the chosen tank must was designed with safety redundancy. The chosen tank material must be safe, durable, and cost-effective. The tank must be designed to be resistant to high pH levels. The current pH level of the wastewater is 11.2. Various prospective materials will be researched to ensure resistance. Various prospective materials will be researched to ensure resistance, including constraints noted by the tank producers. The tank must be designed to be resistant to high temperatures up to 350 F. The boiler wastewater leaves the boilers at 300 F allowing for minor temperature fluctuations in the wastewater. Various prospective materials will be researched to ensure resistance, including constraints noted by the tank producers.

2.3.1.1.2 Ensure Volume Requirements

The team will make sure that the chosen tank meets the minimum volume requirement of 8,000 gallons. If volume is not noted for a tank, it will be calculated from the dimensions. A foot of freeboard will be added to the required volume to ensure a safe design.

2.3.1.1.3 Cost

The tank options will be priced to determine installation costs. Various retailers will be researched to determine viable premade tank options that meet minimum design parameters. Retailer, contact information, cost, material, dimensions, delivery, and insurance will be tracked. This will allow the team to provide total installation and O&M costs to the client for prospective designs.

2.3.1.2 ArcGIS Site Map

A site map will be made in ArcGIS of the tank installation site. The map will display the site chosen by the Grand Canyon Railway for holding tank installation. The design will help estimate installation costs and guide subsequent site installation.

2.3.2 Transport to Grinder Pump

The wastewater holding tank and pretreatment method must be connected to the grinder pump for conveyance to the Williams WWTP. A pipe network must be designed to connect the holding tank to the grinder pump. This will ensure the objective of ultimate wastewater disposal at the Williams WWTP.

2.3.2.1 AutoCAD Design

The pipe network that connects the holding tank and pretreatment to the grinder pump inlet must be designed in AutoCAD. The design will help estimate installation costs and guide subsequent site installation.

2.3.2.2 Choose pipe

The pipe options will be priced to determine installation costs. Various retailers will be researched to determine viable pipe options that meet minimum design parameters. Retailer, contact information, cost, material, dimensions, delivery, and insurance will be tracked. This will allow the team to provide total installation and O&M costs to the client for prospective designs

2.4 Project Management

2.4.1 Group Meetings

Frequent group meetings are necessary to complete the project. Group meetings will be scheduled weekly to cover tasks, deliverables, and necessary project information. These meeting will be recorded using meeting minutes which will be shared with the grading instructor. Meeting minutes are an essential part of project management as weekly tasks for each team member will be listed. These tasks will be completed prior to the next meeting and outcomes will be discussed with the group.

2.4.2 Technical Advisor Meetings

Meeting with the team's technical advisor is a required part of the project. It is solely the responsibility of the team to schedule and run the meetings. The technical advisor will be notified 48 hours prior to scheduling a meeting. Along with the notification, a meeting agenda will be provided to the technical advisor outlining the meeting topics. Technical advisor meetings are meant to advise the team with technical information and to keep the team headed towards its goals. There will be a minimum of four meetings scheduled with the technical advisor.

2.4.3 Client Meetings

The project is being provided for the client, so it is important to understand what is desired of the final product. These meetings will need to be scheduled with the client 48 hours in advance along with the meeting agenda. The agenda will include the meeting topics to allow the client to be prepared. Client meetings will allow the team to better understand the project, and what is necessary to complete.

2.4.4 Transport Forms

To properly complete any field work required, the completion of an NAU travel form is required. This form outlines driver and university liabilities in the case of an accident while in transit to the client or field location. These forms are required for any type of travel. If use of official NAU vehicle is required, then a separate form must be filled out in addition to a driver defensive driver course being completed. This course and form allow NAU to accept liability for the capstone team in the case of an accident. Additionally, cost of travel can be reimbursed if a final travel reimbursement form is filled out and approved by NAU.

2.5 Deliverables

2.5.2 30% Report

During the completion of this project, a 30% report will be written to ensure the project team is on track to complete the project. This report will exclude a summary of the work completed up until that point and any major changes made to the project caused by preliminary results. This report will be submitted to the capstone grading advisors to update them on project progression.

2.5.1 60% Report

During the completion of this project, a 60% report will be written to ensure the project team is on track to complete the project. This report will exclude a summary of the work completed up until that point and any major changes made to the project caused by preliminary results. This report will be submitted to the capstone grading advisors to update them on project progression.

2.5.2 Final Report

This report will be completed at the completion of the project to summarize results and analysis. It will include methodology of the work completed, results from any analysis performed, and the conclusion of the project. This report will be submitted to the grading advisors, technical advisor and client to provide a full understanding of the work completed.

2.5.3 Website

A website for the project will be completed to advertise the project and its impact. This will be done to create an accessible platform for others to be updated on the project. The website will likely be used for future employment of the methods used to complete the project. This deliverable will be submitted to the grading advisor for review and sent to the client as a final resource.

2.5.4 Presentation

A final presentation will be given to provide information to the capstone class about the completion of this project and to discuss results from the project. This will be prepared and given in class and at the campus UGRADS event.

2.6 Impacts

2.6.1 Economic

To determine the economic impact of this project, the cost will be the main parameter evaluated. Since the project will only require the design of an above ground storage tank and a small-scale treatment technique, it is unlikely that the cost of the project will increase much throughout. However, the cost must be controlled to create a viable option for the Grand Canyon Railway. If the company chooses to implement an expensive option, this would likely have an impact of railway ticket prices, employee wages and tax revenue for the City of Williams. These impacts will be considered during the completion of a proposal for this project.

2.6.2 Environmental

The wastewater produced will be treated to Class B+ standards at the Williams wastewater treatment plant and used to water the local golf course, or released into Cataract creek, where it will eventually be treated to drinking water standards. This option reduces the environment impact of GCR by eliminating the waste of water from boiler blowdown. In addition, this prevents any unknown potential hazards from dumping the wastewater directly onto the topsoil. To evaluate this impact, the water will be evaluated prior to treatment and after the determined pretreatment method to ensure the removal of any potentially hazardous materials.

To further minimize environmental impact, a life cycle analysis will be conducted. This is to prevent the design of a system that will be obsolete after implementation and to prevent unnecessary waste of materials. The life cycle analysis will include an analysis of the lifespan of specific materials when exposed to high pH and the long-term availability of treatment techniques proposed. Additionally, maintenance and operation of the storage tank and treatment option will be evaluated to determine the sustainability of each.
Since the GCR does not want to be considered a pretreatment facility, the treatment technique chosen will need to have minor labor requirements. The use of a simply treatment technique will reduce the possibility of improper treatment, which would extend the lifespan of the storage tank. For this reason, the treatment technique determined will impact the life cycle of the design, which in turn would impact the environmental impact of the project.

The maintenance of the storage tank should be regularly performed by the GCR staff to ensure the maximum lifespan of the tank. This process should be simple to prevent the possibility of improper maintenance and prevent sediment buildup in the tank. The maintenance of this project not only impacts the lifespan of the project but will likely also impact the cost of the project.

2.7 Project Limitations

2.7.1 Challenges

There are foreseen challenges within the project that must be dealt with. As these challenges are foreseen, resolutions must be made to ensure the project continues smoothly. These resolutions will avoid setbacks and allow the project to continue on schedule. Unforeseen challenges may occur as well and must be handled in a timely yet professional matter.

2.7.1.1 Sampling

A major challenge that the team is facing is getting samples from GCR. The Grand Canyon Railway washes out the steam engines after the fall and winter season. This does not allow for samples to be taken and analyzed when the wastewater is at maximum use. A way to solve this challenge is to gain a sample of the steam engines water after the summer season. This wastewater will not be at maximum contamination, but it will allow for a greater understanding of the waters contaminants.

2.7.1.2 Testing

Another challenge the team may face is testing equipment. The resources available to the team may not be suitable to correctly test samples according to the ASTM method. To overcome this challenge, testing may need to be outsourced to an outside testing analyst. When outsourcing testing, it will be mandatory to set this up will the analyst well in advance. The team will need to allow the analyst time to complete the testing for the best results. The team will also need to request exactly what the results must include according to the needs of the project.

2.7.2 Exclusions

This project will exclude an analysis of the fully concentrated wastewater. This analysis will be excluded as the time of the boiler washout will occur outside of the desired project timeline. The project will also exclude a site survey, as it is unnecessary for the project completion. The analysis will focus on pH and TDS to solve the issues preventing discharge in the wastewater treatment plant. Additionally, foundation work will not be completed for the tank placement because this is outside the scope of the work and will be completed by contractors prior to construction.

3.0 Schedule

Table 3: Full project schedule.

Task No.	Task	Start Date	End Date	Duration (days)
1.0	Field Work	9/10/2018	9/16/2018	6
1.1	Site Map	9/10/2018	9/14/2018	4
1.2	Transport Forms	9/10/2018	9/14/2018	4
1.3	Sampling Plan	9/15/2018	9/16/2018	1
1.3.1	Boiler Blowdown Water	9/15/2018	9/16/2018	1
1.3.2	Rainwater Reservoir	9/15/2018	9/16/2018	1
2.0	Pretreatment	9/17/2018	10/14/2018	27
2.1	Testing the Wastewater	9/17/2018	9/30/2018	13
2.1.1	pH Measurement	9/17/2018	9/23/2018	6
2.1.2	Dissolved Solids Identification	9/24/2018	9/30/2018	6
2.2	Treatment Options	9/30/2018	10/14/2018	14
3.0	Design Wastewater Holding Tank	10/15/2018	11/11/2018	27
3.1	Holding Tank Design	10/15/2018	10/29/2018	14
3.1.1	Choose Premade Holding Tank	10/15/2018	10/21/2018	6
3.1.3	ArcGIS Site Map	10/22/2018	10/29/2018	7
3.2	Transport to Grinder Pump	10/30/2018	11/11/2018	12
3.2.1	AutoCAD Design	10/30/2018	11/4/2018	5
3.2.2	Choose Pipe	11/5/2018	11/11/2018	6
4.0	Project Management	9/10/2018	11/26/2018	77
4.1	Group Meetings	9/10/2018	11/25/2018	76
4.2	Technical Advisory Meetings	9/17/2018	11/23/2018	67
4.3	Client Meetings	10/1/2018	11/26/2018	56
5.0	Deliverables	11/12/2018	11/26/2018	14

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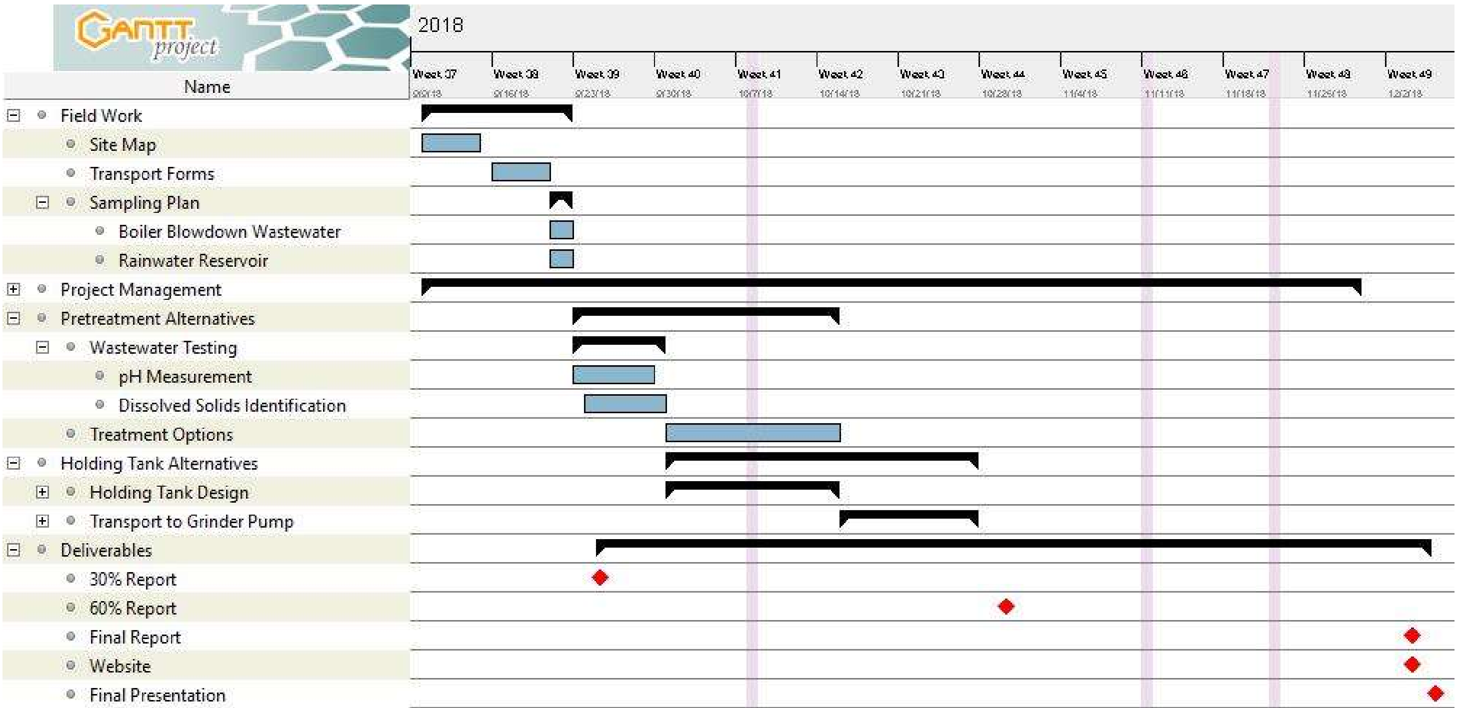

Figure 1: Project Gantt chart.

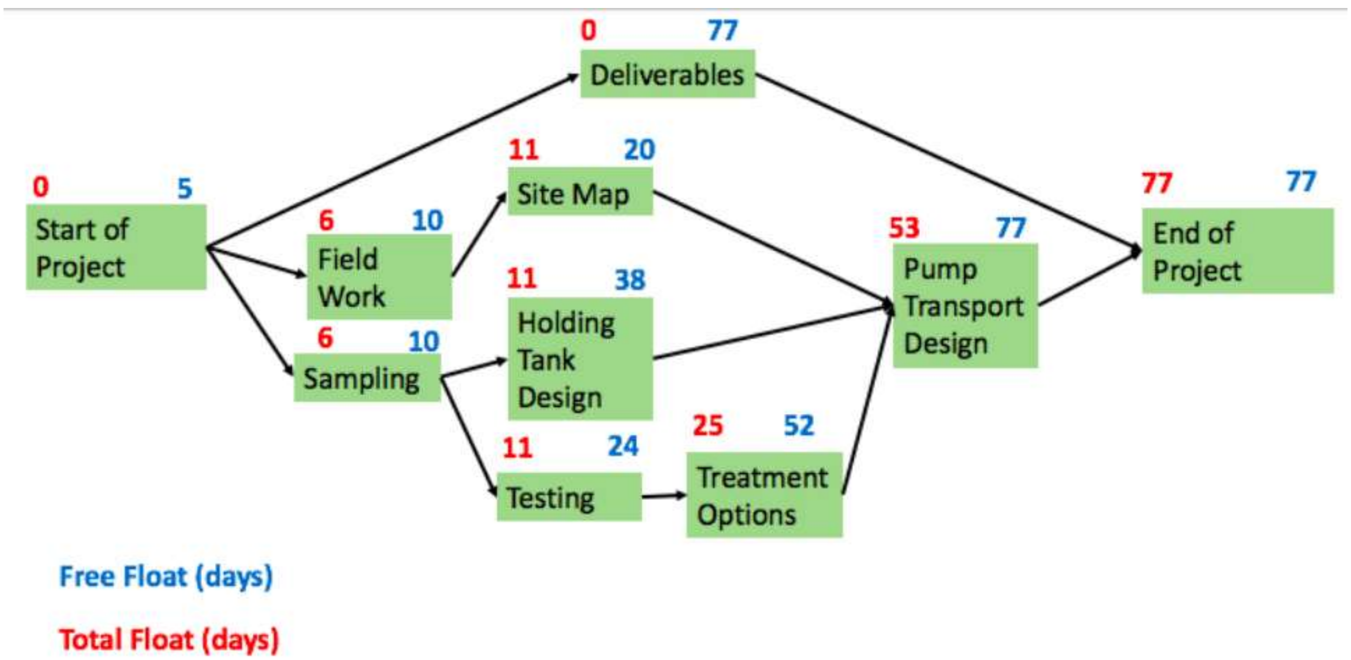

Figure 2: Project critical path.

4.0 Staffing

4.1 Staff Positions

The staff positions on this project include: Senior Engineer (SE), Junior Engineer (JE), Intern (IN), and Administrator (AD). Each team member will fulfill all positions throughout the project; no particular position will be assigned to any one person.

4.2 Qualifications

4.2.1 Stephen Kitt

Stephen is a senior environmental engineering student at Northern Arizona University, expected to graduate in Fall of 2018. He is currently the secretary for the National Society for Black Engineers NAU chapter and an American Society for Civil Engineers member. Stephen is currently working as a student manager for NAU's Student Service Center where he is furthering his leadership skills.

4.2.2 Cydney Matthews

Cydney is a senior environmental engineering student at Northern Arizona University, expected to graduate in Fall 2018. She is currently employed by NAU as a teaching assistant for CENE 280, an introductory course to mass transport and environmental fate. She will be beginning an internship position with Western Technologies this summer as a materials testing technician and assisting with water and wastewater testing. Cydney has extensive knowledge in fluid dynamics and water quality. This curriculum has allowed her to be proficient in the latest software of AutoCAD, MODFlow, Matlab, WaterGEMS, Microsoft Office, HEC-RAS, and Simulink.

4.2.3 Joshua Roubik

Joshua is a senior environmental engineering student at Northern Arizona University, expected to graduate in Fall of 2018. Currently employed part-time as a team leader for a non-profit in Flagstaff, Arizona. In this position it was required of him to lead a team of 10 and fundraise a yearly salary. Has extensive experience leading teams working towards a common goal.

4.2.4 Mellisa Yin

Mellisa is a senior environmental engineering student at Northern Arizona University with an expected graduation of Fall 2018. Her current GPA is 3.88 out of 4.0. She is currently a Water Resources Technician at the City of Flagstaff Water Services Division and is completing undergraduate research on arsenic phytoremediation of BLM mine sites. In the summer of 2018, she is completing research at the University of New Mexico on salt sequestration with halophytes for riparian remediation. Mellisa has acquired knowledge in air and water quality, pollution control and management, solid and hazardous waste management, environmental regulations, toxicology and risk assessment, and microbiological processes. This includes skills in AutoCAD, ArcGIS, and the Microsoft Office suite of programs. She has also developed leadership skills as the president of the NAU chapter of the Society of Women Engineers, as a TA, and as a Peak Performance math tutor. Mellisa also has more than 16 years of non-engineering related work, including supervisory skills.

4.3 Task/Subtask Matrix

Task	Staff				Task Total Hours
	SE	JE	IN	AD	
1.0 Field Work	**30**	**18**	**37**	**20**	**105**
1.1 Site Map	10	10	20	15	19
1.2 Transport Forms	5	5	5	5	20
1.3 Sampling Plan	15	3	12	0	30
1.3.1 Boiler Blowdown Water	8	1	6	0	14
1.3.2 Rainwater Reservoir	7	2	6	0	14
2.0 Pretreatment Alternatives	**39**	**37**	**45**	**40**	**161**
2.1 Testing the Wastewater	14	17	15	20	66
2.1.1 pH Measurement	7	7	5	10	29
2.1.2 Dissolved Solids Identification	7	10	10	10	37
2.2 Treatment Options	25	20	30	20	95
3.0 Design Wastewater Holding Tank	**35**	**65**	**32**	**22**	**154**
3.1 Holding Tank Design	15	25	17	10	67
3.1.1 Choose Premade Holding Tank	5	15	10	5	24
3.1.2 ArcGIS Site Map	10	10	7	5	18
3.2 Transport to Grinder Pump	20	40	15	10	85
3.2.1 AutoCAD Design	10	16	5	4	20
3.2.2 Choose Pipe	10	24	10	6	29
4.0 Project Management	**28**	**28**	**28**	**28**	**112**
4.1 Group Meetings	16	16	16	16	64
4.2 Technical Advisory Meetings	8	8	8	8	32
4.3 Client Meetings	4	4	4	4	16
5.0 Deliverables	**50**	**65**	**70**	**30**	**215**
Total Hours					**747**

4.2 Summary Table

Staff Position	Total Hours	Justification of Hours
Senior Engineer	182	The Senior Engineer has reduced hours as they are mainly approving work and are much more expensive than the other engineering positions.
Junior Engineer	213	Most of the work is done by the Junior Engineer.

Intern	212	The Intern will do most of the menial work and is the least expensive staff position.
Administrator	140	The Administrator will have minimal work, but it will occur throughout the project.

5.0 Cost of Engineering Resources

The cost of engineering resources includes overhead, subcontracting, travel, and staffing costs. Each cost is necessary and will cover the completion of the project. The overhead head cost gives the billing rate of the staff. The billing rate was created from the base pay, multipliers, and profit.

Table 4: Overhead Costs

Overhead Costs							
Personnel	Base Pay ($/hr)	Benefits % of Pay	Actual Pay ($/hr)	OH % of Base Pay	Actual Pay+OH ($/hr)	Profit, % of Actual Pay+OH	Billing Rate ($/hr)
Senior Engineer	80	25	100	60	160	10	176
Junior Engineer	35	40	49	20	59	10	65
Intern	15	20	18	5	19	10	21
Administrator	20	20	24	25	30	10	33

Subtracting costs will occur from the wastewater analysis. Because the tools are not available to the team to conduct a wastewater analysis, the testing will be subcontracted to the NAU analytical lab. There will be three samples tested at three separate times. A multiplier was place on these costs as the team is reliable from that data.

Table 5: Subcontracting Costs

Subcontracting Costs						
	Samples	Units (test type)	Cost ($/sample)	Multiplier (%)	Cost ($)	Billing Cost ($)
Wastewater Testing	3	1	100	15	300	345

The travel costs cover the travel is will take to meet with the client. The team will need to drive 34 miles to meet with GCR. To be reimbursed for this travel, the team will be bill the client at a rate of $0.25 per mile.

Table 6: Travel Costs

Travel Costs						
	Trips	Distance (miles)	Cost ($/mile)	Multiplier (%)	Cost ($)	Billing Cost ($)
Travel to Williams	4	68	0.25	15	68	78.2

The general contracting costs include all the costs the team will need to complete the project. The total cost includes overhead, subcontracting, travel, and staffing. The staffing cost uses the billing rate from the overhead costs with a multiplier associated with each staff member. The more essential the staff member is to the project, the higher multiplier they will have. The total cost the team will need to complete GCR's project is $94,735.83.

Table 7: Total Contracting Costs

General Contracting Costs					
Personnel	Base Pay ($/hr)	Billing Rate ($/hr)	Hours (hr)	Multiplier	Cost ($)
Senior Engineer	80	176	182	3.2	$ 102,502.40
Junior Engineer	35	65	213	2.5	$ 34,612.50
Intern	15	21	212	1.5	$ 6,678.00
Administrator	20	33	140	3	$ 13,860.00
				Total Cost =	$ 157,652.90

6.0 References

[1] C. of Williams, “Chapter 8-3 Article 08-3.” pp. 13–15, 1963.

[2] "Water Quality Division: Permits: Pretreatment Program," 2018. [Online]. Available: http://legacy.azdeq.gov/environ/water/permits/pretreat.html. [Accessed 9 February 2018].

[3] "Arizona Pollutant Discharge Elimination System," Arizona Department of Environmental Quality, Phoenix, 2016.