ALTERNATIVE LANDFILL LINER
PROPOSAL

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SECTION 1: BACKGROUND RESEARCH

1.0 INTRODUCTION

Landfill liners that are currently in use are very expensive, and are not utilizing enough recycled materials. Materials are entering landfills that could potentially be used for landfill expansion as well as for future liners. The following sections will describe the proposed materials to be used for the construction of a new landfill liner. Fly Ash will be used along with polymers, paper pulp sludge, and other materials to create a landfill liner and/or cap that will be help reduce the amount of materials being disposed of in landfills as well as reduce the cost of buying new landfill liners.

2.0 FLY ASH

What is fly ash? Fly ash, also known as pulverized fuel ash, is a residual that is generated through coal combustion. During the coal combustion process, temperatures can reach an excess of 2800 degrees Fahrenheit. Ash is the only material left over after the coal combustion. Two different types of ash are produced; bottom ash and fly ash. Fly ash is carried by flue gases and collected and stored in large silos for later use. Fly ash is typically used in concrete alongside Portland cement. Using fly ash together with Portland cement is beneficial because it is readily available because coal is typically used as an energy source. Because of how fly ash reacts with the cement, concrete made with fly ash is stronger and more durable than concrete made exclusively from Portland concrete [1].

One of the main concerns about using fly ash is “Is it safe?” Fly ash’s structure is similar to volcanic ash, meaning that it is made of natural materials that can be readily found in nature. In December of 2014, the EPA made a final ruling stating that fly ash will not be classified as a “hazardous waste” [2]. Fly ash is no more dangerous than general soil found in the United States [1]. A significant amount of fly ash is made up of silicon dioxide, aluminum oxide, and calcium oxide [2]. Fly ash has many environmental benefits as well. Fly ash, when used in concrete, can increase the concrete’s durability which leads to increasing the concrete’s life expectancy. Using fly ash in concrete can also reduce the greenhouse gasses as well as energy consumption because the materials being replaced by the fly ash will not have to be made [2]. Using fly ash in different applications will also reduce the amount of coal by-products entering landfills [2].

In 2014, the EPA held a hearing to determine whether fly ash would become a “hazardous waste” or not. The EPA presented two alternatives; the first being to name it a hazardous material under The Federal Regulatory Standard Subtitle C or allow it to be a regulated as a non-hazardous waste material under Subtitle D. Subtitle C would allow the EPA to permit and enforce activities related to the disposal of fly ash [3]. Under this subtitle, the EPA would, over seven years, have to phase out existing impoundments of the fly ash [3]. Subtitle D states that it will be managed as a solid waste, not a hazardous waste [3]. Subtitle D’s requirements are implemented by the owners/operators of the disposal facilities [4]. The owners/operators do not need to obtain permits for the disposal of the fly ash but must comply with the requirements in the Federal rule [4]. Subtitle D states that any existing impoundments would be required to be retrofitted with liners 5 years after promulgation of the final rule. The EPA chose to classify it as a non-hazardous waste material, meaning that fly ash falls under Subtitle D of RCRA.

3.0 PAPER PULP SLUDGE

What is paper pulp sludge? Generally, sludge is a term used to describe the solid residue recovered from the wastewater stream of the pulping and papermaking process. Paper pulp sludge is waste generated from the process of recycling paper products, and it has a gray color. Most of sludge that is generated by pulp and paper mills can be removed by a primary mechanical treatment which leaves sludge that contains a high quantity of fibers, papermaking fillers, or both. It has been determined that an average of 35% of materials entering the pulp and paper mills become a rejected residue. This waste includes several materials such as wastewater sludge, mill trash, such as shipping materials, demolition debris, and ash from boilers [7].

Paper mills in the United States currently produce approximately 40,000 tons of Paper Pulp Sludge (PPS) yearly in the southeast. In Arizona, Cinder Lake Landfill is the only municipal landfill that serves the city of Flagstaff. As a result, the landfill decided to use the paper pulp sludge in creating a landfill liner for the landfill, to minimize the amount of waste that is entering the waste stream [8].

The landfill liner that will be created in this project will be made out of 5 components, where PPS will be one of the mixture components. Research has been conducted on PPS that shows that PPS must be at a high water content to be usable. The optimum moisture content for PPS varies depending on the properties of the sludge. Generally, the sludge must have a moisture content that is between 50% and 100% of the optimum moisture content to obtain a minimum hydraulic conductivity. Research indicates that the hydraulic conductivity of PPS varies from 1×10^{-4} cm/s to 1×10^{-7} cm/s, where the required hydraulic conductivity of the landfill liner is 1×10^{-7} cm/s. Another research conducted by the National Council of Examiners for Engineering and Science, indicated that virgin PPS is not optimal for use as landfill liner/cap. They suggested to mix PPS with coal fly ash, wood ash, and lime to construct a landfill liner. The percentage of the mixture that has been found to have a hydraulic conductivity close the EPA regulations is 43.5% coal ash, 43.5% PPS, and 13% wood ash. It has been determined that using PPS in creating an alternate landfill liner would save the landfill $8.3 million per 10 acres than existing landfill design. Moreover, 68,000 tons of PPS will be removed from the landfill, which will extend the lifespan of the landfill [8].

4.0 POLYMERS

Polymers is large molecule, or macromolecule, composed of many repeated subunits. When dissolve polymers in a solvent, it's found that they make the solution viscous. It is because polymers move much more slowly than do small molecules. It makes sense that the faster molecules in a liquid move, the more easily the liquid will flow. When dissolve a polymer in a solvent, the polymer molecules not only block the motion of the small molecules, but also slow down through intermolecular forces. Because of this property, polymers can be used in landfill liner. [9] For this project, there are three different kinds of polymers for using, Base-Seal (BS-100), Enviroseal 2001^{tm}, and $M10 + 50^{TM}$.

BS-100 is a liquid soil stabilizer that bonds and strengthens the subsurface of the road. It's non-corrosive, non-toxic, non-flammable, and non-allergenic. [15] When using fly ash, lime or soil cement, it is possible to use lesser amounts by adding BS-100 which results in substantial savings and added strength. BS-100 is also an excellent additive for cold in-place reclamation of old asphalt and seal coat roads as it interacts as a powerful binder hat keeps all the particles tightly cemented together. [16] Since 1986, it has been successfully used world-wild for new road bases, full depth reclamation, runways, taxiways, tarmacs, mining roads, and landfills to increase structural integrity and flexibility in base course construction, including applications requiring ASTM, ASHTO&DOT standards. Based on the SMDS and contents, BS-100 has been certified for use by the Federal Bureau of Solid & Hazardous Waste Management, Department of Health & Environmental Control, and Environmental Protection Agency.

Enviroseal 2001^{tm} is a stabilizer stabilizing non-clay or silt mica to 100% proctor. Is was designed for in-situ stabilization and sealing for non-clay bearing soils. [14] When mix the Enviroseal 2001^{tm} with others, it will results in substantial savings. For example, in 1999, Enviroseal 2001^{tm} donated 2 drums of their 2001 stabilizer to help with the reconstruction of their country. This particular region had a mixture of 100% mica silt, volcanic sand and crushed volcanic rock, then mixed them together with the Enviroseal 2001^{tm}. By using this method, a 60% saving in total aggregate and resulted in a $5,000 cost saving per kilometer. [13] In addition, mixture will can be applied to a higher unconfined compressive strength by adding Enviroseal 2001^{tm}. According to the exanimation, the silty sand can be applied to the highest unconfined compressive strength with 2.5% dry weight Enviroseal 2001^{tm} among different concentration from 0% to 4%. [17]

$M10 + 50^{TM}$ is a 100% acrylic liquid polymer soil modifier. It was designed to improve the performance of soils. By incorporation this polymer modifier can attain the dramatic improvements in adhesion, abrasion resistance, flexural strength, and exterior durability that are associated with acrylics. The key performance advantages of $M10 + 50^{TM}$ are its improved wet adhesion mechanical strengths, and superior weather ability. [10] These performance advantages make $M10 + 50^{TM}$ an ideal polymer to use in exterior applications that is suitable for this project. Because of its superior weather ability, it has a good exterior durability and outstanding resistance to UV degradation. This property is much better than other stabilizers. For wet adhesion, the mixture mixed with $M10 + 50^{TM}$ show excellent adhesion, as well as thin section toughness. Superior adhesion is observed on a variety of substrates including concrete, wood, metal, gypsum sheathing, cement board, masonry and polystyrene insulation board. [11] For mechanical strengths, according to the examinations, mixture with $M10 + 50^{TM}$ can be applied to a higher strength. In addition, it will obtain a higher impermeability and hydraulic conductivity. [12] [13]

SECTION 2: PROJECT UNDERSTANDING

1.0 PROJECT PURPOSE

The purpose of the landfill liner project is to create a liner for Cinder Lake landfill, made out of materials that are entering the landfill. The landfill liner will be designed using cost-effective materials and techniques. Fly ash, paper pulp sludge, and polymers are the main materials that will be used in the construction of the landfill liner. Materials must withstand shear and hydraulic forces applied on them by the landfill. The team will test samples that include fly ash, paper pulp sludge, polymers, soil, and lime to develop a landfill liner that meets and exceeds the given constraints and criteria. The new liner would be beneficial because it is cheaper than existing liners. This would allow for the landfill to reallocate their cash flow and make improvements to the landfill as a whole. The new liner would be using materials currently entering the landfill, which would reduce the amount of materials present in the landfill over time. This would help extend the life of the landfill.

2.0 PROJECT BACKGROUND

Landfill liners have never before been constructed out of primarily PPS, fly ash, and polymers. Because of the unique nature of the liner, extensive research is required. Each member of the team will be tasked with conducting research to obtain a better understanding of the project as a whole. The team will utilize resources available to them including engineering journals on geotechnical lab results. The team will also review previous landfill liner capstone teams to determine what has already been completed and what work still needs to be completed. Research will be conducted to improve the efficiency of the liner as well as reduce the amount of problems in the future.

The landfill is located approximately 8 miles Northeast of Flagstaff on highway 89 and Landfill Road in Coconino County, Arizona. Figure 1 shows the overhead view of the landfill's location [12].

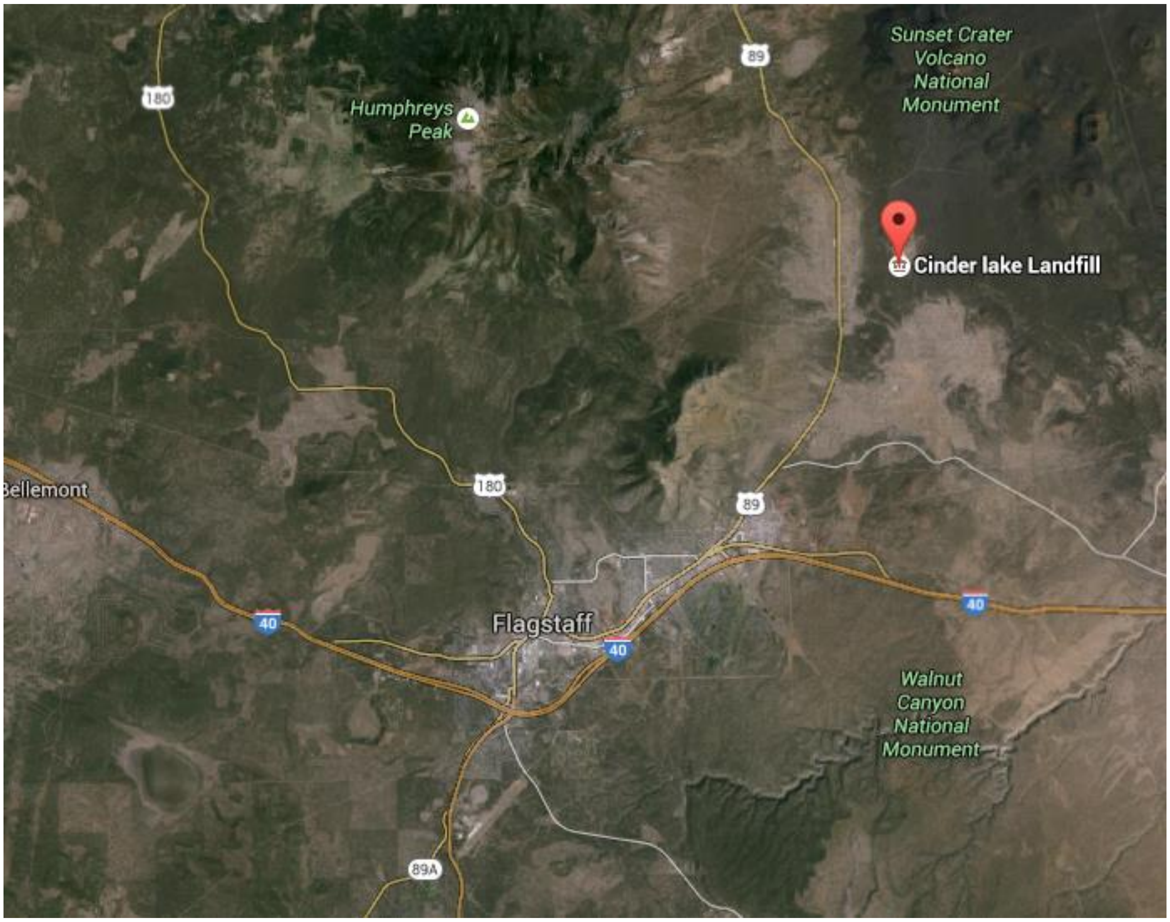

Figure 1: Cinder Lake Landfill Site Location [12].

Cinder Lake landfill accepts household, commercial, and institutional waste. Furthermore, the landfill accepts paper sludge from a local paper recycling plant. The sludge is mixed with wood mulch and used as an alternative daily cover. The landfill receives approximately 122,000 mega grams per day, which is equivalent to approximately 279 tons per day. In the landfill, solid wastes are disposed in layers no thicker than 2 feet. Compacted solid waste are covered with 6-8 inches of alternate daily cover. The landfill is serving approximately 17,000 residential and commercial entities in the City of Flagstaff. The total area of the landfill is 330 acres. Figure 2 shows an overview of the landfill [13]. This landfill is ideal for such a project because it is located far above the water table.

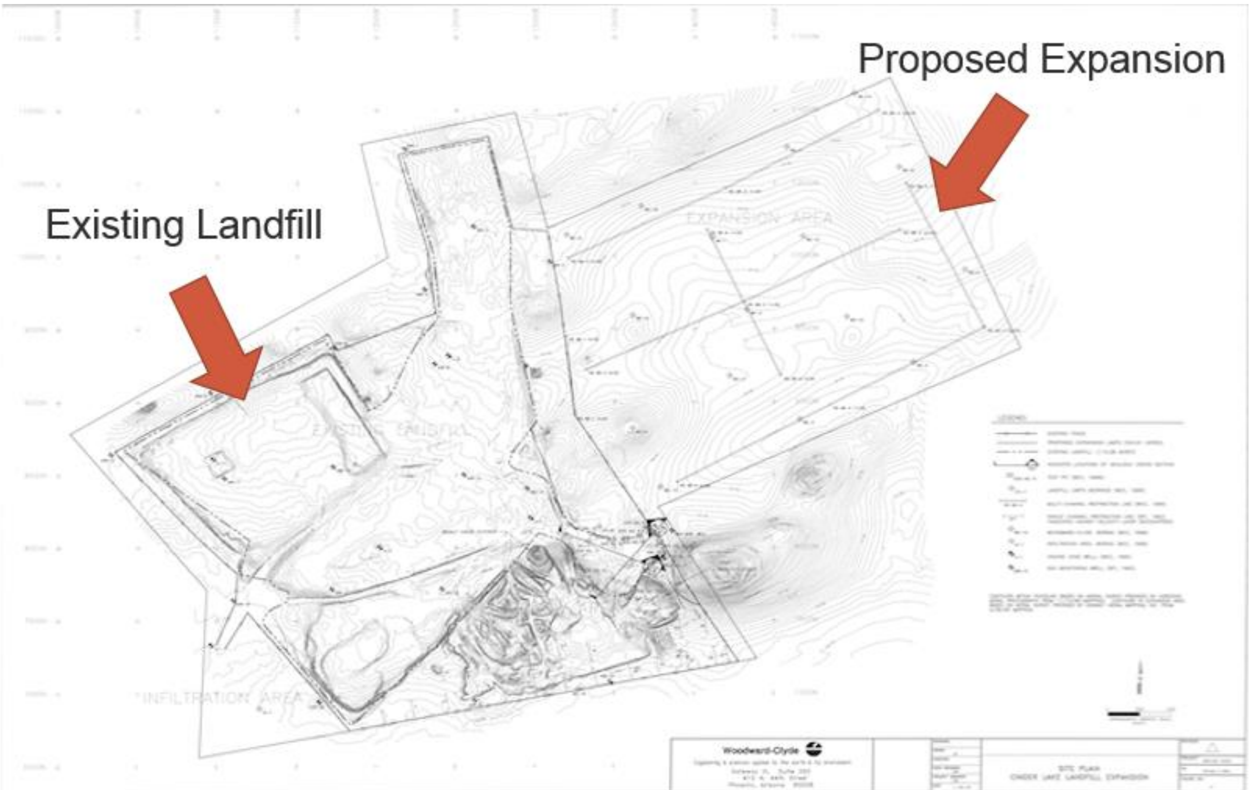

Figure 2: Cinder Lake Landfill Site [13].

3.0 TECHNICAL CONSIDERATIONS

There are many technical considerations for this project. The landfill liner that is going to be designed from paper pulp sludge, polymers, and fly ash needs to support hydraulic, permeability, and shear loading. To achieve the previous results, several lab tests should be conducted to ensure that the designed landfill liner does not fail due to the waste movement. Furthermore, cost of materials should be considered to ensure that the team is generating a cost-effective product.

4.0 POTENTIAL CHALLENGES

For this project, the team will be tasked with determining that ideal mixture of the given materials. As a result, most of the challenges that the team will face will be occur during lab testing.

One potential challenge the team may face in the future is a shortage of materials. Because the team will be conducting many lab tests, the team may run out of the required materials. To avoid this problem, the team will need to alert the material provider when supplies start to run out.

The team will encounter many different material combinations throughout the entirety of the project. The material combinations are determined by the client, and are subject to change as they see fit. Because of this, it is important that the team keep in constant contact with the client as well as keep a very clear record of the tests that have already been completed.

Quality insurance and quality control are one of the team's primary concerns when conducting lab tests. Any errors that occur during testing will result in inaccurate data, meaning that the test would have to be redone. To ensure that there are no errors in the data, the team will work through each lab very carefully and methodically.

5.0 STAKEHOLDERS

The Cinder Lake Landfill's primary stakeholder is the City of Flagstaff. Anyone who contributes to landfills will be affected by the new type of liner. They may not be directly affected, but the new liner will save money which can be re-allocated elsewhere to improve the trash collection/consolidation process or to reduce daily landfill costs.

SECTION 3: SCOPE OF SERVICES

1.0 INTRODUCTION

This section of the proposal will illustrate what the team intends to do throughout the entire project. It will specifically state what is expected to be complete by the end of the project. It will also include a list of services not included in the project. These items cannot be completed due to other factors such as time constraint.

TASK 1.0: HEALTH AND SAFETY PROTOCOLS

The safety of team members during the duration of the project is extremely important and will be a main focus point throughout the project. Typical lab safety measures will be implemented to ensure the team's safety. No food or water will be allowed in the lab at any time. This will help reduce the amount of sample contamination while conducting labs. The team is has not worked with the materials before and are unaware of any additional safety measures that need to be implemented.

1.1 SAFETY PROTOCOL FOR FLY ASH

A recent ruling made by the EPA states that fly ash is not a hazardous material, meaning that it is not toxic or poisonous. As a result, the team does not require any additional safety protocols when hand the ash. Fly ash is a very fine material and will cause large amounts of dust to rise while handling it. As a result, the team decided to require that masks be worn at all times while handling the ash.

1.2 SAFETY PROTOCOL FOR PPS

The team is aware that PPS is a by-product of recycling paper and paper products. Because of this, PPS is considered to be a waste product. The team concluded that nitrile gloves will be required when working with this material. The masks used for fly ash will also be required. The implementation of the gloves and masks should keep the team members safe throughout lab testing.

1.3 SAFETY PROTOCOL FOR POLYMERS

The team will be handling three types of polymers while conducting lab work. Each polymer will be delivered to the lab accompanied by a handbook illustrating how to safely handle the polymer. All instructions listed in the handbook will be followed when conducting tests. The team will determine if any additional safety protocols need to be implemented as lab work progresses.

1.4 PERSONAL SAFETY

Personal safety is a major concern when conducting lab work. The lab contains a number of dangerous machines and objects. Self-awareness is the best way to ensure that one does not get injured or worse. Close toed shoes must be worn before entering the lab and loose fitting clothes are not recommended. Standard safety procedures will be followed to further ensure each team member's safety.

Deliverable: Lab Safety Certification for all members, safety summary flow sheet, safety, health, and awareness contract

TASK 2.0: MATERIAL PREPARATION

There are four testing materials used for the project, PPS, coal fly ash, polymers, and XX soil. All materials are delivered to the group through the NAU facility and at the group's disposal to work with as needed. Once obtained, the group must prepare the materials for testing.

2.1 PPS PREPARATION

The PPS is delivered in a wet form with the consistency of mud. It is placed in drying ovens to be air dried for roughly 16 hours to make sure it is dry before conducting any testing. For compaction tests, the PPS is required to be finer than #4 sieve. The qualified material will be ready for testing after mixing it fly ash.

2.2 FLY ASH PREPARATION

The fly ash has been delivered to the lab and does not require further preparation except mixing with the PPS.

2.3 POLYMERS PREPARATION

The team will test the mixture of PPS and fly ash with 3 different polymers. These polymers have been delivered to the lab and do not require further preparation aside from measuring the correct amount needed for testing.

2.4 LANDFILL SOIL

The soil used for lab testing will be taken directly from the Cinder Lakes Landfill. The soil classification is still unknown.

2.5 LIME

Lime will be added to the sample, although the amount of lime to be used during testing varies depending on what the client wants to achieve.

Deliverable: Log of Lab Hours

TASK 3.0: MATERIALS TESTING

Material testing is an essential part of the project. The team will conduct two geotechnical tests; compaction tests and permeability tests. This task includes gathering materials for testing apparatuses.

3.1 COMPACTION TEST

The compaction tests will be conducted to determine the mixture's optimum moisture content. The team will complete 45 compaction tests on a variety of different mixtures. The mixtures will consist of the same materials but will be run at different percentages. Along with the optimum moisture content, the compaction test will show how the properties of the mixture act when subjected to a load.

3.2 PERMEABILITY TEST

Permeability tests will be conducted to determine how well a substance flows through another substance. Once the optimum moisture content is obtained from the compaction tests, the team will conduct permeability tests. These tests will help determine to what extent the proposed liner will allow leachate to infiltrate the subsurface.

Deliverable: Data Collection

TASK 4.0: DATA ANALYSIS

All raw data collected will be recorded in Excel documents during lab testing. The team will convert the raw data into useful charts to obtain desired results. The data and the results produced will then be shown in tables and graphs in the report. The data generated will be used to help determine the optimum mixture as well as the final liner recommendation.

Deliverable: Data spreadsheets

TASK 5.0: PROJECT MANAGEMENT

This role will be assigned to the team leader. The team leader will be responsible for scheduling team meetings, site visits, and lab times. The leader will also be responsible for ensuring every deadline is met as well communication with the client. Wilbert Odem, Matthew Morales, Gerjen Slim, and Hugo Montealegre are all contacts that will be utilized throughout the entirety of the project.

Deliverable: Schedule (attached), meeting hour logs, email correspondence

TASK 5.1: TEAM MEETINGS

The team will meet every week to discuss the project's progression as well as discuss the raw data obtained from testing. The team will also communicate in such a way to ensure everyone is on the same page.

TASK 5.2: TA MEETINGS

Throughout the entire project, the team will meet with Gerjen Slim, the team's technical advisor. Before each meeting, the team will create a memo that outlines the objectives for the meeting as well as summaries the previous meeting.

TASK 5.3: WEBSITE

The team plans to meet with a web design student to work out any bugs before the launch of the website. The website will be designed to direct users to useful information on the project as well as make their visit enjoyable.

TASK 5.4: 50% REPORT

Halfway through the project, the team will create a 50% report that shows the progress made. This report will consist of all data completed to that point, including lab data.

TASK 5.5: FINAL REPORT

After the completion of all lab testing and data analysis, the team will produce a final report that includes all relevant Excel spreadsheets generated from lab testing. The report will also discuss what all the data means and how it is applicable. The report will make a final recommendation for the alternate liner.

Deliverable: Schedule (attached), Meeting hour logs, Website, PowerPoint, Poster, Reports, Email correspondence

2.0 EXCLUSIONS

The team has identified a few tasks that they will not be conducting. The team reserves the right to add to this list as the project progresses. They will not be implementing the final landfill liner design at the landfill. The team also recognizes that not all lab tests will be conducted by them. More lab tests may be requested at a later date during the project.

3.0 SCHEDULE

The Gantt chart shows all the deliverables for the project as well as their due dates. The team is expected to plan accordingly to ensure all lab testing is complete in order to report to the client. Many deliverables rely on the completion of lab testing, so the team must complete testing in a timely manner to ensure results for the deliverables. All important dates for this project can be viewed in Figure 3.

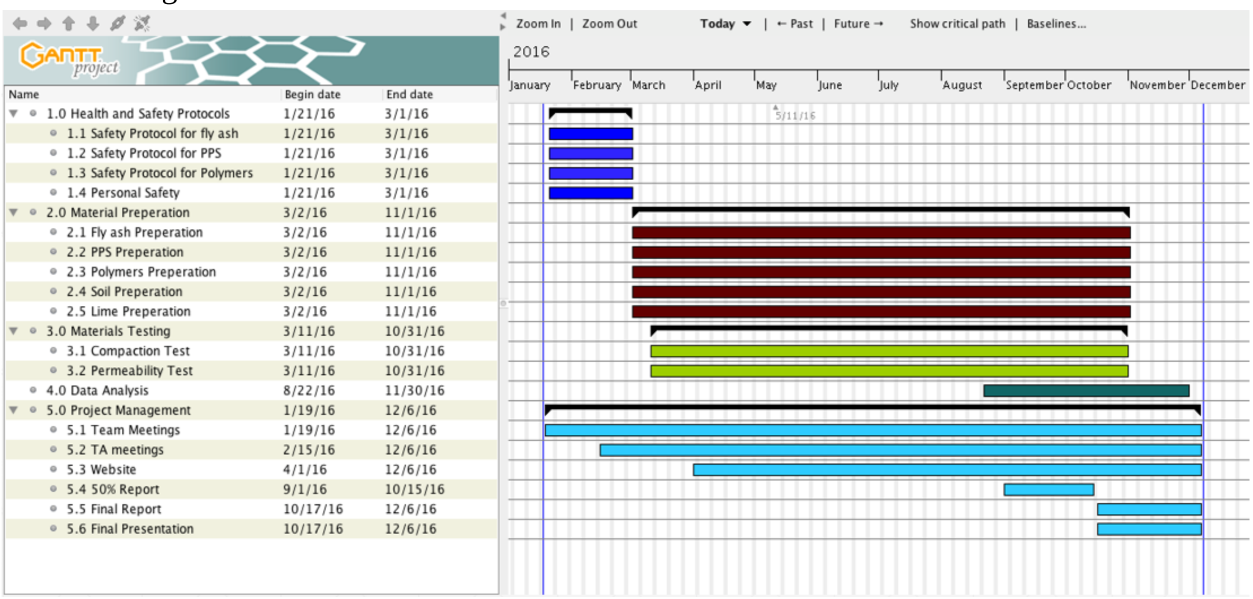

Figure 3: Gantt chart of the Landfill Liner Project

SECTION 4.0: COST OF ENGINEERING SERVICES

1.0 INTRODUCTION

This section will show the required staff needed for the project as well as how much the project will cost to complete. This project requires a team made up of 4 staff members. Section 2.0 will provide a list of qualifications for each team member.

2.0 PERSONAL QUALIFICATIONS

SK Geotechnical Company has formed a team of 4 members to create an alternative landfill liner. Each team member has different experiences in the engineering field prior to the work. The following is a list of qualifications for each of the team members.

2.1 ALI ALRASHED (LAB TECHNICIAN)

- Environmental engineering undergraduate student, senior level, at Northern Arizona University.
- Adept in data analysis and software applications including: Microsoft word and Microsoft excel.
- Effective Communicator with team members.
- Effective problem solver and has good skills for solving complex problems.
- Bilingual, Arabic and English, speak fluently as well as write and translate in both languages.
- Proven leadership abilities.
- Experienced in establishing priorities, time organization, and complying with deadlines.
- Has had two internships in summer 2013 and 2014 at Equate Petrochemical Company.
- Worked at Q8cars Rental Company, department of financial.

2.2 JOE ATKINSON (DEVELOPMENT ENGINEER)

- Northern Arizona University Civil Engineering undergraduate, senior level.
- Minor in Mechanical Engineering.
- Completed coursework related to engineering.
- Completed Geotechnical Engineering I and II.
- Completed Geotechnical Lab.
- Completed Water Resources I and II.
- Completed Municipal Engineering.
- Have a good experience AutoCAD.

2.3 NAYF ALOTAIBI (ENGINEERING INTERN)

- High diploma in civil engineer (Construction Building), graduate in 2012 at the public authority for applied education and training in Kuwait.
- Environment engineering undergraduate, at Northern Arizona University.
- Software experience (AutoCAD, HEC-RAC, Master Culvert, Microsoft)
- Speak two language (Arabic, and English)
- Have done a Team Work course for (communicate, organize the work, solve problem) from Kuwait Oil Company in Kuwait.

2.4 XIAOYI TAN (RESEARCH ENGINEER)

- Civil engineering undergraduate, senior level, at Northern Arizona University.
- Has experience in geotechnical engineering
- Fluent in Chinese
- Proficient in both Microsoft and AutoCAD

3.0 COST ANALYSIS

The following section will provide a complete analysis of the costs required to complete the project. Each cost is explained individually in a subsection.

3.1 POSITIONS REQUIRED FOR COMPLETING THE PROJECT

Table 3.1 shows all of the positions required to complete this project. The table also shows each position's respective code.

Table 3.1: Positions and their codes.

Classification	Code
Development Engineer	DENG
Research Engineer	RENG
Lab Technician	LAB
Engineering Intern	INT

3.2 TOTAL REQUIRED HOURS FOR THE PROJECT

Table 3.2 gives an outline of the estimated billable hours that are required to complete the project.

Table 3.2: Total required hours.

Tasks	DENG (hours)	RENG (hours)	LAB (hours)	INT (hours)
1.0 Researching	30	30		20
2.0 Health and Safety Protocols		12		
3.0 Materials Preparation		2	40	
4.0 Materials Testing		3	300	
5.0 Reporting Data	30		60	
6.0 Project Management	10	60	30	40
Subtotal	70	107	430	60
Total Hours = 667				

3.3 TOTAL PERSONAL COSTS

Table 3.3 shows the costs for the project as well as how much each position is being paid throughout the project. These costs are a summary of all required costs for the project.

Table 3.3: Total Personal Costs.

Position	Classification	Hours	Rate, $/hr.	Cost
Development Engineer	DENG	70	165	$11,550.00
Research Engineer	RENG	106	90	$9,540.00
Lab Assistant	LAB	430	60	$25,800.00
Engineering Intern	INT	60	30	$1,800.00
	Total personnel expenses			$48,690.00
	Lab rental	240 days	$30/day	$7,200.00
Total		$55,890.00		

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