ALTERNATIVE SEPTIC & IRRIGATION SYSTEM

Alternative Septic Team

ABSTRACT

A proposal for an alternative septic system and irrigation system design at the request of Adam Bringhurst.

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1.0 Project Understanding

1.1 Project Purpose

The goal of this project is to provide the client with proposed designs for an alternative septic system, irrigation system, and a 1-ft topographic map of the area in question. As well, the client has requested a water quality analysis on the groundwater well on-site to ensure the current septic system or bordering river have not impacted the aquifer.

1.2 Project Background

The project site is a remote four-and-a-half-acre lot adjacent to the river [1]. The site, located at 2955 N. Echo Canyon Road, Cornville AZ, is a rectangular plot with a small hillside on the western half of the lot that leads up to the road above. On this hillside the client plans to plant a small vineyard. The remaining of the lot is essentially flat, with a small mobile home in the North-East quadrant of the plot. Oak Creek runs along the east border of the lot, and a drinking water well is located adjacent to the house. An aerial photo of the site is show below, and a topographic map containing the floodplain can be found in the appendix.

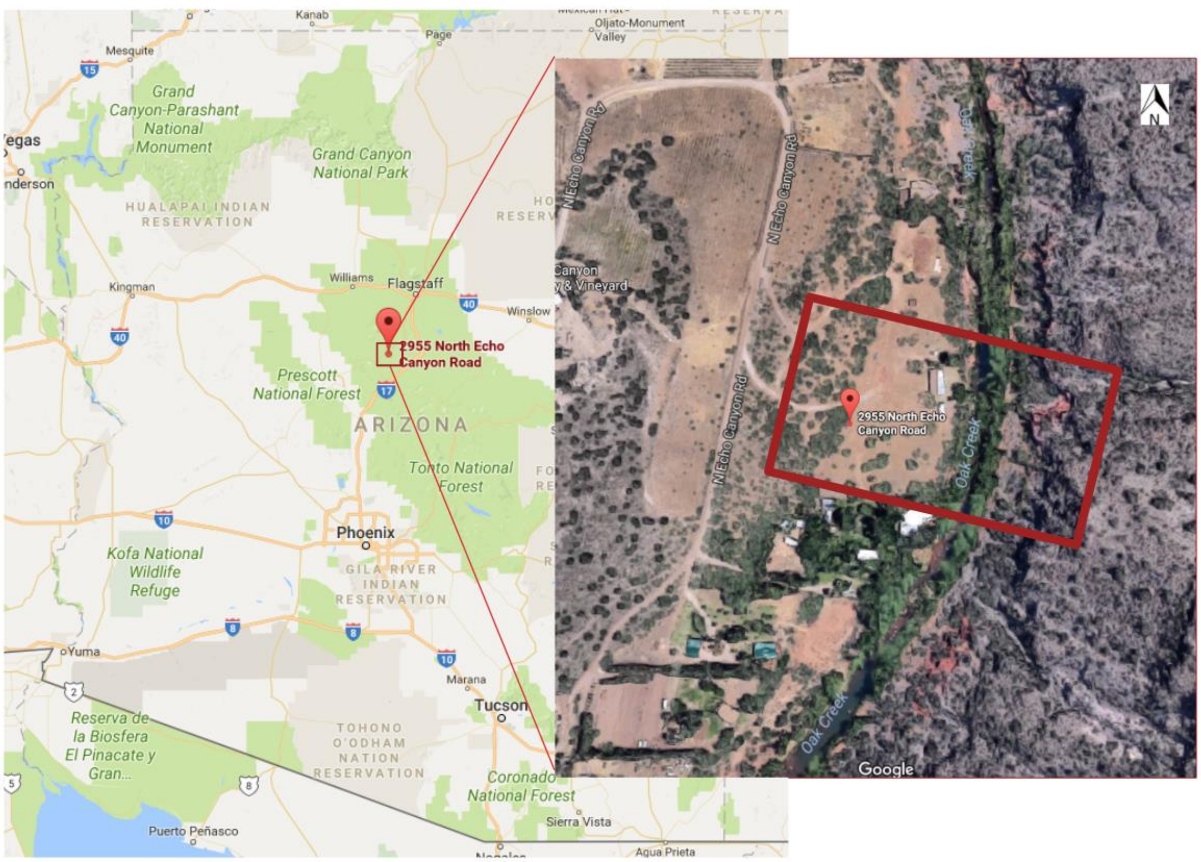

Figure 1 Aerial View of 2955 North Echo Canyon Road [2]

The site is currently under limited use, with no developments since the site was acquired. The current septic system was installed prior to the purchase and is located downstream of the drinking water well. It should be noted that the majority of the site is within the 100-yr floodplain and the client has rights to both aquifer and surface water.

1.3 Technical Considerations

The technical considerations for this project can be broken down into two primary categories; alternative septic systems and irrigation systems. Although more technical considerations may arise during the implementation of this project, the primary considerations are discussed in greater detail below.

1.3.1 Alternative Septic Systems

The primary consideration when designing an alternative septic system is the regulatory requirements, design requirements, and the maintenance required for each system. Such regulatory requirements can be found in 18 A.A.C. 9, Article 3, which describe requirements for design and site investigations for all septic system designs permitted in Arizona. These designs will need to be evaluated to determine which designs are feasible. The designs will be evaluated to determine under which site conditions are needed and the required upkeep of the system. Following a determination of possible designs, the design requirements will be further evaluated to find the best match.

1.3.1.1 Yavapai County Requirements:

When considering the possible septic systems, the possible alternative septic system designs are listed in 18 A.A.C. 9, as R-18-9-E303 to R-18-9-E322 [3]. Although not all of these systems will be feasible for the site conditions, this is the list of systems that may be approved by the county.

As well, the final approval of the system must be approved by the county and can be split into two submittals; Notice of Intent to Discharge, and Request for Discharge Authorization. The Notice of Intent to Discharge has the following requirements for a submittal:

- Application (Alternative System)
- 4 sets of plans
- Site Investigation Report
- 1 set of floor plans
- Plot plan
- Direction to site
- Application fee

Following this approval, the Request for Discharge Authorization has the following requirements:

- 3 sets of as-built plans
- Owner’s operation and maintenance manual
- Leak test
- Engineer’s Certificate of Completion
- Engineers Review fees paid in full

Once these two applications have been submitted an approved, an Approval to Operate will be issued [4].

1.3.1.2 Water Quality Analysis & Testing:

Along with the septic system design, coliform and nitrogen testing may be performed to determine any impact the current septic system has on the drinking water well. The total nitrogen will provide insight as to if the septic system has impacted the well, as it is often a key sign as to a leaking septic tank [5]. The standard methods that may be used when testing for coliform and nitrogen:

- (Ammonia NH_3) Test N' Tube Salicylate Method HACH Method #10031 [6]
- (Nitrate NO_3) Cadmium Reduction Method HACH Method #8171 [6]
- (Total Nitrogen) Test N' Tube Persulfate Method HACH Method #10071 [6]
- Standard Method 9215 C Spread Plate Method [7]
- Standard Method 9215 Heterotrophic plate count [7]

1.3.2 Irrigation Systems

The main considerations with designing the irrigation systems is determining the type of irrigation system and calculating the required dynamic head to pump water through the system. The various irrigation systems that have been deemed feasible for this project include flood irrigation, drip irrigation, and spray irrigation.

1.3.2.1 Flood Irrigation:

This method consists of flooding small trenches through the crops as a means of irrigation, and is generally used in less developed areas. This method is less sustainable compared to the other methods, and experiences greater losses to evaporation. To increase the efficiency of the system, leveling of the fields and surge flooding is used. Leveling the fields removes the slope of the trench and therefore limits the flow of water, increasing the efficiency. Surge flooding is used to reduce unwanted runoff by flooding the trenches at predetermined intervals [8].

1.3.2.2 Drip Irrigation:

In drip irrigation, water flows through pipes slightly above the ground and drips almost directly on the crops. This method reduces evaporation and transpiration that would occur with flood irrigation. This method reduces the wetted area and requires less pressure within the system. This can increase the yield of crops and the efficiency of the system. As well, this system is not labor intensive and can irrigate on a slope or irregularly-shaped land [9].

Alternative to having the pipes above the ground, a study was conducted on the efficiency of placing the drip irrigation system underground and found it to be just as efficient as the traditional above-ground system. As well, the study found that the lifetime of a subsurface drip irrigation is long, assuming the system is designed correctly and maintained [10].

1.3.2.3 Spray Irrigation:

Spray irrigation is widely used, though slightly less efficient than drip irrigation. The most common use of spray irrigation is the "center-pivot" system that utilizes electric motors to pivot a large frame to spray water over crops. Spray irrigation requires a high-pressure system and loses roughly 35% of water to evaporation [11]. Low energy precision application (LEPA) spray irrigation does not shoot water through the air, but the pipes hang low to the ground and spray water directly onto the crops. This type of application allows for only a 10% loss of water as it closer resembles the efficiency of drip irrigation than traditional spray irrigation [12].

1.3.2.4 Hydraulic Considerations:

When designing the system, hydraulic equations must be applied to the system. The head loss within the system and the total dynamic head of the system needs to be evaluated along with the type of system to ensure the system will operate as planned. Following determining the system requirements, the hydraulic equations, such as the energy equation, continuity equation, or Manning's equation can be used to determine the pump requirements of the system [13].

Following evaluation of the system requirements, this information can be used to determine the pump and pump configurations that can be utilized within the system. When considering the pump configurations, the system requirements will determine the configuration. If more than one pump is needed, the pumps can be configured in parallel or series. In parallel, double the flow will be observed at the same head. In serial, the same flow can be observed at double the system head [14].

1.4 Potential Challenges

This project, as with any project, has challenges to overcome. In this section, the potential challenges of the project will be addressed and how the team can overcome these challenges will be discussed.

1.4.1 Site Location

The primary challenges with the site location is the distance from NAU, the coordination required when visiting, and the qualities associated with the location of the site. The site is roughly an hour drive, and in a remote location off a dirt road. To visit the site, the team needs to coordinate between each other and the client. Given the limited site visits, the team will need to work with other faculty members to ensure the team is trained and provided with the correct equipment needed to perform a site investigation. To overcome the challenges associated with site visits, the team will plan site visits well in advance with each other and the client to ensure that the site visit runs smoothly. By planning the site visit well in advance, it will allow the team to coordinate between ourselves and the proper faulty to gain the necessary training and equipment to complete the project.

The physical qualities of the site will pose challenges to the project. The qualities that are specifically a concern is the soil classification and that the site is in the 100-yr floodplain, which can be seen in the appendix. The floodplain and the soil classification complicate the septic system design and limit the possible designs. To ensure the completion of the project and to overcome this challenge, the team plans to ensure that the selected design is approved or will be approved by the Yavapai County Development Services.

1.4.2 Lab Work

The concern with lab work is the lab time available, the time constraints for testing, and the testing available with the lab facilities at NAU. The lab facilities at NAU are not always available, and the team would need to get let into the lab to use the facilities. To overcome the limited access to the lab, the team plans to obtain a key to the lab by completing the chemical hygiene training for NAU and registering the completion of training with Adam Bringhurst. This will provide the team with more access to the lab, which will be needed considering the time constraints for testing.

The time constraints for testing is also a concern considering water analysis will need to be done within hours after the samples are taken. The team plans to collect samples last, allowing for a longer span of time between sampling and lab time. As well, the team will have a key to the lab so that the analysis can be performed once returning to NAU. This is important due to the travel time between the site and the lab facilities. Finally, the team can perform some analysis on-site using Dr. McDonnell's equipment to ensure more accurate analysis the sooner the sample is tested.

Finally, the team must consider the testing that is available at NAU, due to the limitation of materials and equipment. The team can work with Adam Bringhurst, the lab manager, to determine which tests are available and which tests NAU does not have the required equipment or materials for. These limitations apply to both water analysis and soil analysis. By coordinating with the lab manager, the team can guarantee which tests will be performed and will be able to review the methods for sampling and testing.

1.4.3 Limited Residency

The site does not have a permanent resident, and is instead inhabited in-part depending on the season. This further constricts the type of system selected depending upon the maintenance, upkeep, or monitoring required. Although this may minimally effect the irrigation system, it has a greater effect on the type of septic system. Certain alternative septic systems require more monitoring than others, which is a concern for a residency that is not occupied on a regular basis. To overcome the lack of consistent residents, the team will work with the client to estimate the time the residency is occupied and determine the best system for the occupied time. As a system may require more time being monitored than the client is currently available, the team will provide the client with the required time of use/monitoring to ensure transparency between the team and the client.

1.5 Stakeholders

The main stakeholders for this project are Adam Bringhurst, the client, Paul Gremillion, the technical advisor, and the Alternate Septic System Team. Adam, and his family, have a large stake in the project as it is occurring on their property. He is involved with the outcome of this project because everything that is proposed has to be approved by him. Paul Gremillion is involved with the outcome of the project because he reviews work and contributes to research topics throughout the project's life. The remaining stakeholders are the members of the alternate septic system team, because they are conducting the research and proposing the designs.

2.0 Scope of Work

As stated above, the goal of the project is to provide the client with a design proposal for an alternative septic system, the design of an irrigation system for a vineyard, and a one-foot topographic map of the site. In addition, the client has requested we determine if the shallow drinking water well is impacted by the current septic tank or the high coliform content in the surface water adjacent to the well. The scope of work can be broken into eight principal tasks that will be addressed in this section.

Task 1.0: Site Investigation

The site investigation is the first of the principal tasks required to complete the project. The investigation will be done in two visits to perform the subtasks below. The first site visit was completed in October and the site was observed, and unofficial testing and visual inspection was performed to grasp the current conditions of the site. The two site visits next semester will be done to complete the site investigation and obtain technical data described below.

Task 1.1: Site Survey

The site will be surveyed to provide the team with a topographical map that will be used in future analysis and system design. Currently, a 2-ft contour topographic map of the site has been obtained from Yavapai's parcel viewer, and can be seen in figure 2 and 3 in the appendix. Although a current map is available, the team will construct a map in software that can better suit the measurements the team requires and to provide the client with a 1-ft contour topographic map as requested.

The team will use NAU's GPS survey equipment to speed up the surveying process, although traditional total stations may be used as well. The site survey may be done in one visit or two, depending on the length of stay and efficiency of the surveyor.

Task 1.2: On-site Water Analysis

When performing the site investigation, certain water quality parameters can be measured on-site using portable testing equipment. The use of a Hanna Multiparameter Meter will allow the team to measure pH, temperature, conductivity, and dissolved oxygen. Although these parameters are unlikely to provide any insight into the water quality of the drinking water well, it can be compared against data collected from the creek upstream and downstream of the well to determine the validity of tests to be done off-site. Such data will be collected each site visit and compared between site visits depending upon the time of year.

Task 1.3: Sample Collection

The final task of the site investigation is to take samples from the site for lab testing. Such samples will include both soil and water samples. Soil samples will be taken from varying areas along the hillside as a change of slope is observed and at areas around the current septic system. As well, samples may be taken around the drinking water well, and at various areas around the property dependent on visual observations of the site. Soil samples should be taken prior to, or during site surveying, so the point can be marked and recorded on the survey. Water samples should be taken at the end of the site investigation due to the time sensitivity between sample collection and lab testing. Samples will be taken of the groundwater and surface water and must be stored in sterile containers. These samples will be sealed until testing in the lab.

Task 2.0: Off-site Technical Analysis

The off-site analysis can be broken into three tasks; water analysis, soil classification, and the site topographic map. These tasks will be performed off-site and are dependent upon the quality and validity of the data and samples taken from the site investigation.

Task 2.1: Water Analysis

Task 1.3 discussed the collection of water samples from the groundwater and surface water. Task 1.2 addressed the on-site water analysis that can be completed, such as testing the pH. This water analysis will be performed in the NAU Environmental Lab and will be done shortly after the site investigation is concluded. The tests that will be performed include testing the water samples for total coliform, ammonia, nitrate, and total nitrogen. The total coliform test will be performed for both the groundwater and surface water, as it is a good indication of e. coli. As well, the total nitrogen test will be performed on both the surface water and groundwater to determine if there is any concern of the current septic system contaminating the drinking water well. Ammonia and nitrate tests will only be performed on the groundwater, but the surface water may be tested as well dependent on the results of the tests.

Task 2.2: Soil Testing & Classification

As discussed in Task 1.3, soil samples will be taken at various locations on-site and at specific depths. The soil may be visually inspected to determine a rough estimate as to the classification, but to determine an accurate classification, the soil will be further tested in the lab. This can be done by either a wet or dry sieve test to determine percent composition of the soil, and a plasticity index of the soil can better determine the properties of the soil. An accurate classification and assessment of the soil is needed to determine if the soil can be used in the proposed septic system design or not. This classification will provide us with the necessary information to determine the infiltration rate of the soil, a major aspect in the design of the system.

Task 2.3: Site Topographic Map

The final analysis of the data collected will be to construct a topographic map of the site. Although this does not require the use of lab space, the proper software must be used. This software, provided by NAU, will allow the team to construct an accurate map of the site, which will be used in the designs of both systems.

Task 3.0: Alternative Septic System Design Evaluation

This task will compile the bulk of the research and design of the proposed system. This task will require research to determine compliant system and design requirements. As well, this task will evaluate the differences between systems to determine which system best fits the requirements of the site.

Task 3.1: Compliant Systems

Prior to design or evaluation of the system, the team will determine which systems are compliant with county and state regulations for implementation on-site. Although there are plenty of systems that are listed as approved systems by the state and the county, the location of the site complicates the matter. The team must determine which systems are designed to be placed in flood plains and are approved for implementation in a site such as this.

Task 3.2: Technical Requirements

Once the list of feasible systems are determined, the technical requirements of the system must be further researched for the system to operate correctly. The considerations for design requirements include “off-the-shelf” systems that are already designed, systems that require designing, and related technical considerations. This includes county requirements, requirements for maintenance, requirements for performance, requirements for location, etc. This task will determine all technical requirements and considerations for the selected systems.

Task 3.3: Evaluation of Systems

Finally, the technical requirements that were researched and addressed in the previous task will be evaluated to determine the proposed system. This evaluation will include both the technical considerations and costs associated with operating the system. This evaluation is meant to determine which system the team will propose, however, prior to designing the system the selection must be presented to the client and must be approved.

Task 4.0: Irrigation System Design Evaluation

This task is meant to define all technical considerations for the proposed system and evaluate the various systems to determine which irrigation method best fits the site. The team will further research the technical requirements of the vineyard and the irrigation system.

Task 4.1: Operations

Prior to evaluating possible systems, the team will require the client to provide technical requirements for the operation of the future vineyard. This includes the client's water rights to both surface and subsurface water, the size of the vineyard, and the water demand the vineyard will require. This information is pivotal to evaluating the various systems as their efficiency varies upon these variables.

Task 4.2: Evaluation of Systems

The team will use the operation data to evaluate the three systems discussed above; flood irrigation, drip irrigation, and spray irrigation. These irrigation systems will be evaluated to determine the material costs, maintenance costs, operation costs, and feasibility of installation. This evaluation will determine which system the team moves forward into the design phase.

Task 4.3: System Analysis

Once the irrigation system is selected, the team will further analyze the system as it pertains to hydraulic considerations and pump selection. This will include the use of various hydraulic equations along with the system requirements to determine the pump needed to meet the operation demand of the system.

Task 5.0: System Design

This task is comprised of completing the final design of the alternative septic system and irrigation system. The technical analysis and requirements found in the previous tasks will be used to complete the final design of the system.

Task 5.1: Septic System Design

Once the final system has been selected and approved by the client, the team will complete the final design of the system. This will include the location of the system, design of the system, maintenance and operation of the system. This final design will be included in the final deliverable.

Task 5.2: Irrigation System Design

Following the system analysis and hydraulic analysis has been completed for the system, the final system layout can be completed and tested in simulation software, such as WaterGEMS. Once the system has been proven to operate correctly under the required conditions, the design can be finalized and all equipment required can be compiled. The final design and required equipment will be included in the deliverable

Task 6.0: Project Impacts

The project must remain in compliance with national, state, and county regulations. The alternative septic system must be safe for those living on the property, as well as those who live in the surrounding area. If the alternative septic system were to fail it could risk the shallow aquifer being contaminated. This affects the residents on the site and neighboring residents that depend upon the aquifer for drinking water. As well, the irrigation system must be designed to meet the requirements of the vineyard, otherwise the quality of the crops could be affected.

Task 7.0: Project Management

Task 7.1: Deliverables

The deliverables of this project will be provided to the client in a professional manner and include all information needed for the implementation of the project. These deliverables include:

- Alternative Septic System Final Design
- Irrigation System Final Design
- 1-ft Contour Topographic Map
- *Water Analysis of Well* (dependent on results, at request of client)*

Although the final deliverables will not include all technical analysis performed, the team will provide completed analysis upon the request of the client.

Task 7.2: Coordination

To remain on schedule, the team must coordinate between ourselves, grading instructor, technical advisor, and client. This can be done by active communication between parties and identify a clear timeline for meetings, site visits, and deliverables.

Task 7.3: Schedule Management

Proper schedule management will keep the team on track and prevent the team from falling behind. This can be done by following the schedule and work plan and defining an appropriate timeline for the completion of tasks. Along with coordinating between team members, awareness of the schedule between team members will allow for timely completion of tasks.

Task 7.4: Resource Management

Managing resources is extremely important to the completion of this project. Resources, such as equipment used in the field and lab should not be wasted by lack of knowledge, but an understanding within the team on the use and operation of these equipment will result in efficient completion of such tasks. Other resources, such as the technical advisor can be managed well by utilizing the knowledge of the technical advisor, and coming prepared to meetings with knowledge of the subject. This will better utilize the technical advisor when the team is prepared with questions and suggestions for the project so that the technical advisor can provide insight.

3.0 Scheduling

The work plan, or schedule for the project can be seen in the table listed in the appendix. As well, the Gantt chart for the principal tasks is shown below. As can be seen in the Gantt chart below, much of the tasks overlap. This is because a greater time is given for the site investigation and off-site technical analysis due to the fact that two site visits will be done. As well, the design evaluations can begin prior to the site visit being completed. This is because the initial evaluations, such as the operational demands and the compliant systems is not dependent on the site visit. However, the final system design is dependent on the completion of the site visit and technical analysis.

4.0 Staffing & Cost

Below is listed the professional staff that would be needed to complete this project and the expected cost of the project. The staff is ranked in order of seniority and hourly rate.

Professional Engineer (PE)

Multiple professional engineers will be involved in this project by overseeing the design of the systems and approving the final designs that will be presented to the client. Both an Environmental PE and a Civil PE will be involved in this project as two final designs will be presented to the client. The PE(s) will be the responsible for meeting with the client and be the 'face' of the project.

Project Manager (MGR)

A project manager will be included to oversee the multiple aspects and work done for the project. They will also be included in the planning of resource allocation, and time management to help keep the project on schedule.

Engineer-In-Training (EIT)

Multiple junior level engineers, or EITs, will be heavily involved in all aspects of the project. Both Civil and Environmental EITs will collaborate on this project. They will be responsible for the bulk of the research, calculations, and the site visits, as well as be relied heavily on for preliminary designs. The EIT may draft the final design to be approved by the PE, dependent upon the comfort of the PE.

Environmental Technicians (TECH)

Environmental technicians will be responsible for collecting and sampling of soil and water, under the direction of the EIT and/or PE. They will accompany the EIT on site visits for sample collection and be responsible for testing of samples and reporting results. As well, they may be asked to assist with sample analysis results to be submitted to the client.

Administrative Assistant (AA)

The administrative assistant's role in the project is to manage the office information system, including managing files, distributing information, handling phone calls and emails. As well, the Administrative Assistant may set meeting times with clients when appropriate.

Below is the projected cost for the project. It is important to notice that to complete a topographic map of the property, the team would need to subcontract a land surveyor to complete the map. As well, the rate is adjusted for capital costs to simplify the calculations.

Table 1: Project Cost

	Classification	**Hours**	**Rate ($/hr) [16,17]***	**Cost**
Personnel	PE	20	$194.00	$3,880.00
	MGR	70	$95.00	$6,650.00
	EIT	250	$67.00	$16,750.00
	AA	150	$56.00	$8,400.00
	TECH	10	$48.00	$480.00
	Total Personnel Cost			**$36,160.00**
Travel	3 Site Visits @ 110 miles		$0.40 per mile	$132.00
Subcontract	Site Survey [18]			$1,000
Total		500		**$37,300.00**
***Includes base pay and overhead**				

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Appendix A: Parcel Maps

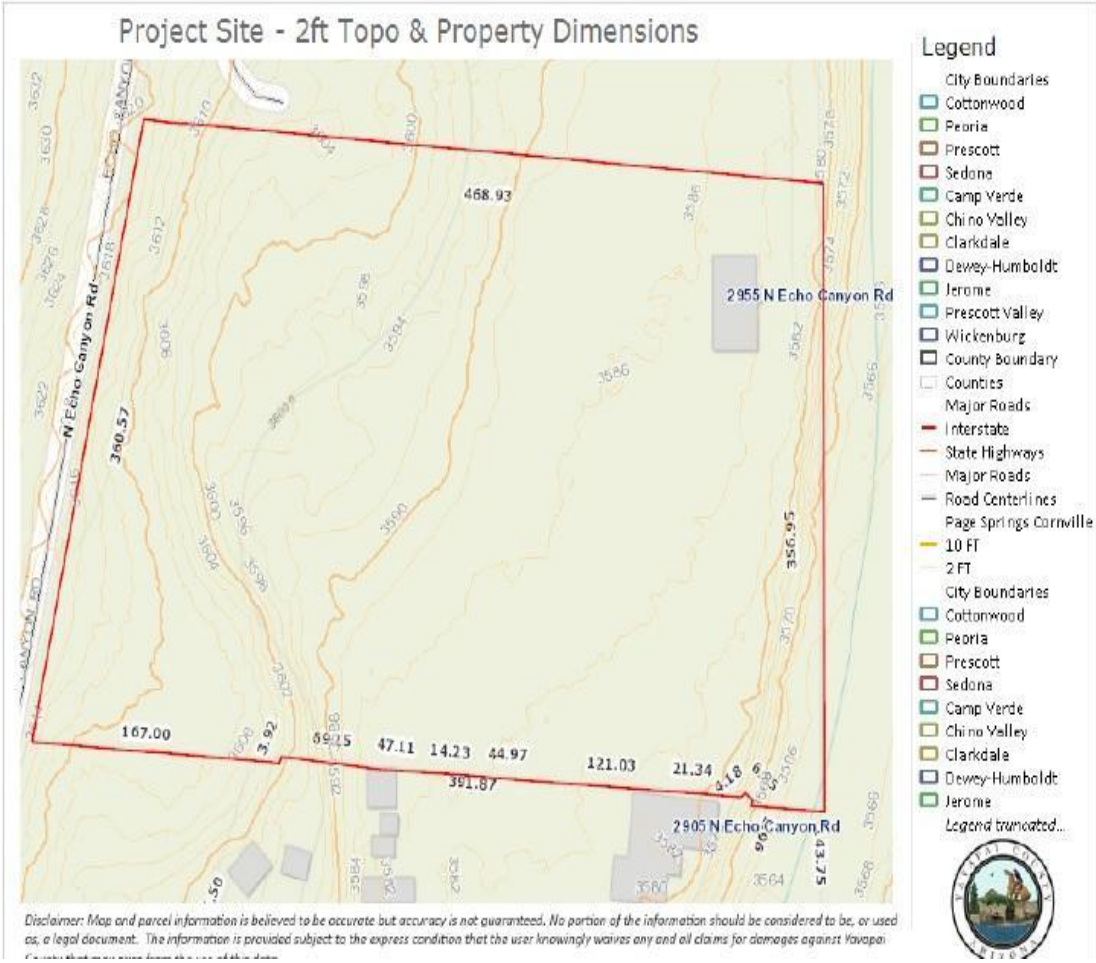

Figure 2: Parcel Map - 2-ft Topographic Map & Property Dimensions [15]

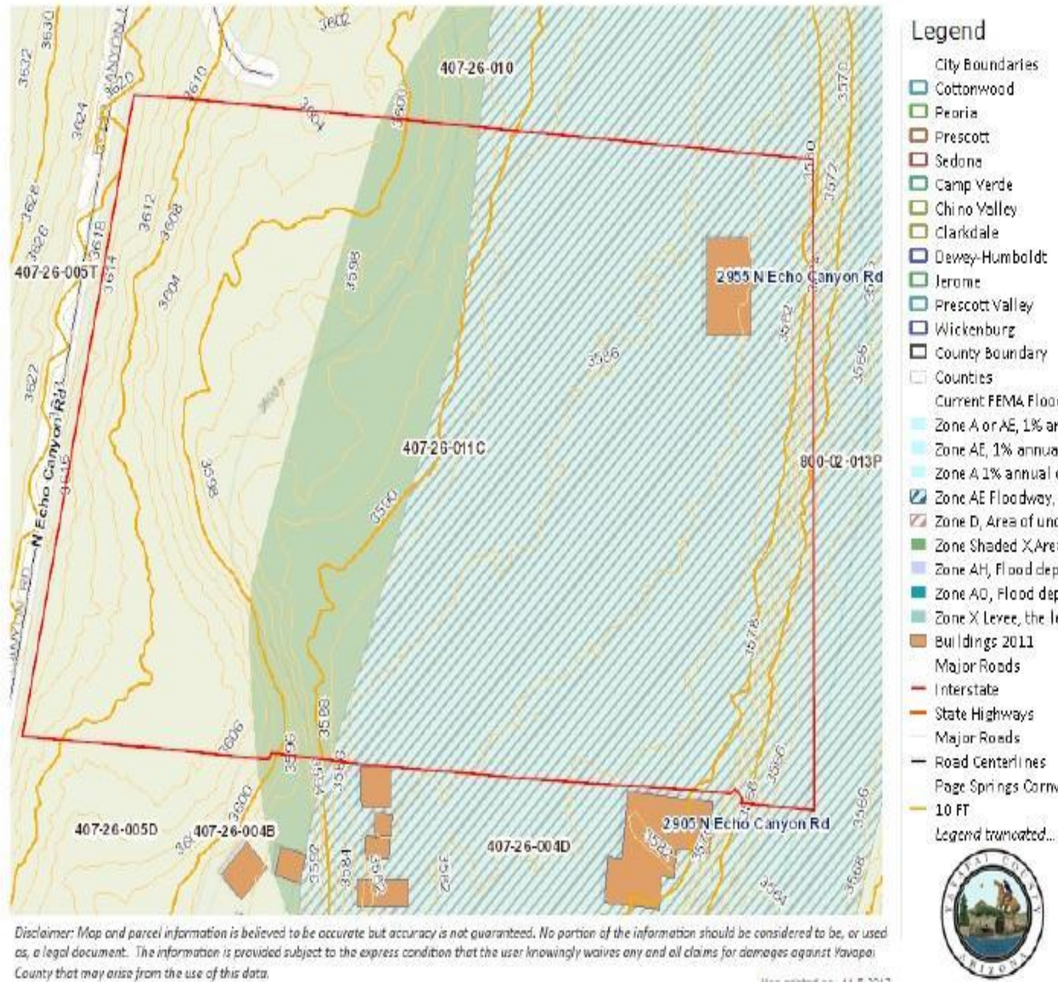

Figure 3: Parcel Map - 2-ft Topographic Map & Floodplain [15]

Appendix B: Work Plan & Gantt Chart

Table 2; Work plan – lists of tasks

Task No.	Task	Start Date	End Date	Duration
1.0	Site Investigation	1/27/2018	1/28/2018	1
1.1	Site Survey	1/27/2018	1/28/2018	1
1.2	On-site Water Analysis	1/28/2018	1/28/2018	0
2.0	Off-site Technical Analysis	1/29/2018	2/4/2018	6
2.1	Water Analysis	1/29/2018	1/30/2018	1
2.2	Soil Testing	1/31/2018	2/1/2018	1
2.3	Site Topography	2/2/2018	2/4/2018	2
	Complete Topography	2/5/2018	2/5/2018	0
3.0	Alt. Septic System Design Evaluation	2/5/2018	3/25/2018	48
3.1	Compliant Systems	2/5/2018	2/22/2018	17
3.2	Technical Requirements	2/23/2018	3/18/2018	23
3.3	Evaluation of Systems	3/19/2018	3/25/2018	6
4.0	Irrigation System Design Evaluation	2/5/2018	3/25/2018	48
4.1	Operations	2/5/2018	2/17/2018	12
4.2	Evaluation of Systems	2/13/2018	3/4/2018	19
4.3	System Analysis	2/24/2018	3/25/2018	29
5.0	System Design	3/26/2018	4/19/2018	24
5.1	Septic System Design	3/26/2018	4/19/2018	24
	Complete Septic System Design	4/20/2018	4/20/2018	0
5.2	Irrigation System Design	3/26/2018	4/19/2018	24
	Complete Irrigation System Design	4/20/2018	4/20/2018	0
6.0	Project Management	1/27/2018	4/29/2018	92
6.1	Risk Management	2/5/2018	3/25/2018	48
6.2	Coordination	1/27/2018	3/22/2018	54
6.3	Schedule Management	1/27/2018	2/5/2018	9
6.4	Resource Management	1/27/2018	2/25/2018	29
6.5	Deliverables	4/20/2018	4/29/2018	9

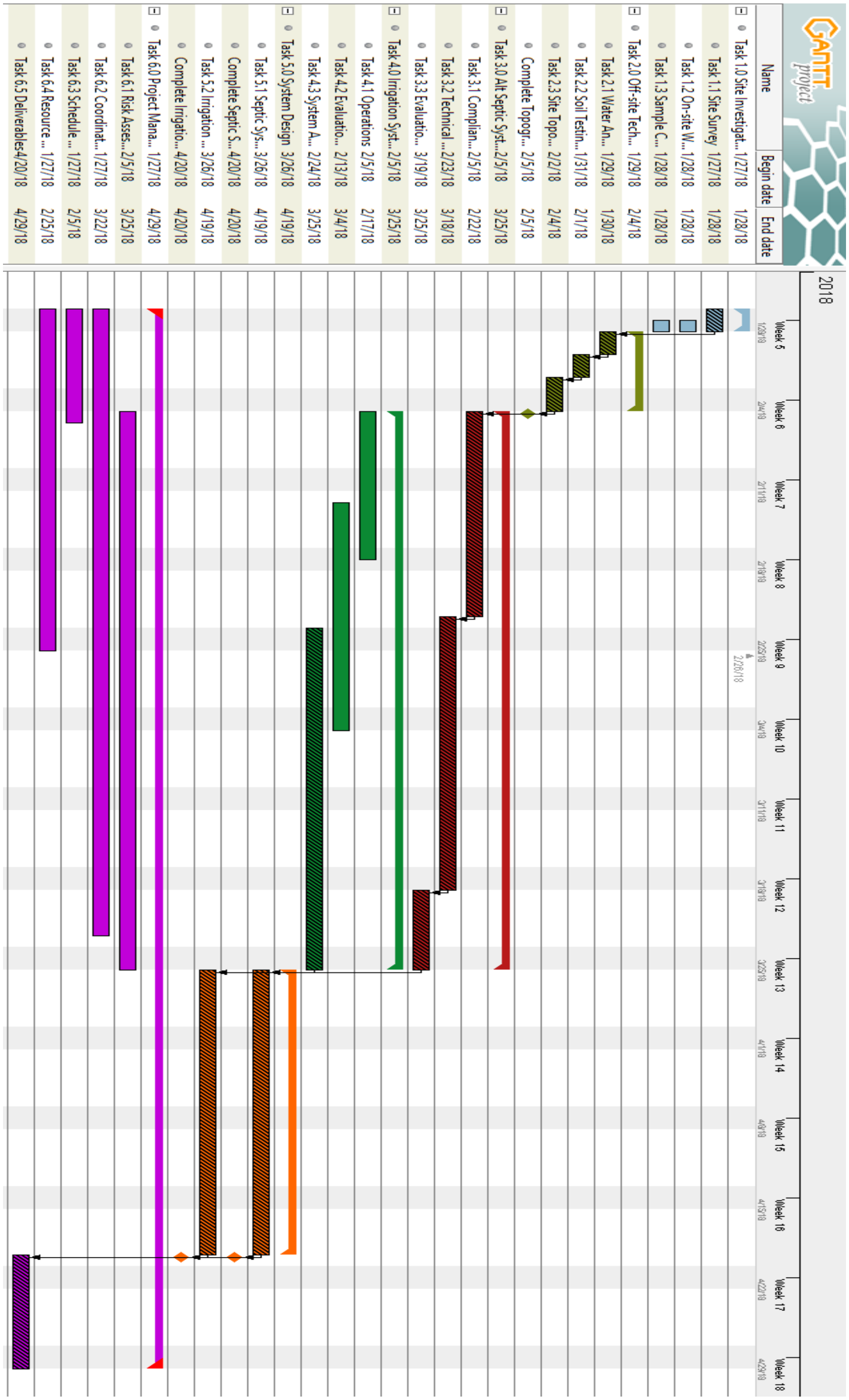

Figure 4: Sub tasks Gantt chart