Pilot Groundwater Monitoring Program in Northern Arizona for the Flagstaff Arboretum

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Abstract

This project involves designing and building multiple components for a pilot groundwater monitoring well in Northern Arizona. The goal is to acquire data to analyze the effect climate change has on the surrounding ecosystem. This will be done by outlining the specific components needed for the successful completion of this project. The data collected from the monitoring well is expected to be shared with the Southwest Experimental Garden Array (SEGA) platform using a data logger. This research will show the impacts of climate change to researchers, community members, and policy makers.

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1.0 Project Understanding

1.1 Project Purpose

The climate all over the world is changing, but the team's focus will be on the climate change in Northern Arizona. The project's purpose is to design and install a groundwater monitoring program in Northern Arizona that will help researchers, policy makers, and community members including k-12 students have a better understanding on the impacts of climate change.

Future groundwater monitoring efforts require a design with static water level measurements, therefore installing a protocol for implementing monitoring wells will aim to be easily re-created by other interested parties.

The warmer temperatures due to climate changes increase the water stress demands on trees and may account for greater mortality amongst them. This could account for the greater intraspecific competition for limited water, beetle infestations, and associated pathogens as well [1].

There is a wide variety of evidence on the ecological impacts of recent climate change, from various environments, like ponderosa, mixed conifer and desert climates, amongst others. The responses of both flora and fauna span an array of ecosystems and organizational hierarchies, from the species to the community levels. Although we are only at an early stage in the projected trends of global warming, ecological responses to recent climate change are already clearly visible [2].

The team is expected to design and build a pilot groundwater monitoring well. This is establish a protocol, which is a necessary step before scaling-up a groundwater monitoring program because it helps reduce risk. Locating a pilot sampling location at the team's client's location at the Flagstaff Arboretum facilitates future training and allows for modification to the monitoring protocol as needed.

1.2 Climate Change and Impacts to the Groundwater Table in Northern Arizona

The proposed site for the monitor well and data collection will be located in Flagstaff, AZ. The implementation of a monitoring well will enable the team to acquire water samples at the top of the water table since that is where contamination that reaches the groundwater is found first [3].

The proposed location is the Flagstaff Arboretum which is shown in Figure 1 as an aerial map. The monitoring well implementation will take place in a location where the shallow aquifer is in good condition to acquire enough data for analyzing purposes.

Figure 1: Arboretum, Flagstaff, AZ [4]

The monitoring well can be implemented in a shallow aquifer which will most likely be unconfined. The team will be using hand-augers to dig the hole where the well will be placed, therefore the depth has to be around 3 meters. The well implementation will take place in a riparian zone like that of the Rio de Flag which is shown in Figure 2. A riparian zone is the interface between land and a river or stream [5].

Figure 2: Rio de Flag, Flagstaff, AZ [6]

Using this location can be informative on the aspects of climate change and how the groundwater can be affected due to the riparian conditions near the well. The water table will vary compared to non-riparian zones.

1.3 Technical Considerations

Technical work will be assigned to team members based on research and assigned tasks. Installing a monitoring well design is the team's first technical consideration. Monitoring wells can be defined as wells that are designed and installed to collect groundwater samples. The purpose of installing monitoring wells is to determine the quality of the groundwater samples. The components of a monitoring well will include a 2" diameter Polyvinyl Chloride Pipe (PVC), 2" PVC well caps, and 2" well screen. Static water level measurement is another technical consideration. The water samples will be collected from the well using a bailer or syringe depending on the well size. The purpose is to detect changes of the water quantity of the wells at different times or seasons. The measurements of the water depth could be different using different devices such as a beeper tape, or a water pressure transducer [3]. Central data logger is the technical consideration to captures well-scale water quality/quantity data. Another technical consideration is to know the operations of streaming data between on-campus Real – Time Data Center (RTDC) and servers by using data middleware [5, 6].

The team's project will be mostly similar and related to the BEMP project, which is located in New Mexico. The BEMP project has a site that is called "Rio Grande Nature Center" and this site will be the team's inspiration to look up the study site designs for the project. Furthermore, the BEMP project will help the team gain knowledge on the type of plots that should be designed for the project. Since the team's project and the BEMP project will be related, then the site will have a similar site map to the Rio Grande Nature Center's [7].

1.4 Potential Challenges

One potential challenge is not having enough water inside the monitoring wells to acquire samples. This could lead to breaks in the consistency of the schedule and budge set up in the proposal. Another challenge is not being able to gather as much funding as the team needs to complete the project. This may require finding alternatives to the methods and equipment the team originally decide to use. One other potential challenge includes finding a way to make the housing for the transducer, battery and data logger waterproof as well as finding a way to keep the battery charged.

1.5 Stakeholders

The team's stakeholders for the project include: The Flagstaff Arboretum, NAU SICCS, and K-12 students.

2.0 Scope of Services

The design and installation of a monitoring well will take place at a specific location in Flagstaff, AZ in order to collect monitoring data. The various tasks to be conducted are the following: Project management, site investigation, estimated budget, final design and exclusions.

2.1 Task 1: Site Investigation

The area where the monitor wells will be set up will be surveyed and mapped using AutoCAD modeling in order to familiarize the team and client with the location, showing distances between wells and relevant vegetation. A soil texture analysis will be conducted in order to identify soil texture with depth.

2.2 Task 2: Design

2.2.1 Monitoring Well Installation Design

2.2.1.1 Design Monitoring Well

The design for the monitoring well will be based on the depth of the shallow aquifer at monitor the site. This includes testing the soil properties and investigating the site in order to determine the appropriate location.

2.2.1.1.1 Bailer

A bailer is simply a one-piece design made of PVC material that will help in receiving a groundwater sample from the well. The bailer chosen for the team project is constructed from Polyvinylchloride (PVC). Bailers usually consists of a nylon tube with a handle at the top, and a check valve at the bottom. Furthermore, a bailer works by having the bottom check valve lowered into the water. The pressure of the water will cause the bottom check valve to open as it will allow water from the well to flow through the bailer. After having the bailer filled with water, the bottom check valve will close, and the bailer can be retrieved by using the handle at the top of the bailer [8,9]. Figure 3 shows the components of a bailer.

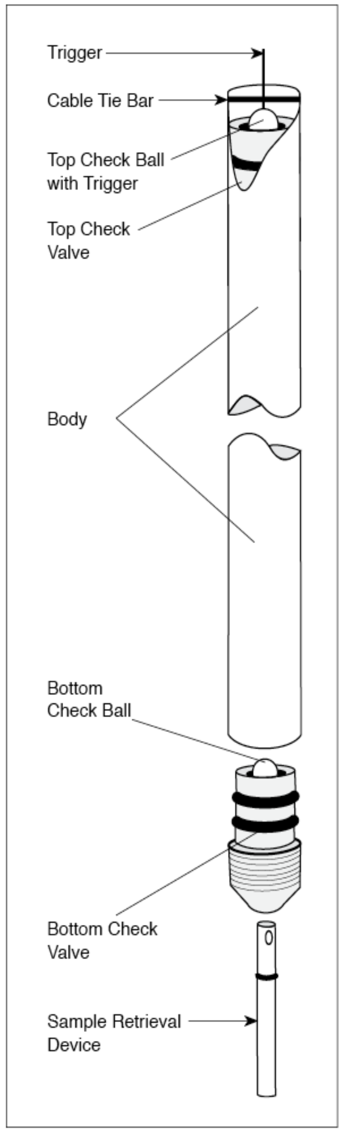

Figure 3: Bailer Components [8]

2.2.1.1.2 Syringe

A syringe is a device used in order to collect the water from the monitoring well. It is a tube with a nozzle and piston that is fitted with a hollow needle for injecting or withdrawing water [10]. This device can be used in a well that has a small diameter, as this is mostly used for smaller extractions than a bailer.

2.2.1.1.3 Water Quality Testing

The YSI 9500 Photometer device can be used for testing for constituents in the water samples like pH, dissolved oxygen, sulfates and hardness [11]. If the team decides to conduct microbial testing, the Del Agua testing kit can be used [12].

2.2.2 Water Pressure Transducer

Since detection of water level is one of the main parts of this project, the team needs to design a water pressure transducer that could monitor the water level in real-time. This design may be separated into three parts including the sensors select/design, electrical circuit design and structure design.

2.2.2.1 Sensors

As the core of the pressure transducer, a suitable pressure sensor is needed to monitor the pressure change. The basic principle is that the conversion of pressure into an electrical signal is achieved by the physical deformation of strain gages, which are bonded into the diaphragm of the pressure transducer and wired into a Wheatstone bridge configuration [13]. In addition, we may need a temperature sensor as the calibration to calibrate the data.

2.2.2.2 Electric Circuit

After we determined the sensors, we need to design an electric circuit to make those sensors work. The components are sensors, resistances, wires etc. We may need to build the circuit based on the microprocessor such as the Arduino platform. The circuit needs to not only supply the power but also transfer the data that detected by the sensor.

2.2.2.3 Structure

Since the pressure transducer would be working underwater in longtime, we need to design a housing for it in order to make it be waterproof anti-corrosion. The PVC-pipe could be good choice for the tubes to be waterproof and anticorrosive [11]. Cables and tubes are needed to keep the water away from the circuits.

2.2.3 Data Collection

Since data collection is another important part of this project, team need to use pressure transducer to collect real time data and use beeper tap to collect data at any time. Using pressure transducer to collect pressure data, team can convert these data to the water depth. Using beeper tap can directly get the data of water depth, but it can only measure it over and over and it cannot support the long-term research.

2.2.4 Data Transmission

2.2.4.1 Transmission Node

The existence of transmission nodes is not only solving data transmission problems of various sensors system, but also receiving download instructions from server. Transmission nodes include a UNO controller, a wireless transmission module and a GSM/GPRS development version.

2.2.4.2 UNO Controller

The operating voltage of UNO controller is 5V in dc. There are three channels providing power supply to UNO controller; the USB port, the power input socket and VIN pin [14]. The main purpose of using it is processing the incoming data from acquisition terminal and send instruction to transmit data to the internet.

2.2.4.3 Wireless Transmission Module

Wireless transmission module reduce the limitations used of Arduino and make it free. The main purpose of using wireless transmission module is receiving data that is sent from acquisition terminal [15,16].

2.2.4.4 GSM/GPRS Development Version

GSM/GPRS development version have the function of texting SMS message, voice calls and GPRS data transmission [17]. The main purpose is to use it as a medium to transmit data from acquisition terminal to the internet.

2.3 Task 3: Building

2.3.1 Building Sampling Well

Building the sampling well will be based on the design task the team presented. Since the design of the monitoring well will be manageable by K-12 students, then there will not be any machines used for drilling. The drilling method used for installing the monitoring well will be hand-augers. The device components completion dates can be seen in the Schedule section.

2.3.2 Building Pressure Transducer

After all the designs of components of pressure transducer are down, we need to assemble the pressure transducer based on our designs. We may need to use the some tools to ensure the device is waterproof. The device should be in a good size for installing and testing in the sample well. The device components completion dates can be seen in the Schedule section.

2.4 Task 4: Test

2.4.1 Measurement Test of the Water Depth

2.4.1.1 Pressure Transducer Test

The team will install the pressure transducer in the monitor well to test its function. Since the pressure transducer will be working underwater for long time, the power supply should be prepared enough. Once the problem occurs, the team should bring it back and try to solve the problems.

2.4.1.2 Monitoring Well Test

The team will install the monitoring well in an optimal location for groundwater monitoring. This will enable the team to observe the well after initial installation in order to determine if it is meeting the objective and working properly. In the case of malfunction, the team can then analyze the problem and find a viable solution.

2.5 Project Management

2.5.1 PDT Meetings

The project development team (PDT) meetings will serve as primary weekly events for the team to report their past work and set up or adjust the plan for next period. During the whole project, PDT meetings should be held at least once a week. Attendees should be all team members. Since the team is made up of two electrical engineers, one environmental engineer and one civil engineer, every team member should report their work clearly to ensure everyone at least understand works in other fields. Throughout the project, every team member will rotate to lead the meeting, take notes and prepare for the meeting agendas. The meeting agendas should be sent out at least 48 hours before the meetings, and the meeting minutes should be shared in two days after the meetings.

Deliverables: Meeting agendas and meeting minutes.

2.5.2 Technical Coordination Meetings

Technical Coordination Meetings will be held for the team to communicate with the technical advisors and clients. The team should have appointments with the technical advisors and clients at least 48 hours before the meetings. During the meetings, the team could share their ideas, ask technical problems, and take notes.

Deliverables: Meeting notes.

2.5.3 Presentations

The presentations are for the team to present and report their past work and future plan to the other teams and clients. During the presentations, the team should show and explain their work clearly and ask for feedback from the audiences. The presentation should be professional and easy to understand.

Deliverables: Feedback.

3.0 Project Schedule

The project schedule developed by the team can be seen in Appendix A which illustrates the tasks that need to be completed, along with their respective due dates and durations. A critical path demonstrates the shortest amount of time it will take the team to complete the project within the alotted timeframe.

4.0 Staffing/Cost

The staff and total cost of the team's project can be seen in Tables 1 and 2, which demonstrate the consulting services and the engineering services, respectively.

Table 1: Consulting Services

Consulting Services	Quantity	Unit	Unit Cost	Total
Senior Engineer	190	Hours	$70.00	$13,300.00
Design Engineer	180	Hours	$80.00	$14,400.00
Project Manager	210	Hours	$80.00	$16,800.00
EIT	150	Hours	$60.00	$9,000.00
Total Consulting cost	730	Hours	$290.00	$53,500.00

Table 2: Engineering Services

Engineering Services				
Beeper tape	1	Piece	$200	$200.00
Arduino	1	Piece	$30.00	$30.00
Wireless transmission module	1	Piece	$10.00	$10.00
GPRS/GSM Development Board Module	1	Piece	$20	$20
UNO Controller	1	Piece	$25	$25
EXELint 60 ml Disposable Syringe	1	Piece	$4.95	$4.95
TDS Water Hardness Test Meter Kit	1	Piece	$15.27	$15.27
Plastic Transfer Pipettes 3ml	1	Piece	$5.41	$5.41
PVC pipe 2”: Solid casing	20	inch	$0.56	$11.20
Well bailer	1	Piece	$90.95	$90.95
Pressure sensor	2	Piece	$30.55	$61.10
Thermistor	2	Piece	$2	$4
3D Printer Filament	1	kilogram	$22	$22
Solderless Flexible Breadboard Jumper Wires	50	Piece	$0.07	$3.50
18 Gauge Silicone Copper Wires	20	meter	$0.35	$7.00
Total Engineering Cost				$510.37

Total Cost (Consulting Services & Engineering Services) **$54,010.37**

References

[1] D. Breshears, N. Cobb, P. Rich, K. Price, C. Allen, R. Balice, W. Romme, J. Kastens, M. Floyd, J. Belnap, J. Anderson, O. Myers and C. Meyer, "Regional vegetation die-off in response to global-change-type drought", Proceedings of the National Academy of Sciences, vol. 102, no. 42, pp. 15144-15148, 2005.

[2] G. Walther, E. Post, P. Convey, A. Menzel, C. Parmesan, T. Beebee, J. Fromentin, O. Hoegh-Guldberg and F. Bairlein, "Ecological responses to recent climate change", *Nature*, vol. 416, no. 6879, pp. 389-395, 2002.

[3] "New Mexico Environment Department - Ground Water Quality Bureau - Monitoring Well FAQ", *Env.nm.gov*, 2017. [Online]. Available: https://www.env.nm.gov/gwb/NMED-GWQB-MonitoringWellFAQ.htm.

[4]"The Arboretum At Flagstaff", The Arboretum At Flagstaff, 2017. [Online]. Available: https://www.google.com/maps/place/The+Arboretum+At+Flagstaff/@35.1606157,-111.7319312,218m/data=!3m1!1e3!4m5!3m4!1s0x872d85a5ede5b7cd:0x83126ce2d92d66ec!8m2!3d35.160305!4d-111.73091.

[5] "Riparian Areas Environmental Uniqueness, Functions, and Values | NRCS", Nrcs.usda.gov, 2017. [Online]. Available: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/?cid=nrcs143_014199.

[6] "Home - Friends of the Rio de Flag", Friends of the Rio de Flag, 2017. [Online]. Available: http://friendsoftheriodeflag.org/.

[7] "Site Maps - BEMP Albuquerque", *BEMP Albuquerque*, 2017. [Online]. Available: http://bemp.org/site-maps/.

[8] "Disposable Bailers", globalw.com. [Online]. Available: http://www.globalw.com/products/bailer.html.

[9] "Bailers", envisupply.com. [Online]. Available: http://www.envisupply.com/equipment/bailers.htm.

[10] "Buy Syringes and Needles For Sale | Syringe Needle Combos", Allegromedical.com, 2017. [Online]. Available: http://www.allegromedical.com/syringes-c570/needle-syringe-combos-c4055.html.

[11] "9500 Photometer | ysi.com", *Ysi.com*, 2017. [Online]. Available: https://www.ysi.com/9500.

[12] "DelAgua - DelAgua Kits", *Delagua.org*, 2017. [Online]. Available: http://www.delagua.org/delagua-kits.

[13] K. Aberer et al., “A Middleware for Fast and Flexible Sensor Network Deployment,” Proc. Of the 32nd Int. Conf. on Very Large Data Bases, 2006, pp. 1199 - 1202.

[14] S. Tilak et al., “The Ring Buffer Network Bus (RBNB) DataTurbine Streaming Data Middleware for Environmental Observing Systems,” 3rd IEEE Int. Conf. on e-Science and Grid Computing, 2007, pp. 125 - 133.

[15] "How it Works - Strain Gauge Pressure Transducer", *Rdpe.com*, 2017. [Online]. Available:

http://www.rdpe.com/ex/hiw-sgpt.htm.

[16] "USE OF SUBMERSIBLE PRESSURE TRANSDUCERS IN WATER-RESOURCES INVESTIGATIONS", *Pubs.usgs.gov*, 2017. [Online]. Available:

https://pubs.usgs.gov/twri/twri8a3/.

[17] "Arduino Uno Function Introduction", *OPENHOME.CC*, 2017. [Online]. Available: https://www.openhome.cc/Gossip/Books/mBlockArduino1-3and1-4.html.

Appendices

Appendix A: Schedule