NORTHERN ARIZONA UNIVERSITY
College of Engineering, Forestry & Natural Sciences

Pilot Groundwater Monitoring Program in Northern Arizona for the Flagstaff Arboretum

Final CENE 486C Presentation

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Introduction

1. Pilot monitoring well in shallow aquifer
2. Study Groundwater Chemistry
   a. Soils
   b. Vegetation
   c. Groundwater table depth
3. Climate change in Northern Arizona
4. Help better understand the impacts of climate change within riparian zones [1]

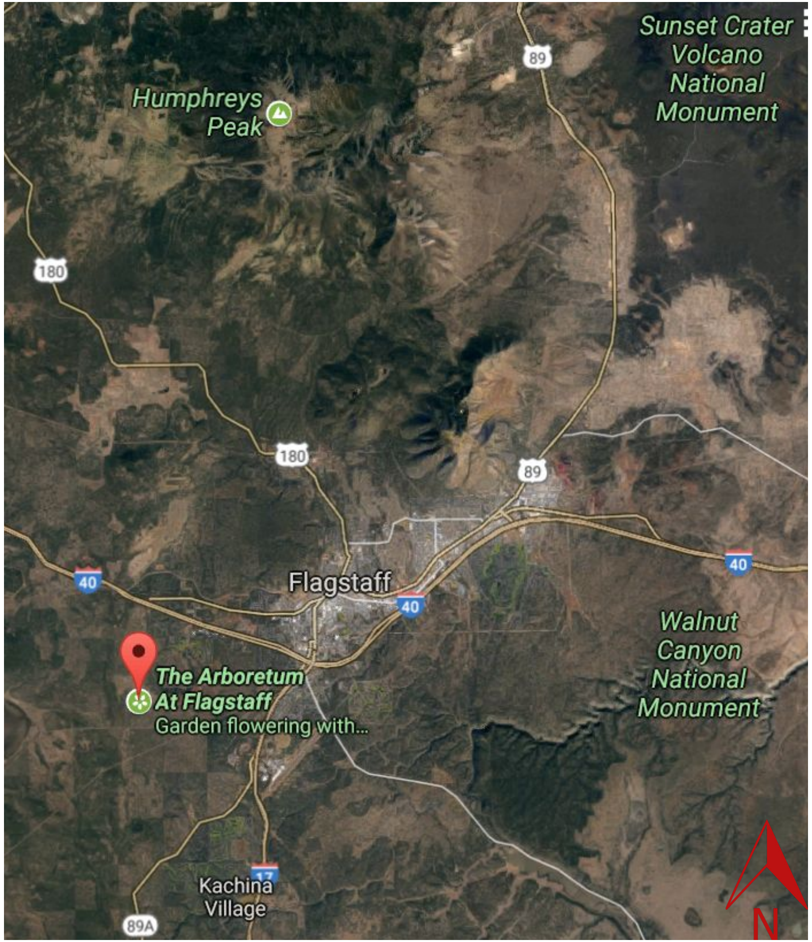


Figure 1: Flagstaff Arboretum location in Northern Arizona [2]

Project Overview

Choose Location

- Riparian zone contains most diversity

Well Implementation

- Acquire all necessary components
- Assemble monitoring well

Electrical System Implementation

- Acquire all necessary components
- Assemble electrical monitoring system

Testing Components

- Sensor
- Data storage & transmission
- Soil samples

Data Collection

- Water depth change
- Soil type determination

Report Findings

- User’s manual including all findings

Monitoring Well- Components and Location

-Ephemeral Wetlands
-Unconfined Aquifer

Figure 2: Monitoring well components

Figure 3: Monitoring well implementation location after site investigation

Monitoring Well- Implementation

Figure 4: Augered hole measuring 126 inches

Figure 5: Team member using auger

Figure 6: Assembled monitoring well

Monitoring Well- Implementation

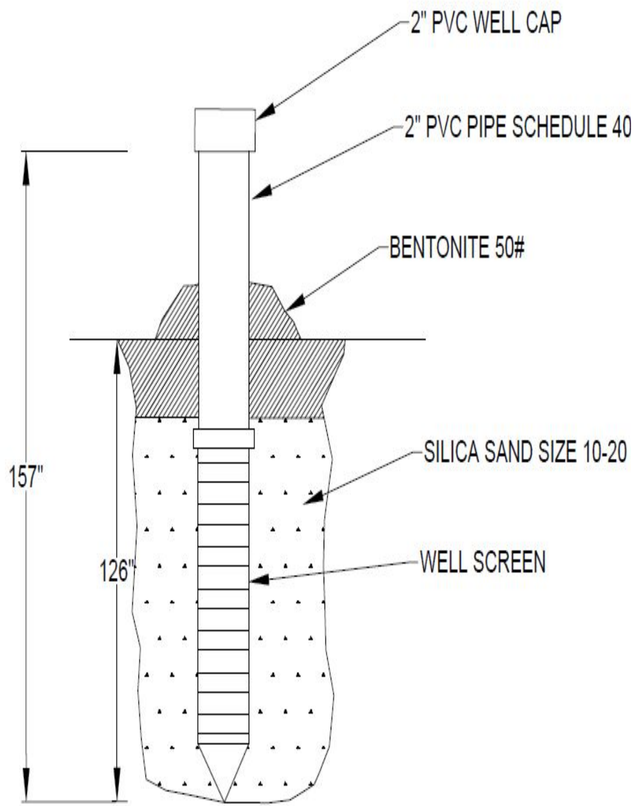


Figure 7: Monitoring well input into augured hole [3]

Figure 8: Packing monitoring well

Electrical Monitoring System

⟹ Measure groundwater table change

Figure 9: Arduino UNO controller[4]

Figure 10: Water level sensor

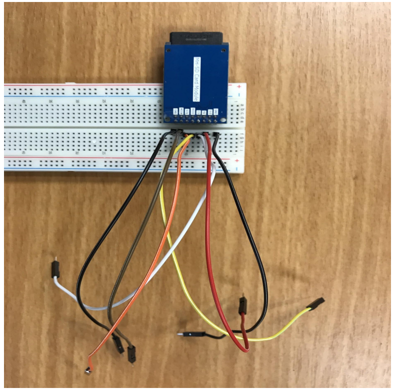


Figure 11: SD card with SD card module

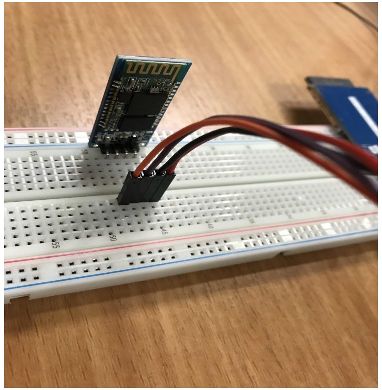


Figure 12: Bluetooth module

Installation of Electrical Monitoring System

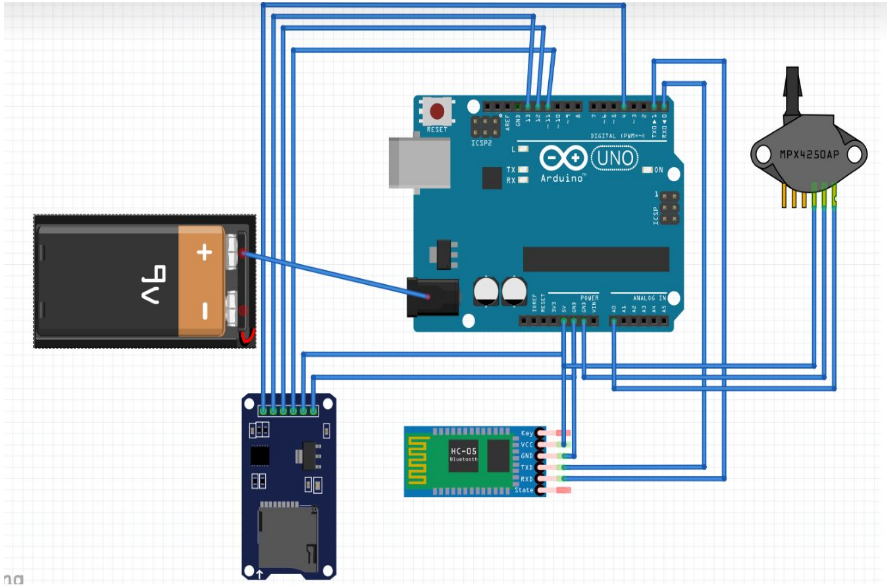


Figure 13: Schematic of the electrical monitoring system

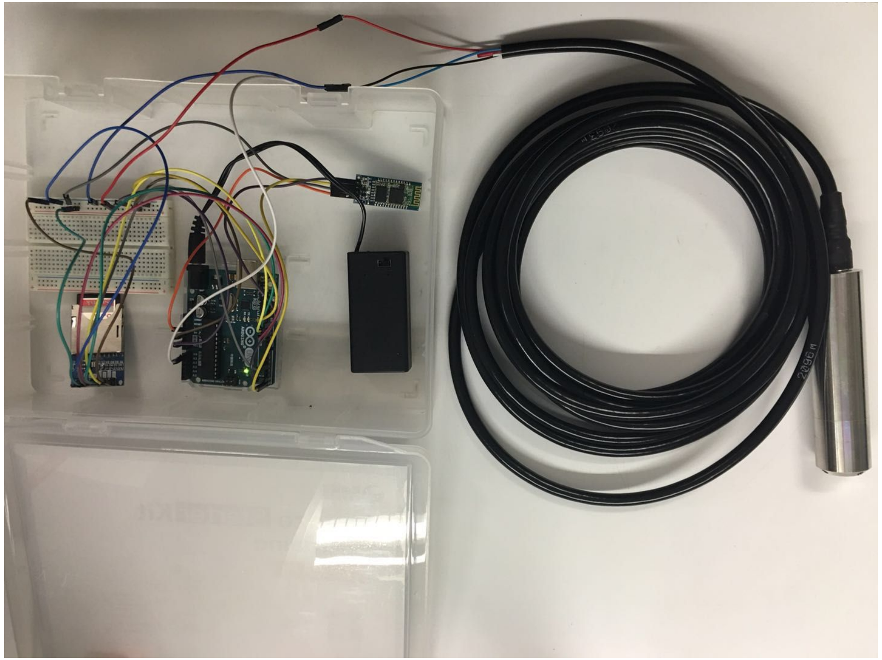


Figure 14: Overview of the electrical monitoring system

Testing of the electrical monitoring system

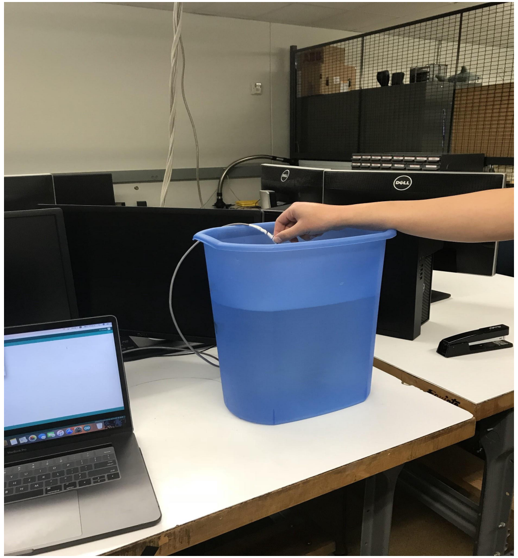


Figure 15: Testing sensor

Figure 16: Old pressure sensor

Figure 17: New water level sensor

Old Sensor: Sensor Value (volts) —Base on instruction→ Water Pressure(psi) —Do extra coding→ Water Depth(m)

New sensor: Sensor Value (volts) —Base on instruction→ Water Depth(m)

Simulation of the electrical monitoring system

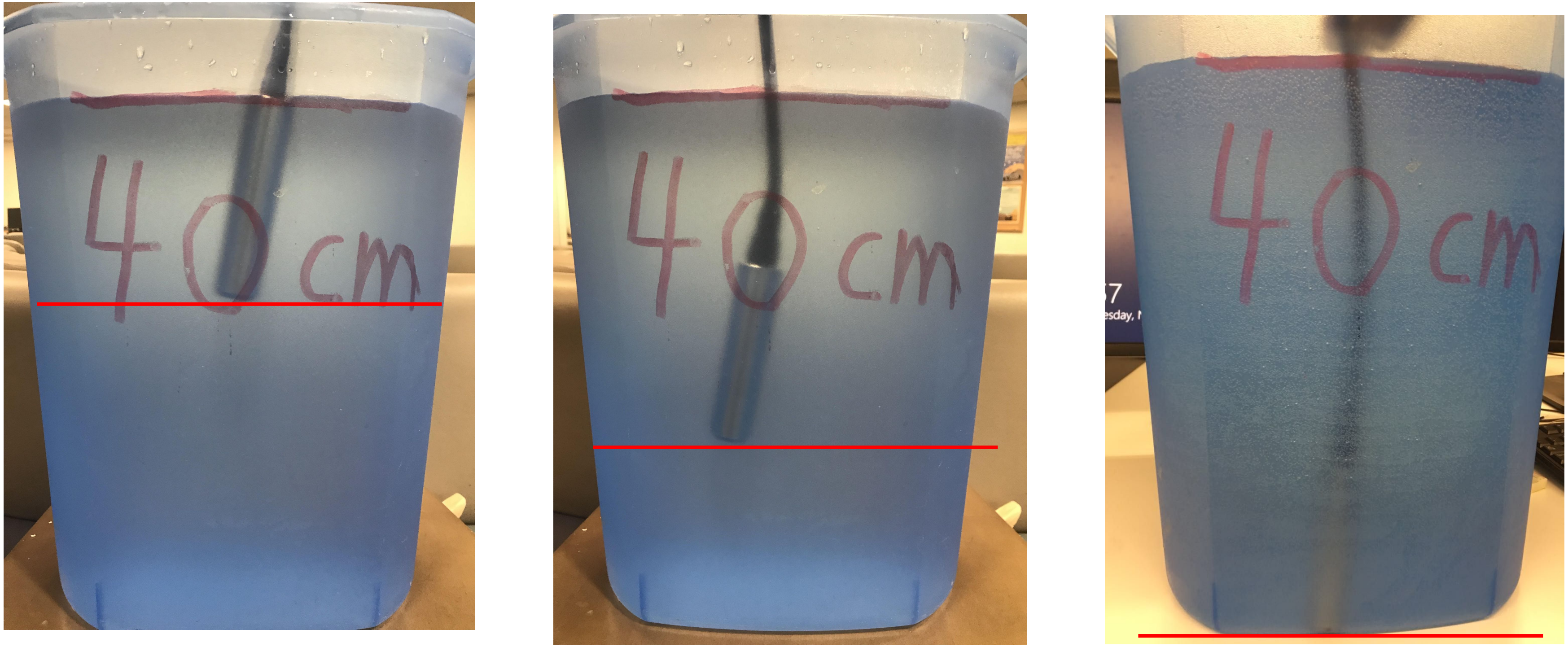


Figure 17: Immerse the sensor into the “well” and pull it up periodically

Simulation of Wireless Data Transmission

Figure 18: Connect the monitoring system with laptop via Bluetooth

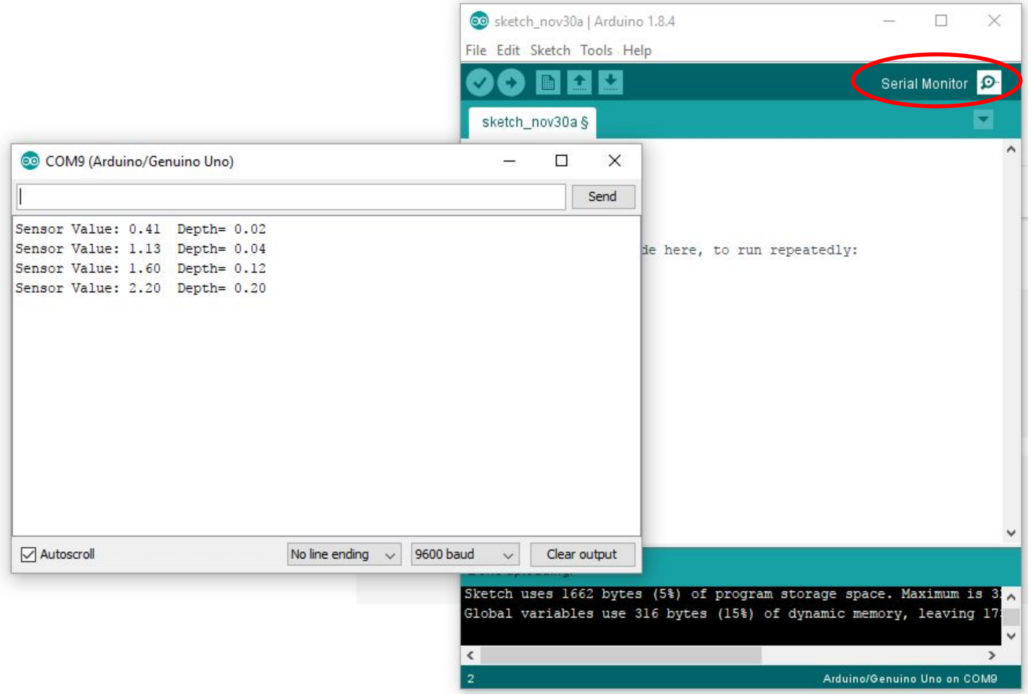


Figure 19: Open the serial monitor in the Arduino software

Data Analysis

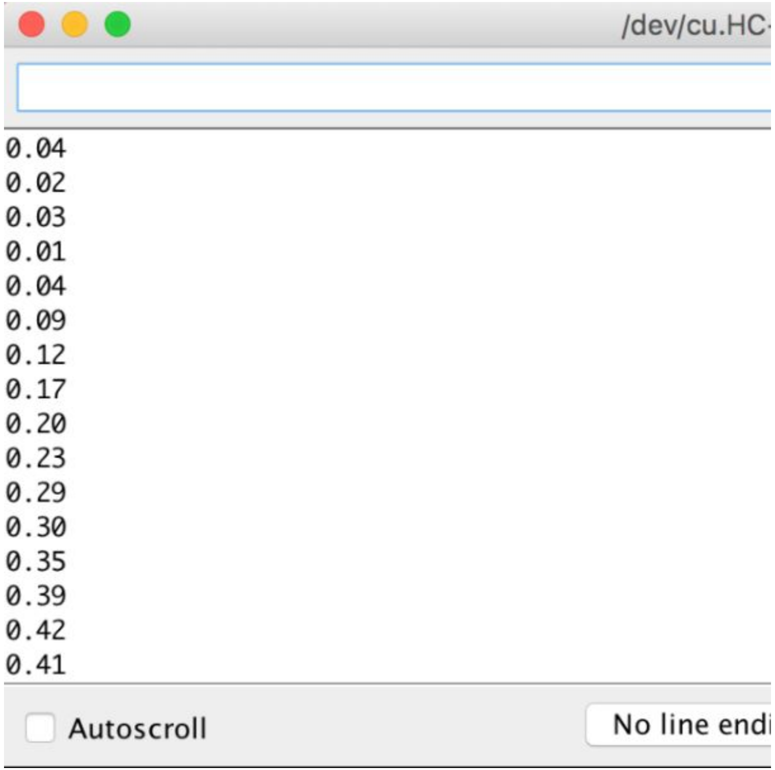
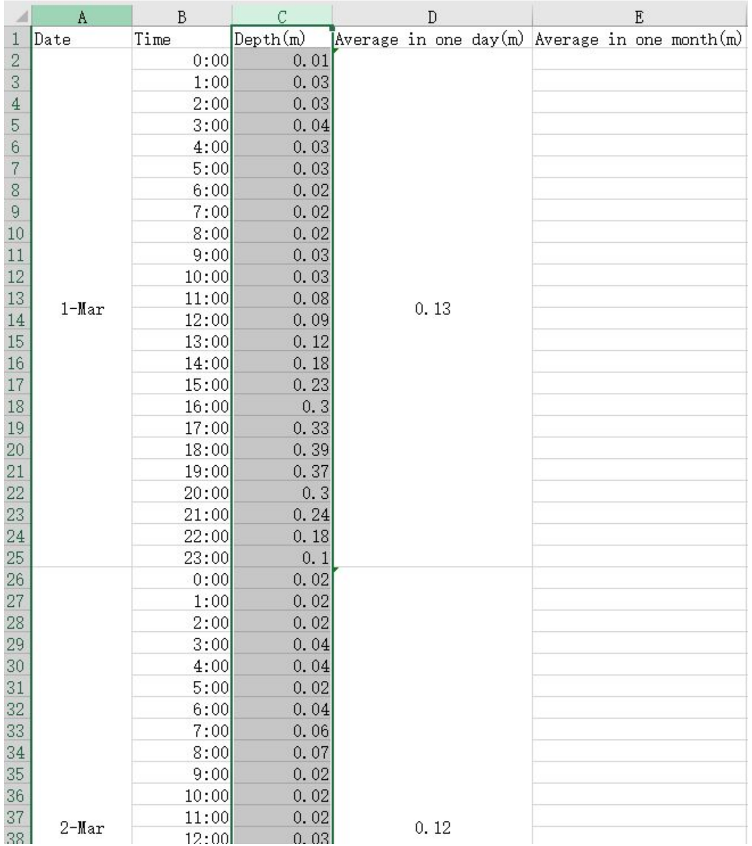


Figure 20: Extract the data saved in SD module.



	A	B	C	D	E
1	Date	Time	Depth(m)	Average in one day(m)	Average in one month(m)
2		0:00	0.01		
3		1:00	0.03		
4		2:00	0.03		
5		3:00	0.04		
6		4:00	0.03		
7		5:00	0.03		
8		6:00	0.02		
9		7:00	0.02		
10		8:00	0.02		
11		9:00	0.03		
12		10:00	0.03		
13	1-Mar	11:00	0.08	0.13	
14		12:00	0.09		
15		13:00	0.12		
16		14:00	0.18		
17		15:00	0.23		
18		16:00	0.3		
19		17:00	0.33		
20		18:00	0.39		
21		19:00	0.37		
22		20:00	0.3		
23		21:00	0.24		
24		22:00	0.18		
25		23:00	0.1		
26		0:00	0.02		
27		1:00	0.02		
28		2:00	0.02		
29		3:00	0.04		
30		4:00	0.04		
31		5:00	0.02		
32		6:00	0.04		
33		7:00	0.06		
34		8:00	0.07		
35		9:00	0.02		
36		10:00	0.02		
37	2-Mar	11:00	0.02	0.12	
38		12:00	0.03		

Figure 21: Part of the water depth table

Data Analysis Result

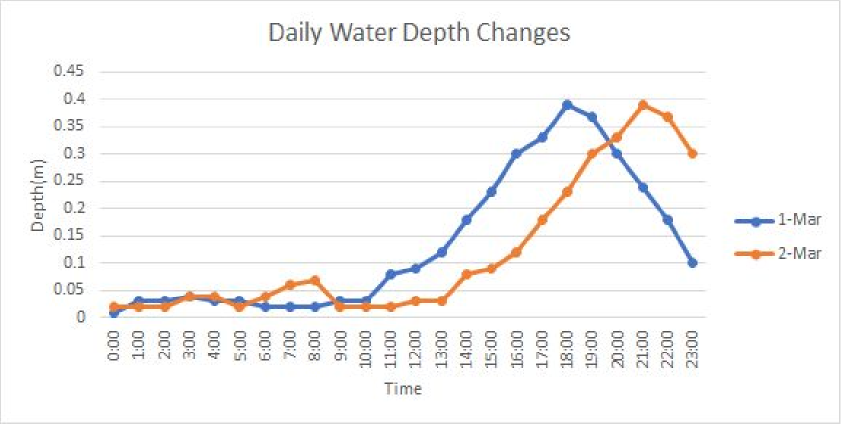


Figure 22: Line chart for comparing two days' water depth changes

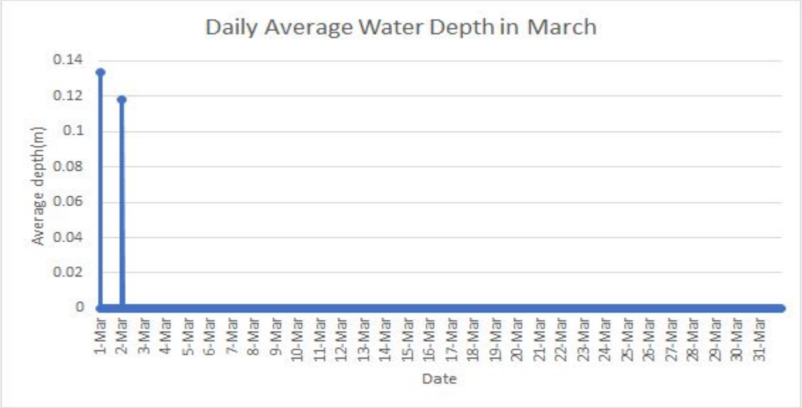


Figure 23: Line chart for comparing average water depth changes in one month or year.

- Varying water level due to weather.
- Diurnal flux

- Varying water level in different season.
- Climate changes.

Soil Analysis- Testing

Total height 1.7in
Clay height 0.5in
Silt height 0.2in

Sand height 1in

Figure 24: Jar test with soil sample #2 used to determine soil type

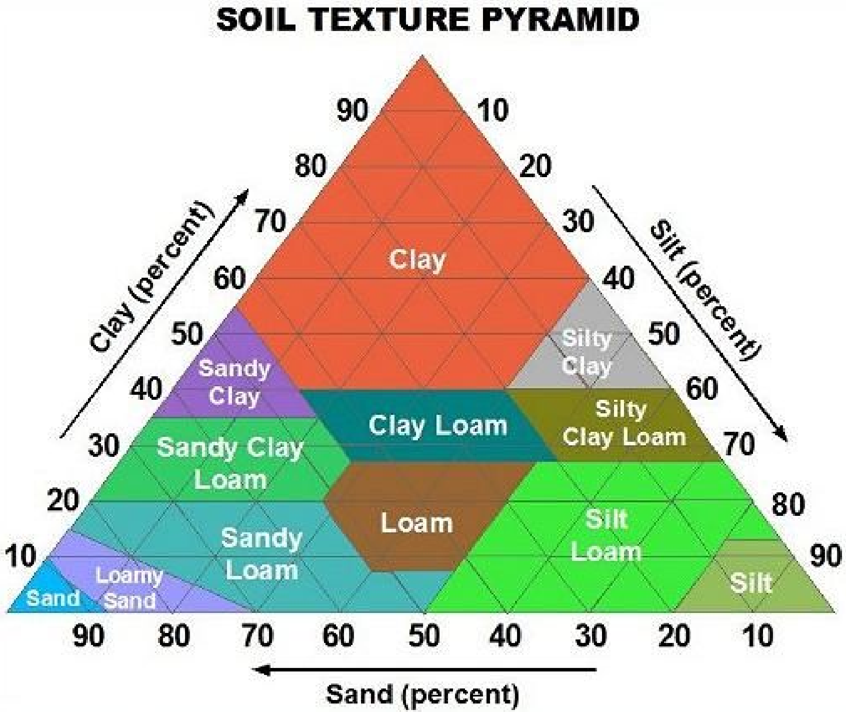


Figure 25: United States Dept. of Agriculture (USDA) Soil Texture Pyramid [5]

Equation 1: Used to determine % sand, % silt, and % clay [5]

$$\frac{Layer\ height}{Total\ height} x100 = \%\ Soil\ of\ Layer$$

Soil Analysis- Results


Figure 26: Soil sample 1


Figure 27: Soil sample 2


Figure 28: Soil sample 3


Figure 29: Soil sample 4


Figure 30: Soil sample 5

Table 1: Soil texture types determined from jar tests

Soil Texture Analysis Results						
Soil Sample	Depth Range (inches)	% Sand	% Silt	% Clay	% Total	Soil Type
1	0 to 4.5	44.4	50	5.6	100	Silt Loam
2	4.5 to 24	58.8	11.8	29.4	100	Sandy Clay Loam
3	24 to 32	50	21.4	28.6	100	Sandy Clay Loam
4	32 to 43	56.3	12.5	31.2	100	Sandy Clay Loam
5	43 to ≥125*	46.7	30	23.3	100	Loam

* Indicates depth at which the team stopped digging.

Budget Comparison

Table 2: Previous cost table associated with consulting and engineering services

Consulting Services	Total Time (hrs)	Rate (USD/hour)	Estimated Consulting Cost (USD)	Engineering Services	Estimated Engineering Cost (USD)
Project Manager	210.00	44.00	9,240.00	**Site Investigation**	80.00
				Monitoring Well	200.00
				Sampling	50.00
Design Engineer	190.00	32.00	6,080.00	**Static Water Level Detection**	85.00
Senior Engineer	160.00	70.00	11,200.00	**Water Quantity Detection**	90.00
EIT	150.00	60.00	9,000.00	**Data Transmission & Storage**	100.00
Total Labor Cost			**35,520.00**	**Total Engineering Cost**	**605.00**

Table 3: Current cost table associated with consulting and engineering services

Consulting Services	Total Time (hrs)	Rate (USD/hour)	Estimated Consulting Cost (USD)	Engineering Services	Estimated Engineering Cost (USD)
Project Manager	150.00	80.00	12,000.00	**Site Investigation**	50.00
				Monitoring Well	100.00
				Sampling	100.00
Design Engineer	180.00	80.00	14,400.00	**Static Water Level Detection**	65.00
Senior Engineer	190.00	70.00	13,300.00	**Water Quantity Detection**	50.00
EIT	170.00	60.00	10,200.00	**Data Transmission & Storage**	70.00
Total Labor Cost			**49,900.00**	**Total Engineering Cost**	**435.00**

USD= United States Dollars, EIT= Engineer In Training

Cost of Materials

Table 4: Costs associated with materials

Material	Unit	Amount	Cost per Unit (USD)	Total Cost (USD)
PVC Pipe	ft	10	1.63	16.3
PVC Pipe (Screened)	ft	2.5	8.84	22.1
Bentonite	lbs	75	0	0
Well Cap	ea	1	0.79	0.79
Well Point	ea	1	8	8
Silica Sand	lbs	100	0.99	9.97
PVC Coupler*	ea	1	2.18	2.18
Battery Holder	ea	1	10	10
PCB Bread Board	ea	1	5.6	5.6
Bluetooth Module	ea	1	9	9
SD Card Module	ea	2	12	24
32G SD Card	ea	1	14	14
Water level sensor	ea	1	65	65
Arduino with supporting tools	ea	1	40	40
Other Expenses:				
Shipping costs				8.95
Overall Cost:				235.89

ea= Each

Schedule

Table 5: Previous project schedule

Scope of Services		
Task	**Sub-Task**	**Sub-Sub-Task**
Site Investigation	Preparation	Investigation
Task 2: Design	Monitoring Well	Design Monitoring Well
		Sampling Equipment
	Water Pressure Transducer	Sensors
		Electric Circuit
		Structure
	Data Collection	
	Data Transmission	Transmission Node
		Arduino UNO Controller
		Wireless Transmission Module
		GSM/GPRS Development Version
Task 3: Building	Building Sampling Well	
	Building Pressure Transducer	
Task 4: Test	Measurement Test of the Water Depth	Pressure Transducer Test
		Monitoring Well Test
Task 5: Project Management	PDT Meetings	
	Technical Coordination Meetings	

Schedule (Cont.)

Table 6: Current project schedule

Schedule		
Task	**Sub-Task**	**Sub-Sub-Task**
Task 1: Site Investigation	Preparation (08/27-09/03)	Investigation
Task 2: Design	Monitoring Well (09/04-09/18)	Design Monitoring Well
		Sampling Equipment
	Water Pressure Transducer (09/04-09/18)	Pressure Transducer
		Wire Extension
	Data Storage (9/19-9/26)	SD Card
		SD Card Module
	Data Transmission (09/19-09/26)	Bluetooth Module
Task 3: Building	Building Sampling Well (09/26-10/17)	
	Building Monitoring System (10/18-10/25)	
Task 4: Test	Soil Analysis (10/26-11/02)	
	Measurement Test of the Water Depth (10/26-11/17)	Monitoring System Test
		Monitoring Well
	Data Analysis (11/03-11/17)	
Task 5: Project Management	PDT Meetings (08/27-11/30)	
	Technical Coordination Meetings (08/27-11/30)	

Triple Bottom Line

Social Aspect

Positive impact on community

- Local organizations get more involved with the community
- Get more involved with the scientific community

Educational purposes

- K-12 student involvement

Figure 31: Triple Bottom Line [6]

Environmental Aspect

Low impact

- Natural implementation location
- Minimal impact on surrounding environment

Economic Aspect

Low-cost

- Materials easily acquired and inexpensive
- Low maintenance, therefore low cost

Life-cycle

- Implementation, upkeep and disposal simple, therefore low cost

Acknowledgements

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References

[1] "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.

[2] "The Arboretum At Flagstaff", The Arboretum At Flagstaff, 2017. [Online]. Available: https://www.google.com/maps/place/The+Arboretum+At+Flagstaff/@35.2241046,-111.8059946,37896m/data=!3m1!1e3!4m5!3m4!1s0x872d85a5ede5b7cd:0x83126ce2d92d66ec!8m2!3d35.160305!4d-111.73091.

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[6] Icastusa.org. (2017).Triple Bottom Line. [online] Available at: http://www.icastusa.org/wp-content/uploads/2017/01/triple-bottom-line1.png

Questions?