OSU Polo Water Well Salinity Investigation in Relation to Natural Upwellings and Waste Water Injection Wells.

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Introduction:

Historically wildcatters and oil barons across the United States have believed they could drill for oil with no environmental consequences. Thoughts about the possible polluting effects that drilling, hydraulic fracturing, and injection wells could have on the water table and fault lines were nearly non-existent. It is not until the past few decades that major evidence has emerged that has demonstrated that these oil related practices are playing major roles in fault slippage that cause earthquakes and the pollution of water tables by injection wells. This has led to numerous studies led by geologists and hydrologists to determine if injection wells on oil rigs in particular, are the main culprit for earthquakes and water table pollution.

Nearly all of the oil rigs in the United States practice hydraulic fracturing and establish injection wells to dispose of waste water. Injection wells are used for “Injecting” waste water that was produced when drilling for oil. This water usually consists of brine (salt water), chemicals, and other various elements depending on the location. The water used in injection wells is a byproduct of hydraulic fracturing, a process where millions of gallons of water, sand, and chemicals are injected into the ground to break apart rock and the underlying surface. Contrary to popular belief “Hydraulic fracturing is used after the drilled hole is completed” (FracFocus 2010); this allows for the passage of water, sand, and chemicals to clear any remaining debris inside the bore hole. After drilling the borehole, the millions of gallons of water undergo multiple recycling processes where it is used for other oil and gas wells (Wastewater 2014). Once the water has been pumped into the well for hydraulic fracturing multiple times it is then sent to water treatment plants and then is injected back into the ground below the freshwater table for disposal. In some cases however, the disposal process of the water has been imperfect and has led to possible environmental issues including the pollution of drinking water (Wastewater 2014).

Project Description:

Premise:

The pollution of water wells from hydraulic fracturing and waste water injection on oil rigs leads me to the study of the OSU Polo Water Well. In January of 2014, the Oklahoma State University (OSU) Polo Club reported that a groundwater well on their property was suspected of being contaminated with salt water. This well once provided water for the stables and for the Polo Team. Personnel from the OSU Polo Club noticed that some of the horses were refusing to drink water sourced from the well (GEOL 5443).

In my research I would like to make progress on determining if the oil rig is causing the well to be poisonous. If it's not the oil rig, then is it natural causes such as an upwelling? Or some other outside force? Finally, in future studies I would like to determine ways to prevent the pollution of fresh water sources when hydraulic fracturing is taking place and conduct a study of the causes and effects and future prevention practices for the oil and gas industry's sake, and more importantly for the public's safety.

Methodology:

The focus of this study is to determine whether an injection well is the cause of polluting the OSU Polo Water Well. This injection well is within a half a mile of the OSU Polo Water Well, giving rise to the suspicion that the waste water being injected is in the same water table the OSU Polo Water Well is in. Permeable rock would allow the transportation of the polluted waste water into the Polo Well.

To determine whether the oil rig is responsible for the now polluted Polo well, direct current electrical resistivity will be used in order to discover the underlying geological structures. The practice of direct current electrical resistivity is when geophysicists go to the field and determine the conductivity of minerals, the thickness of geological strata, and discover geological and structural anomalies (SWRI 2014). Moreover, direct current electrical resistivity is used to obtain electron images of all the different water sources that are going into the polluted aquifer. This is done by "multichannel, multiple-electrode resistivity systems with efficient software to rapidly and accurately conduct electrical resistivity imaging surveys" (SWRI 2014).

After I have done this, I will be able to see a clear image of all the water sources and the tributaries in the study area. This will also allow me to see whether the rock layer within the water table is permeable enough to allow the passage of injected waste water from the oil rig. If I discover that the underlying rock is not permeable, then a natural upwelling is most likely the cause for the salinity of the OSU Polo Water Well. An upwelling is when cold water very deep beneath the surface rises and carries salt and other minerals with it (NOAA 2013). Once it reaches the water table it mixes with surrounding water wells and releases its salts and minerals polluting the water because of an overload of sodium (NOAA 2013). Direct current electrical resistivity would also allow me to determine if a natural upwelling is the cause for the polluted OSU Polo Water Well.

If it is determined that the underlying rock is permeable enough to allow the passage of waste water from the oil rig to the OSU Polo water wells, then I will attempt to gain information on the oil rig. This information will include its exact location and its well depth. This information can be accessed through the Oklahoma Corporation Commission website and also the Payne County Assessor's Office. Information including what is the in the injected waste water such as the chemicals being used can only be obtained through the oil company that owns the oil rig. This information would generally be accessible to the public if they communicated with the oil company, but if the oil company knows it has polluted water wells they may make it more difficult to obtain information due to legal circumstances it could involve them in.

Location:

Address: 1860 W. 32nd St., Stillwater, Oklahoma, 74074 Legal Description: These records were received by the Payne County Assessor and it was indicated that the property is used by OSU, yet it is privately owned. The county assessor's office verified that the account number for the polo club and owner is #4131. Some additional legal information besides what is described in this report for the property can be attained through the Payne County Assessor's office by referencing this account (GEOL 5453).

The legal description of the property is as follows: "Total land area: 30.5 acres within the E\2 of SW \4 of the SE \4 Section 27, Township 19N, Range 2E; and a tract beginning at the SW corner of the E\2 of the SW \4 of the SE \4; W660ft N, 693ft E, 660ft S, 693ft P.O.B. (point of beginning)"(Payne County 2014).

Oklahoma State Geology Class 5443 discovered that the property is an "L" shaped tract, used by the OSU Polo Club for housing, training, riding, feeding, and watering of horses. The main driveway runs into the property in a North-South direction. There are two ponds on the property, one of which is used to water the horses when the water well is unavailable, or in this case, poisonous (NE pond). A well that was regularly used to water the horses is located on the south end of the eastern tract of land. A hand pump well in disrepair was laboriously used to help provide water for the horses and is located shortly NE of the "barn" located on the tract of land (GEOL 5453).

This will be where the majority of the fieldwork will take place including collecting data such as water samples and collecting geophysical data, and making visual observations. Lab work will be done in Geology Lab 007 at Oklahoma State University and will include data interpretation as well as the testing of water and rock samples.

Water Quality:

Geology Class 5443 monitored two wells at the OSU Polo Club for water quality. Well 1 was pumped for approximately 10 minutes to ensure that the sampled water was representative of the aquifer. Water was then run through a flow cell from which samples were collected. The water was sampled with a 50 ml syringe fitted with nylon filters to remove particles greater than 0.45 µm. Two sample container types were used on site for the separate collection of samples for cation and anion analysis. Samples for anions were stored un-acidified in 30 mL HDPE bottles and samples for cations were stored in 60 mL HDPE bottles that were pre-acidified with high purity nitric acid to a pH < 2 (GEOL 5443).

Water quality parameters of a sample from Well 1 (the main water source) were analyzed in-situ using a hand-held YSI556 MPS or multiparameter probe. "Water quality parameters including temperature, pH, and total dissolved solids (TDS) were recorded. The TDS measurements were high, with a concentration of 9,500 mg/L which is too high for human consumption. The favorability limit recommended by the World Health Organization (WHO) is 1,200 mg/L" (WHO 2014). More in-depth analysis of the water chemistry from the well indicated that the hydro-facies is a Na-SO4-Cl composition (GEOL 5443).

The World Health Organization has no set limit for a permissible level of TDS for human consumption however the favorability ranking for TDS concentration is considered unacceptable at concentrations above 1,200 mg/L (WHO 2014). Well 2 water was dark orange and unfilterable and was not analyzed by Geology Class 5443 (GEOL 5443).

In the water test, the relative proportion of the ions in the solution were uncharacteristic for the region, because of this, I will collect more water samples from not only Well 1 but also Well 2 because it will allow me to establish if both wells are contaminated. If Well 2 is also contaminated it could either mean it is being affected also by the injected waste water from the oil rig, or that its water aquifer is interconnected to Well 1's water aquifer. To determine this, direct current electrical resistivity will be used to show a 3D image of the underlying surface allowing me to see if the wells are connected. If Well 2 is not connected to Well 1 and it is also not polluted with sodium (salt), then this would most likely mean that a natural upwelling was the cause for Well 1's salinity. This is suspected because it is theoretically impossible for the two wells to be in a different water table and if injected waste water has poisoned Well 1 it should also poison Well 2 being that they are in close proximity to each other.

Geology:

The OSU Polo site's elevation is approximately 875ft above sea level. It is on the Oscar Group formation that is composed primarily of shale with multiple layers of limestone from the Pennsylvanian age. The thickness of the Oscar group is estimated at 400ft but could vary in some areas. Based on the close relation to another formation and because of its position inaccuracy, the well in review could be part of the Wellington Formation, which is composed of mostly of red-brown shale to fine-grained sandstone and most likely mudstone conglomerate from the Permian age. The thickness of this formation is about 850ft. The north end of the site sits on an alluvium formation of Quaternary age. This alluvium consists of sand silt clay and gravel; ideal for sand storage of groundwater. Thickness ranges from 30ft to 80ft depending on location (GEOL 5443).

Because of inaccuracies in the geological formations, it makes it essential for me to conduct direct current electrical resistivity. This will be done by staking electrode rods into the ground in a linear formation nearly 10ft apart. How many electrode rods we place will be determined by the soil; if the soil is clay (a harder soil) then fewer rods will be placed, if the soil is sandy loam (a softer soil) then it will allow me to place more electrode rods. Once we have the rods in place over the desired distance then I will attach electrode cables to the rods. These electrode cables will run to the switch box which is then attached to the actual electrical resistivity system. The system works by sending electrical waves through the electrode rods which then sends the waves into the underlying earth. These waves then return to the rods producing electrical images. This image is sent to through the electrode cables and is then relayed by the switch box which communicates this information to the direct current electrical resistivity system. Once the system has processed the numerous electrical images it then produces them into a single 3D image that is visual to the researcher. These images should allow me to clearly see if the underlying rock is permeable enough for the waste water to transport through, if this is true, then this should be a clear conclusion that the injection well used by the oil rig is the culprit for the pollution of the OSU Polo Water Well.

Hydrology:

The site of the OSU Polo team property is located above Quaternary alluvium aquifer material. It is not located near any river or stream. It does however have two small ponds with a combined acreage of nearly 0.25 acres more or less. The ponds are primarily filled by surface water runoff and aside from the well being studied they make up the only other source of water for the Polo Club horses. During the summer months it has been noted that the pond levels are low or empty due to evaporation and a lack of rainfall (GEOL 5443).

When Geology Class 5443 was in the process of conducting research they did preliminary investigation that was conducted by online databases accessed through the Oklahoma Water Resource Board (OWRB). According to the OWRB database, the class discovered there are only 16 groundwater wells within a one mile radius of the site location. All of these wells are classified as domestic wells with an average approximate yield of 14 gallons per minute. These wells are recorded as having an average total depth of 167 feet and approximately reach water on average at 95 feet (OWRB 2014). There were groundwater wells within the one mile radius that did not have notable attributes recorded in the OWRB database. Three wells did not have a first water measurement or approximate yield value, while only one well did not have a recorded total depth value, this well was marked for possible reflection later on the study (GEOL 5443).

One issue that will be studied are the surrounding wells in the area. Currently the only wells I have information on are the two water wells on the OSU Polo Club grounds. This is only a small area that the injected waste water could be poisoning. A natural upwelling is also capable of polluting multiple wells that pull water from the same aquifer. The size of this aquifer is unknown and will be determined by direct current electrical resistivity. Once I have information on other wells in the surrounding areas it will allow me to see if the OSU Polo Well is an anomaly of its own, or if other wells are experiencing the same increase in salinity (salt). To gather information of these wells I will have to conduct analytical research through the OWRB data base. This will give me general information such as the wells' locations and who owns the property. Once I have gathered this information I will input it onto an excel spreadsheet for clarity. Then I will go through the list of each property owner and I will attempt verbal communication over the phone or will visit them in hope of gaining permission to access their property in order to take water samples. Once these samples are taken from numerous wells in the surrounding areas it will give me information that will tell me what the "norm" should be. Then I will compare and contrast the characteristics of the given water samples to the water samples taken on the OSU Polo grounds.

Limitations:

Limitations include that the main source for well data is the Oklahoma Water Resources Board (OWRB) which does not have any chemical or precise lithological information for wells in this area. If property owners do not allow me permission on to their property for water testing then significant information could be lost. Chemical data is documented in the Oklahoma Hydrologic Atlases (OHA); however the most recent relevant map data was published in 1975 and 1980, to access more recent information, the OHA will need to produce another map with updated chemical features of the area. If this is not possible verbal communication will be my main source to gather recent up to date chemical data from the OHA. This would not be ideal because it would limit my visual interpretation of the data. In addition, the property managers of the OSU Polo Well had no previous records on water quality for either of their wells.

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Biographical Sketch:

I am a freshman at Oklahoma State University working towards a Bachelor of Science in Geology. After completing my undergraduate studies I plan on attending graduate school at Cornell University in hope of obtaining a Master Degree in Business Management. I hope to do this because of their prestigious reputation in the geological field. After completing my Master's Degree I plan on obtaining a Geologist position for an energy company. After a few years of experience, I will use my Master's degree to pursue a career in the overseeing and management of other Geologists for my given company. Currently I am a member of The Freshman Research Scholars Program at Oklahoma State University; the purpose of this program is introduce high achieving freshmen into the world of undergraduate research under the guidance of a tenured professor which will be our mentor. I am also a member of the Oklahoma State Honors College; this program is for high academic achieving students to participate in smaller classes in hope of enriching the students learning experience.

In the spring, I plan to pursue the proposed study. I selected this topic because my major is Geology and I plan on using my degree to undertake a career in energy and conservation; this topic will help build a foundation of knowledge and experience that will be beneficial in the future. Moreover, I chose this topic because my research mentor, Dr. Halihan, is a Hydrologist and I wanted a topic that would tie into both oil and water. I will be under his guidance throughout this process as we develop a research plan and establish what my future goals will be for this project. I wanted a topic that my mentor would actually have the knowledge to assist me if I ran into trouble or needed advice on my project.

Budget:

The budget for this project will include primarily equipment, transportation, and expendables. Equipment includes: A Direct Current Electrical Resistivity System which costs $20,000 and was provided by the Skinner Scholarship Fund in 2010. A set of Electrode Cables which cost $12,500 and were provided by the Skinner Scholarship Fund 2010. A set of Electrode Stakes which cost $1,400 and were also provided by the Skinner Scholarship Fund 2010. A Switch Box which costs $10,000 and was provided by the Boone Pickens Geology Fund in 2012. A Differential GPS System which costs $30,000 was also funded by the Boone Pickens Geology Fund in 2012. A set of Water Level Meters which cost $750 and Water Sample Tests which cost $50 a piece X 10 water samples was funded by the infrastructure of the OSU School of Geology in 2013. Transportation will be $0.56 per mile and will be funded by the OSU School of Geology but will be subsidized by the US Federal Government. Expendables such as meals will be funded by the OSU School of Geology. All the above equipment is now a part of the OSU School of Geology's infrastructure and is maintained by Dr. Halihan. In total the budget for this project will be nearly $76,000 (Halihan 2014).