Problem Statement

How might we improve drainage systems around septic tanks in clay soil environments in order to prevent further pollution of the water supply that causes adverse environmental and health effects in rural communities?

Problem

The residents of Lowndes County, Alabama are faced with a wastewater management crisis where their failing decentralized wastewater systems are causing harmful pools of wastewater to populate their backyards. Lowndes County is in the Black Belt Region of the United States which is known for its clay soils. Because of the lack of infrastructure and the high concentration of clay in the soil, the traditional septic tank design and other decentralized wastewater systems are unable to disperse the wastewater. Additionally, the pipes that make up underground wastewater systems are broken apart by the expansion and contraction of the clay soil. Depending on the severity of the movement, this can render the wastewater system useless.

Significance

This problem places many residents of Lowndes County in a precarious situation. Due to the failure of traditional wastewater systems, the residents are resorting to straight piping. This practice is attaching a pipe to their appliances and draining their wastewater into their backyards. Because the wastewater is slow to percolate into the soil, it collects and has detrimental effects on human health, as well as environmental health. (Cleek, 2015). Studies show that a significant number of children in Lowndes County carry DNA evidence of hookworm and other parasites foreign to the United States. These diseases are usually found in tropical developing countries where people encounter raw sewage more frequently. Moreover, public health officials have warned children to refrain from playing in the yard because of the contaminated soil. (Koplowitz, 2016). Additionally, if the wastewater discharge or runoff is polluting a nearby body of water, the residents could face legal consequences. The Environmental Protection Agency has set the Clean Water Act which makes it unlawful to discharge any pollutant from a point source into navigable waters per certain water quality standards. (Environmental Protection Agency, 2017).

Allowing this problem to continue comes at a huge cost to the people of Lowndes County. From a financial perspective, the residents must spend at least $1500 to install or replace a septic tank. (Boone, 2014). This is a tremendous burden where 80 percent of residents need to install their own sewage systems and 27 percent live below to poverty line. (Koplowitz, 2016). However, the biggest cost comes from the quality of living for the residents. Beyond the heavy stench of sewage in the area, the pools of wastewater act as breeding grounds for diseases, as mentioned previously, and for mosquitos which facilitate these illnesses.

The single cause of these terrible conditions is the high concentration of clay in the soil. Although the soil consists of many different type clays, they share the characteristic of having low permeability. (United States Department of Agriculture, 2017). The traditional septic design that is used relies on gravity, and the soil around the tank to disperse the water. This has proven to be ineffective in this area because the clay tends to hold the water. Consequently, when it rains, the soil around the tank is already saturated, and the water is trapped in the tank. When it begins to overflow, it cannot exit into the soil around it, so instead, the wastewater is forced back into the residents' homes. Another problem caused by the soil is the breaking of underground pipes. Naturally, the clay soils swell when saturated with water, and conversely, they shrink when the water dries. This process becomes cyclical and causes damage to the underground systems over time. (Rogers, Olshansky, & Rogers, 1985). Unlike other areas of the Black Belt Region, Lowndes County has fallen into these conditions because it lacks the infrastructure and economic stability to support a centralized and more effective solution.

By finding a solution to this problem, the community would grow much healthier. Throughout the county, the spread of foreign tropical diseases and presence of parasites would decrease by having less pools of wastewater collecting on the ground surface. Other than general health, the environment would also benefit. The wastewater running off into rivers and the fields of farmers would be stopped. In general, the overall aesthetic and quality of living in Lowndes County would increase. The smell of sewage would be reduced, and the ominous pools would disappear. Furthermore, the residents can perform recreational activities in their own homes without having to worry about the contaminated soils. (Koplowitz, 2016). C.M Holcombe of Lowndes County said "she is waiting for the year when spring break comes and her son and grandchildren can go outside and play in their yard. Or for the night when she can fall to sleep to the sound of rain and not fear waking up in the morning". (Cleek, 2015).

Stakeholders

The residents of Lowndes County have been trying to get help with this problem for years. Legally, Alabama requires that all homes have a working wastewater management system; however, with a quarter of the residents living in poverty, many residents cannot afford to invest in a septic system that are prone to fail. In the past years, there have been many attempted solutions. Each has failed in succession and has cost the trust and enthusiasm of the residents in a potential solution.

Professor Joe Brown is an environmental engineering professor at Georgia Tech. He describes the problem as "an intractable, unsolved problem and a legacy of the post-plantation non-economy that's in the Black Belt." (Cleek, 2015). Because the people of Lowndes County are not well connected politically or economically, Brown believes that is why this problem has gone unaddressed and unsolved. Dr. Brown remains optimistic in his search for an affordable, effective solution.

In the past, the local government has supported past solutions. These solutions will be discussed and analyzed in more detail later, but in short, they failed. Wasting millions of dollars on rash solutions has made the local government averse to outside ideas and slow to support a new solution. In a report by the Unitarian Universalist Service Committee, "The Invisible Crisis:

Water Unaffordability in the United States", the situation in Lowndes County is blamed on racial disenfranchisement and government neglect. (Koplowitz, 2016).

They are many organizations that have expressed their concern for citizens facing these problems. A report by the Unitarian Universalist Service Committee criticizes the government for making access to sanitary conditions "a privilege, not a right." (Koplowitz, 2016). Another organization in this field is the Alabama Center for Rural Enterprise (ACRE). Founded by Catherine Flowers, whom we have been in contact, this organization is focused on bringing resources and finding solutions to this wastewater crisis that is occurring in Lowndes County. This organization is committed to finding a sustainable solution and expose the systematic and structural injustices that have caused these problems. (Lewis, 2016).

Context and Existing Solutions

In the Lowndes County area, there have been many attempted solutions in the past years. Recently in 2015, the city of Uniontown obtained a $4.8 million grant and hired Sentell Engineering Inc. The city approved of a plan to build a spray field system to disperse the wastewater. Although it may have seemed like an innovative solution, the attempted solution did not account for the low permeability of the clay soil. From this sewer reporting form, it was reported that there was a large amount of contaminated discharge that was unable to percolate into the soil, and it spread into the surrounding area. (Piven, 2015). Thus, the city is left with an ineffective system, and furthermore, the city cannot close out of the grant or apply for additional funding. (Cleek, 2015). Another attempted solution was in Hayneville. The city tried to implement a lagoon sewage system that directed the sewage from the homes into a pond. However, as the report stated "When it rains, raw sewage overflows and backs up into the lawns and bathtubs of residents who live nearby." (Koplowitz, 2016). The inadequacies in these designs are apparent in their attempt to provide an alternative to a septic tank. Ultimately, they switch the design of the wastewater system, but they still fail because they do not account for and innovate around the clay soils. Because of these failed solutions, the local governments have become hesitant to support outside solutions and the residents have become untrusting.

In our solution, we want to alter the septic system so that it will be able to function properly. To help percolate large volumes of water, we plan to incorporate a dry well. To prevent the underground pipes from breaking, we will use a combination of packing and wrapping with geotextiles. To aid in the dispersion of water, we aim to use plants that thrive in clay soil and can uptake large amount of water.

Why is it still a problem?

This is a complex problem that is hindered by a hesitant government and a skeptical community. Our current solution is looking to redesign the traditional septic tank system by supplementing the design with a dry well, incorporating geotextiles with the piping, and planting high water intake plants. More details of this solution will be further discussed and analyzed in the proposed work section. Currently, our team is working on determining the effectiveness of our multifaceted system. Our next step is to create a scaled down model and test the system in a variety of ways. Given the economic status of the community, we would need to search for outside funding and adapt the system to be as cost-effective as possible. A standard concrete dry well costs between $1500 to $4000. (HomeAdvisor, 2017). Adapting this expensive component of our system to be less costly is one of our obstacles. Perhaps, our biggest obstacle would be to implement the final design. Due to the lack of support and enthusiasm for another solution in the community, it may be difficult to find residents who would want us to install our solution.

Proposed Work

Goal

Our goal is to find a cheap system that will contain greywater from homes in the ground and stop it from overflowing, causing septic tank system failure, and contaminating nearby rivers. We are focusing on a decentralized system that can be installed in individual homes, and if we're successful, it can be implemented across the black belt region in the United States. It would prevent sewage from backing into homes, illegal straight piping, and provides a cleaner environment without hazardous disease concerns. Our solution would be simple to implement, so the residents will be more willing to install it to their home. It would also be affordable for the residents as it last for decades so it would not be a recurring financial burden.

Objectives

(Objective I) Objective one for our project is finding an alternative to a breaking pipe by either cushioning the pipe or finding an alternative yet existing pipe material that functions even with expanding and contracting of the vertisol.

The nature of the vertisol causes the soil to contract and expand which causes the pipe to break and eventually the wastewater management becomes ineffective. From previous calculation that our team conducted, it was concluded that that the surrounding pressure of the soil exerted on the pipe is 8300 Ibf which far exceeds the tensile strength of the pipe (5500 Ibf). This eventually causes the pipe to deform and even break. Therefore, finding the alternative to the breaking pipe is a critical step for this project. Having a strong and non-deformable pipe is important since the pipe is an ultimate transport system that transfers the wastewater to the septic tank. The wastewater system's efficiency is highly related to the ability of the pipe to transport the fluid. Moreover, the constant breakage of the pipe is not cost effective in the long term especially for the rural communities where the investment for the infrastructure is low and there's not enough money to improve or fix the infrastructure. Thus, for Lowndes county to have an effective wastewater system, it would be critical to find a long-lasting as well as a durable pipe that is suitable and sustainable in the environment of the Lowndes county.

To achieve this objective, a series of actions would be required. The big idea for the solution is covering the pipe with a geotextile fabric. The geotextile could be used as a cushion for the pipe against the adjacent soils. For the geotextile fabric, the nonwoven one will be used. According to Advanced Drainage System (ADS), for a subsurface drainage, the nonwoven lightweight geotextiles could function as a filter. The nonwoven fabric is a polypropylene filament that is woven into a mat-like fiber and it does not tear. Furthermore, it is excellent filtration of water. Also, this nonwoven geotextile impedes the surrounding soil from clogging or deforming the pipe. It is known for effective for clay soils which is the universal soil in Lowndes county. Thus, to see if this is effective way of solving the problem, we will create a small experiment. The materials used would be a miniature pipe (0.5m length and 0.25m in diameter), tank (0.75m x 0.75m x 0.75m), a nonwoven geotextile sample that could cover the pipe and a vertisol that could fill up the volume of the tank. First of all, the pipe wrapped by the light weight nonwoven geotextile will be placed in the tank. Then, the vertisol will cover the rest of the volume. Next, the soil will be going through various extreme weather conditions, extreme drying for 2 days and extreme saturation of water for another two days. We will observe how effective geotextiles protect the pipes through this experiment for at least seven days. If it doesn't work, we will move on to finding a flexible pipe that is a rubber-based rather than creating a new one. The reason why the pipes are breaking in Lowndes county is that the pipes are not flexible enough to withstand the expansion and contraction of the soil. One solution to this problem is substituting the existing piping with cross-linked polyethylene (PEX) which is more flexible. PEX is known to be resistant to the growing cracks and changing pressure which could be useful for vertisol (Crosslinked PEX).

The success of the geotextile pipe could be measured by the degree of the pipe deformation. If the pipe deforms to an extreme degree, or even a little bit in seven days, it would indicate that this is not the best solution. However, if the pipe barely breaks, and the nonwoven geotextiles indeed act as a cushion against the adjacent vertisol, then that would be the indicator of the success of this method.

There are several anticipated problems in reaching Objective I. First of all, the full-scale analysis of how effective the nonwoven geotextile cushioning works in Lowndes county would be difficult at this stage. Thus, the experiment would start from the miniature scale and carefully implemented if it works through a series of experiments. Furthermore, there may be some cultural barrier where the residents in the Lowndes county may feel uncomfortable to go through another trials and error. However, we will overcome this barrier by doing some activity that could build up strong bond between us and the residents in Lowndes county. For instance, our team could ask residents to help both designing and building the system together. This type of activity will help us to build a stronger connection and trust between us and the residents and allow them to have input on the system we hope to implement. Also, digging up the old pipes and implementing the new pipe system would be a costly process and the cooperation with the local government would be required. Moreover, the funding for the new pipe or covering the existing pipe with a geotextile would need a big investment from the government. Although there are many obstacles presented to achieve the first objective, through many connections that our team has with local experts and our team's hard work, we would be able to plough through these obstacles.

Objective II: Relating to the flooding of the backyard/ back up in the home. (Dry well)

Objective two of our project relates to the decreasing of overwhelming amounts of liquid being put out into the currently used septic tank system in comparison to the rate at which the vertisol in this area can intake and percolate. The main problem with the systems in place in the rural Black Belt region of Alabama is that the tank commonly backs up into the house or overflows, causing the whole unit to fail. This had been the most obvious problem that the sanitation field faces in these homes. Other methods of waste water dispersion, such as drainage fields and spray irrigation, have been attempted but ultimately, it is usual and likely for these to fail as well. The common failure point in these trials has always been efficient percolation of the water into the ground. This is a problem that must be mitigated along with the other failure points, however it is a vital part and it is the core issue of the waste dispersion techniques. If not fixed, there will be no way that the dense clay will be able to percolate the water properly, like the techniques being used already. This objective will need to be accomplished by breaking it down into three main parts, the slowing of the dispersion of liquid into the clay soil, the retention and controlling of the waste water, and the alternate assistance of the percolation.

The slowing of the dispersion rate is a critical step in our solution. Often times it will rain and while clay can absorb the water, the soil is very much characterized as having poor percolation and dispersion rates. One way to slow down the amount of water trying to go into the soil is by having different methods for it to go into the soil. Ideas such as a dry well attempt to maximise this through having a concrete barrier slow the liquid from going into the soil. Also, the idea of adding increasingly sized rocks to an open bottom container is plausible in order to slow this down as well as providing a temporary storage for any water that cannot soak through at that time. This ties majorly into the second part of the objective, controlling the retained water. This is a major problem because when the soil hits its limit, right now the septic tank systems will clog because the water is not filtering out properly, another common reason why the tank will back up. Methods to mitigate this includes the open bottom container as well as second tank area to hold the water while it is being dispersed, either traditionally through the soil or through an alternate way. Alternate methods of dispersion are a great way to try and relieve burden on the soil and provide another route of water percolation. An idea to solve this is the incorporation of high water uptake vegetation in the top of the holding container/ well area, potentially even adding a layer of different soil and combining drip irrigation that can soak through. More tests would need to be conducted on this idea however it is one that can be low cost and potentially, very effective by the moving of the wastewater to a source not reliant on the vertisol.

Success of this objective can be easily determined by checking the amount of water in the tank on a regular basis, focusing on times where the system is processing a higher than usual amount of liquid such as holidays when more people are putting strain on the system and rainy days where the soil is already being saturated with water. Whereas failure would be obvious to see, involving the backing up or overflowing of the system.

Currently, we are working to gain a better of idea of the factors that affect the dry well's effectiveness. Using a mass balance analysis of the well, there are a number of important factors, such as precipitation, runoff, evapotranspiration, and the seepage, that we must take into account. To make sure our calculations are accurate, we are researching and learning about the various parameters that define seepage.

Anticipated problems and obstacles that this objective face in particular that could cause a failure of the system includes the budget, the percolation rates and load management. Budget is a major issue, previously stated, that will also impact this aspect of the system solution. The removal and the new testing and implementation of the units will be even more expensive that testing the pipe strain dispersion. It requires more real life scenarios that not only will be expensive, but also will need a long duration of testing and altering in order to pinpoint what changes are helping and what else can be improved in order to best work with the challenging vertisol, instead of against it.

Project Team

Our team will have about 5 students. A team with an odd number of members prevents a tie when it comes to decision making. Furthermore, we feel as though having a group of this size promotes creativity and a diversity of ideas, which may improve the odds of making a correct decision. Even-numbered groups can make decisions, but the decision-making may take more time on average. A group's collective intelligence is not strongly correlated with the average or maximum individual intelligence of group members but is correlated with the average social sensitivity of group members (Wolley 687). After researching the relationship between group dynamics and group size, Wolley found that the optimal group size is 4.6 members (688). Therefore, in order to be as effective as possible, we will aim to keep about 5 people on the team for next semester.

One person will be the designated liaison. The liaison will keep the group members and our aids in touch. Our aids include, but are not limited to Catherine Flowers, Joe Brown, Susan Burns, and Nelson Brooke. Furthermore, our liaison will contact organizations that will be needed to test our dry wells and pipes as well as organizations that will be able to install the dry wells and pipes into residents' backyards. Additionally, once Catherine Flowers introduces us to some willing homeowners, the liaison will gather their contact information and learn more about the problems the residents are facing, what they want to be accomplished, and what they can afford. The liaison must be social, empathetic, and influential. These soft skills are required to maintain a strong relationship with the people associated with Lowndes County. The liaison will have other responsibilities as well, but those duties will be assigned as they come up.

Primarily, the entire group will brainstorm and create a plan on how to create or find the both the appropriate pipes or geotextiles and the experiment to test the solution. A possibility is to split the team into two groups. The group working on the experiment must be able to recreate the conditions in Lowndes County; therefore, it is preferable that the team working on the experiment visit Lowndes County before beginning. The team working on the solution must be able to foresee the problems each possible solution will face once implemented in Lowndes County. They must be open-minded and persistent. The process for creating new durable pipes may be difficult, but the team must persevere. When the team is stuck on an aspect of the experiment or pipe creation, all members can come up with solutions to overcome these obstacles.

All group members must be respectful and willing to share their thoughts and opinions when they are concerned. This will help the team progress and make sure that no member is left behind. Furthermore, asking questions and sharing opinions will keep the group grounded and realistic. The group members must be devoted to the project and make ample time in their schedules to work on the project effectively. Our time will be spent working on the solution and experiment. Additionally, we want to maintain relations with Lowndes County to improve our understandings and make sure our solution is what the residents need.

Our current advisor, Courtney, has agreed to be our advisor next year as well. However, we know that she will not be completely available during the fall semester; therefore, we have three individuals that we would like to contact who could serve as our official facilitator including Dr. Joe Brown, Dr. Susan Burns, and Dr. Coon.

Timeline

Summer '17

- Action: Collect water quality data from local bodies of water near Whitehall to assess degree of contamination. Goal: Gather data from at least 3 major bodies of water.
- Action: Establish relationship with community in order to conduct demographic surveys on septic tank issues. Goal: Assess at least 100 residents

Fall '17

- Action: Create and conduct an experiment to assess soil compression, flow rate out of septic tank in vertisol, and max soil absorbency. Goal: Collect adequate data to aid the development of a multifaceted solution.

Spring '18

- Action: Create a solution prototype that addresses all aspects of our problem space. Goal: Test solution before the end of the semester and gather data regarding its effieciency.

Summer '18

- Action: Modify existing prototype to meet needs of solution. Goal: Produce fully functional solution by Fall 2018.

Fall '18

- Action: Implement solution in Whitehall on a mass scale. Goal: Install new systems in at least 25% of homes.

Budget

Materials and Supplies

- 50 Gallon Polypropylene Dry Well Kit - $169.00
  - A 2 ft diameter by 2 ft tall (plus 5 inch high lid) 28.75 inch overall height, heavy-duty, recycled high-density polyethylene HDPE drywell provides 48+ gallons of initial surge capacity, which is equal to 74 lineal feet of 4 inch diameter sewer pipe. With several feet of gravel under and around it, a single drywell could dispose thousands of gallons of water in properly percolating soils. https://www.thenaturalhome.com/drywellinstallation.htm
- Nonwoven Geotextile Cost - $99.99
  - This heavy duty 8 oz non-woven polypropylene geotextile provides superior physical and hydraulic properties in addition to high tensile strength. Ideal for soil filtration. In addition to their high tensile strength, these geotextiles offer excellent filter properties and help to prevent the dirt and aggregate from clogging up your drains thus extending the life and increasing the performance. https://www.agriculturesolutions.com/products/agricultural-fabrics/drainage-filtration-and-weed-fabric/srw-ec8-non-woven-8oz-drainage-and-filtration-fabric-6-x-100-detail?
- 10 Hibiscus Seeds - $2.50
  - The Hibiscus plant is a fast-uptake plant that we are planning to incorporate into our design.
- Pipe Development Costs:
  - RS4 Rubber Hose (flexibility): ~$50 per ft
    The Model RS4 is a high grade sanitary suction hose designed for a variety of applications. The white nitrile tube offers excellent protection against oily foods and mild chemicals. This will be used for the inner lining of our pipe design to provide flexibility.
    http://www.flexicraft.com/Industrial_Hose/RS4/
  - RhinoFLEX 20' Sewer Hose Kit with Swivel Fitting: $40.21
    RhinoFLEX sewer hose retains its shape once it's set until unhooked and stored. Made with 23 mils of heavy-duty polyolefin reinforced with steel wire. We will be using this and putting under the stress of the Lowndes County soil to see if it would function in that environment.
    https://www.amazon.com/Camco-39765-RhinoFLEX-Extension-Fitting/dp/B007H2RR78?th=1
  - Industrial Swivel Joint: ~$200
    The swivel expansion joint is capable of rotating + or - 15º from its axis,

combined with the longitudinal expansion, allows stress free installation while at the same time providing flexibility at normally fixed positions to compensate for natural movement of the soil. Wrapped in a waterproofing membrane with copper sulphate to deter root intrusion. The swivel joint will alleviate breakage of pipe line at foundation level and at inlet and outlet of all tank systems. This is for use in underground sewer and storm water drains; it is available in 100 mm, 150 mm and 225 mm pipe sizes.
http://www.stormplastics.com.au/swivel_joints.html

Equipment

- Nonwoven Fabric Cutting Machine - Lab
- Hydraulic Press - Lab

    We will be using a hydraulic press type machine to put pipes and materials under the soil conditions found in the Lowndes County area and analysing their effectiveness.

Travel

- Site Visits: $250-$300 per visit
    - Hotel: $50 per night
    - Mileage: $0.50*400mi = $200 return

Expected Outcomes and Future Directions

Next year we will start collecting water samples, making experiments to test the feasibility of our proposed solutions, and establishing connections with the community. During summer and the fall semester, we will first collect water quality data to determine the degree of contamination and conduct experiments with geotextiles, drywell, and high water uptake vegetation. At the same time, we will maintain contact with Catherine Flowers and Nelson Brooke for local help and gain trust from the residents. Professor Joe Brown and Susan Burns can provide technical expertise for water sampling and consult us with the structural integrity of our solution. By the end of the year we should have a working prototype, and it will have a prototype installed as a test case. If everything worked as intended, we will look into acquiring funding to expand. Possible sources of funding are the local and state government. We believe the Alabama Center for Rural Enterprise Community Development Corporation (ACRE) and the Alabama River Keepers can help us advocate our solution to both the residents and the government.

Sources

Boone, Mary. (2014). *How Much Do Septic Systems Cost to Install?* Retrieved March 29, 2017 from https://www.zillow.com/blog/cost-to-install-septic-system-150191/

Cleek, Ashley. (2015). *Filthy water and shoddy sewers plague poor Black Belt Counties.* Retrieved March 29, 2017 from http://america.aljazeera.com/articles/2015/6/3/filthy-Water-and-poor-sewers-plague-poor-black-belt-counties.html

Crosslinked Polyethylene (PEX) Pipe & Tubing (pp. 1-12, Rep.). (2013). Irving, TX: Plastics Pipe Institute . Retrieved April 11, 2017, from http://www.plasticpipe.org/pdf/tn-17_crosslinked_polyethylene_pex.pdf.

Environmental Protection Agency. (2017). *Summary of the Clean Water Act.* Retrieved March 29, 2017 from https://www.epa.gov/laws-regulations/summary-clean-water-act\

Geotextiles - ADS Pipe. (2017). Retrieved April 11, 2017, from http://www.ads-pipe.com/en/contact/contact.asp

HomeAdvisor. (2017). *How Much Does it Cost to Construct a Dry Well.* Retrieved March 30, 2017 from http://www.homeadvisor.com/cost/landscape/construct-a-dry-well/

Koplowitz, Howard. (2016). *'America's Dirty Secret': Lowndes County singled out in new report on high cost of sanitation.* Retrieved March 29, 2017 from http://www.al.com /news/index.ssf/2016/06/americas_dirty_secret_lowndes.html

Lewis, Shayna. (2016). *Rural Enterprise (ACRE)*. Retrieved March 30, 2017 from http://www .uusc.org/partner-profile-alabama-center-rural-enterprise-acre/

Piven, Ben. (2015). *Sanitary Sewer Overflow Event Reporting Form*. Retrieved March 30, 2017 from https://www.documentcloud.org/documents/2091579-pdf-2-uniontown-sewage.html

Rogers, D., Olshansky, R., & Rogers, R. (1985). *DAMAGE TO FOUNDATIONS FROM EXPANSIVE SOILS*. Retrieved March 30, 2017 from https://web.mst.edu/~rogersda/ expansive_soils/DAMAGE%20TO%20FOUNDATIONS%20FROM%20EXPANSIVE%20SOILS.pdf

United States Department of Agriculture. (2017). *Web Soil Survey.* Retrieved February 21, 2017 from https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx.

Woolley, A. W., Chabris, C. F., Pentland, A., Hashmi, N., & Malone, T. W. Evidence for a collective intelligence factor in the performance of human groups, *Science*, 29 October 2010, *330* (6004), 686-688; Published online 30 September 2010 [DOI: 10.1126/science.1193147]