EXPLORING THE USE OF GROUND PENETRATING RADAR FOR DETERMINING FLOODPLAIN FUNCTION OF RESTORED STREAMS IN THE GULF COASTAL PLAIN, ALABAMA

Samantha W. Eckes (swe0007@auburn.edu), Stephanie L. Shepherd (slshepherd@auburn.edu)
Department of Geosciences, Auburn University College of Sciences and Mathematics
2050 Beard Eaves Coliseum | Auburn, Alabama 36849

Abstract

Accurately characterizing subsurface structure and function of remediated floodplains is indispensable in understanding the success of stream restoration projects. Although many of these projects are designed to address increased storm water runoff due to urbanization, long term monitoring and assessment are often limited in scope and methodology. Common monitoring practices include geomorphic surveys, stream discharge, and suspended sediment loads. These data are comprehensive for stream monitoring but they do not address floodplain function in terms of infiltration and through flow. Developing noninvasive methods for monitoring floodplain moisture transfer and distribution will aid in current and future stream restoration endeavors. Ground penetrating radar (GPR) has been successfully used in other physiographic regions for noninvasive and continuous monitoring of (1) natural geomorphic environments including subsurface structure and landform change and (2) soil and turf management to monitor subsurface moisture content. We are testing the viability of these existing methods to expand upon the broad capabilities of GPR. Determining suitability will be done in three parts using GPR to (1) find known buried objects of typical materials used in remediation at measured depths, (2) understand GPR functionality in varying soil moisture content thresholds on turf plots, and (3) model reference, remediated, and impacted floodplains in a case study in the D'Olive Creek watershed located in Baldwin County, Alabama. We hypothesize that these methods will allow us to characterize moisture transfer from precipitation and runoff to the floodplain which is a direct function of floodplain health. The need for a methodology to monitor floodplains is widespread and with increased resolution and mobility, expanding GPR applications may help streamline remediation and monitoring practices.

Introduction

The need for broad, easy to use monitoring practices within remediated or restored stream sites is more necessary than ever. More than 15 billion dollars has been accounted for annually in domestic ecological restoration through indirect and induced economic impacts of restoration activities in the United States, and at least 18% of ecological restoration is focused on aquatic and riparian restoration and management[1]. Stream restoration projects are expected to expand in the future, particularly in urban areas, and the need for effective monitoring practices is in demand[2]. Two critical factors to consider for comprehensive monitoring are spatial and temporal continuity. Most of the current monitoring practices focus on point data within a stream or along the stream bank (e.g. sediment load, discharge, repeat cross-sectional surveys) which lack the ability to capture the spatial complexity of floodplain, riparian, and stream processes. Furthermore, there is rarely long-term monitoring of restoration sites to determine if the restoration was sustainable. This research will investigate the application of ground penetrating radar (GPR) techniques to study floodplain processes after stream restoration.

Figure 1. Images of case study site in D'Olive Creek watershed pre (Dec. 2016), during (Jan. 2017) and post (Aug. 2017) restoration.

Erosion due to urbanization over the last three decades has caused unconsolidated materials to remobilize and pollute downstream ecosystems and put a large burden on existing infrastructure[3]. The town of Daphne, in coastal Alabama, has been conducting restoration projects to mitigate erosion, but do not have a plan to comprehensively monitor built floodplains long-term (Figure 1). The city of Daphne, as well as other coastal plain stakeholders, have identified the long-term response of the stream system to restoration as a critical research. Since a stable floodplain that promotes infiltration can decrease erosion, floodplain monitoring is essential for a compressive understanding of restoration performance. GPR has the potential to improve and expand our ability to assess floodplain function and health.

The application of GPR to estimate moisture distribution within the subsurface has been around for decades[4,5]. We are attempting to use GPR to estimate subsurface moisture content and distribution in built floodplains with the ultimate goal to make inferences about infiltration rates as an indicator of floodplain health. The focus of this poster is to explain the two experiments that will help determine the limitations of the GPR in coastal plain sediments to 1) detect buried objects and 2) estimate moisture distribution correlated to absolute moisture content measurements. Both experiments will then be applied to a case study in the D'Olive Creek watershed.

Methods and Materials

Figure 2. Images of objects that were buried at 2 m and 0.9 m in trench at E.V. Smith Research Center. (a) Wood logs (~15 cm in diameter), (b) rebar, (c) two cement blocks (center) and two boulders (limestone and quartzite), (d) rectangular plastic cooler (~45 cm tall), (e) 20 L plastic carboy.

Buried object locations were documented with GPS (+/- 10 cm accuracy) for correlated with the processed GPR data. All buried objects were measured to specific depths within and distance along the trench and recorded. The objects were chosen as similar to what is used in floodplain reconstruction in the D'Olive Creek watershed, with the exception of the plastic containers. The plastic containers were placed to try and capture void spaces on a GPR profile. Plastic does not produce a robust reflection (if one at all) on GPR profile, allowing void spaces to be seen, and replicating what large void spaces in a floodplain might look like[10]. After all objects were placed, the trenched was filled and flattened (Figure 4).

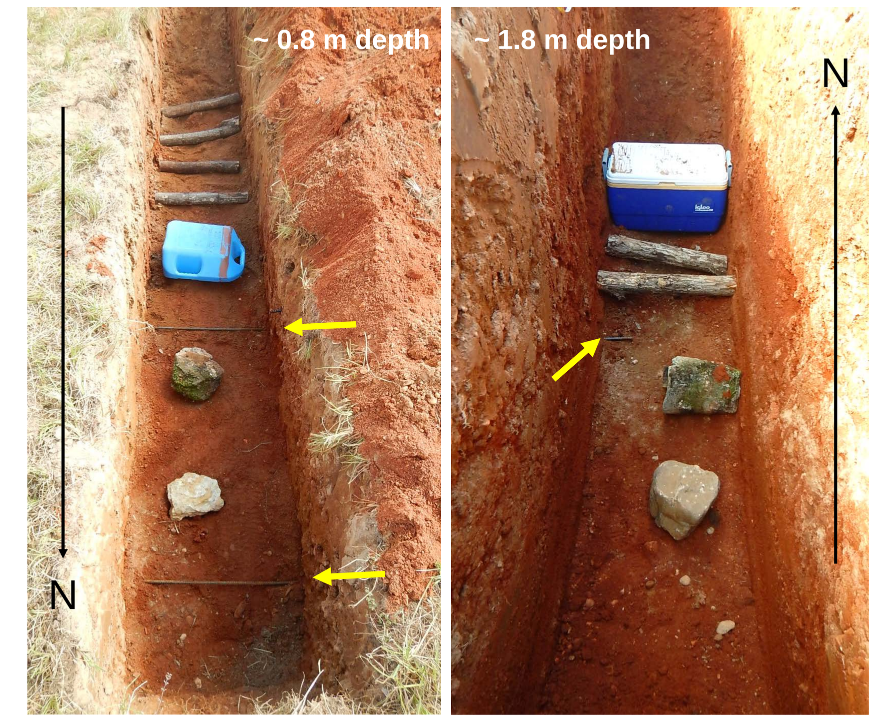

Figure 3. Buried objects identified in Figure 2 and their placement in the trench at two different depths. Yellow arrow indicates rebar location.

Figure 4. Grid set up for 3D GPR data acquisition. Grid is approximately 5 x 10 m.

Once materials were buried, the trench was left undisturbed for three days to allow for the sediment to settle. A 5 x 10 m plot was marked out to take GPR transects in two directions. The perpendicular transects can be combined are then RADAN 7 to create a 3D model of the subsurface (Figure 9). 2D transects were taken with a 400 MHz and 900 MHz antenna. The two antennas were also used in a CMP data line, but these data have yet to be processed.

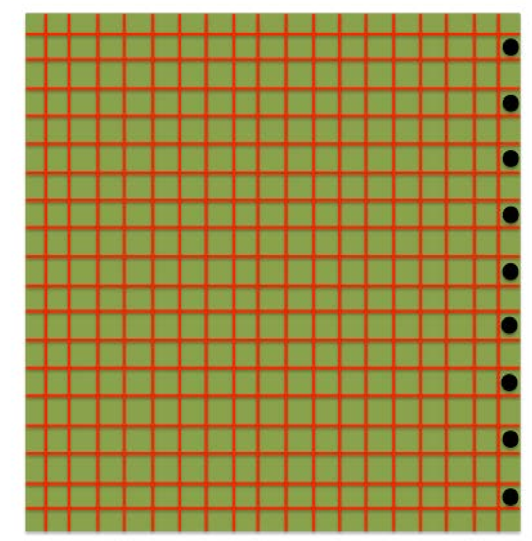

Figure 5. Basic sketch of 10 x 10 meter plot to be used at Turfgrass Research Unit. Red lines indicate transect paths and black circles represent auger hole locations.

Estimating moisture content using GPR will be conducted at the AU Turfgrass Research Unit in Auburn, AL. A 10 x 10 m grid will be set up to run perpendicular transects 0.3-0.5 meters apart. The plot will be saturated from surface to depth (~ 2m) then GPR data will be taken every two to three days until subsurface drying plateaus. Soil auger measurements will be taken concurrently with daily GPR measurements to get volumetric water content at time of acquisition. Volumetric water content data of the surface will be taken using a POGO Turf Pro moisture probe.

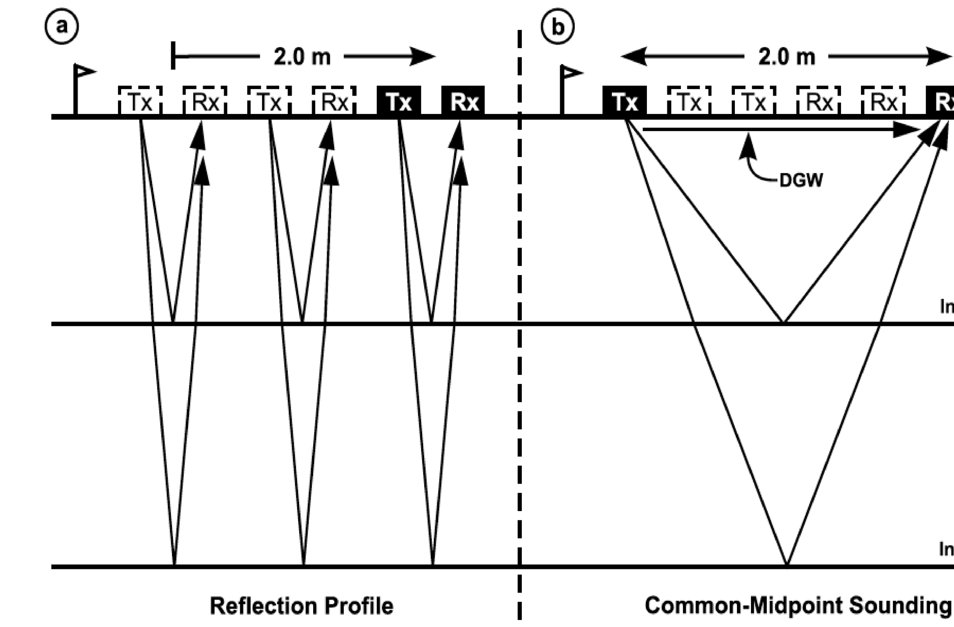

Figure 6. (a) Common-offset reflection profile (CO) and (b) Common mid-point (CMP) reflection surveys using ground penetrating radar equipment[6].

The common offset reflections (a) are used to take 2D transects to image linear profiles to image the subsurface[7]. This method can be used to create 3D models if transects are taken perpendicular to each other. CMP soundings are used to estimate water content of the subsurface by calculating the velocity of the direct ground wave (DGW). Both methods are used within this experiment: method (a) is used to detect buried objects and method (b) is used to estimate floodplain moisture content[6,7,8,9].

Processing and Results

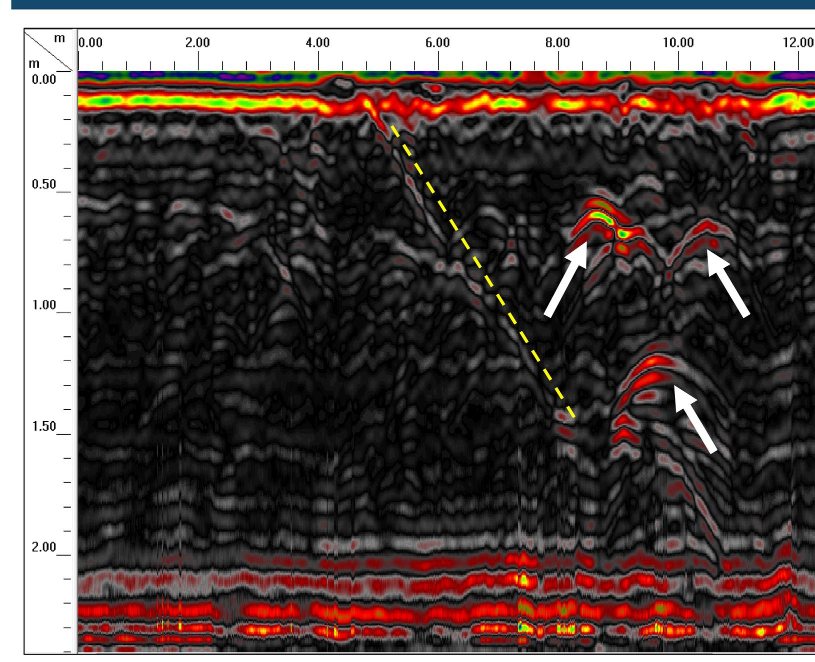

Figure 7. GPR transect (008) processed using RADAN 7 software. Diagonal line (yellow) indicates probable boundary between disturbed and undisturbed sediments at edge of trench. Reflections at ~ 0.7m and 1.2 m correlate to objects at know depth.

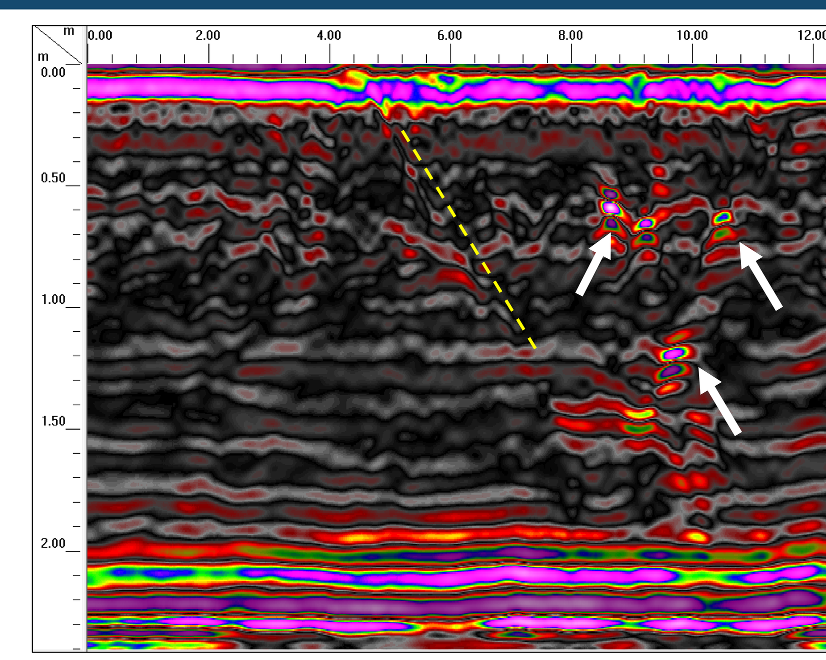

Figure 8. GPR transect (008) processed for migration. Parabolas seen in Figure 7 have been flattened and the interface between disturbed and undisturbed sediments dips less steeply.

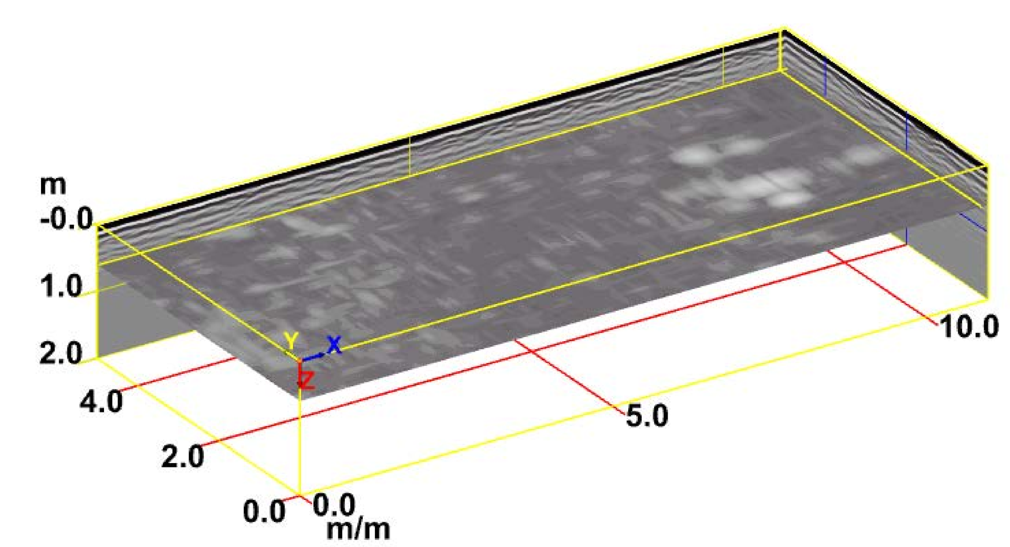

Figure 9. Constructed 3D grid from perpendicular 2D transects of buried objects. Concentrated lighter tone areas correlate to undetermined buried objects in trench. Z axis transect is at ~0.6 m depth.

Preliminary data processing displays returns at approximate locations correlated to burial depths. Minimal processing has been done due to timeline restrictions and machine availability. Comprehensive processing will be completed following the GSA Annual Meeting. The 3D grid displays approximate location of buried rebar and logs at line toned areas. Initial results suggest that plastic containers to create void spaces may not show returns at all and placed rocks may not have any return due to its similarity in composition to surrounding materials.

Discussion and Future Directions

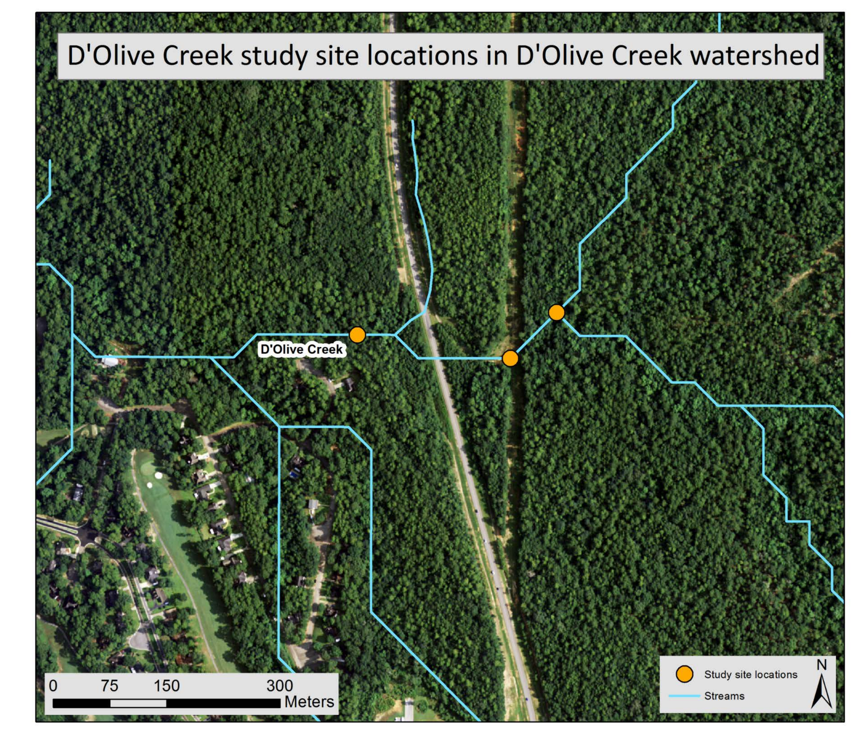

Figure 10. Aerial image of the case study site on D'Olive Creek within the D'Olive Creek watershed. Each orange dot indicates a floodplain no smaller than 30 meters in width. The middle orange dot indicates the restored reach. Starting with the western most study site they are labeled as impacted, restored, and reference sites.

Once both controlled experiments are complete we will assess the methods and apply them to the case study site in the D'Olive Creek watershed in Daphne, AL. GPR surveys will be conducted in the built floodplain of the restored stream. Surveys will be taken over a 4 month period for temporal variability within the data.

This project is important for understanding both the stability of built structures and moisture distribution in restored floodplains as an indicator of floodplain health. Understanding how well restored floodplains work can help improve remediation practices and monitoring methods. Since many restored floodplains are upstream of communities, improving floodplain health can promote ecosystem health white improving water quality for residents. Monitoring floodplains within the coastal plain can also prevent infrastructure from eroding as well as prevent sediment pollution downstream. Since floodplains have multiple functions (e.g. ecological, hydrological) studying the viability of these projects is important to understanding watershed scale processes.

References

1. BenDor, T., Lester, T.W., Livengood, A., Davis, A., and Yonavjak, L., 2015, Estimating the Size and Impact of the Ecological Restoration Economy: Plos One, v. 10, doi:10.1371/journal.pone.0128339.
2. Bernhardt, E.S., and Palmer, M.A., 2007, Restoring streams in an urbanizing world: Freshwater Biology, v. 52, p. 738–751, doi: 10.1111/j.1365-2427.2006.01718.x.
3. Ellis, J.T., Spruce, J.P., Swann, R.A., Smoot, J.C., and Hilbert, K.W., 2010, An assessment of coastal land- use and land-cover change from 1974–2008 in the vicinity of Mobile Bay, Alabama: Journal of Coastal Conservation, v. 15, p. 139–149, doi: 10.1007/s11852-010-0127-y.
4. Hubbard, S., Lunt, I., Grote, K., and Rubin, Y., 2003, Vineyard soil water content: mapping small scale variability using ground penetrating radar: Geoscience Canada Reprint, v. 9, p.193-202.
5. Van Dam, R.L., Van den Berg, E., Schaap, M.G., Broekema, L.H., and Schlager, W., 2003, Radar reflections from sedimentary structures in the vadose zone: Geological Society, London, Special Publications, v. 211, p. 257–273, doi: 10.1144/gsl.sp.2001.211.01.21.
6. Huisman, J.A., Hubbard, S.S., Redman, J.D., and Annan, A.P., 2003, Measuring Soil Water Content with Ground Penetrating Radar: A Review: Vadose Zone Journal, v. 2, p. 476–91, doi: 10.2113/2.4.476.
7. Grote, K., Hubbard, S., and Rubin, Y., 2003, Field-scale estimation of volumetric water content using ground-penetrating radar ground wave techniques: Water Resources Research, v. 39, doi:10.1029/2003wr002045.
8. Lunt, I., Hubbard, S., and Rubin, Y., 2005, Soil moisture content estimation using ground- penetrating radar reflection data: Journal of Hydrology, v. 307, p. 254–269, doi:10.1016/j.jhydrol.2004.10.014.
9. Overmeeren, R.V., Sariowan, S., and Gehrels, J., 1997, Ground penetrating radar for determining volumetric soil water content; results of comparative measurements at two test sites: Journal of Hydrology, v. 197, p. 316–338, doi: 10.1016/s0022-1694(96)03244-1.
10. Metwaly, M., 2007, Detection of metallic and plastic landmines using the GPR and 2-D resistivity techniques: Natural Hazards and Earth System Science, v. 7, p. 755–763, doi: 10.5194/nhess-7-755-2007.

Acknowledgements

I would like to thank Greg Jennings for pictures of the project before implementation. Part of this project would not have been possible without the dedicated Greg Pate and Beth Guertal for help at E. V. Smith Research facility and lending us needed equipment. A big thank you to Ashley Campbell and the city of Daphne, AL for being our liaison to this project and always being a helping hand. Partial funding for research materials was provided by the Auburn Geosciences Advisory Board and the AU Intramural Grants Program. Partial travel funding to the 2017 Geological Sciences of American Annual Conference was provided by the Geological Society of America.