GPGN 420 Advanced EM: GPR Acquisition Lab

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1 Introduction

1.1 Objectives and General Purpose

In this lab, students got experience with using GPR equipment in the field and processing the data obtained. This field lab was conducted on the Colorado School of Mines Geophysics Playground on Kafadar commons. Students attempted to locate a manhole cover buried in the subsurface surrounded with sand. The objective of this lab was to acquire single offset GPR data to locate the manhole cover and a common midpoint gather to conduct a velocity analysis. A second objective of this lab was to become familiar with GPR field equipment, survey designs, and processing techniques.

2 Materials and Site design

2.1 Equipment Used

- Multichannel SPIDAR GPR system attached to cart
- 1000MHz Tx - Rx antenna
- 500MHz Tx - Rx antenna
- Field Laptop
- Tape measure

2.2 Choice of Survey Design

The survey was designed to cross directly over the manhole while ensuring to collect data in the area nearby. This procedure ensured that the reflection created by the manhole was visible when compared to the response created by the near homogeneous ground nearby.

2.3 Survey Parameters

2.3.1 Common-offset

Group 1 used a 500MHz antenna. This group ran several survey lines in order to locate the manhole cover, which were then marked with a flag. Group 1 ran a long $\tilde{6}$0m line passing directly over the manhole cover with an odometer step size of 2cm.

Group 2 conducted a shorter survey directly over the previously located manhole cover. This group used the 1000MHz antenna with a odometer step size of 1cm. The listening time was set to 20 nanoseconds to ensure that the reflections from the manhole cover would be received at the receiver. The survey was set to collect 200 points per trace and have a time sampling interval of 100 picoseconds.

2.3.2 Common-midpoint

The length of the common midpoint gather (CMP) was designed to be 3-4 times the depth to the target on either side of the suspected target location. In this case, the target was expected to be around 0.6 meters deep, which is the required minimum depth of objects buried in the geophysical playground. The CMP gather by this lab group was 3 meters long using the 500 MHz transmitter and receiver. The transmitter and receiver were centered over the manhole. Then the students moved each the transmitter and receiver radially outward 2 cm for each shot, resulting in a 4 cm step size. Additional parameters included a listen time of 20 ns.

An initial CMP was done with the 1000 MHz transmitter and receiver. However, the signal was attenuated too quickly to characterize the velocity of the soil above the manhole cover. The parameters for this CMP included a 2 meter line and 2 cm step size per shot.

2.4 Survey Map

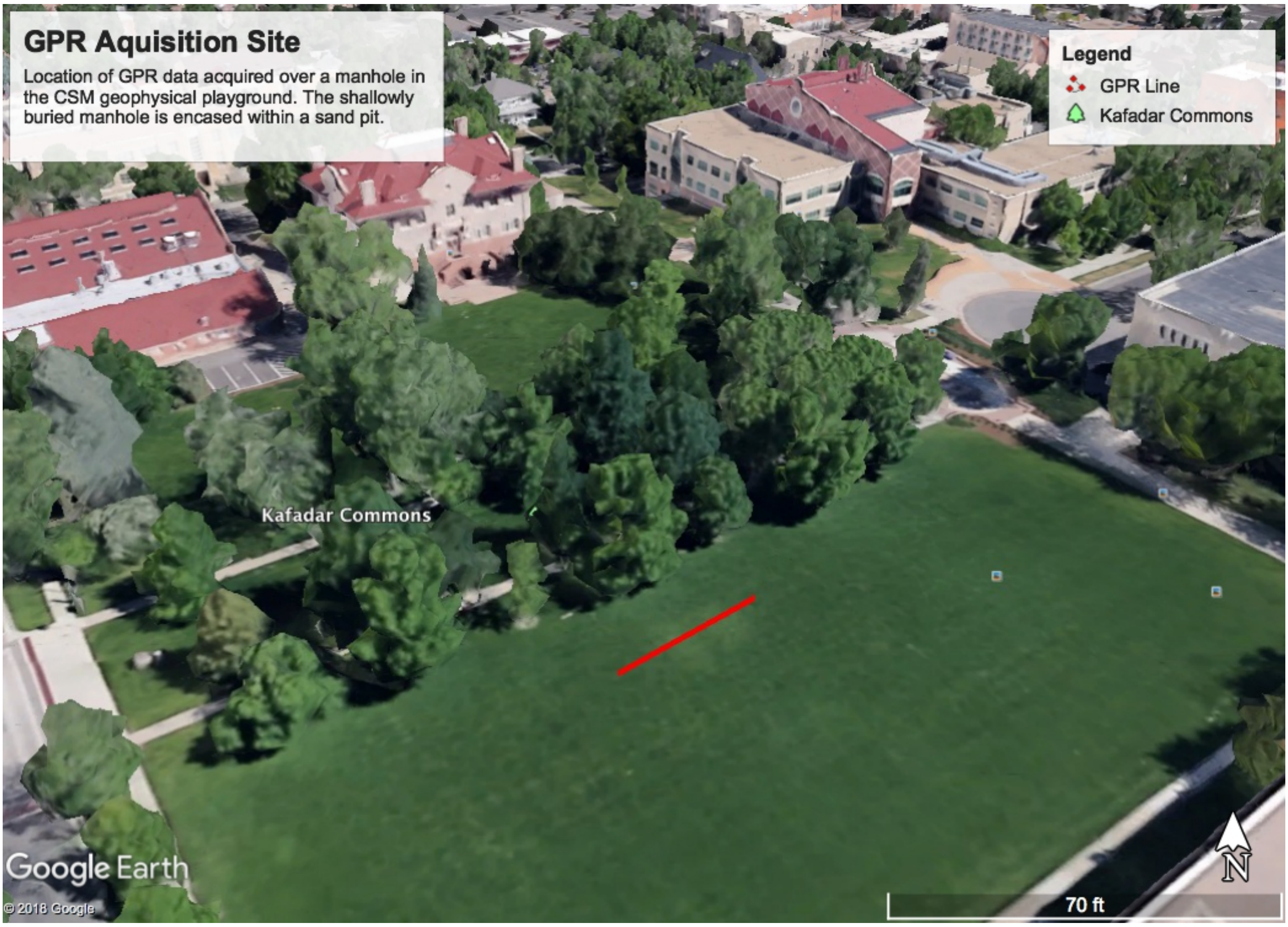

Figure 1: Map showing approximate GPR line on Kafadar field

3 Processing

Students used a MATLAB code provided by Dr. John Bradford to process the GPR data obtained in the field. This code used a variety of different processing functions to highlight the manhole cover in the data. First, students removed the background noise in the data. Next, students set all of the flag parameters to 1 so that the corrections for each flag would be performed. Students then set δ_0 equal to the first arrival time seen in the unprocessed data. Finally, the *gpow* and *sc* parameters were modified to help highlight certain features in the data. The table below shows the parameters that were used for both the 500MHz and 1000MHz data.

Processing Parameters			
Frequency (MHz)	$\delta_0(ns)$	g_{pow}	sc
500	3.0	2	0.45
1000	3.6	2	0.5

3.1 Raw unprocessed data

Figures 2 and 3 show the unprocessed data from both the 500 and 1000 MHz transmitter and receiver, respectively. From these figures it is extremely difficult to pick out the location of the manhole cover.

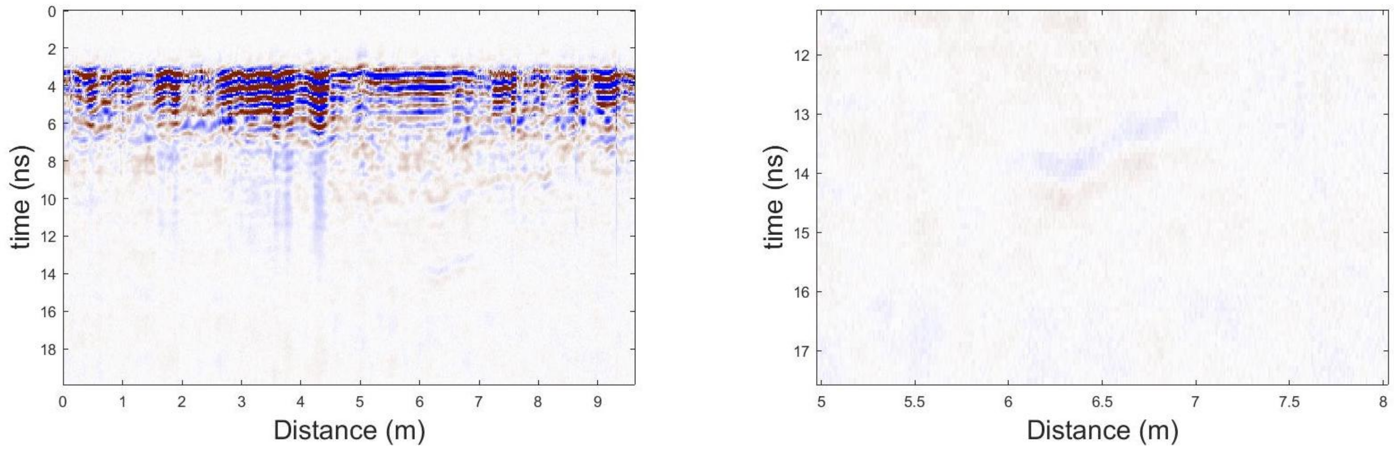

Figure 2: Unprocessed data using the 500 MHz transmitter and receiver. Left: full time stack, Right: zoomed-in on manhole cover

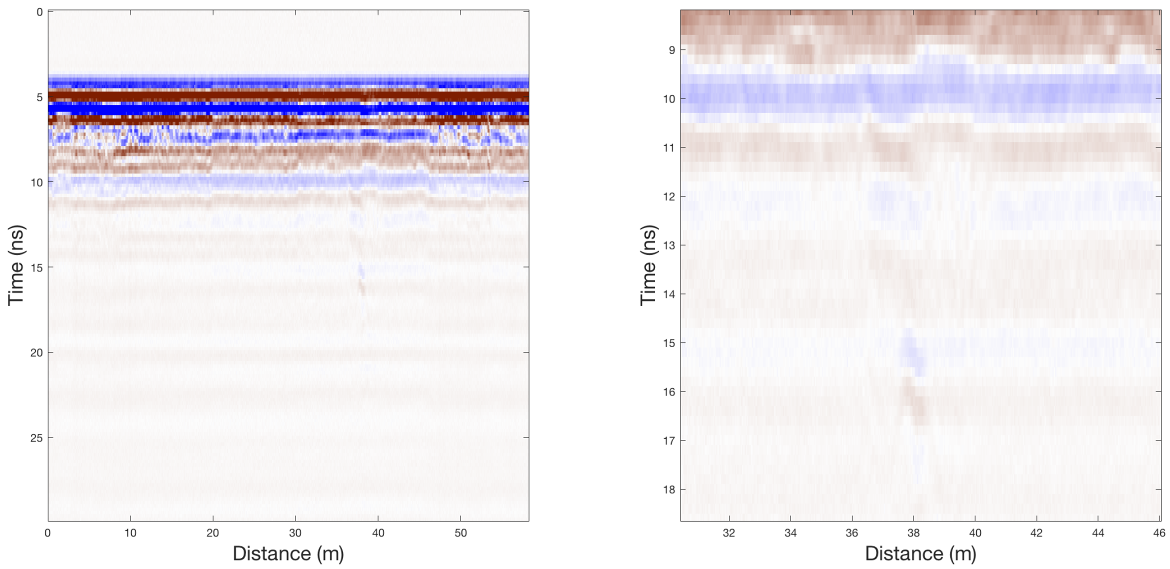

Figure 3: Unprocessed data acquired from the 1000 MHz transmitter and receiver. Left: full time stack, Right: zoomed-in on manhole cover

3.2 Processed Data

Figures 4 and 5 show the processed data for both the 500 and 1000 MHz surveys. The location of the manhole cover is much more clear and can be found at t≈11 nanoseconds and distance≈6.3 meters in Figure 4 and t≈12 nanoseconds and distance≈38 meters in Figure 5.

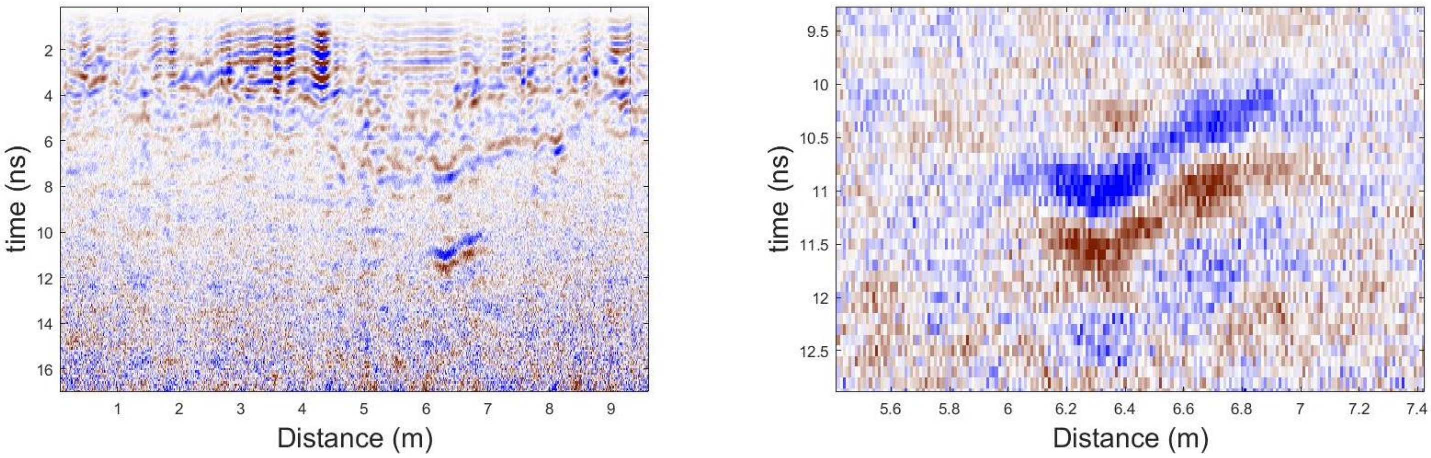

Figure 4: Processed data using the 500 MHz transmitter and receiver. Left: full time stack, Right: zoomed-in on manhole cover

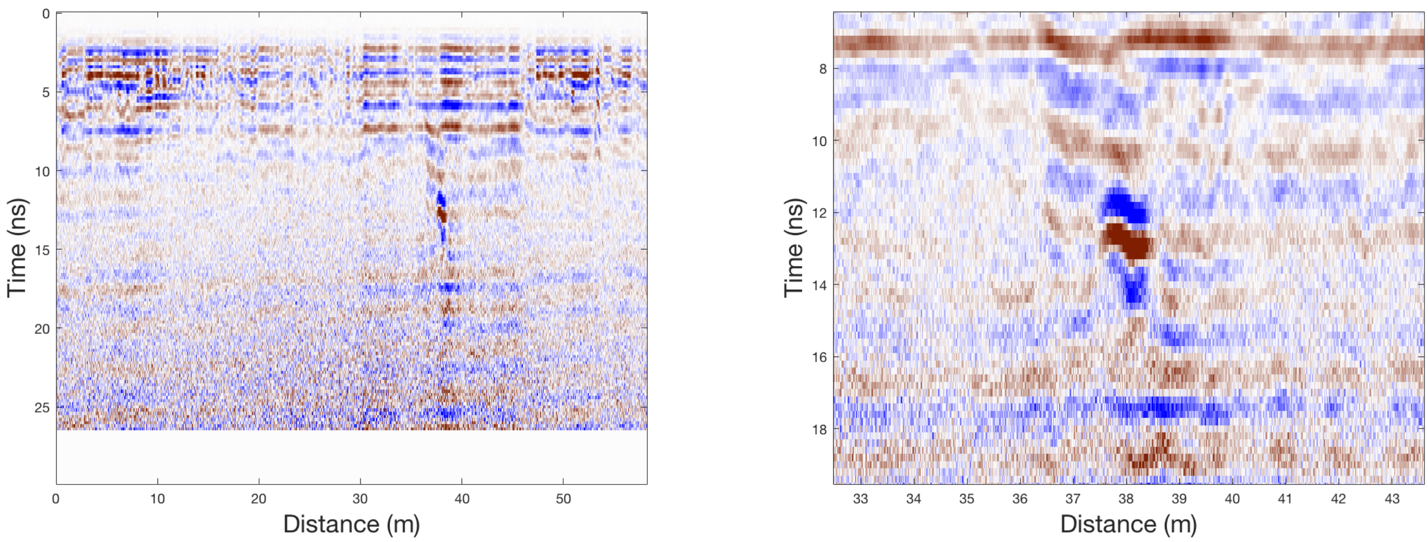

Figure 5: Processed data acquired from the 1000 MHz transmitter and receiver. Left: full time stack, Right: zoomed-in on man-hole cover

3.3 CMP data

Figure 6 shows the unprocessed CMP data using the 1000MHz transmitter and receiver.

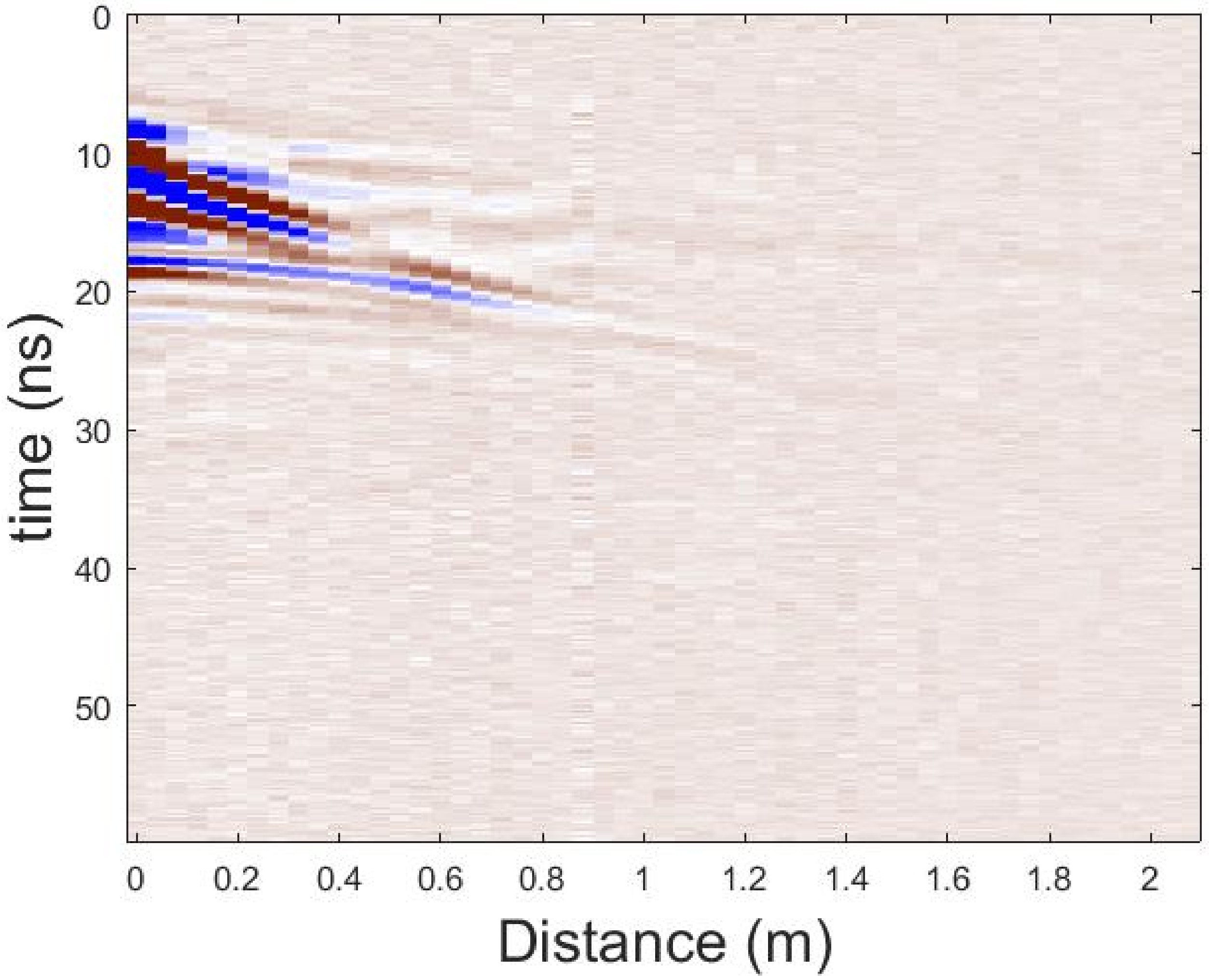

Figure 6: The 1000 MHz CMP unprocessed data

The table below shows the processing parameters used to process the common midpoint data. The processed data is shown in Figure 7. From this figure students were able to calculate the velocity of the earth above the manhole cover to estimate the depth of the manhole cover. Velocity was calculated using the NMO velocity analysis seen in Equation 1.

$$v^2 = \frac{x_2^2 - x_1^2}{t_2^2 - t_1^2} \tag{1}$$

Using this equation, students calculated the velocity above the manhole cover to be about .0767 m/ns or 7.67 x 10^7 m/s. From the processed GPR data, the manhole was determined to appear between 11 and 12 nanoseconds. This means that the manhole cover is located approximately between 0.84 and 0.92 meters beneath the surface.

Processing Parameters - CMP			
Frequency (MHz)	$\delta_0(ns)$	g_{pow}	sc
1000	1.0	1	0.25

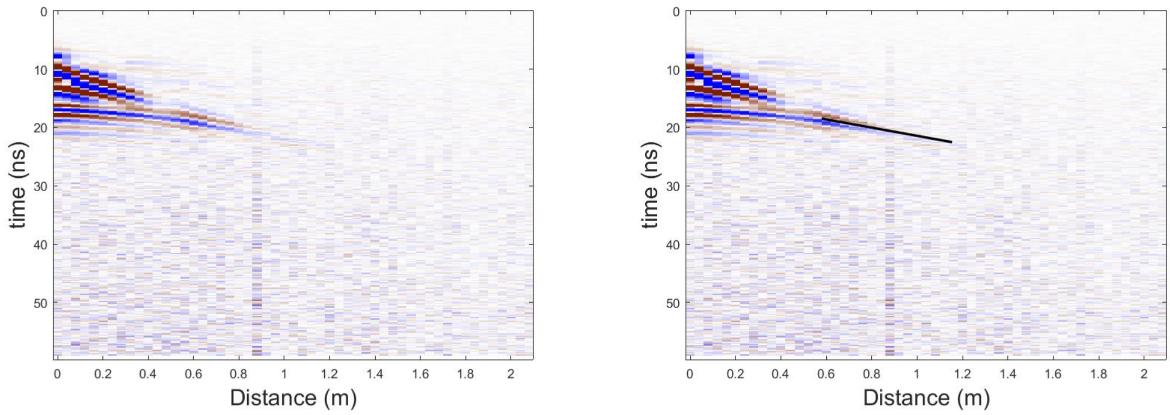

Figure 7: The 1000 MHz CMP processed data. Right: processed data, Left: data with line used to determine velocity

4 Discussion of Results, Conclusion

We believe that there are some compelling results in our processed data and that we see a response from the presence of the manhole cover and the sandbox present at the survey site. For example, take a look at the processed transects in Figures 4 and 5 and note the multiples arriving through time at $x = 6.5[m]$ and $x = 38[m]$ respectively. We think that those multiples are the result of the GPR energy reflecting off of the strong boundary at the conductive manhole cover compared to the relatively resistive sand surrounding the manhole cover. We think these results are compelling since we do not see any other coherent multiples at other offsets in our survey for either of the two radar frequencies. Also note that for both the 500 and 1000 MHz antennas, we see these multiples laterally extend for about a meter. This consistent spatial extent gives us confidence in deciphering where exactly we think the manhole cover is located and how far it extends.

We designed the CMP survey so that at zero offset we were directly over where we thought the manhole cover is located. Unfortunately, from the CMP data, we are not sure if we are able to quantify the spatial extent of the manhole cover. We believe we see a strong signal from the manhole cover at small offsets and at larger offsets, we think we see a strong reflection from the manhole cover and we think from a normal moveout velocity that we can migrate the mahole to have depth somewhere in the range of 84 to 92 centimeters. At small offsets shown in Figure 6, we believe we see multiples again from the reflection directly off of the manhole cover. But then at larger offsets, the multiples appear to fade and the hyperbolic reflection appears most strongly. This hyperbola is what we use for velocity fitting of the top layer assuming that it is the reflection from the manhole cover as shown in Figure 7.

One source of error in this lab is that the ground was wet which might affect how the electromagnetic wave travels and attenuates. Additionally, Lookout Mountain has a ton of antennas on top of it which greatly affects electromagnetic surveys done on the Mines campus. Finally, there is noise from the surrounding buildings, people, and electronic devices on the Mines campus. All of these sources of noise affect the quality of the data and might impact the results.

Moving forward we want to model this scenario in our 1D finite difference forward modeling code to see if we can achieve the same effective response from a manhole cover. We thought that we could use the velocity we found for the sand layer and try to mimic this scene. We are unsure how to estimate the properties of the manhole cover from the acquired data, but we think by adding in a thin layer that is much more conductive than the sand layer we can solve for that we might be able to model the scenario. With this, we could use a brute-force inversion technique to pick physical properties that best fit our observed data.