GEOL 460 Solid Earth Geophysics
Lab 6: Field Magnetometry

Name: ____ Date: ____________

You have been your best trying to find a job. On the online advertising website, you found the following posting:

> Wanted: Someone to help us locate some buried infrastructure. We are a small non-profit corporation and were just gifted some land in the coastal zone. We need to follow all laws, especially those imposed upon us by the California Coastal Commission. A soil scientist conducted a survey to identify wetland soils. Unfortunately, the consultant only provided a map that references a buried water line. We need someone to locate the buried metal pipe without digging up the soil. We are especially interested in someone who can operate a proton magnetometer. We also will be regrading the road, so want to know the depth of the pipe.

Subsequently you have been hired for time and materials (bonus for an early career scientist). You will be paired up with a second early career scientist. You will meet your client near the site at the parking lot to the northern Ma-l'el Dunes natural area. The road north is located on the circa 19th century railroad bed. The water line crosses the road somewhere and you have a rough area where it is. You will conduct a profile survey along the road. Please be diligent about the notes because they are all important factors to your analysis and, therefore, your results.

Please prepare a written report. Due to our funding sources, the report and data products need to be in a certain format. The report needs to be in Times New Roman font size 12, double space, with 1" margins. The report must be 5-10 pages long and include components outlined during the lab. Some data products will not be in the written report and won't contribute to page count. All documents will need to be provided electronically. You will have two weeks to prepare this report.

Part I. Survey and Data Collection

Take notes. Massive notes, like a note taking king or queen. (Each person will run the magnetometer for 1 non-pipe transect and 1 pipe transect, for a lab-total of 4 non-pipe transect surveys and 4 pipe transect surveys.) You will want to make a sketch map of your survey area.

Prepare a transect with 1 meter spacing using the tape provided. You will be shown a region where your client expects the main pipe to be. There may be additional pipes (hopefully also perpendicular to the road). Use 0.5 meter spacing in the region where the pipe is expected. Extend the shorter spacing beyond the "expected" area.

For each survey, to account for temporal drift in the geomagnetic field, you will collect base station measurements. Begin the survey at the base station and end the survey at the base station. For each measurement collect the following data:

- Station
- Distance
- Time
- Northing (optional, but at least collect for endpoints)
- Easting (optional, but at least collect for endpoints)
- Field Intensity (gamma = nT)

Some additional considerations include:

- Temporal drift corrections will be need to be made for each survey.

You will collect two data sets: (1) a road-parallel profile where there is no pipe and (2) a road-parallel profile where the pipe is thought to be. The first data set will be considered a "background measurement." One person in your team will collect the data and the other will record the data. Switch roles for the repeated surveys so that operational bias may be accounted for.

While you are waiting to collect data, answer the questions in the lab assignment. For those with smartphones, find a free magnetometer app so you can see the magnetic changes over rebar using a different "instrument."

Before collecting the data, write a brief paragraph on how physical properties can be related to the goal of this survey. Be sure to include answers to:

- Which physical property is the magnetic surveying method sensitive to?
- What other physical properties of the target (in this case, pipes) would you expect to differ from the surrounding material?

"Noise" is defined as any portion of the signal that does not come from the target of interest. Consult the Applications Manual for Portable Magnetometers. Given the proposed setting of the survey:

- What are some possible sources of noise? How do you think they will show in the data?
- Are there any methods that you can employ while collecting the data to minimize the effects of some of these sources of noise?

The magnetometer is mounted on a pole and is 195 cm above the ground (measure to confirm this). Suppose we are able to estimate that the maximum anomaly is 100 nT and we know that the anomaly is caused by a cylinder. Use the Applications Manual for Portable Magnetometers to help with these (and all) questions.

- Why is the sensor placed at a distance away from the ground surface?
- What is the estimated width of the anomaly at half its amplitude?
- What are appropriate station spacing and line length to map this anomaly?

Collect some notes about your survey. These are in addition to the data that you will collect. Writing notes in a narrative form does two things (1) documents what you are doing in a general sense and (2) is written in a way that can easily be placed into your report. The following is an example list, but feel free to include additional information that you deem might be important.

Provide a brief summary of the survey operations.

- What was your line direction?
- Station spacing?
- What were the weather and ground conditions on the day of your survey?
- Did anything happen while collecting the data that you feel may impact the results?
- Do you think the data you collected will be able to produce the desired results? Why or why not?

Following the survey, look up the geomagnetism summary plot for the observatory closest to where the survey was performed. http://geomag.usgs.gov

- Were temporal variations active or quiet?
- How might this have affected your survey?

Part II. Data Compilation and Analysis

Before you work with your data:

- Look up the orientation (declination and inclination) and total field strength of the Earth's magnetic field in Arcata. Know what these values represent. http://geomag.nrcan.gc.ca/apps/mfcal-eng.php

Prepare a spreadsheet that includes all the survey data. Example columns would include: Station, Latitude, Longitude, Distance (calculated), Measurement, Time, and Notes.

Consider the following steps:

- After de-trending the data, average the data at each location. Are there measurements that are clearly outliers? What is the standard deviation for each dataset?
- What was the magnitude of the Earth's field intensity at the survey location on the day the data was collected? Subtract this value from the two sets of observations. Plot the resulting data lines.
- What are the maximum, minimum, and average values of each data set after the Earth's field has been subtracted?
- What features exist in each of the two datasets? What could be possible causes for these features? Think about where the data were collected and what other possible things can cause anomalies (hint: what else might be in the ground?).
- On your plot of the "with pipe" dataset, circle the feature due to the pipe. Based on your use of the dipole applet, is this what you would expect? Why or why not?
- Subtract the background data from the data with the rebar to isolate the anomaly. Provide a plot of this residual (anomaly) data. What are the minimum, maximum, and average values of the anomalous data?
- Copy the residual data into the forward modeling spreadsheet. Follow the step-by-step instructions on the left hand side of the spreadsheet. The following are some considerations and steps to take when using the forward modeling spreadsheet:
  a. What is the inclination you will use for your modeling?
  b. What is the x-offset you should use?
  c. Estimate the distance between the magnetometer and the pipe, set the depth appropriately. What is the depth you used?
  d. Knowing the distance between the magnetometer and the rebar, the inclination, and the location of the anomaly, what does the forward modeled anomaly look like? Include an image of this in your report.
  e. Paste the data into the spreadsheet. Change the variables to try and fit the forward model to the actual data. What are the depth, moment, and inclination of your best solution?

Credit to Sarah Devriese, University of British Columbia: http://www.ubc.edu

Include an image in your report. Are the depth and inclination compatible with the field variables? If not, what are some explanations for the differences?

f. What is the moment of the pipe that best reproduces the data? For a 2-D structure, the moment is $M = \kappa H_0 \pi a^2$, where a is the radius and H_0 is the magnetic field. Use this formula to estimate the susceptibility κ. Make sure you are using the correct units for H! (Hint: it's not nanoTeslas or Teslas. Look up the relations between H and B in the GPG reading.) There may be too many unknowns to answer all these questions.

g. Depth of investigation: It is often possible to estimate the depth d of burial by evaluating the width w of the anomaly at half of its maximum value. The relationship between w and d is dependent on the structure. For a cylinder, this is $d = 0.75w$. Compute this for the anomaly from the pipe.

Part III. Reporting

Prepare a report that you will submit to your client. Include typical scientific writing sections. There is an example of a scientific paper on the course website. The report should include a detailed description of your survey (magnetometer model, sensor configuration, spacing, etc.). You will want to have a map locating the survey, as well as a map of the survey area (e.g. the non-pipe transect and pipe transects should be shown as they relate to the road and surrounding environs). Present your results in at least one figure and attach any spreadsheets as appendices (extra digital files that do not count towards your page total). Present the results of your forward modeling in a figure. Don't forget to write excellent figure captions for each figure. On the survey area figure, draft the location of where you think that the pipe is located. In your discussion section, provide your interpretation of the location of the pipe, along with its depth. Make sure to include answers to the questions in this lab.

These reports will be submitted by each team of two. Please do not rely on your team partner to do the bulk of the work. The reports are due two weeks from the end of the survey.