Establishing a Baseline of Water Quality along the Coast of Northeastern NC in Response to the Deepwater Horizon Oil Spill

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Abstract

Deepwater Horizon was an ultra-deepwater, semi-submersible, offshore drilling oil rig used for oil exploration and production purposes. The oil rig was owned by Transocean and was under contract to British Petroleum (BP). On April 20, 2010, the Deepwater Horizon had a wellhead blowout which caused an oil spill in the Gulf of Mexico. This incident caused a total of eleven deaths and injured seventeen of the workers. The Deepwater Horizon blowout is the largest oil spill in U. S. history.

The Deepwater Horizon was located north of the Gulf Stream Loop Current which is a warm ocean current that begins its path within the Gulf of Mexico. The Loop Current flows northward between Cuba and the Yucatan Peninsula, eventually curving east and south along Florida's coast and exiting through the Straits of Florida. The Gulf Stream then follows the coastlines of the United States and Newfoundland before crossing the Atlantic Ocean. These currents have the potential to bring oil from this spill to the Outer Banks of North Carolina.

This project sought to establish a baseline on a range of data correlating to water composition along the Outer Banks of North Carolina from Ocracoke Inlet to Corolla with concentrated sampling from Ocracoke Inlet to Cape Hatteras. The spectral fluorescence data was the main indicator for the presence of crude oil. The data obtained predates any appearance of oil from the Deepwater Horizon oil spill on the outer banks of North Carolina. The compilation of data will allow researchers to analyze variations between the baseline and future data collected.

Introduction

The Deepwater Horizon was a floating semi-submersible Mobile Offshore Drilling Unit (MODU) situated around 40 miles off of the Louisiana coast in the Macondo Prospect oil field. Deepwater Horizon was built by Hyundai Heavy Industries in 2001 for $560 million. The Transocean Corporation had the ownership rights to Deepwater Horizon though the oil rig was under lease to British Petroleum (BP) until September 2013.

On April 20th, 2010 an explosion occurred on the Deepwater Horizon resulting in the death of eleven workers and injuring seventeen others. Ninety-eight people managed to survive the explosion without injury. At the time of the explosion Deepwater Horizon was drilling an exploratory oil well 18,360 feet below sea level. It is estimated that around two million gallons of oil at a rate of 16,000 gallons per day has been spilled into Gulf of Mexico since the oil spill began making this the worst oil spill in United States history. BP is currently attempting to drill two pressure relief wells to intersect the pathway of the original ruptured well reducing the pressure and allowing the well to be capped with cement. BP has forecast to have the well capped between July 20th - July 27th according to a July 8th Reuters news release.

Data Collection

The Outer Banks of North Carolina was the location for the collection of water samples. This due to the Loop Current in the Gulf of Mexico is in close proximity to the Deepwater Horizon oil well, which connects to the Gulf Stream, which runs along the coast and has the potential to carry the oil to the Outer Banks.

The water samples ranged from Ocracoke Village, the southern most accessible point to Corolla, the northern most accessible point (Figure 5). The samples were collected from the 7th thru the 18th of June, 2010. Outside air temperature, water temperature, wind speed and wind direction readings were the taken. The pressure readings for each site were obtained by using Weatherunderground.com, which stores historical meteorological data for a given region on an hourly basis. Weatherunderground.com was also used as a comparative tool to confirm wind speed and wind direction readings.

A Meteos branded anemometer was used to measure the wind speed and outside air temperature at each location. a mercury thermometer attached to 40ft cotton line was used to measure the water temperature. The water samples were collected using a 20 oz plastic bottle with a 40 ft cotton line. A weight was attached to the bottom of the line to sink the plastic bottle in order to collect the water sample. Once the samples were collected they were transferred to a tinted glass bottle and put on ice to preserve any organic substances that were present within the water sample. Panoramic and ground images were also taken for each location to give a visual representation and documentation of the sampling sites. Images of this equipment can be found in Figure 2.

Each water sample and collection site was labeled with the date, time, and Global Positioning (GPS) coordinates. The GPs coordinates were recorded using a Garmin GPSMAP 60CSx. The time date and GPS coordinates were recorded to keep the samples in order and so that they could be recorded into a Microsoft Excel sheet to be used as a reference for future research.

Fluorescence Testing

In fluorescence a beam of light is used to excite electrons present in certain compounds within the oil. This beam of light causes the excited electrons to emit a light of a lower energy. There are four important characteristics that are unique to fluorescence; it is the result of the absorption of light, it occurs only during absorption, it involves the emission of light, and an outside source of energy is required.

Polycyclic Aromatic Hydrocarbons (PAH's), are the most common types of hydrocarbons that are found within crude oil. The aromatic hydrocarbons within PAH's gives researchers the ability to detect PAH's in oil due to their highly fluorescent attributes. Due to the recent and still ongoing Deepwater Horizon oil spill, crude oil samples have become essential in testing for water quality. This is due to the crude oils bio-fluorescent qualities, which can be attributed to PAH's. The process of testing for fluorescence is known as fluorescence spectroscopy tested using Fluorometers.

Oils are typically excited using ultraviolet wavelengths (300-400 nm) and fluoresce in the visible wavelength range from 400-600 nm. The composition of the hydrocarbon chain as well as the other compounds present will determine its fluorescent capabilities.

The following items were used in testing the fluorescence of the sample:
- Ocean Optics USB 4000
- Fluorescence Flow Cell
- Spectrasuite Software Package
- Tungsten Halogen LS-1 Light Source

The setup for this test can be found in Figure 3.

Figure 1: Deep Water Horizon being transported

Figure 2: (clockwise) Water collection tool, temperature gauge, Meteos Anemometer, Sony A200 Camera

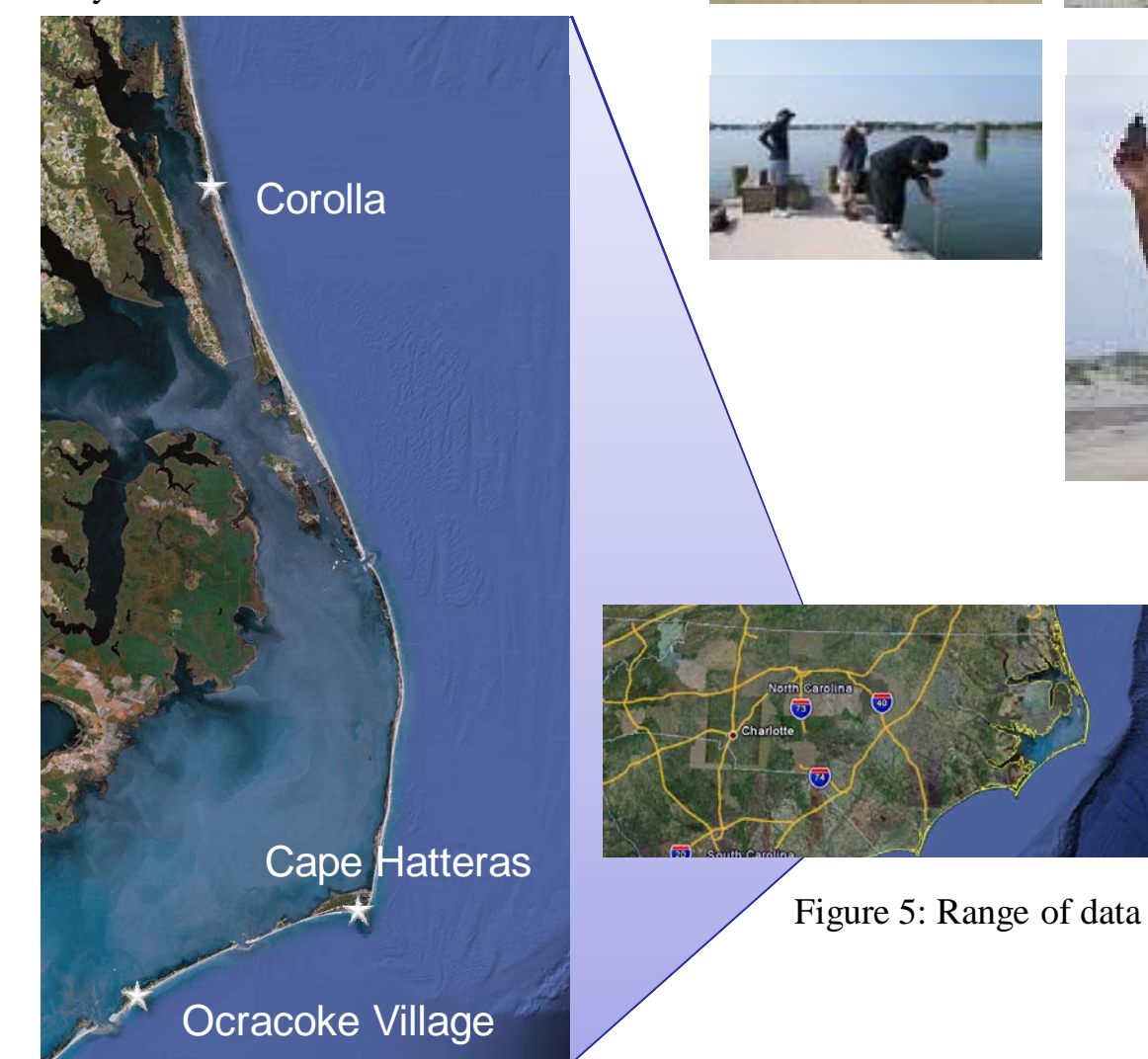Corolla

Cape Hatteras

Ocracoke Village

Figure 5: Range of data collection

Fluorescence Testing Outcome

Resulting fluorescence graphs were collected for all thirty samples and saved in PNG format (Figure 4). It was noted that the only visible difference in all of the graphs was the intensity level. All of the graphs had similar spectrum readings differing only in intensity. In testing the graphs, they were found to be inconsistent with what has been displayed in reference articles. Peaks were also found in the de-ionized water sample which should have had no fluorescence. If the samples had correctly tested they would have differed greatly in wavelength, as well as intensity. Several experiments were performed to try and locate the source of the problem with no positive results.

It is recommended that further contact with Ocean Optics be made to arrive at accurate fluorescence readings. Tests should also be completed to ensure the Fluorescence Flow Cell is functioning properly. In a correctly functioning Fluorescence Flow Cell, de-ionized water would flow completely through without providing a fluorescence reading.

Water Quality

Clean water is essential for the survival of all ecosystems. The plants and animals in rivers, lakes, and oceans react to chemical changes in the natural water quality of their habitat. The change in the composition of species like phytoplankton, algae and bottom dwelling organism may indicate changes in water quality caused by an increase in the concentration of chemical nutrients in an environment, organic pollution, hazardous substances or oil.

The following measurements were collected during this research:
- **pH** - the measure of acidity and alkalinity of a solution
- **Salinity** - the amount of dissolved salt in a body of water
- **Conductivity** - A charge sent through one probe and collected by another probe. The speed of the charge is indicative of the amount of organic materials or dissolved solids present within the samples.

The tests run for this project did not result in any unexpected readings. Salinity was high in the sounds due to extreme heating of the water over an extended period of time. The pH levels centered around 7.2-8.4. Conductivity tests showed high levels of dissolved matter in the samples. Refined oil was added to a sample to illustrate that the conductivity readings drop considerably in the presence of oil. The test results did not show any substantial differences in the readings from the sound to the ocean.
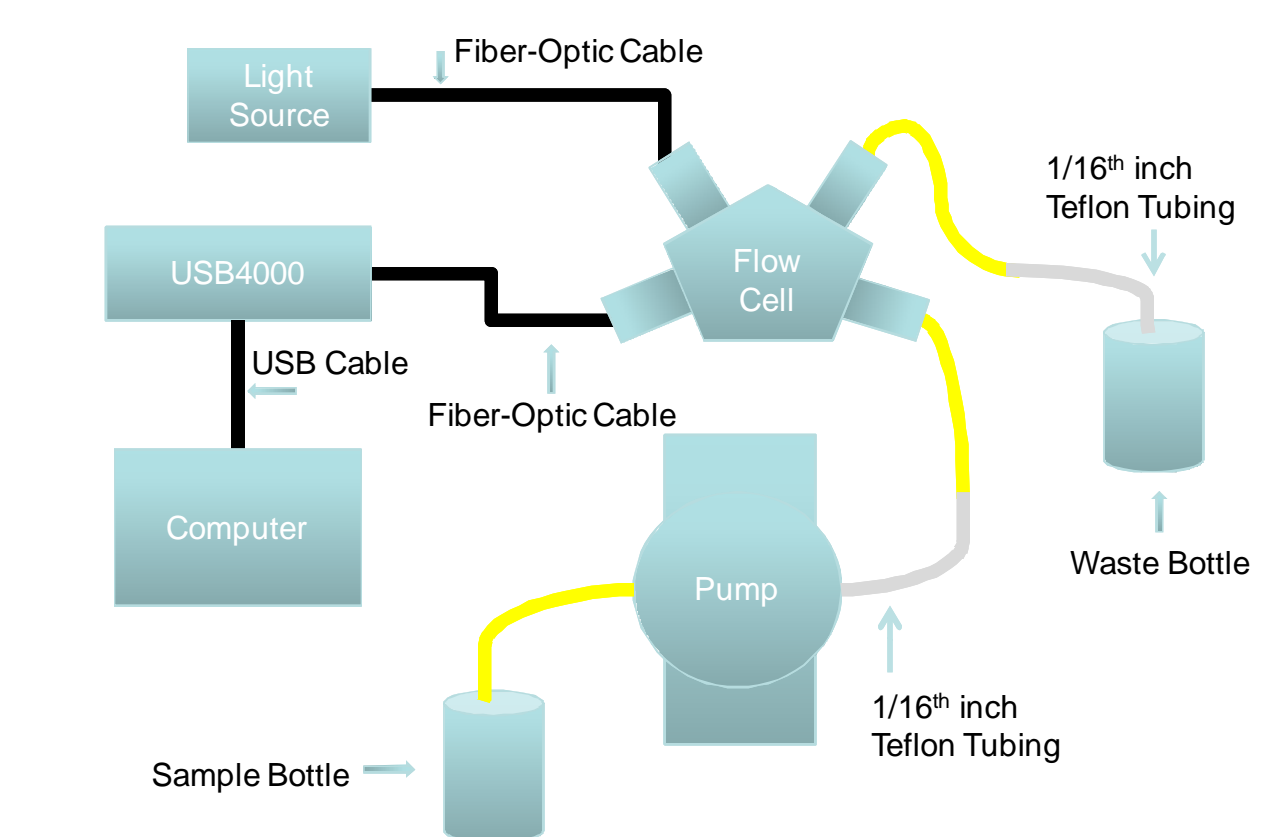

Figure 3: Fluorescence Testing Setup

Light Source — Fiber-Optic Cable — Flow Cell — 1/16th inch Teflon Tubing

USB4000 — USB Cable — Fiber-Optic Cable — Waste Bottle

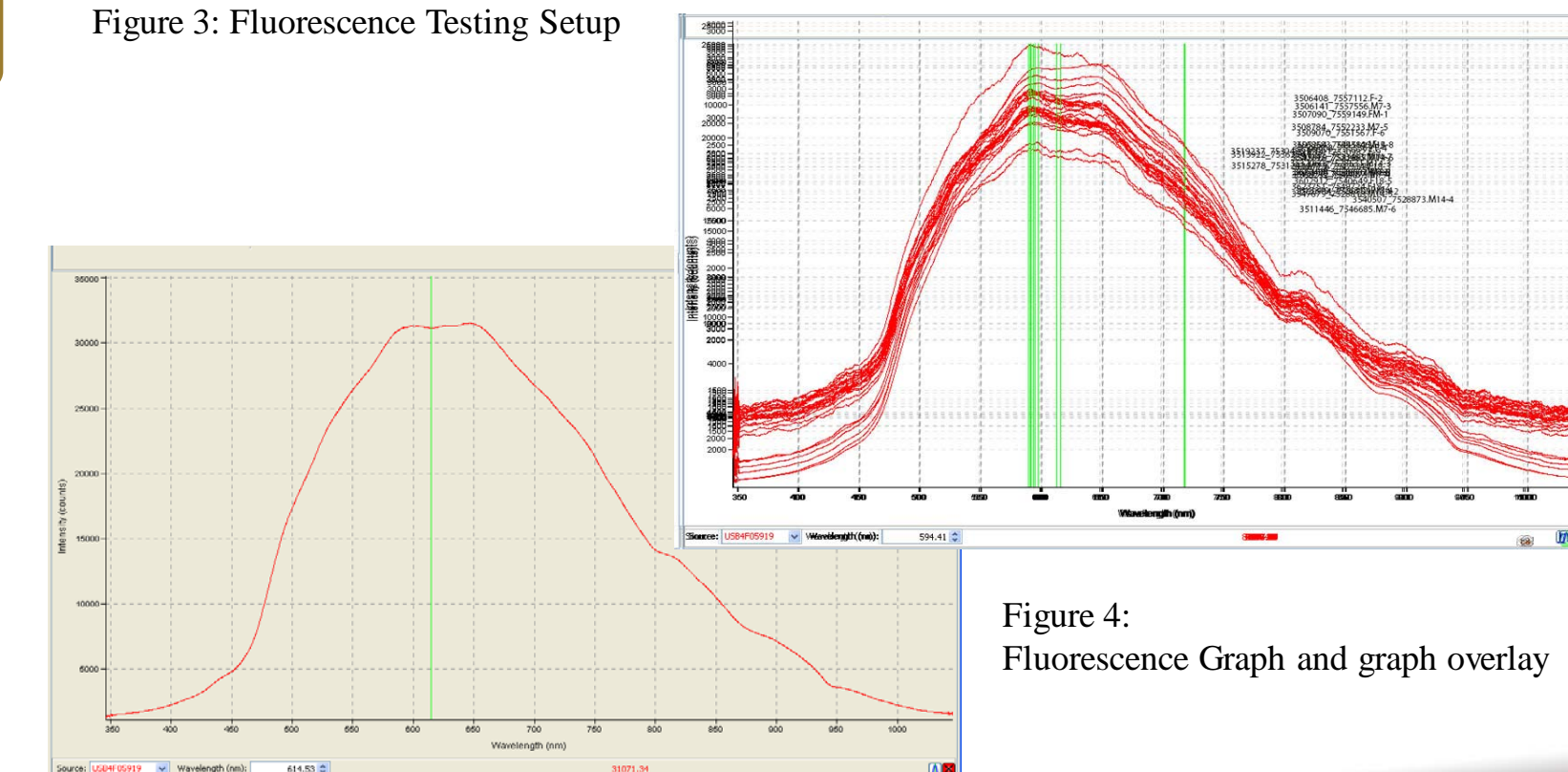Computer — Pump — 1/16th inch Teflon Tubing

Sample Bottle

Figure 4: Fluorescence Graph and graph overlay

Visualizations

Once the data was gathered and tests were completed, the results were gathered into visualization pages to be viewed by other researchers and scientists. This visualization utilized a combination of Google Maps, Adobe Photoshop, and scripting languages to present images and data in a geographic format. This allows the user to select the region of the Outer Banks that data was gathered for. A single view of the map can be found in Figure 6.

The Details Page in shown Figure 7 provides more in-depth information for each location. The following items are displayed on the Details Page:
- Latitude/Longitude
- Description of the location
- Ground Shot to show that there was no oil visible in the water
- 360° Panoramic view of the location.
- Water test results
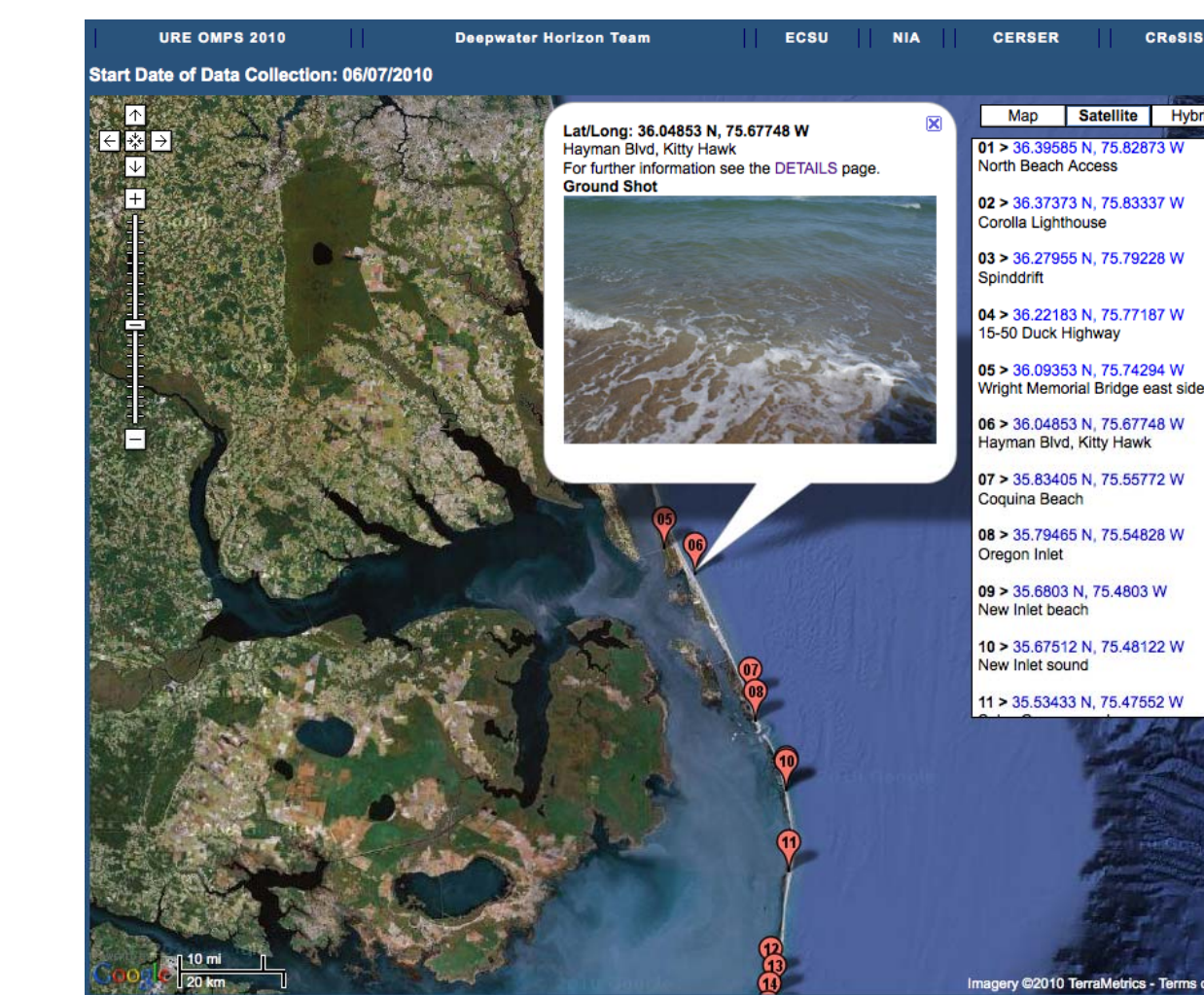- Fluorescence intensity and wavelength graph

Figure 6: Data Visualization

Figure 7: Details Page

Results

Establishing scientific baselines in the face of impending changes in the environment is essential to the further monitoring, research, and recommendation of changes that can be made. This project established procedures, sites, and further tests that should be implemented in the eco-systems that make up the Outer Banks of North Carolina. While some tests did fail, the failures brought out the need for more communication with manufacturers and scientists. The lack of test equipment for more thorough water tests has prompted local managers to take stock of their equipment and the continuing need to keep it in good operating order. These steps will lead to greater success for future researchers continuing this project.

Future Work

Fluorescence procedures should be reviewed with Ocean Optics to establish the correct method by which the fluorescence of oil can be measured. Further enhancements to the data can be made through acquisition of electronic test equipment to replace chemical tests currently utilized. To display data in future projects it is recommended that a comma separated value (csv) file be used to be read by PHP coding. The PHP script will parse the CSV file into multiple variables and create JavaScript code that Google Maps can utilize. To establish a stronger baseline, the sedimentary layers, as well as, the organisms and microorganisms present in the sample locations should also be tested.

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