Analysis of RETTEW
Alligator Jr Aerial MAG Survey

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1 – Executive Summary

Extensive research and anecdotal eyewitness accounts point to the prototype of the Civil War submarine USS *Alligator* being abandoned in the vicinity of Rancocas Creek near Riverside, New Jersey. Extensive side scan sonar and magnetometer searches of the creek failed to locate the vessel. Emphasis shifted to the side creeks colloquially known as “ditches.” These small tributaries currently provide limited access due to very shallow water depths and vegetation blocking easy access, negating typical surface-vessel-executed surveys. Easy walking access is prohibitive due to deep mud.

An aerial drone/magnetometer search was executed over the highest probability area, detecting a significant magnetic anomaly not directly attributable to any known infrastructure. The anomaly size indicates the iron mass of the buried object to be within the calculated range expected of the prototype. However, there is insufficient evidence to conclude that the object is the prototype *Alligator Jr.* The data only confirms the presence of a large mass of metal at the anomaly location. Further investigation is required, and options are provided in the full report.

Analysis of RETTEW
Alligator Jr Aerial MAG Survey

1 - Mission

Extensive research and anecdotal eyewitness accounts point to the prototype of the Civil War submarine USS *Alligator,* dubbed *Alligator Junior,* abandoned in the vicinity of the Rancocas Creek near Riverside, New Jersey. Extensive side scan sonar and magnetometer searches of the Rancocas failed to locate the vessel. Emphasis shifted to the side creeks colloquially known as "ditches." While historically deeper and more accessible, these small tributaries currently provide limited access due to very shallow water depths and vegetation blocking easy access, negating typical surface-vessel executed surveys. Walking access and hand-held magnetometer surveys are prohibitive due to deep mud in the surrounding marsh.

On March 14, 2024, Stockton University executed a high-resolution visual aerial drone survey with negative results. If the submarine was present, the vessel is buried or covered with vegetation. The Stockton high-resolution aerial/visual survey results confirmed that an aerial magnetometer survey was required.

An aerial drone/magnetometer survey was the best option to reliably and accurately survey the marsh and ditches for the remains of the historic submarine. The SubHunt Group hired RETTEW to execute an aerial magnetometer survey of the marsh that potentially contains the remains of the Civil War submarine. RETTEW employed a highly sensitive magnetometer slung under a drone that could detect iron objects buried beneath the sediment. Details of the equipment and methodology are available in the RETTEW report.

2 – Simplified Magnetometer Survey Explanation

In the most simplistic terms, magnetometers detect objects that contain iron, such as steel, also known as ferrous metals. Magnetometers cannot detect gold, silver, brass, or bronze, which do not contain iron or cannot be magnetized.

The earth's flowing magnetic field encompasses the entire planet. This flowing magnetic force is why a compass points north (Fig 1). The earth's background magnetic field strength varies by location and time of day. Metal detection is accomplished by precisely measuring the earth's magnetic field and recording background field levels. Iron objects interrupt the field, causing the field's strength to rise or fall. These disturbances caused by the flowing magnetic field interacting with iron objects are called magnetic anomalies. Disturbances in the magnetic field are measured above or below the background level.

Since the earth's magnetic field is not hampered by water or sediment, the disturbances (Anomalies) can be used to detect buried objects.

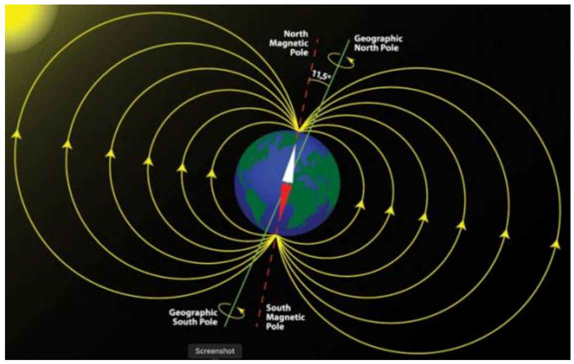

Figure 1 Earth's Magnetic Field

Measurements of the earth's magnetic field collected with a magnetometer are recorded with the GPS position of each measurement. Magnetometers collect many readings per second, producing large amounts of data. This data is plotted on a map using elevation color contours showing high and low values as different colors representing disturbances in the field, i.e., magnetic anomalies (Fig 2).

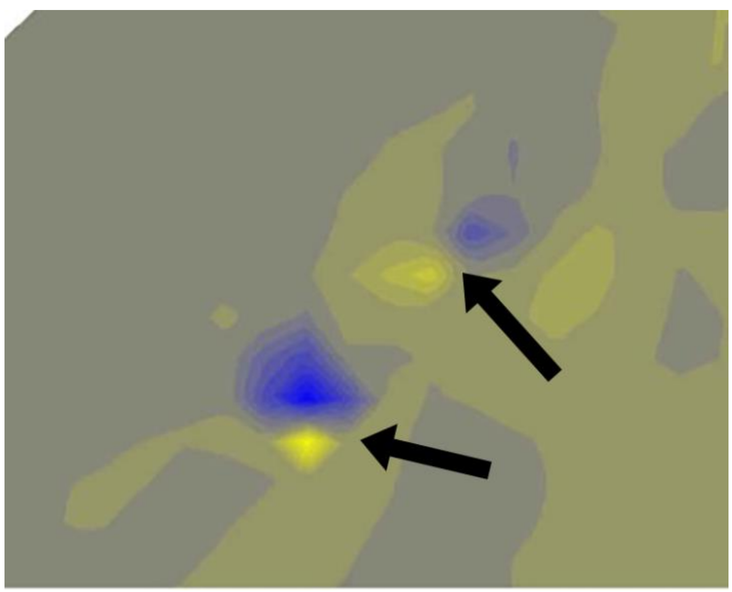

Figure 2 Color Contour Map Depicting 2 Magnetic Anomalies

Think of a magnetic anomaly as a small boulder in a flowing stream causing the water to rise and flow over the top of the obstruction. The water level then drops below normal level on the down-current side. Anyone who has experienced a whitewater rafting trip will know exactly what this phenomenon looks like. The two color pairs shown in Figure 2 represent a dipole magnetic anomaly's high and low magnetometer readings.

The earth's magnetic field is measured in units called nanoteslas, abbreviation nT. An anomaly's size or strength is also reported in nanoteslas. A minor anomaly is usually represented by a value in the single digits. An anomaly of tens of nanoteslas is generally significant while always considering the distance between the magnetometer and the object.

The size of the anomaly is related to the mass of the iron object but is greatly influenced by the distance between the mass and the sensor. A minor anomaly with the sensor three hundred feet from an object will be much larger at one hundred feet. For example, a ton of iron several hundred feet away will have a small anomaly. A fifty-five-gallon drum three feet from the sensor will have a significant anomaly. Thus, the size of the anomaly is greatly influenced by the distance between the metal object and the sensor (Fig 3).

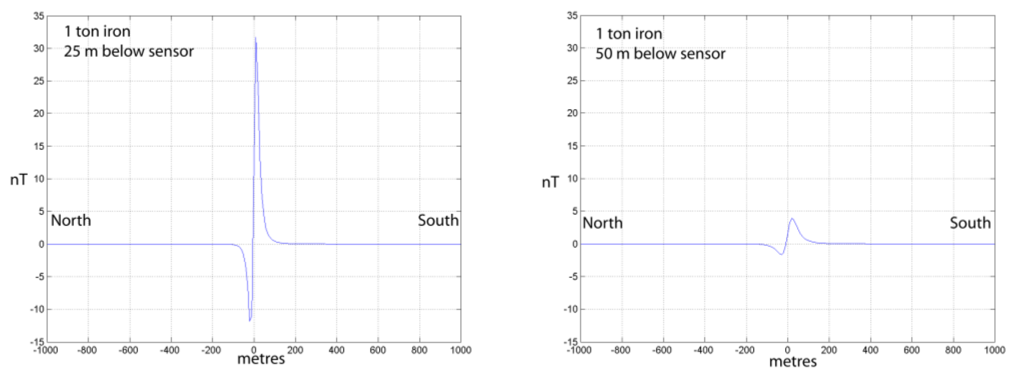

Figure 3 Comparison of Anomaly Graphs
One Ton of Iron At 25m and 50m Distance

While the weight or mass of iron is the object's most important characteristic, another property influences the field disturbance magnitude. Magnetically susceptible objects often have inherent magnetic properties. A magnet will cause a much larger magnetic anomaly than a straightforward iron rock relative to its mass. Iron or steel that has been forged often takes on different magnetic properties that can influence the anomaly's size.

An anomaly has three characteristics essential to understanding the disturbance.

1) General Shape Characteristic: Di-Pole or Mono-Pole
    a. When displayed graphically, a dipole exhibits adjacent high and low field values, as described in the wave example and shown in Figure 2. A single

point, large mass object in the northern hemisphere usually produces a dipole-shaped anomaly.
   b. A monopole is a single up or down-shaped disturbance in the magnetic field that occurs for various reasons depending upon location, survey grid spacing, orientation to the earth's magnetic field, etc.

2) Magnitude (Strength) of the Disturbance
   a. The magnetic field strength of a dipole is measured from the peak of the highest value to the trough of the lowest value.
   b. A monopole is measured from the ambient field strength to its highest or lowest point, depending on whether it is positive or negative.
   c. The larger the anomaly value, the larger the iron mass of the contact, assuming distance remains constant.

3) Shape of the Disturbance
   a. Assuming sufficient measurements, the shape of the anomaly indicates the distance between the sensor and the anomaly. Short, spiky anomalies are close to the sensor, while significant, rounded anomalies are further away. Combining shape and magnitude gives the analyst an indication of contact properties.

   b. How many measurements define the shape? If only a single point creates an anomaly, it is probably noise. If multiple points generate the shape, the analyst has confidence in the anomaly's shape and strength.

3 – Survey Quality

The RETTEW aerial drone magnetometer survey provided the SubHunt Group with high-quality data while efficiently covering a large survey area. The drone offered excellent line steering, ensuring a consistent survey pattern and complete coverage (RETTEW Report Fig 1).

The survey altitude was one hundred feet above the marsh. The altitude was chosen to clear vegetation, provide sufficient coverage, and eliminate magnetic noise from very small metal debris. The data was corrected for diurnal variation via base station magnetic field measurements. These measurements also ensured the data was free of noise generated by external events such as solar activity.

Based on my review, the data is consistent and representative of magnetic conditions within the survey area.

4 – Estimated Iron Mass of Submarine

Naval Captain Retired and professional engineer Walter Lincoln calculated the iron mass of Alligator Jr to be approximately 9,400 lbs (4.7 Tons). If the ballast was iron, the estimated iron mass could be as high as 14,100 lbs (7 Tons).

5 – Survey Results

The color-contoured survey data showed two significant magnetic anomalies: one in the northwest corner of the survey area and a second at an undisclosed location within the survey area. The location was removed to protect the potential historic resource and for the safety of those who may try to visit the site without realizing the dangers of the deep mud. The NW anomaly was caused by local infrastructure, a railroad crossing bridge. The second anomaly is smaller and is independent of any current man-made structures.

The second anomaly is approximately 19 nT. Modeling object mass based on a single altitude survey has a certain degree of error based on many factors. However, we can generate a range assuming the contact is minimally buried. 19 nT could represent a mass ranging in size from two tons to ten tons, depending upon the nature of the contact. The RETTEW report indicates a 20 nT contact can represent 10 tons of iron mass.

The depth of burial cannot be calculated from the existing data. However, the burial should be very shallow if anecdotal eyewitness accounts are correct.

5 – Conclusions

a. A 20 nT magnetic anomaly at a distance of 100 feet is of sufficient magnitude to represent the lost submarine.
b. The anomaly does not conclusively prove the submarine's presence; it only shows that a mass of iron is present at that location.
c. Philadelphia was one of the first American cities to adopt large-diameter cast iron pipes for sanitary sewage lines. A 48-inch cast iron pipe contains approximately 360 pounds of iron per foot. A twenty-foot length would weigh in at 7,200 pounds or approximately 3.6 tons. While less than the mass of the target submarine, unknowns such as length, diameter, and inherent magnetic properties can influence the size of the magnetic anomaly.

d. While improbable, an unknown scenario other than that described in a and c above could cause the anomaly.
e. Further investigation would be required to determine the source of the magnetic anomaly.
f. The aerial drone magnetic data is very accurately positioned. However, because of the anomaly size and its monopole characteristic, the resulting magnetic anomaly does not pinpoint the exact location of the subsurface object causing it. Any further investigation would require localizing the anomaly before excavation.

6 – Options for Further Investigation

Since the contact resulting in the magnetic anomaly was not visible in the Stockton University visual aerial survey, the target is assumed to be covered by sediment and vegetation. The marsh and deep mud are the predominant obstacles to further investigation, hindering physical access to the location. Assuming access limitations could be overcome, options for a subsurface investigation are as follows:

1) Ground Penetrating Radar (GPR)
   a. Ground-penetrating radar utilizes radar pulses to image subsurface features. The radar creates a profile view of sedimentary layers and buried objects directly below the radar antenna.
   b. GPR will not work in salty environments. However, all indications are that the location is a freshwater marsh, and GPR would be an effective tool.
   c. The ground penetrating radar would identify the exact position of the buried contact and, with sufficient transects, provide an approximate size of any buried object.
   d. Ground penetrating radar cannot distinguish between a buried cast iron pipe and the target submersible.
   e. Ground penetrating radar would be an excellent intermediate step before excavation if access and coverage can be achieved within the marsh.
   f. A frozen, snow-covered surface would provide the smoothest and most accessible surface for running GPR transects. If the surface is not snow-covered, vegetation may need to be trimmed, or a drone-mounted GPR may be used.
   g. Alternatively, the GPR can be placed in a plastic or fiberglass case or small inflatable boat and pulled across the marsh vegetation if the obstacle of deep mud can be overcome.

2) Hand Held Magnetometer
    a. A hand-held magnetometer could localize the contact but would not provide the ability to discriminate between pipe and submersible and would require walking the marsh.

3) Test Excavation
    a. The only conclusive method of determining the contact identity is a test excavation.