Aqua-Guardian: Proposal for Continuous Water Quality Monitoring Buoy

Seeking Expert Consultation for the 25-26 Samsung Solve for Tomorrow Competition

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Section 1: The Rationale

Our student team at Atholton High School's Electronics Club is competing in the **2025-2026 Samsung Solve for Tomorrow** competition, aiming to address the environmental vulnerability of Columbia, Maryland's core water resources. The recent 1.3 million-gallon sewage overflow near Watchlight Court, and the recent health advisories due to Harmful Algal Blooms (HABs) in Lake Centennial and Triadelphia Reservoir have sparked the interest of students within Atholton HS to develop a tool that provides early warning of a crisis. Our goal is to augment existing monitoring efforts by providing continuous data and an automated flagging system to direct human attention to areas of heightened risk. Our project, the Aqua-Guardian, is a student-built, cellular-enabled IoT buoy designed to fill the existing data gap by providing real-time environmental intelligence that can be used to… target areas of elevated risk, draw attention to areas that need further testing, and provide citable evidence for research, which can especially be used to advocate for stronger environmental policy.

Competition Timeline: We are currently compiling technical details and data for our submission; this must be done before the *Application Entry Deadline.*

- **Application Entry Deadline -** 11/05/2025.
- **Pre-acquisition of components -** Design the buoy using CAD, and begin software development.
- **Advancement Notice -** 12/05/2025.
- **Build phase** - Bring the idea out of the concept phase.
- **Phase 2: 3 Minute Video Submission -** 01/21/2026.
- **Advancement Notice** - 02/11/2026
- **End of Social Media Voting Period** - 03/06/2026

Section 2: Aqua-Guardian: Low-Power, High-Efficiency Hardware

The single **Aqua-Guardian buoy** is engineered for maximum operational autonomy and precise data collection on one digital asset:

- **Computation & Power Management:** The system relies on the *Firebeetle ESP32 IOT Board* for its remarkable efficiency, achieving a deep sleep, which ensures months of operation via solar power. The board's pin-out is managed using the *DF Robot Gravity Sensor Expansion Board*.
- **Cellular Connectivity:** For guaranteed off-shore data relay, we use the *Adafruit FONA MiniGSM Cellular/GPS Board*. This enables data transfer from remote locations and hard-to-reach areas within a water body.
- **Sensor Array:** The buoy integrates seven sensors to provide a complete picture of water chemistry: **pH**, **Dissolved Oxygen**, **Electric Conductivity**, **Turbidity**, **Temperature**, **Oxidation-Reduction Potential**, and an internal **Water Leak Sensor**.
    - This sensor array uses industrial-grade components mainly from DF Robot to prevent anti-fouling and provide consistent, accurate readings.

Section 3: Environmental Intelligence for Targeted Action

The core innovation is our AI-enhanced platform, which converts raw sensor readings into clear diagnostic indicators, automatically flagging users when follow-up monitoring is needed:

- **Nutrient Enrichment Indicator:** This indicator tracks simultaneous spikes in EC and drops in ORP/DO after heavy rain/runoff. Sustained low ORP and DO also signify decomposing Organic Pollution (like sewage).
- **Algal Bloom Risk Score:** An aggregated score correlating rising Temperature, increasing Turbidity, rising pH, and the severe DO fluctuations (photosynthesis/respiration) characteristic of HABs. This score provides a priority flag for further and more precise testing.
- **Chemical/Industrial Pollution:** Anomalous readings in extreme pH, high EC, and abnormal ORP are flagged.
- Our system will integrate the use of AI to help with deriving a water body's condition and to filter out invalid readings caused by natural weather patterns, ensuring users are alerted only by scientifically significant deviations.

Section 5: Challenges

Building a robust, long-term environmental monitoring system, even on a small scale, presents complex engineering and scientific hurdles. Addressing these challenges effectively requires expert input to ensure the credibility and utility of our single deployment.

- **Sensor Calibration:** Electrochemical sensors like pH and ORP probes naturally suffer from sensor drift over time and require recalibration to maintain data accuracy. The use of industrial probes is meant to counter this, but the timeframe of deployment is still unknown..
- **Data Integrity and Invalid Correlation:** While our AI attempts to filter for external factors (like weather and temperature), unconsidered variables like tidal effects, heavy sediment flow, or seasonal changes could cause invalid correlations between sensors and lead to false flags.
- **Biofouling:** Preventing **biofouling** (algae/bacteria growth) on sensor heads corrupts readings, particularly for optical sensors like turbidity.
- **Determining Sample Rate:** As aforementioned, tides and the presence of daylight can affect what the norm for sensor readouts should be. Not only that, but sampling at various times of the day can indicate other things like algae growth. Sampling rate will be customizable based on application, but for testing, we will need to know what to look out for.

Section 5: Consultation and Sponsorship

As a student team competing in the **Samsung Solve for Tomorrow** contest, our primary need during this application phase is expert consultation to ensure the scientific validity of our unique sensor interpretations and deployment strategy.

We are seeking your support in two ways:

1. **Expert Consultation:** We urgently need your guidance to review our AI flagging logic, set scientifically sound alert thresholds for our derived measurements (e.g., Algal Bloom Risk Score), and advise on the most strategic deployment location in Howard County to prove our solutions use and effectiveness.
2. **Sponsorship for Building:** Should our idea be selected to advance past the initial application phase and into the building phase, we will require financial sponsorship for component acquisition, a data plan for the cellular unit, and waterproofing materials to successfully construct, test, and deploy the final buoy. Currently, the buoy is expected to cost around $550 USD in raw materials.

Consultation will directly enhance a student project aimed at creating a valuable, open-source digital asset for local environmental monitoring. We look forward to collaborating to make this tool a reality.