

2218001 - Independent Project - Proposal

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Department of Electrical & Electronic Engineering

Independent Project – Proposal

From Sensor to Solution: Embedded System for Environmental Spill's

Control

ACCA6020

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2218001

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Introduction

This project is within the field of Electrical and Electronic Engineering and focuses on designing and developing a monitoring system to detect, record and report spills from overflow pipes at Wastewater Treatment Works (WwTW) and Pumping Stations (PS). The system aims to provide continuous and reliable monitoring even during power failures, storm events or excessive inflows, which are common causes of environmental spills [1].

Across the UK, water utilities have faced increasing scrutiny from the public and regulators regarding pollution events caused by unmonitored wastewater discharges. Environmental regulators such as Ofwat (2024) [2] and Natural Resources Wales (2023) [3] have stressed the need for improved monitoring and data reporting to reduce environmental harm.

Continuous and reliable monitoring systems are now seen as essential tools for maintaining environmental compliance and ensuring rapid response to overflow events. The proposed system will be positioned at the start of the wastewater process, where spills are most likely to occur. The design will incorporate a radar level sensor, a PIC microcontroller and a backup power source to ensure data recording continues during power loss [4]. This approach supports the wider goal of improving environmental performance, resilience and sustainability in wastewater operations [5].

Recent advancements in low-power embedded electronics, radar-based sensing technologies and autonomous data logging systems have significantly improved the reliability of environmental monitoring devices. Modern sensor platforms are now capable of operating with minimal maintenance, even under harsh conditions, making them ideal for deployment in wastewater networks. Industry research and environmental reports, such as those from Ofwat (2024) and Natural Resources Wales (2023) highlight the urgent need for improved resilience in spill monitoring systems to support better data reporting and pollution prevention [6]. This project aims to bridge the gap between traditional monitoring and modern embedded solutions by developing a low-maintenance, power-resilient monitoring unit suitable for real-world wastewater applications [7].

Background & Rationale

Wastewater treatment sites are essential for protecting both public health and the environment. However, many sites across the UK face challenges due to aging infrastructure, increased rainfall events and public pressure to reduce pollution incidents [8]. Overflow pipes often discharge untreated wastewater when the system becomes overloaded or when power failures prevent pumps from operating.

Traditional monitoring systems rely heavily on manual inspections or outdated sensors that cannot provide continuous data, especially during critical events. These gaps in monitoring often result in missing data, delayed responses and breaches of environmental permits. Research from the Environment Agency (2024) confirms that storm-related spills and power-related failures are leading contributors to unmonitored pollution events.

New advances in radar level sensors and microcontroller-based systems now make it possible to develop small, reliable monitoring units capable of operating autonomously for long periods. By combining modern sensors with a backup power supply, continuous data recording can be maintained even during power loss [9].

This project addresses this research gap by developing a compact and resilient monitoring device that can record and store data from overflow pipes in real-time, regardless of power conditions. The system will support better data decision making and more effective environmental protection.

Problem Statement

Wastewater treatment sites rely on monitoring systems to detect overflow events and prevent untreated wastewater from entering the environment. However, current systems are often inadequate, or in some cases, not present. Traditional sensors and manual inspections frequently fail to provide continuous, reliable data, resulting in unrecorded spill events and delayed operational responses.

Research from the Environment Agency indicates that the number and duration of sewage spills have increased in recent years, with gaps in monitoring during extreme weather and power loss contributing to these incidents. Reports from Natural Resources Wales (2023) and Ofwat (2024) highlight similar concerns, emphasising the need for more resilient monitoring systems capable of operating even during power failures.

The research gap is clear, while modern sensors and embedded platforms exist, they are rarely combined with backup power supplies to maintain continuous operation during critical events.

This project addresses this gap by designing and developing an embedded spill monitoring system that integrates a radar level sensor, microcontroller, and backup power supply. The system will provide continuous monitoring of overflow pipes at Wastewater Treatment Works (WwTW) and Pumping Stations (PS), ensuring accurate recording of spill events even during power failures or extreme inflow events.

Aim & Objective

Aim:

The overarching aim of this project is to design and develop a reliable embedded spill monitoring system for Wastewater Treatment Works (WwTW) and Pumping Stations (PS) that continuously detects, records and reports overflow events during power failures or extreme inflow conditions, overcoming current monitoring limitations and improving environmental response.

Objectives:

To achieve this aim, the project will focus on the following 'SMART' objectives:

1. To analyse the operational challenges of existing overflow monitoring systems, identifying weaknesses related to data loss, power outages and sensor reliability.
2. To design and simulate an embedded monitoring unit incorporating a radar level sensor, microcontroller-based control, and backup power to ensure continuous data recording.
3. To implement and test the monitoring system under simulated overflow scenarios, including power failure and high inflow conditions, to evaluate its reliability and performance.
4. To evaluate the system's effectiveness by comparing recorded data against expected overflow events and to assess its potential for real-world deployment in WwTW and PS.

Outcomes & Deliverables

At the conclusion of this project, the following outcomes and deliverables are expected:

1. A functional embedded spill monitoring system
 - The system will integrate a radar level sensor, microcontroller-based control and backup power supply to provide continuous monitoring of overflow pipes at WwTW and PS.
 - It will be capable of detecting, recording and reporting overflow events, including power failure or extreme inflow events.
2. Prototype testing and evaluation report
 - A detailed report documenting the system's performance under simulated conditions, including reliability, response time and data accuracy.
 - Analysis of system limitations and potential improvements.
3. Data collection framework
 - A structured dataset of recorded overflow events from the testing phase, which can be used for further analysis or integration into operational monitoring systems.

4. Final project report and documentation

- Complete documentation including system design diagrams, circuit schematics, software code and user guidelines.
- Recommendations for real-world deployment and potential scalability to multiple sites.

Optional outcomes (if feasible, due to Welsh Water Data):

- A visual interface or dashboard for real-time monitoring.
- A comparison of performance with existing monitoring approaches to demonstrate improvements in reliability and continuous operation.

Project Design

This project involves the design, development and evaluation of an embedded spill monitoring system for Wastewater Treatment Works (WwTW) and Pumping Stations (PS). The system will consist of a radar level sensor, a microcontroller-based control unit and a backup power supply. The primary function is to continuously detect, record and report overflow events, including power failures and high inflow scenarios. The project will involve a prototype development, testing and performance evaluation.

Data Collection Methods

Data collection will focus on both system performance and simulated environmental events:

- **Objective 1 (Analyse existing systems):**
 - Collect data from literature reports and publicly available monitoring datasets.
 - Purpose: Identify current limitations in monitoring systems and quantify gaps in performance, reliability and coverage.
- **Objective 2 (Design and develop system):**
 - Gather design specifications, sensor calibration data and microcontroller input/output signals during prototype operation.
 - Purpose: Ensure system can reliably capture overflow events in real-time.
- **Objective 3 (Implement and test system):**
 - Collect sensor readings during simulated overflow events, including high inflow and power failure scenarios.
 - Purpose: Evaluate system reliability, response time and accuracy.
- **Objective 4 (Evaluate effectiveness):**

- Compare recorded events against expected events in simulations.
- Purpose: Assess the overall performance, reliability and feasibility for real-world deployment.

Specialist Methods & Techniques

- **Radar level sensing:** Non-contact measurement of water levels in overflow pipes.
- **Microcontroller-based embedded control:** Processes sensor signals, stores data and manages system operation.
- **Backup power integration:** Ensures operation during power failure.
- **Simulation setup:** Controlled testing of overflow events, including pump failures or heavy rainfall.

These methods are appropriate because they directly address the limitations of existing monitoring systems and provide reliable and continuous data collection.

Risk Management

No.	Risk	Category	Mitigation
1	Electrical faults	Installation/ Commissioning	Complete testing for confirmation of electrical wiring. Ensure cabling is in line with electrical standards
2	Sensor calibration errors	Commissioning	Conduct calibration before handover. Training and seek advice from supplier
3	Data loss		Backup storage on memory sticks
4	Legal/data privacy access issues	Ethical	Seek permission if data is required/follow ethical guidelines
5	Software issues	Commissioning	Implement testing and debugging
6	Sensor readings	Commissioning	Conduct multiple tests under varying conditions to validate sensor accuracy
7	Delays in component delivery	Logistical/Installation	Order components early, prior to installation
8	Hardware failure	Installation	Keep spare components or plan for replacements
9	Data communication	Commissioning	Implement local data logging redundancy

Ethical Considerations

No human subjects are involved, data collection is limited to environmental monitoring and simulated events. Any site-specific data used will comply with Welsh Water's guidelines and will not include identifiable personal information.

An ethics form will be submitted as evidence in line with university requirements.

Environmental & Societal Impact

The system will help reduce unrecorded wastewater spills, protecting rivers, wildlife and local ecosystems. Improved real-time monitoring will allow wastewater operators to react faster to overflows, reducing pollution and public health risks.

The project also supports the UK's sustainability and net-zero goals by promoting smarter environmental management.

Data Analysis & Evaluation

Recorded overflow events will be compared to expected events in simulation scenarios to evaluate accuracy, reliability and response time.

- Basic statistical analysis will include:
 - Descriptive statistics: Mean, max and min water levels during events.
 - Error analysis: Difference between detected and actual overflow events.
 - Reliability metrics: Percentage of events successfully recorded under different conditions.

Results will be used to refine the design and suggest areas of improvement for real-world use.

Resources

Resources Required:

- **Hardware:**
 - PIC microcontroller
 - Radar level sensor
 - Battery module/UPS
- **Software:**
 - Proteus
 - Microsoft Excel (data analysis).
- **Other:** Access to online journals and university technical support.

Planning



Figure 1 - Gantt Chart of Project Proposal

References

- [1] H. L. S. & K. H. Park, "A real-time embedded system for oil spill detection and response. Journal of Environmental Management," 2022.
- [2] O. (2024), "Water Company Performance Report," https://www.ofwat.gov.uk/publication/water-company-performance-report-2023-24/?utm_source, 2023-2024.
- [3] N. R. Wales, "Storm Overflow Spill Data Report," <https://naturalresources.wales/evidence-and-data/research-and-reports/water-reports/storm-overflow-spill-data-reports, 2024>.
- [4] M. I. M. & H. Rahman, "Low-power embedded system design for environmental applications," 2021.
- [5] T. Alshami, "IoT Innovations in Sustainable Water and Wastewater Management and Water Quality Monitoring: A Comprehensive Review of Advancements, Implications and Future Directions," 2024.
- [6] H. Wu, "A Review of Non-Contact Water Level Measurement Based on Computer Vision and Radar Technolog," 2023.
- [7] M. W. Z. & Z. J. Li, "An IoT-based real-time water quality monitoring system using embedded sensors. Environmental Monitoring and Assessment," 2022.
- [8] A. Drenoyanis, "Implementation of an IoT Based Radar Sensor Network for Wastewater," 2019.
- [9] N. Darwin, "IoT-Powered UPS Battery Monitoring: Ensuring High Availability in Remote Systems," 2023.

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GRADEMARK REPORT

FINAL GRADE

72 / 100

GENERAL COMMENTS

1)

Introduction

/ A&O: (15/20 Marks)

Good project title. Identified an industry and societal relevant problem in the water management system and explained why this project is worth doing. The project aim are clearly stated and well-aligned with the identified problem. SMART objectives are relevant, measurable and achievable. Deliverables are mentioned and appropriate, but they could be grouped and presented more clearly. Some parts repeat similar context and can be streamlined.

2)

Background

to the Project / Literature Review: (15/20 Marks)

Engaged with a good range of academic studies, environmental regulatory reports and IoT technologies. The chosen literature is relevant to build a rationale for the project and to identify a clear research gap. It would have been better with providing strong connection between each cited work and your project design. Some references appear incomplete or lack full IEEE formatting.

3)

Project

Design: (21/30 Marks)

The development methods and tools are described well. The description of data collection is good. Good justification for chosen technologies and methods. Strong alignment between objectives and design strategy. However, the section could be improved by explaining how the data will be

analysed. It would have been better if a block diagram of system architecture is included and more detail on testing methodology.

4)

Resources

/ Planning: (11/15 Marks)

Listed the tools and deliverables. Good Gantt chart showing when each tasks to be completed. Ethics form completed. It would have been better if the planning section could describe resource dependencies in more detail..

5)

Document

Presentation: (10/15 Marks)

The document is well structured and presented. The narrative flows logically, with sections transitioning smoothly from one topic to the next. It would have been better with consistent formatting, and spacing. Proofread to find minor errors or inconsistencies. It is better to number subheadings appropriately. Some references require correction (e.g., missing publisher details, incomplete titles, formatting inconsistencies).

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