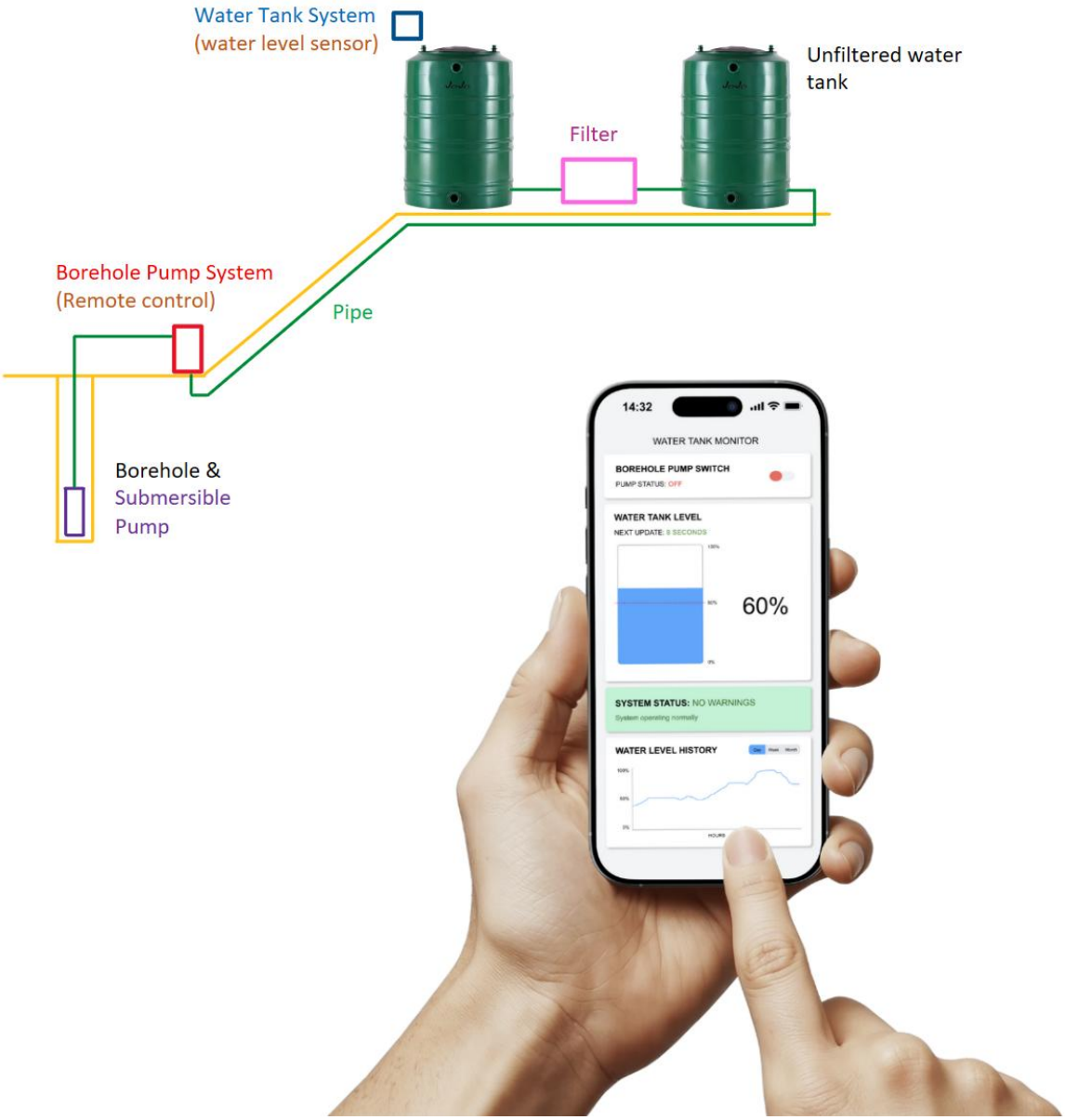
IoT Water Tank Monitoring System & Remote Pump Control



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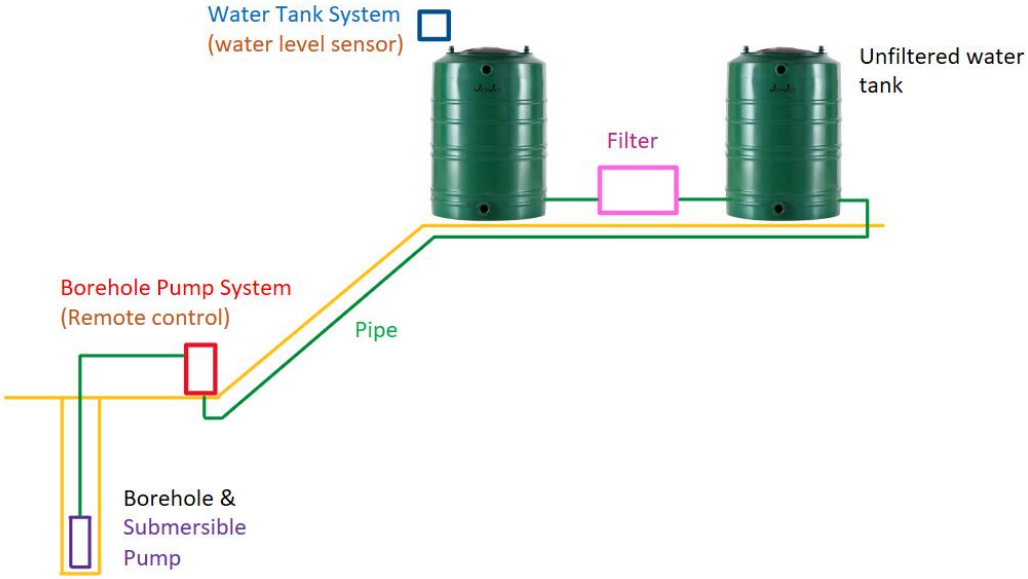
Contents

System Overview

This system is designed to monitor and control a water supply setup. Here's how the current system works:

- Water is pumped from an underground borehole using a submersible pump
- The pump is controlled by a manual ON/OFF switch located in a control box (powered by 220V)
- Water first goes into an unfiltered water storage tank
- Water then passes through a filtration system
- Finally, the filtered water is stored in a second tank for use



The diagram shows the complete water flow:

1. The submersible pump draws water from the borehole
2. Water travels through pipes to the unfiltered water tank (first green tank)
3. Water passes through the filtration system (pink box)
4. Filtered water collects in the second storage tank (right green tank)

Project Goals

The proposed solution aims achieve remote monitoring and control capabilities to this existing system.

Primary goals:

- Allow you to turn the borehole pump ON/OFF remotely from your mobile phone
- Display water levels in your filtered water tank on a simple mobile interface
- Keep the existing manual controls for backup and safety
- Receive alerts about potential leaks or system issues

The two main components to add are:

1. A water level monitoring system at the tank location
2. A remote-control system at the borehole pump

Important System Additions:

- Maintain the current manual ON/OFF switch for safety backup, adding remote control capability without removing existing controls
- Install water level sensors to monitor and display tank levels in real-time on your mobile device
- All components will be weather-resistant and designed for long-term reliability

Safety alerts:

1. Possible tank leaks (detected when water level drops continuously for more than 30 minutes)
2. Possible pipe leaks or pump issues (detected when the pump is running but tank water level isn't rising)

Proposed Solution

The IoT water monitoring solution consists of three main components working together to form a complete system:

System Overview

1. **Water Tank Station:** A solar-powered monitoring unit installed at the filtered water tank
2. **Borehole Pump Station:** A control unit that receives sensor data and controls the pump
3. **Mobile Interface:** A webpage accessible on any mobile device to monitor and control the system

The system uses LoRa (Long Range) communication protocol between the water tank and pump stations. This technology provides reliable wireless transmission over long distances with minimal power consumption. Since LoRa doesn't require any subscription costs, it makes an ideal choice for this remote monitoring application.

Water Tank Station

The water tank station monitors water levels using an ultrasonic sensor mounted at the top of the tank. This sensor measures the distance from the water surface to the top of the tank, which is then converted to a water level percentage. Since there's no grid power available at the tank location, a solar power system will provide the necessary electricity.

Required Components

1. Microcontroller (to process sensor data)
2. Ultrasonic water level sensor
3. LoRa transceiver module and antenna
4. Battery power source
5. Solar panel
6. Solar charge controller

Borehole Pump Station

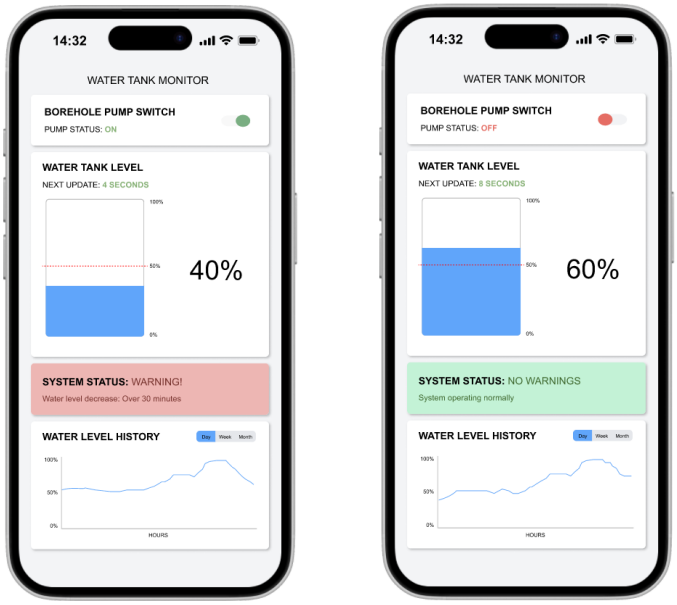
The pump station functions as the control hub of the system. It receives water level data from the tank station and allows remote control of the pump. When a user toggles the pump switch on the mobile interface, the control station activates a relay that turns the pump on or off. The existing manual switch remains functional as a safety backup.

Required Components

1. Microcontroller (with WiFi capabilities)
2. LoRa transceiver module and antenna
3. Relay to control pump
4. Circuit breaker

Mobile interface (Webpage)

The mobile interface provides a simple way to monitor water levels and control the pump from any smartphone, tablet, or computer. Below is a concept that I designed for this system.



I built an interactive webpage which simulates the tank water rising when the pump is on and lowering when the pump is off. Click Example Web Page Link to view the app.

The interface includes:

1. A pump ON/OFF toggle switch
2. Real-time water level display
3. System status indicator
4. Water level history graph

There are two options for hosting this interface:

- **Option A:** Host directly on the ESP32 microcontroller at the pump station (simplest option, no additional costs)
- **Option B:** Host on an external cloud server (adds monthly hosting costs but potentially more reliable)

How the Data will Flow

1. The tank station sends water level data via LoRa to the pump station
2. The pump station processes this data and makes it available to the mobile interface
3. The mobile interface displays current conditions and allows pump control
4. When the user toggles the pump switch, a command is sent to the pump station
5. The pump station activates or deactivates the relay controlling the pump

Recommended Components

This section details the components needed for the water monitoring system, with specific recommendations based on requirements, availability, and ease of use.

Microcontrollers

The system requires two separate microcontrollers - one at the water tank and one at the pump station. Each has different requirements:

Microcontroller at Water Tank

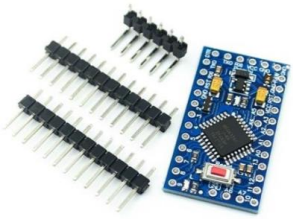
This controller needs to be power-efficient since it runs on solar/battery power.

Key Requirements:

- Low power consumption (critical for battery operation)
- LoRa communication capability
- No need for WiFi capabilities

Microcontroller Options

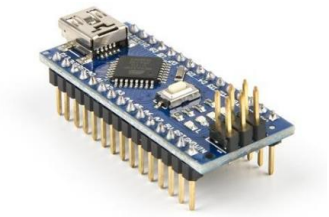
Option 1: HKD PRO MINI 328-3,3V/8MHZ



Product Link

- DC input 3.3V up to 12V
- Extremely low power consumption
- Can enter deep sleep modes to conserve power

Option 2: BDD NANO CH340



Product Link

- Input Voltage: 5 ~ 12V
- More accessible/easier to use than Pro Mini
- Built-in USB for programming

Recommendation: The **BDD NANO CH340** (Option 2) is the better choice for the water tank station. While both options have suitable power consumption characteristics, the NANO CH340 offers easier programming through its built-in USB port, making setup and any future modifications simpler.

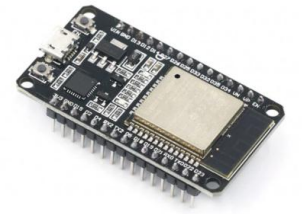
Microcontroller at Borehole Pump

This controller needs to handle both LoRa communication and WiFi connectivity.

Key Requirements:

- MUST have WiFi capabilities for the web interface
- MUST have LoRa capabilities for sensor communication
- Needs sufficient processing power for web server functions
- Will have reliable grid power (not battery-dependent)

Recommended Option: ESP32 Development Board WiFi + Bluetooth



Product Link

- Built-in WiFi and Bluetooth connectivity
- Powerful processor capable of hosting a web server
- Multiple hardware serial ports for connecting various components
- Can easily handle web server and database functions

Recommendation: The **ESP32** is the ideal choice for the pump station controller. It's the only readily available option that combines the necessary WiFi capabilities with enough processing power to host the web interface directly on the chip, eliminating the need for external hosting.

LoRa Modules

For this system to work properly, wireless communication between the water tank and pump stations is essential. LoRa (Long Range) technology is perfectly suited for this application because it provides reliable long-distance communication with minimal power consumption.

Identical LoRa modules are needed at both locations:

- One at the water tank to transmit water level data
- One at the pump station to receive data and send control commands

Both transceivers must be configured to use the same frequency (868MHz) to communicate with each other. The system will require:

- One transceiver module + antenna at the water tank
- One transceiver module + antenna at the pump station

Transceiver Options

Option 1: LoRa RFM95W 868MHz

Product Link

- Supply voltage: 1.8...3.7V DC
- Frequency: 868MHz
- Interface: GPIO, SPI

Option 2: LoRa SX1278 868MHz (with antenna)

Product Link

- Supply: 3.3V
- Spectrum range: 803- 930MHz
- Interface: SPI

Option 3: LoRa RA-08H 868MHz (with antenna)

Product Link

- Power Supply: Voltage 2,7V ~ 3,6V
- Frequency: 803-980 MHz
- Interface: UART / GPIO / ADC / DAC / I2C / I2S / SPI / PWM

Recommendation: While all three transceivers are compatible with the selected microcontrollers, the **RFM95W** transceiver (Option 1) is recommended as it has the most extensive documentation and community support, being commonly used in similar IoT projects. This will make troubleshooting easier during installation and setup.

Antenna Selection

The antenna's gain (measured in dBi) affects how the signal propagates:

- Lower gain (3dBi): Broadcasts signal in a wider pattern (good for covering an area)
- Higher gain (5dBi): Focuses signal in a more directional pattern (better for point-to-point)

Since this application requires communication between two specific points (water tank to pump station), a higher gain antenna is more suitable.

Recommended Option: LPWA Outdoor Waterproof Antenna 5dBi

Product Link

- Gain: 5dBi (focused for longer range in a specific direction)
- Weather-resistant for outdoor installation
- Network Support: 4G/3G/2G/LPWA
- Connector: SMA male connector

Required Adapter: Scoop U.FL to SMA Female Bulkhead

Product Link

- This adapter is necessary to connect the antenna to the LoRa transceiver
- The LPWA antenna comes with an SMA male connector, while the transceiver typically has a U.FL connector

Installation Note: When mounting the antennas, they should be positioned with clear line-of-sight between them whenever possible, and ideally at the same height and orientation for optimal signal quality.

Ultrasonic Sensor

The water level sensor is a critical component of this monitoring system. It measures the water level in the tank by calculating the distance from the sensor (mounted at the top of the tank) to the water surface.

How Ultrasonic Sensors Work

An ultrasonic sensor functions by:

1. Emitting high-frequency sound waves (inaudible to humans)
2. Measuring the time it takes for these sound waves to bounce off the water surface and return
3. Converting this time measurement into a distance calculation

This distance measurement is then used to determine the water level in the tank. For example, if the tank is 2 meters tall and the measured distance to the water is 0.5 meters, then the tank is 75% full.

Sensor Options

Option 1: HC-SR04

Product Link

- Operating voltage: 3V-5.5V
- Detection range:
  - At 5V power: 2cm to 450cm
  - At 3.3V power: 2cm to 400cm
- Detection angle: <15° (narrow beam)
- Not waterproof

Option 2: JSN-SR04T Waterproof

Product Link

- Operating voltage: DC 5V
- Working current: 30mA
- Detection range: Up to 4.5m
- Fully waterproof design

Recommendation: The **JSN-SR04T Waterproof Sensor** (Option 2) is strongly recommended for this application. While slightly more expensive, its waterproof construction provides crucial protection against:

- Condensation inside the tank
- Accidental water exposure during heavy rain
- Water splashes during tank filling
- General humidity and environmental moisture

The standard HC-SR04 would likely fail quickly in the humid environment inside a water tank, leading to system failure and replacement costs. The waterproof sensor represents a small additional investment that significantly increases system reliability and longevity.

Water Tank Power Supply

Since the water tank is located on a hilltop without access to grid power, a solar power system is required to operate the monitoring equipment. This self-contained power system consists of four main components working together.

Components Overview

A complete solar power system for the water tank station requires:

1. Solar panel (to generate electricity)
2. Battery (to store energy for nighttime and cloudy days)
3. Solar charge controller (to manage charging and prevent battery damage)
4. Optional DC-DC voltage regulator (to provide the exact voltage needed by components)

Solar Panel

Recommended Option: 15W Grade A Monocrystalline Solar Panel Charging Station

Product Link

- Output voltage options: 16V/9V/6V
- Output current: 0.9A/1.66A/2.5A (depending on voltage setting)
- Weather-resistant design for outdoor mounting

This 15W panel provides sufficient power to charge the battery even during periods of reduced sunlight. Any Solar panel capable of charging a 12V battery can be used, if the panels output current falls within limits of the batteries charging current.

Lead-acid Battery

Recommended Option: 12V 7Ah sealed lead-acid battery

Product Link

- Maintenance-free sealed design
- 7 ampere-hour capacity (provides multiple days of backup power)

This battery provides enough capacity to power the system through multiple days without sun. Any rechargeable 12V battery with at least 7 amperage hours should be sufficient, if it is lead-acid. The solar charge controller below is specifically for lead-acid batteries, so a different controller is required for a lithium-ion battery.

Solar Charge Controller

Recommended Option: Solar Charge Controller, 12V/24V, 10A

Product Link

- Dual 5V/2.5A USB output ports (can power the microcontroller directly)
- LCD display shows voltage, status, time, and charge level
- Built-in protection against overcharging, over-discharging, and short circuits

This charge controller connects the solar panel and battery, managing the charging process to protect the battery and extend its lifespan. The built-in USB ports provide a convenient 5V power source for the microcontroller, eliminating the need for a separate regulator in many cases.

DC-DC Voltage Regulator

Components that require specific voltages (3.3V) other than what the charge controller's USB ports provide (5V), a DC-DC voltage regulator can be added.

Recommended Option: BMT ADJ DC/DC Module 3A+Display

Product Link

- Input voltage: DC 4~40V
- Output voltage: DC 1.25~37V (continuously adjustable)
- Built-in display shows current voltage settings

This regulator is particularly useful for powering the LoRa module, which may require 3.3V rather than the 5V from the USB ports. The built-in display makes it easy to verify the correct voltage is being supplied.

Power System Setup

The components should be connected in this order:

1. Solar panel → Solar charge controller
2. Solar charge controller → Battery
3. Solar charge controller (USB port) → Microcontroller
4. Battery → DC-DC regulator → LoRa module and sensors

Weather Protection: All electronic components should be housed in a weather-resistant enclosure (IP65 rated or better) to protect against rain, condensation, and dust. The solar panel can remain exposed, as it's designed for outdoor use.

Borehole Pump Station Components

The pump control station requires components that can safely interface between the low-voltage control electronics and the high-voltage pump system. This section covers the power supply for the controller and the components needed to safely control the pump.

Power Adapter for ESP32 Controller

At the pump station, grid power (220V AC) is available but needs to be converted to 5V DC to power the ESP32 microcontroller.

Option 1: PSU SWM 5V 1A SMF AC Adapter

Product Link

- Input: 100-240V AC (standard wall outlet power)
- Output: 5V DC, 1A (sufficient for ESP32 and LoRa module)
- Connector: 5.5x2.1mm centre-positive barrel jack

Required Accessory: CCTV ADPT MJ077 Female DC jack

Product Link

- Converts the barrel jack connector to wires that can connect to the ESP32
- Provides positive and ground connections

Option 2: 5V/2A Power Supply

Product Link

Recommendation: The **1A compact power adapter** (Option 1) is reliable and provides clean, stable power for the microcontroller. While the 10W 5V 2A option provides more current, the 1A adapter is sufficient for this application and is easier to use.

Borehole Pump Relay

To safely control the high-voltage pump from the low-voltage microcontroller, a specialized relay is required. A solid-state relay (SSR) is recommended over a mechanical relay for reliability and longevity.

Recommended Option: Solid State Relay SSR AC 25A (3-32V DC Input)

Product Link

- Can handle up to 250V AC (compatible with 220V pump)
- Accepts 3-32V DC input signals (works directly with ESP32 outputs)
- No moving parts for silent, reliable operation
- Rated for 25A (sufficient for most residential borehole pumps)

The solid-state relay connects between the pump's power supply and the pump itself, allowing the ESP32 to turn the pump on or off by sending a simple digital signal. This provides complete electrical isolation between the control circuits and the high-voltage pump circuit for safety.

Circuit Breaker Protection

A circuit breaker is essential for safety, protecting both the pump and the solid-state relay from damage due to overcurrent conditions.

Recommended Option: Schneider Miniature Circuit Breaker

Product Link

- Rated current: 25A (matches the relay capacity)
- Rated voltage: 230V AC 50/60Hz (compatible with standard grid power)
- Automatic trip during overload or short circuit conditions
- Manual reset capability
- Curve code: C

Cost Breakdown

Below is a comprehensive breakdown of all components required for the complete water tank monitoring system.

Component	Shop	Quantity	Unit Price	Total
ESP32 microcontroller	Robo Factory	1	R188.00	R188.00
NANO microcontroller	Communica	1	R89.00	R89.00
LoRa Transceiver	Micro Robotics	2	R98.00	R196.00
LoRa Antenna	Communica	2	R69.00	R138.00
SMA Female Bulkhead	Takealot	2	R103.00	R206.00
Ultrasonic Sensor	Communica	1	R90.00	R90.00
Solar Panel	Takealot	1	R308.00	R308.00
12V Battery	Takealot	1	R329.00	R329.00
Solar Charge Controller	Takealot	1	R295.00	R295.00
DC-DC voltage regulator	Communica	1	R42.00	R42.00
5V 1A AC Adapter	Communica	1	R80.00	R80.00
Female DC Jack	Communica	1	R6.00	R6.00
Solid State Relay	DIY Electronics	1	R71.00	R71.00
Circuit Breaker	Communica	1	R50.00	R50.00
Other (wires, terminals etc)		1	R400.00	R400.00
			TOTAL:	**R2,488.00**

The total cost provided (R2,488.00) covers only the base components. It is advisable to budget an additional 15-20% (approximately R375-R500).