USER GUIDE
Community Science
Water Quality EC Sensor and Data Telemetry Network

INNOVATE AUCKLAND

Version 0.8.8, Feb 2020
By: Warren Davies

About this User Guide

Who should use this guide:

This guide is for citizen scientists, educators and anyone interested in creating their own real-time environmental data sensing network. It explains how to install and use the open source water quality sensor and the data network that makes your sensor data available on the internet.

Some of the concepts in the guide are quite technical, if you're not sure or need clarification please email us at the address below.

We recommend you have access to people familiar with connecting computer peripherals and WiFi settings.

What is real-time monitoring?

Low cost Real-time monitoring is an amazing new capability made possible by a collection of technologies commonly referred to as the **internet of things (IOT)**. Most monitoring techniques involve a regular visit to the monitoring location where recordings are made and recorded manually. These visits can be weeks or months apart. In real time monitoring, measurements are made automatically every few minutes and the information is immediately processed and stored on the internet creating an up to date, long term and detailed record.

Why is real time monitoring important?

Streams are very sensitive to weather and pollution events. These events can occur over a very short time, often after a few hours or minutes the event is over. Monthly sampling will miss most important events that occur in your stream.
With real time monitoring:

1. **Don't miss events**. Things can change fast in a stream, if you're not there to see it you'll miss it, the sensor watches 24/7 and creates a continuous record.
2. **Narrow down the cause.** If your stream is monitored at multiple points you can narrow down where and when an event occurred and its possible cause.
3. **Create positive behaviours.** We all change how we behave if we know we're being watched. With the stream monitor people become aware that dumping and faults are more likely to be detected.
4. **See the effect of restoration work.** The sensor creates long term trend data. The improvements made by restoration work can be shown over time.
5. **You can learn more** about your stream and others. Combing your data with the work done by others can lead to new insights previously unavailable.

CONTENTS:

This user guide describes the installation and use of **two** Innovate Auckland products. The water quality EC sensor and the network connectivity gateway.

Five Steps: Your journey to learn more about your stream and take effective action starts here:

1. Choose to DIY, or work with us.
2. Buy or build your sensors and network.
3. Pick a location and install your sensor.
4. Make the data connect.
5. View your stream data. Use our mobile apps or install your own.

Web: www.innovateauckland.nz email: aklciot@gmail.com GitHub site: https://github.com/aklciot

Part One:
Using the Stream Sensor

Introducing the Stream Sensor:

If you're like us, you've been wondering why a low cost simple stream monitoring solution is so hard to find. One reason for this is that it is complicated. That's why we worked hard on simplifying it for everyone.

Water is a complex biologically active substance that is very sensitive to changes in temperature, geology and weather conditions. Designing an effective urban stream sensor was a two year project involving lots of trial, error and mostly compromise.

There are many factors that can be measured to quantify the health of a freshwater stream. Dissolved Oxygen (DO), pH (acidity), Phosphates, Nitrogen, clarity, microbes and others.

Your stream sensor can include one or more of these sensors, but they come at a cost, sometimes a high cost. Not just in financial terms but also maintenance and reliability.

To get the most value we worked with experts to come up with the most effective and low cost combination of sensors:

Electrical Conductivity: Also known as **EC** is a simple and effective way of detecting foreign substances in the stream

Water level lets you know how rainfall and flush events influence foreign material inflow, and how rapid changes in level can dislodge delicate water life and wash it out of the stream.

Temperature, is very important as it affects how much oxygen the water can hold and how hospitable it is to life.

See **the *understanding your data*** section or more details on what your data means.

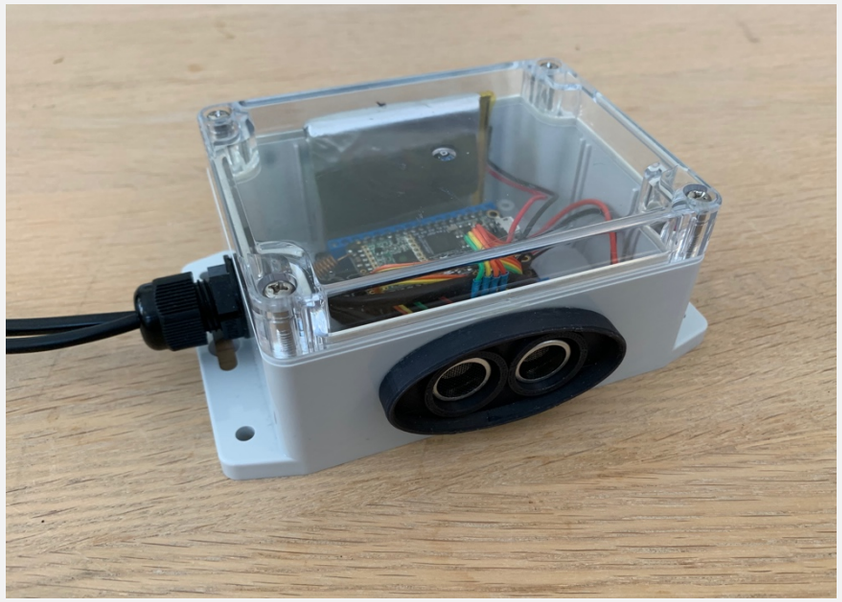
Next step, get familiar with the sensor components. Then we will discuss how to install, maintain and calibrate your sensor.

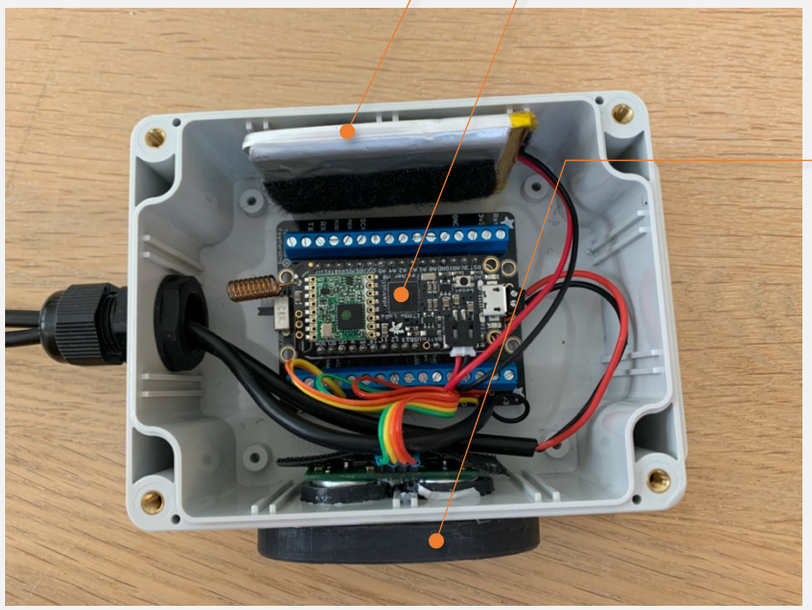
USING THE STREAM SENSOR:

Get to know the sensor.

It is actually four sensors. Two digital thermometers, water level and water EC. Please note the rechargeable battery lasts 4-6 months and can be charged with an optional solar panel if the conditions permit it.

We invite you to build your own. Full design specifications, software code and instructions to build your own are available at our GitHub site.





USING THE STREAM EC SENSOR:

Using the Water EC Sensor:

An E.C. (**electrical conductivity**) probe measures the electrical conductivity in a solution. It is commonly used in hydroponics, aquaculture and freshwater systems to monitor the amount of nutrients, salts or impurities in the water.
Inside the conductivity probe, two electrodes are positioned opposite from each other, an AC voltage is applied to the electrodes causing cations to move to the negatively charged electrode, while the anions move to the positively charged electrode. The more free electrolyte the liquid contains, the higher the electrical conductivity. Pure water has an EC of zero.

How often do you need to recalibrate a conductivity probe?

Conductivity probes work by measuring the electrical current of the water between two graphite plates. The plates do not go bad, or change, so recalibration is not necessary. After the first calibration your conductivity probe is good to go.

Probe cleaning

Over time conductivity probes can become dirty and covered in deposits, which can change the basic electrical properties of the probe and cause inaccurate readings.
Soft coatings can be removed by lightly brushing around the conducting area with a soft toothbrush. Do this once every two months or if your readings seem unusually low.

USING THE STREAM TEMPERATURE and LEVEL SENSORS:

The sensor contains two digital thermometers. One is placed inside the sensor control unit and measure the air temperature. The second thermometer is on the end of the sensor tether cable along side the EC sensor.

IMPORTANT: Avoid direct sunlight. Place the sensor control box in a location where is is not likely to receive direct sunlight for long periods. Heating from the sun will affect you air temperature measurements and may affect the life of the sensor.

How often do you need to recalibrate the temperature sensors?

The digital thermometers read with an accuracy of ±0.5°C from -10°C to +85°C and ±2°C accuracy from -55°C to +125°C. Calibration is not necessary.

Sensor cleaning

Over time the submerged thermometer can become dirty and covered in deposits, this will not affect the accuracy of readings. Soft coatings can be removed by lightly brushing around the sensor with a soft toothbrush.

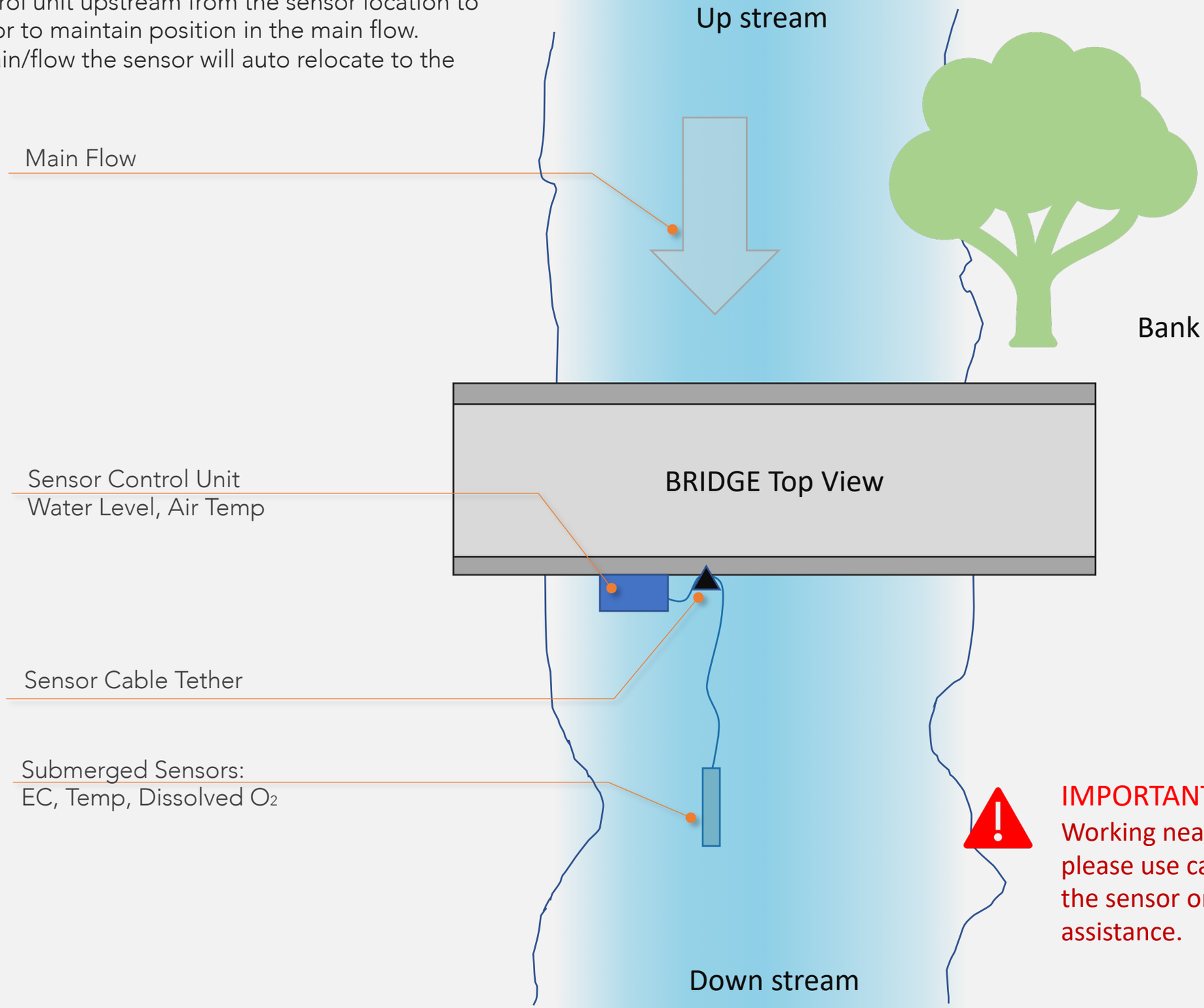
Water Level Sensor

The water level sensor uses ultrasonic sound, like a bat, to measure the time an echo takes to return to the sensor. The return time is converted to distance in centimetres. The water level is calculated by subtracting this value from the distance to the stream bottom. This calibration value is required for your level sensor. Refer to the page on level calibration for more details.

IMPORTANT: The level sensor is sensitive to obstructions that can cause false echoes. Ensure there are no plants or other objects between the sensors and the water level. Also keep in mind that if you place the level senor close to the bank you may not be able to read low water levels. Try to locate it above the main flow.

STREAM SENSOR PLACEMENT

Install the control unit upstream from the sensor location to allow the sensor to maintain position in the main flow. Under heavy rain/flow the sensor will auto relocate to the best position.

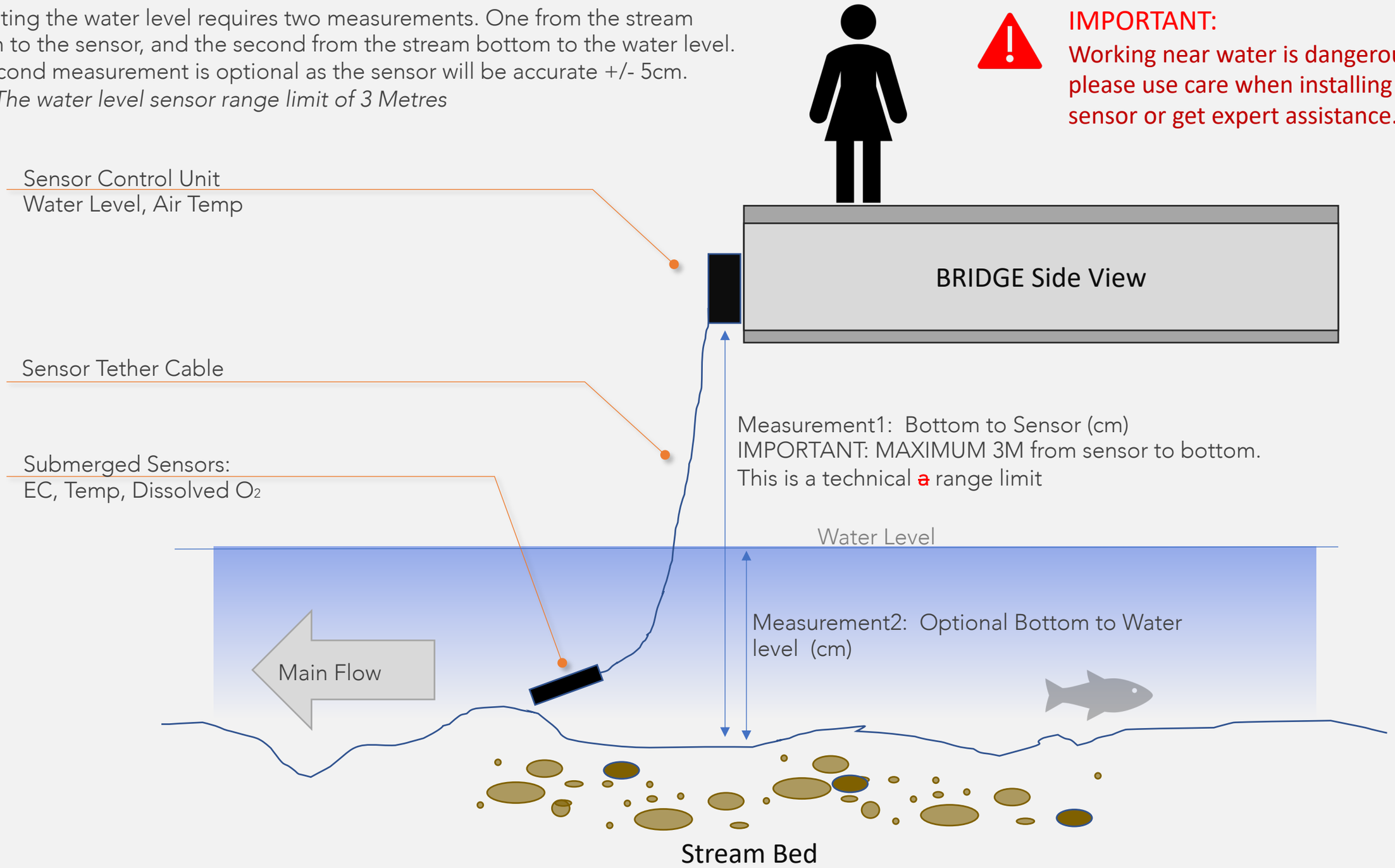


IMPORTANT:
Working near water is dangerous, please use care when installing the sensor or get expert assistance.

STREAM SENSOR: Water Level Calibration

Calibrating the water level requires two measurements. One from the stream bottom to the sensor, and the second from the stream bottom to the water level. The second measurement is optional as the sensor will be accurate +/- 5cm.
Note: The water level sensor range limit of 3 Metres

IMPORTANT:
Working near water is dangerous, please use care when installing the sensor or get expert assistance.



Web: www.innovateauckland.nz email: aklciot@gmail.com GitHub site: https://github.com/aklciot

Part Two:
Making the data connection

About The Gateway

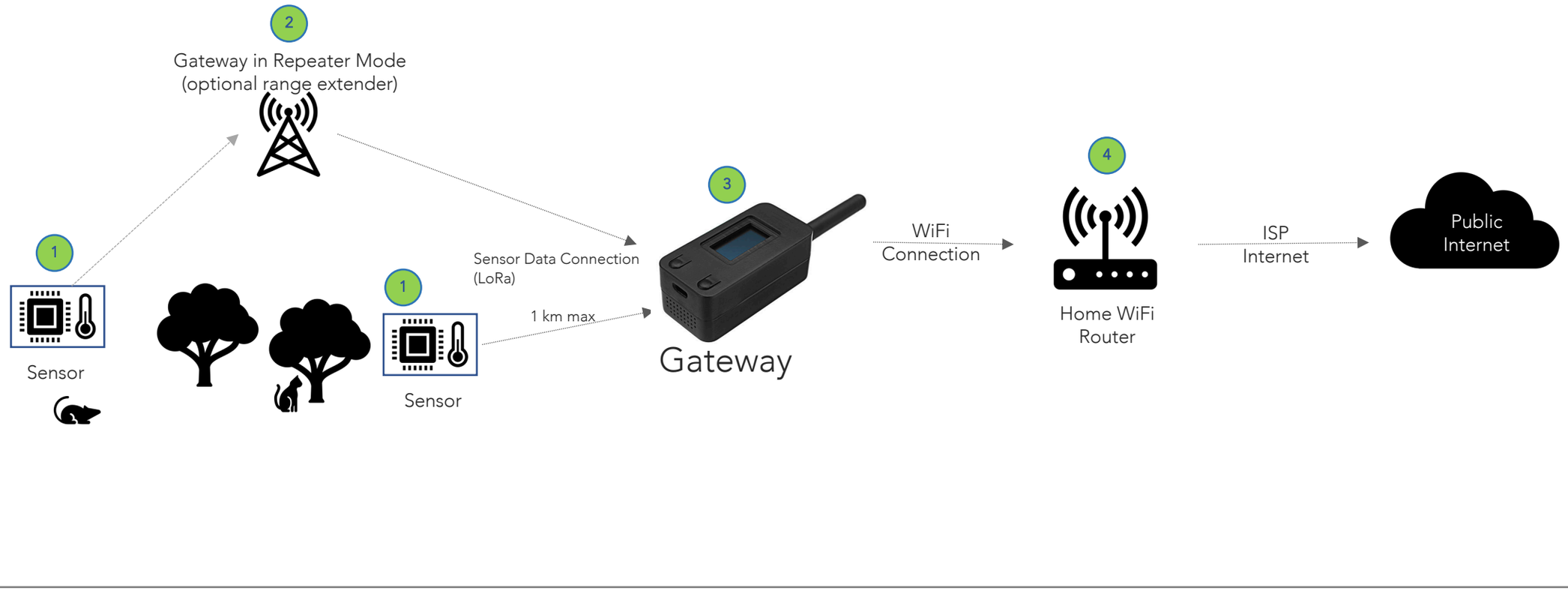
The sensor sends its data over a special radio signal that allows it to connect at long distance using very low power. The signal power used by the sensors is 10X less than that of your cell phone and 100X less than your home WiFi network.

The data from your sensor, item **1** in the diagram below. needs to be converted so that it can be sent to your computer. This job is completed by the Gateway, item **3**.

Just like your smartphone, the gateway needs to know how to connect to your WiFi network, item **4**. To do this it needs your WiFi network name and password. Completing this task is discussed next.
Your WiFi password is stored in the gateway and not sent anywhere else.

Your Privacy:
The gateway contains no personal data, has no camera or microphone. It also does not "listen" to the internet to prevent hacking.

Setting Up the Network



Version 1.2, Warren Davies

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Introducing the Data Gateway

The gateway is low cost single channel device that converts data from your sensor to data that connects over WiFi to the internet. To do this you need to setup the gateway. The following pages describe how to do this.

Getting ready. Connect your Gateway to a standard USB port or phone charger for power and have your PC or smartphone ready.

Make Your Own Gateway.
If you chose DIY, we invite you to build your own gateway. Check out our Github page for details, the TTGO LoRa 915mhz device shown is readily available on the internet.

Next step, Starting Setup Mode

Starting setup mode for the Gateway

1

Connect Power

Press Reset

2

Press and Hold Button A
when you see STARTING

3

Connect your phone or laptop
to the WiFi name shown here

Next step, entering your WiFi connection details and naming your data

User Setup Mode

From you phone or laptop connect to the WiFi called GWSetup_1
no password is required

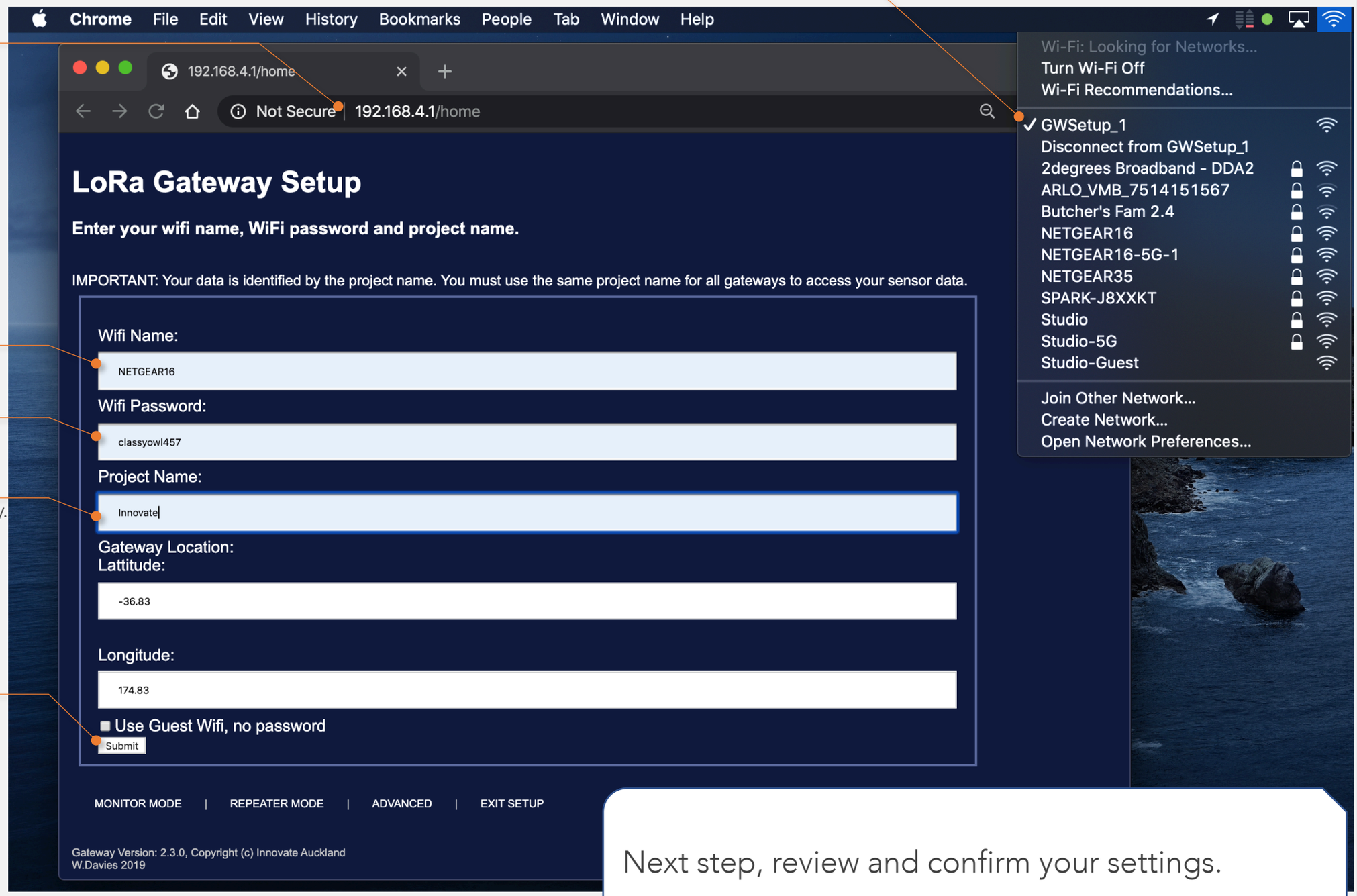
Connect to:
http://192.168.4.1/home

Enter Your WiFi name

Enter Your WiFi Password

Enter a name for your data
NOTE: Letters and numbers only.
No punctuation or spaces.

Submit your settings
Review and Confirm



Next step, review and confirm your settings.

Web: www.innovateauckland.nz email: aklciot@gmail.com GitHub site: https://github.com/aklciot

Completing Gateway Setup

Once you have saved and confirmed your WiFi settings the gateway will automatically restart.

You will notice on the display the gateway will show its ID and software version for a few seconds and then attempt to connect to the internet.

If all goes well you will briefly see connecting messages followed by **READY.**
Congratulations. Its working fine!

Oops. Otherwise.
If your gateway cannot connect to the internet it will show **connect failed, resetting**. Give it a few minutes, it will automatically retry.

If after a few tries you still cannot connect, restart setup mode by **pressing button A** when you see **STARTING.**
Details on page Starting setup mode for the Gateway.

Re-enter your WiFi settings and check for spelling and case errors. Save and confirm.

NOTE: The gateway cannot connect to enterprise WIFI services (EAP) because a certificate is required from your network administrator. Contact us about how to solve this problem.

Final step, send you settings and calibration information to Innovate Auckland

About your data

When your sensor is active, its takes measurements every few minutes and sends them to your computer, usually over the internet. The data generated must be stored so you can see changes over time. The section on understanding your sensor data explains this in more detail.

COPIES OF YOUR DATA:
The system allows your sensor data to be stored in multiples locations, your own database, the Innovate Auckland central datahub and other optional databases that you might want to use for further analysis. For example if you would like a separate copy of the data for learning purposes in a classroom, we can show how to make it connect.

THE BIG PICTURE:
The data your senor(s) generates is accessible to you and can be combined with data from other sensors creating a more complete picture of what might be happening in the environment. This a very exciting and valuable aspect of this product and we invite you to opt-in to help us fill in the big picture. The contact us page will allow you to make this selection.

DATA PRIVACY:
The data your sensor generates contains no personal information. It does however include the sensor values such as, water temperature, level, etc, and usually includes location details. Location is important part of understanding the data, if you are not happy with location details stored for your sensor please let us know.

Information required to complete setup

Please take a moment to familiarise your self with the data we will be collecting during the setup process described in the guide... this is the final step in the setup process.

Information required by Innovate Auckland	
Gateway ID. Used to help us identify your data and monitor the network health.	If we provided the gateway, it will show up on the display when starting. See the setting up your gateway page for details.
Project ID. Used to help us identify your data	You set this during gateway setup. A simple clear name with no spaces or special characters.
Calibration height. This value tells us how far the water level sensor is from the stream bottom	Record this value in cm when your installing your water sensor. We use this to accurately display water level.
Email address and a mobile number.	Pick and email address and number for notifications about your sensor and network. We use this to let you know if there is a significant event, problem or when the battery needs changing
Sensor Location. Put an X on a map	Location is important for understanding the data. You can get the latitude and longitude from google maps or send us a picture with an “X marks the spot”
Sensor Site photo	A picture is worth a 1000 words. This helps us answer your questions.
Data opt-in, contribute to the big picture	We recommend you opt in to share your data and contribute to the big picture so we all can learn more about our environment.

…and Finally:

The last step is to provide the setup and calibration information to Innovate Auckland.
Please enter this on our signup form or send us an email. *Take care to consider capitalised case sensitive text.*

Information required by Innovate Auckland		
Gateway ID. Used to help us identify your data and monitor the network health.	If we provided the gateway, it will show up on the display when starting. See the setting up your gateway page 22 for details.	
Project ID. Used to help us identify your data	You set this during gateway setup. A simple clear name with no spaces or special characters.	
Calibration height. This value tells us how far the water level sensor is from the stream bottom	Record this value in cm when your installing your water sensor. We use this to accurately display water level.	
Email address and a mobile number.	Pick and email address and number for notifications about your sensor and network. We use this to let you know if there is a significant event, problem or when the battery needs changing	
Sensor Location. Put an X on a map	Location is important for understanding the data. You can get the latitude and longitude from google maps or send us a picture with an “X marks the spot”	
Sensor Site photo	A picture is worth a 1000 words. This helps us answer your questions.	
Data opt-in, contribute to the big picture	We recommend you opt in to share your data and contribute to the big picture so we all can learn more about our environment.	

Congratulations: You're ready to go!

Once we receive your email with the setup information we will get in touch with on how to access your data.

Next step, get familiar with the data

Accessing and Understanding your Sensor Data:

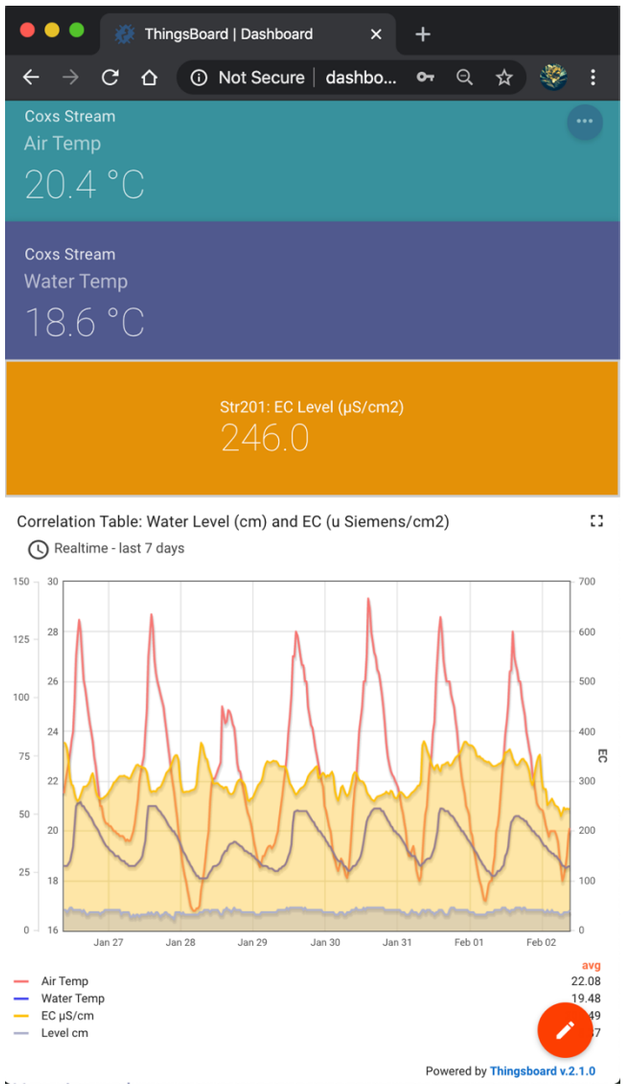
Broadwick Street showing the John Snow memorial for tracing the source of a cholera outbreak to water in Soho, London, in 1854

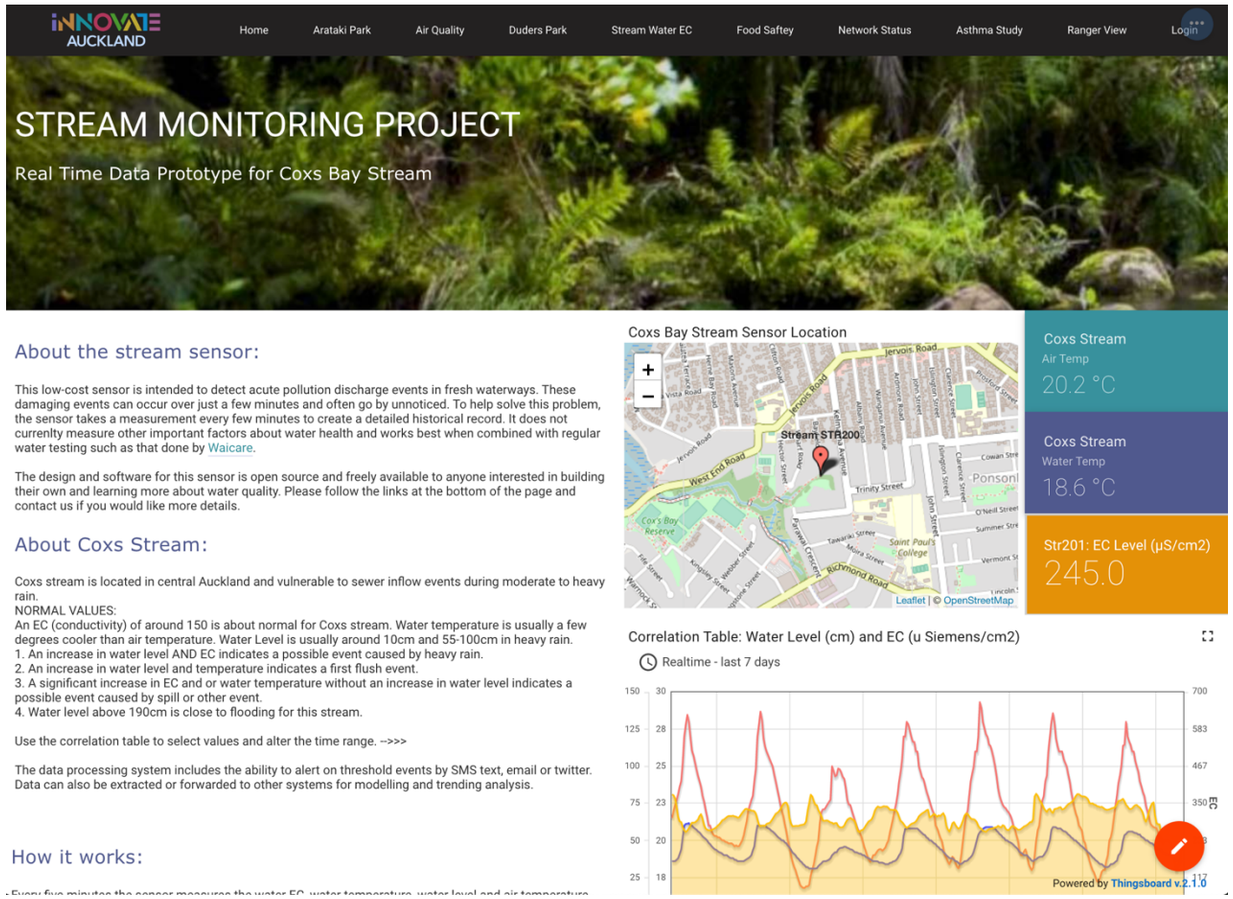
ITS ABOUT DATA

Data leads to insights, insight leads to effective action.

Accessing your data:

If you decided to work with Innovate Auckland you'll get access to a web portal that looks a bit like this. Your data dashboard automatically adjusts to view on your smartphone.





Local Only Mode

If you decided to go DIY. Your data is accessible directly from the Gateway using its USB port. Read the advanced section on local only mode and visit our GitHub page for details on how to download the software that makes this happen.

Understanding your data:

Every stream and location is unique. Get to know what's normal for your stream and when its time to take a closer look…

Establishing a Data Baseline.

First let's discuss baseline. As mentioned, water quality measurement is a complex business. One way to avoid the tricky science of calibrated data and its meaning is to build a base understanding of **your specific location**. Every location has its own character, so you need to observe the location and the data over time to get a feel for what is normal.

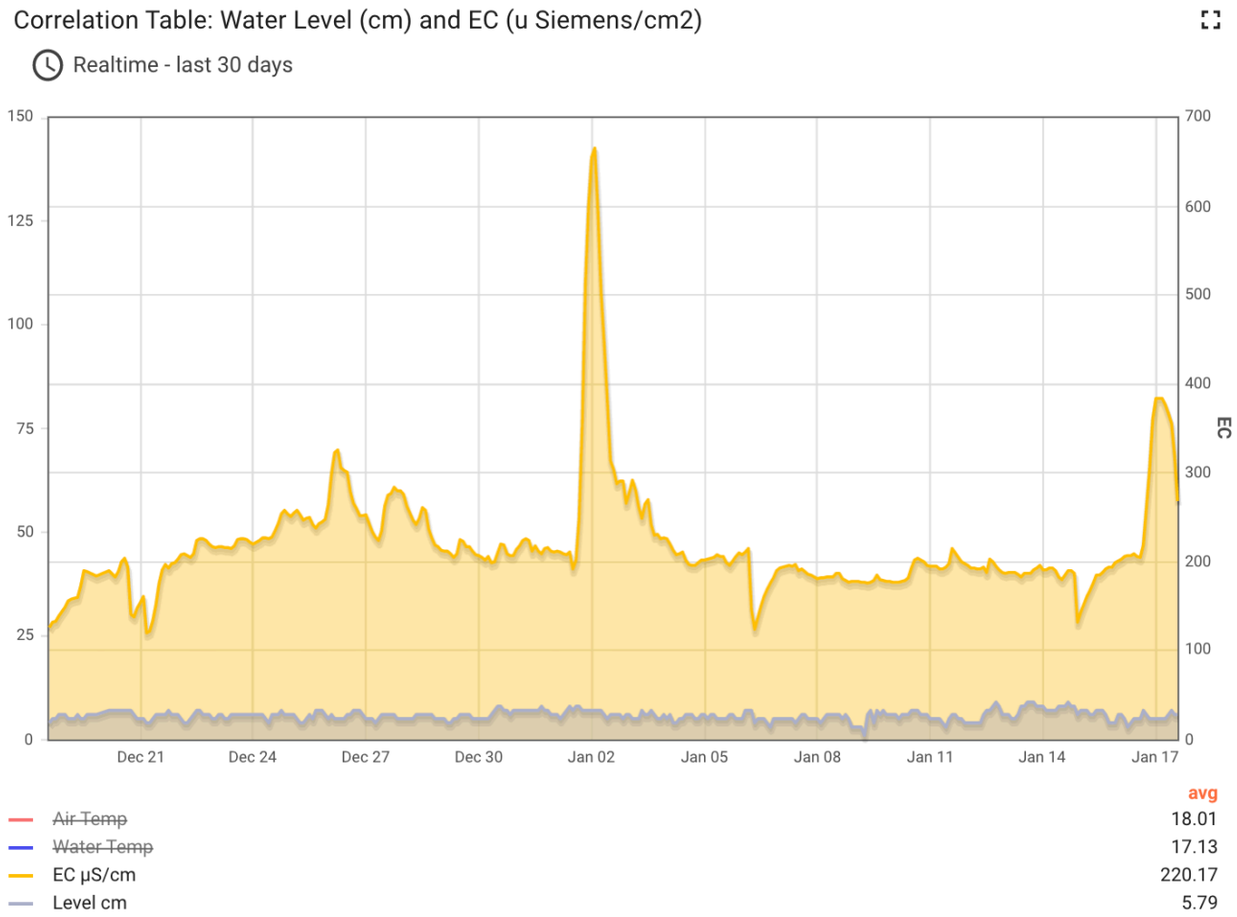
For the Cox's bay stream location shown here, the normal EC is around 200, water level is around 5-10cm.

Data:
The graph shows some significant spikes in EC without a change in water level. This indicates that a pollution event has probably occurred, likely as a result of sewer fault/overflow, a common problem in this location.

Insight:
Verify the data by visiting the site, take photos and ideally some water samples for testing. We recommend joining a volunteer group like Waicare who can provide you with tools and training.

Action:
Make a note of this event, record any lab results. Consider what might have caused the event. Over time you will learn if your stream is getting better or worse.

⚠ IMPORTANT: The sensor is not intended to provide evidence for legal or formal action. But it can tell you when it might be time to take a closer look, take samples and photographs.



For this location, an EC level of 200 is "normal" for this sensor at Cox's Bay stream.

Understanding your data:

Water Level and EC

For this location the water EC level drops significantly when it rains. The water inflow from a large rain event is very rapid and dilutes the EC level almost to zero.

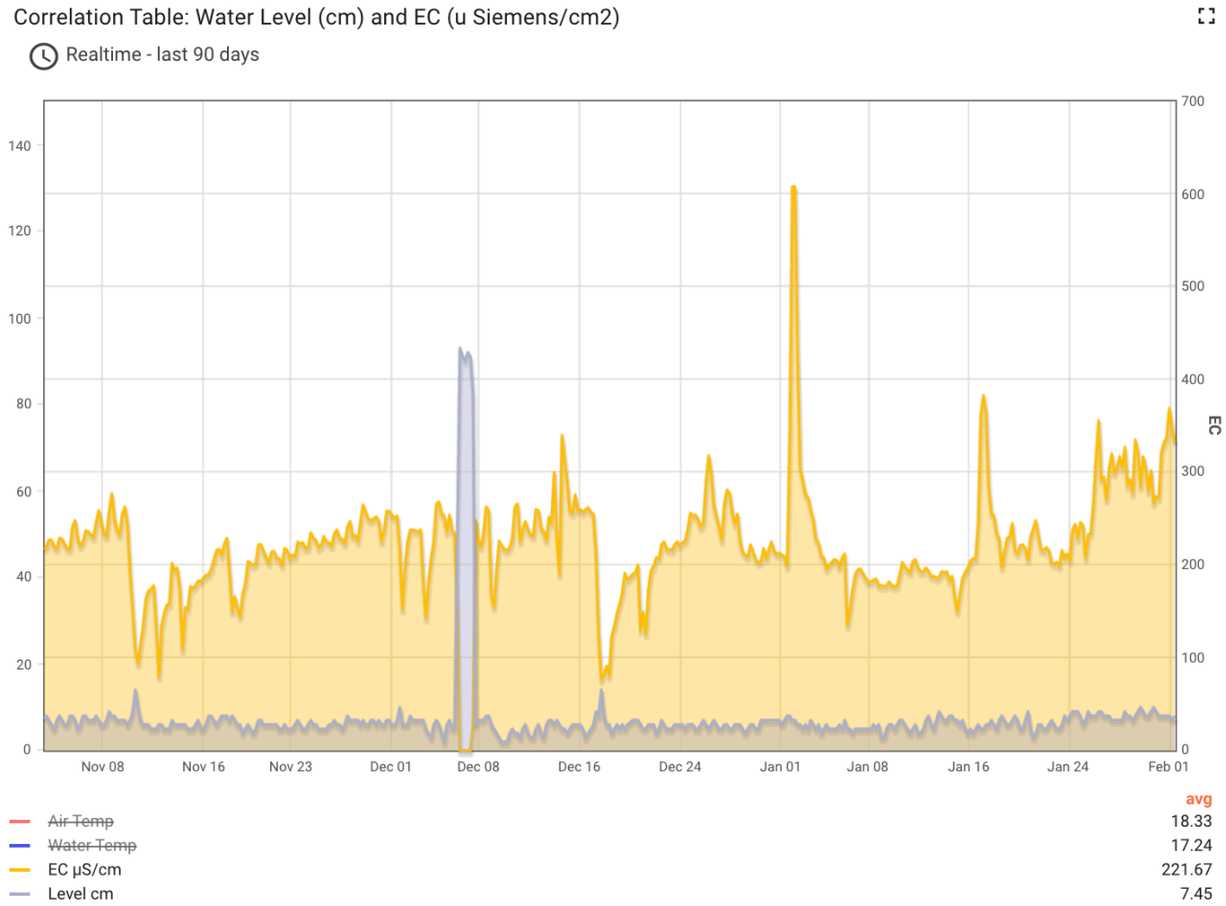
There are three rain events recorded on this graph. Can you spot them?

You can also see a potential pollution event that is not associated with rain fall.

In this location water level rise is very rapid due to the amount of hard non-permeable surfaces in the city catchment area of this stream.

Rapid water level change is not good for aquatic life as they are not able to maintain position in the stream. Any remedial action to create water gardens and flow control would help here and you could see the results of this work in the water level graph during subsequent rain events.

ALWAYS consider the value of direct inspection and photography when looking at your stream data.



Understanding your data:

Water Level and Temperature.

Counter to intuition, water temperature goes up for this location when it rains, sometimes significantly. Often referred to a *first flush event*, in this example water temperature peaked to over 30 degrees C. High water temperate has a negative affect on water's ability to hold dissolved oxygen (DO_2). As heavy rain continued the temperature dropped as the land area cooled.

Daylighting projects and riparian planting would help improve this situation and would be recorded as a lower average water temperature.

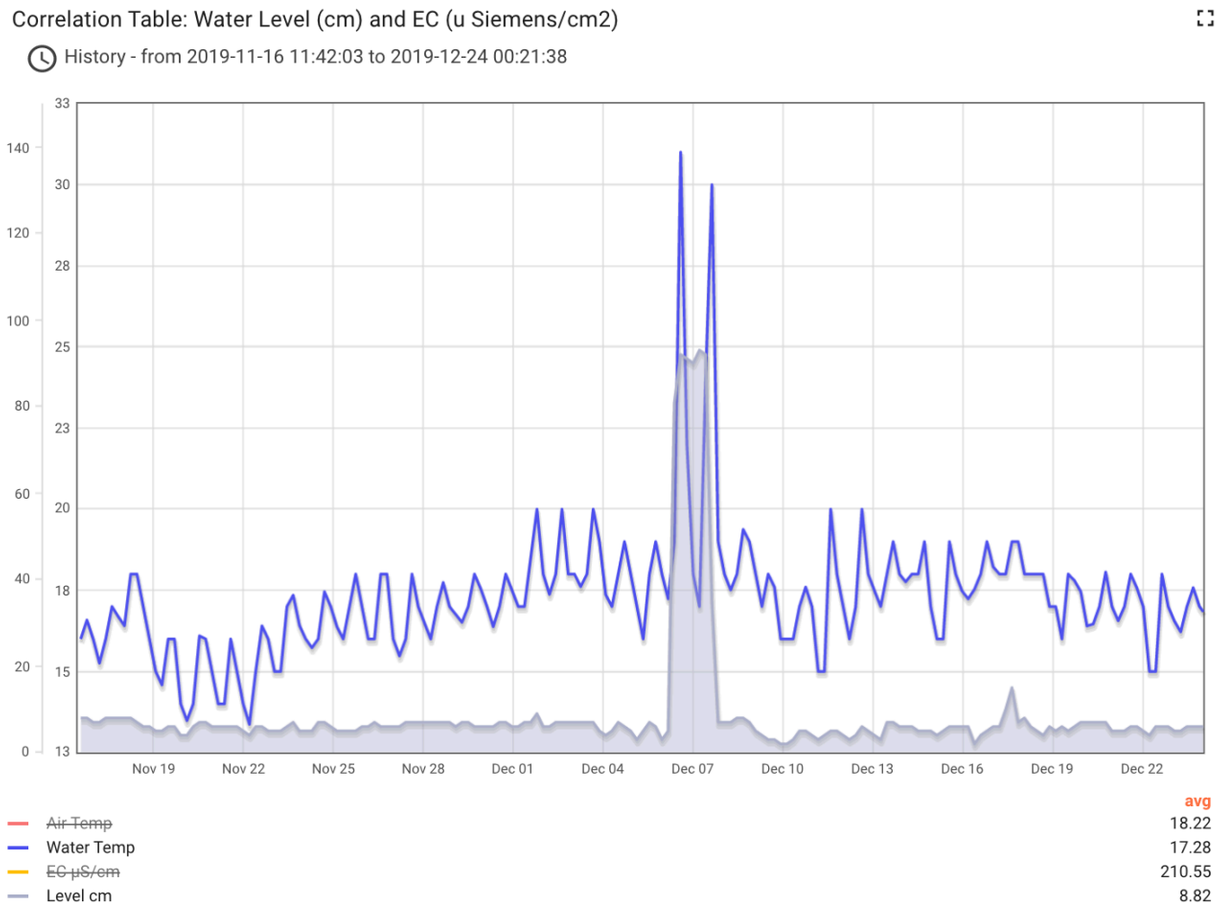
The Stream sensor includes an air temperature sensor to help understand how water temperature is affected by restoration projects. Perhaps high water temperature is due to a very hot day or low flow.

What about other measures such as Dissolved Oxygen (DO_2)?

This important measure is being added to the sensor in a future release. DO sensors are significantly more complicated, delicate and costly than EC.

Alerts:

The sensor system includes the ability for you to receive alerts by text and email when important thresholds are passed. Thresholds are location specific so once you have a baseline, work with experts and Innovate Auckland to set a threshold alert.



Advanced Features: Using Gateway Modes:

Repeater Mode and Local Only Monitor mode.

Using Gateway Modes:

The gateway supports four modes of operation.

Setup Mode:
This mode allows the end user to enter the WiFi connection credentials and select the mode of operation.

Gateway Mode:
This is the main operation mode. Gateway mode receives sensor data over LoRa and sends it over the internet to the data processing service.

Repeater Mode:
This mode converts the gateway into a message signal repeater that extends the range of the network and allows sensors to be put in locations where the gateway cannot otherwise make a connection. Repeater mode is an important capability required for difficult locations.

Monitor Mode:
The signal monitor mode's primary function is during network setup. The monitor provides unique features to assist in location decisions including signal strength and auto reply functions. This mode also provides local only (iwi) mode, this is an important feature identified by Mana Whenua and ensures data remains in the local area.

Switching Gateway Modes:

Switching Modes:
The gateway's built in setup application also allows you to switch between the other modes, Repeater and Monitor mode.

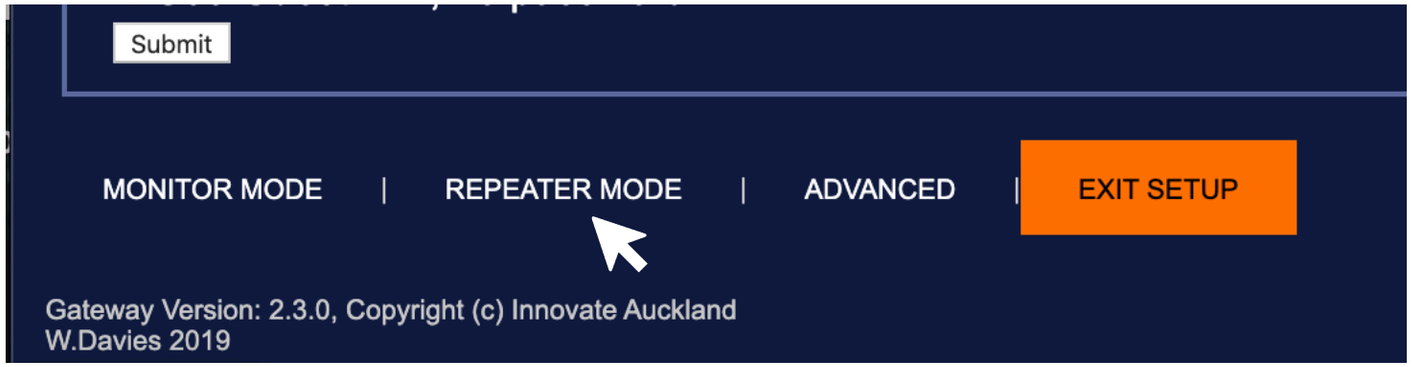
To access these modes follow steps to start setup mode on page 22 and 23 then press the mode button as shown below.

Your gateway will immediately restart and switch into the mode selected.

Choosing "exit" will return the gateway to its current mode

Before using advanced modes read more about each mode below.

NOTE: You need two gateways to use advanced modes.



Repeater Mode:

The repeater does not require any internet connectivity. It listens for messages sent by sensors and other gateways.

The repeater retransmits (repeats) messages. This mode is very useful in situations where the gateway and sensor cannot be placed in range of each other.

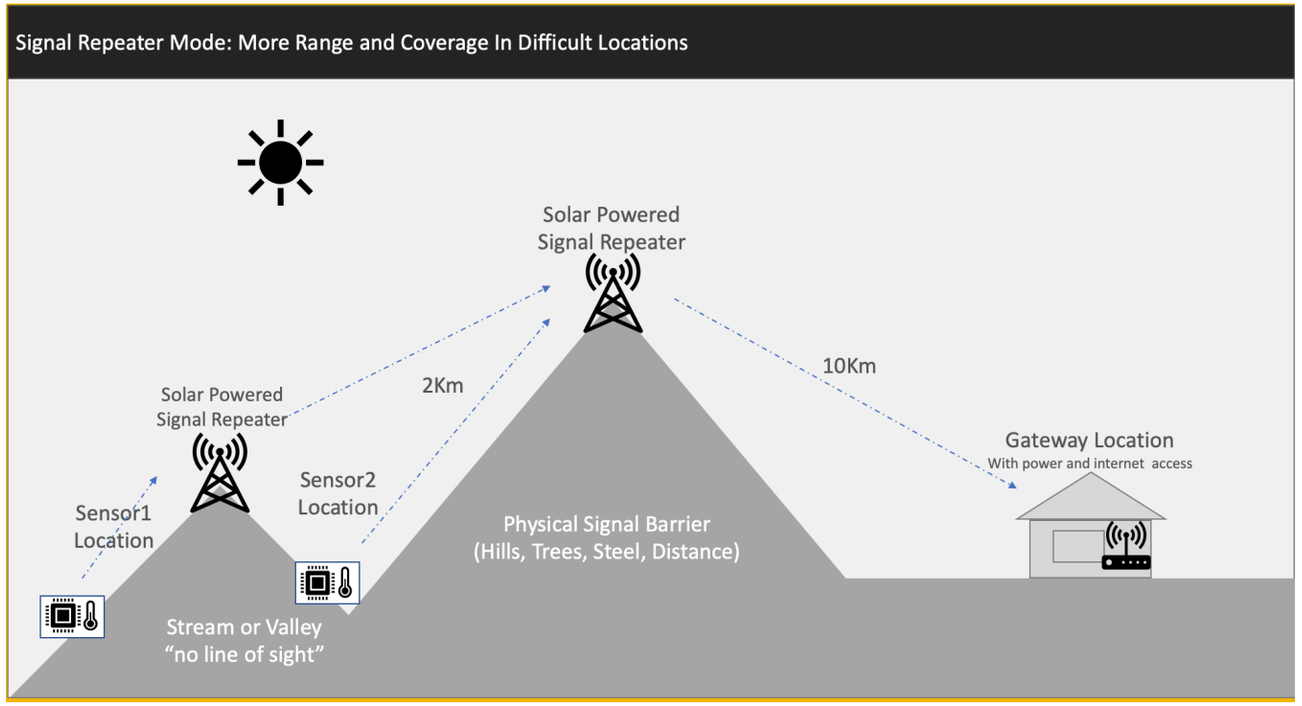
About Line-of-Sight:
Radio signals are like a form of light. If you imagine you use a torch to shine from the the sensor to the gateway; if I cannot be seen from the gateway, you might need a repeater.

This can happen in hilly areas where sensors are often placed in stream valleys, under bridges, holes or at long distances.

Repeater mode is an important way to ensure your sensor location is accessible by the gateway.

The diagram shows how repeaters can be used to make a connection in difficult locations. Note that solar charging can be added if required.

To use this mode you will need two gateways, one in standard Gateway mode and one in Repeater Mode.



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Monitor and Local Mode:

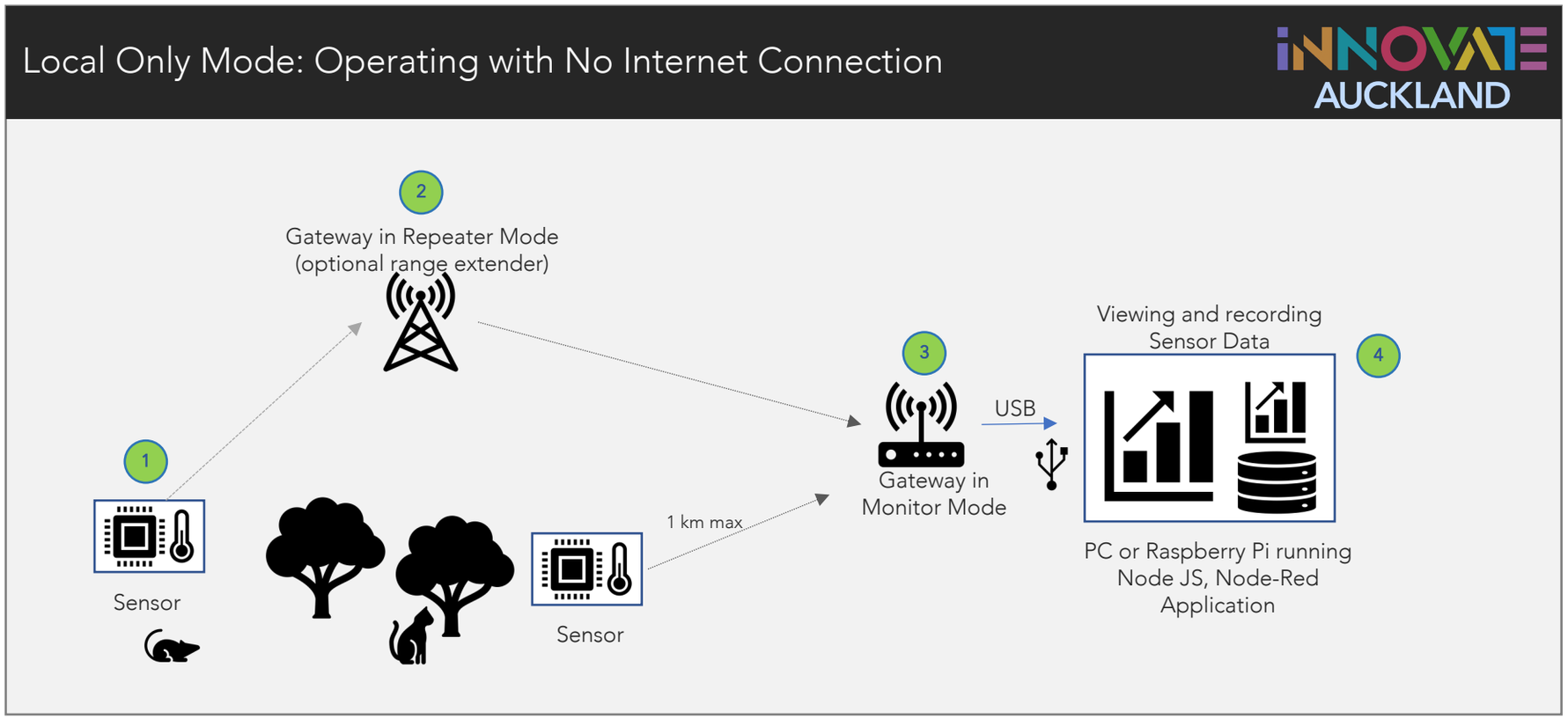
The primary function of Monitor Mode is to display details about received messages from the sensor network. This information assists in decisions where to place gateways. Typically sensors have limited options for placement so where the network gateways and repeaters are placed is vital for successful operation of the solution.

Monitor mode allows the user to check signal levels over the study area. During operation of monitor mode, the function of "Button A" changes from setup to sending a test message which triggers an automatic reply from any gateway in range. The message shows up on the built-in display and USB port. **You need two gateways to use Monitor mode.**

Local only mode:

The secondary function of Monitor Mode is "local only" mode. Like the repeater mode, monitor mode does not rely on any internet connectivity. This is useful for local only operation and allows the sensor network to fully operate "stand alone", off net. You can access sensor data locally by connecting a gateway in monitor mode directly to a PC via its serial (USB) port. Local applications must be installed to view and manage the data.

This feature requires a computer with data viewing applications installed locally. Contact us for advice or visit our GitHub page for details on local mode.



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Working With Innovate Auckland

About Innovate Auckland

Innovate Auckland grew out of a collaboration between Auckland Council and Auckland Tourism, Events and Economic Development (ATEED) and is a group of volunteers who believe environmental technology should be accessible to anyone who values community science, education and environmental restoration.

We produce opensource non–commercial products simplified down to the essentials needed to deliver results. You are invited to get involved. We welcome new ideas and collaboration. Email us using the address below.

We would like to acknowledge the support of:
Gecko NZ Trust,
WaiCare
Tāmaki Estuary Environmental Forum
Tech Futures Lab
Auckland Council Rimu

USEFUL LINKS:

Learn about more about the project, submit your form data and join in the user forum:
www.innovateauckland.nz

GitHub: Gateway
Device design, code and user guide, submit enhancement requests
https://github.com/aklciot/TTGO-Gateway-repeater

GitHub: Water Quality EC Sensor
Device design, code and user guide, submit enhancement requests
https://github.com/aklciot/StreamECSensor

Deciding to do-it-yourself or work with Innovate Auckland

As an opensource project you're in control of how you want to use this technology. Everything is ready for you to go full DIY, build and modify the sensor to fit your needs. Or, perhaps you want to get up and running as fast as possible. If so, then we are ready to help.

Here's some ideas on how to decide.

SHOULD YOU DIY?

You want to build or learn about micro electronics ✓

You have limited internet access or prefer your data stays local to you ✓

You have the skills or want to learn how to install applications to view your data. ✓

You want to modify or adapt the system to your specific needs ✓

DIY is for You! Visit our GitHub page and get started.

WORK WTH INNOVATE AUCKLAND?

You would rather just buy all the hardware pre-built and ready to go ✓

You would like your data accessible to you and contribute to the "big picture" ✓

You want to raise some funds to contribute to the effort (optional) ✓

You want to work together on making the most of the system ✓

You're not sure ✓

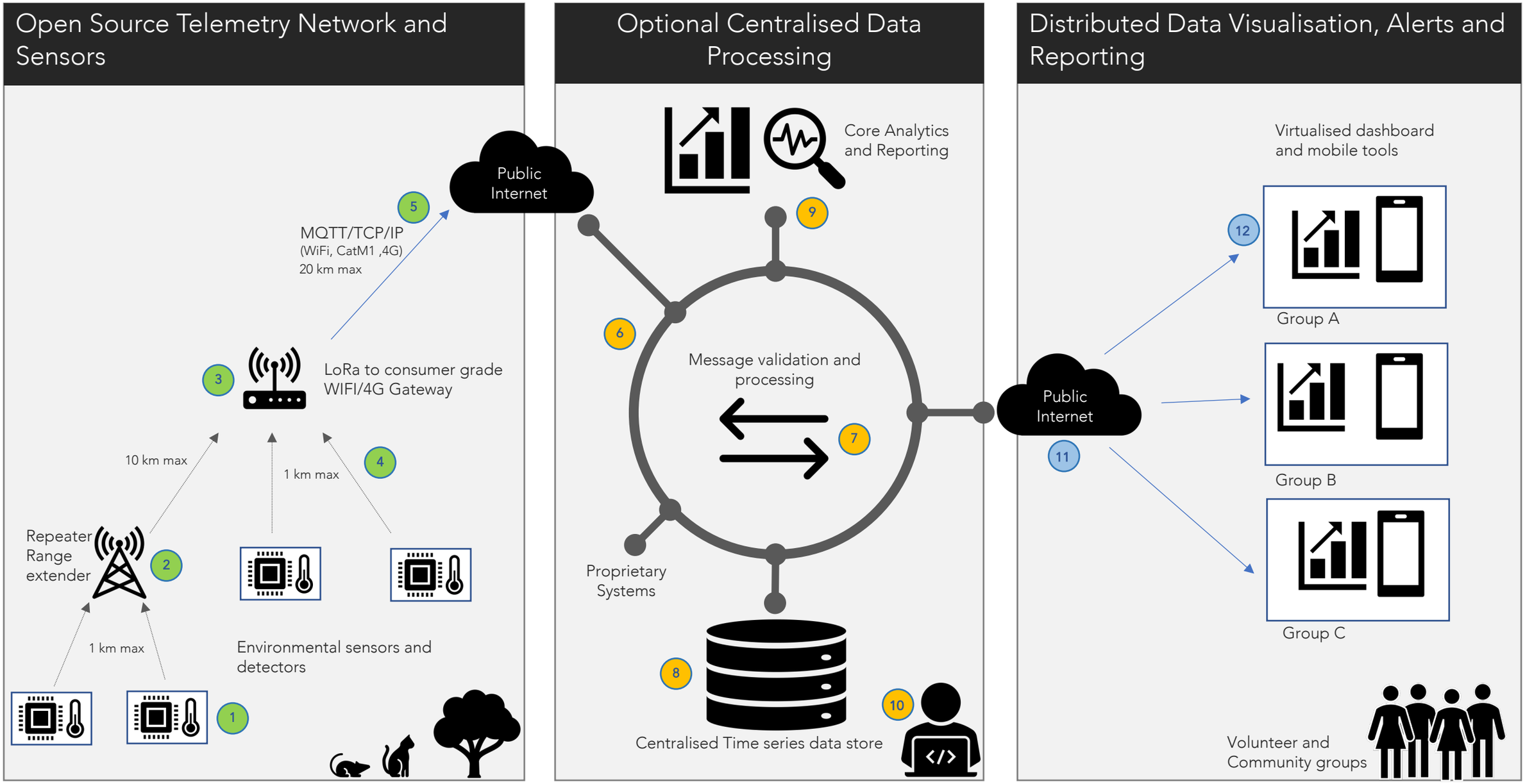
Innovate Auckland can help. Get in touch

Web: www.innovateauckland.nz email: aklciot@gmail.com GitHub site: https://github.com/aklciot

How the open source Internet Of Things (IOT) system works.

Included for your interest only

Opensource IOT System Architecture



Version 1.2, Warren Davies

The following items refer to the IOT solution architecture shown in the diagram above.

1. Sensors: Several types of sensors have been developed for environmental monitoring purposes, Water quality EC and temperature, Air quality particulates mass and count, VOC gases, DOC traps, Trigene tank level, Live traps, pest detection and many others. These sensors include low power management Long Range (1-2km) radio (LoRa) network connectivity.

2. Solar powered signal repeater. Used where terrain is limiting factor on coverage, the repeater is small LoRa signal relay that adds an additional 1-2 km range. The repeater is self-charging and includes the capability to report on its health and power status.

3. LoRa to WiFi/4G Gateway. This is the heart of the telemetry network. It is a very low-cost solution to getting data back to the internet cloud services. The gateway configuration step is how customer and user data are uniquely identified. It includes the simple setup over built in WiFi, the ability to switch between gateway, repeater and monitor modes, auto self-restart and sends regular status updates on health and power. It also includes the ability for remote, restart and signal testing. The gateway requires a connection to a consumer grade data service provider either over WiFi or 4G cellular.

4. LoRa telemetry. LoRa (Long Range) is a spread spectrum modulation technique optimised for long range, low power data transmission. Connectivity is a complicated problem with many options and factors to consider. This solution uses open source LoRa to provide connectivity in remote locations without the need to rely on existing telco or other commercial coverage. Using the gateway and repeaters nodes (items 2 and 3), connectivity can be deployed where ever its required by the user.

5. MQTT is the message transport protocol used to deliver data over the internet to the centralised data process core. This is common protocol used in many IOT systems.

6. MQTT message distribution buss. This component provides the ability for messages to be accessed by multiple systems using publish and subscribe mechanism. Data from sensors is delivered here to processing and control message activations.

7. Data processing. This component validates message for out of range data, raw data conversion to JSON, adds data calibration steps, location correction and message alert processing. It is also responsible for data distribution and data storage.

8. Centralised time series database to meet the goal of a single data “big picture” view.

9. These are the analytics and data visualisation tools for use by the Auckland Council Environment Services team.

10. Expert or volunteers manage the system connectivity and data processing. This component provides access to existing datasets, 3rd party and commercial solutions by exposing MQTT and HTTP connectivity.

11. This the public facing MQTT API that allows groups to connect with their data once it has been processed.

12. Each group using the solution has a preconfigured open source container application that includes the data visualisation, messaging and mobile dashboard application. The application container is optimised to run on a range of technologies including low-cost Raspberry Pi hardware.