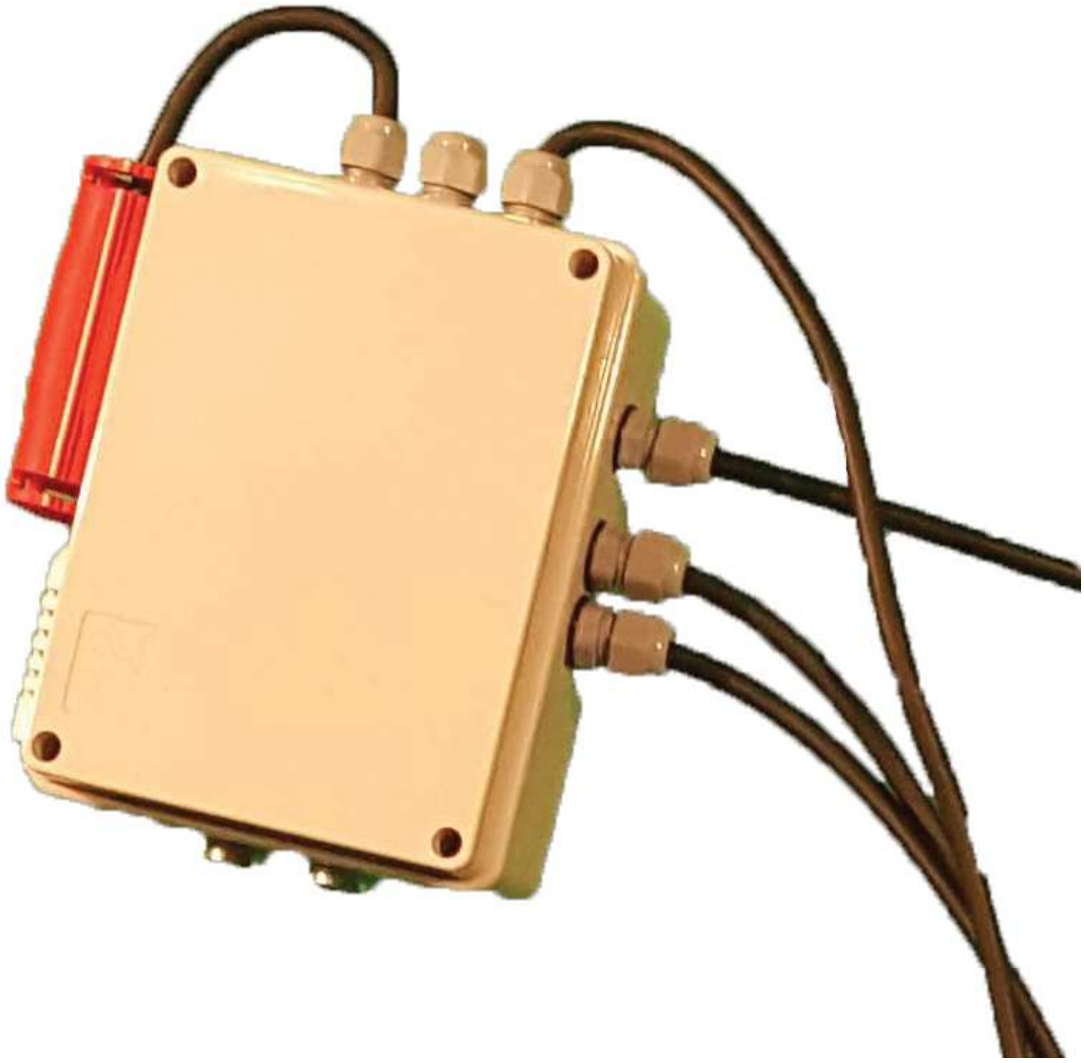
# River-Nanny

The Nanny Which Look's After The River



By Donovan Weiss Webb

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# Introduction

I have competed in the BT Young Scientist and Technology Exhibition for three years, the most prestigious contest in Ireland for under 18's. My favorite project from these entries is River-Nanny which is the subject of my maker's portfolio. I won the Analog Devices best in technology 2018 award for this project as seen in image 1.

River-Nanny is an automated river monitoring system which is installed on the River Vartry which runs through my property. It automatically monitors pH, conductivity, dissolved oxygen, water, temperature, ambient temperature and humidity. All this data is then transmitted to a server over the cellular network every hour. This is the only system that is capable of gathering so much data per day on the health of a river.

The concept of River-Nanny is to try and help to protect and improve the ecology of a river which is under stress from abstraction and other competing interests as shown in image 2. It accomplishes this by allowing scientists to review the data which helps to prove that some of these interests are harming the river. The data can also be used to support assumptions made of the effects of global warming. These subjects are very important to me because I live right by the river and walk my dog by it everyday. I can see that there is not nearly as much water as there used to be years ago, which is because the dam at the top of the river is taking 95% of the water. Global Warming is evident to the eye but there is no data to back this up. During heavy rain fertilizers run off the fields and are filling up the river. This is why I developed River-Nanny to try and protect the River Vartry.

ANALOG DEVICES

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# *Analog Devices Testimonial*

Donovan Webb,
East Glendalough School
Co. Wicklow,
Ireland

**30th October 2018**

**To whom it may concern**

*Donovan Webb receiving the Analog Devices Award for Technology at the BT Young Scientist and Technology Exhibition, Dublin, Ireland – January 2018*

This is to confirm that Donovan Webb, a second level student attending East Glendalough School Co. Wicklow, Ireland has been awarded the Analog Devices Technology Award for his project 'RiverNanny'. This award is presented to an individual or group for outstanding work exhibited in the Technology category at the BT Young Scientist & Technology Exhibition 2018 (see www.btyoungscientist.com).

The Analog Devices Judging team, led by myself found Donovan's project to be an excellent example of multiple sensors to cloud technology being used in an innovative way for the good of society. His project demonstrated an excellent understanding of sensor and interfacing technologies, embedded firmware and control and data to cloud implementations that are significantly beyond the gift or grasp of Donovan's peer student group.

In addition, we found Donovan to be a very engaged and enthusiastic innovator and technologist who has a great grasp of technology fundamentals and more importantly the intellect and ability to apply them. He is an excellent communicator, not only excelling in how he describes his project but also keen to describe some of the challenges he met on his project development journey and he how he overcame those challenges.

Analog Devices were delighted to host Donovan and his parents to our development division in San Jose, California as part of our technology award. While is San Jose, Donovan made a great impression on our wider engineering staff, presenting his project and anxious to learn more about leading edge silicon product development at Analog Devices. We are delighted and not at all surprised that Donovan is applying for a graduate program at MIT and on behalf of Analog Devices, I would highly recommend Donovan for any such program.

Brian O'Mara

**Brian O'Mara,**
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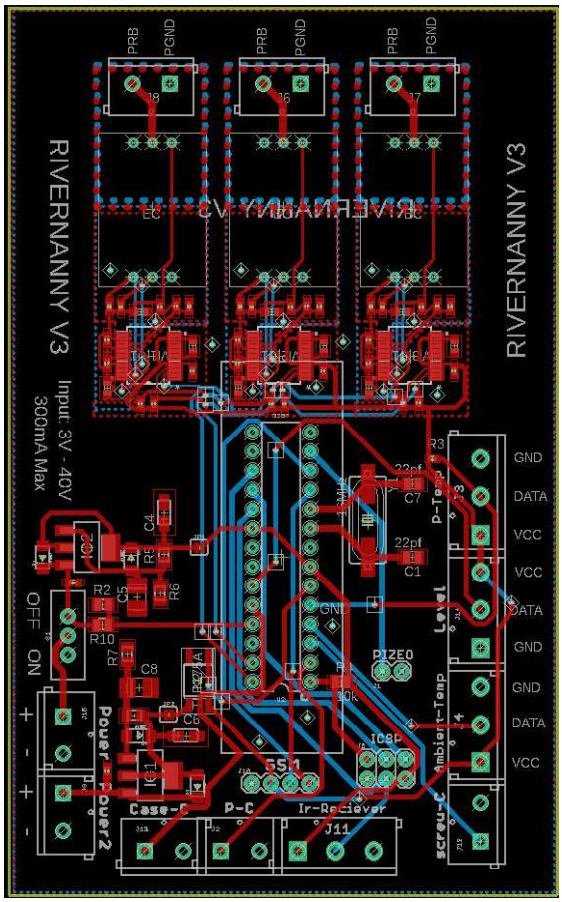
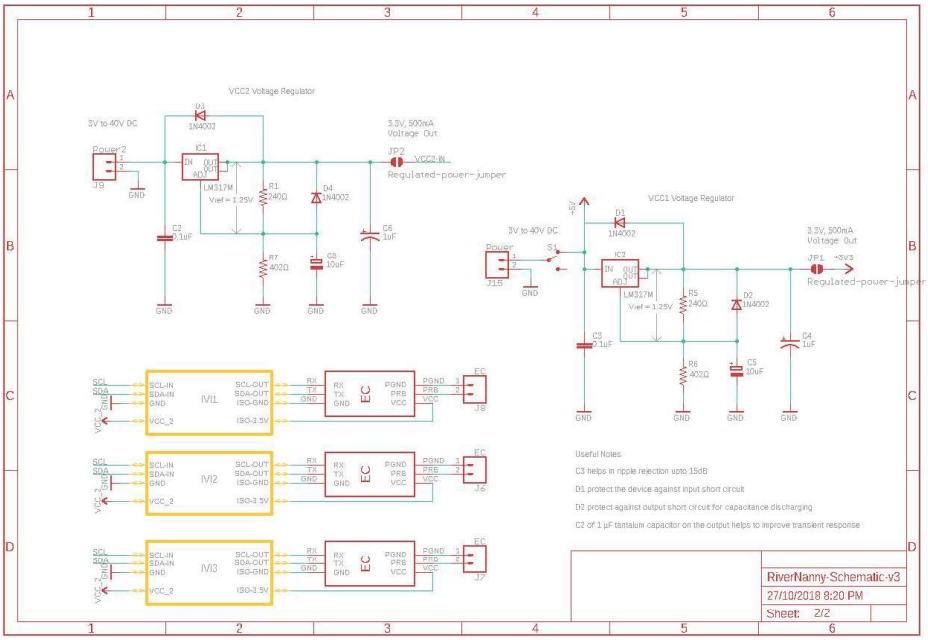
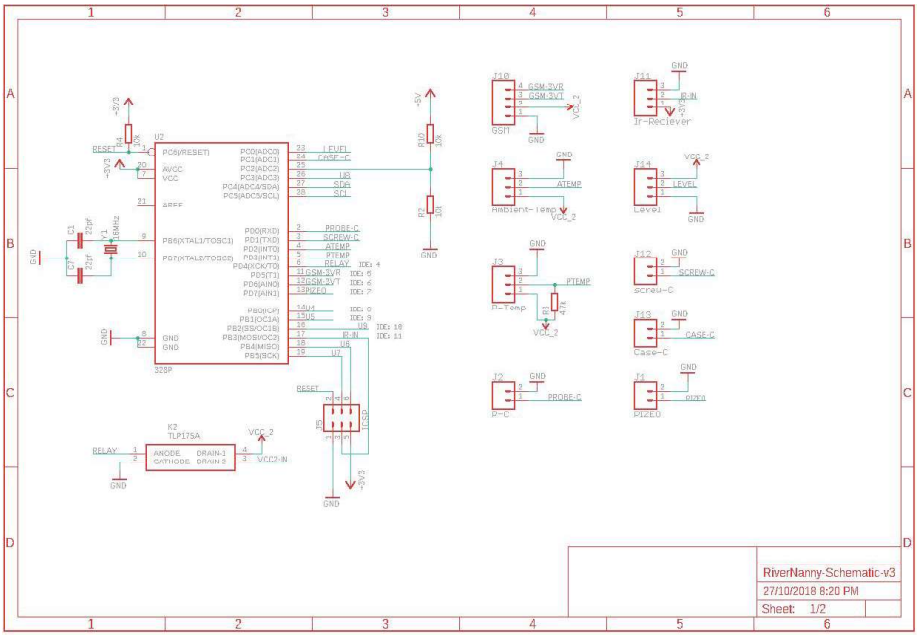
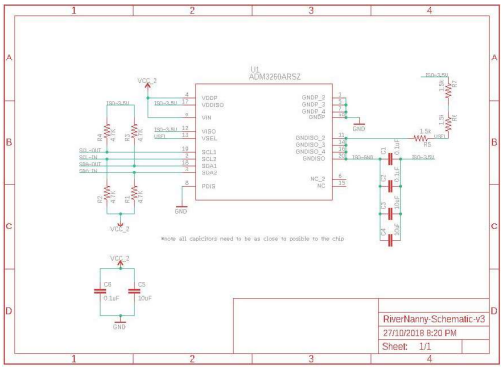
# River-Nanny V3




Shown above are the PCB design and schematics for River-Nanny version 3. As you can see, it is based on a atmega328p which is the same chip which is in the Arduino Uno. I decided to design a PCB from scratch instead of using an Arduino. The requirements are to have to run off small batteries for years, an Arduino would use too much power. The PH, Conductivity and DO sensors are all very sensitive to interference which would not be suitable with an Arduino.

Another main design requirement was to have a low cost, low power solution. The only low-cost sensors which I could find were the Atlas Scientific sensors which are meant for laboratory use. Because of this they required a lot of protection especially as the pH sensor is made of glass. In order to protect them, I designed and made a 3d printed housing for them using ASA filament. It also made it more difficult to achieve the low power usage, as the control boards for the probes are meant to be always on which would use too much power. Instead, I wired up all the sensors to a relay in order to be able to power them down when they were not in use.

Another problem with these sensors is that they are extremely sensitive to interference. This means that each sensor requires a voltage isolator. The official atlas scientific voltage isolators are quite expensive so instead, I decided to design my own. On the PCB these three groups of components are just above the Atmega.

The reason I chose these data points to measure are because, the River Vartry is an EU salmoid river. The water quality specification is shown here. As you can see, River-Nanny measures the main specifications that can be measured automatically.

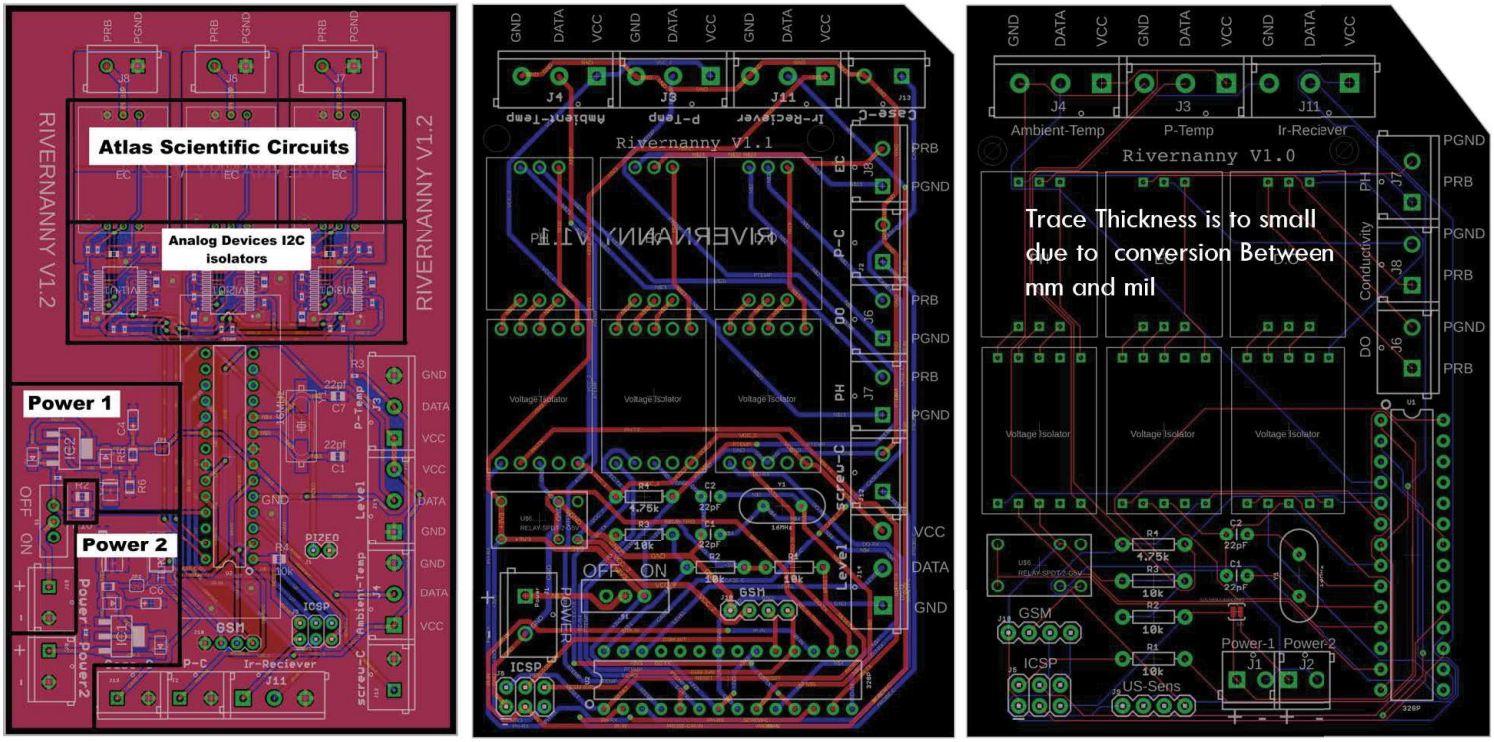
**EU Specification for Salmonoid Rivers**

| | | |
|---|---|---|
| Dissolved Oxygen | mg/litre O2 | ≥ 9 |
| pH | | ≥ 6 ≤ 9 |
| Suspended Solids | mg/litre | ≤ 25 |
| Temperature | °C | < 21.5°C , or 10°C, during the period from 1 November to 30 April where species which need cold water for |

Although the EPA measures these monthly, the River Trust, who commissioned me, wanted the data in their hands and measured hourly or daily at many locations.

The advantage of this approach is that it allows us to install in many locations across the river which opens up other possibilities for example to be able to see where along the river harmful pollutants are being added. It also allows us to see how much of the water is being added by rain water by comparing to the meter near the dam and comparing this to rainfall data.

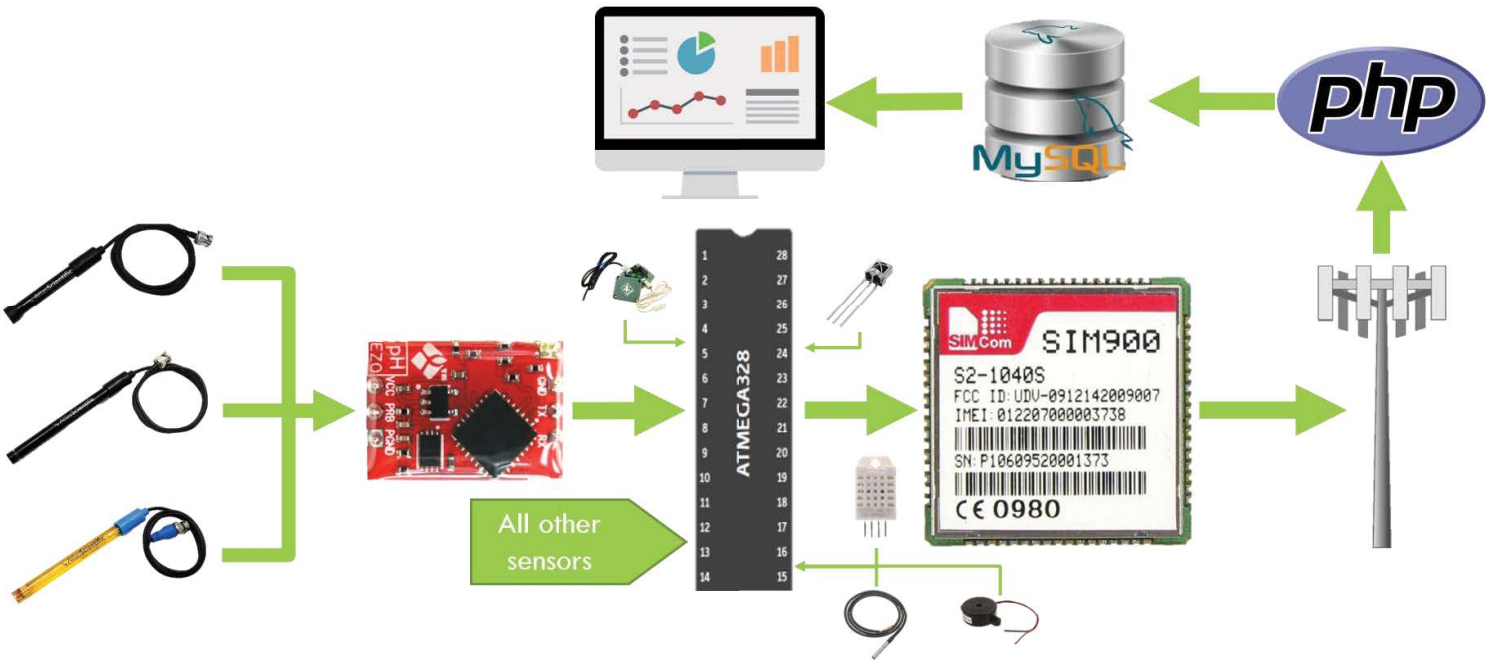
# Evolution Of River-Nanny




Above are the three versions of River-Nanny. As you can see, the right PCB and the middle one is almost identical except that in the right one I used a really small trace width which resulted in the Atmega not being able to boot up. The middle PCB is the one which is installed in the river. there are some problems with it which is why there are a lot of jumper wires. The main new features between the middle one and left one is that I use custom voltage isolator circuits, a fixed relay, two separate isolated power systems, support for a zero force socket and significantly reduced interference.

With every version there is new code to be written. I use code to suit the purpose and write well documented code. I have the advantage of writing in many languages which I inherited from my father and then I have added some. River-Nanny is an ideal project because it requires exchanges of Arduino-language (C/C++) to AT Commands to PHP to SQL to HTML/CSS/ JavaScript. I haven't included code as the complexity of the project necessitates lots of code.

# Putting It All Together




Shown above is the flow diagram of how River-Nanny works. In the center is the Atmega328p which is the core of River-Nanny connected to it is the IR receiver, ambient temperature and humidity sensor, water temperature sensor, a theft alarm, the controller for the capacitive level sensor and 3 atlas scientific control boards for the 3 atlas scientific sensors(PH, conductivity and DO). the Atmega gathers all the data from the sensor and stores it in variables. Then the data is compiled into a string which has all the data as PHP arguments. Then the ATMega sends the string to the GSM shield which calls an HTTP-Get request(goes to that website). Then it powers down everything, sets its alarm clock(a real time clock) and goes to deep sleep for an hour. On the server, the PHP receives the data and writes it to a MySQL database which can be viewed through a React admin panel.

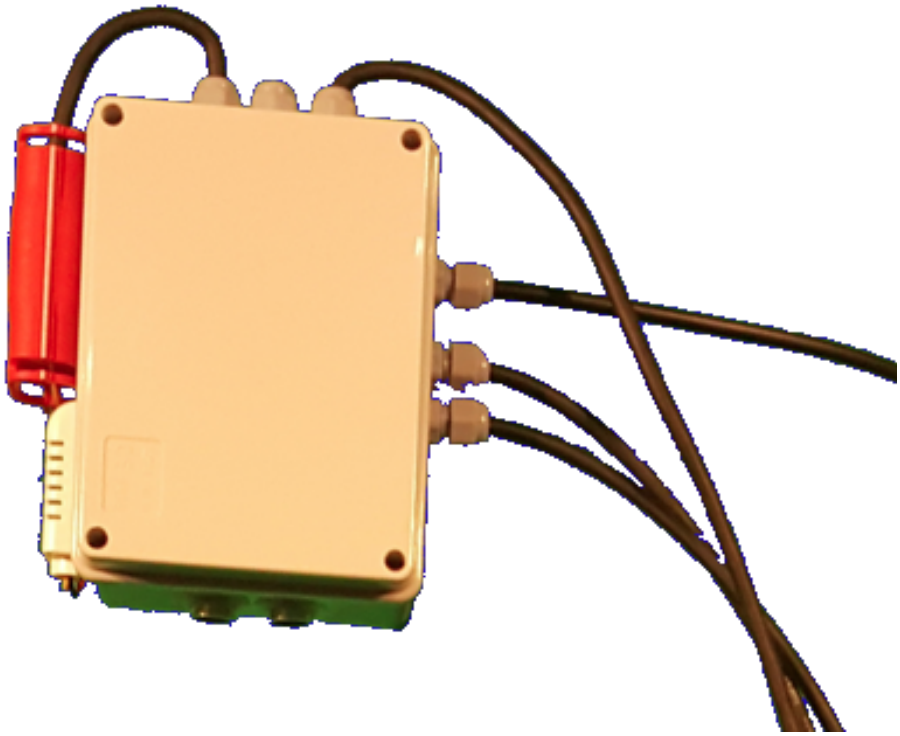
All of this sits in a little box at the end of a pipe hammered into the riverbed, that protects the River Varty now and into the future. My vision is that all the rivers of Ireland, or even the EU, would have such a caring nanny looking after each of them.

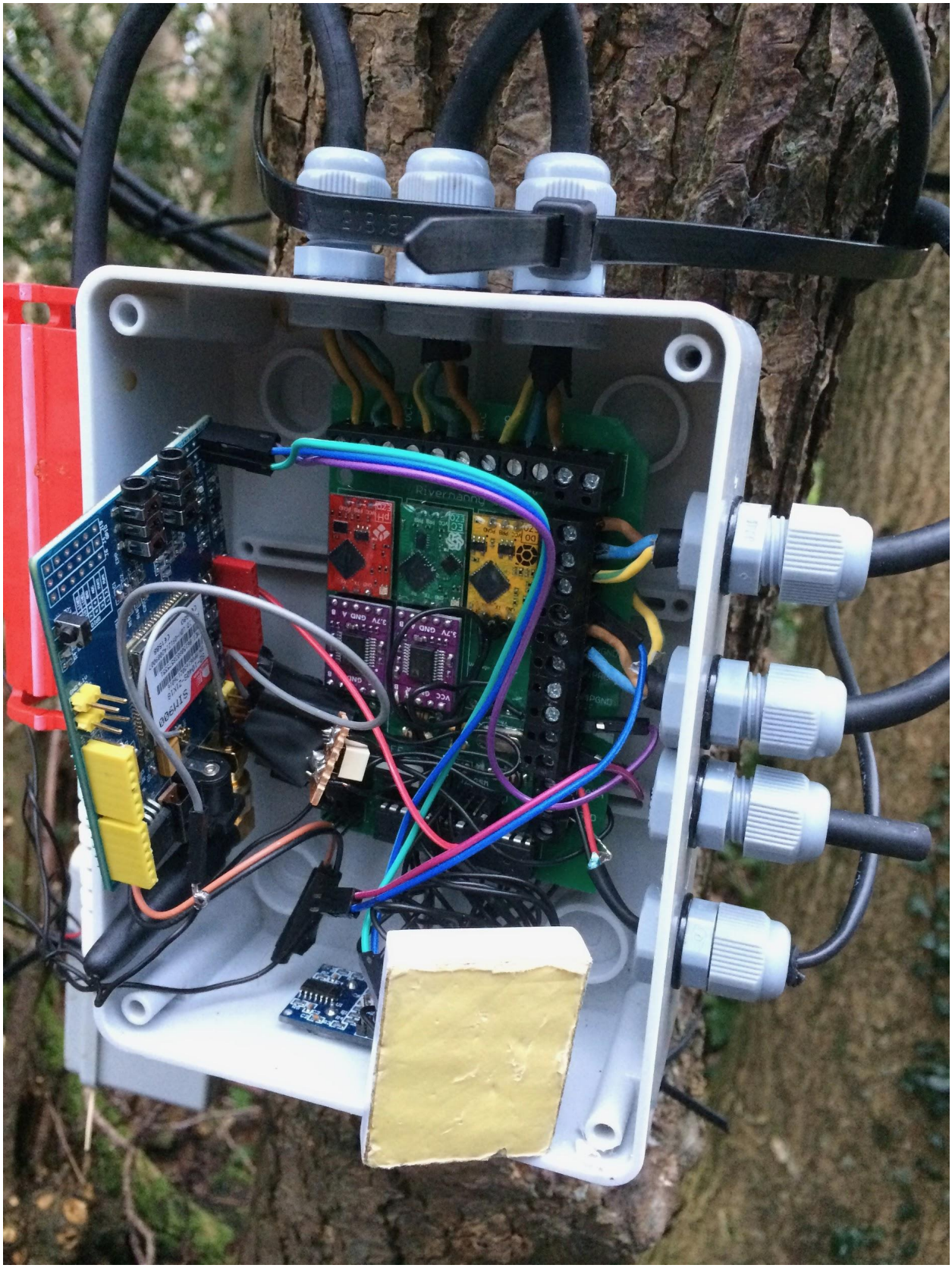
# RiverNanny

**Analysis and Monitoring River Ecosystems – Balancing Drinking Water Use with Natural Environment in a Changing Climate**

## Stand Number: 3304

# Project: RiverNanny
# School: East Glendalough School
# Name: Donovan Webb





# Comments

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# Summary / Abstract

Climate Change is creating increasing pressures on Drinking Water Use. This as a growing concern for Rivers, like the River Vartry, where the resource is shared by both Abstraction of Drinking Water at the top of the River and the Natural Environment and biodiversity of species that find their home along the River Vartry. In current negotiations with the Water Utility the attitude has been, “people before fish”. I believe in finding solutions that can balance between the two needs without destroying the River and loosing the Biodiversity that exists in a small ecosystem. I believe that the River Vartry is an ideal river system to use as a model for other rivers within the EU.

There is a lack of data on the Vartry and Irish Rivers in general, that is a block to progress. This lack of data is European wide with an urgent need for Climate Change data to help mitigate the future issues. In order to prove/discuss/plan and adapt our ways and thinking, we first need a simple system to accumulate scientific data. This data is on the life of the river and all its aspects, on a hour by hour, day by day, year by year basis. This data must be readily available to Stakeholders to share, research and plan. This should have been available many year ago, but I now intending to address this lack of good solid data. Fish need a flow of water, a level to spawn, a water temperature, and oxygen not only in the spawning season. The fish support all of the other species, along the river. There is NO EU specification of minimum flows or levels, as yet. There is NO EU understanding for Alum present in Rivers where a discharge from a Water Treatment Plant is being absorbed. How can the Environmentalists ask authorities to give more flow to a river if we do not know what flow we have, where it comes from, how much is available in drought, what is the result of low flow, whether floods will continue or get worse or not at all, whether droughts will persist, and how much flow we need for the biodiversity to be maintained?

The Vartry is ideal as it basically a closed system with only 3 small tributaries, and no branches. It has EU Salmonid protection and is a very healthy despite the intense pressure on it caused by the WTP (Water Treatment Works) at its source. Many protected species live along the ecosystem, such as otters, badgers, red squirrel, Killarney Fern, and many others. The water in the river is totally dependant on rainfall in the catchment and what is released from the upper catchment by the WTP from 1865. Climate Change is evident in the water that flows over the dam and in the river today. The objective is to find ways of balancing these new conditions with the growing need for Drinking Water.

With the local River Trust (River Vartry Protection Society), I have been commissioned to find a solution to automatically measure many of the important parameters that affect the fish and the biodiversity dependent on it. The requirements are to make it inexpensive to build and deploy, easy and cheaply maintained, low power usage and to accumulate data in a central server that can be accessed and digested by all the different Stakeholders. With unbiased shared data the work of negotiation and compromise can start to find a solution that works for everyone. I understand that in the past, the data has not always been unbiased, recent, and reliable. The approach of "People before Fish" has been used and rather than innovative solutions being sought, that really challenge ourselves to do better, work harder, legal arguments have been used. It is my belief that we must all work to find this balance for the future and it is up to the young to blaze this path by using technology to remove unnecessary legal arguments.

# Introduction

I have been asked by the River Vartry Protection Society, which is the "Custodians", Riparian Owners along the Vartry, to find a technical solution to address the lack of data on the River and Climate Change.

The River Vartry is a closed ecosystem (EU Protected under 78/659/EEC of 18 July 1978) with a Water Treatment Plant at the head of the river abstracting 95% of the flow, leaving 5% to the river. This unprecedented abstraction is already an unsustainable situation which is expanding due to Climate Change. Although perhaps some rivers are not so impacted, all rivers in Ireland and the EU do now or will in the future, suffer from these pressures. Climate Change will make water more valuable and the "People before Fish" argument will eventually see that our Biodiversity and the environment will suffer. If we are proactive and are able to see towards the future, we will have the arguments that enable us find a balance between these needs.

The River Vartry Protection Society has had these arguments over the past 10 years and has voiced them. What they have found is that arguments are qualitative based and the responses are "We see no Climate Change. The River is the same that it has been for 150 years. The needs of the many outweigh the need of the few. People before fish" Their answer is "We have seen the difference. We have heard stories of locals as children, rowing up the river." Without the quantitative analysis of actual data on levels, flows, temperature, dissolved oxygen, pH, Suspended Solids and others, nothing can be proved nor can the administration of the Water Treatment Plant or abstracting authority be encouraged to negotiate and come into balance with the environmental needs.

Since December 2015 the Riparian Owners have seen no floods. The highest water was in February 2016 and since then the water has reduced and reduced. Throughout the Winter of 2016/2017 it as remained no higher than it was in October 2016 which were drought conditions. For two weeks in early November 2016, due several days of continuous rain, the water rose 20 cm allowing for an early spawn of the Salmon. For this one year the water is as low as it has ever been for the past 22 years. If it remains in this condition for the period of the spawn, the Salmon will not be able to reach the Beds. While this is true there is sufficient water in the Reservoirs which the WTP uses to supply Dublin its water. This 2017 spawn was only partially successful due to the lack of water.

It is important to understand why quantitative data is required when finding a balance between abstraction and the environment. In the Summer of 2016 this was a drought and the Roundwood Reservoir was extremely low, near failure. Though the whole winter of 2016 until the present, there has been more than enough water in the Reservoir, yet the river has been even lower than 2016. Some of this has been the result of the WTP "pumping back" water that is leaking to the river for re-treatment in the plant. Procedures and practices like this should be negotiated and part of the "balancing act". With real data, the effects can be shown and this correlated with the effects of Climate Change.

In our dealings with the abstraction interests, they have had "Spot Flow Measurements" taken. These were not correlated with either Rain data or any Climate data. This spot data was used to normalise the only existing flow data collected in the middle of last century, the 1950's. From this normalisation they inferred that the river has always had 5ML/day and this would be continued. This data is very suspect but without anything else, was relied on. It is completely clear that the need for real data is paramount.

I have proposed and designed, developed and deployed a automatic monitoring system for the whole river at various strategic locations along its length. These stations will monitor all the parameters that can be fully automatic. The data will be sent by GSM technology automatically to a Server to make it available to all registered Stakeholders. The technology chosen and the design will focus on price, maintenance, and install simplicity so that more River Trusts can install it and run similar stations along their rivers.

The planned positions of the stations along the river are shown in the Appendix Figure 1. These have been chosen at strategic locations so that inputs from the three tributaries can be measured and quantified. Three Rain Sensor Stations will be located so that the contribution from rain can be measured and compared between the upper catchment and the lower catchment. This will give us all a true sense of the Hydrology of the river and its need for water.

The data that will be collected and will be available for Stakeholders has been simulated in Appendix Figure 2, using mock data. The data will be collected every 4 hours, 6 times a day. This will amount to 48 row of data and 384 data points a day and in a year we will have 140,000 data points. The graphs available will be able to be sliced by day, days, weeks, months, season and year on

year. The sample given is mock flow data which could be used to see the effect of release from abstraction, tributaries or rain on the flow. This will be available for all the other data points and the ability to plot one parameter against another.

The kind of use cases might be

Effect of Climate Change in any parameter, year on year

Compliance with S.I. No. 293/1988 - EC (Quality of Salmonid Waters)

Viewing the moment of flood event

Viewing the lag between rain and flow

Gathering information on the value of tributaries, springs or rain

Isolating a pollution event in time and location (spreading of Slurry or WTP spill) Fish spawn vs. Levels, temperature, DO and Flows

The effects of Flow and Level on DO and Temperature

Hour by hour evidence of a flood (requested by Chief Hydrologist UCD)

Any of the parameters that show emergencies will be alerted in real time to all stakeholders.

Subproject - Chemical Analysis

The project has focused on the real time automatic monitoring of the Hydrological elements of the river. I have chosen these parameters both because of their importance as indicators of the River's state and their ability to be automated. However, there are many other parameters that form part of the EU Quality of Salmonid Rivers that are also important to the health of the river. Most of these require Spot measurement and laboratory analysis so they are currently unsuitable for automatic monitoring, such as I am proposing.

In the future I foresee developing a method which would bring these parameters into automatic monitoring. O understand this would be an Ideal World Scenario but I feel that it is appropriate while developing a viable solution, I should also spend some research effort to see if I can develop a system to viably solve the automatic cost effective, chemical problem. I have suggested that I would examine the possibility of monitoring Alum as this is a parameter that is yet to be determined by the

EU. There is a Drinking Water requirement for less than 200 µg/l but none, as yet, for Salmonid Rivers. In the Vartry it is a growing concern as measured values are increasing due to lack of flow, or changes which could be caused by Climate Change.

The research into Alum and its effect on Fish would make it a useful parameter to be monitoring at the same time, should it be feasible. I intend to research and experiment with this in the future with a minimum cost in parallel with the development of the monitor stations.

This is my main argument for the project.

I must admit that to quantitatively documenting Climate Change is a large task of data engineering combined with hydrology and the science of Climate Change. Data over 20 years will certainly be necessary to conclusively quell all sceptics and to have strong mitigation and adaptation processes in place. The understanding of how this will affect Irish and EU Rivers in the future is unknown. Regardless of these concerns we need to start somewhere and urgently. The best place to start, in my opinion, is with Water and the forces that Abstraction place on the natural environment and biodiversity. This is a clear conflict between needs and is likened to two trains heading towards each other on the same track. We all know a future crash will be there in every water system in Ireland and every Member Country in the EC unless something is done.

I have as a resource a model closed ecosystem that is perfect for this kind of research and development. It would be hard to find a better example of the issues at stake. The River Vartry is an EC protected Salmonid River with a healthy fish population (much better than it should be for a small river). The river has a healthy microbiology and water quality is high. The River Vartry Protection Society has access to the River Vartry all along its banks. With the exception of freshwater mussels, the River has almost all the protected and unprotected species of wildlife and many important fauna. We already have the conflict between Abstraction and the Natural Environment with a Water Treatment Plant taking 95% of the flow of the river. The RVPS are regularly engaged in finding a balance between the two competing interests. They have a vested interest in solving this problem in our small corner of the EU, We are all open to help, cooperation and collaboration with anyone that can further the goals of protecting the habitat.

I am committed to making RiverNanny available throughout Ireland (North and South) and the EC to expand upon what I are going to do and have the real knowledge and data to properly address this important issue within the European Community. It is not Climate Change that is the real issue, but the conflict between competing needs caused by Climate Change. We must learn and educate ourselves to balance these conflicting needs.

# Experimental Methods / Development

My project has both a scientific portion and a technology portion. The parallel to experimentation would be development by the Iteration Method and it is necessary for me to have the hardware and software complete before being able to conduct deeper research into the actual effects of Climate Change.

I was asked by the River Vartry Protection Society to purchase or design a monitoring station that would meet the requirements as set out and the feasibility of the project has been defined by the pilot program goals.

- Low cost components (total cost less than €2000.00 in small quantity)
- High reliability - warranty over 2 - 5 years with little maintenance
- Low Maintenance - low cost of GSM communications, batteries
- Low power management - battery operation for over 2 years.
- Ease of Installation
- High Accuracy - to EU standard and in some cases lab standard
- Fully Waterproof
- Data transfer automatic to GSM Network
- Minimum calibration of sensors
- Most important hydrological parameters recorded
- Non-polluting - All sensors are passive to the environment

Central to the project is the ability to automatically monitor the full hydrology of the River Vartry from source to outlet. This creates the necessary data to analyse the effect of Climate Change on the river and to give us parameters to negotiate a balance between abstraction and natural biodiversity in the environment. To do this it is necessary to be able to prove the concept though a pilot project.

The analysis of the existing technologies indicated that nothing existed in the market that was either fully automatic or that could be purchased for over 10 times the price. This would require limiting the data to a single station and would drastically change the scope and purpose of the project. From this analysis it became evident that the only solution was to make a custom microcontroller that would drive a variety of sensors. This is an innovative solution and not available on the market using a unique design to combine the results of different manufactured sensors into a single data stream sent to the server.

This is being undertaken at the moment and can be discussed in regards to best practices, by separating the components, into Monitoring Station, Backend Servers, and Analysis. There is a Hardware/Software combination in each of these but it will be dealt with together.

## Monitoring Station

The Pilot Program is underway and a single prototype has been installed in the river at a single location.  Some of the goal can be evaluated at the point against the results using the scale of Good Confidence, Achievable, Achieved. Some of these need more time in-situ to prove results.

Achievable

Component Cost, Low Maintenance, Low Power, Ease of Installation, High Accuracy, Fully Waterproof.

Achieved

Automatic Data Transfer, Minimum Calibration Sensors, Most Hydrological Parameters Recorded, Non- Polluting

At this stage, I have a high confidence level that all design goals are achievable and the project can be successful in delivering to a Backend Server all relevant data for assessing the effects of Climate Change on the River. I have used best practice in all our designs and have not had the necessary of sacrificing any quality or best practice goals for meeting the costs.

# Backend Server

The data is sent 6 times a day, every 4 hours, to my backend server from each station. Currently it is planned for 8 stations to be functional by winter spawn in 2018. The server is an Apache/MySQL/PHP WebService designed using best practice. It will be fully protected by password/login or Google two stage authentication. Logins will be made available on request for read only data to all registered Stakeholders.

Besides for myself, within the River Vartry Protection Society they have people with the background and experience of running production large scale servers, specialising in Scaling and Performance. The size of the data is calculated currently as follows:

48 rows a day with 12+ data points. 17,500 rows per year.

This is not really a very significant amount of data to be concerned about as the Backend WebService would handle millions of rows per year.

This is functional at the moment and receiving data from the pilot Monitoring Station.

On the Backend Server I will develop and build a Portal developed to view the data in various way. This work will only be undertaken as more stations are installed but, there are no unknowns or uncertainties. It will also change as partners and stakeholders request different reports to suit their differing interests. I use "Open Source" components whenever possible and build upon these technologies.

# Analysis of Data

I will be analysing data throughout the project as will the Stakeholder for their needs in negotiation with the Abstraction Interests to find a balance. This will be analysis directly related to the River Vartry and additional stressed caused by Climate Change. Its purpose would be directly to show where the flows and frequency of flood event would be reducing, year on year and the need for change. They will have consultants hydrologists to help us better understand the whole ecosystem and help us understand the data better.

The work to fully understand the data will require  engaging a University partner to take a broader analysis regarding Climate Change and use this vast data to model and predict future hydrology. There are many studies on modelling of rivers for this exact purpose in the US but not recent enough nor particularly relevant to Europe and the smaller river systems. These studies were all done without being in a context of Climate Change which changes the dynamics of Abstraction and Natural Use. Using a closed system such as the River Vartry with extensive data to accurate measure the full parameters of a river, gives a unique opportunity.

## Best Practice during the Project

I intend to not only rely on our own measurements for verification of the data but will use our data in conjunction with verification from outside sources. There are spot monitoring of the River Vartry but the EPA and their data will be cross referenced to verify our data is correct at the locations where this is done. The Inland Fisheries Ireland, as well, do regular measurements along the River to study the wellness of the fish populations. This too will be used for verification.

During the project I have planned for independent validation for 4 times in the first year and 2 times the years after. This would be a several of the monitoring stations measuring the same parameters and verifying the accuracy of RiverNanny data. This will be undertaken by one of the most qualified contractors in the field of Hydrology. I feel this is very necessary to insure that there is confidence in the monitoring stations and that it is completely “fit for purpose”.

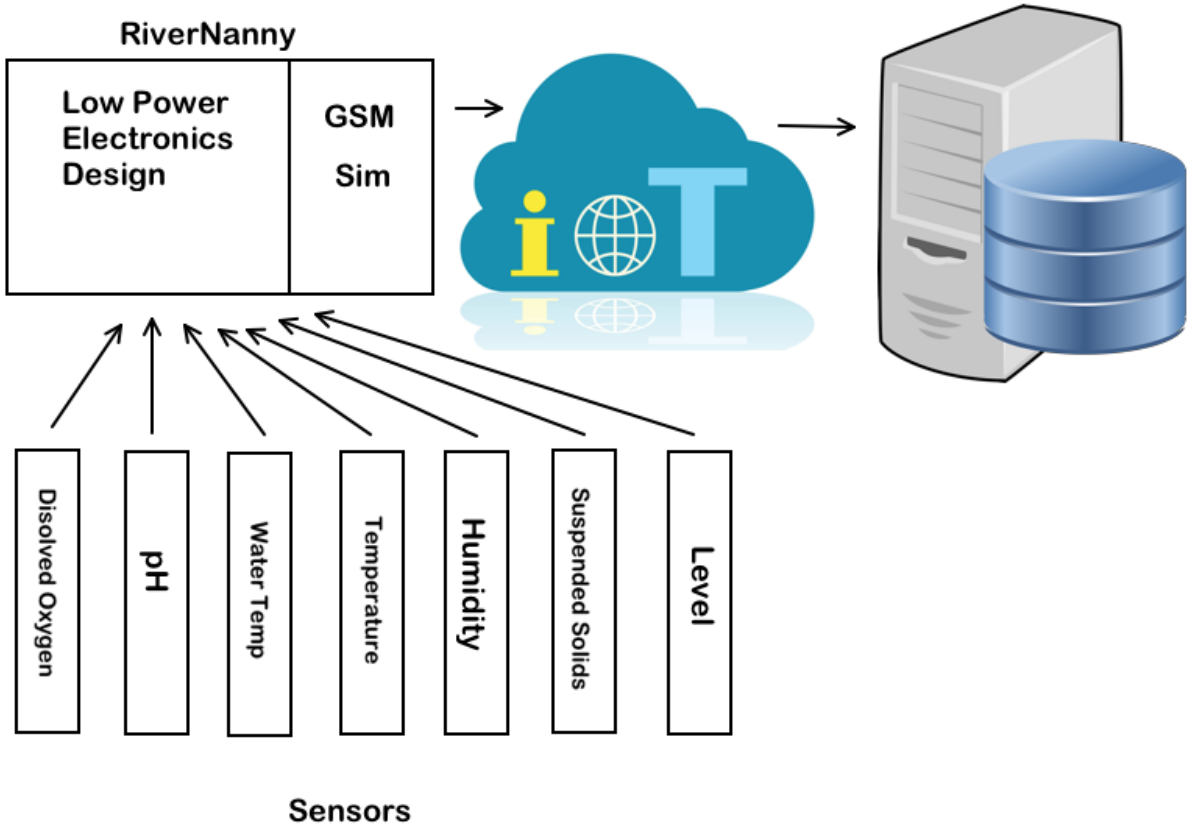
## Innovation

The objective of my Project is to collect data for the purposes of study and there is an innovative solution to the problem which is not currently available. Today new Technology has begun to challenge our old solutions with the phrase “anything, anywhere”. With the Internet of Things, there are cheap communication methods which lend themselves to our IoT hardware. After extensive research we found that there were only data loggers as part of a single sensor system. The Data Loggers alone were €10,000 and upwards and each used a storage chip to store data, or required going to the station to plug in a cable and download, or using bluetooth when in the range of the Data Logger.

The solutions were all unacceptable because of the need to visit these locations regularly, that during the visits data could be corrupted, the cost would be prohibited for most Rivers and might only be used at one location. As well, these solution were single parameter sensors and not a single Data Logger attached to multiple sensors covering most of the important indicators.

It was necessary for me to Design and Develop a new solution suitable for the needs of this study using IoT technology. This allows a central server location to accumulate all of the data from the whole length of the river and make it available to all Stakeholders. Uniquely we have added sensors

which normally would not be automatically available, which includes Dissolved Oxygen, Total Suspended Solids and Ph. These were necessary to be able to isolate any pollution that may come from a tributary or from the WTP. The unique possibility to have an instant alert of changes in these, allows identifying the pollutant, perhaps stop it, and pinpoint where it entered the river. In any river there is the possibility of dumping or careless spreading of Slurry. This will be the first time such monitoring will be possible because of the cost and simplicity of the design. I believe that this technical solution will be sought by many other rivers in the EU as it represents a new important possibility for river monitoring.




RiverNanny has custom code used throughout the microcontrollor, some of which is included in the Appendix. This code deals with controlling and reading the sensors, security software, low power consumption, calibration software and communication software.

# Results

The result of the project is that I have a fully working Prototype RiverNanny system installed in the river which communicates via GSM to my central server. While there will be substantial work to adjust, adapt, redesign and remanufacture circuit boards, the basic sensors seem to be giving “sensible” results. I have contacts with different Chinese Sensor Manufacturers and perhaps I will experiment with these to see if costs can be further reduced.

From a design standpoint that project has developed well from the original concept to the working prototype. The importance of the development will only really be seen in respect to the total project of providing impartial data to help balance the competing needs of the river in a changing environment. Climate Change is a long term goal, but the measuring and collection of data as soon as possible will make possible for mitigation before it is too late.

The River Vartry Protection Society is currently applying for a grant from LEADER for this project based on my design being deployed across the whole of the River Vartry and hope that the funds will be available by the middle of 2018. Regardless of the outcome of the grant (which looks very positive), with other fund raising the monitoring will continue and I will be able to develop new ideas and continue improvement to the prototype design.

I believe that the true importance and result will be only be evident once many of the Rivers adopt RiverNanny or at the least the philosophy of low cost deployment of automatic monitoring of impounded rivers across Ireland.

# Conclusions and Recommendations

It has become clear to me that Ireland and the EU has not paid enough attention to the future of our Water Resources. We are not working from accurate unbiased data and employing the new technology and resources available to us today. I see the opportunity to use this technology and making a common solution to measure and disseminate this data to a wide audience of experts.

I am currently not in a position to make recommendations on how Climate Change will affect the future of Rivers with conflicting use, but I can recommend that without the data produced by RiverNanny or something similar, it will be the Rivers and the Ecosystems supported by them that will suffer.

In Ireland the competing needs for water have become a conflict. Irish Water is a public utility/private company with the National Responsibility of Water Abstraction. In every dealing with planning and trying to improve the supply of drinking water they have run up against opposition from public outrage to public concern taking the matter to the highest Planning Authority, An Bord Pleanála. These conflicts have made it difficult for everyone. This is not a win/lose situation. If it is not solved, everyone loses. We cannot compete for water, we need to balance the needs of Drinking Water with the needs of the Environment and Biodiversity. I believe that this project will make an important socio-economic change to the way these issues are dealt with. With accepted knowledge comes negotiation, innovation and truly worthy solutions that secure our Environment and secure our Drinking Water into the uncertain future of Climate Change.

# Acknowledgments

I would like to acknowledge help from the following persons and thank them.

Mr. Adrian O'Connor - Metalwork and Advisor at East Glendalough School

Ms. Sheridan - Science Teacher and Advisor at East Glendalough School

Ms. Joanna Tottenham - Hydrology Student working for Environmental Services Company

Matthew Weiss - Father and Electrical Engineer

River Vartry Protection Society

# Appendices

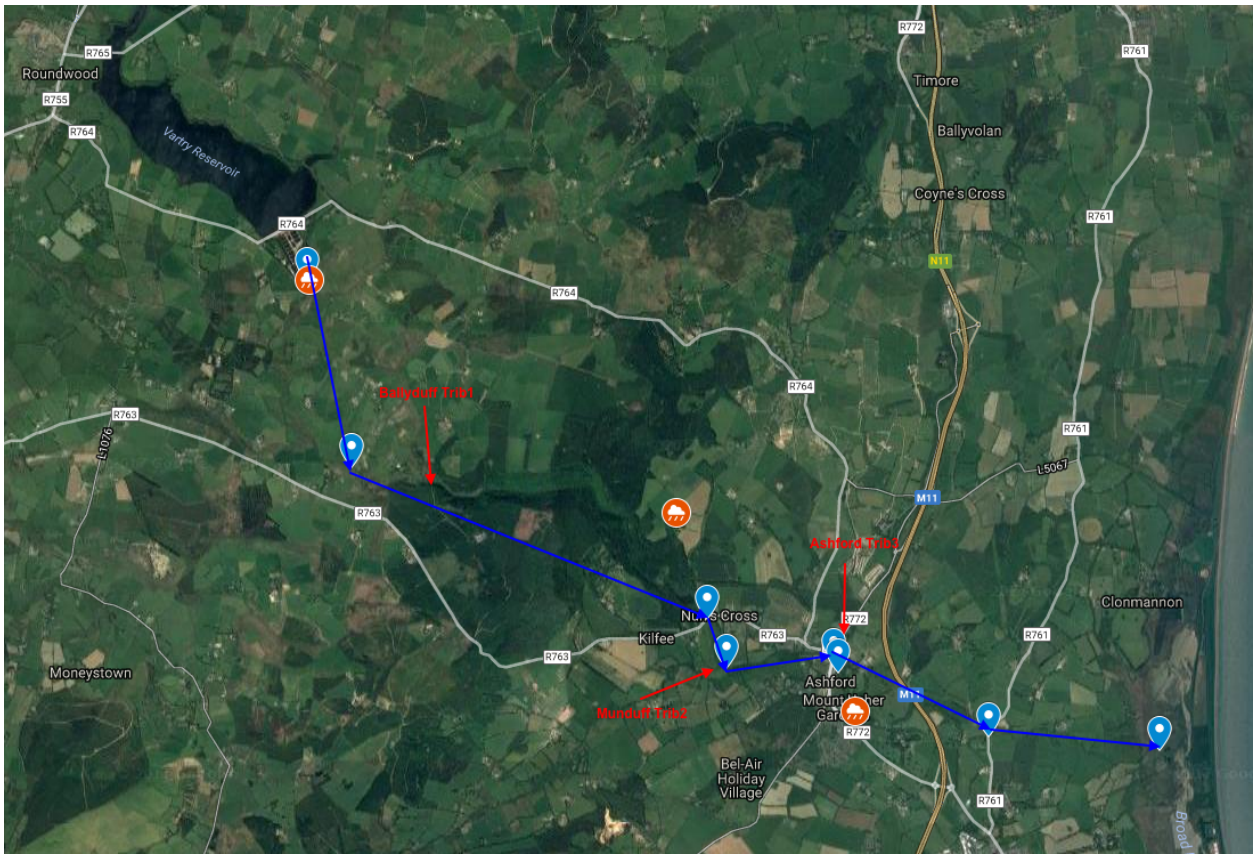



Figure 1 - Station Map

River Vartry

| | 00:00 | 04:00 | 08:00 | 12:00 | 16:00 | 20:00 |
|---|---|---|---|---|---|---|
| **Water Treatment Plant** | 4.8 | 3.8 | 5.8 | 4.5 | 4.9 | 5 |
| **Annagolan Bridge** | 4.8 | 3.7 | 5.9 | 4.3 | 5.3 | 5.1 |
| **Nun's Cross Bridge** | 5.2 | 5.4 | 6 | 4.5 | 5.2 | 5.5 |
| **RiverRun Bench** | 6.3 | 6.4 | 6.8 | 5.4 | 5.4 | 6.3 |
| **Ashford Bridge** | 7.3 | 8.3 | 7.9 | 6.3 | 7.3 | 7.3 |
| **Mt. Usher Gardens** | 8.8 | 8.8 | 8.5 | 7.8 | 8.8 | 9.1 |
| **Newrath Bridge** | 9.2 | 8.9 | 8.7 | 8.3 | 9.5 | 9.4 |
| **Broadlough House** | 9.4 | 9.8 | 9.4 | 8.7 | 9.8 | 9.7 |

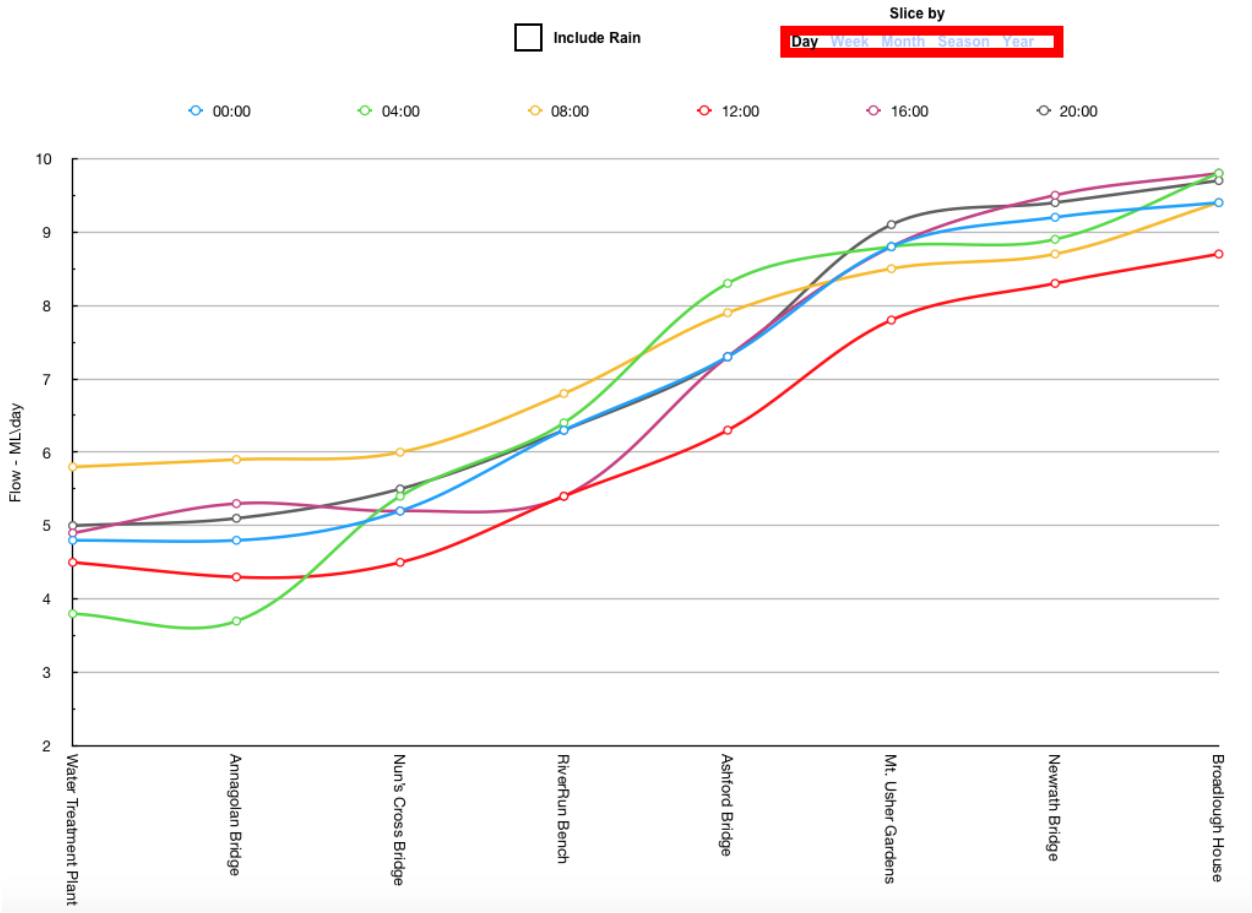



figure 2

```
 /*
This is the source code for rivernanny v1.2
*/
//#include <SoftwareSerial.h>
#include <String.h>
#include "DHT.h"
#include <OneWire.h>
#include <DallasTemperature.h>
#include <Streaming.h>
#include <AltSoftSerial.h>

//information on device
#define locationNum 1
#define customerNum 1

//digital pins used by alarms
#define caseC 4 // analog pin
#define probeC 0
#define ScrewC 1

//digital pins used by sensors
//#define heightTrigPin 0
//#define heightEchoPin 1
#define RTempPin 2
```

```
#define waterTempPin 3

#define relayTrig 10

#define irRec 11

#define gsmTX 12

#define gsmRX 13


//digital pins used for the serial expander

#define s1 7

#define s2 6

#define s3 5


//analog pins used buy sensor

#define Level 4

#define batteryPin 5


//used to select which RT And RH sensor is being used

// Uncomment whatever type you're using!

//#define DHTTYPE DHT11   // DHT 11

#define DHTTYPE DHT22   // DHT 22  (AM2302), AM2321

//#define DHTTYPE DHT21   // DHT 21 (AM2301)



DHT dht(RTempPin, DHTTYPE);
```

```
//used for the water temputer sensor

// Setup a oneWire instance to communicate with any OneWire devices (not just Maxim/Dallas temperature ICs)

OneWire oneWire(waterTempPin);

// Pass our oneWire reference to Dallas Temperature.

DallasTemperature sensors(&oneWire);


//setup Serial communication

AltSoftSerial altSerial;            //Name the software serial library altSerial (this cannot be omitted)


//calibration values

float maxHeight = 2.41;

float volt2Height = 3/maxHeight;




//varibles to store data

float height = 005.1;

float battery = 0.00;

float RTemp = 00.0;

float RH = 00;

float waterTemp = 00.0;

float DO = 00.00;

float PH = 00.000;

float EC = 00.00;
```

```
String stringData = "";
String temp = "";

void setup()
{
  analogReference(DEFAULT);

  //prepare the serial port expander
  //altSerial.begin(19200);               // the GPRS baud rate
  pinMode(s1, OUTPUT);              //Set the digital pin as output
  pinMode(s2, OUTPUT);              //Set the digital pin as output
  pinMode(s3, OUTPUT);              //Set the digital pin as output
  altSerial.begin(9600);            //Set the soft serial port to 9600

  Serial.begin(9600);    // the GPRS baud rate
  Serial.println("");
  Serial.println("");
  Serial.println("Starting RiverNanny V1.1");
  pinMode(12, OUTPUT);
  //pinMode(relayTrig, OUTPUT);
  dht.begin();
  sensors.begin();
}
void loop()
```

```
{
  delay(10);
  WriteToServer();
  delay(1000);



}


void WriteToServer()
{
  //turn on relay
  //digitalWrite(relayTrig,HIGH);

  Serial.println("reading sensors");
  Serial.println("");

  //get battery level
  float sensorValue = analogRead(A5); //read the A5 pin value
  battery = sensorValue * (3.5 / 1023.00) * 2; //convert the value to a true voltage.
  Serial.print("battey voltage: ");
  Serial.println(battery);

  //get water hight
  sensorValue = analogRead(A3); //read the A4 pin value
```

```
  float waterHeightVolt = sensorValue * (3.5 / 1023.00); //convert the value to a true
voltage.

  height = waterHeightVolt/volt2Height*100;  //  2.41/1   1= 3/3

  Serial.print("sensor value: ");

  Serial.println(sensorValue);

  Serial.print("water height voltage: ");

  Serial.println(waterHeightVolt);

  Serial.print("water height: ");

  Serial.print(height);

  Serial.println(" cm");




  //Get ambient temputer and humidity


  // Reading temperature or humidity takes about 250 milliseconds!

  // Sensor readings may also be up to 2 seconds 'old' (its a very slow sensor)

  RH = dht.readHumidity();

  // Read temperature as Celsius (the default)

  float t = dht.readTemperature();

  // Compute heat index in Celsius (isFahreheit = false)

  RTemp = dht.computeHeatIndex(t, RH, false);

  Serial.print("ambiant temputer: ");

  Serial.println(RTemp);

  Serial.print("ambiant humidity: ");

  Serial.println(RH);
```

```
  //get water temputer


  // Send the command to get temperatures
  sensors.requestTemperatures();
  waterTemp = sensors.getTempCByIndex(0); // Why "byIndex"? You can have more than one IC on the same bus. 0 refers to the first IC on the wire
  Serial.print("water temp: ");
  Serial.println(waterTemp);


  //get atlis science sensors
  ReadAtlasScience();


  //turn off relay
  //
  //digitalWrite(relayTrig,LOW);


  SubmitHttpRequest();
}


///SubmitHttpRequest()
///this function is submit a http request
///attention:the time of delay is very important, it must be set enough
void SubmitHttpRequest()
{
```

```
  powerShield();

  open_channel(4);                                //Call the function "open_channel" to open
the correct data path

  Serial.println("starting sending");

  altSerial.println("AT+CMEE=2\r");

  altSerial.println("AT&W\r");

  altSerial.println("AT+CSQ");

  delay(100);

  ShowSerialData();// this code is to show the data from gprs shield, in order to easily see
the process of how the gprs shield submit a http request, and the following is for this
purpose too.

  altSerial.println("AT+CGATT?");

  delay(100);

  ShowSerialData();

  altSerial.println("AT+SAPBR=3,1,\"CONTYPE\",\"GPRS\"");//setting the SAPBR, the connection
type is using gprs

  delay(1000);

  ShowSerialData();

  altSerial.println("AT+SAPBR=3,1,\"APN\",\"NXT17.NET\"");//setting the APN, the second need
you fill in your local apn server

  delay(4000);

  ShowSerialData();

  altSerial.println("AT+SAPBR=1,1");//setting the SAPBR, for detail you can refer to the AT
command mamual

  delay(2000);

  ShowSerialData();
```

```
  altSerial.println("AT+HTTPINIT"); //init the HTTP request

  delay(2000);

  ShowSerialData();


Serial.println("AT+HTTPPARA=\"URL\",\"http://ableroad.com/rn/write.php?a="+String(customerNum)
+"&b="+String(locationNum)+"&c="+String(battery)+"&d="+String(height)+"&e="+String(RTemp)+"&f=
"+String(RH)+"&g="+String(waterTemp)+"&h="+String(DO)+"\"");// setting the httppara, the
second parameter is the website you want to access


altSerial.println("AT+HTTPPARA=\"URL\",\"http://ableroad.com/rn/write.php?a="+String(customerN
um)+"&b="+String(locationNum)+"&c="+String(battery)+"&d="+String(height)+"&e="+String(RTemp)+"
&f="+String(RH)+"&g="+String(waterTemp)+"&h="+String(DO)+"\"");// setting the httppara, the
second parameter is the website you want to access


//altSerial.println("AT+HTTPPARA=\"URL\",\"http://ableroad.com/rn/write.php?a=1&b=1&c=6.08&d=0
&e=19.07&f=39.00&g=0.00&h=0.00\"");// setting the httppara, the second parameter is the
website you want to access

  delay(1000);

  ShowSerialData();

  altSerial.println("AT+HTTPACTION=0");//submit the request

  //delay(200);//the delay is very important, the delay time is base on the return from the
website, if the return datas are very large, the time required longer.

  //while(!altSerial.available());

  ShowSerialData();

  altSerial.println("AT+H.TTPREAD");// read the data from the website you access

  delay(300);

  ShowSerialData();

  altSerial.println("");

  delay(100);
```

```
  powerShield();
  Serial.println("stoped sending");

}

void ReadAtlasScience()
{
  EC = 0;
  PH = 0;
  DO = 0;

  //reads do
  open_channel(1);                                //Call the function "open_channel" to open the correct data path
  altSerial.println("b");                        //Send the command to the Atlas Scientific device using the softserial port
  temp = altSerial.readStringUntil(13);
  altSerial.println("r");                        //Send the command to the Atlas Scientific device using the softserial port
  while (altSerial.available() == 0) {
    delay(100);
    //Serial.println("Waiting");
  }
  temp = altSerial.readStringUntil(13);
  DO = temp.toFloat();     //we read the data sent from the Atlas Scientific device until we see a <CR> and convert it to a float
```

```
  delay(50);

  altSerial.println("sleep");                        //Send the sleep command to the Atlas
Scientific device using the softserial port

  delay(10);

  temp = altSerial.readStringUntil(72);

  Serial.print("disolved oxygen: ");

  Serial.println(DO);



  //reads EC

  open_channel(2);                                  //Call the function "open_channel" to open
the correct data path

  altSerial.println("b");                         //Send the command to the Atlas Scientific
device using the softserial port

  temp = altSerial.readStringUntil(13);

  altSerial.println("r");                         //Send the command to the Atlas Scientific
device using the softserial port

  while (altSerial.available() == 0) {

    delay(100);

    //Serial.println("Waiting");

  }

  temp = altSerial.readStringUntil(13);

  EC = temp.toFloat();     //we read the data sent from the Atlas Scientific device until we
see a <CR> and convert it to a float

  delay(50);

  altSerial.println("sleep");                        //Send the sleep command to the Atlas
Scientific device using the softserial port
```

```
  delay(10);

  temp = altSerial.readStringUntil(72);

  Serial.print("Conductivity: ");

  Serial.println(EC);



  //reads PH

  open_channel(3);                                //Call the function "open_channel" to open
the correct data path

  altSerial.println("b");                        //Send the command to the Atlas Scientific
device using the softserial port

  temp = altSerial.readStringUntil(13);

  altSerial.println("r");                        //Send the command to the Atlas Scientific
device using the softserial port

  while (altSerial.available() == 0) {

    delay(100);

    //Serial.println("Waiting");

  }

  temp = altSerial.readStringUntil(13);

  PH = temp.toFloat();     //we read the data sent from the Atlas Scientific device until we
see a <CR> and convert it to a float

  delay(50);

  altSerial.println("sleep");                        //Send the sleep command to the Atlas
Scientific device using the softserial port

  delay(10);

  temp = altSerial.readStringUntil(72);

  Serial.print("PH: ");
```

```
  Serial.println(PH);
}

void open_channel(int port) {                              //This function controls what UART
port is opened.
  if (port < 1 || port > 8)port = 1;              //If the value of the port is within range
(1-8) then open that port. If it's not in range set it port 1
  port -= 1;                                       //So, this device knows its ports as 0-1 but
we have them labeled 1-8 by subtracting one from the port to be opened we correct for this.

  digitalWrite(s1, bitRead(port, 0));             //Here we have two commands combined into
one.
  digitalWrite(s2, bitRead(port, 1));             //The digitalWrite command sets a pin to 1/0
(high or low)
  digitalWrite(s3, bitRead(port, 2));             //The bitRead command tells us what the bit
value is for a specific bit location of a number
  delay(2);                                        //this is needed to make sure the channel
switching event has completed
  return;                                          //go back
}

void powerShield(){
  digitalWrite(12, HIGH);
  delay(1000);
  digitalWrite(12, LOW);
  //delay(5000);
  delay(10000);
```

```
 }


void ShowSerialData()

{

 while(altSerial.available()!=0)

   Serial.print(altSerial.read());

}
```

# References


http://stackoverflow.com

http://watersandcommunities.ie/

http://www.arduino.org/

http://getbootstrap.com/

http://www.instructables.com/

http://ec.europa.eu/environment/water/water-framework/index_en.html

http://purecss.io/

http://www.irishstatutebook.ie/eli/1988/si/293/made/en/print

https://www.catchments.ie/hydromorphology-what-is-it/

http://php.net