



Design and Application of Automated Flood Water Quality Monitoring Systems in the Wet Tropics

Aaron Hawdon, Rex Keen, Joseph Kemei, Jamie Vleeshouwer and Jim Wallace

CSIRO Land and Water
Davies Laboratory, Townsville



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Cover Photograph:

Description: Lihs Road during Cyclone Larry Flood, Murray Flats, North Queensland.

Photographer: Aaron Hawdon

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Executive Summary

CSIRO Land and Water commenced a floodwater monitoring program for the Tully-Murray Rivers in North Queensland in March 2006 as part of the Australian Government Department of the Environment and Water Resources (DEW) Coastal Catchments Initiative (CCI).

One of the lessons learnt from preliminary manual sampling during the floods that followed cyclone Larry in March 2006 was the difficulty in obtaining access to the catchments during floods. During the first few days of these events roads are often impassable and it can be impossible to reach the centre of the flooded areas from either North or South of the catchments. We therefore developed flood water sampling systems that could automatically collect water samples during the early parts of a flood and these samples are then collected manually several days later when access can be gained.

The most suitable device for water quality sampling is a fully automatic and refrigerated sampler (ISCO Avalanche auto sampler). However, it would be prohibitively expensive to deploy many of these across the floodplain, so a hybrid system was designed that included three automatic water quality monitoring systems that measure sediment and nutrient concentrations in over bank flood waters. The systems include a fully automated monitoring station with a refrigerated auto-sampler and telemetry, two programmable temporal water quality samplers and 8 passive rising stage samplers.

This report details the components, construction and application of each of the above systems. The logic of each of the automated systems is described along with examples of the sampling sequence associated with each system.

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1. Introduction

As part of the Australian Government Department of the Environment and Water Resources (DEW) Coastal Catchments Initiative (CCI), CSIRO and ACTFR are collaborating on water quality monitoring in the Tully-Murray catchments in support of the Water Quality Improvement Plan (WQIP) in those catchments. ACTFR are responsible for a review and synthesis of existing water quality data from the catchments and sampling of water quality at plot and sub-catchment scales to evaluate the effectiveness of best management practices (BMP's) and land use respectively (Faithful *et al.*, 2007). CSIRO's role in the project is to sample water quality during flood events and the subsequent use of these data to make initial estimates of the quantity of sediment and nutrients that are transported across the floodplain in over-bank flow conditions.

The sites selected for taking water quality samples were based on a combination of (i) previous analyses of flood events in the Tully-Murray (Connell Wagner, 2005) and field reconnaissance visits to assess access to various areas in the catchment during floods. Figure 1 shows a peak flood depth map for a major flood that occurred between 31 January and 2 February 1986. To the west of the Bruce Highway there is a region ('sampling domain') where some of the deepest flood waters occur. This is also likely to be the area that will flood most often and stay inundated for the longest period. Inspection of flood depths for other, less severe floods (see Connell Wagner, 2005) also shows this area as being flooded. The Connell Wagner 2005 flood maps also indicate that there is a tendency for flood waters to flow through the low lying 'sampling domain' just north of the Murray River, connecting waters that emerge further upstream from the Tully river with flows that cross the Bruce highway, then tending to follow the Murray river pathway, through the Murray flats, to the sea.

Gaining access to this area during floods is an important issue if water samples are to be collected manually. Approaching along the Bruce Highway from Cardwell there are access roads to the south of the Murray River at points before the Murray Bridge. This bridge often becomes impassable during floods. Access from the north (including Tully) is dependent on the Tully Bridge remaining passable. If this is the case, there is a good access road (Davidson Road) along the higher ground just south of the Tully River. Given the available information on inundation depth and frequency and the logistics of access we selected the area marked 'sampling domain' in Figure 1 as the region from which we would take water quality samples after flood events.

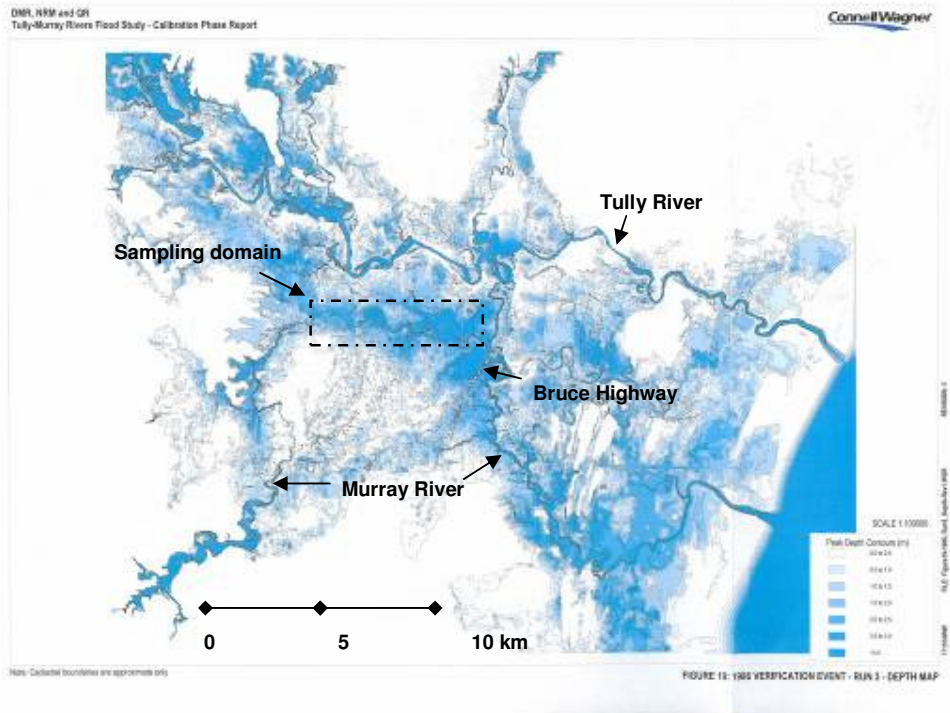


Figure 1. A map of the peak flood depths predicted by the MIKE 21 hydrodynamic model for the major flood event between 31 January and 2 February 1986 (reproduced from Connell Wagner 2005). The location of the water quality sampling domain is shown in the centre of the map.

Water quality samples were collected during the 2006 and 2007 Wet seasons. The 2006 data were collected from the floods that followed Cyclone Larry. At this stage of the project these water quality samples were all collected manually from a small boat. However, one of the lessons learnt from this preliminary manual sampling was the difficulty in obtaining access to the catchments during floods. During the first few days of these events roads are often impassable and it can be impossible to reach the centre of the flooded areas from either North or South of the catchments. We therefore developed flood water sampling systems that could automatically collect water samples during the early parts of a flood and these samples are then collected manually several days later when access can be gained. This document describes the sampling systems that have been used in the Tully-Murray catchments. All locations are given in UTM using the WGS84 datum.

2. Site Locations

2.1. Cyclone Larry Sampling Locations

Three trips were undertaken to collect water quality samples from the Cyclone Larry flood event (on 22, 24 and 27 March). A total of 30 water quality samples were collected manually from a small boat, at the locations shown in (Figure 1). The boat was launched in sugar cane drains as close as possible to the Murray River. Variations in topography prevented access to some sampling locations even during the peak of the flood. Some sampling locations became inaccessible as the floodwater began to recede even though they were still inundated.

These trips highlighted the need to install automated and passive water sampling systems to provide water quality data from the beginning of flood events; over the entire hydrograph and across the entire sampling domain.

Analysis of the Cyclone Larry flood samples (Wallace *et al.* 2007) showed that 15 sampling locations would give reasonable (i.e. coefficients of variation between 10 and 50%) mean flood water quality estimates of total suspended sediments and nutrients within the sampling domain.



Figure 1 Cyclone Larry flood water sample collection sites.

2.2. Floodplain Monitoring Locations

The locations monitored during the 2007 wet season were arranged as 5 approximately North-South transects between the Tully and Murray Rivers, each with 3 sample points, Figure 2. Some sites were relocated to improve accessibility and to prevent interference to farm operations. The locations nearest the Murray River are located in the deepest flood water and those furthest from the River in the shallowest flood water. Details of each site are shown in Table 1.



Figure 2 CSIRO Floodwater monitoring sites. Labels are site identifiers.

Table 1 Flood monitoring site details.

Site	Location (55S WGS84)	Monitoring System	Landholder name
1	378442 8007920	Rising stage	Bill Henry
2	379405 8007790	Full Auto Sampler	Ronald J & Valerie Zamora
3	380401 8007690	Manual sample (no installation access only required)	Ronald J & Valerie Zamora
4	381600 8007770	Manual sample (no installation access only required)	Leslie G & Christine M Jenkins
5	383068 8007520	Manual sample (no installation access only required)	Conti Holdings Pty Ltd
6	378494 8008370	Rising stage	Bill Henry
7	379439 8008300	Programmable Temporal Sampler	Ronald J & Valerie Zamora
8	380416 8008090	Manual sample (no installation access only required)	Ronald J & Valerie Zamora
9	381022 8007940	Programmable Temporal Sampler	Leslie G & Christine M Jenkins
10	383035 8007890	Rising stage	Conti Holdings Pty Ltd
11	378505 8008520	Rising stage	Bill Henry
12	379757 8008620	Rising stage	Ronald J & Valerie Zamora
13	380306 8008610	Rising stage	Ronald J & Valerie Zamora
14	381157 8008230	Rising stage	Leslie G & Christine M Jenkins
15	383015 8008290	Rising stage	Conti Holdings Pty Ltd

3. Sampling Systems

The most suitable device for water quality sampling is a fully automatic and refrigerated sampler (ISCO Avalanche auto sampler). However, it would be prohibitively expensive to deploy 15 of these across the floodplain, so we designed a hybrid system that included 1 fully automatic (refrigerated) sampler (S1), 2 programmable temporal (non-refrigerated) samplers (S2) and 8 rising stage samplers (S3). The remaining 4 locations are accessed manually. All of the landowners and the Cardwell Shire council were contacted and permissions sought for the deployment of the above devices. The entire system installation was completed in January 2007, ready for the high rainfall season in early 2007.

3.1. System 1 - Automatic Sampler

Introduction

One fully automated sampling system was installed at location 02. The design of this system is based on previous CLW stream gauging installations (Figure 3 and Figure 4) with all electrical components mounted on a raised platform. The station measures the depth, temperature and turbidity of flood water and also records local rainfall data. It uses a refrigerated auto sampler to collect fourteen 1L water samples over the flood hydrograph. The station is powered using solar / battery energy and is remotely monitored using telemetry. A daily report can be viewed using any internet browser.



Figure 3 Fully automated flood monitoring station (S1) installed near the Murray River, Tully.

Platform and Enclosures

The platform houses the solar panel array, a rain gauge, and the enclosures for the auto sampler and data logger.

The platform is approximately 1.5m wide, 2.4m long and 3m high. The frame is constructed of 75mm galvanised square hollow section (SHS) and has an expanded mesh floor. The handrails are made from 25mm galvanised SHS with two galvanised safety chains fitted across the platform entrance. This complies with the Queensland Workplace Health and Safety Regulation 1997.

The structure is fixed to four pre-poured concrete footings using 1m high, reinforced modular base plates and chemset anchors (see Figure 4).. It is intended that the platform will be removed at the end of the monitoring period.

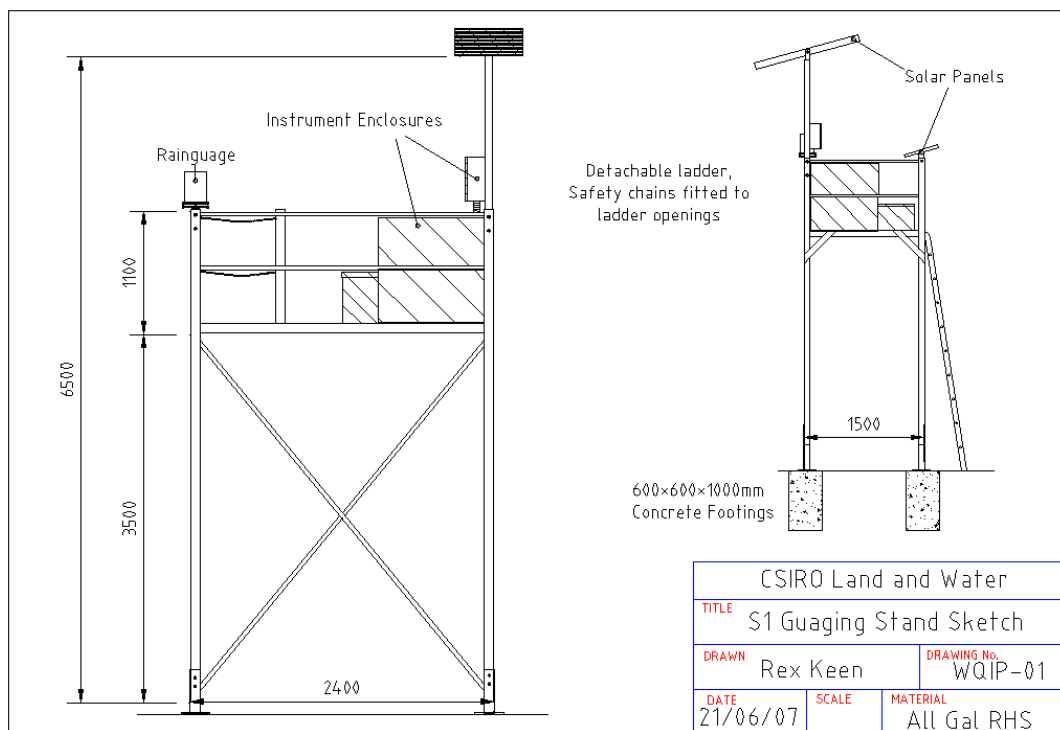


Figure 4 Sketch of fully automated gauging station

Three enclosures are located on the platform. (Figure 5)



Figure 5 Logger enclosure (a), auto sampler enclosure (b) and battery enclosure (c).

The logger enclosure (Figure 5a) is a B&R NI05042 which can be purchased off the shelf at many electrical supply stores. This enclosure protects internal components against the ingress of dust and water (IP56).

The enclosure for the auto-sampler (Figure 5b) is specifically designed for this application. It is constructed of 3mm zinc anneal sheeting with a lockable door. It has a false back to store excess sensor cable. The enclosure was welded to the floor of the platform in this application.

The logger and auto-sampler enclosures are connected using 50mm conduit and glands.

The batteries are housed in a lockable, galvanised steel enclosure (Figure 5c) that is located beside the auto-sampler enclosure.

Electronic Components

The station is controlled using a [Campbell Scientific CR10x data logger](#). These loggers are programmable and permit precise control of all measurement parameters. The logger is housed in the weatherproof enclosure Figure 5a that is mounted above the auto sampler enclosure.

A [Wavecom GSM modem](#), modem interface and depth sensor venting system are also located in this enclosure.

The [ISCO Avalanche refrigerated auto sampler](#) is housed in the weatherproof enclosure that is mounted on the floor of the stand (Figure 5b). The sampler contains fourteen 1L sample bottles and has a refrigeration system that is activated after the first sample is collected. The sampler is triggered using the CR10x logger. The intake hose is attached inside the platform mount (Figure 6). The hose runs through the leg of the stand into the enclosure.



Figure 6 Turbidity probe and auto-sampler intake (left) and depth sensor (right) mounting positions.

Water depth is measured using a [Greenspan ps7000 pressure sensor](#) with a 0 – 10m range and has an accuracy of approximately 0.5% of full scale (i.e. ± 5 cms). This sensor uses a closed-venting system to reduce ambient noise. The sensor itself is attached inside the platform mount (Figure 6). The cabling runs through the platform leg into the auto-sampler enclosure then into the logger enclosure.

Turbidity is measured using a [McVann Analite NEP9000](#) turbidity sensor with a 0-1000ntu range. This sensor is a $\pm 2.5v$ sensor with an accuracy of around ± 50 ntu. It is mounted inside the stand mount beside the auto-sampler inlet (Figure 6). The cabling runs through the platform leg into the auto-sampler enclosure then into the logger enclosure.

Water temperature is measured using two [Campbell Scientific 107 water temperature sensors](#) mounted at 0m and 0.5m. These sensors are mounted inside pvc conduit that is attached to the outside of the stand leg. The conduit provides thermal insulation.

Rainfall is measured using a [Hydrological Services tipping bucket rain gauge](#) with 0.5mm bucket.

System Control and Communications

The logger reads all sensors every 60 seconds. When floodwater rises above the event threshold (150mm), the station begins the pre-programmed sampling routine. The refrigeration is turned on and all data is logged at 1 minute intervals. Samples are collected with every 500mm change in water level or every 12 hours if the water has not risen by a further 500mm (Figure 7). The station uses the stage height and number of remaining bottles to optimise sampling along the falling stage of flooding (see Appendix 2 – Program Flowcharts).

During dry periods, all data is logged at hourly intervals and rainfall is totalled over the same period.

The telemetry system operates on the GSM mobile network. Data is automatically downloaded daily and appended to a database on a remote server. If samples have been collected an SMS is sent to staff mobile phones and an email is sent to staff addresses. This also occurs if data download fails or the stations batteries are running low. A daily data report is generated and can be accessed at the following website.

<http://www.data-tv.csiro.au/Reports/Report.aspx?ReportID=twqip>

Power Supply

Two power supply systems are integrated into the station. One provides power to the logger and instrumentation and the other powers the auto sampler.

The logger power and charging system consists of a 110A/hr deep cycle battery, a 20W solar panel and a power regulator. The battery will power the system for approximately 30 days without recharge.

A secondary power system is used to power the auto sampler. Two power systems were used so that if the refrigerator drains all power, the system can still measure and log water quality parameters.

The auto sampler power system is comprised of four 120A/hr sealed, deep cycle batteries, a solar regulator and a 60W solar panel. The batteries will power the sampler for a maximum of 10 days without recharge.

Example of sampling program

Figure 7 shows an example of how the sampling program for the S1 would operate during a four day flood event. In this example, sampling commenced after the water level reached the 150mm threshold and the station collected a further 8 samples over the hydrograph. This sampling sequence gives a comprehensive set of samples across the entire hydrograph and allows the system to be reset after a manual visit to the station towards the end of the flood when the site is accessible.

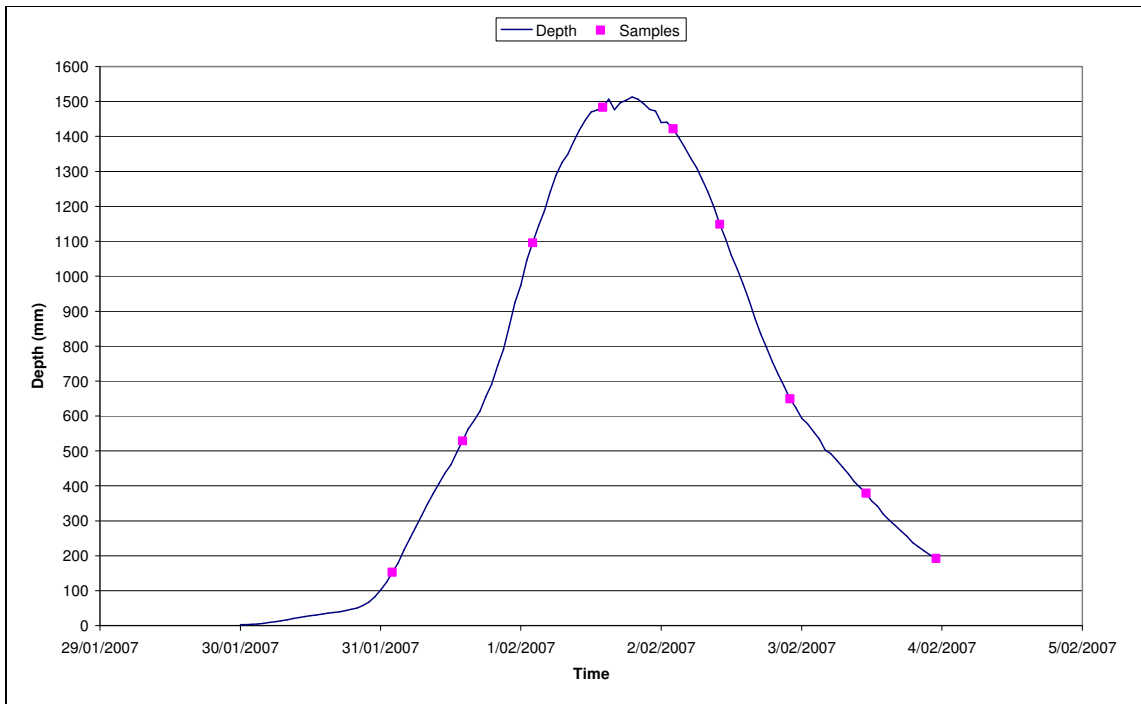


Figure 7 Flood depth and sampling times for S1 sampler during a four day flood.

3.2. System 2 - Programmable Temporal Samplers

Introduction

Two Programmable Temporal Water Quality Samplers (S2) are installed at locations I07 and I09. This is a prototype configuration (Figure 8 and Figure 9) that has been developed for this particular sampling program. It is controlled by a Campbell Scientific CR10x data logger and uses a submersible pump to collect four, time-based samples during a flood event. The stations are positioned next to existing drainage channels to ensure they do not disturb on-farm activity.



Figure 8 S2 sampling system installed at location 07 on the Murray River floodplain.

Infrastructure

The main infrastructure is comprised of two 75mm SHS poles with an integrated ladder. The poles are 4m high and spaced 0.45m apart. A 20W solar panel and two weather proof enclosures are mounted on the top of the structure. The structure is mounted in a concrete footing approximately 0.6 m wide and 1 m deep.

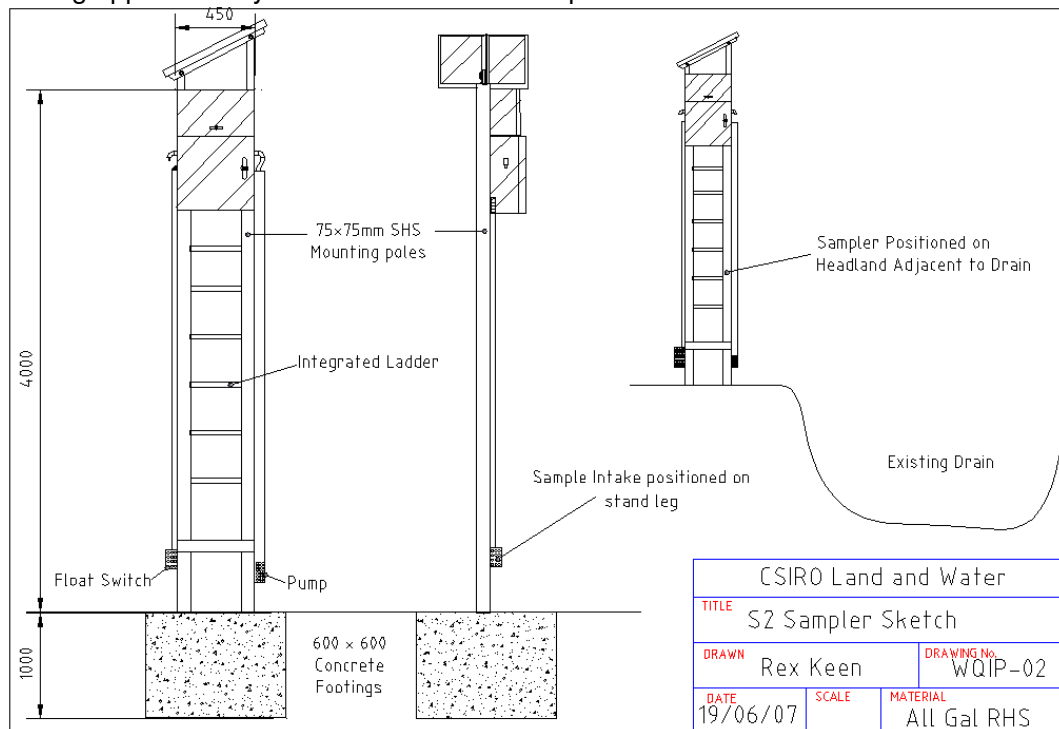


Figure 9 Sketch of a programmable temporal water quality sampler.

Electronic Components

The station is controlled using a Campbell Scientific CR10x data logger. This provides a high level of control and also allows the system to be upgraded with additional sensors if required.

Power is provided using a 20w solar panel that charges a 12A/hr battery through a solar regulator. The system will operate for approximately six days in sampling mode and 10 days in standby mode without recharge.

An [Enviroequip Mini-Typhoon submersible pump](#) is located inside a galvanised steel pipe that is attached to the leg of the station. This 12v pump is able to pump water up to 12m in depth. The pump hose is 19mm diameter and is reduced to 9mm at the outlet. This was required to provide enough pressure to open the solenoid valves.

A bank of four [HR Products MV75 solenoid valves](#) control the flow into the four sample collectors. These valves operate using 12v and are nominally closed.

The pump and solenoids are switched on and off using five [Omron G3R-ODX02SN solid-state relays](#).

The logger, regulator, battery and relays are located in the top enclosure to reduce the risk of water damage from the pumping system (Figure 10). The sampling lines and bottles are located in the lower enclosure.



Figure 10 Components of the S2 sampling system.

Two [RSF50 series float switches](#) are located on the leg of the structure. Two switches were used for redundancy purposes.

Operation

The S2 sampler is programmed to initiate sampling when either of the two float switches becomes activated by rising flood water. The switches are located above the level of the submersible pump to ensure the pump is primed. Floodwater is purged through the sampling system before each sample is collected.

Four one litre sampling bottles are located in the lower weather proof enclosure. Each bottle is filled using a sample tube that is opened and closed by a solenoid valve.

The logger is programmed to collect samples every 12 hours after the first sample is collected. Samples are collected over a 48 hour period before sampling stops.

The system is restarted by replacing the bottles and pressing a reset switch located on the logger. If flood waters are still above the float switches, sampling will recommence after 12 hours.

Example of sampling program

Figure 11 shows an example of how the sampling program for the S2 would operate during the same four day flood event shown in Figure 7. In this example, sampling commenced after the water level reached the 150mm threshold and the station had finished sampling close to the peak of the hydrograph. The samples would be collected at the same time as the S1 system if the datum (0mm) is consistent between locations. For locations with different elevations, samples would be collected at different times, but still on the rising stage of the hydrograph in the new location.

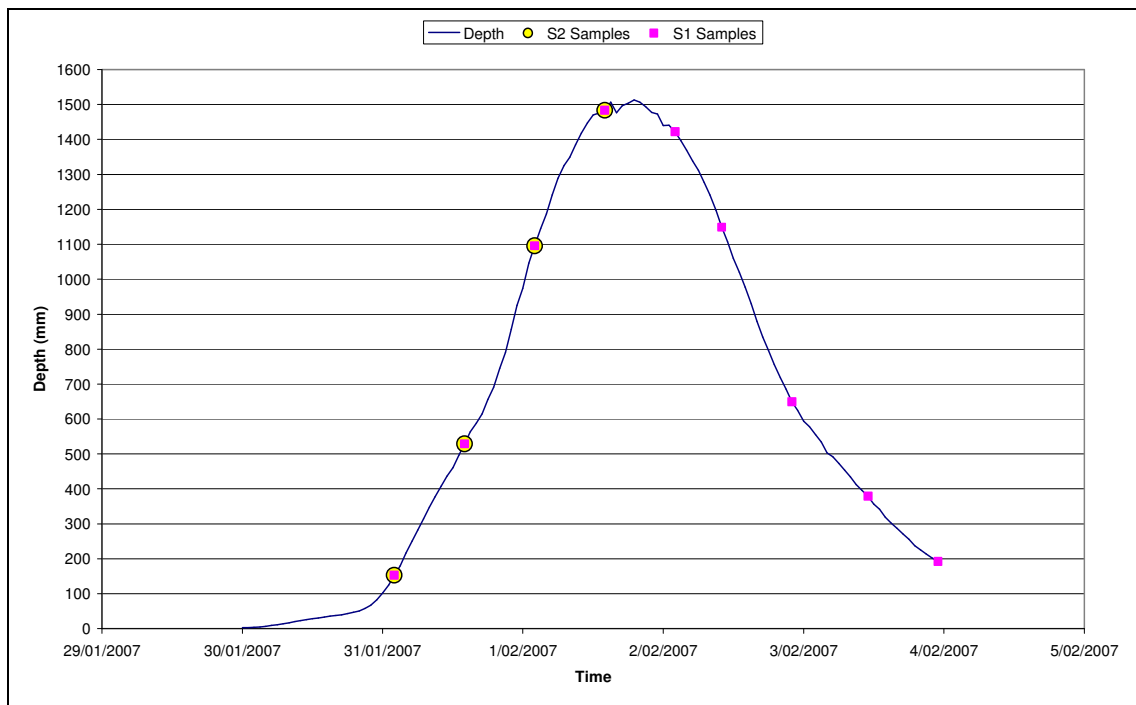


Figure 11 Flood depth and sample times for an S2 sampler in comparison with the S1 sample times during a flood hydrograph.

3.3. System 3 - Rising Stage Sampler

Introduction

Rising stage sampler (RSS) systems (Figure 12) are used to collect a water sample on the rising limb of a flood event at eight locations within the sampling domain. They are a passive style of sampler that automatically collect one litre of flood water. [Hydrological Services RSS](#) have been installed at 0.5, 1 and 1.5m depth at each site. Sites I01, I10 and I12 have an additional bottle located at 2m.

The sites were located close to existing roads or tracks to allow easy navigation through flood waters. Samplers are positioned close to fence lines or drains to provide unfettered access for on-farm activities.



Figure 12 Rising stage sampler located at location 06 before (left) and during flooding.

Infrastructure

The samplers are attached to either a 3m or 2m SHS pole. The pole is mounted within a concrete footing approximately 0.3m wide and 1m deep (Figure 13).

Samplers

The RSS are comprised of a one litre sample vessel fitted with a stainless steel inlet and vent tubes (Figure 13). Three or four RSS bottles are mounted within a 100mm pvc pipe at 0.5, 1, 1.5 and/or 2m from ground level.

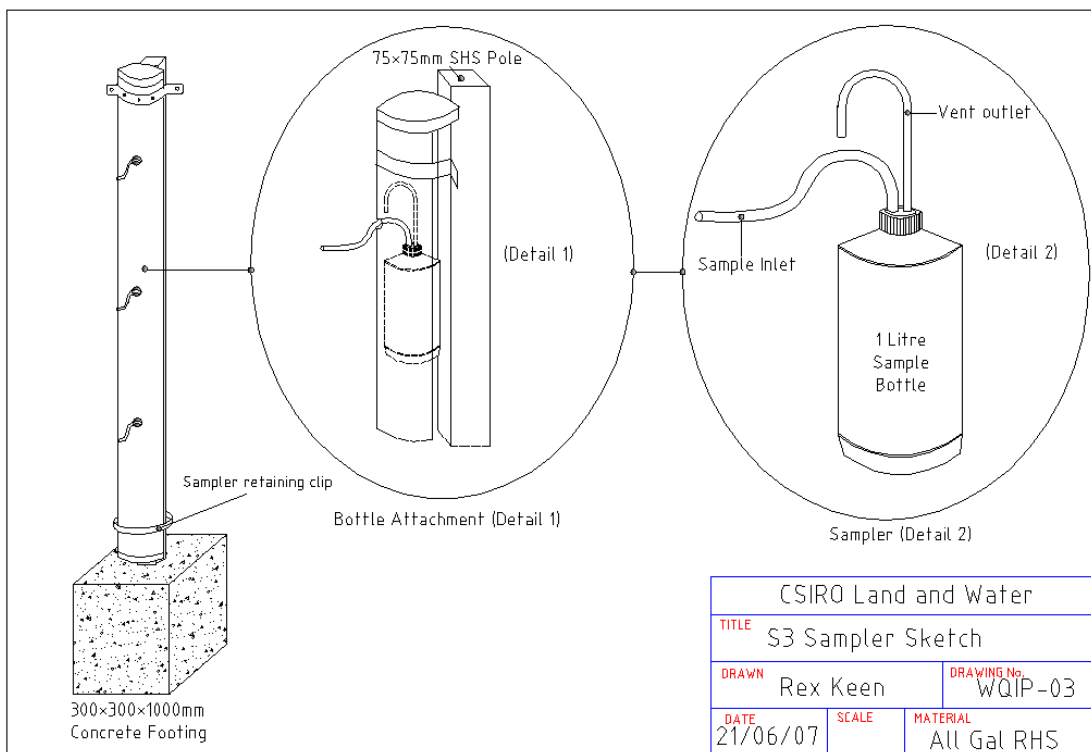


Figure 13 Sketch of Rising Stage Sampler unit including detail of mounting (Detail 1) and individual sampler units (Detail 2).

The pvc tubes are attached to the pole with a clamp at the top (Figure 14). The clamp is comprised of two parts. A back plate is attached to the pole and a 100mm saddle is attached to the pvc tube. The two parts are held together by wing nuts. Pipe clips are used to provide support for the tube along the length of the pole. The tubes are located on the downstream side of the mounting poles.



Figure 14 Close up of RSS clamp configuration.

Operation

As the water level rises above the crown of the inlet tube, water begins to fill the sampler. The bottle fills until it is full or until the water level rises above the vent tube. There is no further exchange between the collected sample and the outside water.

The system was designed to facilitate the removal of the sample bottles prior to the regression of flood waters. This is achieved by unscrewing the clamp and raising the entire unit. When the bottles have been removed, the RSS can be replaced onto the pole.

Each sample is assigned a unique sample number. The details of the sample are then entered into a spreadsheet on a pocket computer.

Example of sample collection

Figure 15 shows the sampling times for the S3 during the same four day flood event shown in Figure 7 and Figure 11. In this example, samples are collected every 500mm to the peak of the hydrograph. The samples would be collected at similar times to the S1 and S2 systems if the datum (0mm) is consistent between locations. However, as with the S2 samplers, at locations with different elevations, samples would be collected at different times, but still on the rising stage of the hydrograph in the new location.

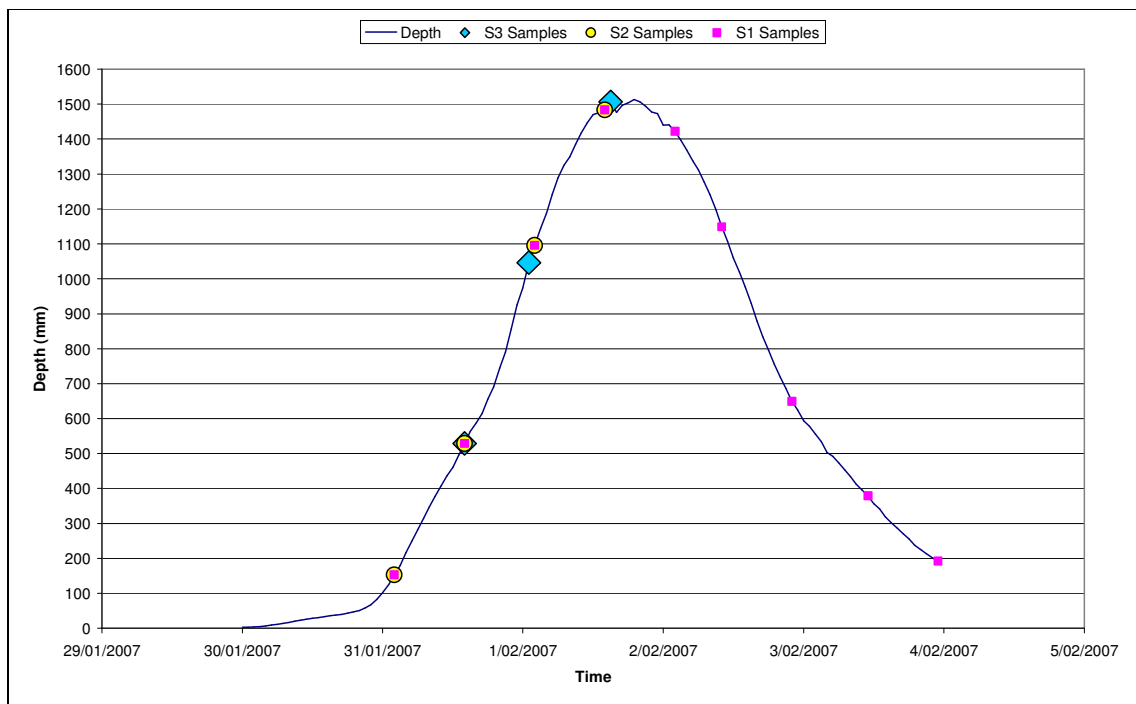


Figure 15 Flood depth and sample times for S3 sites in comparison with the S1 and S2 sampling times for a flood hydrograph.

3.4. Manual Sampling

Sample Collection Procedures

Manual samples are collected approximately half way down the water column from the four sites shown in Figure 2. Manual samples are also collected from all sites as they are visited. Water depth, turbidity, velocity and velocity direction measurements are made during each sampling interval.

Turbidity was measured using a [McVann Instruments Nep160](#) handheld turbidity probe. Velocity was measured using a [Marsh-McBirney Flo-mate portable flow meter](#).

4. Access

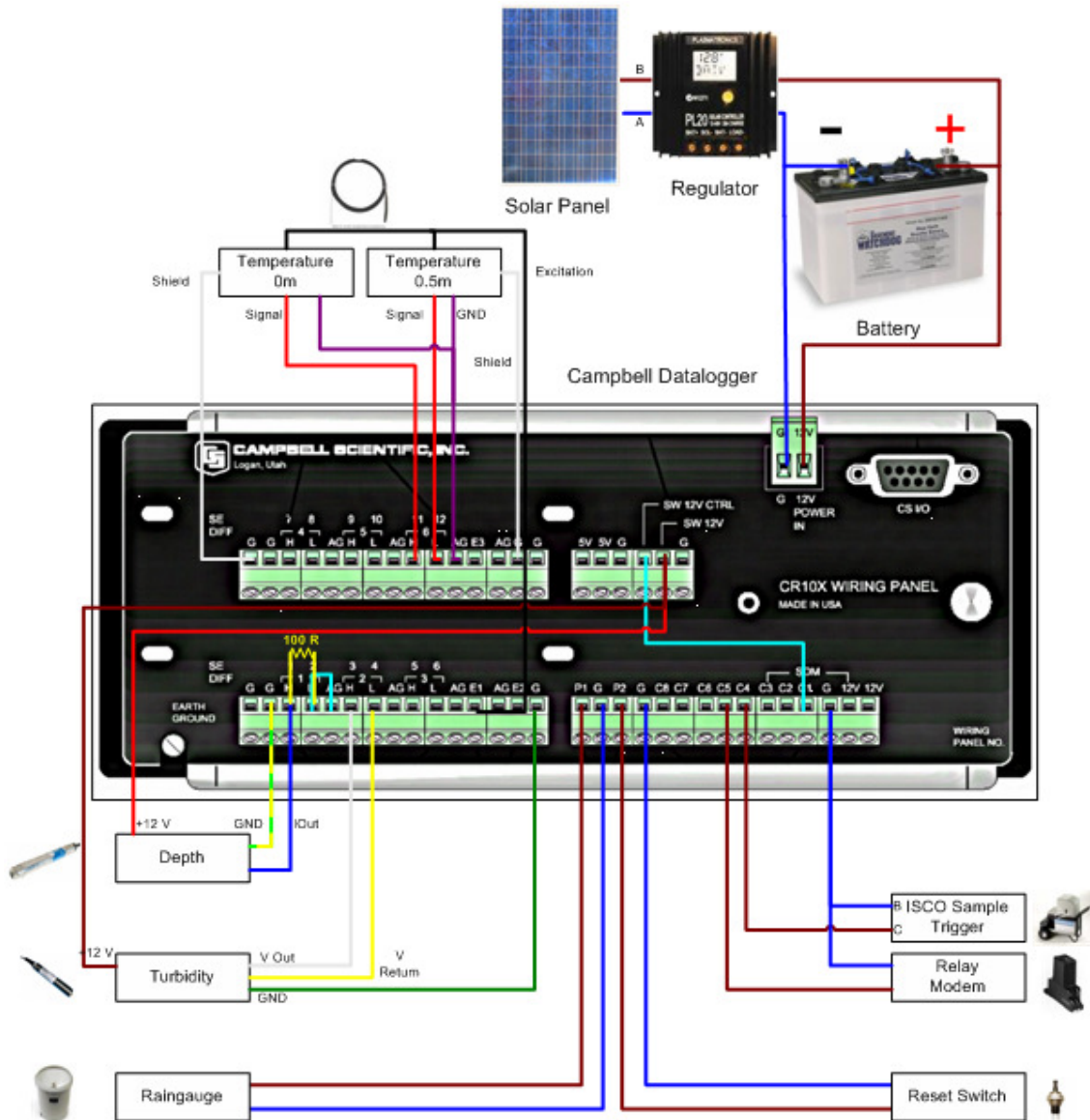
During flood events samples are collected as soon as is practically possible. During inundation access is only possible via boat.

5. Removal of equipment

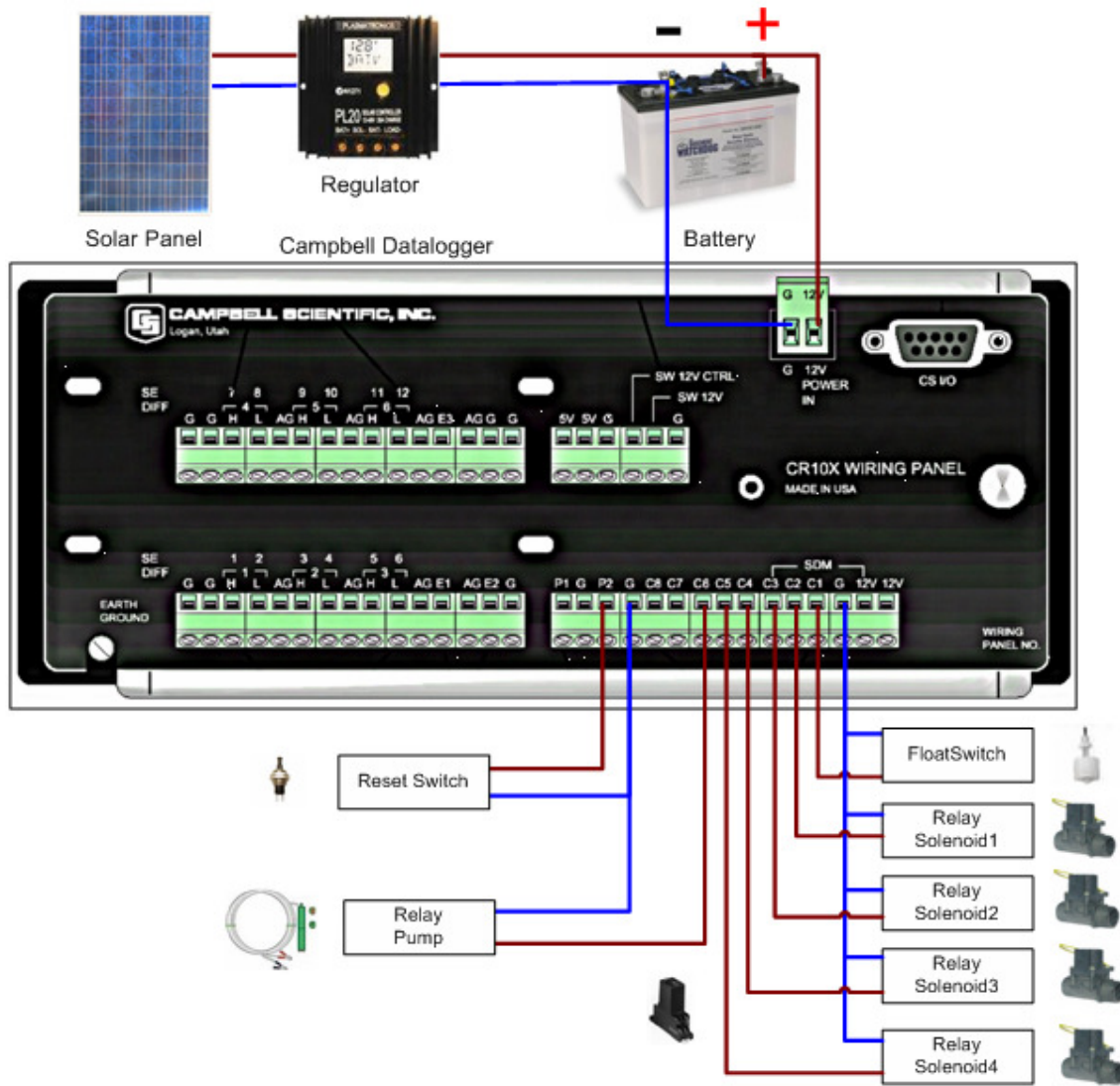
At the conclusion of the monitoring program, all equipment and infrastructure will be removed and each site will be rehabilitated to a condition acceptable to the land holder.

6. Appendix 1 – Wiring Diagrams

6.1. S1 wiring diagram

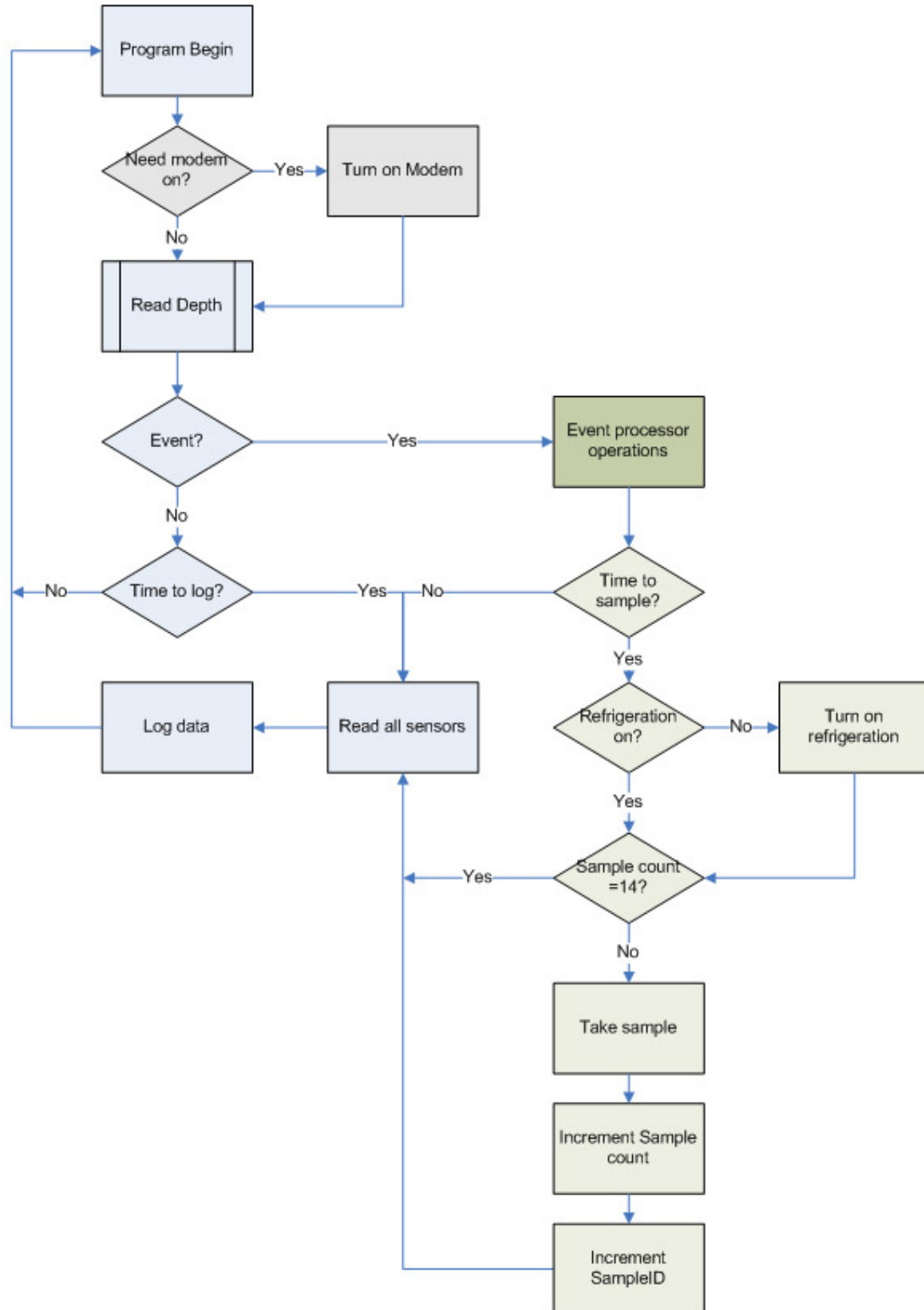


6.2. S2 wiring diagram

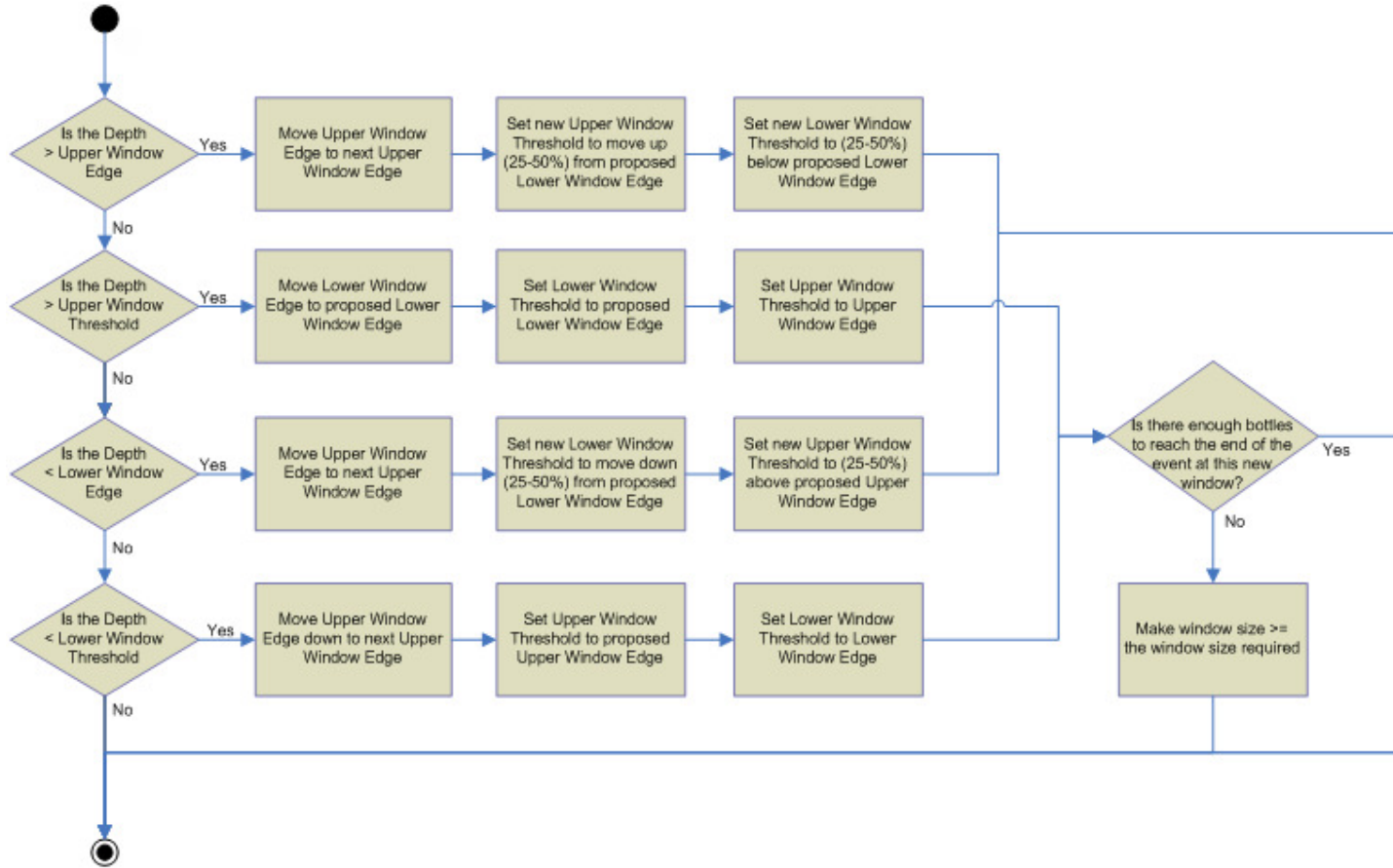


7. Appendix 2 – Program Flowcharts

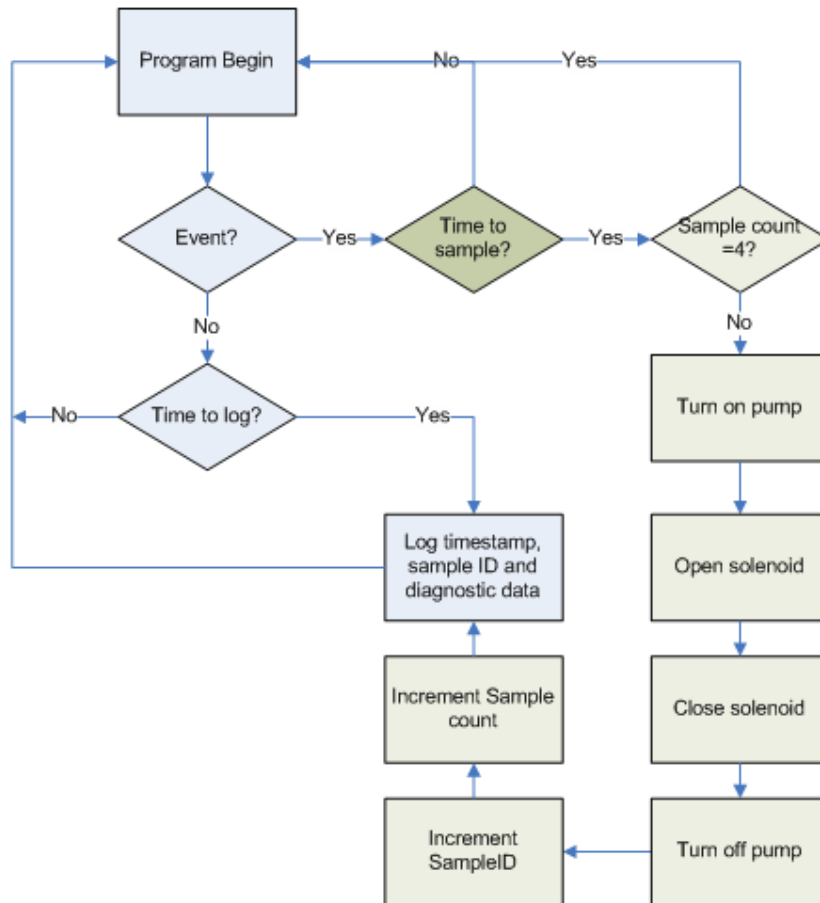
7.1. S1 Program flowchart



7.2. S1 Event processor flowchart



7.3. S2 program flowchart



8. Appendix 3 – Maintenance Schedule

S1

Each visit

Inspect for damage
Replace desiccant
Check function of all equipment

Annual

Replace batteries
Test charging circuits
Test sampler function
Test telemetry system

S2

Each visit

Inspect for damage
Download and check data
Test charging circuits
Replace desiccant

Annual

Replace battery
Test charging circuit
Test sampler function

S3

Each visit

Inspect for damage

9. Further Reading

9.1. Reports

Connel Wagner 2005. Tully-Murray Rivers flood study: Calibration phase report. Department of Main Roads, Department of Natural Resources and Mines and Queensland Rail. 17 May 2005.

Faithful, J., Liessmann, L., Brodie, J., Ledee, E., Sydes, D. and Maughan, M. 2007. Water quality characteristics of water draining different land uses in the Tully/Murray rivers region. Australian Centre for Tropical Freshwater Research, Report No 06/25, February 2007, 46pp.

Wallace, J.S., Hawdon, A., Keen, R. and Stewart, L.S. 2007. Water quality during floods and their contribution to sediment and nutrient fluxes from the Tully-Murray catchments to the GBR lagoon. Report to FNQNRM for their Water Quality Improvement Plan. CSIRO Science Report YY/07; 35pp.

9.2. Technical Literature

Rising Stage Samplers

<http://www.hydroserv.com.au/products/pdf/rss.pdf>

12v submersible pump

http://www.enviroequip.com/sales/12Vbore_pumps.htm#Specifications

Float Switches

<http://docs-asia.electrocomponents.com/webdocs/00b9/0900766b800b98af.pdf>

Relays

<http://docs-asia.electrocomponents.com/webdocs/002b/0900766b8002b88e.pdf>

Solenoids

<http://www.hrproducts.com.au/products/valves/Micro%20Solenoid%20MV75.pdf>

Greenspan ps7000 Depth sensor

http://www.tycoflowcontrol.com.au/TES_Greenspan_Analytical/_data/page/12410/PS700.pdf

Isco Avalanche Auto Sampler

http://www.isco.com/WebProductFiles/Product_Literature/201/Portable_Refrigerated/Avalanche_Sampler_datasheet.pdf

Campbell Scientific 107 Water Temperature sensors

<http://www.campbellsci.com.au/documents/manuals/107.pdf>

Campbell Scientific CR10x Data logger

http://www.campbellsci.com.au/documents/lit/s_cr10x.pdf

Queensland Workplace Health and Safety Regulation 1997

<http://www.legislation.qld.gov.au/LEGISLTN/CURRENT/W/WorkplHSaR97.pdf>