Equipment, Set-up and Water Quality Analyses for Propriety Stormwater Quality Improvement Device (SQID) Field Testing

Taking a new Stormwater Quality Improvement Device (SQID) to market is expensive and a long and drawn out process. For a product that is developed locally (in Australia) one could expect a time line in the order of 5 years by the time it has gained acceptance from some local Authorities. This can be shortened by importing technologies from overseas that have already been extensively and independently tested, but this would still typically take 2 to 3 years after agreements have been made with the technology owners.

There are two main implications of these approaches and timelines.

1. Locally developed technologies: 5 years of research and development comes at significant cost that few organisations in Australia can afford to fund. Now with the additional demands of local field testing, over and above other testing approaches such as laboratory analyses and overseas field testing, means additional financial burdens.
2. Importing overseas technologies: this approach still involves a long timeline, though not as long as the above, but it also incurs additional costs that can be prohibitive to smaller companies. It is usually a requirement in this situation for a supplier of a technology to demand a licence agreement that involves a once off license fee plus ongoing royalties, which is based on a certain percentage of each sale.

In both cases the overall costs are similarly high, which begs the question – why do we do it?

The answer is simple: there is a market for all forms of stormwater treatment devices, whether they are natural or propriety. Sometimes it's not possible or practical to use natural forms of Water Sensitive Urban Design (WSUD), and instead a propriety device/s is a better fit for the project. The designers will choose the best option, often guided by the requirements of the Developer.

There is stiff competition among the suppliers of the various propriety devices currently in the market, but let's not forget that the proponents of the natural forms of WSUD are also often competitors themselves.

Up until recently it was possible to gain Authority acceptance for devices that had been extensively and independently tested by overseas research institutions, however, there has been a significant drive of late for localised testing – even though no protocol or standard method currently exists.

At present this is serving to delay acceptance by local Authorities even further; to the point now where, at worst, some are questioning whether or not they should continue to participate in this market segment, and at best, it is having the effect of limiting competition and stifling innovation. If we are ever going to move beyond the current requirements of 90/80/60/45 pollutant removal rates (GP/TSS/TP/TN), then industry must be allowed to innovate.

In any case it's clear that there is no longer any time to waste discussing what needs to be done, and we need to simply get on with it and develop the protocol. There are many examples around the world from which we can develop a hybrid that suits the local conditions and needs. Let's not re-invent the wheel.

There also needs to be a standard method of testing that can be adopted by all devices that is consistent across the industry. It needs to be robust and technically and scientifically sound, and widely accepted by manufacturers/suppliers of these devices, and well as being accepted by the broader scientific and technical communities.

The following is an approach currently being undertaken for the field testing of a propriety stormwater quality improvement device (SQID) in South East Queensland. It is offered as a basis for a standard approach, which has proven to be robust, transportable and does not require an external power source. The method has been developed such that it can be replicated at any location in any region.

Experimental Equipment List

Table 1 - Equipment list

Qty	Description
2	ISCO 6712 automatic sampler units
2	24 x 1 litre bottles with caps, distributer arm, retaining ring and two discharge tubes
2	1800mm x 800mm x 800mm aluminium enclosures for automatic sampler units
1	Pole mounted 0.2mm tipping bucket rain gauge c/w 3m high pole, rainwater sampling line and sampling container
2	20 watt solar panel
2	100 amp hour non-spillable deep cell battery
2	Solar regulator
1	Campbell Scientific CR800 data logger and control module c/w custom data logger program
1	Cellular modem kit c/w sim card (annual rental)
1	Pressure transducer for measurement of water depth – 0.1% accuracy
1	8” Palmer-Bowlus Flume c/w MJK713 open channel flow meter
1	Miscellaneous – installation hardware, conduit, cable, sampler hose, etc

Experimental Setup and Sampling Procedure

There are two sets of experimental equipment, the first that collects influent water samples from a stormwater pit immediately before the device being tested, and the second located immediately after the device being tested to collect effluent samples. The SQID is located between the two sets of sampling equipment.

It is important when setting up the equipment to ensure that the sampling points are as close to the device as possible, and also that the downstream sampling point cannot be contaminated from any external sources so as to not influence the effluent results. A schematic diagram of the general configuration is shown in Figure 1.

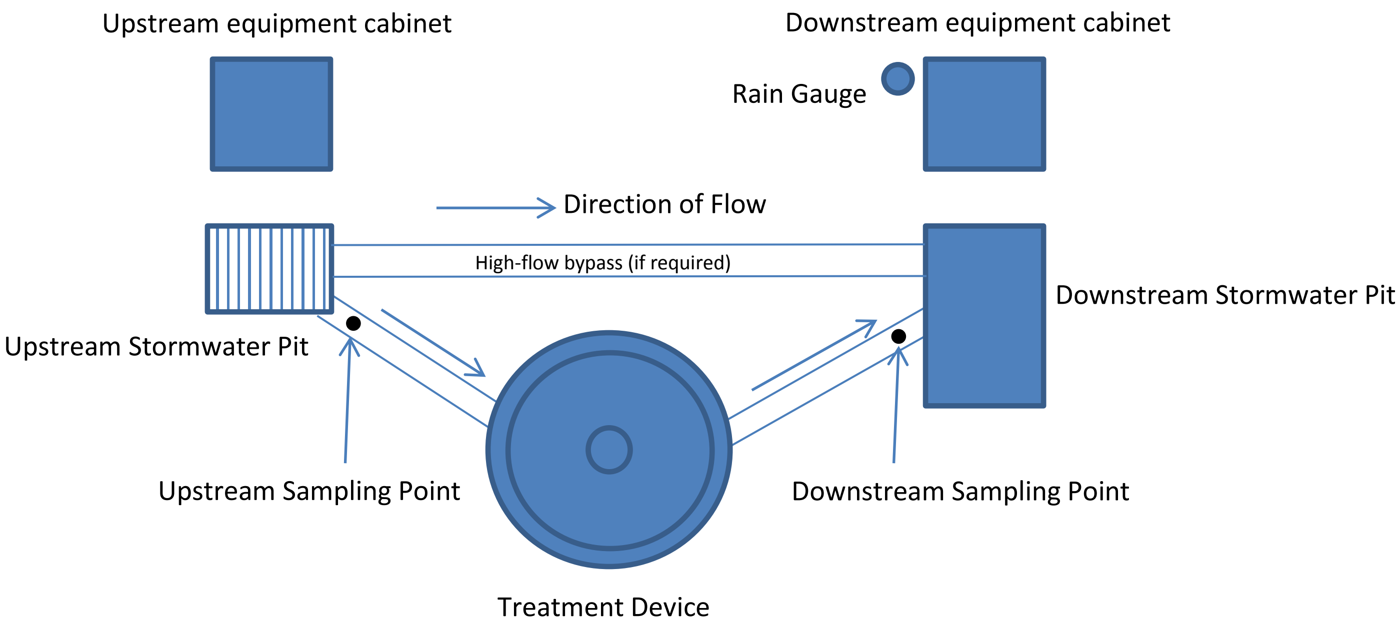

Figure 1: Schematic diagram of the experimental set-up

Below is a more detailed explanation of the cabinet configuration.

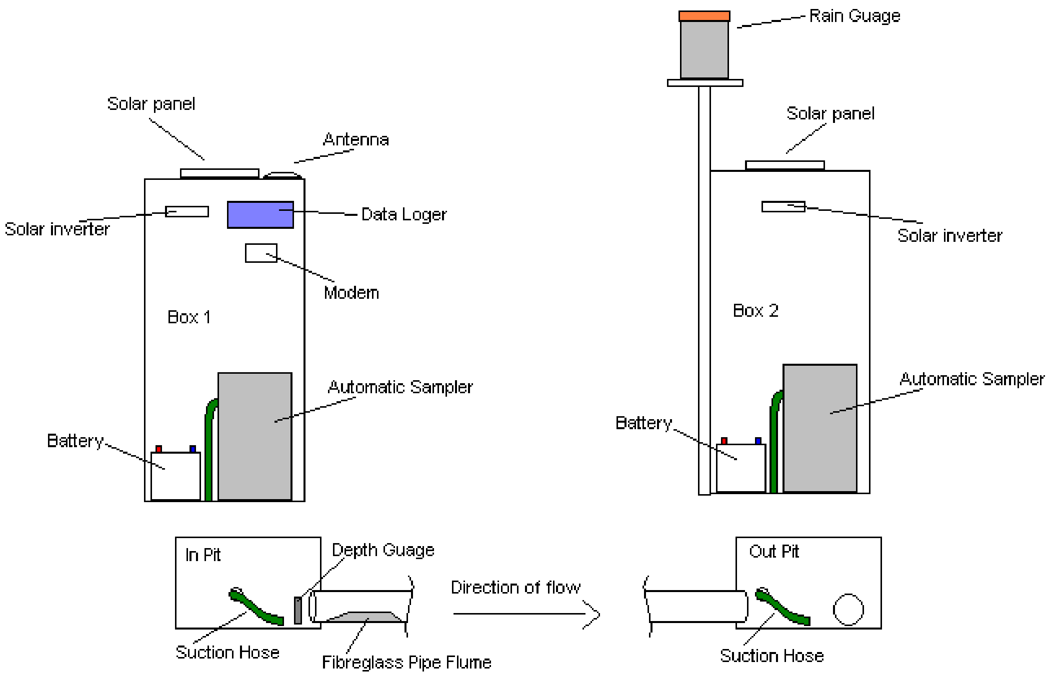

Figure 2: Equipment configuration within the cabinets

The depth of water is measured by a high accuracy Control Logic LMP307 pressure transducer with a range of 0-1 metres. The pressure transducer is mounted to the wall of the pit in a location next to the inlet pipe. The sensor has a 4-20mA output that is read by the datalogger and converted into engineering units. The sensor is mounted just off the base of the pit, 12mm, to prevent any build-up of debris that may cause inaccurate readings.

The water flowrate is measured with an 8” pipe insert Palmer-Bowlus flume in the pipe between the grated pit and the inlet to the treatment device. The flume had the calibration checked over a range of flowrates after being installed.

Figure 2 - Palmer-Bowlus flume

Note: Initially water flow was measured by a 90^{o} v-notch weir mounted over the end of the pipe shown in Figure 3. It was found that the v-notch weir was preventing much of the entrained sediment from entering the pipe and so was not allowing a representative sample of the stormwater influent. Further, and more importantly, there was not enough gradient on the pipe to allow the required drop to prevent drowning out of the weir, which is a requirement of Australian Standard *AS 3778.4.1-1991: Measurement of water flow in open channels - Measurement using flow gauging structures - Thin-plate weirs, Australian Standard.*

Figure 3 - Instrumentation in grated pit, looking downstream

Two ISCO 6712 automatic samplers, Figure 4, one for the influent and one for the effluent are installed in weatherproof security cabinets near to the treatment device (Figure 5). The suction hoses were kept as short as possible and routed in such a manner to prevent kinks, loops and low points to prevent air bubbles and build-up of contaminants. The sample hoses are mounted with the open end facing downstream to prevent debris building up inside of them between sampling events.

Figure 4 - ISCO automatic sampler

Power for each system is provided by a 105 Amp/hr battery with a trickle charge from a 20 Watt solar panel mounted on the roof of each enclosure.

Figure 5 - Sampler enclosures with treatment device in foreground

Rainfall is measured by a RIMCO RIM7499 tipping bucket rain gauge with a resolution of 0.2mm. The rain gauge is mounted on a three metre pole, Figure 6, attached to one of the sampling enclosures to reduce the chance of vandalism and reduced catch due to the proximity of the neighbouring building. Total daily rainfall is checked against a BOM rain gauge situated approximately 600 metres away.

Figure 6 – Rain gauge mounted against cabinet

All sensors are read by a Campbell Scientific CR800 datalogger and control module, Figure 7.

Figure 7 - Datalogger, modem and solar regulator

A Maxon Intellimax modem, Figure 7, provides SMS reporting at the beginning and end of an event.

The datalogger was programmed to measure parameters every ten seconds and output the data to tables within the datalogger every six minutes and increase the frequency of recording to every one minute during an event. The list of parameters recorded is given in Table 2 and Table 3. The water level and subsequent flowrate are recorded as 30 second averages (three readings ten seconds apart) to reduce errors due to wave or ripple action on the surface of the water in the pit.

Table 2 - One minute data recorded during an event

Parameter Recorded	Value Recorded
Rainfall	Current value
Rainfall intensity	Current value
Water level in flume	30 second average
Flowrate	30 second average
Cumulative flow	Current value
Sample number	Current value

Table 3 - Six minute data recorded

Parameter Recorded	Value Recorded
Water level in flume	30 second average
Flowrate	30 second average
Cumulative flow	Current value
Total flow	Current value

When the rain gauge detects a tip of the tipping bucket, the time of that tip is stored to the datalogger. The time, in seconds, between the current tip and previous tip is calculated and used to calculate the rainfall intensity. The rainfall intensity is used to select the wait time between samples according to Table 4.

Table 4 - Wait times between samples

Annual Recurrence Interval of rainfall event	Rainfall Intensity (mm/hr)	Wait between samples (minutes)
One year	0.42< x >=9	12
Two year	9< x >=13	8
Five year	13< x >=16	6
Ten year and greater	x >16	4

At the end of the wait time the automatic sampler is triggered to take a sample. The automatic sampler has a short period of expelling any water that may be sitting in the sampler hose (pre sampling purge) before drawing a sample into a one litre bottle. After the sample has been taken the automatic sampler then purges and rinses the sampler line and waits for the next sample trigger.

This experimental set-up enables the presentation of the data as per Figure 8.

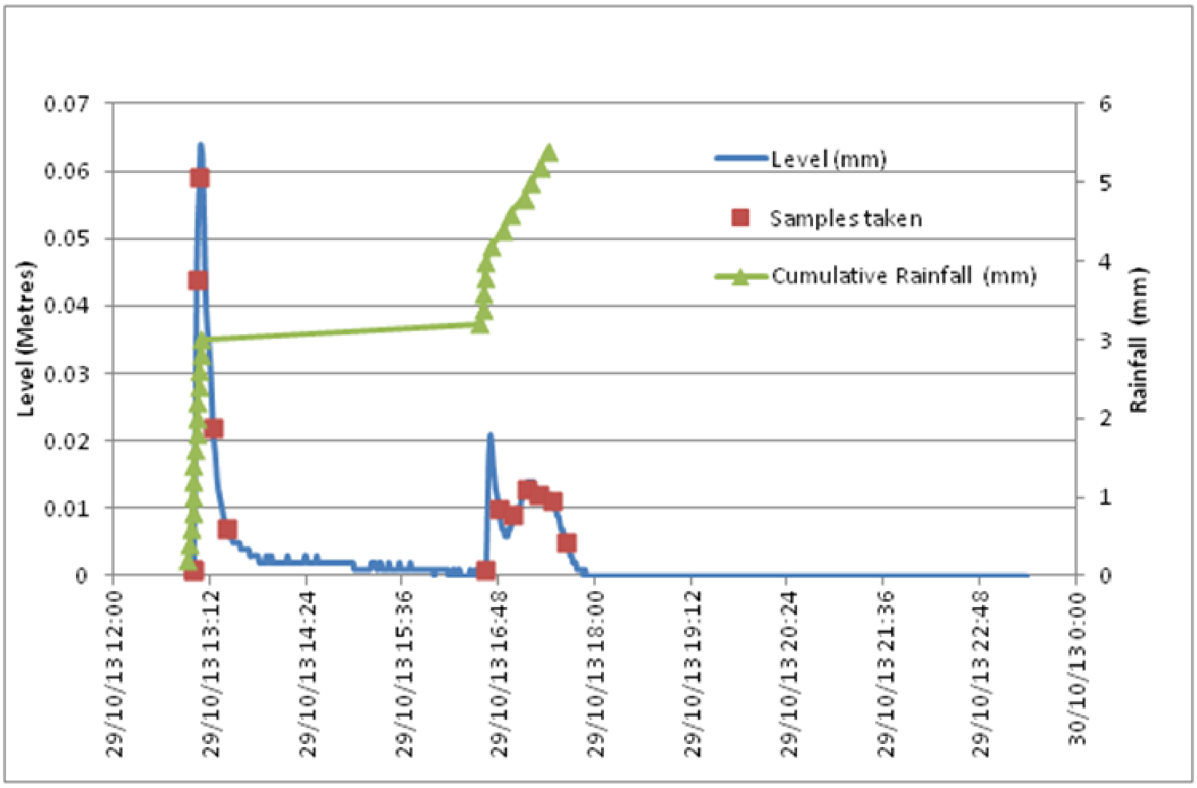

Figure 8 - Event captured on 29/10/13

Figure 9 - Influent samples showing variation

All samples from an event are combined to create composite (Event Mean Concentration – EMC) influent and effluent samples. Subsamples of these composite samples were created using a churn sample splitter (Bel-Art Products) before being submitted for laboratory analysis. Details of what each sample are analysed for is presented in Table 5.

Samples were collected and handled in accordance with AS/NZS 5667.1:1998, *Water quality—Sampling, Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples, Australian/New Zealand Standard.*

Table 5 – List of analyses and methods

Analysis	Method
pH	APHA 4500
Electrical conductivity	APHA 2510B
Total metals – Fe , Al, Mn , Cu, Cr, Pb, Ni, Zn, Cd	USEPA 200.8/3050/6010B by ICPMS
Total nitrogen, NO3, TKN	APHA 4500 by discrete analyser with persulphate digestion
Total phosphorus, FRP (orthophosphate P)	APHA 4500 by discrete analyser with persulphate digestion
Total suspended solids (103°C)	APHA 2540 D
Total organic carbon	APHA 5310 by TOC analyser
Total petroleum hydrocarbon (C10-C40), silica gel	NEPM 2011 (draft)
Particle size distribution	Laser diffraction method using a Malvern Mastersize instrument

It might not be necessary to conduct all of the above analyses of the water samples. The addition of total metals and total petroleum hydrocarbons can add significant costs to the overall study and only needs to be included if the device under investigation specifically targets these pollutants. If these analyses are requested, then total organic carbon (TOC) should also be investigated, as this enhances the bioavailability of these pollutants.

Qualifying Events

For the event to be deemed qualifying and the samples collected to be submitted to the laboratory for analysis, the ***T**echnology **A**cceptance **R**eciprocity Partnership **P**rotocol for Stormwater Best Management Practice Demonstrations* (TARP) was adhered to. In accordance with TARP a qualifying event has to have at least 2.6mm of rainfall with an antecedent dry period of at least six hours between events. If less than six hours has passed, it is deemed to be the same event.

Further, in line with the Proprietary Devices Evaluation Protocol (PDEP) for Stormwater Quality Treatment Devices (Wong, G., Ansen, J., Fassman, E. (2012), a minimum period of three days (72 hours) is recommended between events to allow the site to fully dry. **Note:** a rainfall event with a depth greater than 0.4mm resets the start of the 72 hour drying period, as less than 0.4mm of rainfall will not produce run-off.

If the event is non-qualifying (greater than 0.4mm but less than 2.6mm of rainfall and within 72 hours) the sample bottles are emptied, rinsed and replaced and the samplers reset ready for the next event.

Wong *et al.* also stipulate that a minimum of 15 qualifying events must be collected to achieve a satisfactory level of statistical significance between paired samples (influent Event Mean

Concentration (EMC) and effluent EMC) of 90%. If the level of statistical significance is not achieved within 15 events, more events must be sampled until the 90% statistical significance is achieved.

Data Analyses

As a minimum the analysis of the data should include:

- Parameter values for the influent and effluent samples are analysed to assess the percentage removal values and compliance with local authority requirements.
- It is advisable that a detailed statistical analysis is undertaken rather than just a simplistic comparison of before and after treatment values.
- The statistical analysis should potentially include an uncertainty assessment of measured parameters values due to inherent variability of stormwater quality.

Independence and Acknowledgement

As much as possible all of the above should to be conducted by individuals or groups that are independent of the device being evaluated. Under no circumstances should an individual or group involved in the handling and manipulation of the raw data have any commercial or financial interest, directly or indirectly, with the device being evaluated.

The field research discussed above is being conducted under the guidance of Professor Ashantha Goonetilleke of Queensland University of Technology as a completely independent research study, and the experimental equipment design and set-up is by Grant Millar of Environmental Monitoring Solutions (Qld).

References

AS/NZS 5667.1:1998, Water quality—Sampling, Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples, Australian/New Zealand Standard.

AS 3778.4.1-1991, Measurement of water flow in open channels - Measurement using flow gauging structures - Thin-plate weirs, Australian Standard.

Technology Acceptance Reciprocity Partnership (TARP), The TARP Protocol for Stormwater Best Management Practice Demonstrations, *http://www.state.nj.us/dep/stormwater/docs/tarp_stormwater_protocol.pdf* (2003).

Wong, G., Ansen, J., Fassman, E. (2012), GD03 Proprietary Devices Evaluation Protocol (PDEP) for Stormwater Quality Treatment Devices. Prepared by Auckland Regional Council, New Zealand.