AUSTRALIAN HYDROGRAPHERS ASSOCIATION

Australasian Hydrographer

Is our Gender Mix Right?
Photo. ©R. M. Clavton

February 2003

Australasian Hydrographer is the Journal of the **Australian Hydrographers' Association Incorporated**. **ISSN 0812-5090**

THIS ISSUE

EDITORIAL

Welcome to the February, 2003 edition of our quarterly newsletter.

This year is the International Year of Freshwater (IYF)- did any one notice through the haze of bushfire smoke and drought dust being blown from off the land? The IYF was proclaimed by the United Nations General Assembly in resolution 55/1196 after being put up by Tajikistan - interestingly it wasn't a developed western nation that seemed to put it up.

Our New Zealand cousins are getting involved in some activities in their part of the world (check out their website). In our part of the world activities are generally being coordinated through local community groups and government departments. Are any of our members involved in these activities – let everyone else know what you are up to through the newsletter/journal or via the web site (www.aha.net.au)

This issue sees a couple more papers are presented in this Journal from the conference. Glenn McDermott's paper is challenging not only to us but to those who take our data further in modelling scenarios. Often we are questioned as to how accurately we are measuring real things because our data doesn't agree with the model! Looking at our data objectively and quantifying its limitations will give us the authority to turn back to the modellers and ask them what their uncertainties are!

Doug McMillan's article shows how the responsibilities and functions of hydrographic work have evolved over the last 50 years. At the time of going to print it was understood that while OTEN has offered enrolments in the Hydrography Certificate IV the final subjects being developed for industry requirements are still not finalised. Let us hope that final teething problems can be sorted out so that we retain a suitably recognised training accreditation for future hydrographers as well as those of us who seek to bring our knowledge and skills up to date.

Contributions are certainly welcome for future issues - everyone's an expert out there aren't they? I would also like to see someone volunteering for 20 Questions - its not really that scary!

Mic Clayton

The **Australasian Hydrographer** is the Journal of the **Australian Hydrographers' Association Incorporated**. The Journal is distributed quarterly to Members. **ISSN 0812-5090**

Visit our **Web Site** at: **http://www.aha.net.au** to download a Membership application and to find contact details for your state representative.

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Australian Hydrographers Association, who are we.

The following article was presented to the world in the last edition of *WATER* to introduce our Association to other professional bodies who are members of the Australian Water Association.

'You're what? A hydrographer? That's got something to do with water doesn't it ?'

How many times has a hydrographer heard that line? Hydrographers have been described in the past a surveyor who can swim. Needless to say hydrographers in this country have had an identity crisis.

So what do they do? Hydrographers measure, describe and map the earth's surface waters and related meteorological areas (surface waters include oceans, seas, rivers, lakes, estuaries and the water in channels and pipes). They are also involved in collecting and analysing information on surface and sub-surface flow and quality. The information obtained by hydrographers is used to design dams, weirs, bridges, irrigation projects, water supply schemes, sewerage systems, flood protection works, warning services and marine facilities. The information is also used to compile navigational charts and other data for the safe navigation. Hydrographers may perform the following tasks: select, install, calibrate, maintain and repair instruments which monitor water levels, rainfall, sediments and water quality; design, construct, install and maintain civil works associated with hydrographic activities; collect sample data at various locations to confirm data gathered by automatic monitors; use underwater acoustic equipment to establish and monitor tidal data; outline coastlines; measure seabed, lakebed and reservoir depths and siltation; search for underwater obstacles in oceans or lakes; site reports and surveys; prepare data for use by other professionals and archive and qualify collected data. Hydrographers work a large percentage of their time in offices and in their field expeditions can find them on foot, horseback, underground, on ships, in four-wheel-drives, in boats, planes or helicopters.

Hydrographers fall into two basic categories, "Oceanic" and "Terrestrial".

One of the most famous oceanographic hydrographers that Australians might be familiar with is Captain James Cook.

On the discovery of land or islands, he was directed the following. "Explore as great an extent of it as you can, carefully observing the true situation thereof both in latitude and longitude, the variation of the needle, bearings of headlands, height, direction and course of the tides and currents, depths and soundings of the sea, shoals, rocks etc. Also surveying and making charts and taking views of such bays, harbours and different parts of the coast, and making such notations thereon as may be useful either to navigation or commerce". Cook was well provided with some of the best instruments available for astronomical observation and surveying. Apart from the usual instruments (quadrants, sextants and compasses) a theodolite, survey chains and a plane table were included, indicating that Cook was equipped for trigonometrical surveys.

Terrestrial hydrographers or hydrometric hydrographers don't feature as prominently in the Australian psyche. However in the driest inhabited continent the hydrometric hydrographer should feature more and more in the minds of think tanks, policy makers and politicians in this country. The input they can have to the debates on how to manage Australia's water resources cannot be understated. For anyone to make any suggestions on how to best manage the rivers, the water table, salinity, algae blooms, evaporation or even water recycling they need information and that information comes from hydrographers.

The Australian Hydrographers Association was established in 1979 to encourage the development of all aspects of hydrometric data collection, processing, analysis and presentation. It contributes to the knowledge of, and to encourage interest in the management and utilisation Australia's water resources. It provides a forum for the interchange of knowledge and ideas and to represent the interests of all Australian hydrographers and support staff. The association is open to anyone interested in Australia's and indeed the world's water resources issues.

Water resources issues are surely destined to weigh more and more on the minds of Australians as predictions indicate droughts in this country can be expected to arrive more frequently and last longer. The Australian Hydrographers Association has recently developed a diploma course through the NSW distance learning network to ensure that the hydrographers of tomorrow are trained to highest of industry standards. The Australian Hydrographers Association also coordinates and encourages ongoing training, workshops and forums within the industry so that hydrographers can meet the challenge of providing crucial accurate data for the schemes that lie ahead to manage Australia's most precious natural resource: Water.

Letters to the Editor

BTG Polymetron clarification.

Andrew Pearce mentioned in his article (Dec02/Jan03 Newsletter) that the BTG Polymetron tested operated to within a 10% accuracy of its range. Just to clarify this it was pointed out that in the my original presentation that the unit tested was calibrated as a 0-250 NTU range but when it was found that the dam would exceed this range it was rescaled to 500 NTU. In the paper it was stated that this was an inappropriate procedure for setting up this instrument and coupled with the fact that the unit was quite elderly in comparison to the other units being tested this would have contributed to the errors encountered. In the field situation the BTG's have proven to have better accuracy than that encountered in the test and have generally been a delight to work with given the versatility of the sensor/transmitter combination. Unfortunately they came with a much higher price tag so continued use was being constrained by ever shrinking budgets!

Mic Clayton

28th International Hydrology and Water Resources Symposium

Monday 10 to Thursday 13 November 2003
Novotel Northbeach
Wollongong NSW Australia

Why You Should Be There
The Hydrology and Water Resources Symposium brings together a diverse range of academics, researchers and practicing scientists and engineers from both the public and private sectors. The fundamental objective of the Symposium is to provide a forum for the exchange of ideas and experiences and discussion of issues relating to the broad field encompassing hydrology and water resource management.

Go To http://www.hwrs2003.org.au/ for more information.

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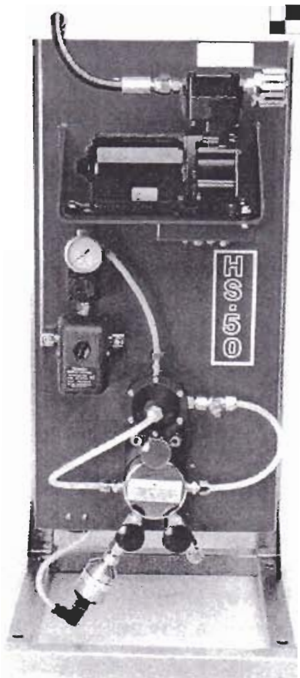

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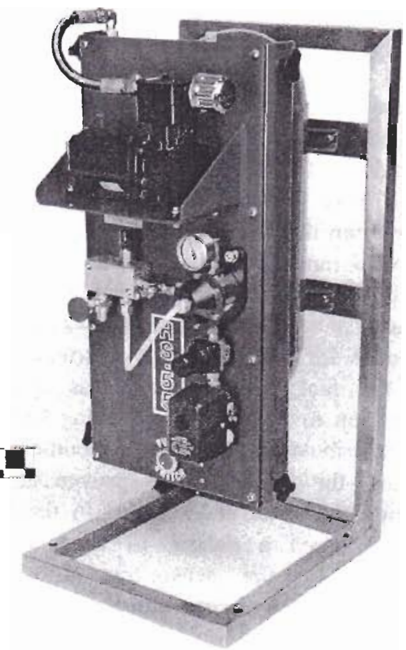
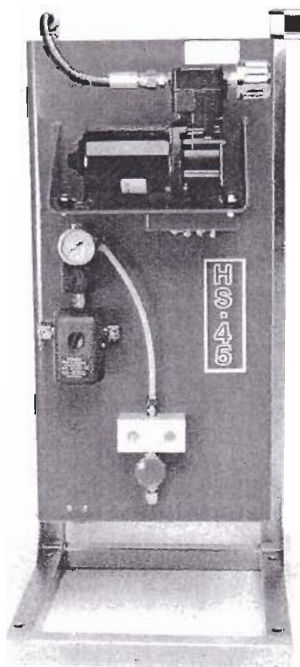


HS-55 COMPRESSOR



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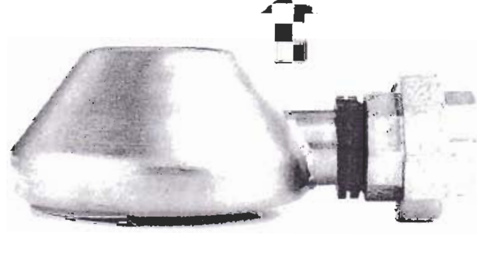


Gas Chamber Orifice

EVOLUTION OF THE FIELD HYDROLOGIST

A lot of hydrological agencies in New Zealand and Australia are advertising for experienced hydrologists, and there seems to be a shortage of this breed of person on both sides of the Tasman.

The following article was published in the 1955 N Z Hydrology Annual:

HYDROLOGICAL SURVEYS - THE CHOICE OF PERSONNEL

by B. J. Speight, Officer-in-Charge, South Island Hydraulic Survey Party, Blenheim. December 1953.

Hydrological surveys with properly trained staff and complete modern equipment are new to New Zealand. The peculiarities of the work are frequently not appreciated, and it is desirable that some publicity be given to the ways in which hydrological surveys differ from ordinary engineering surveys and to the special requirements in the choice of personnel for this work.

Personnel engaged on discharge measurements should have a long and wide experience in their work as it is only by long experience that the observer discovers the numerous pitfalls, how to avoid some of them, and how and when to assess the allowances that should be made for others. Generally, the longer the observer has been engaged in this work the more skeptical he becomes and the more forcibly he appreciates his own shortcomings.

Since the days of Galileo it has been known that measurements of the flow of fluids are amongst the most difficult to carry out, and it is in most cases impossible to obtain standards of accuracy comparable with such precise operations as ordinary land and engineering surveying. The measurement of lengths and angles on the earth's surface can be made with an accuracy such that errors of ordinary work need not exceed 0.01% and, when refinements are used, accuracies better than 0.001% can readily be obtained. Moreover, ordinary survey work conforms to theoretical laws which allow absolute proof of the accuracy of the work done to be established to fine limits.

The measurement of the flow of water, however, is subject to laws having empirical formulae and in general there is no known way of easily checking on the accuracy of the work. Further, the number of variables is great, and inaccuracies in the measurement of any or all of them affect results to an extent that is difficult to establish.

Field measurements of the flow of water are estimated to be reliable within 2% under very good conditions of observation only, and it is known that what may be thought by the inexperienced observer to be very accurately made measurements of discharge, may be in error up to 25%. The only method of checking is that of comparing a measured discharge with other measured discharges made of the same flow of water by as many check methods as can be applied.

Current meters cannot easily be checked for the accuracy of their performance, which varies with the state of their bearings and alterations to the shape of the surfaces acted on by the flowing water. Also, the state of the water - temperature, turbulence, and suspended sediments - all disturb measurements to an extent practically unknown at present.

These considerations demand that personnel for hydraulic surveys should be trained in sound scientific method and should have a good background knowledge of the fundamentals of physics and mechanics and be able to apply such knowledge to the job in hand. They must be honest, keen observers who do not jump to conclusions or allow themselves to be tempted to adjust observed data to conform to opinions held without sufficient knowledge of the facts.

Keen, sustained interest in work is essential as the subject is one about which more is to be learned than is at present known, and an observer who takes his work seriously will be constantly expanding his knowledge and handing that knowledge on to others. As Lord Kelvin put it 'nearly all the greatest discoveries of science have been but the reward of accurate measurements and patient, long-continued labour in the minute sifting of numerical results."

Observers should have considerable mechanical aptitude and must be able to diagnose and rectify obscure mechanical and electrical faults.

At least elementary inventive ability is necessary in order that improvised equipment may be constructed to meet the needs of unusual circumstances in the field.

Unless personnel taking on hydrological duties are prepared to stay at it for many years they should not enter the field, firstly in their own interests as seldom is the saying "a little knowledge is a dangerous thing' so true as it is in this occupation, and secondly much of the knowledge that is acquired cannot be left behind to a successor. Also, it takes a very long time to become thoroughly familiar with the vagaries of gauging sites and the peculiar characteristics of individual rivers and streams.

The duties of hydrologists require them to possess considerable knowledge other than that required for stream discharge measurements. They must be capable of carrying out necessary engineering surveys for site plans and they must have a working knowledge of meteorology in order that they may correlate their discharge measurements to the meteorological data.

It is desirable that they should take an interest in geology and the fauna and flora of the country so that they may intelligently relate these factors to the characteristics of the rivers. The work involves some hardships such as spending considerable periods away from home and sometimes working in the very worst weather conditions, perhaps in very remote localities, and at any time of the day or night.

As field parties have not merely to work together, but have also to live together for considerable periods, it is essential that the members of a party should be congenial to each other and should not possess traits which would engender discord.

In conclusion, the work has so much of interest pertaining to it, and presents so many problems to which the answers are unknown that it should attract young men who desire to do work which will be of the greatest value to engineers and others requiring reliable hydrologic data in the years to come.

The Hydrologist : 50 years on

The article written by "Daddy' Speight (as he was known) indicated that our work in those days was pioneering work with engineering applications to the fore. It was the job that us 'older-hands' joined in the days of Barry Crump and the outback-man appeal to the job was to our liking. You needed a penny, a threepence, and a ten bob note in your pocket in those days. The penny to unscrew the Columbus weight, the three pence for the Watts meter connector and the ten bob note for the bar on the way home. Hell we carry the corporate visa for all three nowadays.

Times have changed and the five qualities identified in the 1953 article to be a successful member of a hydrological survey team:

1 the ability to become a skeptical, experienced observer with surveying and meteorological knowledge;

2 be trained in sound scientific methods, being honest with observations and take an interest in geology, fauna and flora;

3 have considerable mechanical aptitude;

4 have a keen (Good Keen Man !), sustained interest in the job and be congenial to your workmates, and;

5 be prepared to stay away from home for long periods of time, and stay in the job for many years (a worthy career);

are still required.

However, fifty years on and the job has become more sophisticated with high-tech equipment, changes in the roles of hydrological agencies due to the Resource Management Act, and accountability require some different abilities to maintain what was once a fairly breezy job with few responsibilities. Lets mention some of the extra skills now required to manage an environmental monitoring team, and the multi-talented animal it has created to take hydrology into the 21st Century.

The additional skills and new areas of knowledge that the Hydrologist now needs, are:

1 **Computer technology**, has changed the job substantially, with the ability to 'number crunch' at great speed. Data entry is no-longer a lengthy manual chore, and daily-mean-discharges are calculated and spat out with ease. We have also learnt a new language, and converse in computer lingo, 'macro, baud rates etc'. (not like the old pub chatter at all). We have also become slaves to the word-processor and also need the knowledge to diagnose computer faults.

2 **Electronics**, has transformed our easy clock-work and electro-magnet recorders (that could be repaired in the field with a screw-driver, 4 inch Crescent and a 5lb. hammer), into sophisticated loggers that you need a licenses to drive, with few moving parts to "stuff-up". An ability to use a test-meter is now a must.

3 **Radio technology**, has brought real-time data into the office. Luckily the question of air-waves ownership was cleared up before this new technology was affected. Again new skills and a different language was learnt as we went, with phases like "comms, back-to-back repeaters etc." becoming common pub talk. This is not to mention the "yuppie phone" that are increasingly polluting our vehicles, which can now interrupt the snooze between sites.

4 **Accounting**, is now a subject that is essential, with budgets, quotes, spread-sheets and financial reports giving team managers ulcers as a health hazard for the job, rather than the drinkers elbow we suffered from in the past. There are several staff members who left jobs with trading banks and the like to get away from this boring career path, only to find they have to interpret monthly income and expenditure accounts as part of today's job. Billable hours have also taught us how to do an 80 hour week in 37.5 hours, just to keep the books straight.

5 **Quality assurance,** has also brought it's own language with TQM and ISO 9001:2000 Standard becoming part of our day-to-day requirements. The advantages of this endeavor and third-party registration are becoming apparent, with a 'Do it once - Do it right" philosophy being inbreed to our work. The agencies most successful with QA are the ones that have found the appropriate venue for the "Quality Circle meetings, over a beer on Friday afternoon!

6 **Hazard** identification, is one of the new skills required, with the introduction of the Occupational Health and Safety Act and Risk Analysis. We will be scared to take on the "Good Keen Man" attitudes of past, or face the consequences. Water is a hazard, fatal if you drown, near fatal if you contract giardia, non-fatal if you catch a cold, and enjoyable if you swim. Just think of all the other hazards, driving 4X4 on motorways, getting down sewers, facing your annual personal assessment just to name a few.

7 **Marketing**, skills have become important for our very survival. Trips overseas to sell our expertise are becoming the norm, and the three piece suit has replaced the gummies and swannie appearance of the field hydrologist. Going from data collectors to information providers has required an increase in technical skills and change in personal character.

8 **Qualifications**, for the job have changed dramatically, with a lot of the 'old-hands' being welcomed into the science with a good pass in school certificate maths (some with less I believe). This is reflected in the 1953 article, where the guy (not many ladies in the job in those days) had to be down-to-earth and practical, where nowadays a degree seems to be required (even though it could be in any subject) to enter the industry. On-going study towards certificates in management, quality assurance, home-brewing etc. are encouraged to meet the challenges of the future.

9 **Psychology**, is the final skill required now to be a "Good Keen Manager". This is to ensure the "best" is achieved by the staff, without them knowing it, and to convince Top Management the Annual Plan is being achieved. Reverse

psychology is another art in itself, mastered by some but used by a few.

So the field hydrologist of 1953 (the average outdoor chap), has become a technologically orientated fella, or fellese with an ability to learn new skills outside the science of hydrology to achieve today's requirements.

I guess the "old-hands" have always enjoyed this career as it has been an on-going experience of facing new challenges every day, and the skills required to achieve them. Some changes we have not liked, and others have created that adrenalin buzz we need to face life, and to make going to work each day worthwhile.

I believe we are all born hydrologist's, as water is essential for life to continue, and a flooded river has always been a fascination to everyone.

No matter how sophisticated the equipment gets, and the skills required for the job, the field hydrologist will always rise to the challenge. The five original requirements will always stand, but the best part of this job is the friendships we make, and the family we have created that will outlast technology changes.

Who else can stand in a river looking at beautiful scenery, listening to the birds (and sand-flies) singing and call it 'their office' – THE HYDROLOGIST. Bugger of a life isn't it ?

Doug McMillan

EQS, Christchurch

NEW ZEALAND

Use it or Lose it

A New Zealand Hydrological Society workshop promoting innovative use of Environmental Data

Unlock those archives. How can the data we collect best be displayed, disseminated and utilised? Operational or 'field" hydrologists have recognised skills in collecting and storing information, but how good are we at passing that information on? This is an opportunity to learn how others are approaching this challenge, and pass on advances you have made.

Presentations are equally welcomed on wider Environmental Monitoring issues, such as the growing requirement to collect water quality information with river and groundwater flows, or even traditional topics such a rainfall measurement.

The workshop will be held in Whangarei on Wednesday 12 March 2002. It is expected the cost will be $80, to be confirmed. You do not have to be a member of the New Zealand Hydrological Society to attend.

Expressions of interest and enquiries should be directed to:

Martin Doyle
Tasman District Council
Phone (03) 544 3414
Email martin.doyle@tdc.govt.nz

Techno Head

As often happens in the hydrographic world a weekend or holiday period had just passed and as a result Techno Head walked into the local cop shop to report theft and vandalism from one of his gauging stations.

As usual solar panels and batteries had been taken with substantial damage to the shelter as well.

The weary Constable Plod went through the usual rigmarole and paperwork in a tired sort of way such as to what was taken, how much was it worth, is there any other use for it and so on. He was probably getting sick and tired of taking gauging station theft and vandalism reports and that the stolen items were probably ending up on peoples holiday houses in the bush.

Then came the question of 'When did you last see the items that were stolen or damaged?' Normally an answer would be that it was at the last routine visit, often many weeks if not months before the damage or theft is actually discovered but Technohead replied, "I last saw the equipment on November 11 but the solar panel was most likely stolen sometime between 6 pm on December 9 and 6 am on December 10. The damage to the shelter and batteries stolen was between 11 pm and 1130 pm on December 27."

Plod stopped writing. "Are you having a lend of me?" he asked.

"No sir" came the confident reply, "The onsite monitoring equipment wasn't stolen and the data retrieved from it shows when things happened. Our system monitors battery voltages as well to monitor system performance and the logger also has internal battery backup which kept the data logger operational even though external power was removed"

Technohead whipped out some data plots and showed the Plod the battery data.. "See here are the daily variations normally associated wiith solar panel charging. On December 10 the trace changes, becoming more flat line, indicating that the panels were most likely removed then. Then on December 27 the voltage drops to the backup battery voltage and all the water quality sensors dropped out as well. The sensors were on the external supply and removal of the batteries would have caused this drop out".

"Thats pretty impressive" Plod replied slowly. "What else can those data trace things tell you?"

Whipping out some more plots Techno Head continued. "Well this one shows when illegal water extraction was occurring, of course lets not confuse that with the diurnal variations caused by the water uptake of the plants in swamps or during periods of low flows."

"Now see this one here - well it shows when someone dumped some dairy effluent into a stream in the middle of the night - bit suspicious don't you think. Then there's this trace showing someone building a temporary dam in a stream without permission from the authorities, but again don't confuse that with the local yobboes building some rock pools on your control to keep the stubbies cool while having a swim near the gauging station, then there's these............."

Somehow Constable Plod wished he'd never asked.

Establishment of Performance Monitoring of a Rural Constructed Wetland on the South Coast of Western Australia

Andrew Maughan
Water and Rivers Commission
(Paper presented at the 11th Australian Hydrographic Conference, July 2002)

Abstract
Performance monitoring of artificial wetlands constructed for contaminant removal from urban stormwater and agricultural runoff has not been comprehensively undertaken, particularly in Western Australia. Evaluation information from constructed wetlands in a variety of settings is required to allow informed decisions to be made on the effectiveness of their design and operating principles.

A performance monitoring program has been established at a rural constructed wetland receiving runoff from 150 ha of beef grazing land between Albany and Denmark on the south coast of Western Australia. The performance monitoring program aims to scientifically determine how effectively the wetland retains the contaminants it is designed to treat, whether design modifications may be required and to assist informed decisions on whether constructed wetlands are an appropriate strategy to treat rural runoff in this area. In addition, the program will enable development of a cost-effective long-term monitoring program for the wetland and generic monitoring programs based on manual grab sampling suitable for other constructed wetlands.

The overall wetland monitoring program has several components and this paper will concentrate on detailing the inflow, outflow and storm-event-bypass nutrient and sediment flux monitoring. This data will allow determination of the wetland's Contaminant Removal Efficiency (CRE).

Flow rates are measured using either calibrated weirs or an acoustic Doppler depth-velocity logger. Water quality variations are determined by a combination of grab sampling, flow stratified autosampling and continuous turbidity sensing.

Introduction to the Wetland

An artificial wetland was constructed with the aim of reducing the sediment and nutrient contribution of an area of artificially drained low-lying grazing land in the catchment of the Torbay Inlet. Torbay Inlet is a seasonally open estuary which suffers from sedimentation and algal blooms. The estuary and adjacent waterbodies have recreational and commercial values that the community and the Water and Rivers Commission are working to protect.

The Water and Rivers Commission initially proposed the wetland as one of nine sites demonstrating best practice for urban and rural drainage management in the area. The Marshalls Wetland project was jointly managed by the landholders Phillip and Sheelagh Marshall, the Torbay Catchment Group, Water and Rivers Commission and the Water Corporation. Funding was provided through the National Heritage Trust's Coast and Clean Seas program, which is administered by Environment Australia. The wetland was designed by Wood and Grieve Engineers with reference to a Water and Rivers Commission guidance manual (Water and Rivers Commission, 1998).

The wetland receives runoff from 150ha of grazing land used principally for beef production. The area has a Mediterranean-type climate with cool, wet winters and relatively warm dry summers. Annual average rainfall is 930mm with most rainfall occurring with the passage of cold fronts associated with low pressure systems between May and October. Annual pan evaporation is approximately 1200 mm and is less than rainfall for four to five months of the year. The catchment has shallow gleyed duplex soils is underlain by granitoid gneiss (Smith, 1997, Churchwood *et al*, 1988). The drainage in the catchment has been enhanced with a network of shallow feeder drains. The catchment has a relatively shallow water table which contributes to the main creek flowing for approximately ten to eleven months of the year.

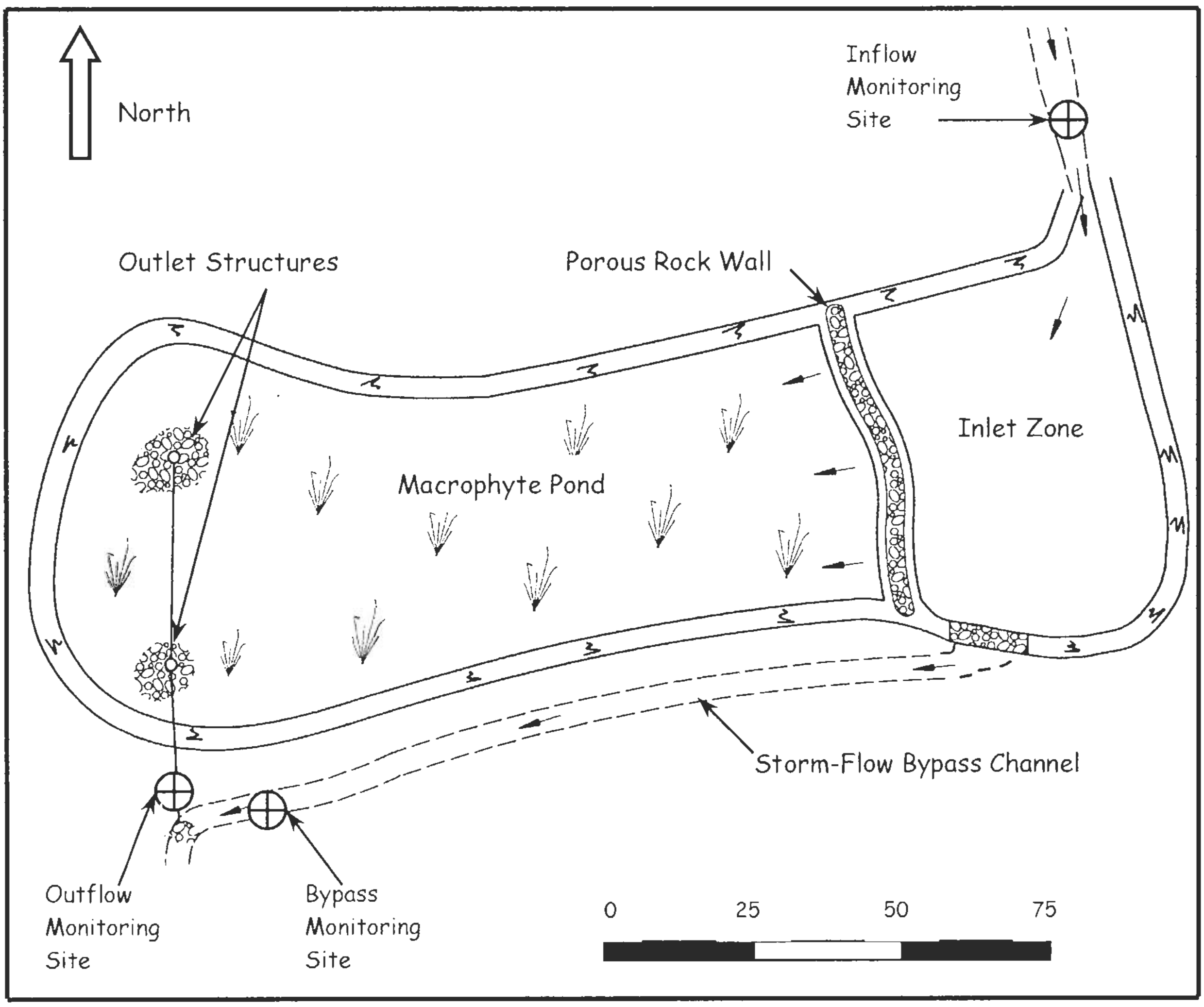
The wetland covers an area of approximately 1 ha and consists of five main features:

- A relatively deep inlet zone/sediment deposition pond of 2500 m^2 which allows inflow to attain sufficiently low velocity and turbulence for larger sediment particles to drop out of suspension.
- A macrophyte pond of 7000 m^2 which has been densely planted with 17000 individual plants of six species of sedges and rushes

native to the area. These plants improve the effectiveness of the pond, further reducing flow velocity and turbulence to allow deposition and entrapment of finer sediment particles and the nutrient compounds adsorbed to them. The rapid growth of these plants will use nutrients in the sediment store and the bacterial bio-film on the plant stems provides a large surface area for further entrapment and biological transformation. The dense planting of vegetation also reduces the re-suspension of deposited sediment from wind action which often occurs in shallow, unsheltered wetlands.

- A porous laterite rock wall which separates the two ponds and ensures even flow into the macrophyte pond.
- Two perforated riser outlets at the macrophyte pond which are designed to allow optimum retention of storm runoff within the wetland while still allowing sufficient release to provide storage and treatment for subsequent storm events.
- A storm-flow bypass channel which operates from the inflow pond to divert water around the macrophyte pond once it is has reached capacity to protect vegetation and prevent re-suspension of sediment.

The combination of pond size, outlet structures and the bypass channel determines the wetland's hydrological effectiveness. This wetland is designed to retain and treat 60% of annual catchment yield for 24 hours.



Representative sketch of Marshalls Constructed Wetland (from Wood & Grieve Engineers)

The Requirement and Opportunity for an Evaluation Program

The Cooperative Research Centre for Catchment Hydrology, based at Monash University have evaluated monitoring data from 76 constructed wetlands from Australia and overseas (Wong, *et al*,1999). Of this large number of data sets only approximately 20% had a sufficiently rigorous and comprehensive approach to data collection to meet the needs of the research group in assessing their performance (Wong, pers. comm, 2002). The Water and Rivers Commission initiated a review of monitoring data for an evaluation of constructed wetlands designed for urban stormwater treatment in Perth in 1997. This review found that most constructed wetlands seemed to be ineffective in removing the nutrients entering them however data for evaluation of these constructed wetlands was limited.

An initial performance monitoring program for Marshalls Wetland was extended as a result of savings in costs of the wetland construction. Environment Australia agreed to a proposal for funds to be applied to a detailed performance evaluation project supported by the Water and Rivers Commission. The external funding has been matched with significant contributions of time and equipment from the Water and Rivers Commission to ensure that a high standard, comprehensive, performance evaluation program may be undertaken. The program is intended to continue for at least five years and it is expected that the performance of the wetland will improve over this period as the wetland vegetation matures.

This paper is presented with the intention of seeking feedback which may lead to improvements and refinements of this and future constructed wetland performance monitoring programs.

Overall Wetland Evaluation Program

There are several components to the overall proposed monitoring program for the wetland. These components will be managed and undertaken by a team comprised of community members, agency staff and university researchers and students. The proposed overall monitoring program includes:

Habitat Creation and Biological Functioning

- Macro-invertebrate sampling within the wetland to determine colonisation and composition
- Fixed point photography to record changes in wetland and fringing vegetation cover and composition
- Water bird and fish monitoring

Nutrient-Sediment Stripping and Hydrological Performance

- Tracer studies to determine hydraulic efficiency and flow patterns within the macrophyte pond
- In-pond nutrient and sediment sampling during storm events to aid in understanding the effective contaminant reducing areas of the ponds and for input to modelling of optimum wetland design criteria
- Establishment of piezometer transects to investigate groundwater interactions
- Rainfall, climatological and pond level monitoring to allow water balance studies and examine wind affects
- Inflow, outflow and bypass flow rate measurement and water quality sampling to determine Contaminant Removal Efficiency (CRE)

- This paper will concentrate on detailing measurement of flow rate and water quality variations at the inflow, outflow and bypass channels by employing both traditional and innovative flow gauging techniques, grab and flow-stratified autosampling and turbidity sensing. These strategies will provide sufficient data to determine the Contaminant Removal Efficiency (CRE) of each parameter of interest. These will be expressed as the average percentage reduction in flow weighted concentrations of outflow related to inflow.

$$CRE = \frac{(\text{inflow concentration} - \text{outflow concentration}) \times 100\%}{\text{inflow concentration}}$$

(Wong et al, 1999)

Assessment of the wetland performance will consider both inter-event and storm event periods and also take into account that proportion of events which bypass the macrophyte pond.

Characteristics of Water Quality Variations

Reliable determination of the timing, quantity and nature of contaminants entering, leaving and bypassing the wetland requires consideration of both the variability of water quality produced by the catchment and the processes occurring within the wetland.

Particles and particle-associated contaminants are mobilised mostly by storm events. This may be material mobilised by the action of rainfall on the catchment surface and also material mobilised within the drainage system (Symander, 2002, Settle and Goonetilleke, 2000). The mean concentration of contaminants in runoff for each storm event will vary depending on the antecedent conditions, particularly related to pasture or crop and stocking conditions and the intensity and duration of rainfall events.

Water leaving the wetland during a storm event is expected to have a pattern of concentration changes quite different to the inflow water. Assuming 'plug-flow' conditions are attained in the wetland, the initial increase in flow from the wetland would be expected to have concentrations not appreciably higher than the background baseflow conditions while treated water is displaced by incoming runoff. As the event progresses however, concentrations will increase as the wetland is unable to store all of the runoff from the event and also some re-suspension of sediment will occur. As inflow to the wetland recedes and inflow concentrations reduce to typical background levels, water leaving the wetland would be expected to continue to be higher in both flow rate and concentration for some time. Therefore, detection of concentration changes in the inflow and outflow water requires different sampling strategies. Bypass flows will have similar nutrient and sediment concentration patterns to inflows.

Water Sampling Strategy

Fixed time interval manual grab sampling will provide information on the broad patterns of nutrient and sediment variations over time. Furthermore, nitrogen and phosphorus speciation can be reliably measured in manual grab samples since samples can be filtered and preserved for analysis immediately after collection. Fixed time interval grab sampling will however tend to miss storm events and will tend to produce biased and imprecise estimates of nutrient and sediment loads. (Donohue and Nelson, 1999)

Stage height or flow rate initiated automatic sampling of streamflow has typically been employed to enable measurement of contaminant concentration changes due to storm events. Many sampling programs use either fixed interval stage increment initiation of auto-samplers or flow-proportional systems where a sample is automatically collected as equal quantities of streamflow pass the monitoring site. These samples are often composited and sub-sampled to give an approximate 'flow-weighted' concentration over a period. There is little opportunity to effectively optimise these sampling protocols without knowledge of the temporal patterns of nutrient flux which is not available with composite sampling. The long term viability of mass load estimation strategies depends on optimising sampling to minimise analytical costs while ensuring that samples are taken during times of greatest nutrient and sediment flux and greatest variation, which do not necessarily occur at the same times. (Degens, 2002)

The approach taken for sampling of storm events for this performance evaluation program uses autosamplers which are initiated by data loggers directly accessing stream stage or flow rate. This particular system was developed in the USA (Peters, 1994) and modified and adapted by the Water and Rivers Commission (Donohue and Nelson, 1999). The datalogger program detects short term changes in stream stage or flow rate and is able to reliably and comprehensively sample the commencement, rise, peak and recession of storm events. Parameters are set to ensure detection of the start of events, the peak and the return to baseflow conditions as well as the increment for samples to be collected during the rise and recession. Previously collected stage or flow rate data or data from catchments with similar characteristics can be run with the datalogger operating parameters through a simulation program developed by the Water and Rivers Commission to optimise the number of samples likely to be collected.

The collected samples are individually analysed and used to create an interpolated time series of concentration changes which is later combined with flow data. This approach will provide information on both the nature of concentration changes during storm events as well as mass loads and flow weighted concentrations.

It can rightly be assumed that concentrations will be most variable during storm events, and therefore stage or flow initiation of autosamplers is sensible. It may however be more effective to initiate the autosampling by detecting an actual 'indicator' change in water quality. This would ensure that samples are taken at times when the greatest concentrations and variations of nutrients and sediment are likely to occur. This may not occur at the time or to the same extent for all events as is implicit in stage or flow initiated sampling. The feasibility of continuously sensing turbidity, particularly at the outflow point, and using this to initiate an autosampler will be trialed. A turbidity sensor will be operated for one winter to obtain baseline data to use for preparing the autosampler initiation software. Investigation will also be made into the significance of relationships between recorded turbidity and sampled turbidity, total suspended solids, total phosphorous and total nitrogen. If suitable relationships do exist for this study area then there may be opportunities for sampling to be rationalised with continuous turbidity then used as a surrogate in load and concentration calculations.

Establishment of Monitoring Equipment

The information needs for this project require very precise flow measurement and there were considerable impediments to achieving this. The wetland site is in a very flat landscape which imposed constraints on the type of technology able to be applied. Further to this were the needs to establish infrastructure which would have minimal impact on the farming operation and performance of the wetland and also be able to be removed at the end of the project with as little disturbance as possible.

Triangular round-nosed broadcrest weirs were chosen for the inflow and bypass channels because of their sensitivity and tolerance of high and variable tailwater conditions (Bos, 1989). Stainless steel weirs were prefabricated inside upturned concrete box culverts which were then placed with sealant onto formed concrete slabs with cut-off walls extending into clay in the stream channels. The space between the weir culverts and channel banks was filled with a compacted clay/gravel/cement mix. Stage is recorded using Unidata model 6509 shaft encoder water level instruments inside 'Blue Brute' PVC floatwells and tailwater levels are recorded using Dataflow capacitance probes immediately downstream of the weirs.

The wetland outlet system has critical design features to ensure appropriate retention and discharge from the macrophyte pond. Installation of a weir or flume downstream of the outlet pipe was not possible as the lack of available slope would have meant the weir or flume would retard discharge from the wetland, particularly during storm events. To meet the need for high quality flow gauging data without impacting on wetland operation, a Unidata acoustic Doppler, depth-velocity logger was installed in the outflow pipe. This system has two components. A hydrostatic pressure sensor measures water depth in the pipe which is converted to cross-sectional area using an appropriate depth-area relationship loaded into the logger. Flow velocity is sensed using the Doppler principle where an acoustic signal is transmitted into the water column and the reflected signal, which is changed in frequency depending on suspended particle velocity, is processed and multiplied by the cross-sectional area to record and output a computed flow rate.

The shaft encoders and depth-velocity logger also output to Campbell CR10X dataloggers which contain the autosampler initiation algorithms. The dataloggers connect to American Sigma 900 autosamplers which use a peristaltic pump to fill up to 24 one litre sample bottles. The autosamplers which are fully programmable are set to purge the intake line with both air and then stream water prior to taking a sample. The autosampler intake filters are constructed from copper and the intake lines are fully enclosed to limit algal growth. The intakes are situated so they sample from an area where flow conditions allow maximum mixing with minimum interference from the bed and banks to ensure samples are representative of the sediment and nutrient conditions passing the site.

A tipping bucket pluviometer is installed at the site and a shaft encoder/floatwell system records the macrophyte pond water level. A climatological station recording wind run and direction, temperature and radiation is likely to be established in the future.

Data collection

Despite the amount of automated recording equipment established at the wetland, regular visits to the site are required at a range of intervals to carry out various tasks including:

- Approximately weekly during flow season as required to retrieve sampling record and autosamples for basic analysis (total nitrogen, total phosphorous, total suspended solids and turbidity)
- Fortnightly to collect grab samples for full analysis (total nitrogen, ammonia, nitrite + nitrate, total phosphorous, soluble phosphorous, total suspended solids and turbidity)
- Opportunistically to collect grab samples during storm events for full analysis and to compare to autosamples
- Approximately monthly during flow season to carry out current metering to verify and refine stage - discharge relationships of the weirs and refine the recorded - representative velocity relationship for the depth-velocity logger.
- Quarterly for other instrument checks, maintenance and retrieval of data

All water samples are dispatched within the permissible time period to a NATA certified laboratory for analysis. To identify, control and quantify errors within the sample collection and analysis process the following quality assurance measures are undertaken:

- Sampling staff training and competence is addressed
- Detailed Chain of Custody procedures are followed and documented
- Field blanks, replicate samples and field and laboratory duplicate samples are all introduced into the sampling program
- Simultaneous grab and auto samples are collected

Data analysis

Analysis will focus on evaluation of wetland performance, relating this to wetland attributes and condition and optimisation of sampling strategies for longer-term performance monitoring.

Evaluation of wetland performance

- Analysis of CRE changes over time in relation to wetland development. Assessment of how the CRE changes related to establishment, maturation and stabilisation of wetland vegetation and in-filling of deeper pond areas and inflow zone as sedimentation occurs
- Relating other measures of wetland performance such as macro-invertebrate, vegetation and faunal surveys to CRE and nutrient retention characteristics
- Analysis of CRE in relation to event size, load and timing to determine how these factors influence wetland performance
- Evaluation of long-term nutrient storage within the wetland

Optimisation of sampling strategies

- Evaluate effectiveness of fixed interval sampling strategies and combinations of fixed interval and limited event-based sampling for long-term performance evaluation of both this and similar wetlands in the region. This will include evolution of sampling programs over time to account for wetlands at different stages of development.
- Evaluate strategies to optimise automated sampling to ensure it is no more expensive than fixed interval sampling. This would involve determining the best allocation of say 50 samples across one year to ensure effective performance monitoring.
- Determine whether there is value in using fixed interval or fixed interval and event driven instantaneous sampling of both water quality and flow rate for low cost wetland performance evaluation.

Conclusions

This monitoring program will be as comprehensive as possible within budget constraints and draws on experience gained from local nutrient and sediment flux monitoring projects as well as lessons learned from other published wetland performance monitoring projects. It is recognised that there may be room for improvement in the approach and processes involved and therefore feedback is encouraged.

Acknowledgments

Chris Gunby and Brad Degens of the Water and Rivers Commission have provided significant input into and made this project possible.

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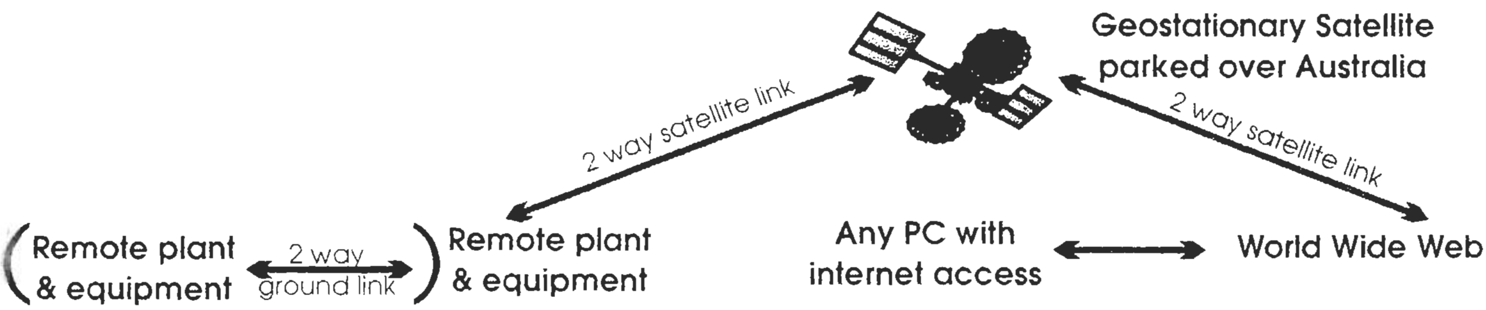
Satelemetry

Satelemetry is affordable satellite telemetry with starting prices from $9,000 & $60/month operating costs.

The Satelemetry terminal is tiny, about half the size of a VHS video casette, and has an inbuilt GPS receiver. The terminal is fully sealed including the internal antennas.

Satelemetry is a low data rate, low cost scada (supervisory control & data acquisition) system for tracking, monitoring & controlling remote plant & equipment.

In fixed plant applications the Satelemetry system can be interfaced to short haul terrestrial radio. These ground links can expand the reach of a single satellite terminal to anything within a 5 km radius.



Suitable applications for satelemetry are;

- River, pipeline & bore pump monitoring. Combined with 2 proximal, radio licence ground links, satellite terminals at 10 km intervals provide a cost effective wireless alternative to cabling

- Vehicle tracking, control & monitoring. Satelemetry is third generation mass produced technology that costs a fraction of traditional satellite based systems. The Satelemetry terminal can monitor refrigerated truck temperatures, check aircraft cabin pressurisation or vital engine parameters & can even provide limited messaging from an internet PC.

- Satelemetry is ideal for isolated environmental monitoring where cell phone or trunked radio services are unavailable.

What can't Satelemtry do? The system is unsuitable to any high data rate application making it inappropriate for web camera situations or any long term, real time demanding scada task (access plans vary from 40 to 720 messages per month)

Mclean Automation

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Measurement Uncertainty – Ramifications and Issues

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Paper Presented at 11th Australian Hydrographic Conference, July 2002

Abstract

The primary reference standard for open channel flow measurement, AS3778, clearly advocates the need for measurement uncertainty characterisation. It also explains how to calculate measurement uncertainty. This then poses the question – why have so few measurement companies and clients taken it up and used it? This paper explores this question by looking at several case studies of measurement uncertainty calculation and use, with particular emphasis on identifying the issues and perceptions preventing or restricting it's uptake.

Introduction

The most frequent activity in the flow measurement industry is the taking of measurements and comparing them to some reference standard, to validate or calibrate them. If differences are small, we say that the measurement or instrument (or computer model!) is calibrated or validated. If differences are large, we say the opposite, that either the measurement method or the reference method has drifted out of calibration, or both are out of calibration. The initial suspect is of course the measurement method rather than the reference method, and we usually proceed to correct the suspect instrument or method.

These types of comparisons always raise the question of how significant is the observed difference between the two methods? For example, for a multi-point river gauging, what percentage difference from a gauge site's rating table should trigger either a change in the rating table or a careful scrutiny of the particular gauging? At this point we would probably refer to our quality procedures, and the particular work instruction for that aspect of our business.

This is where the "use" of measurement uncertainty characterisation should be considered, as an objective means for defining what differences should be tolerated before remedial actions would be triggered. This same point is expressed in the introduction to the draft international standard on expressing measurement uncertainty (ISO, 1995):- *When reporting the result of a measurement of a physical quantity, it is obligatory that some quantitative indication of the quality of the result be given so that those who use it can assess its reliability. Without such an indication, measurement results cannot be compared, either among themselves or with reference values given in a specification or standard. It is therefore necessary that there be a readily implemented, easily understood, and generally accepted procedure for characterising the quality of a result of a measurement, that is, for evaluating and expressing its uncertainty.*

In addition to the general ISO guidelines for uncertainty expression, in the flow measurement industry we have the very specific guidelines for defining the measurement uncertainties of depths and multi-point gaugings and rating curves, given in AS3778.

A brief verbal survey of organisations with substantial measurement service groups suggests that this "discipline" of measurement uncertainty characterisation has not been generally adopted. In fact it seems that only the WA Water Corporation has made efforts to incorporate this additional discipline into its measurement procedures, through the efforts of Mr.Brian Chester.

In practice, the additional discipline required to characterise measurement uncertainty would require the hydrographer to fill in a "shadow" data field next to each measurement result data field. Given these data, measurement uncertainty can then be characterised for each site and/or for each instrument, back in the office, by following standard calculation procedures.

So, despite the small effort (and cost) required to establish this additional calculation discipline, and the potentially large benefits to practitioners and clients, why is it's adoption not more widespread?

The remainder of this paper looks at some of the issues relating to this "impasse", gives some case studies to illustrate these issues in practice, and concludes with a suggested way forward.

Terminology

To characterise the uncertainty of a measurement unavoidably requires use of statistical methods, expressions and terminology. The main terminology used in this paper is:-

- *H – the measured quantity or measurand (eg depth in metres)*
- *X(H)- "X" stands for the relative (±%) uncertainty of the measurand "H", at a recommended confidence level*
- *x(H)- "x" stands for the absolute (±measurement units) uncertainty of the measurand "H", at a recommended confidence level, such that:-*
- *X(H) = 100 * x(H) / H , and:-*
- *Recommended confidence interval (in AS3778) is 95%ile – ie the true value of "H" will lie within the range from "H-x(H)" to "H+x(H)", with 95% confidence.*
- *"μ" and "σ"- population mean and standard deviation (ie given a theoretically infinite number of repeated readings)*
- *"mean" and "s" – sample mean and standard deviation (ie given a limited number of repeated readings, such as normally occurs)*

No uncertainty definition without process definition!

It is not possible to define the uncertainty of a measurement without defining the uncertainty of each step in the measurement process. This of course means that each step in the process needs to have been objectively identified and defined, without missing anything out - which is not as easy as it sounds.

For example, at a river gauging site with staff gauge plates up the bank, the level is read off the gauge plates on each site visit, as a check calibration of the depth sensor and logger behaviour. To determine the measurement uncertainty of this gauge plate reading:-

- ±2.0mm = Source 1: Precision of level difference between top of plate and cease to flow level of control weir, using a dumpy level
- ±2.0mm = Source 2: Precision of aluminium gauge plate position relative to top of post, in terms of the work procedure for acceptable tolerance (ie it's glued on position)
- ±1.5mm = Source 3: Intermittent slime growth on weir crest
- ±5.0mm = Source 4: Value judgement on effect of local surface wave action in the weir pool, creating non-ideal plate reading conditions. At some sites this increases during high flows (eg up to ± 100mm)
- ±5.0mm = Source 5: Resolution of staff gauge plate markings (ie 1 cm black and white marking bars)

The uncertainty can then be calculated as the larger of:- (a) "root-mean-square" of sources 1, 2, 3, and 4, OR; the resolution of gauge plate reading (source 5). Here, that is $x(H) = \sqrt{(2.0^2+2.0^2+1.5^2+5.0^2)} = \pm5.9$mm, which is larger than the ±5.0mm quoted for Source 5. Each process step is thus accounted for.

Accuracy expression versus Uncertainty expression

A well recognised dilemma which causes confusion when calculating the measurement uncertainty of a measurement, is when one or two steps in the measurement process are defined in terms of "accuracy" rather than "uncertainty". This typically occurs when faced with an instrument manufacturer's technical specification for, say a depth sensor – which is inevitably quotes as an "accuracy" rather than as an uncertainty. Mr. R.W. Herschy in his excellent reference text on Hydrometry (Herschy, 1978), defines the difference as follows:-

Accuracy – The accuracy, or more correctly, the error of a measurement of discharge, may be defined as the difference between the measured flow and the true value.
In open channel flow measurement, Herschy points out that:- The true value of the flow is unknown, and can only be ascertained within close limits by weighing or by volumetric measurement. *So, for practical purposes, our current methods cannot define the "true" value of the flowrate we are measuring.*

He then explains why the "measurement uncertainty" approach is necessary in such a situation:- An estimate of the true value has therefore to be made, by calculating the uncertainty in the measurement, the uncertainty being defined as the range in which the true value is expected to lie, expressed at the 95% confidence level.

A common problem in converting accuracy to measurement uncertainty is that the ±% confidence level (at which the accuracy rating is given) is not given! In this situation, a general confidence level has to be assumed, and the measurement uncertainty estimated as described in the general guidelines in the draft ISO standard, which states that, in this situation, where a manufacturer quotes an accuracy rating without reference to how frequently the equipment can achieve this:-

Measurement Uncertainty ~ 1.13 * Accuracy

For example, if the accuracy of "H" was given as ±3.0% (with no ±%ile confidence level), then it's measurement uncertainty equivalent can be estimated as:- 1.13 * 3.0 = ±3.4%

Another aspect to be aware of about accuracy specifications, is how they don't take into account local site conditions impacts, as expressed in a recent article by Dr. John Miles on Magflo and transit time pipe flow meters (Miles, 2002):- *information in the meter manufacturer's literature can only give us an indication of the meter's capability. It cannot possibly tell us what the installed uncertainty of the meter will be.*

Resolution and Precision versus Uncertainty expression

Unlike "accuracy" expressions, "resolution" and "precision" expressions are explicitly limited to their stated physical characteristics. What often causes confusion is how and when to incorporate these in the uncertainty calculation process.

As regards "when" to incorporate them, this will be specific to each measurement process, and will require common sense and careful thought, to decide.

As regards "how", this again requires careful thought, such as for the gauge plate example described earlier. "Precision" sources are normally included directly, whereas "Resolution" sources are usually an "either-or" type of allowance. For example, if the instrument uncertainty due to accuracy might be ±3.4mm, while it's logger resolution is ±10.0mm, so, the resultant measurement uncertainty is ±10.0mm (ie "gazumps" the accuracy source component).

Another practical example of this is when using an current meter to measure point velocity in a very slow moving flow regime, say registering 10 revolutions in 30 seconds. Here, the theoretical accuracy of the meter at these slow velocities may be ±5.0%, but this can be superceded by the resolution of the counter which registers only to the nearest revolution (ie 10 counts ±1 revolution, i.e. ±10.0%). So, the resultant uncertainty of this measurement process is ±10.0%.

Determining each source's uncertainty – method A or B?

The draft ISO guidelines for determining the component of uncertainty due to a particular measurement step or source, describe two ways in which this can be calculated:-

Method A – Where there are sufficient repeated measurements versus precise reference measurements, to enable formal statistical definition of the source's uncertainty.

Method B – Where this is not possible (ie not possible to take precise reference comparison measurements – such as with flow measurements), then the uncertainty of each process step needs to be characterised and added together (using standard error theory), to estimate the overall measurement uncertainty of the measurement.

For example, a depth sensor's accuracy, as provided by the manufacturer, may be the result of many benchtop calibration tests against a reference pressure testing device, which essentially makes it a "Method A" type derivation of uncertainty. However, the final depth data delivered to the user from that logger, will need to take account of not only this source of uncertainty but also site specific conditions such as surface wave action, calibration reading error etc. (as per earlier gauge plate reading example). The resultant combined uncertainty would then be obtained using the Method B approach.

The "A-B-C" of using measurement uncertainty for quality assurance

In Australia, the CSIRO's National Measurement Laboratory in Melbourne, has national responsibility to educate measurement bodies on measurement uncertainty and how to use it in the measurement industry. One of their main tools for promoting this discipline, are the draft ISO guidelines referred to previously, and the regular training courses they offer bi-annually in each capital city.

A standard use of measurement uncertainty has been developed by this group, and is now in widespread use in Scientific Laboratories for retaining their NATA certification. A particular example of this is in the conduct of the standard NATA test of a laboratory's ability to replicate known concentrations in a pre-mixed sample.

The standard test relies on measurement uncertainties being provided up front for the particular analysis process, by both the Reference laboratory (A) and the laboratory being tested (B), such that the allowable tolerance for an observed difference in sample results – can be calculated. An example to illustrate this concept is given below for Nitrate concentration analysis:-

- Reference laboratory "A" gives its characteristic measurement uncertainty as:- *X(A)=±5.0%*
  - Test laboratory "B" gives its characteristic measurement uncertainty as:- *X(B)= ±7.0%* (noting that they use a different analysis process)
    - The "allowable" difference tolerance "C" , accounting for the uncertainty of both measurement processes is then calculated as:- *Tolerance* $= \pm\sqrt{(5.0^2 + 7.0^2)} = \pm 8.6\%$
      - The actual test results for Lab "A" were 5.8 mg/L, while for Lab "B" were 6.1 mg/L, which, relative to the reference laboratory (ie "A") gives a difference of +4.9%
      - The "test" laboratory "B" would then be declared as having past the NATA certification test, as conforming to being within the ±8.6% tolerance
      - If the results had indicated a difference in excess of the tolerance, then a test non-conformance would be indicated, leading to remedial actions in the test laboratories processes, or a downgrading of its characteristic measurement uncertainty (ie to achieve conformance).

This simple "A-B-C" approach to using measurement uncertainty for quality control and quality assurance will very likely spread into the flow measurement industry, and can be used in many ways – as instanced by several of the examples given later.

Subtract and Add versus Multiply and Divide Uncertainty Steps

Given the characteristic uncertainties of each step in a measurement process, expressed as either absolute ±measuring unit uncertainties or as relative ±% measurement uncertainties, the overall uncertainty of the final delivered measurements can be calculated by application of standard error theory.

For calculation steps which add or subtract quantities, all uncertainties must be expressed in their absolute measuring units, and the resultant products uncertainty expressed in the same way, for later conversion to relative measurement uncertainty. For example, at a sewer flow gauge site with an ultrasonic depth recorder mounted on the roof of the channel, the uncertainty of it's depth measurement at a particular time can be defined as:-

- Process:-
  Depth = Gauge zero - Distance to surface, which for this example assume = 2.23m minus 1.46m = 0.77m depth of flow above invert
  - Sources of "Distance" uncertainty :- instrument limitations under ideal conditions (from manufacturer's specification); surface wave action at the site; occasional foam occurrences; instrument drift over time vs frequency of site visits; sensor installation verticality. For this example, assume that these source uncertainties add up to an overall Distance uncertainty of 1.46m ±6.0mm
  - Sources of "Gauge Zero" uncertainty:- precision of survey method used to measure level difference between sensor head and invert; condition of invert. Assume here that these sources add up to an overall 2.23m±5.0mm
    - Absolute uncertainty of Depth, then:- $x(H) = \sqrt{(6.0^2 + 5.0^2)} = \pm 7.8$mm. Note that the contributing uncertainties are added, despite the fact that the product is achieved by subtraction.

For calculation steps involving multiplication or division, the relative uncertainties of each contributor to the product must be used to calculate the relative uncertainty of the product. For example if flowrate at the sewer site example above were to be calculated as the product of average Xn velocity and Xn area, then this approach applies, as below:-

- Process:- Flowrate (Q) = Average Xn velocity (v) * Xn area (A), which for this example assume = 0.75 (m/s) * 2.35 sq.metres = 1.76 cumecs
  - Sources of "Xn area" uncertainty :-
    - Xn survey uncertainty, which the surveyor may define as ±3.0% on Xn area;
    - Xn area uncertainty due to depth sensing uncertainty:-

- Ultrasonic distance sensor- distance to surface measurement uncertainty (see eg above), of ±6.0mm and;
- Gauge zero uncertainty (see eg above), ±5.0mm.
- So, the resultant depth uncertainty would be ±7.8mm (as given defined previously), which can then be used to determine the component of Xn area uncertainty due to depth uncertainty, which will vary with depth of flow (eg for a 1m depth in a 2.35m wide channel, this depth uncertainty would equate to a ±7.8% area uncertainty.
  - The combined uncertainty of these two sources would then be = $X(A) = \sqrt{(3.0^2 + 7.8^2)}$ = ±8.4%
  - Sources of velocity sensing and average cross section velocity calculation uncertainty:- manufacturer's "ideal" conditions specifications; local site conditions (eg any false signal noise due to local turbulence, etc.); uncertainty of calibration method and equipment. For this example, assume this amounts to ±10.0% for the practical range of velocities.
  - Additional uncertainty created by timing differences between velocity sensor and depth sensor operation, relative to local site flow regime volatility. Here assume this is negligible.
  - So, the "root-mean-square" uncertainty of flowrate calculated using the recorder is:- $X(Q) = \sqrt{(8.4^2 + 10.0^2)}$ = ±13.0%.

Random and Systematic "Errors"

"Error" is not "uncertainty". "Error" is an idealised concept which depends on the existence of an exact reference measurement, from which the "error" of a measurement method can be defined, as either "Random"or "Systematic" – see ISO (1995) guidelines. In the flow measurement industry, for field measurements, no such "exact reference" measurement method exists. So, for the purpose of this paper, uncertainty has been assumed to include the effect of random errors, and whatever portion of systematic error cannot be removed by normal work practices and methods.

Examples of recent applications – in practice!

Maintain Level sensor integrity

Maintaining the integrity (or validity) of a gauge site's level sensing equipment, is one of the most frequent operations in the flow measurement industry. SWC have recently taken the time to characterise the level sensors's uncertainty as well as our check measurement uncertainties. These have then been used in conjunction with the *A-B-C* approach, to provide an objective method for maintaining level sensor integrity. For example:-

- Characterising Level sensing equipment uncertainty, as being ±12.5mm, comprising:-
  - ±10.0mm for instrument accuracy (ie 0.1% of 10m range)
    - This "accuracy" translates to an uncertainty ~ 1.13 * 10.0 = ±11.3mm
  - ±2.0mm for gauge zero survey precision
  - ±5.0mm for local surface wave effects, sensor reading uncertainty
  - ±1.0mm logger resolution
  - = $\pm\sqrt{(11.3^2 + 2.0^2 + 5.0^2)}$ = **±12.5mm**, which is larger than the ±1.0mm logger resolution

- Characterising Staff gauge plate reading uncertainty, as being ±7.3mm, comprising:-
  - ±2.0mm for plate position survey precision
  - ±5.0mm for parrallex and meniscus effects on reading errors
  - ±5.0mm for local surface wave effects, reading uncertainty
  - ±5.0mm gauge plate reading mark resolution
  - = $\pm\sqrt{(2.0^2 + 5.0^2 + 5.0^2)}$ = **±7.3mm**, which is larger than the ±5.0mm plate reading resolution

- How these "uncertainty" characteristics are used in practice:-
  - Define the allowable "tolerance" of differences between the gauge plate reading, and the level sensing equipment = $\pm\sqrt{(12.5^2 + 7.3^2)}$ = **±14.5mm**
  - On each site visit, observe the difference between the gauge plate

depth, and the logger sensed depth (as usual), and only take remedial action if the difference exceeds **14.5mm!**

Maintain discharge rating table integrity
Maintaining the integrity (or validity) of a gauge site's discharge rating table is another task at the core of the hydrographic industry service. In a similar way to the depth sensing integrity maintenance, once the rating table uncertainty has been characterised, and individual field gauging uncertainties are characterised, they can be used as objective tools to determine when to change and update a rating table:-

- Characterising the existing rating table's uncertainty of discharge estimate, over a flow range of interest, as being **±8.0%** (for example), comprising the degree of scatter of points about the curve:-
  - Calculating the standard error of estimate of the least squares fit of the field gaugings taken versus the "best-fit" rating curve
  - Multiply this standard error by 2, as per AS3778 procedures (ie to give 95%ile uncertainty)
  - The resultant uncertainty represents the combined uncertainty of each of the multi-point current meter gaugings, as well as the uncertainty of the rating curve
- Characterising the uncertainty of each new multipoint field gauging, using AS3778 procedures, for example as being **±9.8%,** comprising:-
  ±9.0% for only having 10 verticals
  ±10.0% for using a limited exposure time of 30seconds, at a slow velocity of 0.3m/s
  ±7.0% for using 2 points per vertical
  ±1.0% for the point velocity uncertainty, using the individually calibrated current meter
  ±1.0% for depth measurement uncertainty (eg ±10mm over 1m), and
  ±1.0% for width measurement uncertainty
  $= \pm\sqrt{(9.0^2 + (1/10)*[10.0^2+ 7.0^2+ 1.0^2+ 1.0^2+ 1.0^2])} = \pm 9.8\%$, which is larger than the ±5.0mm plate reading resolution
- How these "uncertainty" characteristics are used in practice:-
  Define the allowable "tolerance" of differences between the rating table discharge (from level), and the latest multi-point current meter gauging, as being the larger of either ±8.0% or ±9.8%, ie **±9.8%,**

  Use the "three strikes and you're out" approach – if three successive current meter gaugings have consistent differences exceeding the above tolerance, then adjust the rating table to suit. If not, then accept that the rating table is still applicable.

North Head STP effluent flume – enable improvements to be considered
With suitable approach conditions and construction standards, most flume and weir installations are capable of achieving discharge measurement uncertainties of ±5.0% or better.

The large long throated flume in the effluent channel at SWC's North Head sewage treatment plant (STP) is no exception, and in theory could be achieving such low uncertainties (ie ±5.0%).

However, due to the non-ideal approach conditions caused by upstream penstocks, measurement uncertainties were suspected to be higher, by a previously undefinable extent.

To answer local action group concerns about the accuracy of sewer flows being quoted, the increase in measurement uncertainty caused by the non-ideal approach conditions was assessed as follows:-

- Characterising the existing rating table's uncertainty of discharge estimate, over the flow range of interest, as being **±16.8%** , comprising the degree of scatter of points about the curve:-
  - Calculating the standard error of estimate of the least squares fit of the 25 field gaugings taken versus the "best-fit" rating curve
  - Multiply this standard error by 2, as per AS3778 procedures (ie to give 95%ile uncertainty)
  - Acknowleding that this "scatter" uncertainty includes the uncertainty of both the flume rating table (with non-ideal approach conditions) line of best fit and the individual gaugings.

- Characterising the uncertainty of each new multipoint field gauging, using AS3778 procedures, for example as being ±**11.8%,** comprising uncertainty for:-

- Number of verticals (5)
- Exposure time of meter (15 seconds)
- Number of points per vertical (3)
- Velocity reading accuracy of current meter
- Depth and width measurement uncertainties
- An "uncertainty reduction" allowance, for the fact that in smooth man-made channels, velocity distributions are far more predictable (otherwise uncertainty would be ±15.7%)

♦ Calculating the "actual" uncertainty of the flume discharge indication, using the *A-B-C* approach, in reverse:-

- Given that *Combined Uncertainty* = $\pm\sqrt{(X(Flume)^2 + X(Gaugings)^2)}$ = ±**16.8%,** as defined already, then
- Rearrange the relationship to calculate the practical flume uncertainty:- $X(Flume) = \pm\sqrt{(16.8^2 - X(Gaugings)^2)} = \pm\sqrt{(16.8^2 - 11.8^2)} = \pm\mathbf{12.0\%}$

Now that the severity of the uncertainty impact of the penstocks has been defined, plans can be evaluated for the cost benefits of re-arranging their settings to gain flow accuracy improvements, which can potentially reduce uncertainty of discharge from **±12.0% to ±5.0%.**

AS9001 Process Certification at SWC STP's

SWC has recently achieved AS9001 certification of all operational processes at it's STP's. As part of the traceability and audit obligations involved in retaining this certification, the method of auditing each process for conformance has had to be defined.

In the case of flow measurement processes, we have been able to implement characterising the measurement uncertainty of each flume and weir site, taking into account equipment differences, approach condition non-conformances, and any other relevant local site conditions.

Having characterised the measurement uncertainty at a discharge measurement site, it can then be used as an objective audit tool, to:-

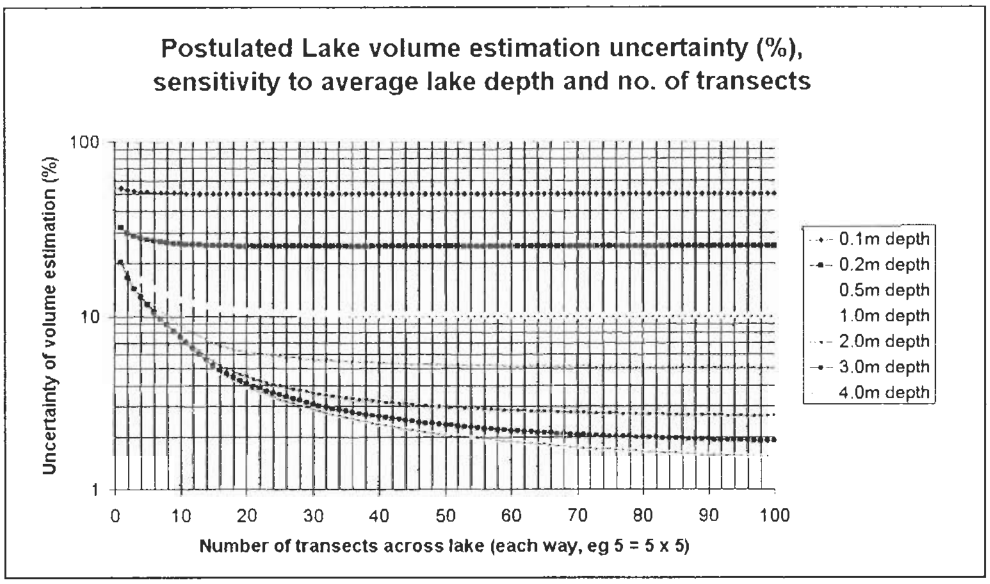
- ❑ State the quality of the flow data being provided, in terms of its ±% rating table uncertainty
- ❑ Identify sites with unacceptably high measurement uncertainties, and design and prioritise improvements
- ❑ Determine when rating tables have suffered a significant change, using independent multi-point gaugings (and their characteristic uncertainty) , and the *A-B-C* approach- and taking remedial action (eg where backwater effects start to drown a flume, due to a downstream process change)

Reservoir Depth versus Volume relationship uncertainty

In being part of SWC's AWT division, hydrographic tender bids have included several lake depth versus volume definition project proposals. As part of the strategic thinking behind such proposals, the relationship between "quality" of volume estimate versus "cost" to obtain it, was recognised as being directly related to the measurement uncertainties involved.

By way of illustration, Figure 1 demonstrates the uses of characterising the main uncertainty sources, and using these to inform clients of the relationship between cost (in terms of number of transects) and volume measurement uncertainty – assuming gradually varying lake bottom relief.

Figure 1 General relationship between Lake volume uncertainty & no. transects



From the figure, for example, even for a relatively deep average lake depth of 4.0m, only 6 transects are necessary to achieve a volume estimation uncertainty of ±10.0%, but to improve this down to ±2.0%, at least 50 transects would be necessary.

Computer model "accuracy" characterisation
One of the most frequently asked questions about mathematical models of river or sewer flow systems, when they are used to design and cost large capital works, is:- *How accurate is the model??*
Although this is a valid question to ask, it is not so easy to answer. This is where gauge measurement uncertainty characterisation can provide one of the few ways to answer the question objectively.

For example, say the the model of a river system has been calibrated to the last 5 years of river flow (and rainfall) records, at 15 minute time steps. This means that there are potentially 175,320 comparison points to look at differences between the gauge records of discharge, and the model estimated discharge, as below:-

- Calculate the combined uncertainty of the gauge and model discharge estimates, as twice the standard error of their 175,320 differences. Say this equalled ±20.0%
- Characterise the uncertainty of gauge flows derived from the site rating curve, as defined in earlier examples, as, say, ±10.0%, then
- Infer the model accuracy, applying the *A-B-C* approach, as being:-

Given that *Combined Uncertainty* = $\pm\sqrt{(X(Gauge)^2 + X(Model)^2)}$ = **±20.0%,** as defined already, then

- Rearrange the relationship to infer the model's uncertainty:- *X(Model)*= $\pm\sqrt{(20.0^2 - X(Gauge)^2)}$ = $\pm\sqrt{(20.0^2 - 10.0^2)}$ = **±17.3%**

Determining the significance of changes in catchment flow behaviour
There is frequent interest in attributing a significance to changes in flow regime at a gauge site, by users of the data. This includes but is not limited to noting flow increases or decreases due to:- increased development on the catchment; catchment management policies to reduce flow to the system; drought impacts; wet period impacts, etc.

Again, this is where knowing the characteristic measurement uncertainty of the gauge(s) involved can provide one of the few "objective" means of saying whether or not an apparent change is significant.

For example, say a more efficient crop watering method is developed, and water is metered through standard pipe meters, and a "before" vs. "after" study is done (eg similar to SWC's urban demand management initiatives). If the old crop usage need was 8 ML/Ha, while the new usage need was measured at 7.5ML/Ha – is this a significant reduction?

Characterise the combined meter measurement uncertainty, as, say ±10.0%

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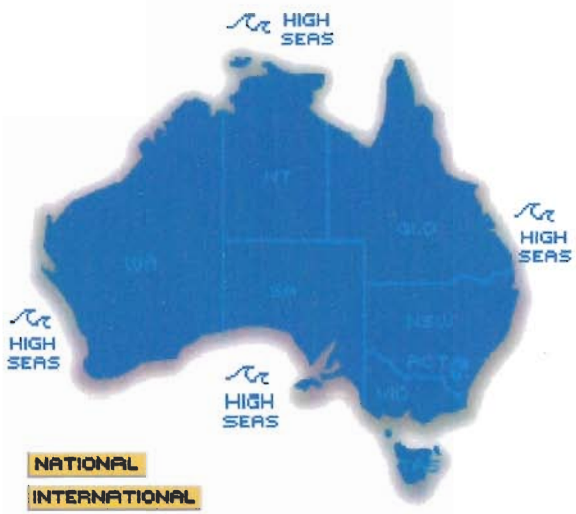

WEATHER FORECASTS WARNINGS and OBSERVATIONS

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Western Australia
Northern Territory
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International
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WARNINGS SUMMARY

THIS MONTH'S FEATURE (previous)

Visit Flood Warnings Rainfall and River Information for up to date data and other flood related information.

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A wide range of climate related data, information and products are available.
Of Particular interest to people in the water industry are:

- **Real time rainfall and river height data**
- **Climate averages in map and graph form**
- **National catalogues of river stations**
- **Drainage divisions and river basin boundaries**

Features currently under development include:

- **National catalogue of rainfall station**
- **National evapotranspiration maps**

The Bureau of Meteorology's Hydrology Program would like to thank the Hydrographic and data management groups in all States and Territory water agencies for their support over the years. Data and information have been provided for many projects, including:

- **Gobal Runoff Data Centre sponsored by WMO**
- **UNESCO Asian Pacific Friend Project**
- **Stream Gauging Information, Australia**
- **Flood warning system development and operation**
- **Rainman Streamflow Project**

- Apply the *A-B-C* approach, to determine the implied "tolerance" of differences (comparing gauge to gauge readings before and after the new method), as being $\pm\sqrt{(2*X(Gauge)^2)} = \pm\sqrt{(2*10.0^2)} = \pm 14.1\%$
- Calculate the % change as (7.5-8.0)/8.0, ie 6.25%, which is less than what could be explained by gauge measurement uncertainty alone.
- So, the apparent "reduction" is not significant, at the 95%ile confidence level.

This particular type of use of measurement uncertainty has wide application potential.

Microbiology: Biovolume Uncertainty in water quality reporting

Recent changes in NSW to environmental reporting licences have switched from reporting cell concentrations, to cell volumes. Along with this change, the uncertainty of the bio-volume measurements can be defined, to later enable the assessment of "changes", similar to the above crop efficiency example.

The biovolume of a particular cell taxa is calculated as the product of *cell abundance* and *average cell volume.* Establishemnt of each of these (cell abundance, and average cell volume), in turn, requires several process calculation steps, each with contributing uncertainties to be characterised.

These uncertainty calculation tools have recently been developed for use in reporting water quality results to the Sydney Catchment Authority. No further detail is given here, but these will probably be described in a related paper.

Conclusion and Where to from Here ?

Some of the main benefits obtained by implementing the measurement uncertainty discipline in a flow measurement business, are:-

- Enable network owners to answer the question "How accurate is the flow data", and subsequently to design and prioritise measurement improvement works (such as low flow weirs, etc.)
- To have an objective starting point from which to evaluate new technology
- To enable clients, who use the gauge data to calibrate computer models and develop capital works plans, to answer the most frequent "public" question :- *How accurate is the model?*
- Enable clients to determine if apparent flow regime changes are within gauge measurement uncertainties (eg in response to catchment management initiatives), ie identify "false" trends.
- Gradually form an understanding of the relationship between cost of data versus quality of flow data

In opposition to these are the main impediments to adoption of this additional measurement discipline:-

- Perceived additional costs, and changed work practices – which may initially be significant
- The additional "statistical" understanding necessary to succesfully implement it, appears overly complex
- Traditional culture of trust by clients, to deliver good quality flow data, without looking too closely at what that means. Note however, that these days, ongoing cost-cutting initiatives would have caused unknown increases in measurement uncertainties (ie lower quality data)
- Some uncertainty sources are technically difficult to define (eg rating table extrapolation)
- Concerns about "client shock" (ie losing business) – if the first go at defining the objective measurement uncertainty shows all low flow sites to have uncertainties of ±30% or worse, then clients may decide to prefer other service providers

Whether or not the costs outweigh the benefits is worth debating. As far as this author is concerned, the benefits do outweigh the costs, substantially.

The only "where to from here" suggestion to make is to recommend pilot study applications to develop the basic calculation tools and understanding required for it's wider and ongoing use – as it will revolutionise work practices in the industry.

References

- AS3778 (circa 1990): *Measurement of Water Flow in Open Channels*, various parts, Standards Australia
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- Herschy, R.W. (1978), et al: *Hydrometry*, John Wiley and Sons, 1978, ISBN 0-471-99649-1
- Miles, Dr.John (2002):- *Are you certain about uncertainty*, Water 21, pp 43-44, April 2002

Contributions to the Journal and Newsletter

Member contributions to the Journal and newsletters are most welcome. You are the Association and hence it is helpful if you provide input into it.

At present the Editor is limited to steam driven Word 6.0 so if you have a contribution could you please submit in that format.

Advertisers could also assist by providing TIF, GIF or JPG images or similar of their ads - while PDF format is handy it means cut and paste has to be done - literally!

I look forward to getting summaries of papers from the conference from those who have indicated that they are willing to provide them. Summaries of the summaries are also welcome as I can use them as a precursor in the newsletters for items appearing in the next Quarterly Journal.

Photographs are also welcome for the cover of the newsletter - final use of a submitted photo will depend on how well the image transposes onto the cover of the Journal, so the clearer the better.

Shakers and Movers

Current S&M's are:

Les Marshall - DLWBC to currently relaxing

Ben Martin - Hydro Tasmania to Snowy Hydro

On The Web.

Have a look at how some of our members and their employers are getting data onto the web.

Time Studio Based:

Tassie: www.wired.dpiwe.tas.gov.au

HYDSYS Based

NSW: www.waterinfo.dlwc.nsw.gov.au

WA: www.wrc.wa.gov.au/waterinf/telem/contents.html

Who Knows What Based

Australia Wide: www.bom.gov.au

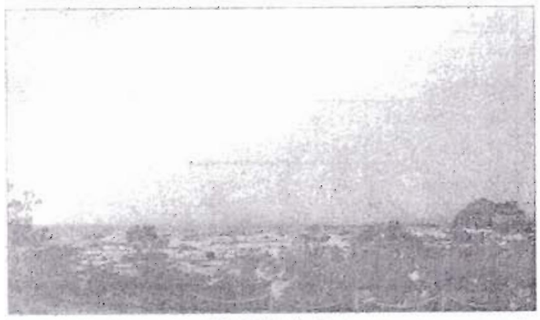
Corporate Membership

Corporate Membership of AHA includes the following "benefits"

- Free full page ad in the quarterly Journal
- Free quarter page ad in the monthly newsletter (mainly due to space requirements)
- Free page and links on our web site.
- Use of our name in a manner of the form "All of our hydrographers are members of the AHA" when advertising/tendering etc.

Individual members receive a 10% discount on there membership if their employer is a current corporate member.

Todd on the run as dust storms gather



Big dry: A huge dust storm engulfs Griffith in the Riverina Picture: Vince Bucello

Big wet: Children enjoy the water in the normally dry Todd River Picture: Steve Strike

Paul Toohey

As eastern Australia continues to suffer from the worst drought in a decade, the place often so wrongly called the Dead Heart is awash with rain.

Central Australia is a place of weather extremes. This has been the driest year on record with eight rainless months. Then two weeks ago the thunderstorms began to gather over Alice Springs.

The average rainfall for November is 30mm but 130mm have fallen in the last two weeks over Alice, making it the wettest November on record.

The deep tropical air of the north has wandered down to the Alice, replacing the dry southern air. The result has been fierce electrical storms and even some hail.

On Tuesday night at about 4am the Todd River, which runs through the middle of Alice, began to flow for the first time since February.

It was no flash flood but a walking-pace awakening witnessed by few except for those who happened to be sleeping on the river's sandy bed and Anthony Fasman, a hydrographer who was up and about doing his business of monitoring the situation.

"We've had our driest year plus our wettest month all in the same year. It's weird," Fasman said.

"Three weeks ago we had bushfires. Now the place has suddenly gone green."

Yesterday, some of the wet weather found its way to eastern states.

At the same time as a huge dust storm descended on the NSW Riverina town of Griffith, reducing visibility to [illegible] metres, a localised thunderstorm dumped almost [illegible]mm on the central-west NSW town of Mudgee, forcing the annual Mudgee Cup race meeting to be abandoned.

Rain also hit the Sydney and north coast areas, while scattered storms moved across the central areas of Queensland towards the coast.

W/E Australian 30/11/02

Application For-Renewal of Membership

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