In-situ Acoustic Doppler Velocity Meter Study.

Funding Partners Department of Sustainability & Environment Victoria and Bureau of Meteorology

Background:

In 2008 the Victorian Department of Sustainability and Environment commissioned a pilot investigation into the Feasibility of the use of Acoustic Doppler Velocity Meters (ADVM) to improve the accuracy of hydrometric flow data.

Four sites were selected for the earlier study and the findings from that suggested that accuracy in flow data could be substantially improved at difficult or challenging sites utilising ADVM technologies.

An additional investigation was also commissioned at a site on the Latrobe River, near the Gippsland Lakes, suspected of being subject to lake-surge and salt intrusion.

Subsequently a decision was made to further test the findings by installing an ADVM at each of twelve sites recognised as presenting substantial challenges when obtaining stage-discharge relationships utilising conventional methodologies.

Introduction:

In 2009 an opportunity was presented, through the Bureau's Modernisation and Extension of Hydrologic Systems program, to obtain funds for further evaluation of ADVM technologies.

The ADVM technology is established to analyse velocity and average it over a 890 seconds period. The results are then logged electronically and flow for the period calculated, after which the processes starts again. Consequently flow is calculated continuously at 15 minute intervals.

The channel cross-section is surveyed at the ADVM and the cross-sectional area multiplied by the average flow velocity to determine the passing flow in the sample period.

Funding was provided through this program to study 12 surface water monitoring sites, across Victoria, where accurate stage-discharge relationships could not be obtained using conventional practises. In addition, the selected sites were crucial to meeting the needs of jurisdictional Business Drivers and thus required a higher level of confidence in the data produced from them.

Each of these sites was subject to one or several of the following constraints to the capture of accurate data;

- Variable back water influences
- Pooling of water within river reaches
- Suspected lake-surge
- Impacts of regulated flow (i.e. Releases from storages)
- Site access during high flows
- Resourcing difficulties during large storm events.
- Inadequate channel conditions for installing conventional streamflow measurement infrastructure across.

Eight sites were selected for their potential to provide a regionalised analysis of ADVM technologies. Those sites were located within Gippsland where it was postulated that the Gippsland Lakes might have a substantial influence on flows at the lowest monitoring point on those streams discharging to the Lakes or, where greater operational accuracy might be achieved on crucial sites upstream and downstream from controlled releases at a storage.

An eighth site was selected in Gippsland for the degree of difficulty presented in obtaining high flow measurements due to both the channel width and variances in flow regime as the stream transited from a mountainous terrain to coastal plains.

In addition, several of the sites selected were located within the same stream system thus presenting a potential opportunity to further test the results by undertaking water balances analysis.

Three additional sites were selected in Northern Victoria to reflect the challenges of flow monitoring in the broad river valleys of the Murray-Darling Basin system where there is minimal bed slope.

The last site was selected to provide a preliminary analysis of marine impacts resulting from tidal influence.

Finalised cost estimates for all installations resulted in sufficient funding only being available to evaluate ten sites. Cost overruns can primarily be attributed to the cost of bank boring required at two sites to install power/communications cabling from the ADVM to the loggers. Bank boring costs were not anticipated at the time of initial estimates for the funding bid but it was determined that boring offered the preferred option for maintaining bank stability.
Additionally a decision was taken to establish more permanent infrastructure than first intended. The purpose behind this was to design and manufacture infrastructure that could be quickly dismantled and relocated if sites proved to be unsatisfactory or if the later part of the study required data from additional sites.These had a substantial impact on the funding stream.

Project Outline

Thiess Services has been involved in extensive field trials for the Department of Sustainability and Environment to prove the accuracy and reliability of Acoustic Doppler technology. These trials have proven the value of this technology in providing streamflow data in situations where it has not been possible with traditional methodologies.

This project is designed to extend our knowledge on the feasibility of using Acoustic Doppler technology, throughout Victoria, by monitoring ten sites, with a range of flow and site conditions, in Gippsland and Northern Victoria. Nine of these sites are at existing gauging stations that have established rating tables and many years of flow data. This will enable direct comparison between traditional and acoustic methodologies of flow calculation and will enable the accuracy of both methods to be compared at various points throughout the flow range.

This technology has major implications for sites which are downstream of gated structures or large storages and should provide a more accurate estimation of flows during unsteady flow conditions such as major events and storage regulation. This will improve dam safety, flood mitigation and operational efficiencies. Acoustic instrumentation should enable a higher accuracy of total volumes to be achieved by continuously monitoring the changes in velocity during the rising and falling limbs on the hydrograph. This project will also enable the effects of multiple loop ratings for a range of events at a variety of sites to be monitored and compared.

Thiess adopt methodologies which are considered best practice for undertaking confirmation gaugings and applying Index ratings to derive the actual flows at all sites. This will build on the experience that has been gained through operating trial sites over the past 12 months to get a better understanding of the instrument limitations.

Sites Selected for the study

The following sites were originally selected for inclusion in the study;

222200C	Snowy River	@	Jarrahmond	Gippsland
224217B	Mitchell River	@	Rosehill	Gippsland
225201A	Avon River	@	Stratford	Gippsland
225232A	Thomson River	@	Bundalaguah	Gippsland
226027B	Latrobe River	@	Swing Bridge	Gippsland
226227A	Latrobe River	@	Kilmany South	Gippsland
225209A	Macalister River	@	Licola	Gippsland
225204A	Macalister River	@	D/S Lake Glenmaggie	Gippsland
235224a	Gellibrand River	@	Burrupa	South Coast
405200A	Goulburn River	@	Murchison	Northern Victoria
405232C	Goulburn River	@	McCoy Bridge	Northern Victoria
414203C	Murray River	@	Euston	Northern Victoria

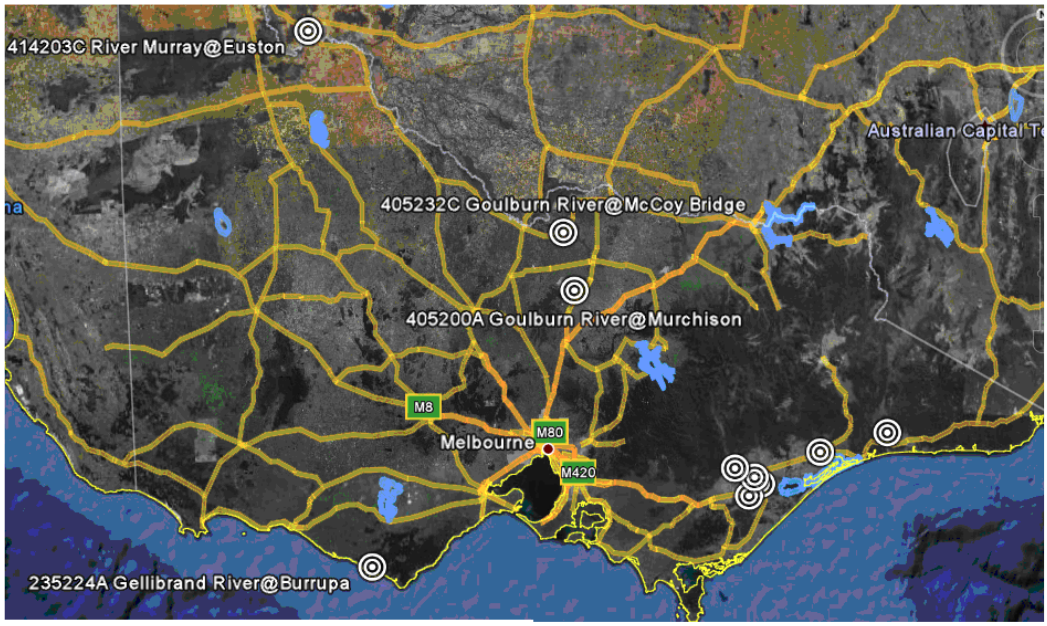


Figure1. Geographic location of ADVM sites in Victoria

As indicated costing constraints necessitated the exclusion of two sites. Although it was decided not to include Gellibrand River at Burrupa and Murray River at Euston in the final study, this paper discusses the purpose for their original inclusion in the project.

Business Driver needs

Victoria has a well developed Water Resource Monitoring Framework which addresses the key Business Drivers for agency collection of water monitoring information.

At the outset of the ADVM evaluation it was determined that the study should focus on the operational difficulties associated with collection of high quality fit for purpose data and also target sites crucial to meeting the Business Driver needs of one or more of the Victorian agencies within the partnership

Site Selection Philosophy

The following discussion focuses on the purpose for including each of the selected sites in the study program. As stated, it also includes the two sites that were omitted from the final study due to funding constraints.

Gippsland sites;

The Gippsland sites can be separated into three sub-groupings for the purpose of this study. They include:

- ❖ A site located at the transition from mountainous terrain to coastal plains
- ❖ Those sites suspected of being impacted on by the Gippsland Lakes.
- ❖ Sites crucial to the safe operation of a large water storage.

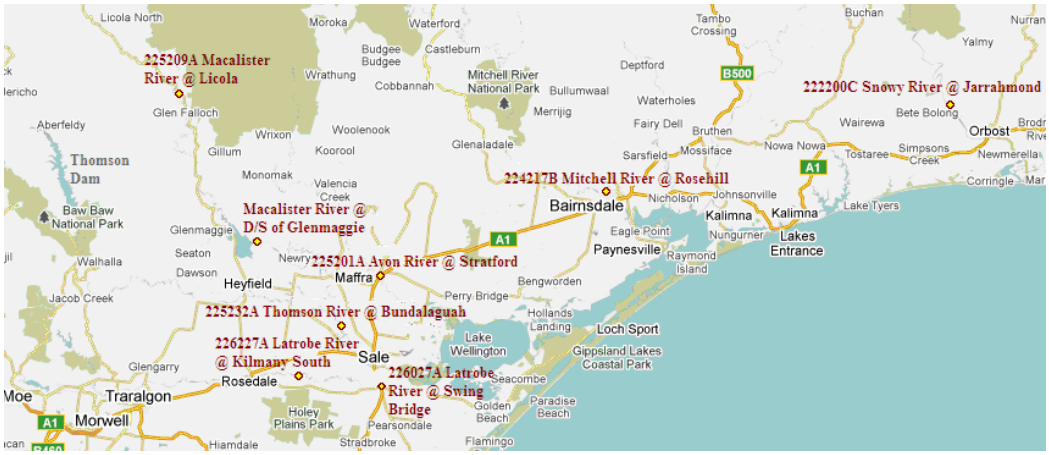


Figure 2: Location of Gippsland ADVM sites.

Gippsland Lakes influence.

Five sites have been selected for this component of the study because they are believed to be impacted on by the Gippsland Lakes system.

224217 B Mitchell River at Rosehill

This site is located in the broad Mitchell River flats, has a tortuous and unstable primary river channel shown on the left and has a very wide secondary channel shown at right. The Mitchell River terminates at Lake King within the Gippsland Lakes system. The river downstream from the site covers approximately 20 Km with very little fall before discharging to Lake King. It flows along the boundary of the lake for approximately 6 of those Kilometres. The Mitchell River is also unique in that it flows, as a perched stream several kilometres, into Lake King before discharging its flow. Irregular occurrences within the lakes system have the potential to quickly impinge on data accuracy at the Rosehill site

(e.g. elevated lake levels may cause back-up at the site). The drainage area monitored by the site could be classified as moderate at approximately 4,000 km2.

The steep and unstable nature of the primary channel bank required that this site be bored to install the power/communications cabling to the ADVM rather than use open trench techniques.

Access to the existing suspension monitoring installation is difficult during moderate flows and flows cannot be monitored using any of the conventional techniques when the river breaks out of the primary channel. The effectiveness of the existing suspension monitoring installation can be rated as marginal.

This is a crucial site for Key Water Allocation and critical to REALM and Bulk Entitlement modelling. Additionally it provides key information for the State Water report.

225201A Avon River at Stratford

This site is located on a very broad channel section and is subject to flashy and intense flood events from a relatively small drainage area of 1485 km2. The stage-discharge relationship is premised on a potentially unstable natural gravel and sand control. The Avon River discharges to Lake Wellington within the Gippsland Lakes system. The stream channel is heavily vegetated and the vegetation density can vary considerably between flood events.

The width of the channel section presents specific challenges in utilising the suspension monitoring installation at this site especially during extreme events. The effectiveness of the existing suspension monitoring installation can be rated as marginal. The high velocities occurring during major events also preclude the use of other conventional techniques such as boat observations.

Site access is not a problem here. In the past access has been possible even at the highest event ever recorded. However staffing requirements are high during major events if satisfactory stage-discharge observations are to be obtained.

This site is classified as a Key Water Resource Assessment site, collecting critical information for the State Water Report and providing data for trend analysis. It is also utilised to assess important state WQ parameters and is critical for flood warning within the Gippsland Lakes Flood Warning Network.

225232A Thomson River at Bundalaguah

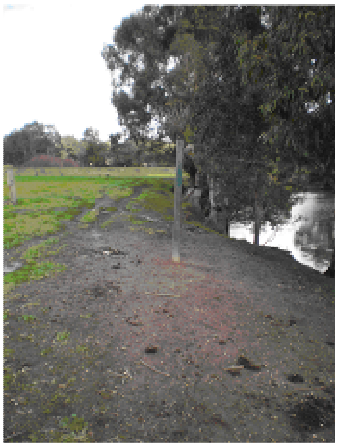
This site has been selected for inclusion in the ADVM study as the close proximity of two other monitoring sites (Latrobe River at Kilmany South and Swing Bridge) provides a unique opportunity to undertake some water balance modelling and comparative statistical analysis. It also allows analysis to be made on the back-water effects created through varying flows in each of the streams. The drainage area monitored by the site could be classified as moderate at approximately 3,538 km2

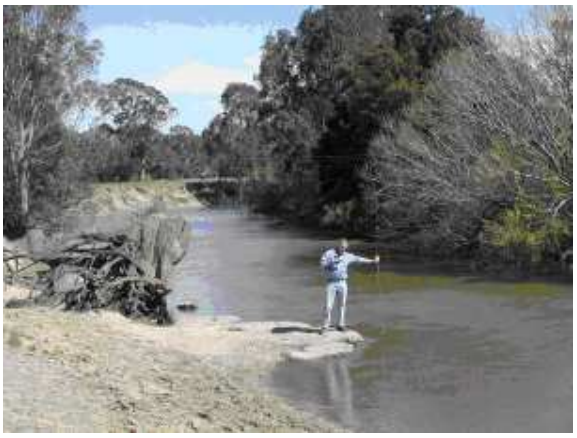
This site is located approximately 5 km upstream from the confluence of the Thomson and Latrobe Rivers within the flood plain section of those rivers. Both streams are significant to the water harvesting activities of various agencies. There are several water storages upstream from the Thomson River site. Controlled releases are often made from those storages. The site is also impacted on by surge actions of Lake Wellington within the Gippsland Lakes system and the subsequent short term variance in back-water that can occur.

Site access for high flow monitoring is extremely challenging and break-outs occur on the right bank at moderately small flows. The tortuous nature of the primary channel also tends to create non-laminar flow patterns.

The data collected is currently crucial to the Key Water Allocation Sites Business Driver and is utilised for REALM and Bulk Entitlement monitoring.

226227A Latrobe River at Kilmany South.





As the accompanying photographs indicate the site quickly becomes inundated in high flow events. It is located approximately 5 km upstream from the confluence of the Thomson and Latrobe Rivers within the flood plain section of the broad Latrobe Valley flood plains.

This site has been selected for inclusion in the ADVM study as the close proximity of two other monitoring sites (Latrobe River at Swing Bridge and Thomson River at Bundalaguah) provides a unique opportunity to undertake some water balance modelling and comparative statistical analysis. It also allows analysis to be made on the back-water effects created through varying flows in each of the streams. An earlier investigation clearly proved that the back-water and/or surge effects at this site impact significantly on data accuracy and hence further comparative studies against the other two sites were required.

The drainage area monitored by the site is in excess of 4,460 km2 and could be classified as of moderate area.

Both streams are significant to the water harvesting activities of various agencies. There are several water storages upstream from the Latrobe River site from which controlled releases may be made. The site is also impacted on by surge actions of Lake Wellington within the Gippsland Lakes system and the subsequent short term variance in back-water that can occur.

The primary channel can be adequately measured from the suspension monitoring installation at this site. However access is extremely challenging at those times and, the flow tends to break-out across the gently sloping right bank at relatively minor levels and isolating portions of it from the measuring system.

The data collected at this site is crucial for REALM or Bulk Entitlement monitoring, forms part of the State Water Report and is critical for surface water information

226027A Latrobe River at Swing Bridge

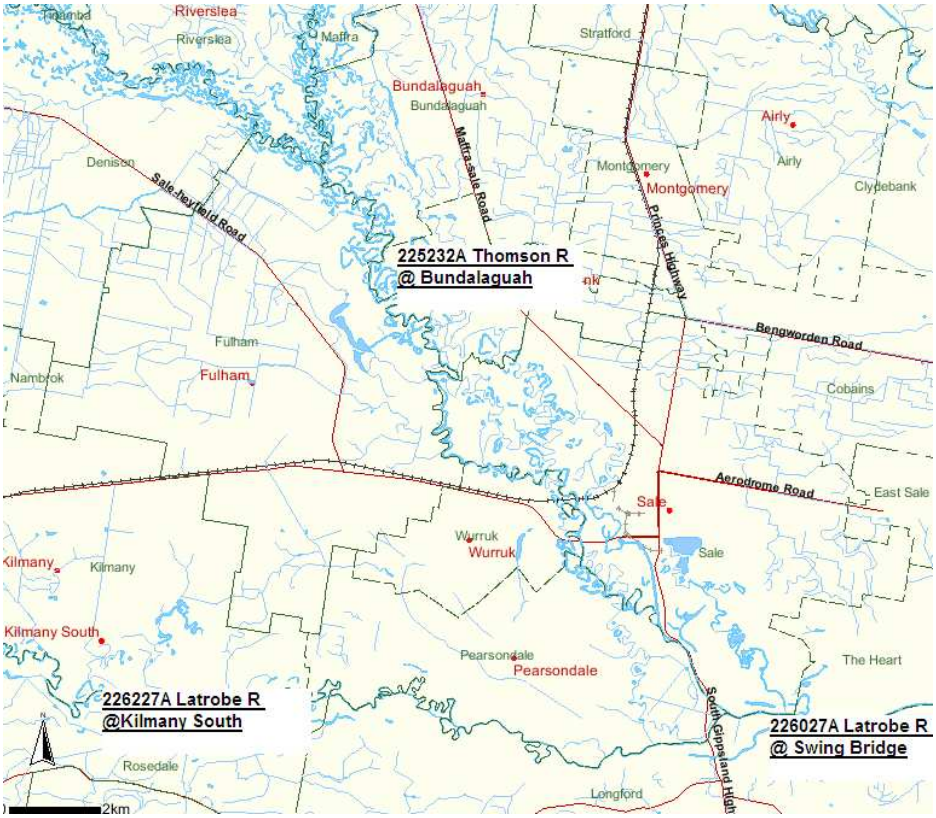


Figure 3. Aerial showing the geographic relationship of Kilmany South, Bundalaguah and Swing Bridge sites

This site is located immediately downstream from the confluence of the Latrobe and Thomson rivers (See figure 2 for layout) within the immediate influence of Lake Wellington in the Gippsland Lakes system and hence is subject to channel seeching. Although the site is an identified Bulk Entitlement monitoring point hither-forth conventional flow monitoring technologies have not permitted accurate collection of the necessary data. Hence a “virtual site” was created whereby data from the Latrobe River at Kilmany South and Thomson River at Bundalaguah were summed and assumed to represent the true flow conditions at the Swing Bridge site.

ADVM technologies now appear to provide a solution for direct monitoring of flows at this site. Consequently an initiative has commenced to establish a comprehensive stream flow monitoring site here to monitor flow. Obviously, this site will pose the greatest challenge to the versatility of ADVM technologies within this study. Conversely it provides a unique opportunity to test and analyse the Salinity and Suspended Load monitoring capabilities of the instrumentation in a difficult environment. The ADVM has the capacity (when linked to continuous salinity monitoring probes) to monitor and calculate slat loads and salt wedge intrusion. The viability of these calculations has been investigated in the earlier study where its viability was proven. However a comprehensive analysis of salt load is outside the parameters of this project.

This site has been selected for inclusion in the ADVM study as the close proximity of the two upstream monitoring sites (Latrobe River at Kilmany South and Thomson River at Bundalaguah) provides a unique opportunity to undertake some water balance modelling and comparative statistical analysis. It also allows analysis to be made on the back-water effects created through varying flows in each of the streams and will provide detailed information, and analysis opportunities, on the surge effects of lakes systems on streamflow.

The drainage area monitored at this site cannot be accurately calculated due to its location within a flood plain area and its close proximity to Lake Wellington. However contemporary estimates put it in excess of 8,000 km2.

Access to this site will not be possible at higher flows and the flow patterns of the two rivers suggest that the site may be isolated for protracted periods in any single event. Hence it is anticipated that instrument reliability may be severely tested as part of the study. The site will only be capable of monitoring moderate events as it is not possible to calculate velocities when the river breaches the primary channel and spreads across the broader flood plain.

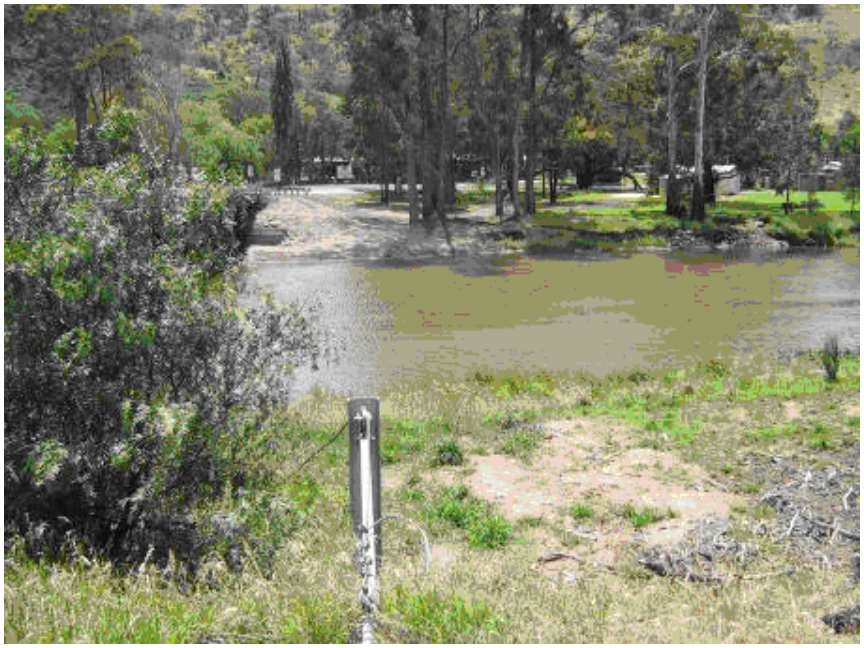
The potential improvements in data collection at this location make it the most exciting single part of the study.

Sites critical to safe operation of a Large Water Storage.

Two sites located on the Macalister River in Gippsland were included in this study to evaluate the consequent improvement in operational safety of a Large Dam that might be achieved through employing Acoustic Technologies.
The two sites were Macalister River at Licola upstream from Lake Glenmaggie and the tail gauge immediately downstream from the storage.

Accurate inflow and outflow data are essential when operating Storages during flood events. Inflow data assists in estimating stresses and loads being imposed on the dam structure whilst assisting with release decisions which can have catastrophic impacts on downstream communities if managed incorrectly. Concurrently confirmation of accurate release data is also required at the tail gauge site.

225209A Macalister River at Licola.



This site is approximately 40 km upstream from the storage and provides critical early warning for flows reaching Lake Glenmaggie. It is located within a catchment severely impacted by the 2006 Great Divide South fires. As a consequence the soils of the entire catchment became extremely unstable and subsequent high rainfall events caused mud slides and severe erosion within the catchment and stream channel. In the highest flow event ever recorder (peak of 220,000 Ml/D) in July of 2007 evidence suggests that the

stream bed was severely scoured on the rising leg of the hydrograph and then deposition on the falling leg raised the streambed 1 meter above its pre-event level. Soil stability is slowly returning to the catchment but it is anticipated that several more years will elapse before an acceptable level of stability returns.

The area is difficult to access during and following high rainfall events and is totally inaccessible in extreme events thus making it difficult to measure flow using conventional methods.

High flow events in 2007 destroyed the sites suspension monitoring installation and it has been estimated that the reconstruction cost would exceed $40,000. Hence the ADVM technology offers a cost effective alternative.

The drainage area for this site is relatively small at 1233 km2. However the steepness of the catchment results in rapid run-off especially during high rainfall events. This can result in “flashy” variations to flow and stage.

The data collected at the site is utilised for the State Water report and State-wide Surface Water Information and flood warning for downstream communities at risk.

225204A Macalister River Downstream from Lake Glenmaggie.

This site is located 500 meters downstream from a major storage fitted with 14 radial lift gates. The flow at this site is well contained within a stable channel. However data accuracy can be impacted by debris passing through the storage.

The catchment area is large relative to the storage capacity and manual flow releases are common during many rainfall events. There are a number of populations at risk downstream from the storage and all releases must be carefully planned to ensure a minimum impact on those growing communities. Those decisions are heavily premised on the accuracy of real-time flow release information.

Although a suspension monitoring installation is located at the site the current practise is to make releases based on theoretical stage-discharge relationships developed for gate openings at the storage. This is because rates of change of stage are often to frequent and

extreme to be able to gain accurate stage-discharge measurements employing conventional methods. There is some doubt surrounding the accuracy of the theoretic tables and more accurate data and less uncertainty in that data is preferred.

The drainage area for this site is relatively small at approximately 1891 km2.

The data from the site is utilised for Key Water resource Assessment purposes including REALM and Bulk Entitlement activities.

Southern Victoria

235224A Gellibrand River at Burrupa

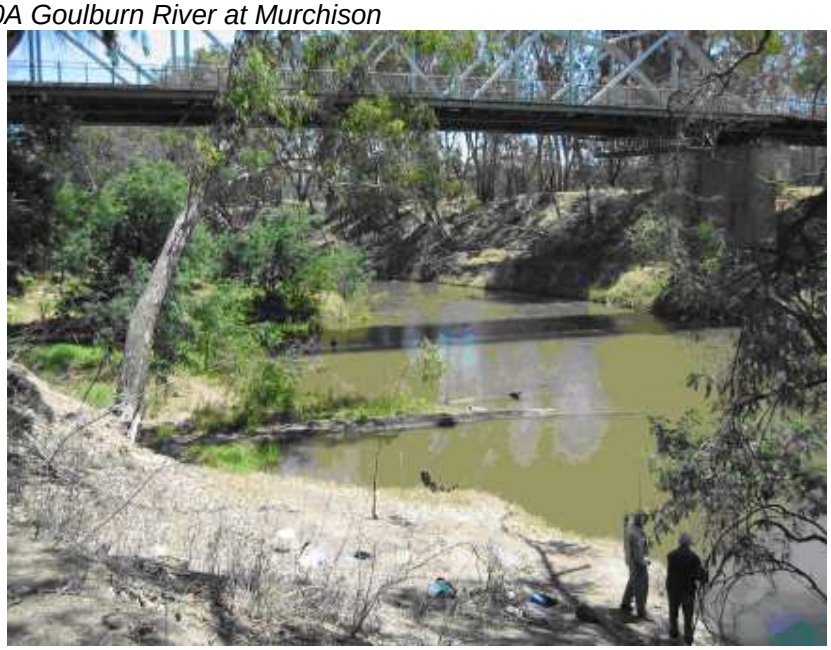
This site is located approximately 16 km upstream from the ocean. It is suspected to be impacted by tidal variations and possible salt wedge intrusion. The site was selected for the unique opportunity of studying those impacts and determining how accurately flows could be monitored in such an environment.

However financial constraints for the project dictated that several components of the study could not proceed. Consequently it was decided that the Gellibrand River site be placed on hold as it was considered that similar research information could be obtained from the Latrobe River at Swing Bridge site.

Northern Victoria.

The area within Victoria to the north of the Great Dividing Range is dominated by large and broad river valleys with minimal bed slope along the river reaches. Three sites were selected in Northern Victoria as being representative of the difficulties encountered in establishing accurate stage-discharge relationships in that region.

405200A Goulburn River at Murchison



This site is located approximately 185 tortuous river kilometres upstream from the confluence of the Goulburn River with the Murray. However it is known to be impacted by back-water and during major events flow conditions are disrupted by water passing to and pooling in the Barmah Forrest approximately 35 river kilometres downstream from the site.

The site is located downstream from the Goulburn Weir which is used to divert flows to the irrigation system, manage passing river flows and regulate environmental release requirements. Consequently multiple and rapid flood peaks pass the site during high flow events. The energy in the peaks varies from event to event depending on downstream conditions and hence makes it difficult to determine true flow conditions at each event using conventional methods.

The flow is contained within a well defined river section and an effective suspension monitoring installation is located at the site. Access is possible to the site in all but the most extreme events.

The drainage area of the site is estimated to be 10,772 km2 and can be classified as large.

It is a Key Water Resource Assessment, Sate Water Report, Trend and State-wide Surface Water Information site

405232C Goulburn River at McCoys Bridge

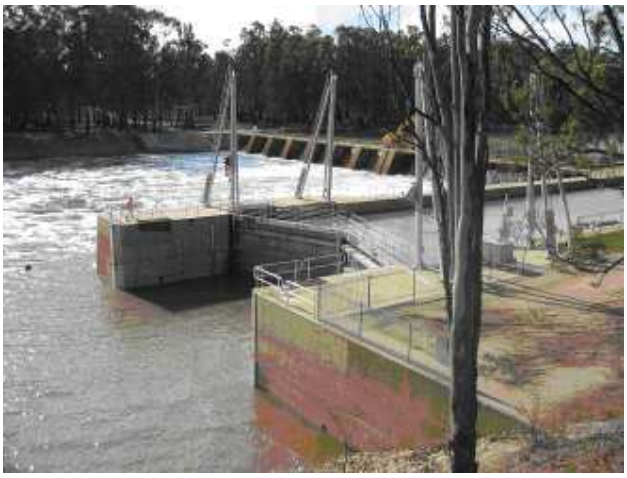
This site is located approximately 55 tortuous river kilometres upstream from the confluence of the Murray and Goulburn rivers and is heavily impacted by varying back-water effects from the Murray River. Flows at this site are heavily impacted on by multiple peaks in the hydrograph.

Accurate stage-discharge relationships are essential as this site plays an important role in determining Bulk Entitlement releases from the Goulburn to the Murray.

The drainage area of the site is estimated to be 16,806 km2 and can be classified as large.

It is a Key Water Resource Assessment, Sate Water Report, Trend and State-wide Surface Water Information site

414203C Murray River at Euston



This site is the final monitoring point before the Murray enters South Australia and is critical for determining accurate pass-down river flows. It is located within the loch system of the Murray and consequently is subject to continual, but variable, back-water from the upstream loch. The site is politically sensitive and data derived at the site is under constant scrutiny for accuracy.

The site is located in an extremely hostile environment on the downstream side of Loch 7 in the turbulent tail-water area when flows are released from the loch.

During the development phase of the ADVM project this site was identified as offering substantial long-term advantage if in fact the ADVM technologies provided an identifiable improvement in data accuracy and a commensurate reduction in data uncertainty. Consequently it was to be included in the project.

However, it was subsequently established that the turbulent flow regime at the existing site would not facilitate the establishment of and ADVM index. The alternative was to establish an entirely new water monitoring site in a section of the river where a more laminar flow regime existed. As this alternative was costly and there was no financial support for the ongoing operation and maintenance of the site unfortunately the location was withdrawn from the project.

Conclusion.

Earlier studies have indicated that Acoustic technologies have the potential to dramatically improve stage-discharge estimate accuracies at sites where conventional methods of observation are not feasible. In addition they present an opportunity to more effectively calculate Salinity and Suspended Loads at critical sites.

This study presents an exciting opportunity to thoroughly assess the technology and obtain data that can be statistically analysed at a later date.

The perceived benefits from utilisation of Acoustic technologies is improved data accuracy, reduction in data uncertainty and improved stakeholder confidence in data collected from crucial water monitoring sites.

The adjunct to this study is a later investigation into statistical analysis of data when a sufficient data set has been aggregated.