# AIDS TO NAVIGATION PLANNING
# And the use of
# GEOGRAPHIC INFORMATION SYSTEMS

**Australian Maritime Safety Authority**

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## ABSTRACT

*Geographic Information Systems (GIS) can be used to enhance the efficient management and analysis of information that has a spatial component (i.e. information linked to a physical location). The routes taken by ships, ship position information (from AIS or VTS etc), existing and/or new planned Aids to Navigation (AtoN), hydrographic data and virtually all other navigationally related information can be used within a GIS to provide opportunities for analysis. As a result, GIS technology can provide AtoN regulators with opportunities for improvement in the efficient delivery of relevant and appropriate AtoN.*

*This paper is based on a paper and presentation given at IALA's 16th Conference held in Shanghai in May 2006, entitled "GEOGRAPHIC INFORMATION SYSTEMS AND AIDS TO NAVIGATION'. The aim of this paper is to explore further the application of GIS to the planning of new AtoN, the review of existing AtoN networks, and other AtoN information management applications.*

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## INTRODUCTION

AtoN service providers are having to adapt to new decision making methods and technology to help stay abreast of the increased uses being made of waterways and to strive to be more efficient and cost effective in the delivery of their services. Information about AtoNs needs to be more accurate and up to date, and this requires planning, research and the application of good information management systems. At the same time AtoN service providers need to work within tight financial constraints and hence efficiency is paramount.

A significant problem for AtoN service providers has been a lack of information about the needs of their customers, mariners. It can often be the case that shipping traffic density, the precise location of routes taken by ships and the types of ships are not well known or understood. Without this information the provision of AtoN can be a hit and miss affair.

However, the collection and storage of ship position information from ship reporting systems and vessel traffic services provides a valuable resource for AtoN providers. The advent of AIS provides an even richer source of ship position information if it can be collected. The use of this information within GIS enables the mapping of routes used by mariners and this in turn provides a relatively easy and efficient way to meet their needs as customers by providing optimised AtoN services.

Over the past decade the way that most mariners navigate has changed in that there is now almost a ubiquitous use of satellite positioning. Whilst not revolutionary in itself, coupled with

this is the ability for a vessel's position to be automatically plotted using ECDIS or ECS. Stemming from these developments a question arises; what use does the mariner have for traditional AtoN? No doubt this question will be considered as part of the development of e-navigation, both by the IMO and in particular by IALA.

However, for the purposes of this paper, and as concluded at IALA's 16th Conference, it is assumed there will remain an ongoing need for short to medium range AtoN. Such AtoN are used in complex coastal or 'pilotage-like' navigational situations and provide a visual link between onboard electronic navigation systems and the 'real world'.

## NOT ALL MARINERS CAN BE EASILY MAPPED, YET

Whilst ship position data for large vessels is becoming widely available, at the smaller end of the spectrum (leisure craft and smaller commercial vessels) such information is still difficult to obtain.

Australia's experience is that smaller vessels are more frequently visiting new and remote areas. This is possibly due to an increase in affluence, allowing more people the opportunity to own boats (larger, faster and more capable boats).

To help ensure the safety of navigation of smaller vessels and the protection of sensitive remote marine areas, AtoN service providers need to consider the provision of new AtoNs. However, such mariners generally do not participate in reporting systems, or vessel traffic services, and so there is not yet a ready supply of vessel position information for these craft.

AIS Class B may in the future result in a wealth of small vessel position information available for collection and subsequent use in a GIS to better understand the need for AtoN to service the navigation needs of smaller vessels.

## WHAT IS GIS?

There are many definitions of what GIS is, but it is simply 'a collection of computer hardware, software, and geographic data for capturing, managing, analysing, and displaying all forms of geographically referenced information.'[1]

An easy way to think of how data is managed and displayed in a GIS is to consider each data type as a layer which when viewed together describes a completed picture. In addition, with many data types there is related qualitative and quantitative information attached to graphical data. An example of this could be the attributes attached to ship position data, and these can include various vessel specific details such as date, time, course, speed, draught etc.

The power of GIS software is not just its ability to create tailored maps and diagrams, but also its capacity to analyse data. Geographically related qualitative and quantitative data is typically managed in a tabular or spreadsheet like manner. The GIS software used by AMSA makes it a relatively simply process to link spreadsheets (for data capture) to a GIS project, and provides tools to execute queries and searches to separate particular vessels or groups of vessels, the results of which can of course be displayed graphically and mapped.

[1] http://www.gis.com

It is not the intention of this paper to detail particular GIS software, suffice to say that there is a variety of GIS software available. Should IALA want to provide advice to its members about particular GIS software then it will be necessary to research the GIS software market having regard for the tasks needed for marine AtoN planning, including but not limited to:

- relevant analysis tools,
- an ability to integrate nautical charts (vector (ENC) and raster (generally geotiff)),
- intuitive usability,
- ease of importing a wide variety of data types, and
- cost.

## AMSA'S EXPERIENCE WITH GIS IN ATON PLANNING

Shipping routes described by ship position data can be interactively displayed as a GIS layer along with nautical charts, source hydrographic data, light sector and range diagrams, charted routes and other relevant information such as Marine Parks or Particularly Sensitive Sea Areas. The result is an interactive map that provides new ways of looking at problem areas and can facilitate the optimisation of an AtoN network. This in turn can lead to improved navigation safety solutions, cost minimisation and the meeting of community expectations for marine environment protection.

If a new shipping route is required, for example due to port enhancements and deep draught ships, then GIS can used to help display relevant information, such as nautical charts, and provide an easy way of identifying a suitable route and producing diagrams. These diagrams provide a simple way to visualise the new or altered route and can also be used to communicate with stakeholder groups, such as other water stakeholders or interest groups.

AMSA is currently planning adjustments to a charted preferred route in the Spencer Gulf, South Australia. As a part of this task a new section of 'deep draught' route is being added. The diagrams at the annex are examples of GIS products recently used to negotiate suitable buoy positions with local fishermen.

Figure 1 (next page) shows shipping patterns as displayed using Esri Arc GIS, off the coast of Gladstone (central Queensland). Vessels not participating in ReefVTS participate in AusRep and hence a combination of both data sets provides a clear indication of shipping traffic. In this example the interactive map was used to review the use of existing AtoN and the possible need for new or enhanced AtoN.

Figures 2 to 6 show AusRep or AIS ship position information off the coast of northwest Australia where it has proved useful for AtoN network review and ship route design in and around offshore resource industry facilities. AusRep data at a scale of 1:6 million provides a good indication of generalised ocean shipping routes. At a scale of 1:1.6 million AusRep data becomes too coarse to be useful (figure 3).

AIS data collected by the port of Dampier provides a rich and detailed information source that can be used at larger scales (shown in figures 4, 5 and 6).

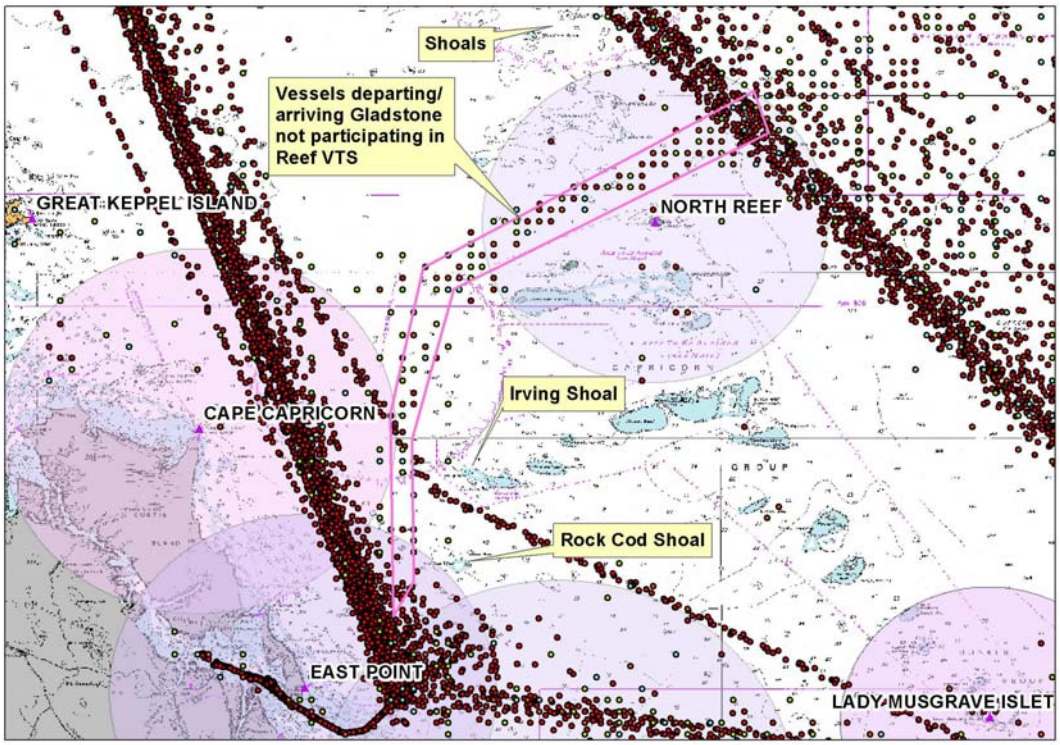



*Figure 1 – SatC VTS data and AusRep data used for AtoN review and network design in the approaches to Gladstone, Queensland*

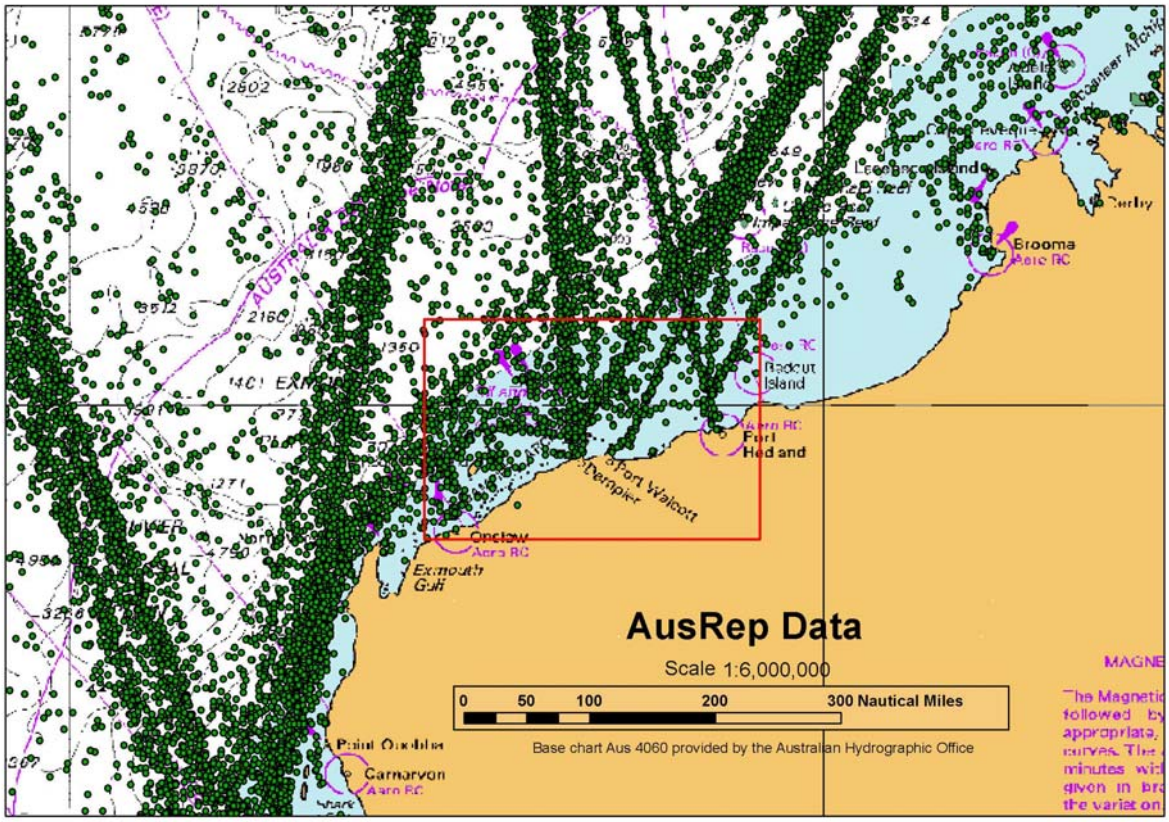



*Figure 2 – AusRep data off northwest Australia (1:6 000 000)*

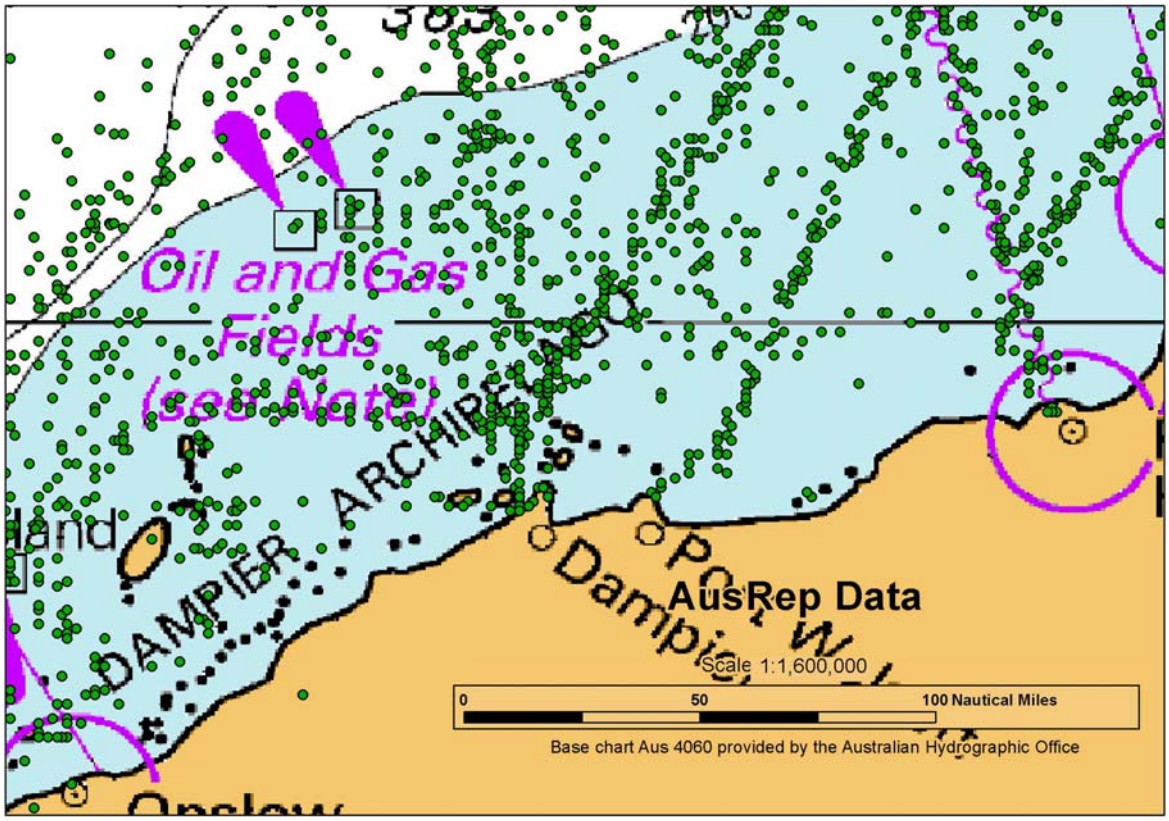



*Figure 3 – AusRep data off northwest Australia (1:1 600 000)*

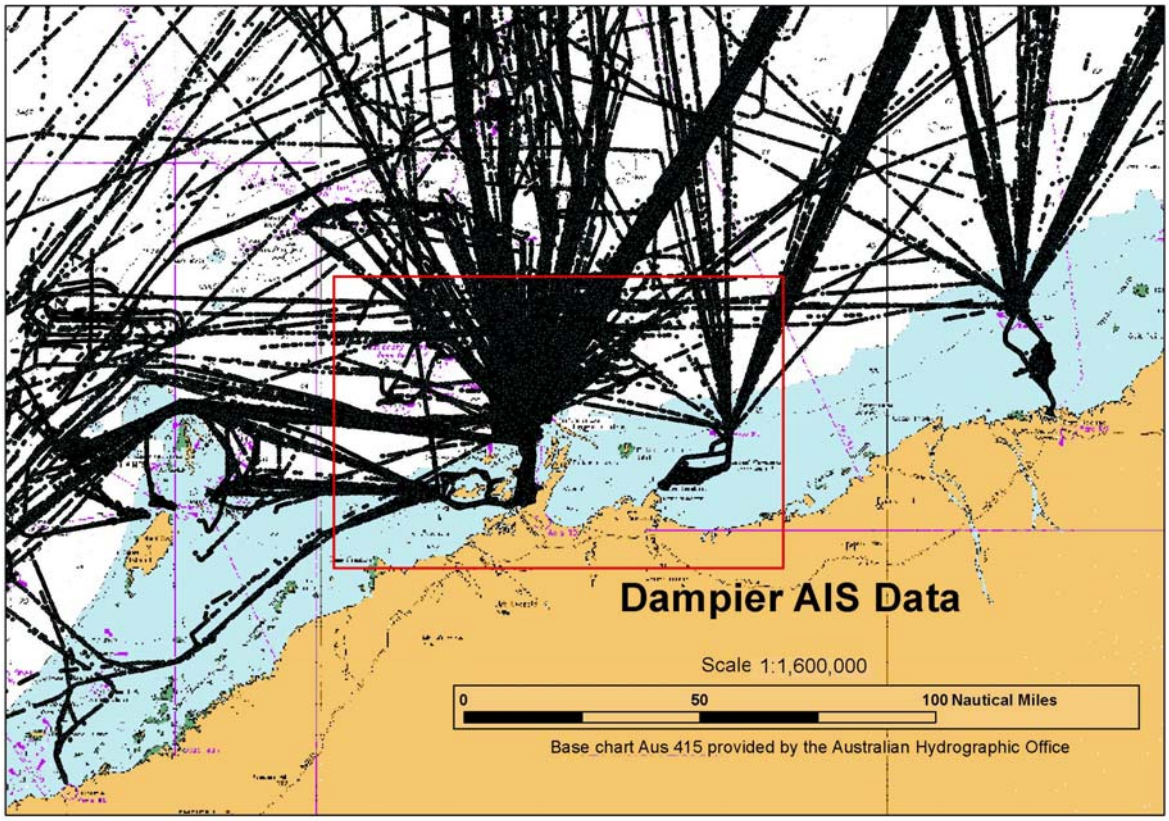



*Figure 4 – AIS data off northwest Australia (1:1 600 000)*

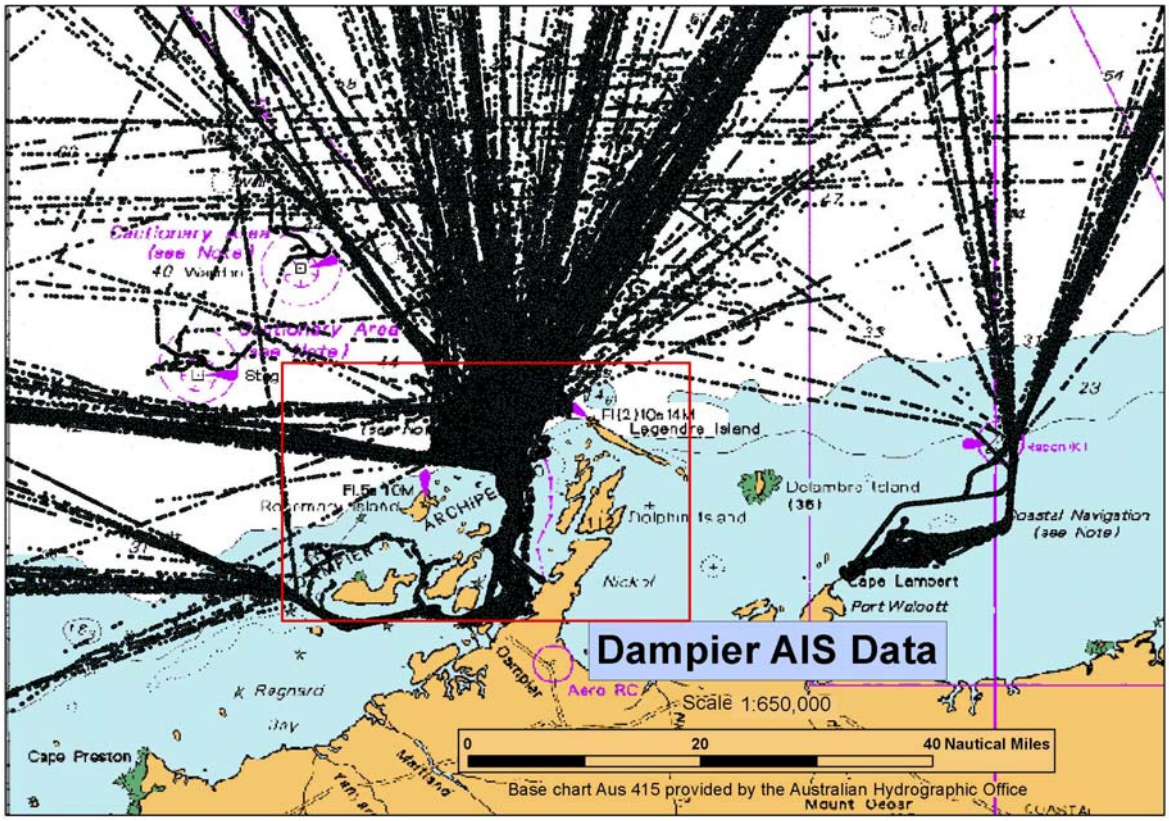



*Figure 5 – AIS data off Dampier (1:650 000)*

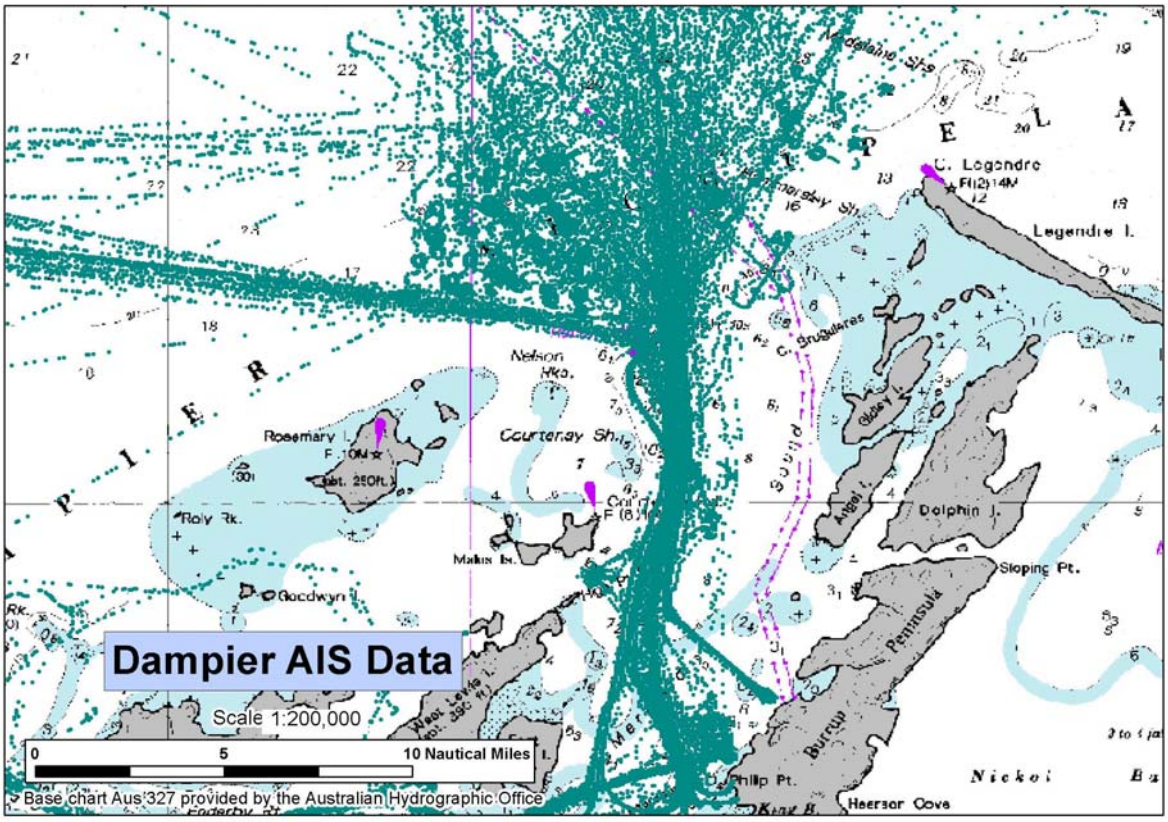



*Figure 6 – AIS data off Dampier (1:200 000)*

GIS software will permit searches based on data attributes and this functionality can be used to identify particular groups of vessels. For example, in the approaches to Dampier Figure 7 shows vessels at anchor (speed less than 1 kt – coloured brown), vessels inbound and vessels outbound (coloured red and green respectively). When reviewing the use of existing AtoN, or when planning for new AtoNs, it is useful to be able to differentiate between traffic based on these and other attributes. If the vessel data in use contains information on vessel size, type, cargo or draught, then it is equally possible to execute queries on these attributes to differentiate vessels of particular interest.

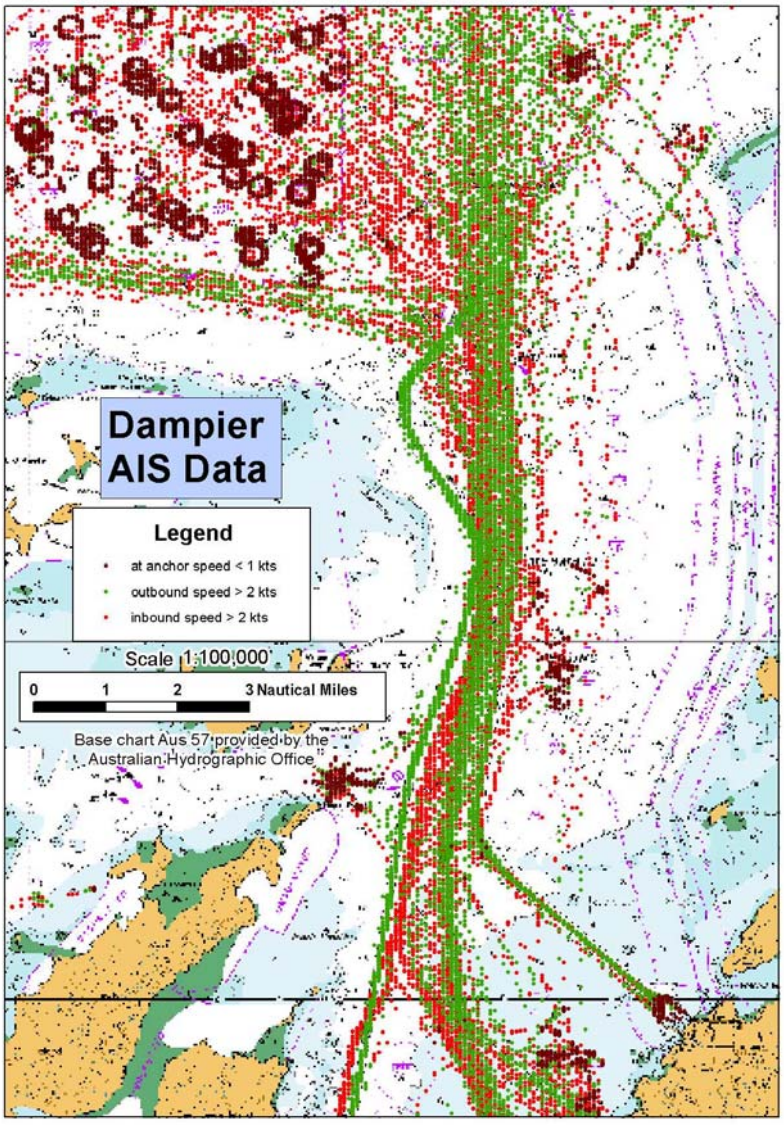



*Figure 7 – Results of a GIS software query based on vessel course and speed*

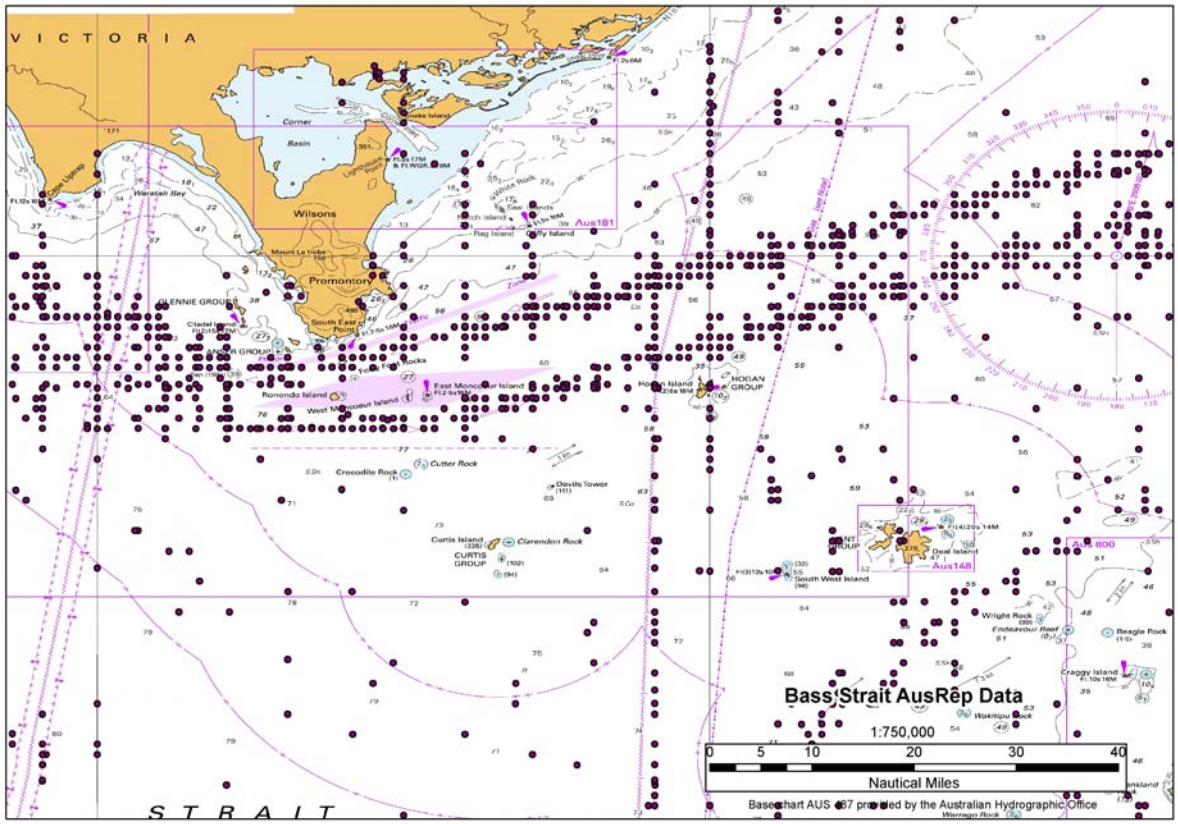



*Figure 8 – AusRep data in Bass Strait's traffic separation area*

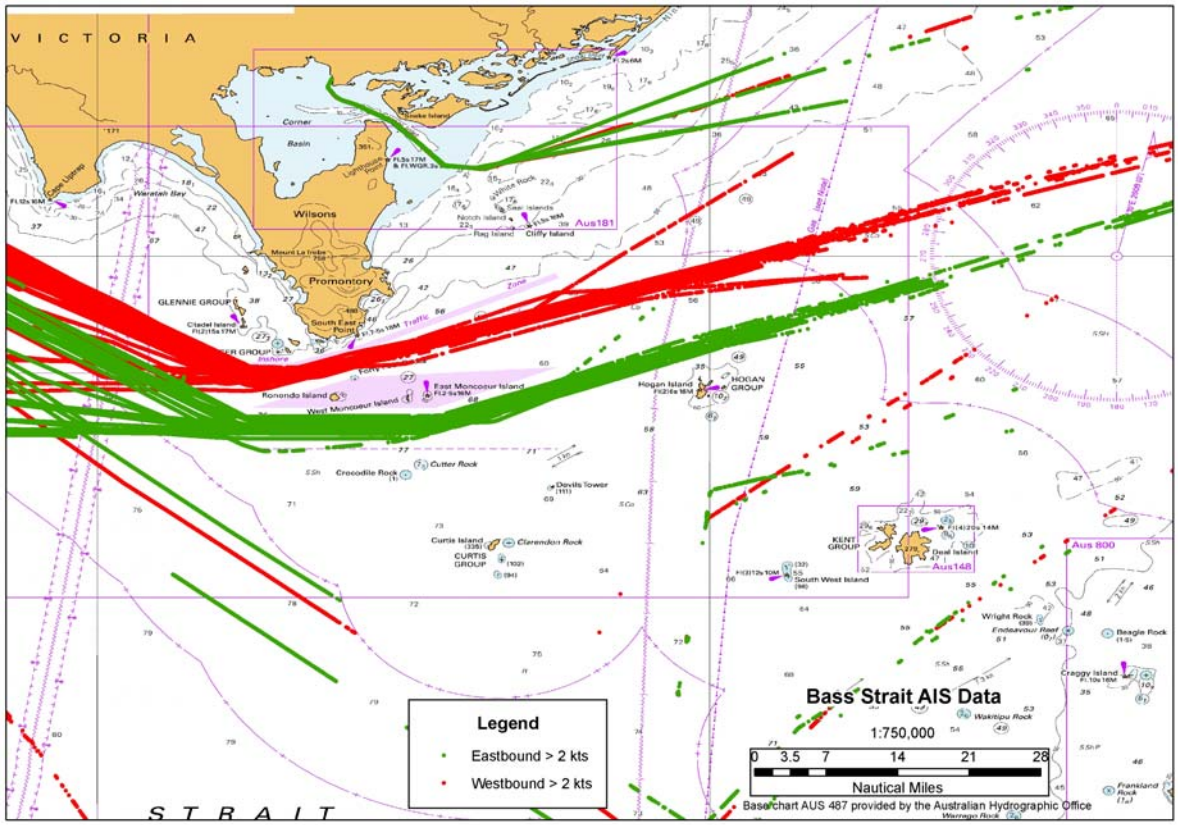



*Figure 9 – AIS data in Bass Strait's traffic separation area*

## GIS AND AtoN MAINTENANCE MANAGEMENT

In Australia there are many thousands of AtoNs ranging from major lights to small internal waterway beacons and buoys. These AtoNs are administered by a variety of organisations ranging from the Federal level (AMSA) to State government organisations as well as non-government organisations (ports).

Each AtoN organisation has a need to track the maintenance and servicing status of its AtoNs, and this is an area where the linking of existing maintenance and asset management systems with GIS can provide increases in efficiency, primarily through a more coordinated use and transfer of information.

As an AtoN authority, AMSA is obliged to report on its AtoN infrastructure, which is operated and maintained using funds provided by levies on the shipping industry. The use of electronic technology to capture, store and interrogate data about AtoN assets is quickly becoming incompatible with the capabilities of now out dated 'hard copy' information recording and reporting methods.

Over recent years there has been significant improvement in field and office computing hardware and software which now makes it possible for a shift to electronic asset information capture and management.

AtoN asset data and functions required to satisfy AMSA's needs include:

- Positional information;
- Comparison of designed build to 'as built' for new AtoN assets;
- Establishment of base data sets including aerial photography;
- Integration of electronic and structural design drawings;
- Development of data libraries;
- Provide a 'manager friendly' interface to spatial data;
- Provide reports on maintenance requirements and asset value;
- Access methods (routes and safe pathways);
- Financial statutory requirements (regular asset revaluations);
- Formulation of budget programs to adequately maintain AMSA's AtoN infrastructure using a life cycle approach, and
- Professional and private stakeholder enquiries regarding public utilities and infrastructure.

Data processing to fulfil these requirements can be handled in an electronic environment through the use of digital asset management software and other business software systems.

Web based software is now becoming available which can provide Internet access to corporate information systems, and there is an ever increasing use being made of Internet enabled GIS. Some examples include:

- Google maps (http://maps.google.com/)
- Flicker (http://www.flickr.com/map)
- Acts of piracy (http://www.icc-ccs.org/extra/display.php)
- Weather radar (http://mirror.bom.gov.au/products/IDR402.loop.shtml#image)

These examples help provide a foretaste of how navigational information can be shared and viewed.

AtoN organisations that employ contractors to establish and maintain their AtoN could benefit from the use of web enabled asset management systems with links to GIS databases. Information management and exchange between AtoN organisations and their contractors could potentially reduce workloads for AtoN organisation staff whilst at the same time improving the currency and accuracy of AtoN information databases.

AtoNs located in remote locations that suffer unforeseen defects can result in expensive and time-consuming repair activities. Even routine servicing in remote locations can mean that maintenance teams may be away from their base for several weeks at a time. In such circumstances AtoN information databases are not updated as quickly as is desirable and this has both business and operational disadvantages.

A Web based maintenance management system that uses Personal Digital Assistants (PDAs) for data capture can enable a maintenance team to enter service and repair information in near real-time with updates to the AtoN maintenance information systems being transmitted via mobile or satellite communications.

There are several advantages this scenario could offer:

- The task of updating information and report generation on return to the office is eliminated, or at least reduced,
- AtoN information distributors, such as those that promulgate radio warnings and Hydrographic Offices, could have access to updated data almost immediately,
- In the case of service information, the use of near real-time feedback from maintenance teams could be used for the timely and appropriate ordering of spare parts which would bring with it financial efficiencies, and
- Invoices and reports can be dispatched as soon as work is ‘filed’ as complete, again providing financial benefits.

AMSA has started to use PDA technology in other areas of its operations; for example, in ship inspections. In the Navigation Safety area AMSA is using a combined PDA and DGPS data logger to collect AtoN site information and to investigate the potential uses for AtoN maintenance and service information collection. An example of this particular use is provided later in this paper.

The full integration of web-based Asset Management Systems, web-based GIS, PDA devices and a centralised relational database can enable full life cycle management of AtoN networks, including asset creation, asset maintenance, and asset disposal or replacement (see Figure 10).

Such a system links GIS AtoN asset records with corresponding Asset Management System records. Users are able to edit asset information in either system, and the relational database that stores this information is automatically updated.

The system also has the functionality to transfer data between PDA devices and the centralised relational database, via the web-based GIS or Asset Management System. AtoN maintenance contractors who are required to visit AtoN sites would be able to upload data into their PDAs

before visiting an AtoN, and then update any pre-existing asset information onsite (e.g. audit inspections, equipment maintenance, equipment replacement, equipment renewal etc).

Updated information could then be sent back to the relational database via an Internet link either on site via a mobile or satellite phone, or afterwards through an accessible internet link.

This would also mean the GIS and Asset Management System users will have access to near real-time asset maintenance data.

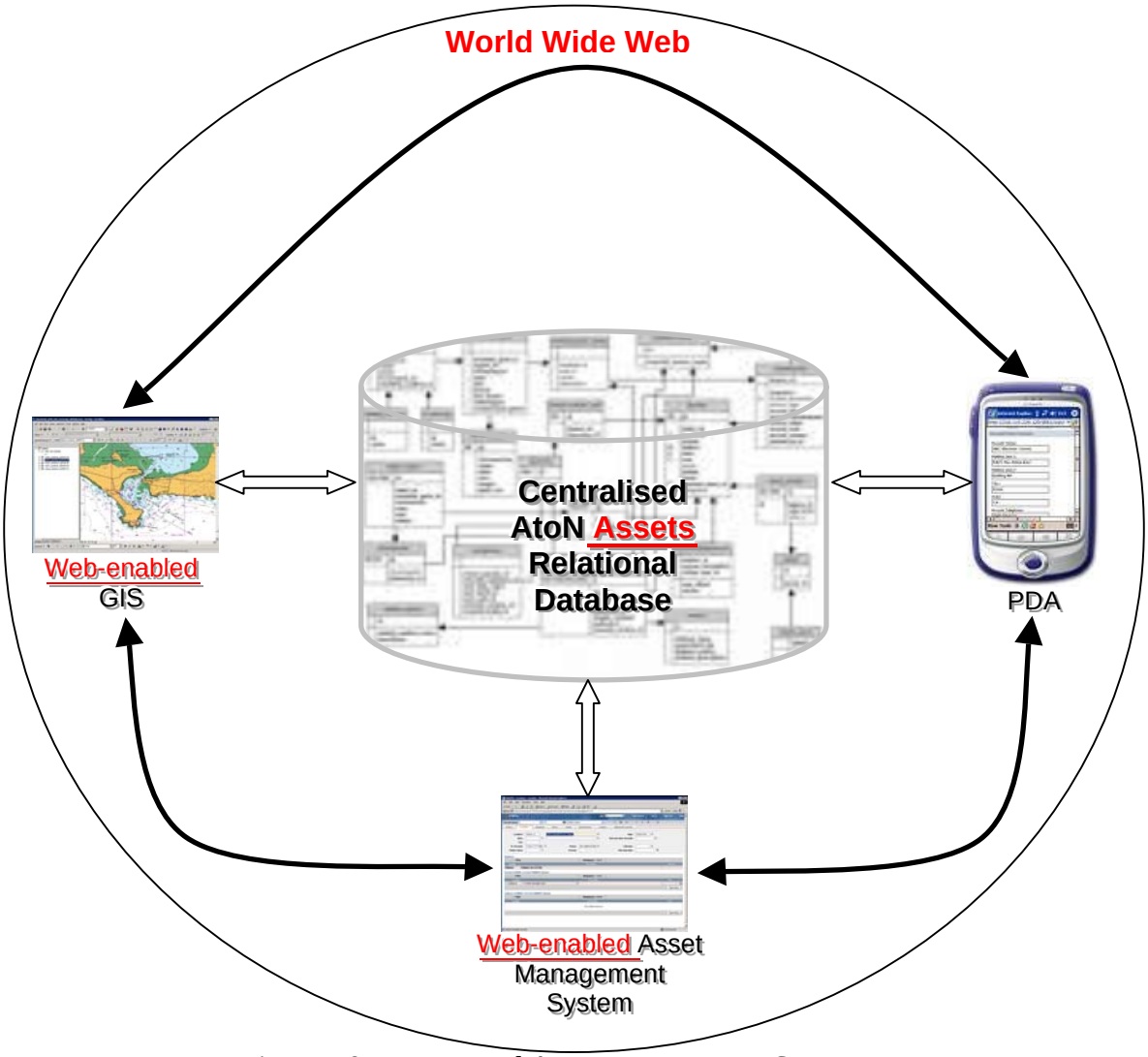



*Figure 10 – Integrated Asset Management System, GIS and relational database*

In November 2004 a detailed site survey, including AtoN data collection, was carried out at Dent Island, off the coast of Queensland. DGPS positional information, photographs and other observations were made to determine the extent of possible site work. With the subsequent use of GIS software a detailed site map was created. Figures 11 and 12 show the Dent Island data collection activity and one of the maps that was produced using GIS software upon return to the office.

*Figure 11 - AMSA officer with handheld GIS data capture device at Dent Island*

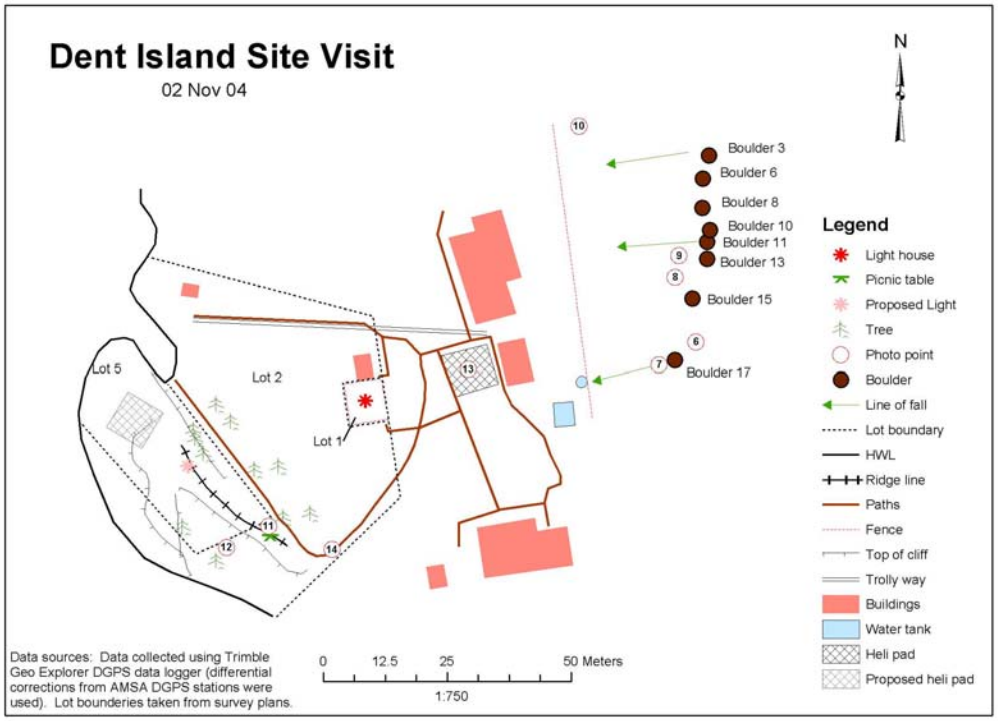



*Figure 12 – Dent Island Light GIS site plan*

## PROVISION TO MARINERS OF AtoN INFORMATION (THE AtoN INFORMATION SUPPLY CHAIN)

There is a clear need for providers of maritime information products, such as charts, publications and Maritime Safety Information (MSI), to have access to good quality and timely information about AtoNs. This is necessary in order that they in turn can issue accurate and timely information to mariners about the nature and status of AtoN.

AMSA's AtoN network of 376 sites aims to enable safe navigation for SOLAS class vessels as they approach and then traverse the Australian coast up to the point where pilotage takes over for port entry. However, in Australia there are many thousands of AtoNs ranging from major lights to smaller harbour and internal waterway beacons and buoys. These AtoNs form an interconnected network, which in turn enables seamless marine navigation for all waterway users.

The collection, management and communication of AtoN information forms a 'supply chain' which involves many information originators (the various AtoN regulating organisations/ authorities and their contractors), many information promulgators (including ports, AMSA's RCC and the Australian Hydrographic Office) and many end users (mariners). Figure 13 portrays the approximate working of the existing AtoN information supply chain in Australia.

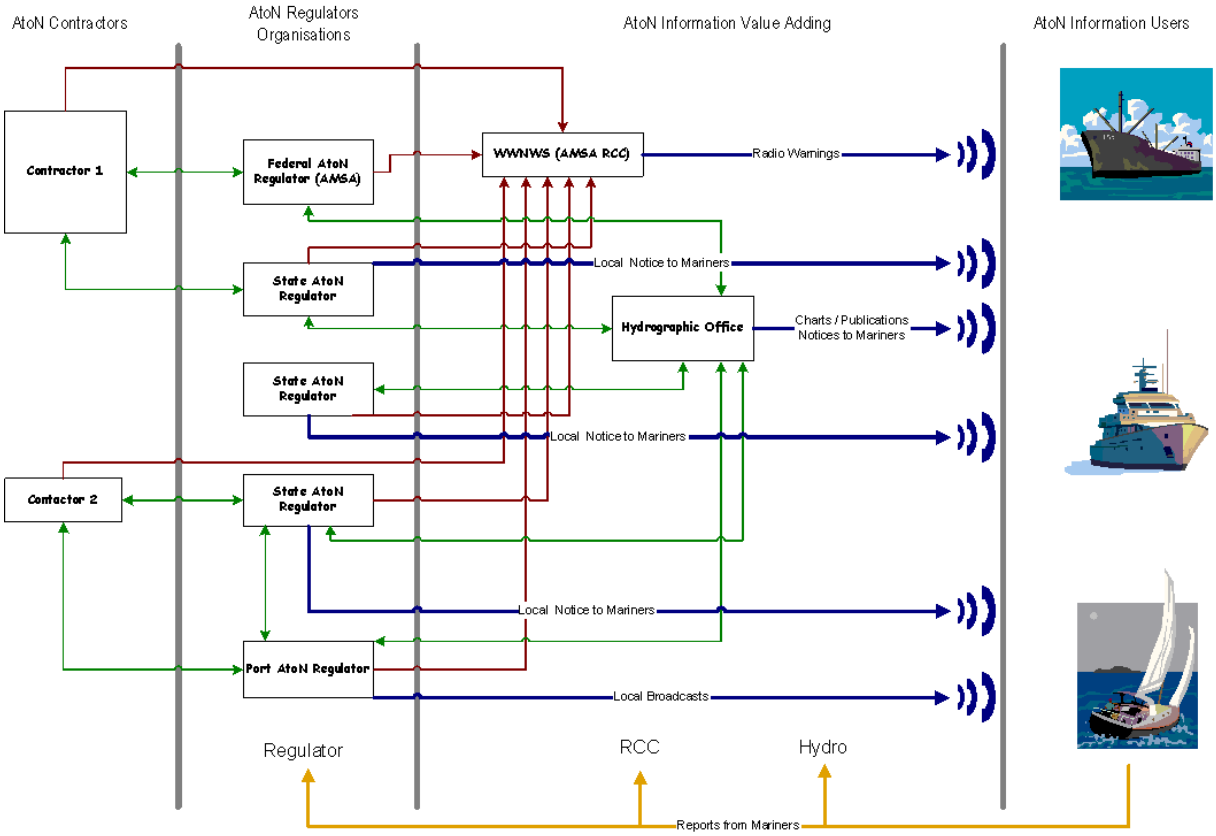



*Figure 13 – Existing Australian AtoN information supply chain*

The Australian AtoN information supply chain has developed in response to needs and operates reasonably effectively, but the volume of AtoN information is increasing as regulators are endeavouring to improve quality and timeliness of their information. Furthermore, the use of database systems by information providers (primarily the Australian Hydrographic Office and AMSA, as a World Wide Navigation Warning System coordinator) is driving a need for the originators of information to systemise their processes. The end result is that a more capable AtoN information supply chain is needed; one that will better support AtoN information provision to mariners in the future, and one that will support initiatives such as enhanced navigation (e-navigation) and electronic AtoN Service Information (eANSI).

In March 2005 AMSA hosted a two-day AtoN symposium that was attended by 50 to 60 representatives from each of the State AtoN authorities, several of the large port organisations, as well as the maritime safety authorities of Australia's near neighbours, New Zealand and Papua New Guinea. Stemming from this symposium Australian AtoN regulators have started to work collaboratively to develop ways to improve the sharing of information between regulators, but more importantly, on a strategy to enhance the quality and timeliness of AtoN information provided to mariners.

It was agreed at the symposium to form a working group to study the need for an improved AtoN information supply chain. This group is working on three objectives:

- Development of the business drivers (benefits) that will enable individual AtoN regulators to justify their participation in a national shared AtoN information system,
- Development of an initial AtoN information data standard that can be used to improve the quality of AtoN information being passed from AtoN regulators to the Australian Hydrographic Office, AMSA's RCC and other parties that provide information to mariners (eg. port operations and VTSs), and
- Investigate the technology, including web-enabled GIS that might enable a national semi-automated AtoN information management/communication system.

The use of a coordinated national AtoN information management/communication system has the potential to simplify the AtoN information supply chain at the same time as improving quality and timeliness. An example of what this might look like is shown in Figure 14.

Furthermore, when the flow of AtoN information is mapped out in this way, it becomes apparent that there are presently many avenues by which information is transmitted to mariners. In the years ahead, as initiatives such as e-navigation and eANSI are progressed, questions need to be asked about what information the different mariner segments require and what methods should be used to provide (transmit) this information. With the move towards electronic systems supporting navigation for the majority of mariners, it is suggested that regional MSI pools could collate all MSI for onward electronic promulgation in a format that could be automatically added to onboard navigation information display systems. Such systems could manage and appropriately present the information mariners require.

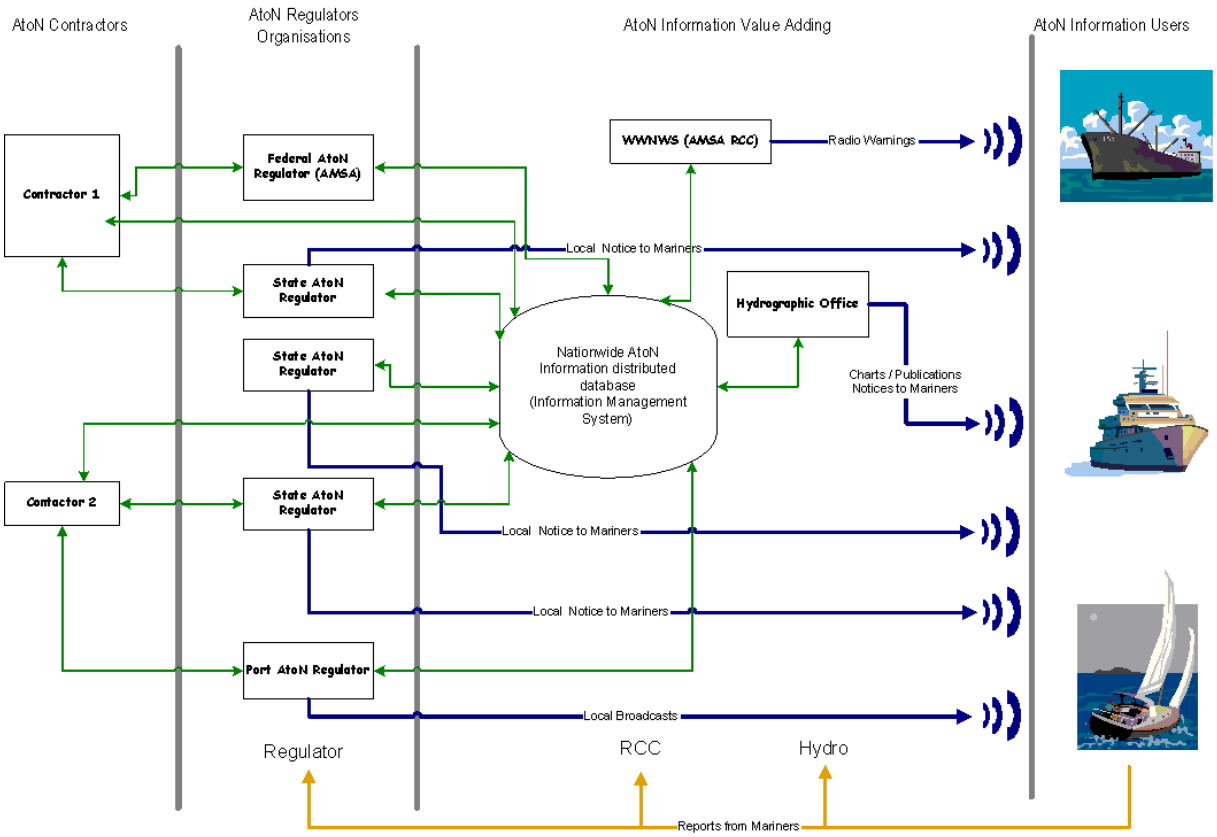



*Figure 14 – Potentially simplified and more efficient AtoN information supply chain*

## CONCLUSION

AMSA is actively pursuing the application of GIS and other information management and communication technologies to its AtoN planning and management roles. AMSA, through its membership of IALA would like to encourage other AtoN providers to also consider the use of GIS for the purposes outlined in this paper.

The use of GIS technology to display and model AtoN networks in relation to shipping patterns described by ship position data (derived from reporting systems, vessel traffic systems or AIS) can assist in design of new AtoN networks and the review of existing networks.

Areas in which AtoNs need to be linked in their operation to other AtoNs, particularly in pilotage waters, makes it possible to rationalise the number of AtoNs required in a network whilst at the same time enabling networks to be made more intuitive to use.

In the area of AtoN maintenance, GIS and other asset information management systems have been identified as being able to produce efficiencies. Maintenance and service information can be automatically exchanged between owner organisations and contractors to reduce staff workloads as well as the chance of errors being made. More significantly there are opportunities to improve business effectiveness and hence reduce costs.

In Australia the use of GIS and other information management technology is being explored to bring about better AtoN information management and communications in the AtoN information supply chain. It is hoped that a greater degree of systemisation and the use of

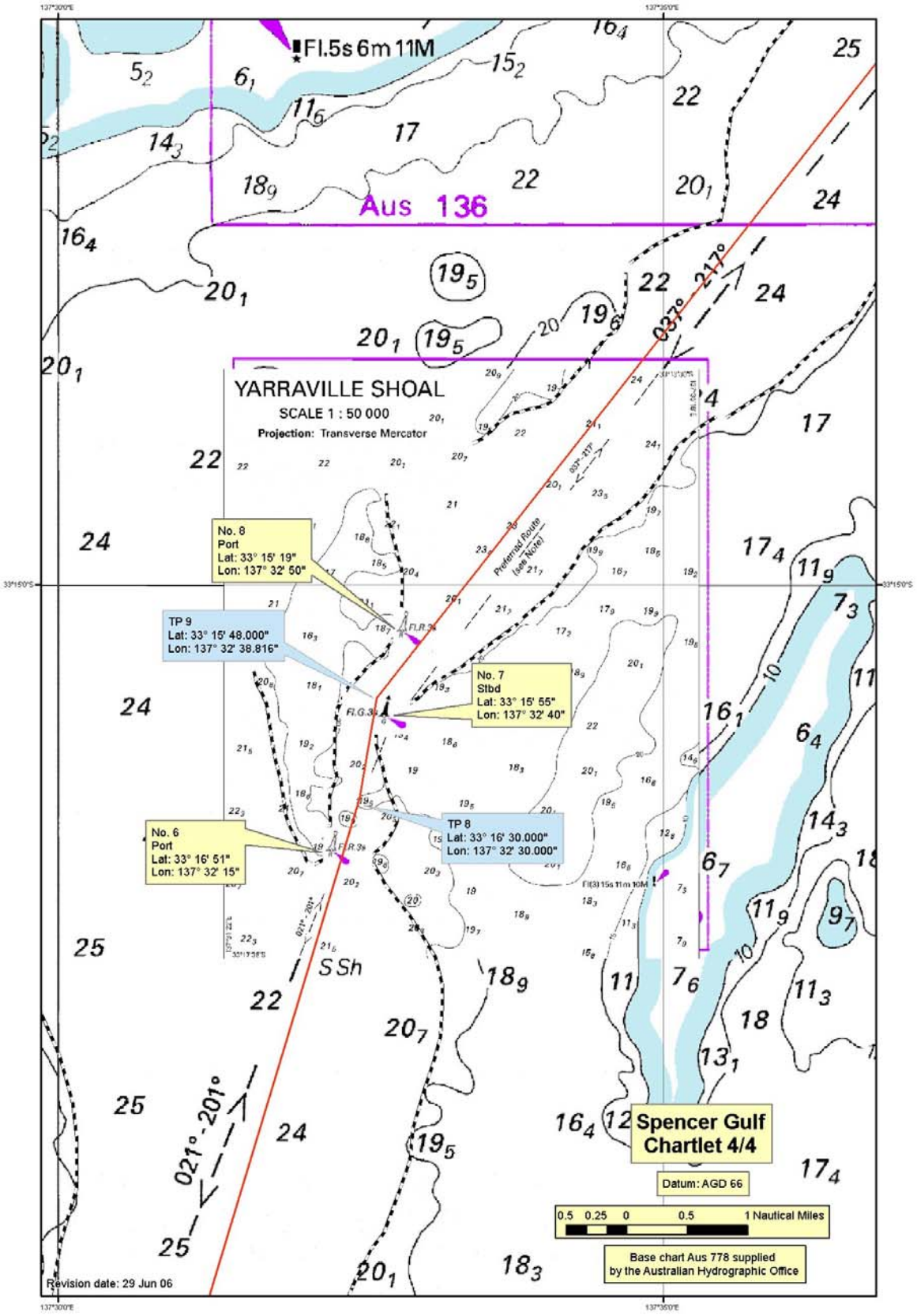
distributed database technologies and/or Web enabled GIS will improve the quality and timeliness of information available to mariners. This application of GIS may also be of benefit to other IALA members.

All of the uses of GIS technology described in this paper help underpin the safety of navigation for mariners, who are increasingly relying on computerised automation underpinned by a ubiquitous use of satellite positioning. In the future it is not unrealistic to expect that mariners will require the provision of information in a way that can be automatically assimilated with onboard digital navigational information. This requirement needs to be considered as IALA's eANSI and e-navigation initiatives are developed.

**Annex:**

A. Spencer Gulf route design diagrams

## Spencer Gulf route design diagram 1



# Spencer Gulf route design diagrams 2