Wetland vegetation mapping using a Global Positioning System

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Payne, Robert[1] & Harty, Chris[2] ([1]15 Mountain-Ash Way, Umina Beach, NSW 2257; [2]Corangamite Shire Council, PO Box 84 Camperdown,Victoria 3260). Wetland Vegetation Mapping using a Global Positioning System. Cunninghamia *5(3): 633–643.* A methodology for mapping wetland vegetation of coastal wetlands within the City of Gosford, including those listed under State Environmental Planning Policy No. 14, is described. The methodology and principles, including their advantages and disadvantages, are explained. They may have further application for other large scale vegetation and fauna habitat mapping projects. The outcome of the project is seen to be important for preparing a conservation plan for the wetlands.

Introduction

Local Government plays a pivotal role in planning and controlling development within wetlands in New South Wales. Local Council is, in most cases, the decision making authority responsible for assessing and approving Development Applications and as such has responsibility for ensuring that all due consideration is made for wetland protection throughout this process.

Coastal wetlands within NSW are the subject of State Environmental Planning Policy No. 14 — 'Coastal Wetlands'. The aim of the Policy is to ensure that the coastal wetlands are preserved and protected in the environmental and economic interests of the State of NSW. SEPP 14 applies to the City of Gosford, in the general vicinity of the seaboard estuarine fringe where coastal lagoons, rivers and creeks are associated with wetlands.

The Brisbane Water Area Wetland Management Study was initiated and formally adopted by Gosford City Council in September 1993. The aim of this study was to accurately map all wetland vegetation in the Gosford Local Government Area and describe the status of each site. With this information the following objectives were considered attainable.

- Establish a Priority List of sites of community value which are in Public Reserve.
- Amend the boundaries of State Environmental Planning Policy No. 14 (SEPP 14) to ensure that they accurately reflect the ecological significance of the wetlands.
- Provide base data for Development Control Plans, Local Environmental Plans and Site Specific Management Plans.
- Provide information for the assessment of developments in wetland catchments.

An initial study (Jones 1991) identified over 50 wetland sites within the Brisbane Water and estuarine area which were considered as ecosystems worthy of conservation for the following reasons.

Wetlands:

- have a limited distribution due to Australia's dry climate (Giles, 1983).
- support a unique array of native mammals, reptiles, fish, amphibians, flora and waterbirds (Giles 1983).
- are sometines of critical importance to internationally important migratory wader birds (Giles 1983).
- can provide drought refuge for native fauna (Giles 1983).
- form the basis of fish food chains (Harty 1997).
- provide for a range of recreational experiences (Harty 1997).
- act as flood retardation areas (Briggs 1983).
- filter nutrients and sediments from runoff entering waterways (Harty 1997).

In accepting the study, Gosford City Council adopted a Wetland Strategy which, amongst other things, included amending the boundaries of SEPP 14 Coastal Wetlands to ensure that they accurately reflected the ecological significance of wetland communities. Gosford City Council was also to produce a Local Environmental Plan and Wetland Management Strategy. This procedure was to ensure greater protection of wetlands and improved integrated management of wetlands into the long-term.

However, when it came to implementing the Wetland Strategy it was found that the quality and accuracy of the mapping did not provide accurate enough information for zoning purposes or to locate the boundaries of the identified wetlands on the ground and on the Planning Scheme Maps. Pressure from development, however, required a means had to be found for redefining the SEPP 14 wetland boundaries in relation to cadastral boundaries.

Standard methods for mapping vegetation and fauna habitat use aerial photography or satellite imagery combined with ground truthing. In recent years the introduction of Geographic Information Systems (GIS) and Global Positioning Systems (GPS) have improved the potential and capability of mapping. In particular, the use of GPS has application for identifying the boundaries of sensitive habitats at large scales (Payne 1996a).

The aim of this project was to determine how accurate and efficient the use of the GPS could be applied to the wetland project. At the time the accuracy and efficiency of the GPS for mapping vegetation was uncertain because of the presence of the canopy covering the vegetation. However, a quick and efficient method with a relatively high degree of accuracy for defining wetland boundaries based upon vegetation and the degree of inundation was needed. GPS was considered to have potential, although it had not been previously trialed for wetland mapping.

The project involved over 50 wetland sites of various sizes. The methodology involved may have potential for other mapping projects, especially for defining sensitive flora and fauna habitats that may be required for identification and management under the New South Wales Threatened Species Conservation Act, 1995.

Location

State Environmental Planning Policy No. 14 (SEPP 14) applies to the City of Gosford in the general vicinity of the estuarine fringes where coastal lagoons, rivers and creeks are associated with wetlands. The Policy does not apply to the wetlands associated with the Hawkesbury River and its tributaries which are located west of the coastal escarpment but also within the City boundaries. Those areas are subject to State Regional Environmental Plan No. 20. Sydney Regional Environmental Plan No. 20 covers the Hawkesbury-Nepean River system and is a landuse planning instrument prepared under the New South Wales Environmental Planning and Assessment Act, 1979. The aim of the Regional Environmental Plan No. 20 is to protect the environment of the Hawkesbury-Nepean River System, including all of the riparian wetlands, by ensuring that the impacts of future landuses are considered in a regional context. The wetlands surveyed during this exercise incorporate all the coastal lowland areas located east of the Brisbane Water National Park and the Somersby-Kulnura Plateaus.

Methods

Most of the wetlands were initially identified by Adams et al. (1985) and then subsequently updated by Jones (1991). The database involved over 50 wetland sites and if the additional wetland sites identified by Jones (1991) were to be included the number almost doubled. Furthermore, Jones (1991) included all the Swamp Mahogany forests that have since been identified as being 'keystone' habitat for a large number of nectivorous animals and habitat for at least nine threatened species (Payne 1996b).

In both cases aerial photography was used to map the wetlands at medium to small scales (1: 16 000 and 1: 25 000). This has led to inaccuracies when used in conjunction with property boundary information. The problems considered to be issues were :

• Aerial photographs have a variable scale over every point on a photo and in general 'rectified' photos are not available.

• The identification of wetland vegetation on aerial photographs is only partially accurate and is limited by how well the structural detail of the vegetation can be seen.

• There are now extensive public reserve areas which are mown and merge into the wetlands. The identification of the remaining wetland vegetation (herbland and grassland) in these circumstances, using aerial photography, is difficult.

During 1996 GPS technology was used to revise the boundaries of all the wetlands listed under SEPP 14 within the City of Gosford. The project took twelve months to complete and involved the use of a differential GPS and the 'OmniSTAR' network system.

Two personnel were involved in the survey. A botanist was required to identify the vegetation boundary and to measure any offset distances and bearings, and a surveyor operated the GPS (Fig. 1). A portable backpack type 'Trimble' GPS coupled to the differential GPS service was used which involved the 'OmniSTAR' network system. The 'OmniSTAR' system involves a number of reference stations located throughout Australia and New Zealand which have been accurately connected to the Australian

Fiducial Network. All of these reference stations use high quality geodetic receivers which transmit GPS corrections every second to the National Control Centre (NCC) in Perth. Following rigorous quality checks, the corrections are broadcast through the Optus B1 satellite. The GPS receiver and 'OmniSTAR' demodulator are used whereby corrections to coordinates are updated every two seconds. This method can give an accuracy of ± 1 m in position as compared to true Integrated Survey Grid (ISG) coordinates as determined by McKinleyside & Bannister (1995).

The boundary of the estuarine wetland was determined as the landward limit of the SEPP 14 wetland as documented by Adam et al. (1985). This boundary was based upon plant species (vegetation) and/or the zone of inundation. For the Swamp Mahogany forest the landward limit was joined onto the SEPP 14 wetland boundary. Vegetation boundaries were then presented as a series of coordinated fixed points which on a plan are represented as a series of connected straight lines rather than curved lines.

Fig. 1. Surveyor (David Gee) with GPS equipment used in the study.

The distance between coordinated points was variable and was dependent upon the changes in direction of a vegetation boundary and capability of access through the vegetation with the GPS equipment. The total distance between any two coordinated points on the boundary, however, never exceeded 100 m. Once a boundary was surveyed in the field, the coordinates were downloaded into a computer and subsequently overlaid onto the cadastral database. The resulting map product, in digital format, then has the advantage of being able to be reproduced at a number of map scales. Furthermore it is available as a set of coordinates to be further used by a surveyor to locate the wetland boundary in the field.

Results

Technological issues

The availability of satellite signals and topographic position were the two main problems encountered during the survey. Although over 30 satellites are available from which to receive signals their positions are at times not optimal to achieve a coordinate fix of sufficient accuracy. Precision Dilution of the Point (PDOP) varies over time during the day and a coordinate fix will not be achieved unless the PDOP is less than 6.0 on the vertical scale. For example, from Fig. 2 it can be seen that optimum times for signal availability at Hardys Bay on 26 February 1997 occurred between 0800 and 0930 hours and between 1045 and 1130 hours. Access to satellite signals cannot be achieved throughout all of the day, limiting the efficiency of the GPS for such projects.

The position of the wetland in relation to the topography can also be a constraint. Satellites are present in the northern hemisphere and access to signals is best achieved with the antennas having a line of sight to the northern sky. During this survey, difficulties were encountered where the escarpment and ranges blocked signal access to the northern sky even though access to the satellites was still possible in the eastern and western skies. Access to the northern sky from Hardys Bay on 26 February 1997 was blocked by the escarpment, and this also limited the time that signals were available (Fig. 2). Fig. 3 shows that at this location satellites 25, 15, 29, 14 and 16 were available in the western sky at this time. Thus prior prediction of satellite availability became extremely relevant during the project at particular locations.

Within the City of Gosford, estuarine wetland vegetation communities vary from closed herblands dominated by *Sarcocornia quinqueflora* to semi-closed forests of *Casuarina glauca.* Most importantly the vegetation varies in structural composition and as structural complexity and height of the vegetation increases, available light to the forest floor decreases. This factor has important implications with respect to accessing satellite signals and defining the wetland edge.

Access to satellite signals was achieved easily whilst surveying through the *Sarcocornia samphire* meadows and in open forest eucalypt vegetation (Swamp Mahogany forest). In the latter vegetation type, if a signal could not be achieved, it meant moving a short distance from the desired point and obtaining the signal at an offset point. In these

Fig. 2. Computer output from the GPS software showing both the availability of satellites and the PDOP for Wednesday 26 February 1997 at Hardys Bay. The threshold elevation was 15 degress and 27 satellites were considered.

circumstances, an offset bearing and distance was taken and entered into the GPS logger which automatically adjusted the coordinates to those of the desired point.

Some difficulty, however, was encountered beneath the forests of *Casuarina glauca.* The dense foliage of these trees blocks satellite signals. In these circumstances, substantial traversing had to be undertaken to coordinate the boundary of the vegetation. It was considered, therefore, that the boundaries derived for these forests may have a greater degree of variance using the GPS technique.

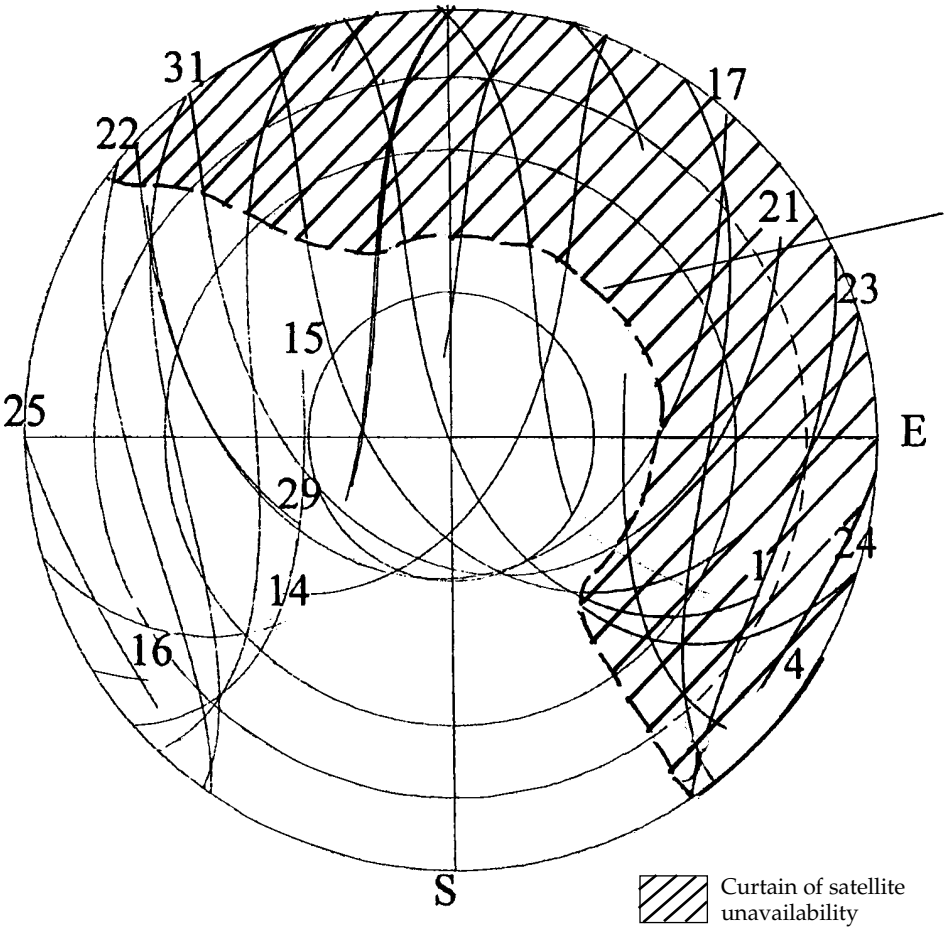

Fig. 3. Computer output from the GPS software showing the position of the satellites given certain threshold levels for the topography. The output is for Hardys Bay and shows that satellites 25, 15, 29, 14 and 16 are available in the western sky on that day. The threshold elevation was 15 degrees and 27 satellites were considered.

Vegetation

The field definition of the wetland boundary using plant species was found to be relatively easy. Dominant reeds, sedges, herbs and grasses were used as indicator species. Such species included *Selliera radicans, Schoenoplectus littoralis, Sporobolus virginicus, Cotula australis* and *Cotula coronopifolia.* Such a method has been previously outlined by Winning (1993) for the wetlands in Wyong Shire, where the following criterion was used: 'wetlands occur on lands on which non-estuarine water ponds or is capable of ponding to a depth of 0.12 metres or more, over 70% or more of its total surface area.'

The boundaries that were mapped in this study involved the foreshore fringe and Swamp Mahogany vegetation of the Brisbane Water, Narara, Kincumber and Erina Creeks and the coastal lagoons — a length in excess of 70 km. Overall the task took twelve months to complete working an average of two to three days per week. Access to the vegetation of the Brisbane Water foreshore was relatively easy because of the many pathways, tracks and boat ramps which lead into the wetlands.

The criterion developed by Winning (1993) strictly relates to those wetlands having conservation value, because many of the wetlands in Wyong are disturbed from past pastoral activities. For our survey all wetlands were remapped according to the database prepared by Jones (1991). Some wetlands could never meet the criterion of conservation value prepared by Winning (1993) and in some cases the wetlands could never meet the SEPP 14 criteria. Under these circumstances Gosford City Council still required the information on these wetlands for inclusion under a separate Local Environmental Plan.

Discussion

Our wetland boundary information will now enable Gosford City Council to prepare a Local Environmental Plan and to introduce a protective zone for wetlands. The technology has raised the standard of mapping for SEPP 14 Coastal Wetlands administered by the NSW Department of Urban Affairs and Planning and may have pioneered a new era for defining the boundaries of those coastal wetlands. The mapping system developed with the use of GPS in conjunction with GIS at an individual wetland scale (Payne & Palmer 1997) will help the protection of some unique and valuable ecosystems in the state.

Our results indicate that high orders of accuracy can be obtained for defining a vegetation boundary provided that a repeated series of coordinates is obtained at each point surveyed. As normal procedure the survey involved remaining at the desired point to be coordinated for 15 seconds (where 15 fixes were obtained and meaned) to obtain a more accurate position from the satellites. In denser vegetation the same procedure could take as long as one minute depending on the signals. As a check numerous state survey marks were coordinated during the wetland traverses and 'tied' into the vegetation boundary survey. It was found that high orders of accuracy could be obtained when a comparison was made with true Integrated Survey Grid (ISG) coordinates (e.g. ± 1.5 m).

Mapping vegetation using GPS avoids digitising a line on a map for the boundary. The coordinates obtained for each point in the field are downloaded directly into the computer and reproduced as a set of points on a map with a grid and with the cadastral database if desired. The method is very efficient and only requires the points to be joined by a straight line in the computer. A disadvantage is that the boundary becomes a series of straight lines whereas in conventional GIS mapping a curved line traced from an aerial photograph can be digitised as the vegetation boundary.

The GPS technique can be time-consuming due to satellite unavailability at certain times. However, it does have the advantage of being accurate and it is certainly accurate enough to define a vegetation boundary. Our experience has shown that orders of accuracy of ± 1.5 m are obtainable in ideal circumstances. The method revealed that some boundaries shown by the earlier methodology prepared by the Department of Urban Affairs and Planning (Adam et al. 1985) are in error by up to 50 m in position, for example Terrigal Lagoon (Fig. 4).

Accuracy of locating a wetland vegetation boundary is important particularly where private property developments are concerned. Gosford City Council, as a result of this exercise, will now be anticipating an update of the SEPP 14 boundaries through the Department of Urban Affairs and Planning both on their mapping GIS system and on the ground. Council will also be able to establish appropriate protective zonings for all coastal wetlands (not just SEPP 14) using either a 7(g) Wetlands Management Zone or the 7(a) Conservation Zone under a Local Environmental Plan. Council will also be able to develop a more detailed Wetland Management Strategy which would incorporate a set of management prescriptions that can ensure the proper management of wetlands and their ecological functions with cooperation from other State Government departments, private landholders and the general community.

The methodology requires that an entire wetland boundary line be traversed and although the method would appear to be time-consuming it is necessary to re-establish the full length of a boundary. Access is therefore required to all of the wetland and during this survey only one section of one wetland was encountered which could not be traversed. This occurred in a section of low closed forest of *Melaleuca nodosa* which had to be mapped. The antennas associated with the GPS equipment are 2 m high and the GPS is carried in a backpack — the dense vegetation made access with the equipment impossible.

Conclusions

The wetlands of the City of Gosford make an important contribution to the character of the estuarine systems of Brisbane Water. However, there is pressure on the wetlands from development and there is a need to integrate the development within an overall conservation plan for the wetlands. To achieve accuracy, ground location of wetland boundaries is required. GPS in conjunction with GIS has potential for updating the boundaries of wetlands for this purpose. The method can be slow depending upon the availability of satellites and topographical constraints. However, this project proved to be

accurate and such accuracy will contribute to the conservation and management of wetlands.

One of the main conclusions derived from the survey was the presence of a zone of deterioration at the wetland boundary. This zone was found wherever fill was placed against a wetland for the purposes of development whether it be for a playing field or a housing estate. The zone of deterioration is caused by the encroaching fill material which gradually creeps onto the wetland and becomes colonised by exotic grasses and weeds. Only in certain circumstances was this zone absent, such as when a sandstone retaining wall was placed to support the fill material and prevent soil creep. Measures should be undertaken to ensure that developments do not infringe on wetland edges and that fill material is effectively retained on the development site.

Acknowledgments

We wish to thank all of the staff of Trehy, Ingold and Neate for data collection and preparation of the wetland boundaries. David Gee and Craig Palmer undertook the GPS survey and computer techniques. Mick Glossop gave advice on satellite technology. We would also like to thank Gosford City Council for allowing us to trial GPS. Doug Benson and the editorial committee are acknowledged for editing the manuscript and Margaret Payne for word processing.

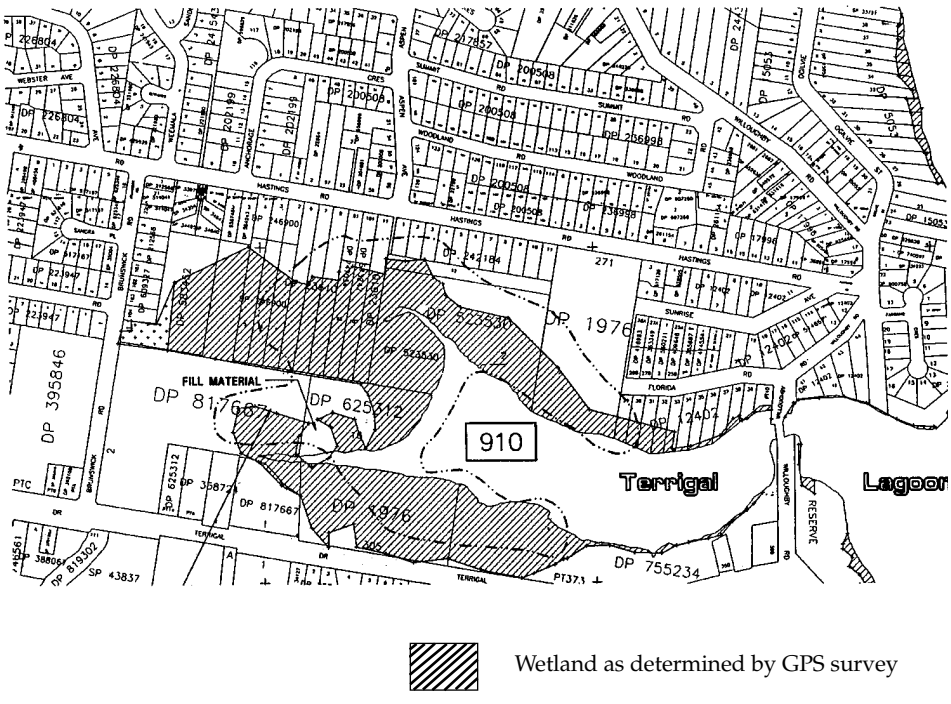

Fig. 4. Terrigal Lagoon showing the SEPP 14 boundary (_ .. _ .. _) and the same boundary determined by GPS survey. Note there ae large differences in position.

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Manuscript accepted 8 May 1998