REMAPPING OF SEPP 14 WETLANDS IN THE SHOALHAVEN DISTRICT.

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Abstract

A photogrammetric survey of SEPP 14 coastal wetlands within the Shoalhaven City Council area from aerial photographs dating 1981 and 1997 revealed significant changes in wetland extent. Differences were frequently related to temporal changes in wetland extent due to environmental factors and development. A number of wetlands not identified as coastal wetland in the original SEPP 14 mapping were identified. The most significant of these is within the Currambene Creek estuary and was later gazetted following an amendment to SEPP 14. Given the changes in wetland extent since SEPP 14 was gazetted and the omission of several wetlands from SEPP 14 legislation, it may now be appropriate to review SEPP 14 boundaries using current image processing and GIS based technologies. Furthermore, wetland boundary delineation would be enhanced as current technology has a higher order of accuracy and can incorporate buffer zones into mapping if appropriate.

Introduction

The introduction of State Environmental Planning Policy 14 (Coastal Wetlands) in 1985 was an important step in the conservation of coastal wetlands in New South Wales. The two basic aims of the survey of Adam *et al.* (1985) were to identify the state's coastal wetland resources for gazetting under SEPP 14, and to provide a baseline inventory and a framework for ongoing evaluation of the wetland resource of the coast.

The present survey reviewed the boundaries of SEPP 14 wetlands within the Shoalhaven City Council area. This does not alter the status of SEPP 14 wetlands as they are gazetted under the provisions of the policy. However, remapping coastal wetlands provides a useful foundation for the process of altering their status, particularly given the dynamic nature of wetland boundaries and the developments in mapping technology since the original survey was undertaken nearly 20 years ago.

As in the original survey, the accuracy of mapping was limited by the amount of ground-truthing and boundaries were determined based on aerial photograph texture and geomorphic context. Given the developments and availability of geographic information systems and digital imagery it was anticipated that significant differences would emerge between present and past mapping.

This survey aims to highlight the methodological differences between the original SEPP 14 wetland mapping and current GIS based techniques for delineating wetlands. In addition, it also highlights the dynamic nature of wetland boundaries, and the need for review of SEPP 14 wetland boundaries

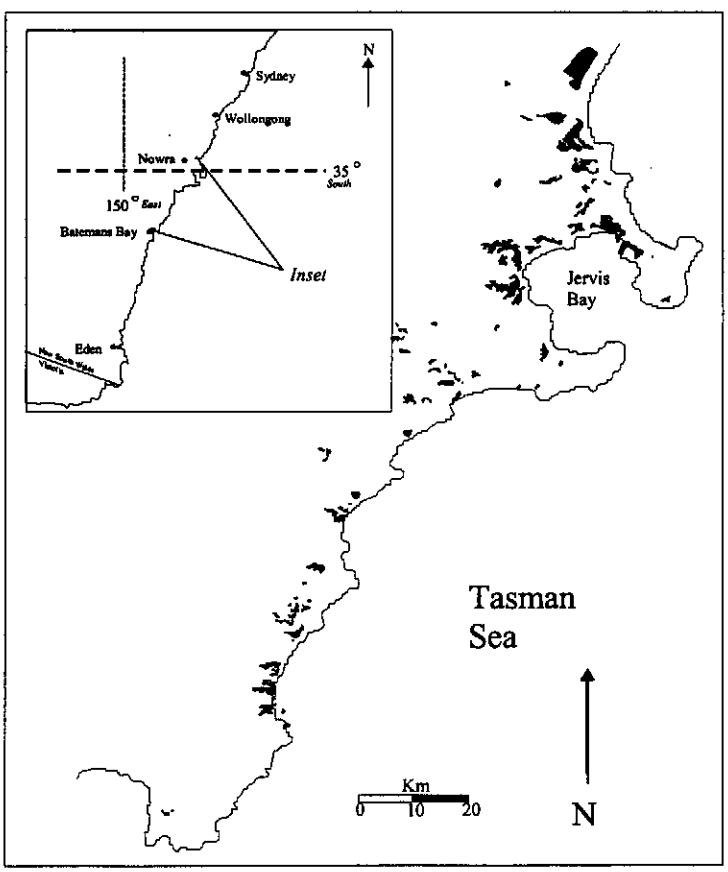
and re-evaluation of the wetland resources of the coast.

Methods

The study sought to map all SEPP 14 wetlands in the Shoalhaven City Council local government area from 1981 aerial photographs, which were utilised in the original SEPP 14 wetland delineation and 1997 aerial photographs. The relevant area extends from south of Gerroa (35°47'00" S, 150°45'00"E), incorporating SEPP 14 wetland 370 (Coomonderry Swamp), south to SEPP 14 wetland 253 on Durras Lake (35°37'30"S, 150°15'00"E) (Figure 1). The survey encompasses 117 wetlands mapped by Adam *et al.* (1985) and an additional 10 wetlands that conformed to the definition of coastal wetland in Adam *et al.* (1985) but were not originally gazetted as SEPP 14.

The 1981 aerial photographs, at a scale of 1:25000, and 1997 aerial photographs, at a scale of 1:50000 were scanned and saved as digital images. The 1981 and 1997 photographs were scanned at 150 dots per inch and 300dpi, respectively, so that image resolution was consistent between the 1981 and 1997 aerial photographs. Digital images were imported into the ArcView (*ESRI Inc.* version 3.2) geographic information system (GIS). Using the ArcView Image Analysis extension (*ESRI Inc.* version 1.0), images were georectified to Australian Map Grid co-ordinates using a minimum of six ground control points for each image (Wilton & Saintilan 2000). Ground control points were identified from relevant 1:25000

Figure 1: Location of wetlands



topographic map sheets. During the georectification process, a root mean square (RMS) error of ±5m was deemed acceptable.

Wetland boundary delineation was achieved at the image resolution using on-screen digitising techniques. SEPP 14 wetlands were discriminated from the surrounding vegetation using the mapping of Adam *et al.* (1985) and on the basis of structural, tonal and colour differences in the enlarged digital images, geomorphic context and general ground reconnaissance in the area. Additional wetlands not gazetted as SEPP 14 coastal wetlands were also identified based on the botanical definitions of Adam *et al.* (1985), thereby not including littoral rainforest due to its inclusion in SEPP26 (littoral rainforest) and wet heath due to its indiscernible gradation into dry heath.

SEPP 14 wetland coverage was determined and changes in the extent of wetlands between 1981 and 1997 analysed. Mapping was guided by the extent identified and ground-truthed by Adam *et al.* (1985), however limited ground-truthing was performed in May 2000 to determine the accuracy of wetland boundary delineation from the 1997 aerial photographs. While substantial changes in the species composition of boundaries may have occurred between 1997 and 2000, this was the best accuracy check that could be performed at the time as current aerial photographs were not available.

Results

SEPP 14 wetland extent in 1981 and 1997 are summarised in table 1. The estimated area of wetlands not previously classified as SEPP 14 is summarised in table 2. Frequency histograms of wetland area change (in hectares and proportion) are illustrated in figures 2 and 3. Wetland extent increased by an average of 5.87% between 1981 and 1997 within the Shoalhaven City Council area. A number of wetlands increased extent by greater than 50%, while SEPP 14 number 266 (Figure 4 and 5) increased extent by 113%. Alternatively, wetland losses at individual sites did not exceed 30%, with the exception of SEPP 14 number 352, which underwent significant coastal development (Figure 6 and 7).

Table 1: Changes in SEPP 14 wetland extent between 1981 and 1997, as interpreted y the authors.

SEPP 14 No.	1981 Area (ha)	1997 Area (ha)	Change (ha)	Percent Change	SEPP 14 No.	1981 Area (ha)	1997 Area (ha)	Change (ha)	Percent Change
370	705.673	714.368	8.695	1.232%	323	7.829	7.776	-0.053	-0.678%
369	3.431	2.759	-0.673	-19.605%	322	9.312	9.425	0.113	1.211%
368	6.985	8.923	1.938	27.743%	321	4.325	3.588	-0.737	-17.037%
367	116.415	122.386	5.971	5.129%	320	8.250	11.344	3.094	37.506%
366	320.649	325.096	4.447	1.387%	319	22.696	25.215	2.519	11.099%
366a	170.755	154.563	-16.192	-9.483%	318	11.128	14.176	3.048	27.387%
366b	No Data	No Data	No Data	No Data	317	55.802	55.359	-0.443	-0.793%
366c	No Data	No Data	No Data	No Data	316	6.035	8.547	2.512	41.622%
365	5.776	4.448	-1.329	-22.999%	315	2.670	2.204	-0.466	-17.461%
364	4.871	5.175	0.303	6.229%	314	3.555	3.166	-0.389	-10.938%
363	325.615	329.612	3.997	1.227%	313	6.631	6.867	0.236	3.562%
362	11.814	10.476	-1.338	-11.328%	312	2.822	1.837	-0.985	-34.905%
361	11.211	8.019	-3.193	-28.477%	311	3.618	4.368	0.750	20.716%
360	24.214	21.392	-2.822	-11.653%	310	12.311	11.662	-0.650	-5.278%
359	0.121	0.122	0.001	0.662%	309	24.258	22.469	-1.789	-7.377%
358	1.669	1.669	0.000	0.014%	308	4.261	4.960	0.699	16.396%
356	4.864	4.585	-0.279	-5.732%	307	0.443	0.603	0.159	35.943%
355	3.186	2.724	-0.463	-14.520%	306	45.686	50.186	4.500	9.850%
354	1.409	1.510	0.101	7.171%	305	12.889	14.515	1.626	12.618%
353	21.605	20.061	-1.545	-7.150%	304	10.078	11.248	1.169	11.600%
352	14.741	7.339	-7.402	-50.215%	303	10.589	10.608	0.019	0.177%
351	6.351	6.636	0.285	4.483%	302	45.541	48.267	2.726	5.985%
350	62.643	58.249	-4.394	-7.014%	301	3.181	3.892	0.711	22.365%
349	4.473	3.906	-0.567	-12.682%	300	19.509	21.646	2.137	10.953%
348	8.895	7.900	-0.995	-11.188%	299	14.363	No Data	No Data	No Data
347	14.676	15.024	0.348	2.370%	298	4.767	4.555	-0.212	-4.445%
346	3.712	4.324	0.612	16.480%	297	0.262	0.371	0.109	41.369%
345	No Data	No Data	No Data	No Data	296	4.172	4.388	0.216	5.183%
344	34.534	28.423	-6.111	-17.695%	295	9.703	8.407	-1.296	-13.358%
343	15.228	17.583	2.355	15.462%	294a	2.144	2.302	0.157	7.328%
342	5.798	6.392	0.595	10.258%	294b	50.307	43.347	-6.960	-13.836%
341	15.718	17.320	1.601	10.188%	293	1.186	2.093	0.907	76.463%
340	12.638	12.901	0.264	2.086%	292	12.882	15.349	2.466	19.146%
339	2.311	2.830	0.518	22.431%	291	No Data	No Data	No Data	No Data
338	21.687	21.894	0.207	0.955%	290	29.245	25.367	-3.879	-13.262%
337	24.810	28.171	3.361	13.546%	289	7.432	7.162	-0.270	-3.628%
336	22.678	22.984	0.306	1.350%	288	33.774	36.984	3.210	9.503%
335	101.322	87.469	-13.854	-13.673%	287	7.882	8.295	0.414	5.249%
334	35.539	46.831	11.292	31.773%	286	17.673	17.541	-0.132	-0.749%
333	103.635	102.866	-0.769	-0.742%	285	23.972	24.516	0.544	2.270%
332	17.314	22.414	5.100	29.456%	284	12.104	11.907	-0.197	-1.629%
331	23.025	27.063	4.039	17.541%	283	1.975	1.859	-0.115	-5.839%
330	15.839	16.099	0.260	1.642%	281	3.102	2.477	-0.625	-20.154%
329	50.377	48.957	-1.420	-2.819%	280	1.903	1.890	-0.012	-0.657%
328	1.438	1.701	0.263	18.298%	279	7.476	8.540	1.064	14.234%
328a	18.985	18.824	-0.161	-0.848%	278	15.461	16.361	0.901	5.825%
328b	5.496	5.266	-0.230	-4.178%	277	14.861	15.584	0.723	4.867%
328c	73.920	73.113	-0.807	-1.092%	276	16.635	14.101	-2.534	-15.233%
327	11.783	11.625	-0.158	-1.338%	275	17.192	18.560	1.368	7.956%
326	3.753	3.794	0.041	1.083%	274	28.839	29.669	0.831	2.881%
325	246.997	255.346	8.350	3.380%	273	24.595	28.675	4.080	16.589%
324	44.355	54.254	9.899	22.318%	272	1.342	0.916	-0.425	-31.709%

Table 1 cont.

SEPP 14 No.	1981 Area (ha)	1997 Area (ha)	Change (ha)	Percent Change
271	1.897	2.637	0.740	39.018%
270	8.691	15.769	7.078	81.438%
269	14.493	13.714	-0.779	-5.373%
268	10.579	11.498	0.919	8.692%
267	7.779	7.694	-0.086	-1.100%
266	11.583	24.703	13.120	113.265%
265	7.178	9.539	2.361	32.896%
264	87.971	104.366	16.395	18.637%
263	1.899	2.068	0.169	8.888%
262	3.750	6.058	2.308	61.539%
261	16.720	19.268	2.548	15.240%
260	25.409	31.229	5.820	22.903%
259	7.509	6.756	-0.753	-10.026%
258	9.136	8.975	-0.161	-1.757%
257	0.983	1.418	0.435	44.193%
256	1.680	1.417	-0.263	-15.653%
255	2.617	2.939	0.322	12.320%
254	1.528	1.207	-0.321	-20.987%
253	2.537	2.501	-0.036	-1.423%
Total	**3687.545**	**3754.283**	**66.738**	**1.810%**

Table 2: Changes in wetland extent for wetlands omitted from SEPP 14 between 1981 and 1997.

Wetland No	1981 area (ha)	1997 area (ha)	Change (ha)	% Change
1	1.672	1.360	-0.312	-0.186
2	5.163	4.929	-0.235	-0.045
3	0.218	0.207	-0.011	-0.050
4	0.686	2.189	1.503	2.189
5	2.326	2.427	0.101	0.043
6	0.673	0.494	-0.179	-0.266
7	0.700	0.727	0.027	0.039
8	0.213	0.113	-0.100	-0.470
9	0.265	0.210	-0.055	-0.208
10	1.320	1.458	0.138	0.105
Totals	**13.235**	**14.113**	**0.878**	**6.634**

Figure 2: Frequency histograph of wetland area change. Most wetlands demonstrated changes of less than 2 hectares.

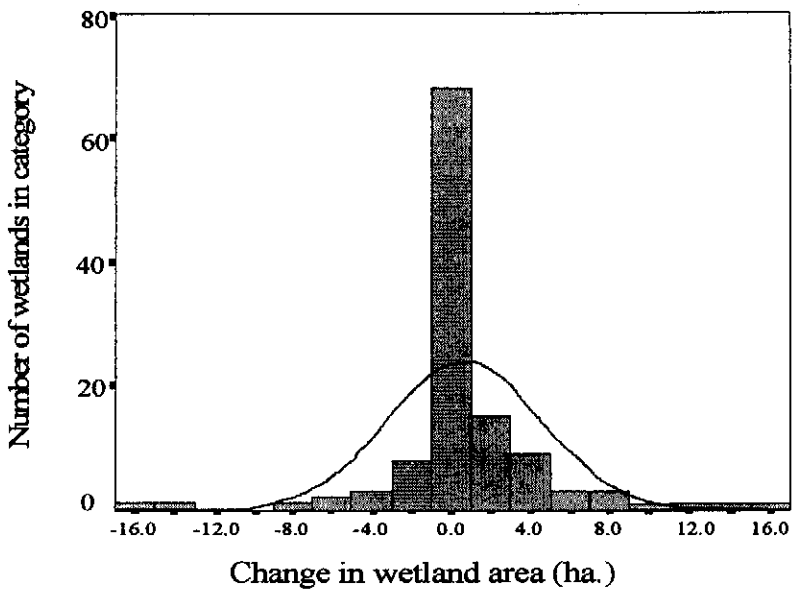


Figure 3: Change in wetland area and a percentage of original wetland area.

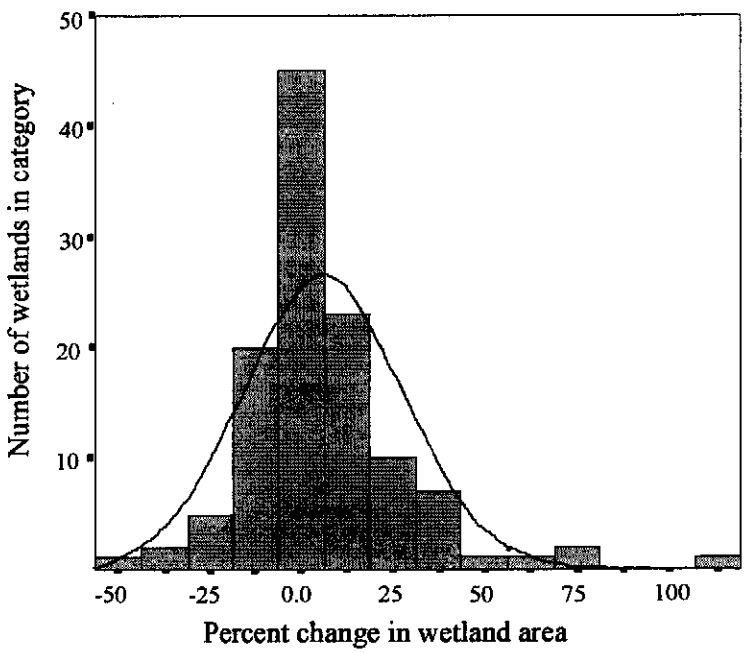


Figure 4: 1981 wetland extent at Termeil Lake.

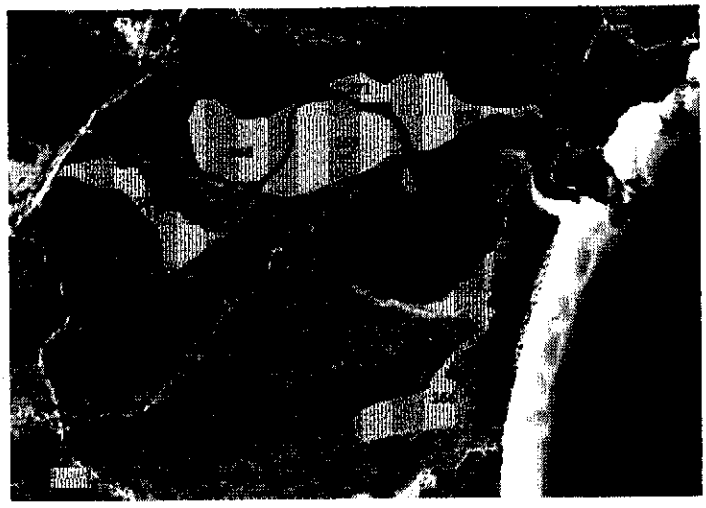


Figure 5: 1997 wetland extent at Termeil Lake.

Figure 6: 1981 wetland extent at Crookhaven River.

Figure 7: 1997 wetland extent at Crookhaven River.

Discussion

Methodological Differences

The 1981 Coastal Wetlands Series, originally used for delineating SEPP 14 coastal wetlands, consisted of 96 north-south runs with a total coverage of approximately 2000 standard format colour photographs. Using a camera focal length of 152mm, the flying height was determined by the contractor to achieve closest possible approximation of 1:25000 scale.

The original mapping of SEPP 14 wetlands conducted by Adam *et al.* (1985) used a Bausch and Lomb stereo zoom transfer scope. Four times magnification was the highest practical magnification that could be used. Most wetlands were mapped if they could be unambiguously identified on the photographs and no minimum size was therefore used. Maps were produced at 1:25000 and reduced to 1:100000 for publications. Using this technique, calculation of wetland areas on a consistent basis was not possible due to differences in photograph scale resulting from relief displacement, tilt and other sources of distortion inherent in aerial photography.

For the present survey, photographic images were scanned and converted to digital images that were georectified using the ArcView Geographic Information System. By scanning the 1981 aerial photographs at 150dpi and 1997 photographs at 300 dpi commonality of scale was achieved, in spite of differences in original photographic scale between 1981 (1:25000) and 1997 (1:50000). Adjustments to the appearance of digital images by altering the brightness, contrast and hue or applying different stretches and manipulations to the images enabled simple comparisons between aerial photograph images and amplified the textural appearance of SEPP 14 wetlands. The zoom function of ArcView allowed high magnification of the images, within the constraints of the photograph quality and scanning density, and wetland areas were calculated on a consistent basis.

Changes between 1981 and 1997

Wetland boundaries are dynamic, changing in response to factors including climatic variability, geomorphic change and fire. It would be remarkable if wetlands had not changed in the twenty years since the original coastal wetland photographs were produced. This survey illustrated that significant changes in the areas of individual gazetted SEPP 14 wetlands are evident. The overall change within the Shoalhaven City Council area is approximately 88ha, increasing from 3587ha to 3675ha between 1981 and 1997.

Within estuaries some intertidal wetlands have increased in area apparently due to sedimentation at the seaward edge. An example is SEPP 14 wetland 270 (Figures 4 and 5), where significant sedimentation on the fluvial delta enabled the size of the wetland to double. Alternatively, in the case of wetland 352 (Figures 6 and 7) significant losses have resulted due to coastal developments.

More frequently, small temporal differences in wetland areas relate to difficulties differentiating between the wetland and the surrounding upland forest. The 1981 coastal wetland series was taken near the height of the *El Nino* drought of 1982 and wetland boundaries are reasonably sharp and are likely to be at a temporal minimum. The 1997

photographs show more luxuriant growth, and the boundaries are obscured by the apparent expansion of the wetland into surrounding community types.

Additional wetlands

A number of wetlands not identified as coastal wetland in the mapping of Adam *et al.* (1985) were identified as wetland in this report. The most significant of these coastal wetlands are within the Currambene Creek estuary. Consultation of current SEPP 14 maps held by the Department of Urban Affairs and Planning (now Planning NSW) show these to have been subsequently gazetted as SEPP 14 following amendment 19 to SEPP 14 dated 11 June 1993.

However, other small areas were identified that were omitted from SEPP 14 mapping. While the majority of these wetlands are less than 4 hectares, which was chosen as the minimum size for the mapping of sedgeland, freshwater swamp and wet meadow; one wetland does exceed this limit and others have increased extent since 1981 and may well exceed 4 hectares in the future. These can only be corrected by a formal gazettal of an amendment to the policy because the gazetted text of SEPP 14 refers to the areas delineated on the maps rather than to the definitions advanced by Adam *et al.* (1985). Since SEPP 14 refers to the areas delineated on the maps, it should mean that all relevant wetlands are adequately delineated and that a review process whould be in place so that revision of boundaries is regularly undertaken.

Criticisms of SEPP 14 wetland mapping

Errors are inherent in both mapping from aerial photographs and orthophotograph derived mapping, however studies indicate that by applying standard and appropriate procedures to produce orthophotograph based maps, mapping errors can be in the order of 3.4±3.4m (Barrette August and Golet 2000). In addition studies also show that ground truthing using a global positioning system, which allows information to be simply transferred to GIS, can produce 5m accuracy 95% of the time (Hook *et al.* 1995) or accuracy in the order of ±1.5m (Payne & Harty 1998).

Criticism has also arisen from discrepancies between mapped wetland boundaries and ground observations of the wetland edge (Winning 1991). This study illustrates that wetlands are dynamic and temporal changes in extent do occur. While issues of dynamic wetland boundaries may be overcome by gazetting SEPP 14 wetlands based on wetland definition, which is the situation in USA (U.S. Army Corps of Engineers 1987, Federal Interagency Committee for Wetland Delineation 1989), mapping of wetland extent is still appropriate for planning and inventory purposes. By revising SEPP 14 wetland boundaries using current GIS based techniques, ground-based identification of mapped wetland boundaries becomes a simpler task for developers and planners. Since wetland boundaries are dynamic, a review process should also operate to ensure that wetlands are adequately protected from development in the future.

In this study, and others (Winning 1991; Winning, King & Bailey 2000) issues have arisen in regards to the dynamic nature of wetlands and wetland gradation into surrounding upland forest, making it difficult to identify a true wetland edge. In the provisions of SEPP 26 (Littoral Rainforest), a 100m buffer zone is included around littoral rainforest to protect against margin dieback, maintain the forest environment and protect species using habitat margins (Mossop 1992). While the optimal criteria for placing buffer

zones around wetlands are unclear and should be adressed by policy makers, the task is simplified using GIS technology by establishing buffers according to a defined criteria. By including a buffer zone around SEPP 14 wetlands, both wetland gradations into upland vegetation and future minor changes in wetland extent could be protected.

References

Adam P, Urwin N, Weiner P and Sim I (1985) Coastal wetlands of New South Wales. Coastal Council of NSW, Sydney, 125pp.

Adam P. (1992) Wetlands and wetland boundaries: problems, expectation, perceptions and reality. *Wetland (Australia)* 11: 60-67.

Barrette J, August P and Golet F (2000) Accuracy assessment of wetland boundary delineation using aerial photography and digital orthophotography. *Photogrammetric Engineering and Remote Sensing* 66(4): 409-416.

Federal Interagency Committee for Wetland Delineation (1989) *Federal manual for identifying and delineating jurisdictional wetlands.* US Army Corps fo Engineers, US Environmental Protection Agency, US Fish and wildlife service, and USDA Soil conservation service, Washington, US, 76pp.

Hook DD, Davis B, Scott J, Struble J, Bunton C and Nelson EA (1995) Locating delineated wetland boundaries in coastal South Carolina using global positioning systems. *Wetlands* 15(1): 31-36.

Mossop D (1992) Coastal wetland protection law in New South Wales. *Environmental and Planning Law Journal* 9(5): 331-359.

Payne R and Harty C (1998) Wetland vegetation mapping using a Global Positioning System. *Cunninghamia* 5(3): 633-643.

US Army Corps of Engineers (1987) *Corps of Engineers Wetlands Delineation Manual,* US Army Corps of Engineers Waterways Experiment Station, Wetlands Research Program Technical Report Y-87-1, 100pp.

Winning G (1991) Some problems in determining the boundaries of SEPP 14 wetlands. *Wetlands (Australia)* 11: 10-17.

Winning G, King JP & Bailey S (2000) How wide is a wetland boundary? *Wetlands (Australia)* 18(2): 64-71.