J. Aquat. Plant Manage. 26: 38-43

An Automated Positioning System for Determining Aquatic Macrophyte Distribution

R. M. HARVEY, G. G. PATTERSON, AND J. R. PICKETT[1]

ABSTRACT

Quantitative data on the areal distribution of aquatic macrophytes were determined through the use of electronic automated positioning equipment for Lake Marion, South Carolina's largest reservoir. Due to the complex nature of the study area, a method was needed to map extensive plant populations while allowing simultaneous on-site inspections of the macrophyte communities. Within the open portions of the reservoir, the boundaries of macrophyte beds were identified and their coordinates determined by the Automated Positioning System (APS). However, due to line-of-sight limitations, the APS could not be effectively used in areas dominated by dense tree stands. For the 1983 growing season, we identified boundary coordinates for more than 200 individual macrophyte beds (subsegments), located within 13 segments of upper Lake Marion. The entire process required approximately 80 man-days of field effort. The time required for mapping was reduced to 40 man-days for the 1984 growing season.

Key words: mapping, areal coverage, aquatic macrophytes.

INTRODUCTION

Accurate and current information on the location, character, and extent of both submersed and emergent aquatic macrophyte populations is frequently desired by water-resources managers and researchers. A variety of methods have been employed to locate and quantify aquatic plant populations. Factors generally considered in method selection include the size and complexity of the water body of interest, the species of macrophytes present, the degree of accuracy required, and the time and monetary resources available. Reported methods vary from relatively simple shoreline or boat-based visual inspections (Leonard 1981; Inabinet 1985) to the more complex acquisition and interpretation of satellite imagery (Long 1979; Hathout 1980).

Macrophyte populations in small ponds and lakes are generally surveyed from the shoreline or by boat (McGhee 1983). An increase in the size or number of water bodies requires a corresponding increase in the resources necessary for adequate on-site surveying. Several investigators have used remote sensing in conjunction with appropriate ground-truth to map macrophyte populations in large water bodies. Dardeau (1983) reports aerial surveying to be an accurate and effective planning tool, becoming more efficient as the size of the water body and the plant populations increase. Although remote sensing may be more appropriate for large study areas, it does have limitations. Cowardin et al. (1974) reported difficulty in distinguishing macrophyte bed boundaries under the canopy of a hardwood forest. Surface waves, clouds, turbidity, and water levels also can obscure target plants (Long 1979; Bogucki et al. 1980).

The areal distribution of both emergent and submersed aquatic macrophytes was desired for the headwaters of Lake Marion, the largest reservoir in South Carolina. Lake Marion is a large, shallow multipurpose reservoir located on the Coastal Plain of South Carolina (Figure 1). Upper Lake Marion, from Interstate 95 to the confluence of the Congaree and Wateree Rivers, includes an area of about 16,600 ha with an average depth of less than 3 m. Approximately 65% of that area consists of a flooded river swamp dominated by dense stands of cypress (*Taxodium ascendens* Brongn. and *Taxodium disticum* (L.) Richard) and tupelo (*Nyssa aquatica* (L) Walter G.) trees. Each year extensive populations of both native and nonnative macrophytes grow from mid-spring to late fall throughout upper Lake Marion. Some species, including hydrilla (*Hydrilla verticillata* Royle), alligatorweed (*Alternanthera philoxeroides* (Mart.) Griseb), elodea (*Egeria densa* Planch.) and naiad (*Najas* spp.) are considered nuisance plants by several user groups. The purpose of this paper is to describe the mapping method used to quantify the areal distribution of aquatic macrophyte populations in upper Lake Marion, for the 1983 and 1984 growing seasons.

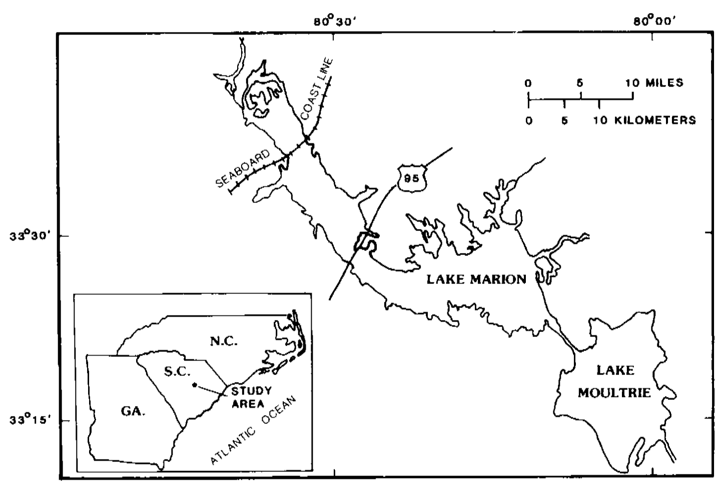

Figure 1. Location of Lake Marion.

[1]Hydrologist and Hydrologist, respectively. U.S. Geological Survey-WRD, 1835 Assembly St., Columbia, South Carolina 29201 and Environmental Quality Manager, South Carolina Department of Health and Environmental Control, P.O. Box 72, State Park, South Carolina 29147.

[2]Use of the brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

METHODS

The positioning system used for mapping aquatic plants in Lake Marion was the Miniranger III Automated Positioning System (APS), manufactured by Motorola (Figure 2). The APS uses microwaves to measure the distance between a moving boat and two stationary remote transponders positioned at predetermined locations with known X and Y coordinates. The boat's position relative to the remote stations is automatically computed by triangulation, and reported by the APS as a continuous computation of X and Y coordinates. The APS consists of several components (Figure 2). Power is supplied by a 750-watt, 120-volt gasoline generator with built-in voltage regulator. A range console controls the microwave transmissions and distance measuring. Signals are sent and received by a receiver/transmitter, mounted on the boat, and the two remote transponders. The transponders are powered by 24-volt rechargeable battery packs. Distances up to 37 km may be measured as long as line-of-sight communication is maintained between the receiver/transmitter and both transponders. A data processor converts the information to X and Y coordinates which are then sent to a portable printing terminal (Texas Instruments Silent 700) and a data cassette tape drive (Tektronix 4923). The printing terminal provides communication between the operator and the system while the tape drive stores the data on tape.

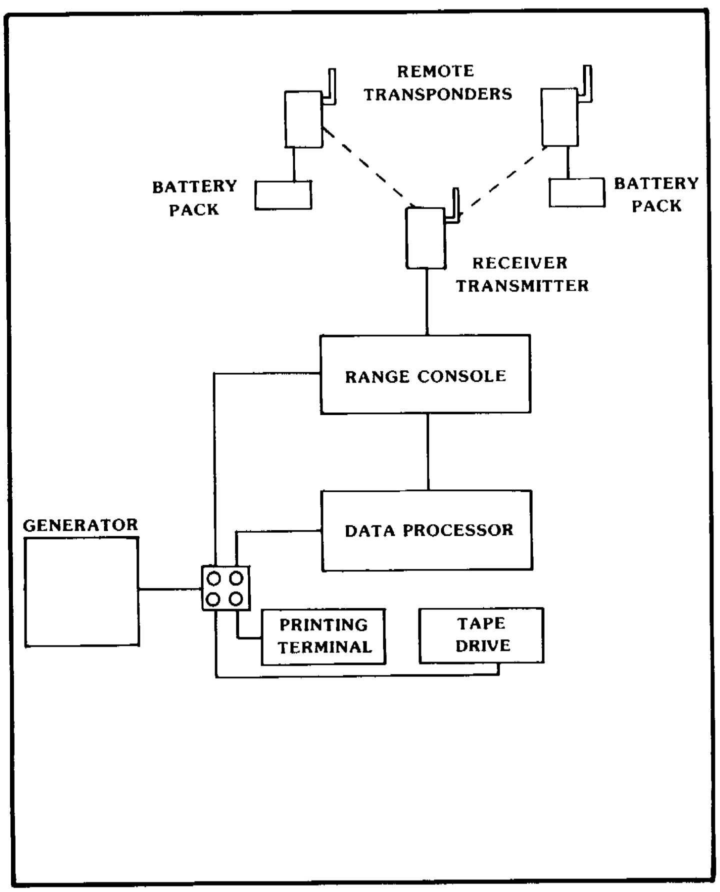

Figure 2. Diagram of Automatic Positioning System components.

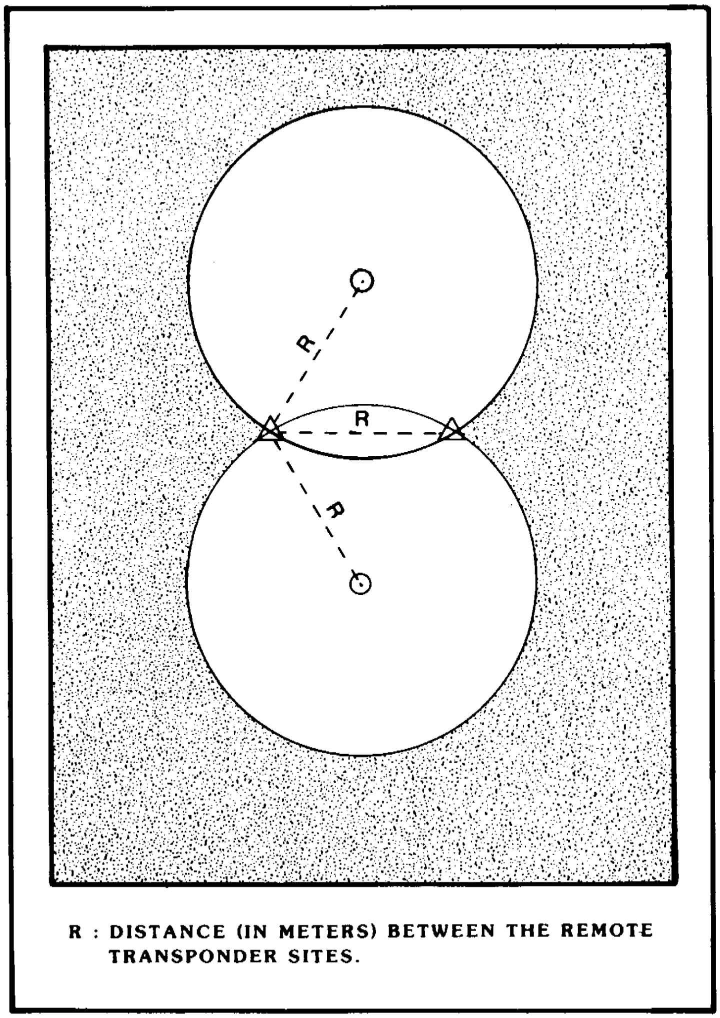

Figure 3. Area of acceptable geometry for two remote transponder sites.

For reliable triangulation the angle between the two transponders as viewed from the boat must be between 30 and 150 degrees (Motorola Inc. 1980). This condition is satisfied everywhere within two identical, overlapping circles with radii equal to the distance between the remote transponders, intersecting at the remote transponders, with the exception of the overlap area (Figure 3). If the APS is operated outside this area, or if the distance information received is not consistent enough for accurate triangulation, an error message is printed and no data are stored on tape. Whenever possible, during mapping the remote transponders were located at points easily identifiable on U.S. Geological Survey advanced prints of 1:24,000-scale orthophotoquads. The remote transponders, mounted on swiveling brackets, were suspended from trees or posts and aimed in the direction of the area to be mapped. Battery packs were usually placed on styrofoam floats tethered to trees. If the X and Y coordinates for a selected remote site were in question, due to a problem with the identification of the site on the map, an accuracy check was performed. The accuracy check consisted of comparing distances between the remote transponders measured by the APS to distances determined

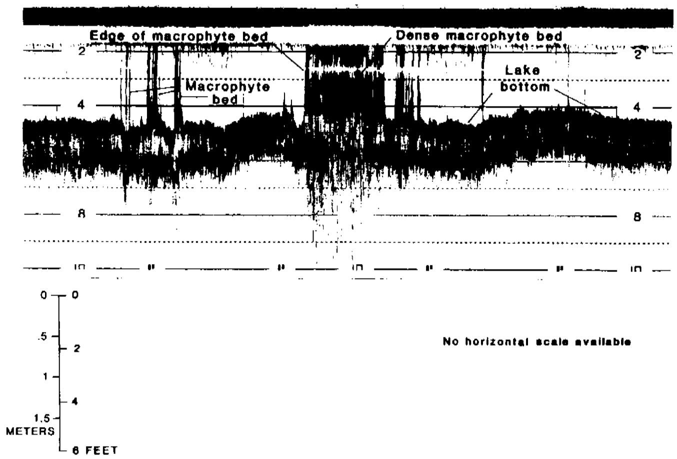

Figure 4. Strip chart from recording fathometer showing areas of dense vegetation.

from the maps and comparing reported boat positions with identifiable features on the maps. When necessary, adjustments were made to either the transponder coordinates or to their locations.

Once the transponders were in place, we determined boundary coordinates by driving around the perimeter of an aquatic macrophyte bed. The X and Y coordinates were recorded on tape every 5 seconds and printed every 10 seconds. Numerical "event" marks were placed on the printout to identify the coordinates of points of interest such as buoys, reference marks, and vegetation types. When possible, adjacent aquatic plant beds with similar species composition were mapped as a single unit. However, the remote transponders were relocated when line-of-sight or geometric limitations were encountered; resulting in the subdivision of beds into multiple units (here-inafter referred to as subsegments). When the limit of acceptable geometry was reached or when line-of-sight communications were interupted, X and Y coordinates were obtained either from the APS or the orthophotoquads for repositioning the remote transponders.

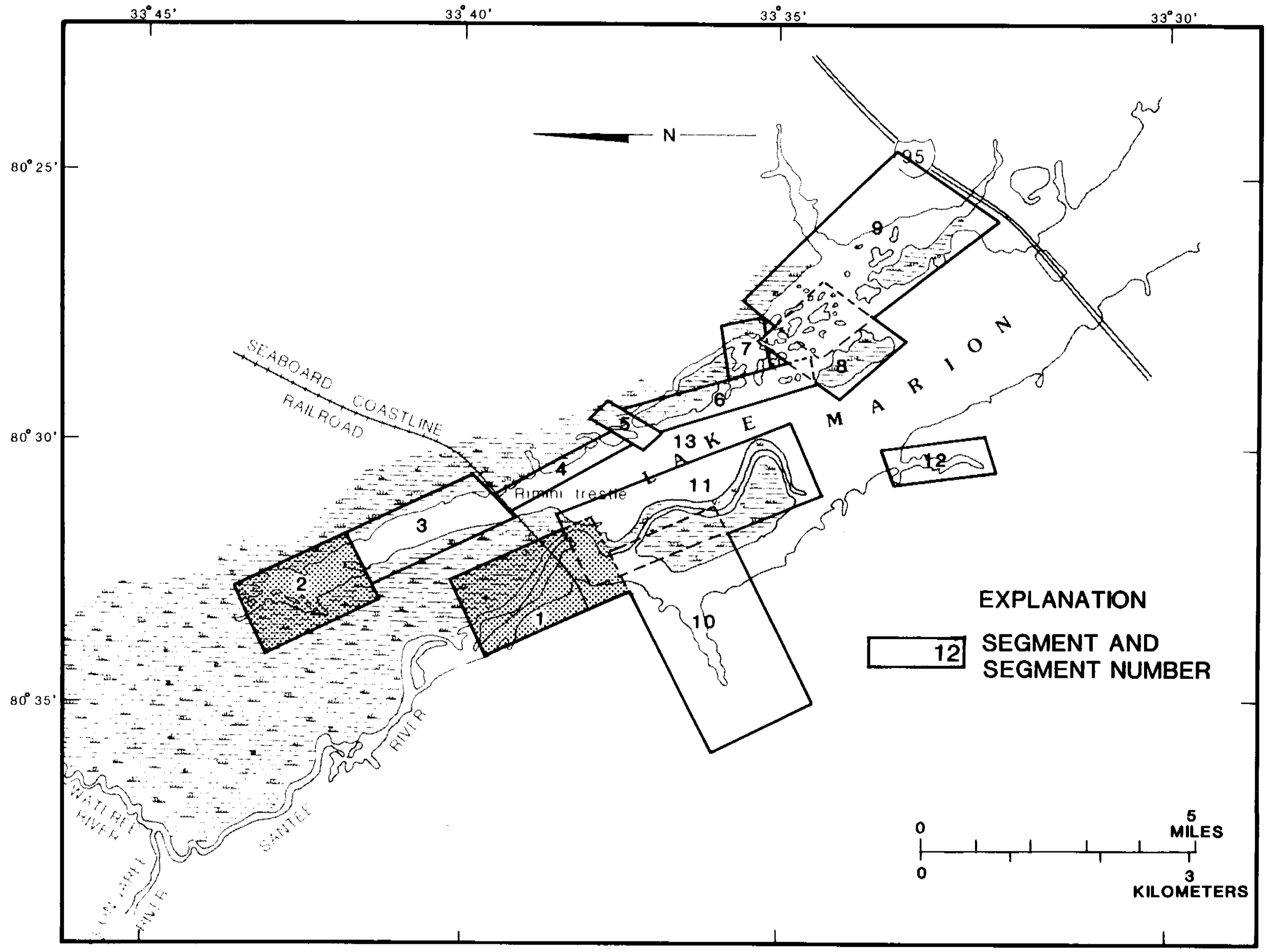

Figure 5. Areas of Automatic Positioning System utilization in upper Lake Marion.

If the perimeter of a submersed macrophyte bed was invisible from the surface we marked it in advance with a series of buoys. We determined the edge of a macrophyte bed by its characteristic markings on the chart of a recording fathometer (Figure 4). The recording fathometer (Raytheon model 119-D) with a wide angle transducer was mounted on a jon-boat and driven along transects 30 to 50 m apart. Once the edge was located the boat was driven back over the transect to double check the position. To further insure the accuracy of the location, a dethatching rake tied to a rope was cast into the water every 10 to 15 m along the transect. This was done to snag any plants growing close to the bottom, which might not be indicated by the fathometer, and to obtain plant samples for the determination of species composition. As a final check, boundary locations were verified by diving. Once the plant bed boundaries were positively located, buoys were placed around the perimeter as guides for the airboat.

Representative aquatic plant samples were collected from each macrophyte bed for species identification. Each sampling site was marked with a buoy, the depth noted, and the position recorded by the APS. Macrophyte samples were placed in plastic bags for transportation and were identified by the University of South Carolina's Herbarium Curator.

For a permanent record and to facilitate data presentation, the coordinates of the beds were transferred to a minicomputer and plots of the data were overlain on the quadrangle maps to check for position accuracy. Adjustments for incorrect coordinates for the remote sites were made by computing distances based on the unadjusted coordinates for the boat position, correcting the coordinates for the remote sites, and again triangulating to obtain corrected coordinates for the boat positions.

RESULTS AND DISCUSSION

The requirement for line-of-sight communication between the receiver/transmitter and the remote transponders was satisfied in approximately 5,300 ha of the 16,600 ha area of upper Lake Marion (Figure 5). Within this 5,300 ha area, for the 1983 growing season, boundary coordinates were identified for more than 200 individual subsegments, located within 13 segments (Figure 5). Segment areas ranged from 10 to 280 ha. As examples, the boundaries determined for 2 of the 13 segments, #1 (105 ha) and #2 (220 ha), are shown in Figures 6 and 7, respectively. Similar boundaries (not shown for brevity's sake) were determined for the remaining 11 segments. Tables 1 and 2 list the size and species composition for each subsegment mapped in Segment 1 and Segment 2, respectively.

Line-of-sight restrictions, boating access problems, and the inability to accurately determine coordinates for the remote transponders made use of the APS in densely wooded portions of upper Lake Marion impractical. Therefore, quantitative descriptions of aquatic macrophyte distributions for that 11,300 ha portion of the system were not made. Kilgore and Payne (1982) also identifed interruptions and interferences with radiowave transmissions due to trees and brush as method limitations in the use of electronic positioning equipment.

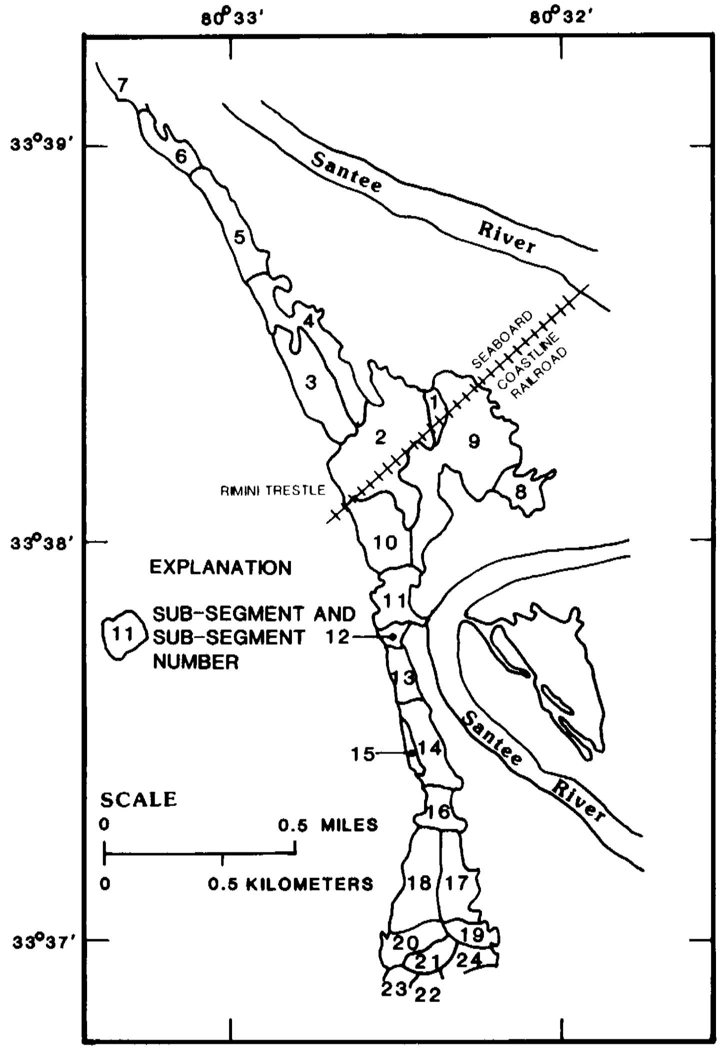

Figure 6. Segment and subsegment boundaries for segment number one.

With a range of up to 37 km, segment and subsegment dimensions for those areas of upper Lake Marion where the APS could be used were determined primarily by the geography of the area. Due to line-of-sight and geometric limitations boundaries were developed for more subsegments in Segment 1 than for Segment 2. Segment 1 has an elongated configuration, averaging 0.16 km wide by 4.2 km long. This narrow configuration required placement of the transponders relatively close together. This limited the area of acceptable geometry that could be mapped with any one set-up of the transponders to 16 ha (Table 1). In several locations within the segment, dense tree stands and other vegetation blocked microwave communications between the APS components, requiring additional movement of the remotes. As a result of these limitations and differences in macrophyte composition, we determined boundaries for 24 subsegments for Segment 1. In contrast, Segment 2 was larger and more open than Segment 1 and had fewer obstructions to interfere with the microwave transmissions. The 0.8 km average width of Segment 2 permitted wider spacing between the transponders; thus increasing the maximum area which could be mapped to

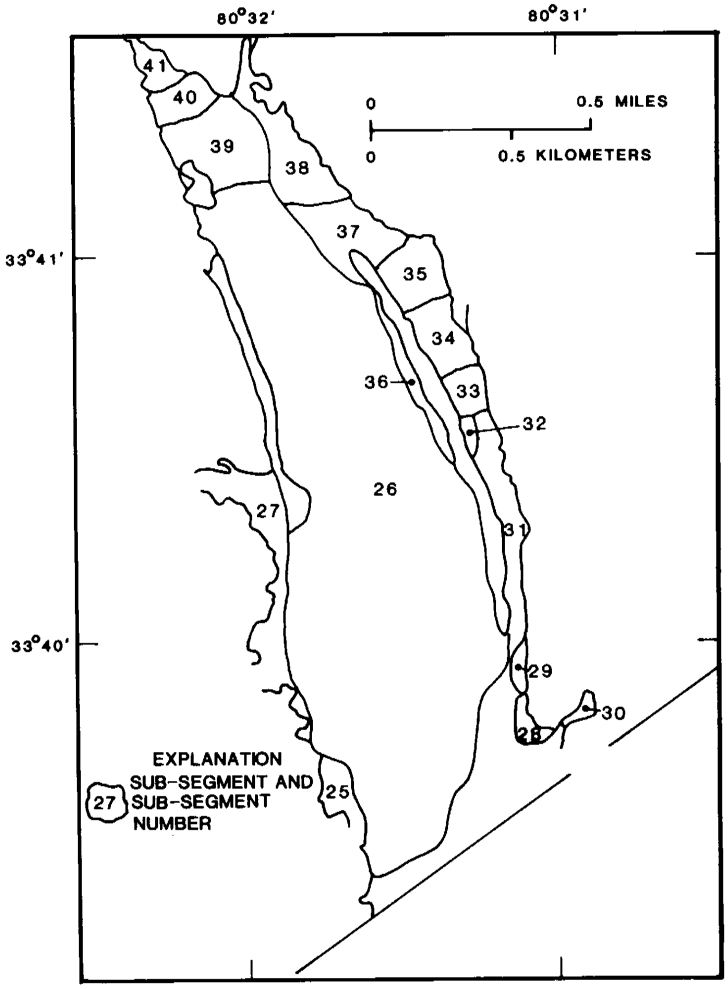

Figure 7. Segment and subsegment boundaries for segment number two.

approximately 160 ha. As a result, larger and fewer subsegments were mapped for Segment 2.

In general, the APS worked well in open areas where coordinates for the remote transponders could be accurately determined. In those areas more time was necessary to identify and mark the boundaries than to determine boundary coordinates with the APS. In confined areas, the time required to move the remotes and determine boundary coordinates was sometimes equivalent to the time it took to identify and mark macrophyte bed boundaries. For Segment 2 it took approximately one day to identify and mark macrophyte bed boundaries; while less than a half day was necessary to determine boundary coordinates. In the more confined and complex Segment 1, we needed approximately 2 days to both mark the boundaries and determine coordinates. It should be noted, however, that Segment 1 was the first area where the APS mapping technique was tried and subsequent use of the system improved as the procedure was refined.

For the 1983 growing season, approximately 80 man-days of field effort were required to map the aquatic macrophyte distribution in upper Lake Marion. With an increased familiarity with both the study area and the APS, only about 40 man-days of field effort were required in 1984.

Mapping locations of aquatic plants and monitoring population changes are essential to the successful planning and implementation of an aquatic plant management program. Except for the previously noted limitations, the APS or similar electronic positioning equipment can be used in support of such programs. The precision obtainable appears to be limited only by the amount of time the investigator is willing to spend in delineating species composition. If desired, field determinations of surface areas oc-

TABLE 1. SIZE AND SPECIES COMPOSITION OF EACH SUBSEGMENT MAPPED IN SEGMENT #1.

Subsegment Number	Area (Hectares)	Ludwigia uruguayensis	Egeria densa	Ceratophyllum demersum	Potamogeten pusillus
1	2.1	X[a]		X	X
2	13.6	X	X		
3	7.4	X		X	X
4	7.4	X	X	X	
5	5.2	X	X	X	X
6	2.8	X	X	X	
7	3.7	X	X	X	
8	2.8	X	X		
9	15.7	X	X		
10	6.1	X			
11	3.9		X		
12	1.0	X	X	X	X
13	2.2	X	X	X	
14	3.3	X	X		
15	1.2	X	X	X	X
16	2.6	X	X		
17	4.8	X			
18	6.2	X	X		
19	1.9	X			
20	3.2	X	X	X	
21	1.9	X	X		
22	1.8		X	X	
23	2.2	X	X	X	
24	2.0	X	X		

[a]The 'X' denotes species presence.

TABLE 2. SIZE AND SPECIES COMPOSITION OF EACH SUBSEGMENT MAPPED IN SEGMENT #2.

Subsegment Number	Area (Hectares)	Ludwigia uruguayensis	Egeria densa	Ceratophyllum demersum	Potamogeten pusillus	Najas minor	Hydrilla verticillata
25	2.8		X[a]	X	X		
26	135.0		X	X	X	X	X
27	4.9	X					
28	1.2	X	X				
29	0.9		X	X	X	X	
30	0.6					X	
31	4.8	X	X	X	X		
32	0.7	X	X	X	X		
33	2.3				X	X	
34	4.4	X					
35	4.7				X	X	
36	2.7	X	X	X	X		
37	6.8		X		X	X	
38	8.1	X	X	X	X		
39	9.0	X	X	X	X		
40	3.0	X	X	X		X	
41	2.0	X	X	X			

[a]The 'X' denotes species presence.

cupied by aquatic macrophytes could also be made by plotting the printed boundary coordinates on orthophoto or topographic quadrangles and using a polar planimeter.

The APS could also be used in support of related research activities. Kilgore and Payne (1984) report success using electronic positioning equipment for measuring aquatic plant treatment efficacy, and for relocating unmarked sampling sites. In related investigations on upper Lake Marion, we have used the APS to identify and relocate sampling stations for water circulation studies and when used in conjunction with a digital fathometer, to determine bathymetric profiles for open and vegetated areas.

LITERATURE CITED

Bogucki, D. J., G. K. Gruendling, and M. Madden. 1980. Remote sensing to monitor water chestnut growth in Lake Champlain. Jour. Soil Water Conser. 2:79-81.

Cowardin, L. M. and V. I. Myers. 1974. Remote sensing for identification and classification of wetland vegetation. J. Wildlife Mgt. 38(2):308-314.

Dardeau, E. A., Jr. 1983. Aerial survey techniques to map and monitor aquatic plant populations—four case studies. Tech. Rpt. A-83-1. USAE-WES. Vicksburg, MS. 49 pp.

Hathout, S. A. 1980. Mapping vegetation by Landsat image enhancement. J. Envir. Mgm. 11:111-117.

Inabinet, J. R. 1985. History of aquatic weed control of the Santee Cooper Lakes, South Carolina. Newsletter S.C. Aquat. P'nt Mgt. Soc. 6(2):11-16.

Inabinet, J. R. 1978. Lake Marion—an environmental assessment. Lake Study Report Number One. South Carolina Department of Health and Environmental Control. Columbia, South Carolina: 232 pp.

Kilgore, J. K. and B. S. Payne. 1982. A positioning system for field studies in aquatic habitats. Info. Exch. Bull. A-82-3. USAE-WES. Vicksburg, MS. 11 pp.

Kilgore, J. K. and B. S. Payne. 1984. Field methods to measure aquatic plant treatment method efficacy. Misc. Paper A-84-3. USAE-WES. Vicksburg, MS. 22 pp.

Leonard, J. M. 1981. Boat and aerial surveys of giant cutgrass in Lake Seminole, Fla. Proc. 15th Annu. Meeting, Aquat Plant Contr. Res. Plann. Oper. Rev. Misc. Paper A-81-3. USAE-WES. Vicksburg, MS. pp. 79-84.

Long, K. S. 1979. Remote sensing of aquatic plants. Tech. Rpt. A-79-2. USAE-WES. Vicksburg, MS. 82 pp.

McGhee, J. T. 1983. Aerial monitoring of aquatic plant management programs. Aquatics. 7(1):20-23.

Motorola Inc. 1980. Users manual-operation and installation instructions-Miniranger III Positioning System. Motorola document No. 68-P03802R revision I. Motorola Position Determining Systems. Tempe, Arizona. 70 pp.