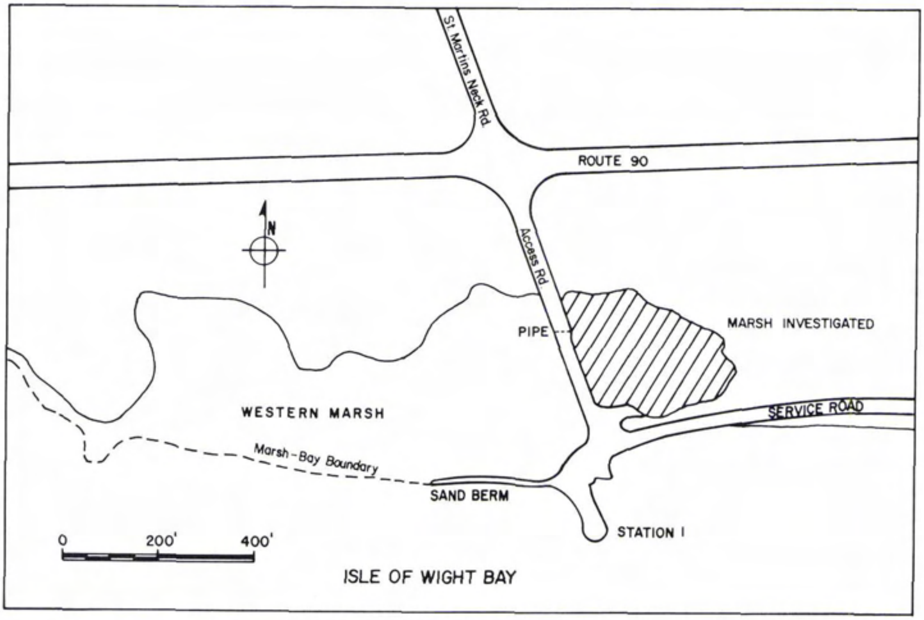

FIG. 1. Map of marsh area.

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Hydrographic Verification of Wetland Delineation by Remote Sensing

Two methods for determining the area of a marsh agree within reasonable error limits.

(Abstract on page 76.)

INTRODUCTION

THE STATE OF MARYLAND has recently completed an inventory of its tidal wetlands. The purpose of this inventory was to delineate those areas defined by the 1970 Maryland Wetlands Act, as lands "which are subject to regular or periodic tidal action and which support aquatic growth." The act defines regular or periodic tidal action as the "rise and fall of the sea that is produced by the attraction of the sun and the moon uninfluenced by winds or other circumstances." The inventory was implemented by the analysis of aerial photographs in terms of plant species and communities believed to be indicative of tidal inundation (Garvin and Wheeler, 1973). Apparently no tidal measurements were taken to verify that the areas so defined were in fact subject to at least the spring tides. This paper reports observations bearing on this point for a small marsh in Worcester County, Maryland.

* Supported in part by Office of Naval Research Contract No. N00014-69-A-0407. Mr. Salter is presently at the Dept. of Oceanography, Univ. of Washington, Seattle, Wash.

General Description

The marsh investigated is on the Isle of Wight near Ocean City, Maryland. It is located on the south side of Maryland Route 90 and on the north side of Isle of Wight Bay.

The marsh is presently cut off from direct access to Isle of Wight Bay by a service road, and perhaps formerly by the sand berm which continues 280 feet west in front of the neighboring marsh area (See Figure 1). The area was previously part of the neighboring marsh, but is now isolated by the access road—the sole connection with the tidal regime being a 2.0 ft. diameter corrugated pipe 51 ft. long which runs beneath the roadway as shown in Figure 1. This circumstance allows a direct measurement of the flow on and off the marsh.

The marsh terrain is flat except for the presence of mosquito control ditches. Its boundary, however, is generally steep. On the south and west this is the result of fill from road construction. The northern (upland) boundary has a natural gradient of perhaps 1 in 5 to 1 in 10. Only on the east can the boundary be characterized as gently sloping.

Abstract: *The Maryland wetlands have recently been defined by a combination of photoanalysis and botantical field checks. We have verified the area extent of one marsh so defined by an analysis of tidal height and volume transport data.*

The area of the marsh was determined by planimetering the wetlands boundary drawn on aerial photo no. WO3-17 RIL-76, which is sheet 18 of the Wetlands Boundaries for Worcester County. The area determined by this means is $6.24 \pm .13 \times 10^4$ ft^2. The scale of the aerial photo was verified by direct measurement of linear features on the ground.

Biologically, the marsh is dominated by *Spartina patens* (salt marsh hay), which occupies an estimated 75-80 percent of the area. Another species of spartina is also present, S. *alterniflora* (salt marsh cord grass), covering 10-15 percent of the area. The third species is also a grass, *Phragmites communis* (reed grass), with about the same amount of area covered as for S. *patens*. In addition, a few shrubs are also found in the area, growing in those places that are not normally flooded by the tide. The marsh is bordered by several *Pinus* species (pine trees).

The species found in the area can be used as indicators of the extent of tidal inundation of the marsh. Of the two Spartina species, S. *alterniflora* is found in areas flooded by salt water a greater percentage of time than the areas occupied by S. *patens*.

The *Phragmites* species is also indicative of tidal influence. Presumably, the presence of these three species formed the basis for the delineation of this marsh from aerial photographs.

Hydrographic Observations

On December 21, 1972, the area was instrumented with six tide staffs and observations were made over a twelve-hour-and-fifteen minute period. The six tide staffs were located as follows: staff station 1 was on the Isle of Wight Bay (see Figure 1), Station 2 was at the entrance to the pipe, Station 3 was at the end of the pipe and Stations 4, 5, and 6 are in the marsh as shown in Figure 2. At this same time the flow through the pipe was observed by injecting vegetable dye (food coloring) in one end of the pipe and recording its transit time to the nearest 10 seconds. Errors in the current velocity were estimated by assuming a maximum error of ± 5 seconds. This corresponds to an *rms* error of about ± 3 seconds, which was used in calculating the error in the current speed. Wind and weather were also observed. The data gathered are displayed in Table 1 and shown graphically in Figure 3. The tidal heights are given relative to the lowest level observed at the station rather than some absolute datum plane. The use of a relative datum has no effect on the subsequent calculation as only differences in tidal stage are used.

The mean tidal range shown in the National Ocean Survey Tide Tables for the Isle of Wight Bay is 2.2 ft., while the average spring range is 2.7 ft. This is for Ocean City, four miles south of our site and next to the inlet. Daily tides are not predicted for this station, but may be computed using the predictions for Sandy Hook, New Jersey. Calculations resulted in the following predictions for the times and heights of high and low tide

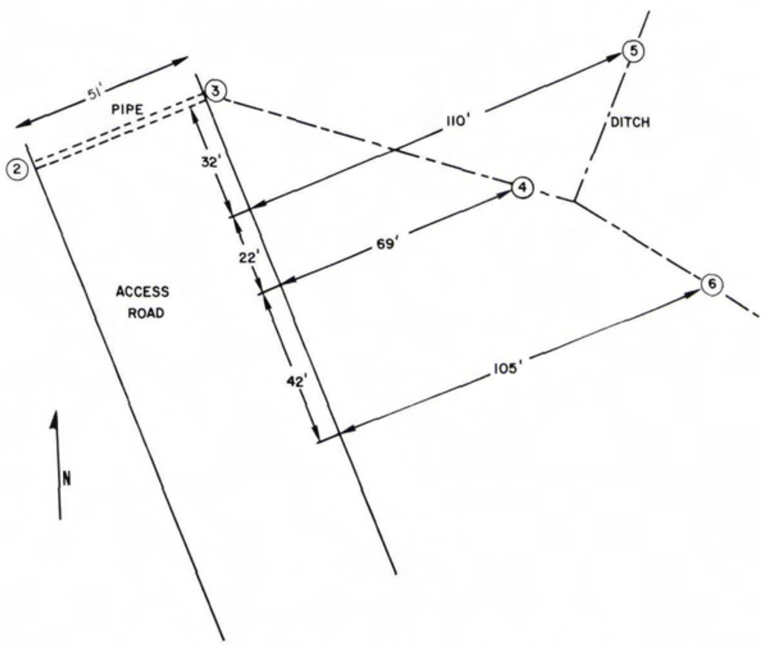

FIG. 2. Location of the marsh tide stations.

on December 21:

0124	−0.5 ft.
0749	2.8 ft.
1414	−0.6 ft.
2022	2.2 ft.

The range during the time of observation, 3.4 ft., was thus predicted as 126 percent of the average spring range and 155 percent of the mean range at this station. The time of occurrence of the tide at our site, as shown for Station 1, does not agree with these predictions. Given the complex hydrography of this coastal estuary, one would expect that reflections and damping, together with the slow propagation of the tidal wave in shallow water would complicate the tidal situation. This, in turn, means that tidal *range* predictions of the foregoing type are somewhat suspect. Thus, although we can be fairly certain that we observed a higher than normal tide, the exact relation of the observed to the mean tide is uncertain from the available data. The mild winds occurring on the day of observation should have had little influence on the tidal height.

TABLE 1. HYDROGRAPHIC DATA

Time	*Pipe Flow (fps.)*	*STA 1 (ft.)*	*STA 2 (ft.)*	*STA 3 (ft.)*	*STA 4 (ft.)*	*STA 5 (ft.)*	*STA 6 (ft.)*	*Wind (kts.)*	*Weather*
0700	0	0.04	0.00	0.00	0.00	0.00	0.00	0	Clear
0800	0	0.36	0.07	0.07	0.01	0.01	0.01	0	"
0900	F 0.212±.003	0.71	0.27	0.27	0.07	0.08	0.08	0	Overcast
1000	F 0.73±.03	0.85	0.51	0.51	0.18	0.18	0.17	0	"
1100	F 1.7±.17	0.95	0.92	0.79	0.59?	0.44	0.44	3 E	"
1200	F 1.7±.17	0.83	1.01	0.87	0.65	0.65	0.65	4½ E	"
1300	F 0.65±.02	0.61	0.87	0.87	0.76	0.79	0.77	3 E	"
1400	E 0.64±.02	0.37	0.76	0.76	0.73	0.74	0.73	4½ N	"
1500	E 0.64±.02	0.19	0.70	0.70	0.68	0.69	0.68	3½ NW	"
1600	E 0.64±.02	0.03	0.64	0.64	0.61	0.62	0.62	3 NW	Drizzle
1700	E 0.51±.02	0.00	0.58	0.58	0.55	0.57	0.55	6 N	"
1800	E O.42±.01	0.17	0.53	0.54	0.50	0.52	0.51	—	Rain
1915	E 0.33±.01	0.21	0.50	0.50	0.43	0.46	0.46	—	"

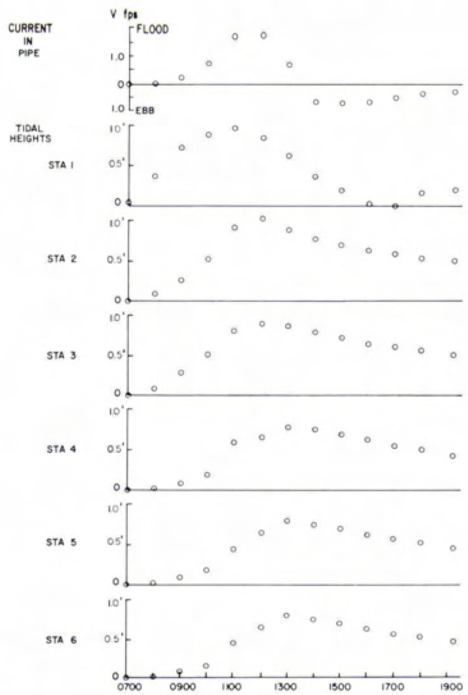

FIG. 3. Observed currents and tidal heights.

Table 1 indicates that Stations 4, 5 and 6 have virtually the same tide at all times (an exception is Station 4 at 1100—this may be an error in the data). We conclude that this is the normal state of affairs for stations with their separation in the marsh. Accordingly, these stations are taken as representing the average tide in the marsh. There is a great deal of difference between Stations 3 and 4 all during the flood portion of the cycle. The effect is one of a hill of water at Station 3 flowing down to Stations 4, 5, and 6. This is a result of the constricted flow through the pipe and has the effect of introducing a small positive error into the area calculated by dividing the mean tidal height at Stations 4, 5, and 6 into the tidal volume measured at the pipe.

The volume flow through the pipe during the flood portion of the cycle was calculated from the current in the pipe on the assumption of plug flow through the pipe at the current calculated from the transit times of the dye. In these calculations the entire cross-sectional area of the pipe was used as: (1) the dye method provides an average transport velocity for the pipe and (2) the pipe was submerged at all times when current was flowing except 0900 when only 0.2 ft. was exposed. The total volume was then calculated by taking the time integral of the transport using the trapezoid method of numerical integration and was found to be $5.27 \pm .48 \times 10^4$ ft^3. An attempt was made to check this result using an empirical pipe flow formula and the difference in head across the length of the pipe (the difference in tidal height at Stations 2 and 3); however, as can be seen from Table I, the difference in heard is not measurable except at the higher current speeds.

The tidal range during this time was 0.78 ft. Due to the generally steep sides of the marsh, its area may be approximated by assuming it to be a vertical walled container. This implies a flooded area of $6.75 \pm .62 \times 10^4$ ft^2 compared with $6.24 \pm .13 \times 10^4$ ft^2 by planimetering the delineation arrived at by remote sensing. Thus, we have agreement within the errors of the two methods.

The perimeter of the marsh is about 1010 feet, giving a development (ratio of the perimeter to the circumference of a circle of similar area) of 1.18. Given that the difference of the areas measured by the two methods is $5.1 \pm 6.3 \times 10^3$ ft^2, the linear error in determining the boundary may be estimated at 5.1 ± 6.3 ft, thus verifying the method of Garvin and Wheeler.

The agreement could be improved if more data were available in the vicinity of the pipe, for, as mentioned above, there is a hill of water in this area which introduces a small but unknown positive error in the calculation of the area from the hydrographic data. A second source of error is the assumption of vertical walls on the marsh instead of considering it a trapevoidal prism; however, such a calculation would require an *a priori* knowledge of the areas flooded at high and low tide.

REFERENCE

Garvin, Lester E. and Richard H. Wheeler, "Coastal Wetlands Inventory in Maryland." *ACSM Proceedings*, 33rd Annual Meeting, March 11-16, 1973, Washington, D.C. (Also presented at Coastal Mapping Symposium, June 1973, in Washington, D.C.)