1974

# Optimized measurements of discharge and suspended sediment transport in a salt marsh drainage system

John D. Boon III
*Virginia Institute of Marine Science*

## Recommended Citation

Boon, John D. III, Optimized measurements of discharge and suspended sediment transport in a salt marsh drainage system (1974). *Memoires- Institut de Geologie du Bassin d'Aquitaine*, 7, 67-73.
https://scholarworks.wm.edu/vimsarticles/2203

Mém. Inst. Géol. Bassin Aquitaine
1974, n° 7, p. 67 - 73

# OPTIMIZED MEASUREMENTS OF DISCHARGE AND SUSPENDED SEDIMENT TRANSPORT IN A SALT MARSH DRAINAGE SYSTEM

*John D. BOON, III - Virginia Institute of Marine Science Gloucester Point, Virginia 23062*

Detailed measurements of current speed and suspended sediment concentration distributions in a channel cross-section of a tidal marsh creek were analyzed. Subsequent sampling intervals in time and space were selected to provide acceptable estimates of flood and ebb transport of water and suspended sediment past the cross-section. Data from eight 13-hour measurement runs taken at various times of the year seem to favor a net ebb residual of suspended sediment transport for the year in question.

A number of environmental factors appear to influence suspended sediment transport in marsh channels.Residual transport of sediment in these systems is, however, considered to be primarily related to a diffusive mechanism associated with a pronounced asymmetry in the time-varying discharge and velocity curves. This mechanism and the observations made to date suggest that the inner-marsh drainage system is, on balance, an erosional feature and not a conveyance for marsh building sediments.

## INTRODUCTION

Virginia's Eastern Shore Peninsula borders the Atlantic Ocean in a long chain of barrier islands, behind which are found large areas of marsh, interspersed with shallow bays and tidal flats connected by a complex configuration of tidal channels. In addition to the major tidal channels, there are hundreds of smaller channels winding into the marshes, which twice-daily convey a sizeable quantity of water to and from the marsh surface. This paper reports the results of experiments conducted at the entrance to one of these small channel networks which drains a definable area of marsh. The purpose of the experiments was to examine the temporal and spatial distributions of the flow field and suspended solids concentration and to evaluate the role of the channel system in achieving a residual (nontidal) transport of material between the marsh and adjacent waterways. Significantly, there are no major river systems on Virginia's Eastern Shore and the transport of the abundant fine cohesive sediments found in the bays, marshes, and channels is effected solely by alternating tidal currents modified to some extent by wind-driven currents.

## EXPERIMENTAL DESIGN

A lumber bridge was built across the entrance to a small marsh channel known as Little Fool Creek (fig. 1) to serve as a sampling platform. The channel width is about 12 meters at this section, the bottom being about I. 5 meters below the creek banks. The length of the creek is about 400 meters. Figure I shows the creek at low tide (mean range : I. 2 m).

If the distributions of current speed (u) and suspended sediment concentration (c) were both steady and uniform throughout the channel cross-section, the flux of suspended matter, $q_s$, could be easily determined as

$$q_s = uc \times \text{area of flow section}$$

where $q_s$ has the dimensions $MT^{-1}$. Initial experiments, however, revealed sizeable variations in u and c, in both time and space. Additional experiments were undertaken utilizing a large number of ducted current meters

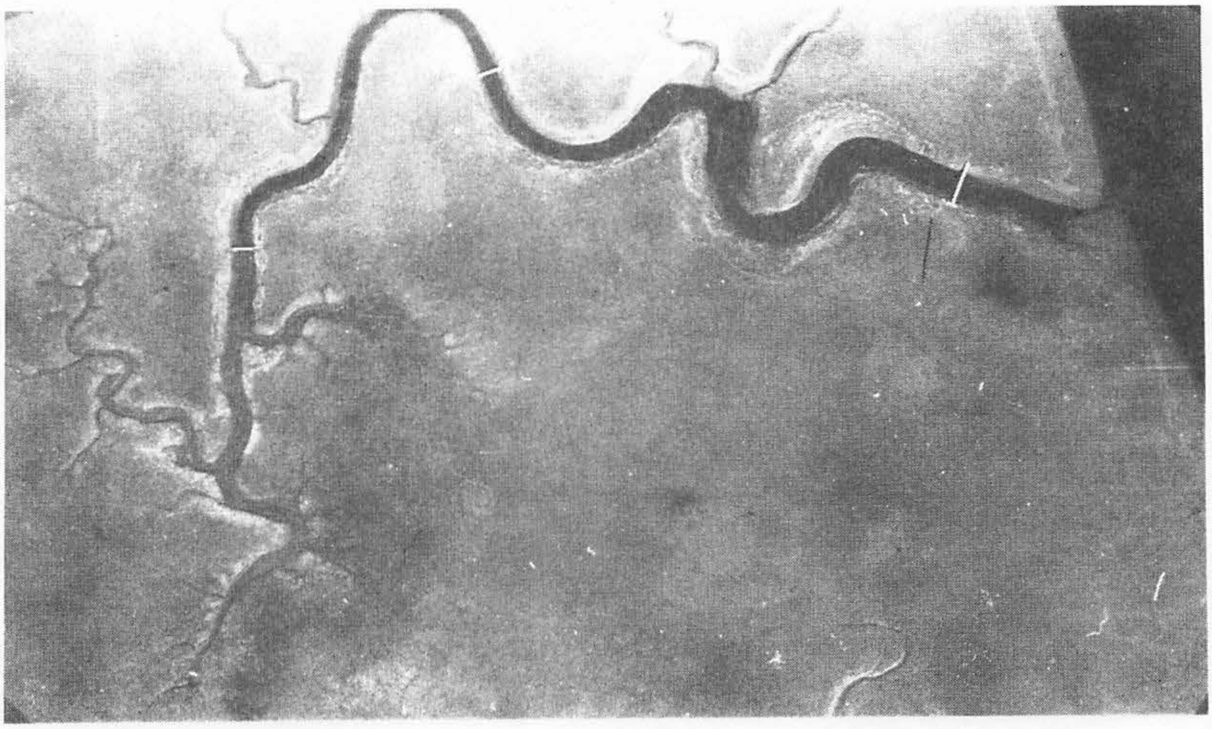

Figure 1 - Little Fool Creek shown during a low tide.

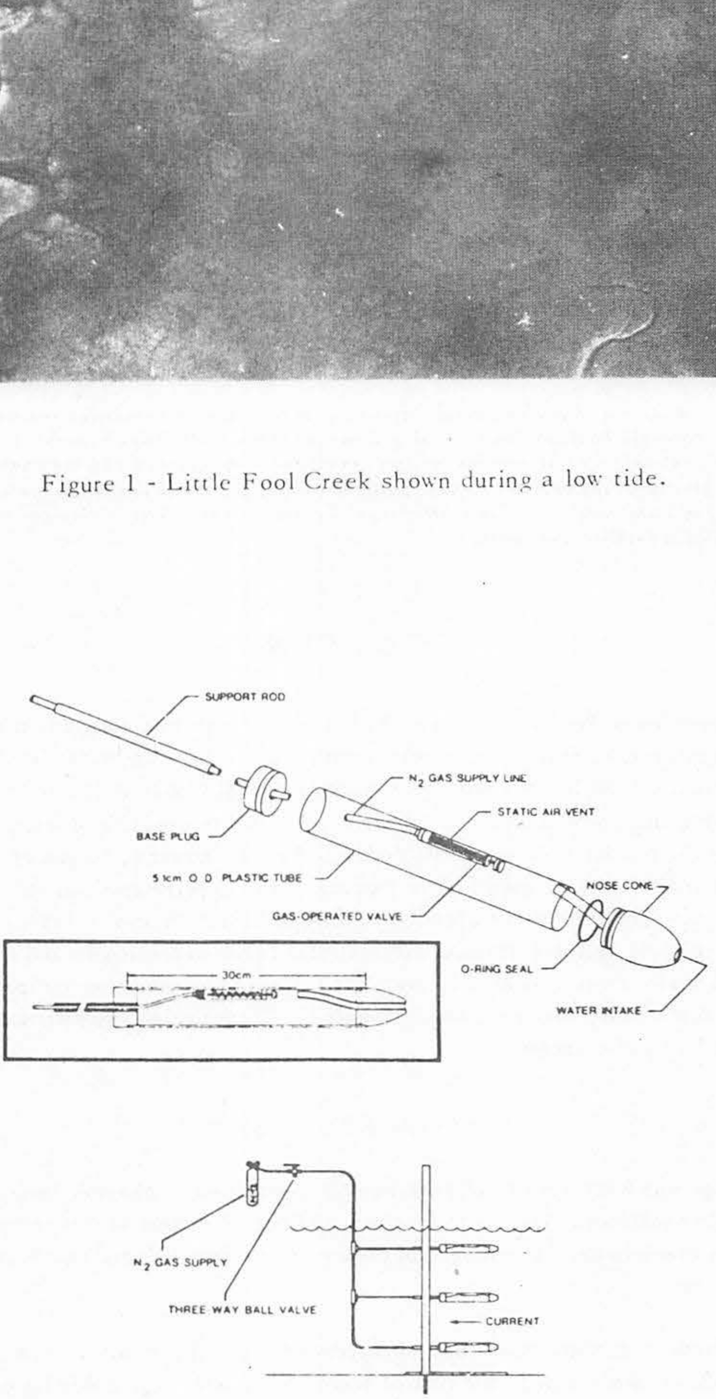

Figure 2 - Gas-operated water sampling device (concentrations determined by filtration).

(Byrne and Boon, 1973) and water samplers (Fig. 2) to observe these variations in some detail, estimating mean value error associated with various sampling configurations. The configuration ultimately adopted (Fig. 3) contained as many as 12 water samplers and 8 current meters, depending upon tidal stage, all of which were activated simultaneously at intervals of 30 minutes. This procedure permitted development of the curve of $q_s$ through time which can be integrated to obtain the flood, ebb, and residual transport of suspended sediment. A similar process applies to the discharge (q) curve and the residual transport of water, if any.

An important point worth noting is the following : If the flood and ebb transports of either water or sediment are known within certain limits of accuracy, say 10% for each quantity, no residual transport should be inferred unless the residual exceeds that limit (e. g., 10% of the gross average of flood and ebb transport).

The present experiment was designed to attain the "optimum" sampling configuration in time and space, beyond which further sampling detail produces little additional reduction in sampling error (see Gunnerson, 1966; Boon, 1972, 1973). For the results which follow, the sampling error estimates were placed at 5% for flood or ebb discharge measurements and 7% for flood or ebb measurements of suspended sediment transport.

## RESULTS OF THE EXPERIMENT

Total flood and ebb discharge measurements at the entrance to Little Fool Creek were obtained during runs made at different times of the year. In Table 1 these are compared with the tidal prisms computed for the creek using a hypsometric (water surface area-height) model of a closed drainage system in conjunction with actual tide data. This model will be fully described in a forthcoming paper.

As shown in Table 1, most of the residual water volumes are close to the 5% level (except during run 10 in which very weak flows were encountered). This result and the general agreement with model transport volumes supports the adequacy of the transport measurement scheme and the assumption that the drainage network in Little Fool Creek behaves as a closed system. Without this support, differential sediment transport estimates would have little meaning.

Table 2 contains the results of the sediment flux runs. Except for Run 8s, the larger transport residuals favor the ebb direction. Three of the runs (5s, 6s, and 7s) evidence very little transport which is largely due to the low suspended solids concentrations normally observed in this area when water temperatures are low. Low water temperatures may either increase the resistance of cohesive bottom sediments to erosion (Grissinger, 1966), or may possibly reduce turbulent mixing through a well-formed laminar sublayer at the flow boundary (Partheniades, 1970).

In addition to the temperature effect, a well-known seasonal variation in monthly mean sea level (Pattulo, et al., 1955) was observed in tide records collected near the study site. Monthly mean sea level values are normally highest in September and October and lowest in January and February, the maximum difference amounting to some 30 cm. This effect leads to less flooding of the marsh and fewer prisms of large magnitude during the winter months. In combination with the temperature effect on concentration levels, the marsh creeks then normally experience very little transport of suspended sediment in winter.

## DISCHARGE CURVE ASYMMETRY

The most consistently observed feature in terms of flow characteristics in marsh channels is that of a pronounced asymmetry in the time-varying discharge (and current) curve for a given flow section. Both flood and ebb discharge maxima occur approximately 1.5 to 2.0 hours before and after the time of high water slack. An example of this type of curve is shown in Figure 4. The cause of the asymmetry lies in the fact that large volumes of water must pass the channel section as large areas of marsh are inundated or uncovered at the higher tidal stages. At the lower stages, only the volumes confined to the channel are in transit.

Postma (1961, 1967) and Groen (1965) both describe current asymmetries in their work in the Dutch Wadden Sea. Groen has presented a theoretical explanation of how such an asymmetry can effect a residual transport of suspended sediment in an alternating flow with equal flood and ebb maximum current strengths and no net transport of water. Basically, residual transport occurs because of an imbalance between suspension of

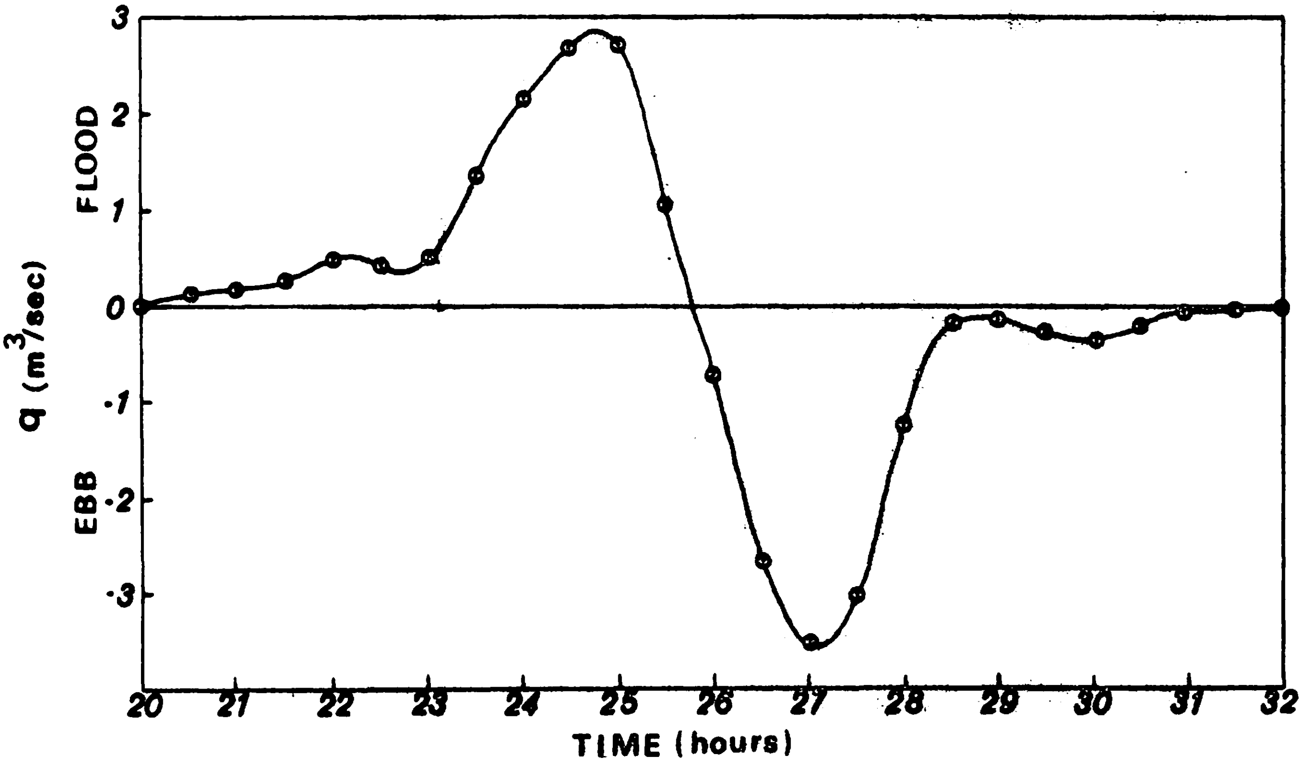

FIGURE 4. Discharge curve, q determined at 30 min. intervals, entrance to Little Fool Creek, 8/31/73

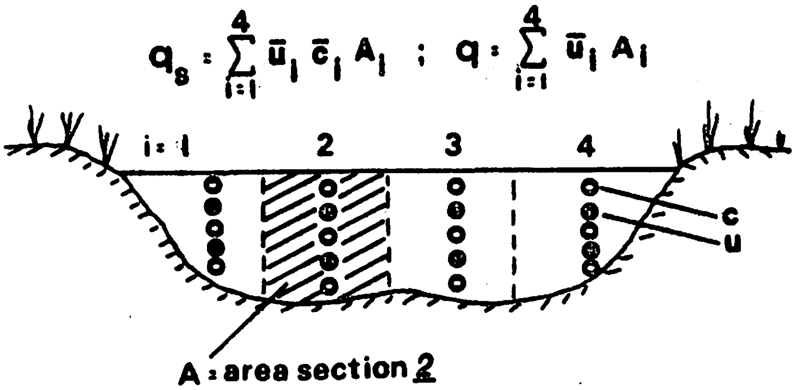

FIGURE 3. Sampling configuration, channel cross-section; sediment flux, $q_s$, and discharge, q, are computed from simultaneous measures of u and c (bars denote section average) over 2 min. interval

particles by turbulent diffusion and settling due to gravity. The current maximum preceded by a relatively longer period of low velocities (low turbulence) is then less effective in terms of suspended transport. The asymmetry described in the Wadden Sea relates to tidal flat channels and is exactly opposite to that produced in marsh channels (cf., Myrick and Leopold 1963; Pestrong, 1965). Hence, one may infer that the direction of the residual transport is also reversed (Landward in tidal flat channels, seaward in marsh channels).

Other factors undoubtedly affect residual sediment transport. Among these, horizontal advection and diffusion attending flows in the presence of horizontal concentration gradients may be important. The action of wind waves during storms often stir more sediment into suspension in the tidal flats and shallow bays than in the marshes themselves which is conducive to the formation of gradients. Data from the present study are insufficient to evaluate this method of transport between bays and marshes.

## CONCLUSIONS

On balance, the marsh drainage channel is considered to be an erosive feature, removing more sediment from the inner marsh than it brings in. This is a very tentative conclusion, owing to the complexity of the system under consideration which shows a variable pattern of residual sediment transport. The physical mechanisms by which this transport occurs are very helpful in this regard, particularly those related to the discharge asymmetry. Broken into seasonal components, the residual transport may be characterized as heavy and ebb-oriented during summer and early fall, light and variable during winter months, heavy and flood-oriented during early spring. Further field experiments are needed to strengthen this conclusion.

Having concluded that small marsh channels are unlikely conveyances for a net transport of sediment into the marshes, it remains to be explained how marshes grow by vertical build-up of sediments as indicated by stratigraphic evidence. The autor suggests only that the marsh channel systems are not themselves responsible but that other avenues of transport must be investigated. A large part of the marsh boundaries are formed against the edges of the larger channels and tidal flats, which, during extreme tidal stages, convey a sheet-flow of water onto the upper marsh surfaces. The potential for entrapment of sediment may be quite for this type of conveyance and should be investigated.

## REFERENCES

Boon, J.D., 1972, Optimum sampling intervals for measurement of discharge and suspended sediment transport in a low-order tidal stream typical of salt marsh drainage systems: Chesapeake Res. Consortium, Inc., Annual Rpt., pp. 186-215.

1973, Ph.D. Dissertation, College of William and Mary, Williamsburg, Virginia.

Byrne, R.J. and Boon, J.D., 1973, An inexpensive, fast response current speed indicator: Chesapeake Sci. (in press).

Grissinger, E.H., 1966, Resistance of selected clay systems to erosion by water: Water Resources Research, Vol. 2, N° I, pp. 181-138.

Groen, P., 1965, On the residual transport of suspended matter by an alternating tidal current : Netherlands J. Sea Res., Vol. 3n° 4. pp. 564-574.

Gunnerson, C.G., 1966, Optimizing sampling intervals in tidal estuaries: J. Sanitary Eng. Div., A.S.C.E., Vol. 92, n° SA2, pp. 103-125.

Myrick, R.M., and Leopold, L.B., 1963, Hydraulic geometry of a small tidal estuary: U.S. Geol. Survey Prof. paper 422-B, 18 p.

Partheniades, E., 1965, Erosion and deposition of cohesive soils: J. Hydraulics Div. A.S.C.E., vol. 91, n°HY L, pp. 105-139.

Patullo, J., Munk, W., Revelle, R., and Strong, E., 1955, The seasonal oscillation in sea level: J. Mar. Res. vol. 14, n° 1, pp. 88-155.

Pestrong, R. , 1965, The development of drainage patterns on tidal marshes, : Ph. D. dissertation Standford Univ. , 87 p.

Postma, H. , 1961, Suspended matter and Secchi Disc visibility in coastal waters : Neth.J. Sea Res., vol. 1, pp. 359-390.

, 1967, Sediment transport and sedimentation in the estuarine environment; Estuaries (G. Lauff, ed.) pub. n° 83, A.A.A.S., pp. 158-179

TABLE 1

A COMPARISON OF TIDAL PRISM VALUES (m3) DERIVED BY THE HYPSOMETRIC MODEL AND BY FLOW MEASUREMENT AT THE ENTRANCE TO LITTLE FOOL CREEK

| Run | Phase | Model | Measured | Tide |
|---|---|---|---|---|
| 1 | Flood | 46,224 | 44,661 | -.12 to 1.52 |
| (5/16/72) | Ebb | 46,119 | 45,979 | 1.52 to -.06 |
| | Residual | + 105 (0.2%) | -1,318 (2.9%) | |
| 2 | Flood | 26,468 | 27,871 | 0.15 to 1.28 |
| (6/30/72) | Ebb | 26,595 | 29,982 | 1.28 to 0.09 |
| | Residual | -127 (0.5%) | -2,111(7.3%) | |
| 3 | Flood | 38,965 | 40,624 | -.09 to 1.43 |
| (8/1/72) | Ebb | 38,741 | 42,269 | 1.43 to 0.03 |
| | Residual | + 224 (0.6%) | -1,645 (4.0%) | |
| 4 | Flood | 19,140 | 21,433 | 0.21 to 1.19 |
| (8/31/72) | Ebb | 19,340 | 22,542 | 1.19 to 0.12 |
| | Residual | - 200 (1.0%) | - 1,109 (5.0%) | |
| 5 | Flood | 7,034 | 7,184 | 0.17 to 0.97 |
| (10/16/72) | Ebb | 7,105 | 7,347 | 0.97 to 0.14 |
| | Residual | - 71 (1.0%) | - 163 (2.2%) | |
| 6 | Flood | 37,613 | 37,288 | 0.44 to 1.43 |
| (11/12/72) | Ebb | 37,613 | 37,679 | 1.43 to 0.44 |
| | Residual | 0 (0) | - 391 (1.0%) | |
| 7 | Flood | 28,909 | 30,201 | 0.41 to 1.32 |
| (11/30/72) | Ebb | 29,608 | 32,232 | 1.32 to 0.18 |
| | Residual | - 698 (2.4%) | - 2,031 (6.5%) | |
| 8 | Flood | 22,575 | 24,530 | 0.10 to 1.23 |
| (12/11/72) | Ebb | 22,449 | 24,048 | 1.23 to 0.16 |
| | Residual | + 125 (0.6%) | + 482 (2.0%) | |
| 9 | Flood | 47,889 | 41,986 | -.47 to 1.54 |
| (12/20/72) | Ebb | 47,889 | 44,962 | 1.54 to -.20 |
| | Residual | 0 (0) | - 2,976 (6.8%) | |
| 10 | Flood | 6,569 | 6,201 | -.02 to 0.94 |
| (1/24/73) | Ebb | 6,695 | 6,992 | 0.94 to -.10 |
| | Residual | - 126 (1.9%) | - 790 (12.0%) | |

| | | | | |
|---|---|---|---|---|
| 11 | Flood | 28,641 | 26,275 | -.35 to 1.30 |
| (3/19/73) | Ebb | 28,580 | 28,405 | 1.30 to -.13 |
| | Residual | + 60 (0.2%) | - 2,130 (7.8%) | |

TABLE 2

TRANSPORT OF SUSPENDED SOLIDS OBSERVED AT THE ENTRANCE

TO LITTLE FOOL CREEK TIDAL DATUM IS MLW

| Run | Phase | Transport (Kg) | Tide (m.) |
|---|---|---|---|
| 1S | Flood | 2119 | -.12 to 1.52 |
| (5/16/72) | Ebb | 3574 | 1.52 to -.06 |
| | Residual | -1455 (51.1%) | |
| 2S | Flood | 890 | 0.15 to 1.28 |
| (6/30/72) | Ebb | 2174 | 1.28 to 0.09 |
| | Residual | -1284 (83.8%) | |
| 3S | Flood | 2065 | -.09 to 1.43 |
| (8/1/72) | Ebb | 2821 | 1.43 to 0.03 |
| | Residual | - 756 (30.9%) | |
| 4S | Flood | 793 | 0.21 to 1.19 |
| (8/31/72) | Ebb | 1043 | 1.19 to 0.12 |
| | Residual | - 250 (27.3%) | |
| 5S | Flood | 276 | 0.17 to 0.97 |
| (10/16/72) | Ebb | 230 | 0.97 to 0.14 |
| | Residual | + 46 (18.1%) | |
| 6S | Flood | 723 | 0.10 to 1.23 |
| (12/11/72) | Ebb | 548 | 1.23 to 0.16 |
| | Residual | +175(27.5%) | |
| 7S | Flood | 101 | -.02 to 0.94 |
| (1/24/73) | Ebb | 62 | 0.94 to -.10 |
| | Residual | + 39 (47%) | |
| 8S | Flood | 3054 | -.35 to 1.30 |
| (3/19/73) | Ebb | 1617 | 1.30 to -.13 |
| | Residual | + 1436 (61.5%) | |