Sebastian Inlet – Tidal Hydraulic Characteristics

By Ralph R. Clark, P.E.

August 2004

Florida Department of Environmental Protection
Division of Water Resource Management
Bureau of Beaches and Coastal Systems
August 2004

Sebastian Inlet – Tidal Hydraulic Characteristics

Every coastal tidal inlet is unique in its hydrodynamic and morphological regime and Sebastian Inlet (Figure 1) is no exception. Generalizations about details of its behavior may be risky. However, clearly a rough understanding of the general hydraulic characteristics gives us an insightful knowledge when contemplating management strategies.

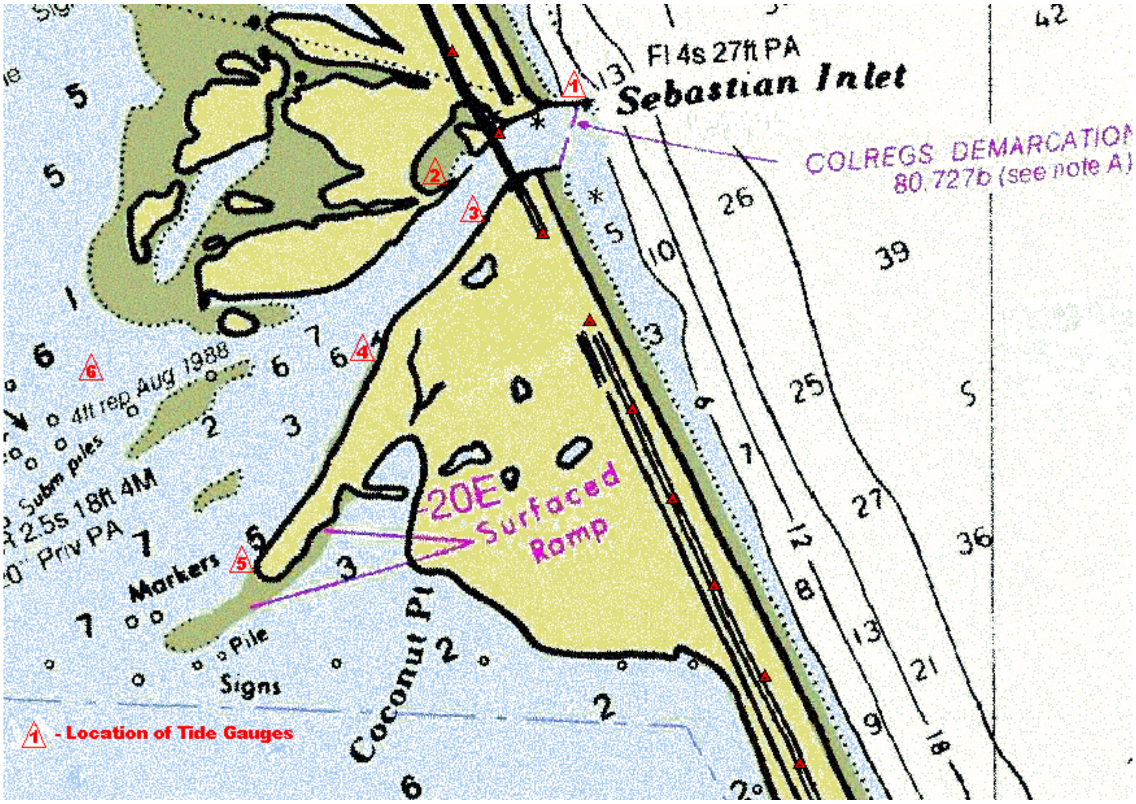


Figure 1. Sebastian Inlet (NOAA Nautical Chart)

A few coastal engineers over the past 40 years have investigated the tidal hydraulics of Sebastian Inlet. The most notable investigation was conducted by T.Y. Chiu while with the Coastal Engineering Laboratory at the University of Florida between 1963-1965. The tide and current data obtained during this study remains probably the most useful tide and current data set available today (Appendix A).

The University's studies conducted during the 1960's followed some major construction activity in the inlet. There was jetty construction in 1955 and 1959, followed by the excavation of an 11-foot channel in 1962. The first hydraulics investigation was actually conducted in 1962 when the Coastal Engineering Laboratory measured surface currents in the inlet [Reference 1]. Data obtained in the center of the channel peaked at 6.0 ft./sec. during flood and 6.1 ft./sec. during ebb. Data obtained north of the channel peaked at 6.1 ft./sec. (flood) and 8.2 ft./sec. (ebb).

The best data was obtained the following year when the Coastal Engineering Laboratory conducted tidal observations from July 1963 to April 1964 [References 2 and 3]. Over this time period, these records reflect an ocean mean tide range of 3.4 feet and a spring tide range of 3.9 feet. Some extreme tide ranges reached 4.3 feet. From data obtained at the west end of the inlet, a lagoon tide range averaged 0.23 feet.

The University of Florida field study in 1963 obtained current measurements which showed a peak flood velocity, $V\text{MAX}_F$, of 7.2 ft./sec. and a peak ebb velocity, $V\text{MAX}_E$, of 9.1 ft./sec. A semi-diurnal spring tidal prism may be calculated to be 3.04 x 10^8 ft.^{3} for an ebb tide with a peak maximum ebb velocity of 9.1 ft./sec. A semi-diurnal spring tidal prism for a flood tide may be calculated to be 2.35 x 10^8 ft.^{3} for a peak maximum flood velocity of 7.2 ft./sec. The daily tidal prism (twice the semi-diurnal tidal prism) would be about 6 x 10^8 ft.^{3} for ebb flow and 4.75 x 10^8 ft.^{3} for flood flow. The Coastal Engineering Laboratory incorporated these current velocity data into the design of a fixed bed, steady flow physical model and reported the results in References 2 and 3.

In 1976, the Florida Sea Grant Program published a third "Glossary of Inlets Report" for Sebastian Inlet (Reference 4). Mehta et al (1976) noted that for a tidal prism calculated in the 1963-65 studies, a stable sandy inlet cross-section in sedimentary equilibrium would be about 8,460 ft.^{2}. The actual reported throat section at the time was only 3,900 ft.^{2} (below mean low water) or roughly half the predicted stable flow area. This existing flow area is constricted by the armored inlet shorelines and the rocky bottom of the inlet. Conversely, the tidal prism flowing through Sebastian Inlet is roughly twice the volume that should flow through a sandy inlet of the existing cross-section. This explains the very high flow velocities, likewise at least twice what they should be for a stable flow area in a sandy inlet.

In 1988, an inlet management planning study was conducted by Coastal Technology Corporation (Reference 5). Some tidal observations and currents were measured during neap tide conditions. Inlet stability computations were conducted which used a bay or lagoon surface area, A_b, equal to 1.5×10^9 ft.^{2}, a bay or lagoon tide range, $2a_b$, of 0.35 ft., a potential or volumetric tidal prism, P_v, equal to 5.2×10^8 ft.^{3}, and an ocean tide range, $2a_o$, of 3.8 ft (Appendix B). A critical cross-sectional area was calculated to be 1.5×10^4 ft.^{2}, which is substantially greater than the existing cross-section of 3,900 ft.^{2} (below mean low water) or 4,400 ft.^{2} (below mean sea level). These calculations were additional evidence to the instability of the inlet, which would close were it not for the existing stabilization (jetties, shoreline armoring, rocky bottom). Coastal Technology Corporation further calculated that in order to have an inlet in sedimentary equilibrium having a maximum velocity of 3.5 ft./sec., would require a throat cross-sectional area of 1.5×10^5 ft.^{2} or roughly 38 times the existing throat section of Sebastian Inlet.

In 1990, the Coastal and Oceanographic Engineering Department, University of Florida, collected field data during January at Sebastian Inlet (Reference 6). Ocean tide ranges ($2a_o$) during this period of record varied from about 5 ft. to 2 ft. Two gages recorded data within the inlet, but no lagoon tides were obtained. Currents were measured from the bridge and unexpectedly the flood currents were slightly greater than the ebb currents. The maximum currents measured reached 6 to 6.5 ft./sec. A fixed bed model based on a 1989 bathymetric survey was conducted to evaluate various jetty modifications. The University then conducted a movable bed model; however, no new hydraulic data was obtained (Reference 7).

No new hydraulics information appears to be available since the 1990 study. The most complete and useable tidal hydraulics data for the inlet appears to be the data obtained in the 1963-64 field study. Using these 40 years old data today, various additional computations may be developed so that we can make generalized comparisons to other stabilized inlets nearby. The tide and current data obtained specifically on September 5, 1963, was used by the University to calibrate the physical model that was constructed in the mid-‘60’s study.

Using the tide and current data obtained in the 1963-64 field study, various additional computations may be developed (Appendix A). Using a spring tide range in the ocean ($2a_o$) of 3.9 feet and a lagoon tide range ($2a_b$) of 0.23 feet, the ratio of tide ranges, $a_b / a_o = 0.06$.

Realistically, the Keulegan coefficient of repletion, K, would be indeterminately small (approaching zero). This is to be expected for a small inlet connecting a very large lagoon system. There is simply too great a surface area within the Indian River lagoon system. The semidiurnal tidal period (12.4 hours) is too short and the discharge insufficient to allow significant tidal filling (repletion) within such a large lagoon system.

The tide and current data from September 5, 1963, may be used to compute coefficients of impedence, F, which represent the effect of all influences restricting the flow through the inlet, not just the entrance and exit losses and the bottom friction. One might guess that given the high velocity currents at Sebastian Inlet, that there probably is a relatively low impedence to flow. For the stated tide data and current data, the following values are computed,

Ocean tide range................................. $2a_o = 3.9$ ft.
Maximum ebb velocity........................ $V_{MAX_E} = 9.4$ ft/sec
Averaged max. ebb velocity................ $\overline{V}_{MAX_E} = 8$ ft/sec
Duration of ebb.................................. $\Delta T_e = 380$ min.
Lag of slack after low tide.................. $\Delta t_e = 170$ min.
Phase lag, ebb..................................... $\varepsilon_e = 80.5$ degrees
Maximum flood velocity..................... $V_{MAX_F} = 7.3$ ft/sec
Averaged max. flood velocity............ $\overline{V}_{MAX_F} = 6.2$ ft/sec
Duration of flood................................ $\Delta T_f = 370$ min.
Lag of slack after high tide................. $\Delta t_f = 180$ min.
Phase lag, flood.................................. $\varepsilon_f = 87.6$ degrees

Impedence... $F = \dfrac{2a_o g \sin \varepsilon}{(\overline{V}_{max})^2}$

Impedence calculated for ebb and flood tide conditions on September 5, 1963, resulted in the following values:

$F_e = 1.94$

$F_f = 3.26$

$F_{ave} = 2.6$

These values for impedence at Sebastian Inlet are lower than any of the impedence values that the author has computed at 26 other inlets (O'Brien and Clark, 1973).

It may be of some value to compare the hydraulic characteristics of Sebastian Inlet with other nearby coastal inlets. The following table is provided for such a comparison with the three stabilized inlets to the south of Sebastian Inlet.

Table 1. Tidal Hydraulic Characteristics of 4 Southeast Florida Inlets.

Inlet	$2a_o$ (ft)	$2a_b$ (ft)	$\frac{a_b}{a_o}$	K	$\overline{V}_{MAX_E}$ (ft/s)	$\overline{V}_{MAX_F}$ (ft/s)	F_{ave}	P_H (x10^8 ft^3)
Sebastian	3.9	0.23	0.06	~0	8	6.2	2.6	3.5
Ft. Pierce	3.1	1.5	0.5	0.46	5.2	4.4	7.2	6.4
St. Lucie	3.3	1.3	0.4	0.43	5.7	4.3	10.2	5.6
Jupiter	3.0	2.2	0.7	0.75	3.8	4.5	6.3	2.9

In Table *1*, Sebastian Inlet clearly stands out for its low ratio of ranges, its low repletion coefficient, its high current velocities, and its low impedence to flow.

O'Brien and Clark (1973) identified a few characteristics that permit a rough classification of inlets. One category of inlets identified were those inlets having **a very large lagoon area**. Sebastian Inlet would definitely fall into this category. For inlets where the ratio of the surface area of the lagoon (A_b = 1.5 x 10^8 ft.^{2}) to the flow area of the inlet (A_c = 4,400 ft.^{2}) is very large (A_b / A_c = 340,000), then the repletion coefficient should be small ($K \cong 0$), the lag of slack water should approach 90 degrees (ε_f = 87.6 degrees), and the range of tide in the lagoon should approach zero ($2a_b$ = 0.23 ft.). Sebastian Inlet's hydraulic characteristics meet these criteria in every respect. For large shallow lagoons like the Indian River lagoon, a tidal effected surface area may only be a small fraction of the actual surface area of the lagoon. One should recognize that the long tide wave itself advances across the lagoon at a wave celerity of $\sqrt{gh}$, where g is the acceleration of gravity and h is the depth of the lagoon.

The significance of the inlet's hydraulics to sediment transport within the inlet and to fluvio-hydrodynamic factors which affect the morphology of the inlet and adjacent areas, while a given, is perhaps not well understood, even though there has already been three physical models (two fixed-bed and one moveable-bed). These models were sophisticated tools that appropriately evaluated major structural modifications to the inlet.

The fact that current velocities remain high throughout the inlet provides a reasonable expectation of minimal sediment layers within the channel above the Anastasia rock formation. The strategic location of the sediment trap at its more interior location where the inlet width begins its expansion is a recognition of the reduced interior flow velocities. The sediment trap is sited and dimensioned (trapezoidal) consistent with an actual flood tidal delta.

The ebb tidal delta is more perplexing. Walton and Adams (1976) developed an empirical relationship between the inlet tidal prism and the outer bar storage volume. The tidal prism employed was for the spring tide range of inlets in long-term sedimentary equilibrium. Of course, Sebastian Inlet would be highly unstable were it not for the existing jetties, etc., and sand transport through the inlet probably would be very low relative to the high flow conditions. The relationship developed for inlets like Sebastian Inlet that are exposed to a moderate wave climate is

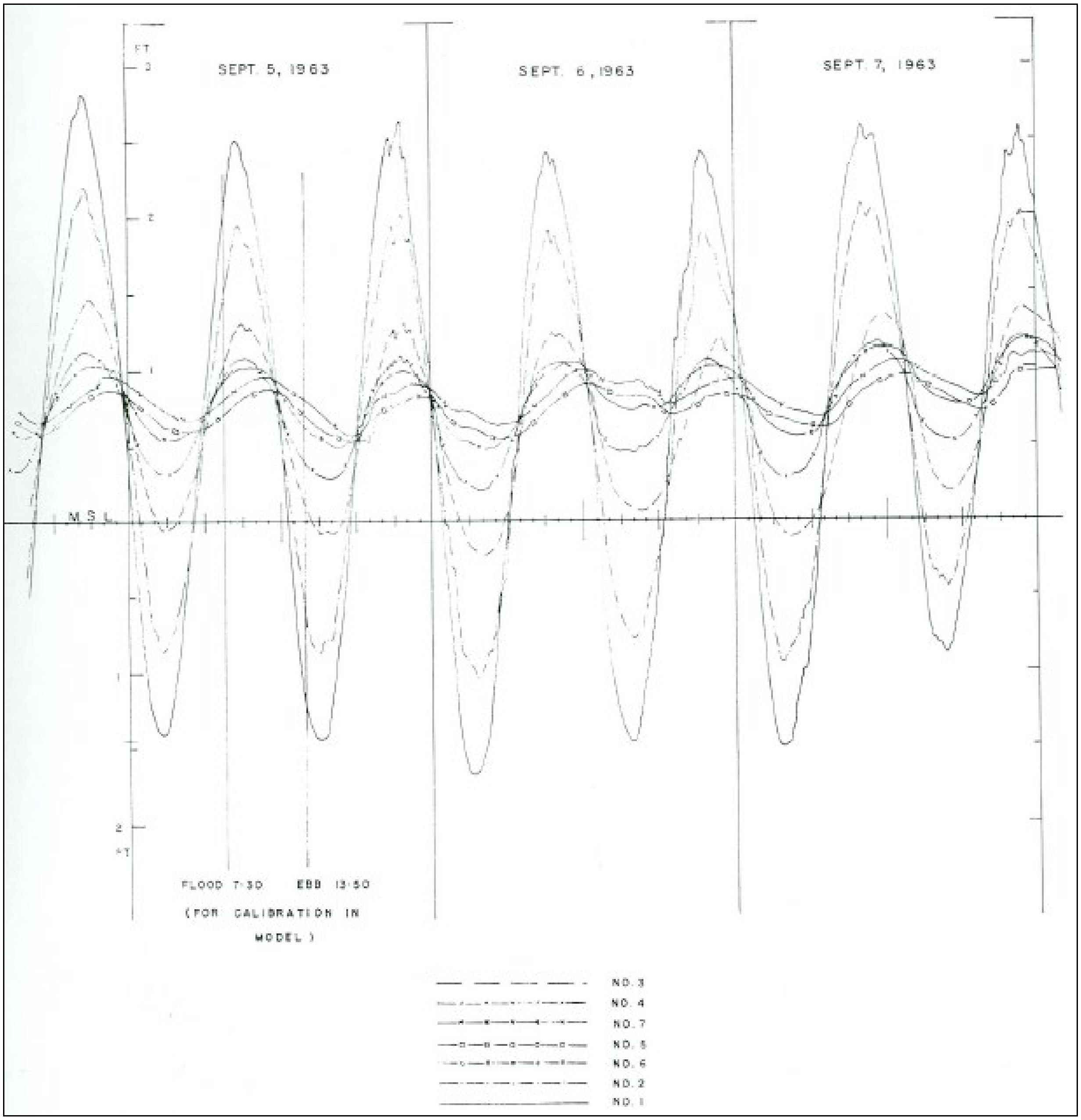
$$\rlap{-}V = 10.5 \text{ x } 10^{-5}\, P_S^{1.23}$$

where the spring tidal prism, P_S, is expressed in ft.^{3} and the outer bar volume of sand, $\rlap{-}V$, is expressed in yds.^{3}. For Sebastian Inlet, using a tidal prism of $3.5 \text{ x } 10^8$ ft.^{3}, yields a volume, $\rlap{-}V$, equal to $3.39 \text{ x } 10^6$ yds^3. Based on a 1987 survey of the inlet, Coastal Technology Corporation (1988) estimated the storage volume of approximately $1.5 \text{ x } 10^6$ yds.^{3} of sand in the inlet's ebb shoal. This estimate represents about half the potential storage volume that an inlet in sedimentary equilibrium would be expected to have based upon the given spring tidal prism.

In summary, based on available data and additional computations that can be made from this data, various conclusions may be reached. Most important is Sebastian Inlet falls into the category of inlets having a very large lagoon area. The lagoon tide range, $2a_b$, and the repletion coefficient, K, are very small, approaching zero, and the phase lag of slack water after low tide or high tide in the ocean, ε, approaches 90 degrees.

Sebastian Inlet would be unstable were it not for the jetties, shoreline armoring and rocky bottom, as its critical cross-section is much greater than its existing throat cross-section. For its tidal prism, a stable sandy inlet cross-section in sedimentary equilibrium would be about twice the existing throat cross-section. Because of this constriction, Sebastian Inlet has flow velocities about double what they should be for a stable flow area in a sandy inlet. Consistent with these high flow velocities, Sebastian Inlet has a very low impedance to flow. A comparison with nearby inlets shows Sebastian Inlet standing out with its low ratio of ranges, its low repletion coefficient, its high current velocities, and its low impedance to flow.

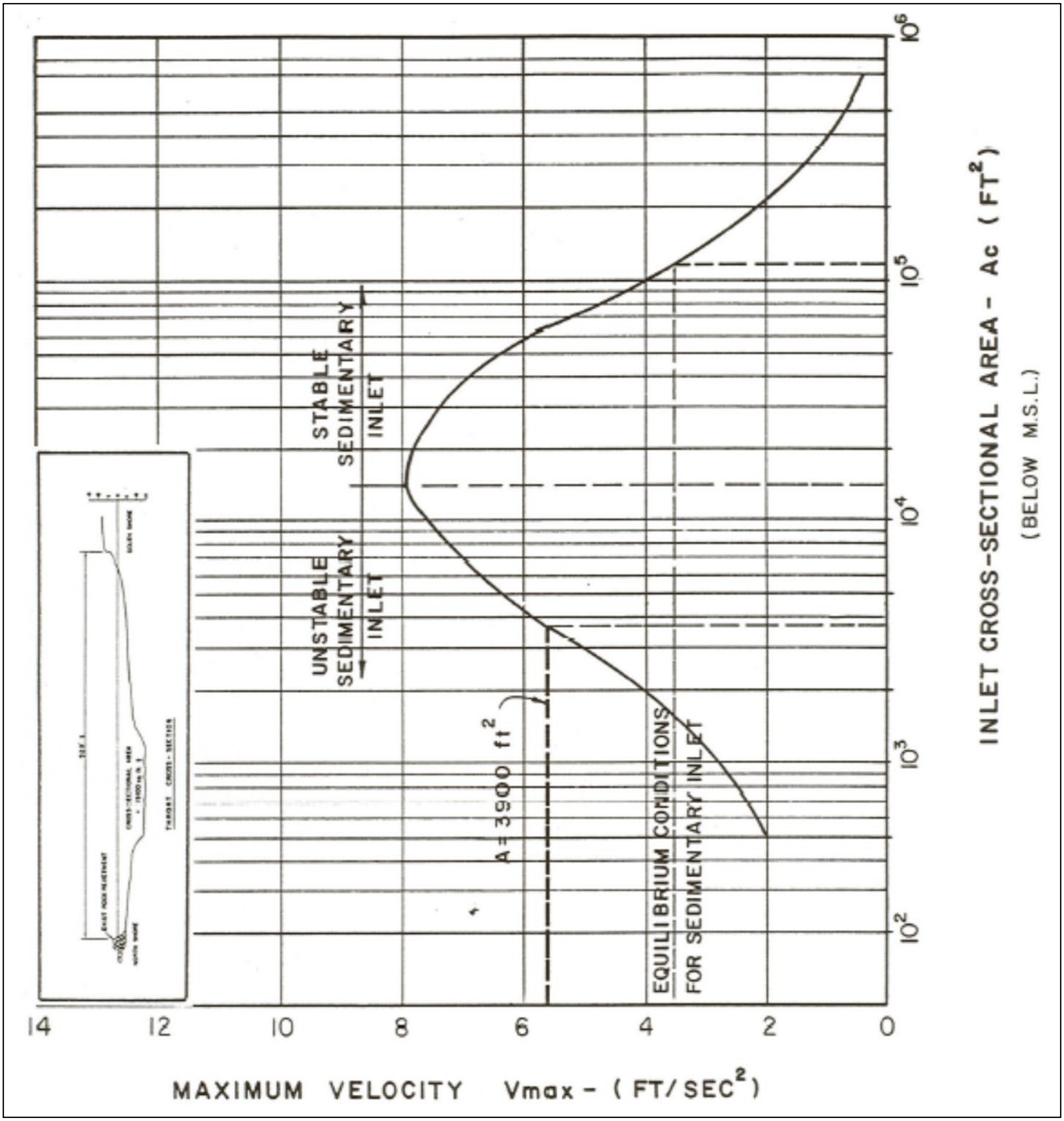
Appendix A



Sebastian Inlet Tidal Chart

[From "Model Study of Sebastian Inlet" T.Y. Chiu in Reference 3, page 15]

Appendix B



Maximum Velocities versus Inlet Cross Sectional Area

[Coastal Technology Corporation, Reference 5, Page A21]

References on Sebastian Inlet Tidal Hydraulics

1) Coastal and Oceanographic Engineering Laboratory, University of Florida (1962). *Coastal Engineering Study of Current Activity at Sebastian Inlet,* UFL/COEL-62/011.

2) Coastal and Oceanographic Engineering Laboratory, University of Florida (1965). *Coastal Engineering Hydraulic Model Study of Sebastian Inlet, Fl.,* UFL/COEL-65/006.

3) Bruun, P.M., Battjes, J.A., Chiu, T.Y., and Purpura, J.A. (1966). *Coastal Engineering Study of Three Florida Coastal Inlets,* Engineering Progress at the University of Florida, Vol. XX, No.6, Bulletin No.122.

4) Mehta, A.J., Adams, W.D., and Jones, C.P. (1976). *Sebastian Inlet Glossary of Inlets Report #3*, Florida Sea Grant Program Report No. 14.

5) Coastal Technology Corporation (1988). *Sebastian Inlet District Comprehensive Management Plan*.

6) Wang, H., Lin, L., Zhong, H., and Miao, G. (1991*). Sebastian Inlet Physical Model Studies - Part I - Fixed Bed*, UFL/COEL-91/011.

7) Wang, H., Lin, L., and Miao, G. (1992). *Sebastian Inlet Physical Model Studies – Final Report – Movable Bed Model*, UFL/COEL-92/006.

Other Cited References

1) O'Brien, M.P., and Clark, R.R. (1973). *Hydraulic Constants of Tidal Entrances I: Data from NOS Tide Tables, Current Tables and Navigation Charts*, Coastal and Oceanographic Engineering Laboratory, University of Florida, Technical Report No. 21.

2) Walton, T.L., Jr., and Adams, W.D. (1976). *Capacity of Inlet Outer Bars to Store Sand*, Proceedings of the 15th Coastal Engineering Conference, pp.1919-1937.