

**Sabine and Neches Rivers and Sabine Lake Bay Basin and Bay Expert
Science Team (BBEST)
Thoughts on what is Carried by Inflows and Bay Adaptive Management
Paul Jensen, 2-20-09**

Under SB 3 one of the key missions of the Environmental Flow Science Advisory Committee (SAC) is to advise the Bay Basin Committees on the science of bay inflow needs. Two basic ideas have emerged.

- The inflow needs should be expressed as an **inflow regime** (including seasonal patterns and attainment percentage goals) rather than a single inflow requirement, and
- There will be a need for some form of **adaptive management**.

Both of these ideas are in the process of being defined. One purpose of this document is to suggest more specific aspects of both ideas to advance the process of consensus building towards specific environmental flow recommendations.

There are two fundamental concepts behind the specific ideas suggested. One is that society desires a sound ecological environment for our bays and the other is recognition that bay systems have been extensively modified.

Sound Ecological Environment—There is a widely accepted view that our goal in managing the bays is and should be to maintain a sound ecological environment. There can be many definitions of this idea, but in brief it means providing the conditions necessary to support sustainable and productive bay ecosystems. A common element of the sound ecological environment is that it is defined in terms of the systems that we have studied and understand today. The studies that support that understanding have largely been conducted in relatively recent history—the last 30-40 years. Most studies and assessments are more recent.

Texas bays we know today are not natural systems—Beginning well over a hundred years ago, there have been a number of man-made changes to the natural bays.

- The watersheds were heavily modified by agricultural activity,
- Navigation channels were constructed and inlets stabilized,
- The bays were physically modified by shell dredging and subsidence,
- Commercial fisheries began to make a significant impact on the systems,
- Inflows were regulated,
- Waste discharges become large enough to have an impact on nutrient loads in some systems.

All of these changes have had significant effects on the bays, and most of these changes occurred prior to the studies that serve to define the sound ecological environment we know today. Change continues in most aspects.

Watershed Changes--The change from natural vegetation to row crop agriculture (and the more recent reversal of this trend in many areas) has altered the amount of runoff and concentrations of major flow constituents. Watershed changes started as cotton became important before the Civil War, and increased substantially through the 19th century and into the mid 20th century. There appears to have been a reversal of this trend in the later part of the 20th century. Data to quantify the effect of this change on the bays is lacking because it tends to be merged with other watershed changes. But monitoring for runoff concentrations indicates a substantial difference in runoff event mean concentrations (EMC) between forested and agriculture lands. The following examples illustrate the differences found in the runoff literature.

Parameter	EMC Values (mg/L)	
	Forested Open Land	Agriculture/Pasture
TKN	0.94	1.92
NO2-3-N	0.80	4.06
TP	0.11	0.37

In addition to changes in runoff characteristics, there is another change taking place in the type of nitrogen used in fertilizer. This is the increasing use of urea and a corresponding reduction in the use of inorganic forms such as ammonium nitrate. Figure 1 shows the trend with worldwide data. There is a substantial amount of literature dealing with the relation between the increasing amount and proportion of organic N available and the frequency of harmful algal blooms and other undesirable responses. Some examples include Glibert and Terlizzi (1999) and Switzer (2008).

Navigation Channels—The creation of stable navigation channels has increased the tidal exchange with the Gulf in all the bays, and appears to have increased average salinity in the eastern bays. Work on navigation channels began well over a century ago.

- Sabine-Neches: Jetties constructed in 1896 and Port Arthur Canal west of Sabine Lake completed in 1899. By 1916 there was a 25 ft channel to Beaumont.
- Galveston: Work on the Galveston Channel jetties that deepened and stabilized the entrance began in 1880 and was complete in 1897 (GBEP-39, 1993). By 1908 the Houston Ship Channel was 18 ft deep and 150 ft wide.
- Brazos: Freeport jetties 1889-1896. Mouth relocated 1929. No bay involved.

- Matagorda: Channel and jetties not constructed till early 1960s.
- Corpus Christi: 25 ft channel complete in 1926 and 30 ft by 1930.
- Brownsville: 32 ft channel complete in 1936.

The normal process for inlets is to be opened by strong river flows and to be closed or made shallow by sand moving in the longshore system at lower river flows. Building jetties to maintain channel conditions for navigation allowed steady tidal exchange even in lower flow periods. The navigation channels up the bays allowed salt from the Gulf to mix over more of the bays than would have been the case under natural conditions. In addition to making the bays better mixed and more salty than they were naturally, the improved mixing with Gulf water tends to increase the rate at which nutrients introduced at the upstream end of the estuaries are transferred to the Gulf. This accelerated transfer tends to reduce the bay concentrations of materials such as nutrients introduced from the watershed.

Physical Changes: The physical nature of the bays has been changed by activities such as sea level rise, subsidence and oyster shell dredging. Figure 2 shows the rate of relative sea level rise in some Texas bays as recorded by NOAA (2001). The plots shown are linear models fitted to tide gauge data along the coast to yield an average rate of relative sea level rise. Part of the increases can be attributed to human activities such as subsidence from water pumping and oil and gas extraction, and part is simply sea level rise combined with compaction of more recent coastal sedimentary deposits. Whatever the causes, the changes have not been inconsequential. For example, Ward (1993) found that the volume of Galveston Bay had increased by 30% between 1900 and 1990.

Fishing pressure: This may not have caused any species extinctions, but fishing pressure clearly affects populations and shifts in the balance between estuarine species. Regulating this fishing pressure is a major role of TPWD.

Reservoir Development: Inflow regulation allows for more consumptive water uses, greatly reduces the frequency and magnitude of flood flows and introduces lower flows during dry periods where none may have existed. Overall, reducing the extremes of inflows has allowed greater stability. An argument can be made that a reduction in extreme conditions might allow an overall higher level of biological production in our bays, but there are no comparative data to allow evaluation of this point. Inflow regulation does greatly reduce the supplies of sediment and nutrients to the bays. Heitmuller (2008) has noted the importance of sediment supplies in maintaining sound ecological conditions. Mathewson and Minter (1976) analyzed the effect of flow regulation on the sediment supply of the Brazos River and found that relative to 1920, the start of reservoir construction in the Brazos basin, the transport of sand to the coast had been reduced by roughly 76%. The ability of water supply and flood control reservoirs to retain particulate matter and to reduce the magnitude and frequency of flood flows that are the

major carriers of particulate matter downstream of control structures is both significant and reasonably well understood. A similar process occurs with nitrogen and phosphorus that would normally be carried by river flows to the bays. A high fraction of particulate forms of N and P are trapped and settled in reservoirs, and dissolved forms are provided sufficient residence time for biological uptake and retention in aquatic life and ultimately sediments.

Jensen et al. (2003) provides a quantification of the effect in the Trinity River and Galveston Bay system. The key findings of the paper are that relative to the mid 20th century, there has been a net reduction in the load of N to the bay despite substantial population increases. The reduction in N inputs was tracked by a reduction in bay chlorophyll *a*, a measure of primary productivity.

Wastewater Discharge: Wastewater from a growing population can be a significant source of nutrients to Texas bays. Whether this can compensate for reduced nutrient input will likely be different for each bay. It is noted that continued increases in the level of wastewater treatment will tend to reduce this source of nutrients.

As noted at the beginning of this section dealing with anthropogenic changes, Texas bays have been substantially altered. These alterations have affected the volume, salinity levels and supplies of nutrients and sediment. Each bay system is unique with its own balance and needs. A key point is that healthy bays don't just require inflows. What is carried in the inflows is also very important and needs to be considered when we address inflow needs.

Inflow Regime

As noted above, there is a measure of agreement that a definition of inflow needs for bays should be in the form of a flow regime, including seasonal distribution and target attainment frequencies, rather than simply specifying a single total annual flow amount. Some have suggested that this flow regime should reflect natural conditions while others recognize that natural conditions are not practical or even desirable in a state with over 20 million residents and with bays that have been greatly modified from natural in the ways described above. We need to protect bay inflows, but the conditions we need to protect are those that currently support the sound ecological environment that we know today.

Several methods have been proposed to estimate an appropriate flow regime. The Bay & Estuary methods developed by the TWDB and TPWD are one important method that includes a monthly distribution of flows. The IHA (Indicators of Hydrologic Alteration) method, applied to current conditions, could be another method to produce a flow regime. The detailed studies that have been performed for the Colorado River and Eastern Matagorda Bay are a third method. Whatever method is ultimately employed, a flow regime is needed that is representative of the **current** sound ecological environment.

In this context it is worth repeating a point that is sometimes overlooked. Texas bays and estuaries exhibit a wide range of inflow regimes. Even the Laguna Madre system, which receives a tiny fraction of the inflows going to bays on the upper coast, is healthy and productive. While the amount of inflow may not be directly related to overall health and productivity for individual bays, inflow regimes for different bays are critical to support the currently existing ecosystems.

Adaptive Bay Management

The bays have been substantially modified over the last 150 years. These modifications can be considered to be management actions that affect important dimensions of the bays: inflows, water exchange with the Gulf, inputs of particulate matter and nutrients, and harvest by sport and commercial fisheries. These management actions have been taken within their own regulatory sphere, and while there is usually a review process for each action, it can't be said that there has been coordination of these actions to achieve more effective bay management. In short, for a long period of time we've been moving many of the bay management levers with little attempt at coordination or a shared set of expectations.

The term **Adaptive Management** has been used to describe how new modifications might be addressed, but as yet there has been little in the way of specifics on what it means or how adaptive management might be implemented. One of the SAC charges in SB3 (11.02362(p)) is to assist with the development of adaptive management work plans.

One way that the term adaptive management has been discussed is as a check or test. For example, a permit for a water use might be issued based on WAM results, but because there is some uncertainty on biological effects, an adaptive management test is proposed. In shorthand, a permit would require a given set of flows and the test would be that a specified biological result would be achieved. If the biological result were not achieved, there would be the expectation that the flows and associated water right permit would be revisited.

While this may or may not ultimately prove to be the adaptive management path selected, it appears to have the potential to generate problems both in formulating and grading the biological test. Every year will bring a new set of inflows, local weather, antecedent conditions—things that individually and interactively can play big roles in the biological community. If field studies for several years bring a set of results and our predictive models say we should have had more of this habitat and higher numbers of that fish, there might be a finding of failure for the test. A major question will be how much confidence can be placed in predictive models? Year to year variations are important and it is unlikely the detailed patterns found in historical studies would be repeated during

a test period. In short, it appears that developing consensus on biological tests could be a challenge, and there is also the potential for conflict in grading such a test.

An alternative to the "test and modify" approach is to improve the process of actively managing the ecological health of each bay/basin system with the tools that are available. To that end, it is proposed that each of the Bay/Basin Stakeholder Committees work to facilitate and support the bay management process in coordination with TPWD, TCEQ, TGLO, and TWDB, as well as the Coastal Coordination Council and with two bays, an Estuary Program office. The Stakeholder Committees could provide input on the best use of any dedicated environmental flows that might be available, coordinate with the regional water planning process, provide input in the regulation of N and P levels in wastewater discharges, and begin to focus attention on the chemical form on nutrient inputs. A longer term role of the Bay/Basin Stakeholder Committees could be to track the status and condition of their respective bays, and work to monitor, analyze and develop coordinated management recommendations to be implemented through existing regulatory processes. One product would be to help develop and coordinate specific recommendations for the amount of future change in inflows and other important controls over bay conditions such as harvest pressure and nutrient supply.

Assuming we can obtain consensus that improved coordination or active bay management is preferred over the current situation, the proposed approach to adaptive bay management would seem in line with our mandate. This is envisioned in the enabling legislation (11.0235 (d-5)). Also included in the legislation is the recognition of an estuary advisory council (11.02362(r)) to perform the duties envisioned.

References

- Glibert, P. and D. Terlizzi. 1999. Cooccurrence of elevated urea levels and dinoflagellate blooms in temperate estuarine aquaculture ponds. *App. Environ. Microbiology*. 65(12) 5594-5596.
- Glibert, P., J. Harrison, C. Heil and S. Seitzinger. 2006. Escalating worldwide use of urea--a global change contributing to coastal eutrophication. *Biogeochemistry* 77: 441-463.
- Heitmuller, F., 2008. Fluvial Sediment Transport. Paper presented SAC meeting, December 5, 2008.
- Jensen, P.A., K.L. Lee, Y.C. Su, M.T. Garrett, G.H. Ward, and G. Clingenpeel. Nitrogen Inputs to Galveston Bay and Upcoming Criteria Considerations. Paper at 2003 GBEP State of the Bay Symposium.

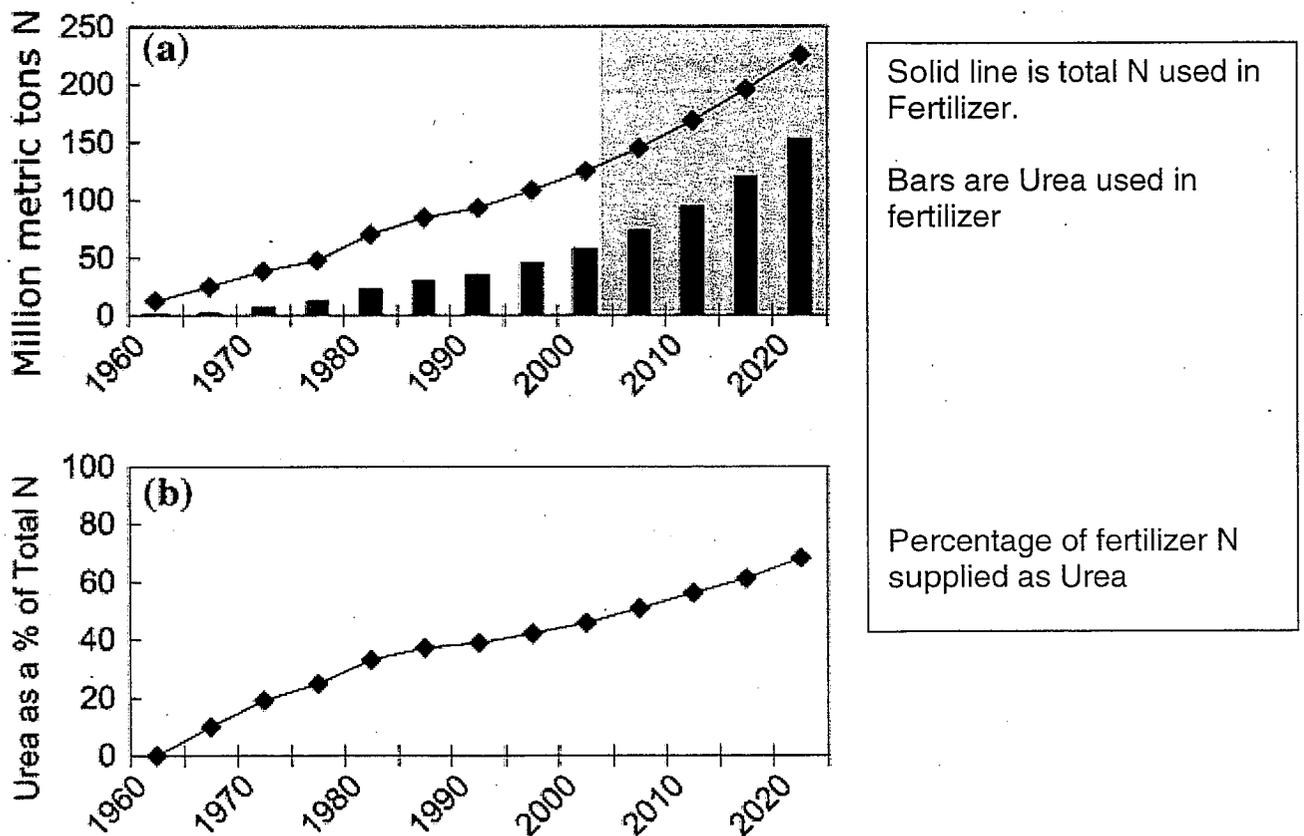
Mathewson, C.C. and L.L. Minter. 1976. Impact of Water Resource Development on Coastal Erosion, Brazos River, Texas. Texas Water Resources Institute Report TR-77. Texas A&M University.

National Oceanic and Atmospheric Administration (NOAA). 2001. Sea Level Variations of the United States 1854-1999. NOAA Tech Report NOS CO-OPS 36.

Switzer, T. 2008. Urea loading from a spring storm--Knysna estuary, South Africa. Harmful Algae, Vol 6. pp 66-69.

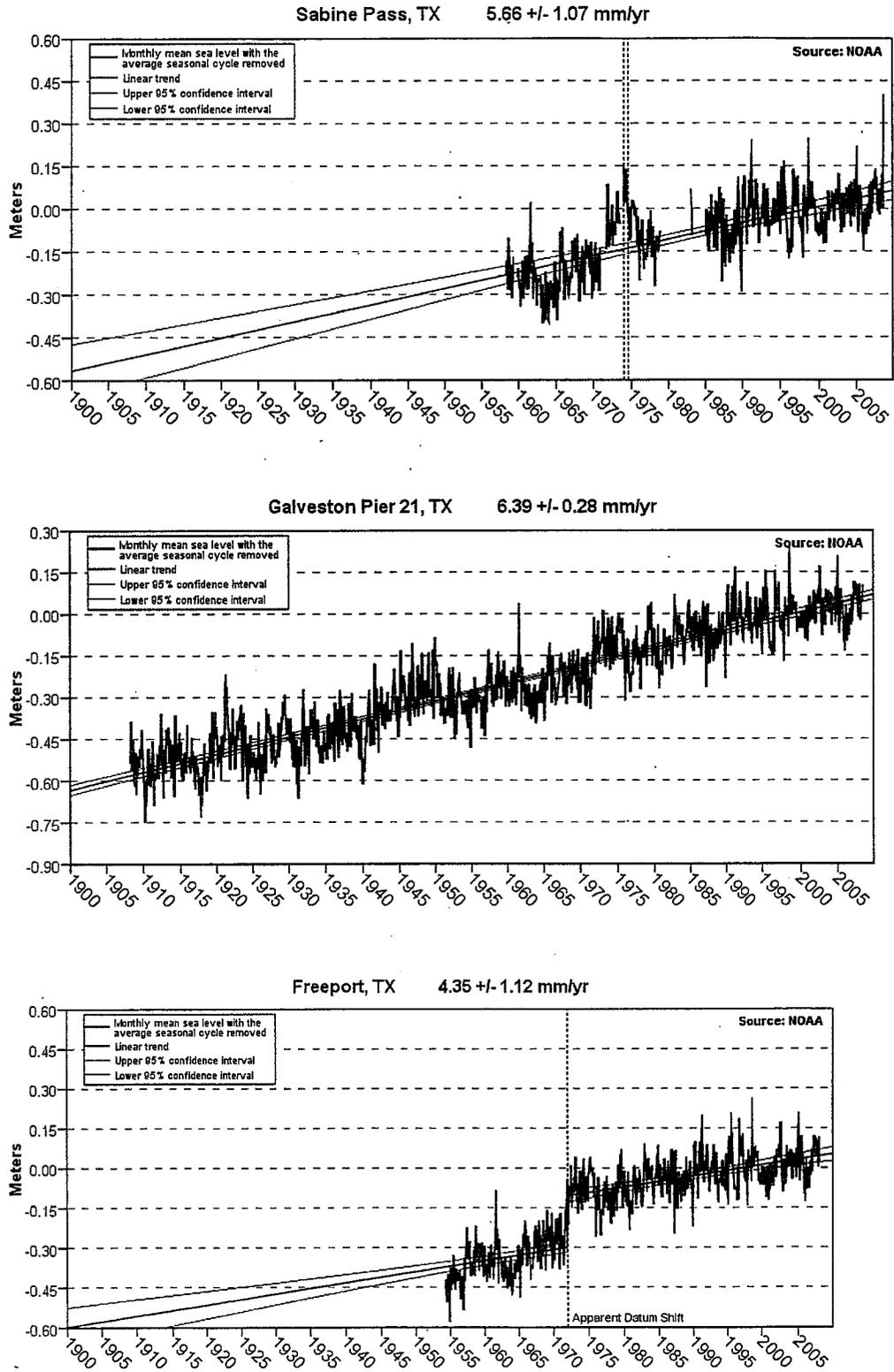
Ward, G.H.1993. Dredge and fill activities in Galveston Bay. Report GBNEP-28, Galveston Bay National Estuary Program, Webster.

Figure 1 Increases in the worldwide use of Urea Fertilizer

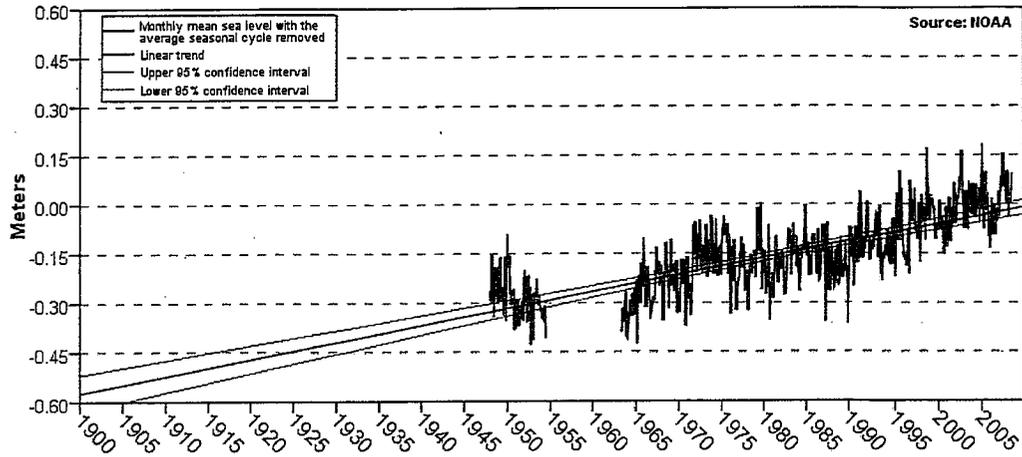


Source: Glibert, et al. 2006

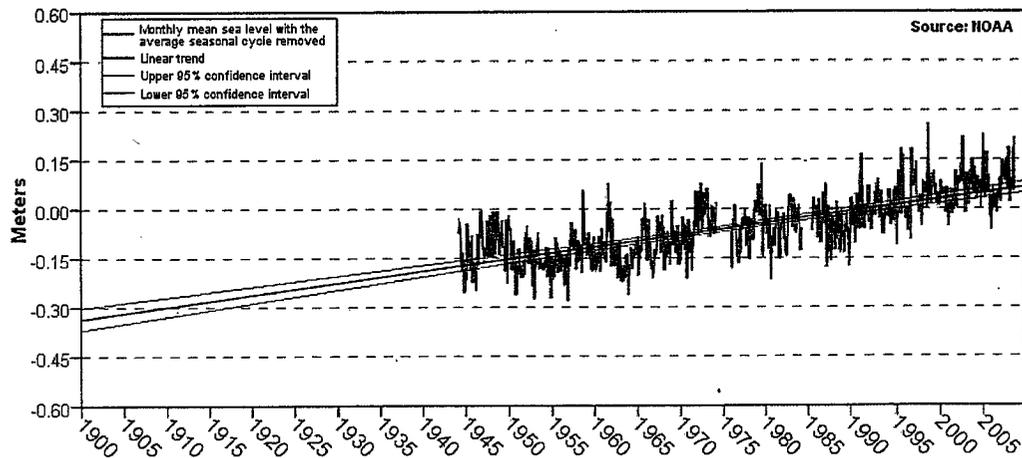
Figure 2. Trends in Relative Sea Level at Texas Tide Gauge Locations



Rockport, TX 5.16 +/- 0.67 mm/yr



Port Isabel, TX 3.64 +/- 0.44 mm/yr



Source: NOAA: Tidesandcurrents.noaa.gov.

