The Submergence of Fort Proctor

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Fort Proctor is a pre-civil war military installation on the shore of Lake Borgne, southeast of New Orleans (**Figs. 1** and **2**). Historical records state that the fort was constructed 150 feet inland from the shore of the lake just north of the mouth of Bayou Yscloskey. This was also the site of Proctorville, a rail depot at the terminus of the Shell Beach Branch of the New Orleans and Gulf Railroad, which ran along the east bank of the Mississippi River to the town of Poydras, then down the natural levees of Bayou Terre aux Boeufs, Bayou La Loutre, and Bayou Yscloskey to the shore of Lake Borgne. While it can logically be assumed that the original elevations of the fort and the railroad depot were necessarily at least a few feet above sea level, neither of the architectural studies of the fort conducted by Tulane Uiversity or Louisiana State University (LSU) appear to include any definitive values for the land elevation at the time of construction.

CHRIS MCLINDON was employed as an exploration geologist in the oil and gas industry between 1980 and 2020. He received a B.S. in Geology from the Louisiana State University in 1979. Chris has worked for several companies in the New Orleans area including Stone Energy, McMoRan Exploration, and Helis Oil, as well as being self-employed for several years. Chris is currently the manager/member of McLindon Geosciences, LLC in Mandeville, LA. He is a past-president of the New Orleans Geological Society and a member of the Geological Society of America, the American Geophysical Union, and the Society of Independent Professional Earth Scientists. Chris was named to an oversight position for the Louisiana Coastal Geohazards Atlas Project by Dr. Charles Groat of the Louisiana Geological Survey in 2018. In that same year, he was the recipient of the Gulf Coast Association of Geological Societies Statesmanship Award in recognition of work associated with the atlas project.

The fort is about 1000 feet from the Shell Beach Continuously Operating Reference Station (CORS) of the National Geodetic Survey (**Fig. 3**). This station is a part of the Global Navigational Satellite System that provides data for the 3D Global Positioning System (GPS) network. In addition to surface positioning data, this station provides a measurement of the vertical movement of the earth's surface, which in this case can be used to estimate a rate of subsidence.

Evaluation of data from the Shell Beach CORS by the LSU Center for GeoInformatics indicates a current rate of subsidence at this location of about 6.263 millimeters per year (mm/yr) or about 2.5 inches per decade (**Fig. 4**). The premise of the illustrations of the impacts of subsidence over time that follow is that this subsidence rate can be used to estimate the elevation of Fort Proctor at various points of time in the past relative to its current elevation. This relative approximation is made without knowledge of the absolute value of the elevation at any time. If data for the elevation of the fort at some point of time in the past were known, it could be used to calibrate the estimated relative rates of change based on current subsidence data.

An elevation profile of the fort taken from a Historic American Building Survey published in the

Figure 1. Fort Proctor (photo credit, Marco Rasi).

Figure 2. Fort Proctor is located at the mouth of Bayou Yscloskey on the south shore of Lake Borgne.

report "Fort Proctor: A Conditional Preservation" by Ursula Emery McClure and Bradley Cantrell of the LSU Coastal Sustainability Studio in 2013 (McClure and Cantrell, 2013) is used as the basis for **Figure 5**. The profile has a proportional vertical scale and a reference for the elevation of "high tide," but it is not otherwise referenced to a defined benchmark elevation. For the purposes of illustrating the relative effects of subsidence and sea level rise, the high tide level is taken to be current sea level.

For the purposes of constructing **Figure 6** (and additional illustrations in McClindon [2020]), the rate of global sea level rise and the rate of local subsidence at Fort Proctor are assumed to be constant for the time period from 1856, when the fort was constructed, to the present. A constant subsidence rate of 6.263 mm/yr for this 160 time span results in a total elevation change at the site of the fort of 39.45 inches. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) Marine and Atmospheric Research website published a graph of long-term sea levels showing an average rate of sea level rise of 1.7 mm/yr (CSIRO, 2014). This results in a change in global sea level of 10.71 inches during the same time period. This means that in 1856 the elevation of the foundation of the fort was about three and a half feet higher than it is today and sea level was almost a foot lower than it is today. The total combined "relative sea level rise" experienced at the site of Fort Proctor between 1856 and the present has been 50.16 inches based on the extrapolation of these data. In other words, the site of Fort Proctor was over four feet higher than it is today relative to sea level at the time of construction. For the purposes of constructing illustrations (**Fig. 6**; and in McClindon [2020]) of the relative changes of land elevation and sea level over time, the elevation of the "high tide" line on the architectural drawings of the fort that follow is assumed to be current sea level. This assumption is certainly not accurate, but it allows for tying relative changes in elevation to a scaled vertical elevation profile of the fort, and it is not intended to represent an actual elevation. It is also important to note that recent rates of sea level rise are greater than the 1.7 mm/yr long-term average used here. Recently published research by Applied Coastal Research and Engineering (ACRE) (2019) set the current rate of sea level rise in the Gulf of Mexico at 2.0 mm/yr. A gen-

Figure 3. The Shell Beach CORS station on the left and Fort Proctor as seen from the station on the right.

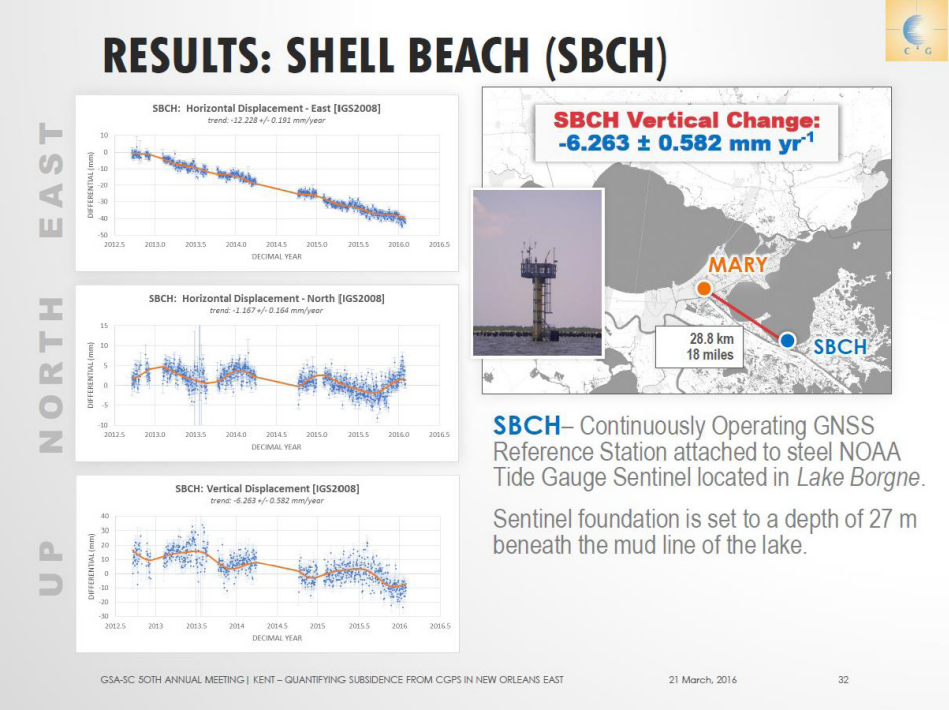

Figure 4. A slide from the presentation given by Dr. Josh Kent of the LSU Center for GeoInformatics at the Geological Society of America South-Central meeting in 2016 (Kent, 2016). Data from the Shell Beach CORS station show a subsidence rate of 6.263 mm/yr or ~2.5 inches per decade.

erally accepted rate of sea level rise for the rest of the world since the 1990s is 3.0 mm/yr.

McClindon (2020) provided a link to a video progression of shoreline changes with time at Fort Proctor from 1856 to 2010 using maps, aerial photography, and depiction of elevation profile. **Figure 7** illustrates a dramatic aerial view comparison between circa 1959 and 2019.

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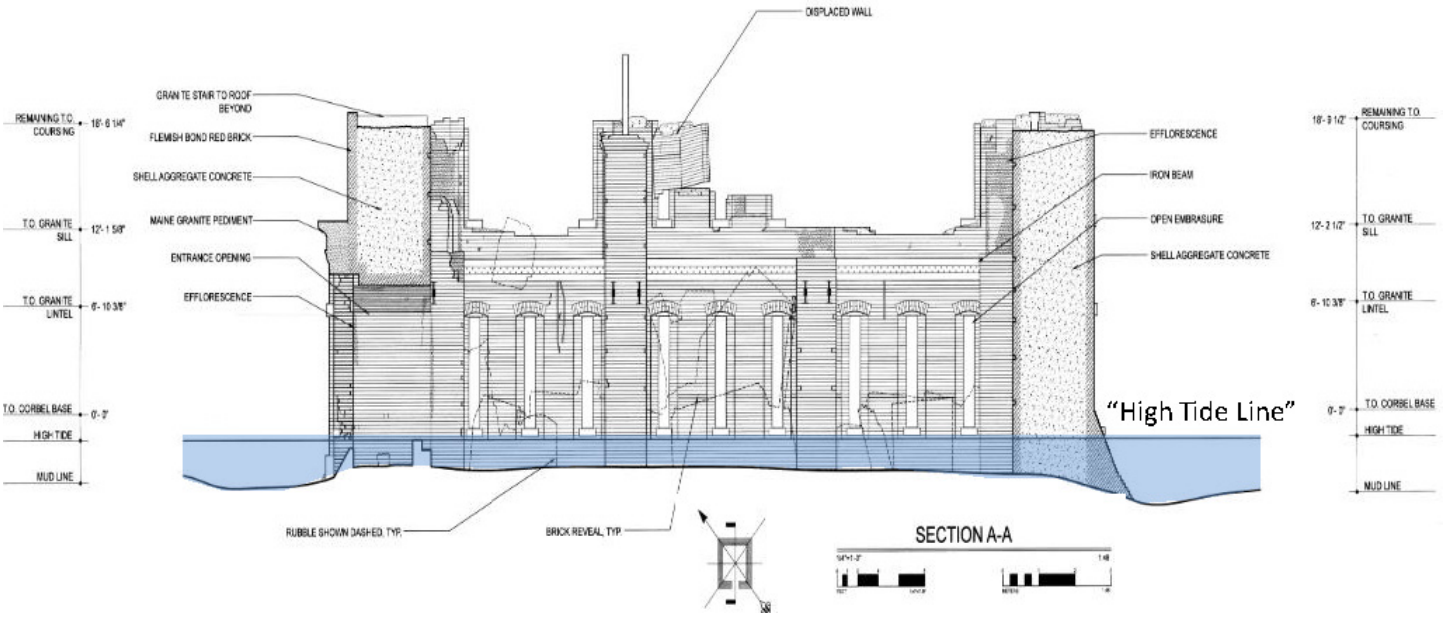

Figure 5. Elevation profile of Fort Proctor (modified after McLure and Cantrell [2013]).

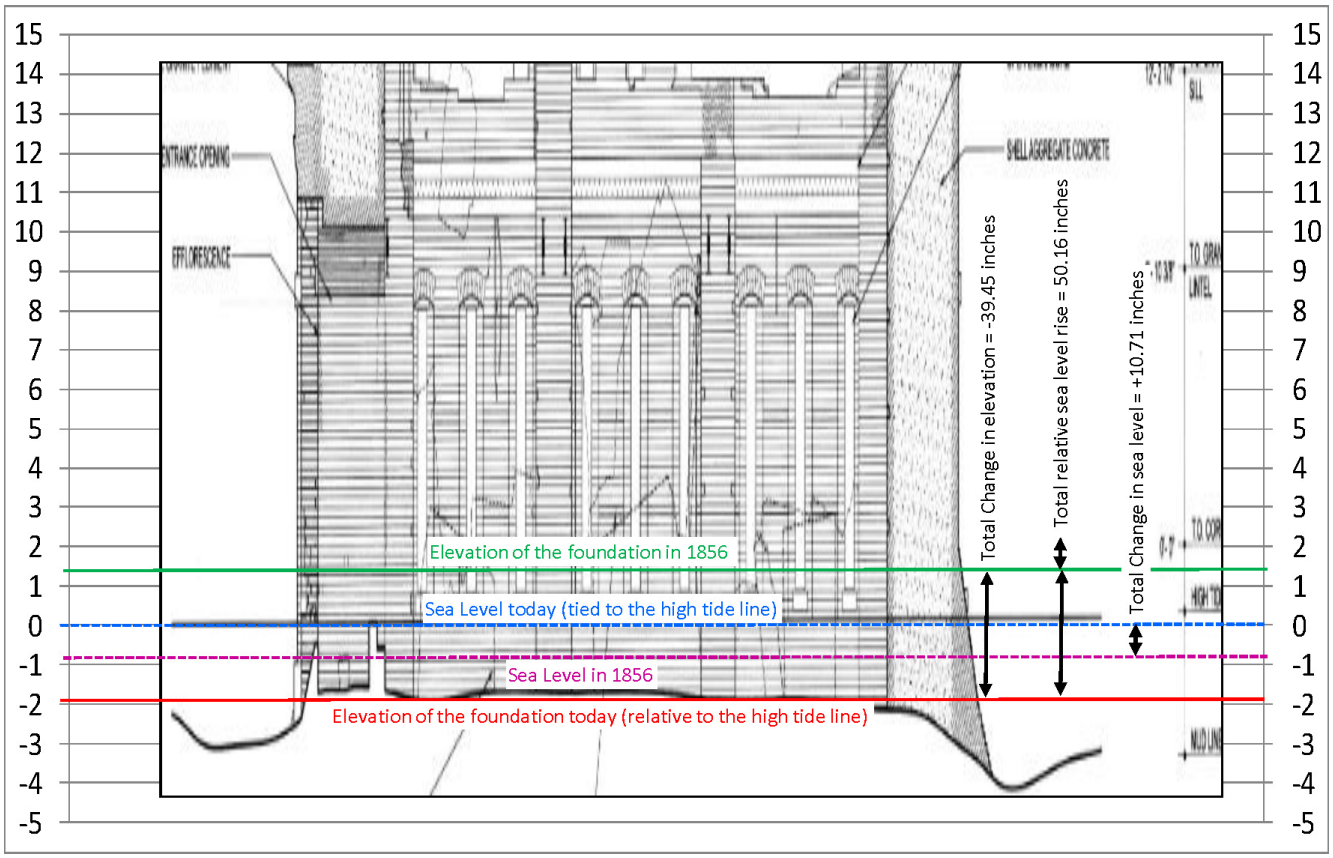

Figure 6. Vertically exaggerated elevation profile tied to a vertical scale (in feet) in which the "high tide line" is equal to current sea level.

Figure 7. A side by side comparison of an oblique aerial view of Fort Proctor circa 1959 and a recent perspective view from Google Earth.

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