No. 142, Original

In the

Supreme Court of the United States

STATE OF FLORIDA,

Plaintiff,

v.

STATE OF GEORGIA,

Defendant.

Before the Special Master

Hon. Ralph I. Lancaster

PRE-FILED DIRECT TESTIMONY OF FLORIDA WITNESS SCOTT DOUGLASS, PH.D

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1. I, Scott L. Douglass, PhD, PE, DCE, offer the following as my Direct Testimony concerning the response of Apalachicola Bay to the potential effects of future sea level rise.

2. The primary purpose of my testimony is to provide an expert opinion regarding the impacts of sea level rise in Apalachicola Bay and any offsetting factors, which include sedimentation and changes to tidal exchange between the Gulf of Mexico and the Bay in the 21st century.

3. The barrier islands in Apalachicola Bay have adapted and will adapt to any sea level rise that may occur going forward. The physical geomorphic forces that control barrier island and inlet formation will maintain a dynamic equilibrium at potential projected rates of future sea level rise. An accurate geomorphic analysis of these processes, which Georgia's Expert Dr. McAnally did not do, is necessary for a hydrodynamic model of the Bay to accurately predict future salinity levels.

I. EDUCATION AND PROFESSIONAL BACKGROUND

A. Education

4. I have three degrees in civil engineering: a PhD from Drexel University, awarded in 1989; a Master of Science degree from Mississippi State University, awarded in 1985; and, an undergraduate degree from Virginia Polytechnic Institute and State University, awarded in 1981. While my PhD and master's degrees were awarded in civil engineering programs, my work on both focused on coastal engineering, specifically. My dissertation for my PhD, for example, focused on the effect of wind on breaking waves, while my master's thesis explored longshore sand transport statistics. (Expert Report of Scott Douglass, FX 788 at Attachment A).

B. Professional Experience

5. I have 35 years of coastal science and engineering experience. I have worked for

the government, in the private sector, and in academic settings. Through my work, I have visited over 500 beaches, including almost every beach in the continental United States. I have worked on beach-related projects from Alaska to Long Island, down through Virginia and Maryland, to the Outer Banks of North Carolina and all along Florida's coasts.

6. For 26 years, I served on the faculty of the University of South Alabama, where I am now an Emeritus Professor in the Department of Civil, Coastal, and Environmental Engineering. During my time as an active professor, I primarily taught courses on fluid mechanics, water resources engineering, and coastal engineering. I also developed an active, funded research program in coastal engineering.

7. In addition to my time teaching at the University of South Alabama, I taught Coastal Geomorphology for 20 years at the Dauphin Island Sea Lab, which is the Marine Environmental Sciences Consortium for all of Alabama's colleges and universities.

8. For the past 25 years or so, I have also performed work as a consultant with my firm, South Coast Engineers LLC.

C. Publishing History

9. I have published extensively in the academic and technical literature, including many peer-reviewed articles. Altogether, I have published over 100 technical papers on my original research in breaking wave mechanics, surf zone dynamics, longshore and cross-shore sand transport, tidal inlet processes, beach erosion solutions, beach nourishment, coastal zone management, living shorelines techniques, wave transmission through breakwaters, wave loads on bridge decks, shoreline recession measurements, nearshore placement of dredged sands, the effects of coastal structures on adjacent shorelines, tidal hydrodynamics, storm surge modeling, forensic hurricane damage, coastal highway design principles, the tolerance of marsh grasses to

wave action, pocket beach design principles, and coastal infrastructure resilience to extreme events and climate change.

D. Professional Affiliations

10. I have several professional certifications and affiliations and have received numerous honors and awards. Of primary importance here, I am a registered engineer in the States of Florida, New Jersey, Alabama, and Mississippi, and I am a Diplomate of Coastal Engineering (DCE) as recognized by the Academy of Coastal, Ocean, Port & Navigation Engineers, which is affiliated with the American Society of Civil Engineers.

11. I have expertise in coastal geomorphology, coastal geology, coastal ecology, coastal sediment transport, coastal oceanography, tidal inlet dynamics, and the effects of sea level rise on coastal systems.

II. OPINIONS IN THIS CASE

12. I reviewed numerous technical papers on the geomorphology of the Apalachicola Bay and barrier island system. I also reviewed numerous technical papers related to sea level rise generally and specifically in relation to the Apalachicola Bay, and sedimentation generally and specifically in relation to the Bay. I have also visited Apalachicola Bay and the barrier islands to conduct my own assessment of the system based on my 35 years of experience and expertise. My opinions are presented with a high degree of scientific certainty.

13. The barrier islands, which protect the unique estuarine environment of the Apalachicola Bay, have been adjusting to sea level rise for at least the past 6,000 years, and will continue to do so for at least the remainder of this century and likely far beyond that time.

14. The rate of sea level rise in the Bay has remained approximately steady over the past 150 years. Georgia witnesses rely on various predictions for future sea level rise. Even if

one were to credit those projected levels of sea level rise, including any acceleration in the rate of sea level rise that may occur, geomorphologic processes in the Bay system would keep pace as seas rise and maintain the general state of Apalachicola Bay's estuarine systems. Processes such as additional sediment deposits by the Apalachicola River into the Bay would have an offsetting effect on future sea level rise and barrier island processes, primarily by tidal inlet dynamics, would maintain the current tidal exchange between the Gulf of Mexico and the Bay. This is primarily because the tidal inlets would also adjust to sea level rise.

15. Even if the rate of sea level rise were to increase beyond the observed historical rate, the barrier islands protecting the Bay would be able to adjust through the same natural processes that have shaped those islands and allowed them to withstand sea level rise for centuries. This will mean that the tidal exchange would not be significantly altered from the existing tidal exchange, even at the higher-end projections that have been published by the IPCC and other organizations.

A. Sea Level Rise

16. Globally, sea levels have likely been rising for about 12,000 years. The rise was relatively rapid until about 6,000 years ago, when the rate of rise slowed. While there is debate in the academic literature about the specific fluctuation of sea levels over the past 6,000 years, it is generally accepted that the overall rate of rise is greatly reduced than it was in the years preceding.

17. As part of my work, I have considered the Intergovernmental Panel on Climate Change ("IPCC"), along with other scientific organizations; projections of the rate of sea level rise across the planet to increase over the remainder of the century. I have reviewed the IPCC reports as they relate to sea level rise, and a true and accurate copy of *Climate Change 2013, The*

Physical Science Basis, Chapter 13, Sea Level Change ("IPCC Report") has been submitted as exhibit FX-339. This exhibit is a true and accurate copy of the document described. It is a chapter from the Fifth Assessment Report issued by the IPPC, which I downloaded from their website, http://www.climatechange2013.org/images/report/WG1AR5_Chapter13_FINAL.pdf, in 2016. The IPCC reports are the most authoritative literature assessments on climate change, and are regularly relied upon by experts in my field. I reviewed and relied on the IPCC Report to form my opinions in my report and in this testimony.

18. Over the past 150 years, tide gages have shown a global sea level rise. Based on tide gage measurements, the global, or eustatic, sea level rise rate has been estimated at a 7-inch rise in global sea level, over the past century. (*See* IPCC Report, FX-339 at 1146-1150). Eustatic sea level rise is the rate with land mass elevation effects removed.[1]

19. It is my opinion that any potential sea level rise in the Apalachicola Bay has been modest over the past century allowing the geomorphology of the system to gradually adapt. Based on tide gage measurements, the rate of sea-level rise in the Bay does not appear to be accelerating. The tide gage at Apalachicola has measured an average rate of rise of 1.96 mm/year over the past 40 years. (*See* NOAA Mean Sea Level Trend, 8728690 Apalachicola, Florida, JX-127). JX-127 is a true and accurate copy of a graph of the publicly available mean sea level trend at NOAA tidal gage 8728690, which I obtained from NOAA's website, http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8728690, in 2016. This website is a government source. It is regularly relied upon by experts in my field, and I reviewed

[1] Some land masses are slowly rising, like the State of Alaska, while other land masses, such as the State of Louisiana, are slowly subsiding. The relative rate of sea level rise depends on location. In other words, the sea level in Louisiana is rising faster than the global average, while relative sea level in Alaska in dropping because of a higher rate of continental uplift. Apalachicola Bay is located on a very stable landmass that is not rising nor subsiding.

and relied upon in it forming my opinions in this case.

20. For purposes of this analysis and to respond to Georgia's allegations, I considered the range of potential sea level rise values in forming my opinions. The IPCC's reports contain a range of future sea level rise projections between 0.9 feet and 2.7 feet higher by the end of the century.[2] (*See* IPCC Report, FX-339 at 1140, 1180). Based on the IPCC data, the median of this range of projection values suggest sea levels will be about 5 inches higher than they are today by mid-century and 1.8 feet higher by the end of the century. (*See* IPCC Report, FX-339 at 1180-81).

21. The U.S. Global Change Research Program also issued a multi-author summary report, the National Climate Assessment ("NCA"),[3] which I reviewed and relied upon for my expert report. According to the NCA, projections of global sea level rise were similar to those in the IPCC report, projecting that sea levels will be between 1 and 4 feet higher in 2100 than they are today.

22. Likewise, the National Research Council ("NRC"), the working arm of the National Academies of Science and Engineering in the US, developed its own report on sea level changes in 2012. The median projections for global sea level rise in that report shows sea levels 2.7 feet higher than today by 2100.

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[2] This is the projected global mean sea level rise for 2081–2100 relative to 1986–2005. Tidal epochs are 18.6 year time lengths required to remove the effects of periodic trends in sea level due to known astronomic effects.

[3] Melillo, J.M., Richmond, T.C., and Yohe, G.W., Eds. (2014) Climate Change Impacts in the United States: The Third National Climate Assessment, U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2, http://nca2014.globalchange.gov/system/files_force/downloads/high/NCA3_Climate_Change_Impacts_in_the_United States_HighRes.pdf?download=1. The National Climate Assessments are regularly relied upon by experts in my field, and I reviewed and relied on it to form my opinions in my report and in this testimony.

23. As I discussed previously, tide gage observations do not currently show an acceleration in sea level rise. Nevertheless, I have considered all the range of values and conservatively assumed for purposes of this analysis that sea levels will rise at an accelerated rate in the coming decades, based on these publications.

B. Barrier Island Processes

24. The Apalachicola Barrier islands include St. Vincent Island, St. George Island, Little St. George Island, and Dog Island. The islands were formed by sands largely washed out of the Appalachian Mountains and down the ancient Apalachicola River system over several hundred thousands of years. Those sands were reworked by waves during the past 20,000 years as sea level rose. During the past 6,000 years, waves drove sand up onto beaches from the continental shelf and along the beaches to form the Apalachicola Bay barrier island system as we see it today.

25. The present day locations and shapes of the islands are primarily due to storm and wave-driven processes, which have continually reworked the sands over the past 6,000 years. These processes include wave-driven cross-shore sand transport from the extensive shoals south of Cape St. George, wave-driven longshore sand transport (also called littoral drift), and island overwash in major storms. Additionally, wind-driven (or Aeolian) processes build formerly overwashed sands into sand dunes.

26. Essentially, the islands are slowly rolling over themselves and migrating landward. The three fundamental sand transport processes – feeding of sand from the nearshore to the beaches, movement of sand along the beaches by waves, and barrier island rollover – continue to the present day and are still responsible for changes occurring on the islands, including the size and depth of tidal inlets.

27. Over the past 150 years or so, the islands have continued to move slowly north due to the processes described above. Over that time, inlets have been opened and closed, and there have been some changes in the shape and movement of the islands, but generally, they are in the same shape and location, just a little farther north.

28. Almost every day, wave-driven longshore sand transport moves sand along the southern beaches of the islands, generally from east to west, although it can move the opposite direction as well. The eastern one-third of St. George, for example, has a net sand transport direction to the east. (R. Clark, Report on St. George Barrier Island System, FX-341 at 2). FX-341 is a true and accurate copy of a scholarly report on the St. Georgie Barrier Island System in the Apalachicola Bay, which I obtained directly from the author. It is the kind of report regularly relied upon by experts in my field, and I reviewed and relied upon it in forming my opinions in this case.

29. These processes have, over the past 150 years, contributed to the Apalachicola Barrier Islands slowly migrating generally to the north. Over the coming centuries, these processes will continue to push the islands north on the order of hundreds of feet per century, whether or not sea levels continue to rise and whether or not that rise accelerates as projected in the scientific literature.

C. Tidal Exchange

30. Even taking into account various projections of future sea level rise, three of the tidal inlets in the Apalachicola Barrier Island system would still likely preserve their cross-sectional areas, and the other two will likely get smaller, not larger, in area. As a result, tidal flow, which brings saline water from the Gulf into the Bay, is likely to stay the same or decrease slightly over the coming century as sea levels rise. In my opinion, it was reasonable for Dr.

Greenblatt's hydrodynamic modeling to include this assumption.

31. I have reviewed Dr. William McAnally's expert report filed by Georgia, which describes the findings of his hydrodynamic model of Apalachicola Bay, as well as his deposition testimony. I would like to respond to Dr. McAnally's analysis and conclusions. Dr. McAnally's modeling scenarios for future sea level rise are flawed because he assumes that the cross-sectional area in the tidal inlets to Apalachicola Bay will increase as sea level rises. Dr. McAnally concedes that he did not model, nor did he take into account, geomorphic changes that we know are to occur to the barrier islands and the tidal inlets in the future. While he did model a future scenario where East Pass, one of the Apalachicola Bay tidal inlets, would continue closing laterally, he fails to account for the rest of the geomorphic processes.

32. Most importantly, his modeling assumes that the depth of the inlets will increase equal to the level of future sea level rise. This assumption is incorrect and is not supported by any geomorphic analysis. If Dr. McAnally had correctly modeled the likely inlet cross-sections when he modeled sea level rise, the salinity model results would have been different and he would have found much less effect on salinity from sea level rise. It is likely that those salinity values, with future sea level rise, would be very similar to present day salinity values.

33. Instead, Dr. McAnally chose to model deeper inlets, and his resulting "finding" of increased salinity with sea level rise is a physically meaningless *fait accompli*. Basic physics being considered, a deeper channel means less friction and more flow to and from the Gulf of Mexico. Once he decided to hold the tidal inlet bottom elevations constant in his model, while he raised the sea level, his modeling outcome was essentially pre-selected by his incorrect assumptions.

34. Tidal inlets (or "passes"), which allow for the exchange of water between the Bay

and Gulf during every tidal cycle, are shaped by the processes of longshore sand transport and daily tidal forces. Thus, tidal inlets on sandy coasts like the Apalachicola region exist in essentially a form of “dynamic equilibrium,” as two different, primary forces move the inlets in different directions. Sometimes they grow larger, sometimes they get smaller. Nevertheless, the two competing processes tend to keep inlets open: the longshore sand transport tries to close the inlet, while the tidal currents try to open it. Because of this dynamic equilibrium, the tidal inlets in Apalachicola Bay remain open.

35. The size of three of the tidal inlets in the island system – Indian Pass, East Pass, and Sikes Cut – is primarily controlled by that dynamic equilibrium.[4] The processes I have just described occur on a day-to-day basis. They are happening right now, this second, and every day, at a much faster time scale than sea level rise, which happens on a decadal time scale. Therefore, I anticipate that the depth of the inlets will adjust to the higher sea levels that may occur in the future, just as the barrier islands also will adjust.

36. The two other inlets to Apalachicola Bay – East Pass and the opening to the northeast of Dog Island – are not controlled so much by dynamic equilibrium as much as by relics of geomorphic processes that formed those portions of the barrier island chain. East Pass has gradually been closing down over the past 160 years, and has closed by 1.5 miles as the east end of St. George Island grew. (Report on St. George Barrier Island System, FX-341 at 2). Longshore sand transport will likely continue to slowly close it, although not fully, during the next century, reducing tidal exchange. As described in more detail in my report and my deposition, the northeastern end of Dog Island has been growing to the northeast for about the

[4] I also recognize that Sikes Cut is artificially dredged and maintained, though the same processes affect the Cut between episodic dredging.

past 160 years, and that northern migration will continue to slowly close the pass there.

D. Bay Sedimentation

37. A second factor that will act as an offsetting force to potential future sea level rise is natural sedimentation in Apalachicola Bay. Bay sedimentation is the process whereby fine sediments coming down the Apalachicola River disperse out into the Apalachicola Bay, with some deposits causing growth around the mouth of the river, and some gradually infilling low areas of the bay.

38. One NOAA estimate has put the rate of sedimentation in the Bay at 8mm/year. (Effects of Near-Term Sedimentologic Evolution on the Lifetime of Estuarine Resources, FX-332 at 6). FX-332 is a true and accurate copy of a technical memorandum produced by the National Oceanic and Atmospheric Administration, which I obtained online during the course of my search for literature on Apalachicola Bay and which was produced to Georgia as part of this litigation. It is the kind of report relied upon by experts in my field, and I reviewed and relied upon it in forming my opinions in this case. Bay sedimentation is not occurring at a sufficient rate to significantly impact the overall depth of the bay for centuries; however, I and Dr. McAnally agree that potential sea level rise would partially offset Bay sedimentation. Basically, as bay sedimentation raises the bay floor, sea level rise raises the elevation of the water, helping to preserve the existing depth of the bay.

39. Dr. McAnally excluded any analysis or assumptions for future Bay sedimentation when he performed his hydrodynamic modeling of the Bay. His future sea level rise scenarios should have accounted these well documented phenomena. Without some accounting of sedimentation process, Dr. McAnally's sea level rise modeling scenarios fail to accurately predict and overstate the impact of potential future sea level rise on Apalachicola Bay salinity.

III. CONCLUSION

40. As I have described, the geomorphic changes to Apalachicola Bay, such as sedimentation, longshore sand transport, and inlet dynamics, act as offsetting forces to increasing sea levels. These forces have kept pace with historic sea level rise and will keep pace with future sea level rise, within the ranges predicted by the IPCC and NCA. Dr. McAnally's modeling of the impact of future sea level rise scenarios on Bay salinity is flawed because it fails to account for these processes, and therefore his salinity predictions are incorrect. The more reasonable assumption is that geomorphic change in the Bay will keep the tidal exchange with the Gulf of Mexico similar to current conditions for many years to come.

41. In my testimony, I referenced several documents, all of which were which I reviewed and relied upon in preparation of writing my expert report. True and accurate copies of all of the documents have been submitted into evidence, and I describe the documents and my familiarity with each of them below.

a. JX-127 - NOAA Mean Sea Level Trend, 8728690 Apalachicola, Florida: Described in text.

b. FX-332 - Joseph F. Donoghue and William F. Tanner, Effects of Near-Term Sedimentologic Evolution on the Lifetime of Estuarine Resources, NOAA Technical Memorandum NOS SRD 27 (1994): Described in text.

c. FX-339 -J.A. Church, et al., 2013: Sea Level Change. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Stocker, T.F., et al., eds) (2013): Described in text.

d. FX-341 - R. Clark, St. George Island Barrier System: Described in text.

e. FX-788 - Expert Report of Scott Douglass: This is a true and accurate copy of my expert report, which I prepared for this litigation using generally scientifically accepted principles and methodology.