With funding provided by the Florida Legislature as part of DEP Grant Agreement Nos. S0714 and NS005 and administered by Brevard County, environmental muck dredging research was conducted by the Indian River Lagoon Research Institute (IRLRI) at Florida Institute of Technology. Important findings and recommendations from peer-reviewed final reports are listed below. ***Numbers after findings or recommendations refer to report titles on page 5.

IMPORTANT FINDINGS AND RECOMMENDATIONS FROM 17 FINAL REPORTS

Findings: Lagoon-wide Muck Investigations

MK.1. All major and many minor muck deposits in the IRL and Banana River Lagoon (BRL) were likely sampled during this study, excluding the northern BRL near NASA property, where access is limited. **19, 20*

MK.2. A rapid technique called Quick Flux was developed to collect sediment pore water to determine fluxes of N and P from muck to the overlying water. The method was validated against an accepted method that used detailed interstitial water samples. More than 400 Quick Flux determinations of benthic fluxes of N and P were obtained to provide a robust data set that complements biological and geochemical studies. **9, 19*

MK.3. A Grand Survey of 53 sites, followed by detailed geochemical and biological study of the top 20 (of 53) sites in the IRL and BRL (Brevard County), was carried out; it greatly enhanced available data and perspectives on the lagoon-wide distribution of muck. The top 20 sites were prioritized for muck projects by first using a geochemical ranking and then confirming choices using biological indices for benthic fauna and seagrasses. **19, 20*

MK.4. Baseline biological (seagrass and infauna) and geochemical data were obtained for the IRL near Mims, for Sykes Creek and nearby comparison sites prior to dredging. **17*

MK.5. Dredging of sand and shells can be precluded using a newly designed prototype with variable intake and shrouded dredging suction head. Treatment with ferrate (a very reactive iron oxide) removed nutrients. Field testing of the coupled system confirmed the feasibility of small-scale muck sump operations along canals and rivers that flow into the IRL. An autonomous scaled-up system could be developed and installed at permanent locations in canals to manage muck removal prior to entering the Lagoon. **14*

Findings: Turkey Creek Muck Removal

TC.1. Environmental dredging of 160,000 m^3 of muck from Turkey Creek removed about 300 metric tons of nitrogen (N) and 70 metric tons of phosphorus (P). **9, 17*

TC.2. Dredging reduced the volume and surface area of muck in the dredged area by >60% and <20%, respectively; slumping and redistribution of adjacent muck sediments following dredging limited the surface area dredged. **17*

TC.3. Water volume in the dredged area increased by 160,000 m^3 after dredging, a direct result of the volume of sediment removed from Turkey Creek. Concentrations of dissolved oxygen in the creek increased after dredging in proportion to a deeper basin and larger volume of water. **7, 17*

TC.4. N and P fluxes from muck sediments were >50% lower 3 months after dredging. **17, 19*

TC.5. >99.9% of the solids pumped from Turkey Creek were retained in a Dredge Material Management Area (DMMA) at US1 and Robert J. Conlan Boulevard in Palm Bay until trucked to central Florida for use as a soil amendment. Chemical treatments effectively controlled concentrations of dissolved phosphate in the DMMA. Concentrations of nutrients in water discharged from the DMMA were not identifiable at 100 m from the outfall. **9, 17*

TC.6. Despite significant environmental variability and muck removal activities in Turkey Creek, the habitat supported an abundant and diverse assemblage of fishes. **8*

TC.7. Muck sediments in Turkey Creek likely contribute to, and may be the primary reason for, seagrasses struggling in what would otherwise appear to be an ideal location in Turkey Creek. **2*

TC.8. Infauna which live in nearby sediments with a modest organic matter content can benefit from dredging muck that has a very high organic matter content and little or no infaunal life because the new conditions will likely be an improvement and infaunal life will migrate by tracking improved sediment composition. Seagrasses and fishes, in contrast, are populations we expect to respond to longer term, general improvements in regional estuarine water quality, but were not observed to respond directly to local dredging. **2, 7, 17*

TC.9. A new method for capturing near-bottom moving fluid mud with suspended particulate matter showed a reduction in fluid mud and muck near the bottom after dredging in Turkey Creek. Overall, it appears that the basin near the mouth of the creek may be acting like a muck trap. Both the IRL and Turkey Creek (west of railroad bridge) appear to be acting as muck sources. **4, 12*

Findings: Tributary and Groundwater Inputs of Nutrients and Suspended Sediments to IRL

TR.1. Mean concentrations of total N (TN) for the four tributaries studied (St. Sebastian River, Turkey Creek, Crane Creek and Eau Gallie River) were 30–50% lower than the USEPA standard of 1540 μg N/L for Florida inland waters. However, two of the four tributaries (the St. Sebastian and Eau Gallie rivers) had mean concentrations of total P (TP) that were 80% and 100% higher than USEPA criteria of 120 μg P/L. **10, 18*

TR.2. Dissolved organic N (DON) made up more than half of the TN in IRL tributaries. The more biologically available forms of N (ammonium, nitrate and nitrite) made up only ~25% of the TN. In contrast, phosphate, the more biologically available form of P, made up about half of the TP. Understanding harmful algal blooms requires knowing concentrations of specific forms of N and P (e.g., nitrate or organic nitrogen) not just TN or TP. **10, 18*

TR.3. About 60% of TN and TP fluxes from tributaries to the IRL were carried during the wet season in 2016 (June 1–October 31). During 2017, >50% of the various chemical forms of N and P were delivered to the IRL during a 7-week period of rain and flooding following Hurricane Irma in mid-September. These results support the present fertilizer ordinance. **18*

TR.4. Estimated fluxes of TN (300–400 metric tons of N/y) and TP (30–80 metric tons of P/y) from major tributaries were at the same order-of-magnitude as benthic muck fluxes from the north IRL (300 metric tons N/y and 45 metric tons P/y). **18*

TR.5. Concentrations of total suspended solids, dissolved organic carbon, TN, ammonium and phosphate were not significantly different in water samples collected from Turkey Creek during 2016–17 relative to 1988–89. In contrast, significant increases over three decades were identified for TP (+82%), particulate P (+90%), particulate N (+300%) and nitrate + nitrite (+400%). Only dissolved organic N showed a significant decrease (-25%). Increased urbanization and residential property, plus decreased natural lands, supported the trends observed. **18*

TR.6. After 10 months of groundwater sampling, the three communities (septic, sewer, and sewer with reclaimed irrigation) had significantly higher groundwater total nitrogen concentrations than the natural area, but they were not significantly different from each other. Organic forms of N (TKN and NH4+) were significantly higher in the sewer community than the community receiving reclaimed irrigation water. But the reclaimed community had significantly higher inorganic nitrogen (NOx) than the septic or sewer communities. In surface water, the organic forms of N comprise ~90% of the total dissolved N in the water column. The organic forms of P comprise ~70% of the total dissolved P in the water column. In groundwater, organic forms of N were the dominant form in septic and sewer communities, but inorganic forms of N were found in the community receiving reclaimed water for irrigation. **15*

TR.7. Based on measured groundwater data, modeled TN loading to groundwater in the Turkey Creek area was at least 2100 kg N/year or 6 kg N/year for each household. Furthermore, N plumes extended well beyond the 20–60 m previously reported, indicating that distance from an Onsite Sewage Treatment & Disposal System to the receiving waterway should not be the only indicator used to predict loading. **15*

<u>Findings: Modeling Water Quality Related to Muck Deposits and Dredging</u>

ML.1. Modeling of muck zones shows that muck dredging has the potential to reduce N concentrations in the water column within dredged areas as well as up to 8 km away from dredged areas. The impact of muck dredging in all areas was detectable in model results which show a post-dredging reduction of TN. However, the impact of dredging was less for zones influenced by strong freshwater inflows, particularly during the wet season. **21*

ML.2. The IRL hydrodynamic and water quality model continues to be developed through updated boundary conditions and inclusion of additional muck zones. As more information is acquired on the extent of muck deposits in the IRL, these areas can be incorporated into the model and tested for the potential benefits of muck dredging at other locations. **5, 11, 21*

ML.3. Using a wind gust approach, an assessment of published estimates for surface roughness at the three ASOS (Automated Surface Observing System) sites was performed. Results for the Fort Pierce and Vero Beach systems, but not for Melbourne, were consistent with the data. For some flow directions, published roughness estimates at the Melbourne ASOS were too low due to difficulties in accurately determining low-end roughness values; this is a possible issue if one chooses to adjust roughness values from land to water. Such discrepancies have important implications and thus ASOS wind direction should be considered when using National Weather Service data to represent IRL locations. **13*

Recommendations

RE.1. Successful management plans for controlling muck and nutrients in the IRL require continuing assessment of external and internal inputs of substances that are precursors to algal blooms and future muck deposits. Therefore, more data are needed for (i) major tributaries to the IRL during regular and storm flow, (ii) atmospheric inputs, (iii) direct runoff from hundreds of outfalls along the lagoon and (iv) fluxes of nutrients from IRL muck to the overlying water. **10, 18, 19*

RE.2. Continuous chemical data for tributaries and the IRL are needed to better assess nutrient inputs, especially during extreme water flows that accompany hurricanes. The fertilizer ban is worth continuing with a possible shift to both start and end one month later, this shift better incorporates recent tropical storms in September and October. Decreases in the N and P content of reclaimed water is recommended. More data are needed to identify the specific components that make up dissolved organic N and dissolved organic P. Furthermore, wherever possible, isotope data for specific chemical forms of N are needed to help better identify nutrient sources. But, most of all, we need to work to restrict or treat nutrient runoff during periods of extreme water flow. **18*

RE.3. We encourage, where possible, that muck remediation efforts be carried out in the top 20 sites prioritized for muck projects. We also recommend increased focus on closely spaced areas and those noted for the onset of major algal blooms. Moreover, geochemical and biological rankings from this study must be considered in context with other pertinent variables including cost, proximity to a DMMA, assessments of likely muck migration, benefits of formation of a trap for future muck accumulation, project constructability and other factors as applicable. **19*

RE.4. Muck management efforts should focus on projects that reduce areal coverage of muck deposits more than muck volumes. **20*

RE.5. Cost effective strategies should be employed to reduce nutrient levels in water from settled muck before release to the IRL. **17*

RE.6. Baseline data for seagrass and drift algae are critical to future evaluation of potential environmental improvements. **7*

RE.7. Although residential communities along Turkey Creek appear to be equally polluting with nutrients, this can only be confirmed by repeating the study design in different areas. **15*

RE.8. The distance from an Onsite Sewage Treatment and Disposal Systems to the receiving waterway should not be the only indicator used to predict nutrient loading potential. Nitrogen plumes in our study extended well beyond the 20 to 60 m reported in the literature. **15*

Florida Institute of Technology Environmental Muck Dredging Research Reports*

FIT EMD Year 1 peer-reviewed final research reports are found in:
Impacts of environmental muck dredging 2014–2015. Final Project Report to Brevard County Natural Resources Management Dept., J.G. Windsor, Jr. (Ed.), July 2016

1. *Muck Dredging Research Project Management (Subtask 1)*, John Windsor
2. *Biological Responses to Muck Removal (Subtask 2), Kevin Johnson and John Shenker*
3. *The Efficiency of Muck Removal from the IRL and Water Quality after Muck Removal (Subtask 3), John Trefry*
4. *Movement Measurements of Muck and Fluidized Mud at Dredge Sites (Subtask 4), Charles Bostater*
5. *Hydrologic and Water Quality Model for Management and Forecasting within Brevard County Waters of the IRL (Subtask 5), Gary Zarillo*

FIT EMD Year 2 peer-reviewed final research reports are found in:

6. *Muck Dredging Research Project Management (Subtask 1)*, John Windsor, June 2019
7. *Biological Responses to Muck Dredging in the Indian River Lagoon, Part I. Seagrass Monitoring and Infaunal Surveys (Subtask 2)*, Kevin Johnson, September 2017
8. *Biological Responses to Muck Dredging in the Indian River Lagoon, Part II: Fish Populations and Sea Grass Restoration (Subtask 3)*, Jonathan Shenker, March 2018
9. *Determining the Effectiveness of Muck Removal on Sediment and Water Quality in the Indian River Lagoon, Florida (Subtask 4A)*, Austin L. Fox, John H. Trefry, Robert P. Trocine, Stacey L. Fox, Jessica E. Voelker, December 2017
10. *Inputs of Nitrogen and Phosphorus from Major Tributaries to the Indian River Lagoon (Subtask 4B)*, John H. Trefry, Austin L. Fox, Robert P. Trocine, Stacey L. Fox, Jessica E. Voelker, Katherine M. Beckett, October 2017
11. *Hydrologic and Water Quality Model for Management and Forecasting within Brevard County Waters (Subtask 5)*, Gary Zarillo, April 2018
12. *Moving Muck & Fluidized Mud & Tributary Bedload Measurements at Dredge Sites (Subtask 6)*, Charles Bostater, May 2018
13. *Wind and microclimate analysis for application to fetch-limited wind wave growth analysis at IRL dredging locations (Subtask 7)*, Steven Lazarus, November 2017
14. *Feasibility of muck removal at fixed locations in the IRL watershed and subsequent ferrate treatment to remove nutrients and contaminants (Subtask 8)*, Robert J. Weaver and Thomas D. Waite, January 2018
15. *Source to Slime Study in Indian River Lagoon (Subtask 9)*, Leesa Souto, May 2019

FIT EMD Year 3 peer-reviewed final research reports are found in:

16. *Muck Dredging Research Project Management (Subtask 1)*, John Windsor, February 2021
17. *Muck Removal Efficiency plus Biological and Chemical Responses/Improvements after Muck Dredging (Subtask 2)*, Kevin Johnson, Jon Shenker, and John Trefry, June 2020.
18. *Trends for Inputs of Muck Components from Rivers, Creeks and Outfalls to the Indian River Lagoon (Subtask 3)*, John Trefry and Austin Fox, December 2019
19. *Lagoon-Wide Application of the Quick-Flux Technique to Determine Sediment N and P Fluxes (Subtask 4)*, Austin L. Fox and John H. Trefry, June 2019
20. *Optimizing Selection of Sites for Environmental Dredging in the Indian River Lagoon System (Subtask 5)*, John H. Trefry and Kevin B. Johnson, November 2019
21. *Sediment & Water Quality Modeling for Nutrients, Muck and Water Clarity Scenario Assessments (Subtask 6)*, Gary A. Zarillo and Claudia Listopad, January 2021

***Funding through DEP Grant Agreement Nos. S0714 and NS005 administered by Brevard County**