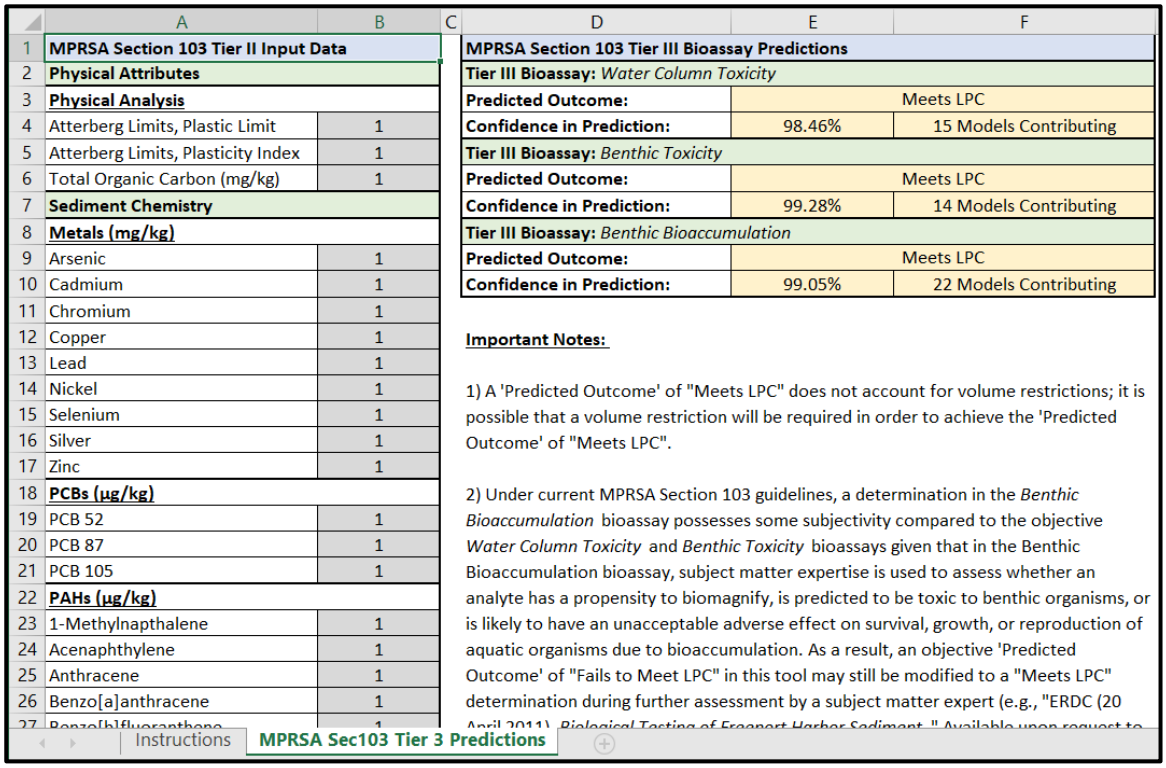
Predicting Outcomes of Tier III Environmental Testing of Dredged Material: A Machine Learning (ML) Approach to Aquatic Disposal

Impact Statement: The results of this study show that a decision tree Machine Learning (ML) algorithm can help optimize the way the Marine Protection, Research, and Sanctuaries Act (MPRSA) Section 103 Tier III evaluations are performed and has the potential to reduce the cost and time associated with compliance testing when certain bioassays are predicted to be unnecessary. The ML algorithm can predict, with confidences varying from 88-96%, whether Tier III bioassays will meet Limiting Permissible Concentration (LPC) based on physical and chemical characteristics of the source sediment. Outcomes from the study also suggest that the majority of the 480 possible parameters measured in MPRSA Section 103 evaluations may not be reliable indicators of the final compliance decision.

ERDC Environmental Laboratory (EL) and USACE New England District (NAE) CW R&D researchers published their findings from the USACE Dredging Operations and Environmental Research (DOER) Program, Research Task 21-07 "Predicting Outcomes from Tier III Environmental Testing of Dredged Material:
A Machine Learning Approach", in the Western Dredging Association's *Journal of Dredging* (Volume 21, Issue 2, 2024) https://www.westerndredging.org/journal.

In the study, the researchers examined whether a Machine Learning (ML) algorithm could be applied to Marine Protection, Research, and Sanctuaries Act (MPRSA) Section 103 environmental compliance testing and could help inform the need and design of Tier III testing based on physical and chemical characteristics of the source sediment. After analyzing over 100 historical environmental evaluations across 9 USACE Districts and training and testing various ML models, the team's results showed that (1) MPRSA section 103 Tier I/II/III datasets are conducive to ML, and (2) the 36 Tier I and II physical and chemical parameters that are most impactful to Tier III outcomes can be pinpointed. Additionally, results showed that sufficient data from the USACE currently exist from historical dredging evaluations to train and test ML models that produce confident predictions (88-96% confidence) of water column toxicity outcomes, but more data is needed to produce confident predictions of sediment toxicity and sediment bioaccumulation potential outcomes. Additional environmental compliance evaluations with acceptable 'input' to 'output' mappings will only improve the strength of the developed ML models' predictions.

The team also developed an easy-to-use Microsoft Excel-based tool that accepts user input values for the most sensitive Tier I/II 'input' parameters and utilizes ML models on the back end to output a 'predicted outcome' and 'confidence in prediction' value for each of the three Tier III 'outputs' (Figure 1). Should this tool be converted to a web-based platform where standardized input files can be uploaded, the ML models could continually learn and improve over time. Because the 'input' and 'output' arrangement of MPRSA Section 103 Tier I/II/III datasets make them conducive to ML, evaluations can be converted to a standardized format (that the project team has already created) relatively easily and fed automatically into the ML model if it exists as a software tool.



	A	B	C	D	E	F
1	**MPRSA Section 103 Tier II Input Data**			**MPRSA Section 103 Tier III Bioassay Predictions**		
2	**Physical Attributes**			**Tier III Bioassay:** *Water Column Toxicity*		
3	**Physical Analysis**			**Predicted Outcome:**	Meets LPC	
4	Atterberg Limits, Plastic Limit	1		**Confidence in Prediction:**	98.46%	15 Models Contributing
5	Atterberg Limits, Plasticity Index	1		**Tier III Bioassay:** *Benthic Toxicity*		
6	Total Organic Carbon (mg/kg)	1		**Predicted Outcome:**	Meets LPC	
7	**Sediment Chemistry**			**Confidence in Prediction:**	99.28%	14 Models Contributing
8	**Metals (mg/kg)**			**Tier III Bioassay:** *Benthic Bioaccumulation*		
9	Arsenic	1		**Predicted Outcome:**	Meets LPC	
10	Cadmium	1		**Confidence in Prediction:**	99.05%	22 Models Contributing
11	Chromium	1				
12	Copper	1				
13	Lead	1				
14	Nickel	1				
15	Selenium	1				
16	Silver	1				
17	Zinc	1				
18	**PCBs (µg/kg)**					
19	PCB 52	1				
20	PCB 87	1				
21	PCB 105	1				
22	**PAHs (µg/kg)**					
23	1-Methylnapthalene	1				
24	Acenaphthylene	1				
25	Anthracene	1				
26	Benzo[a]anthracene	1				

Important Notes:

1) A 'Predicted Outcome' of "Meets LPC" does not account for volume restrictions; it is possible that a volume restriction will be required in order to achieve the 'Predicted Outcome' of "Meets LPC".

2) Under current MPRSA Section 103 guidelines, a determination in the *Benthic Bioaccumulation* bioassay possesses some subjectivity compared to the objective *Water Column Toxicity* and *Benthic Toxicity* bioassays given that in the Benthic Bioaccumulation bioassay, subject matter expertise is used to assess whether an analyte has a propensity to biomagnify, is predicted to be toxic to benthic organisms, or is likely to have an unacceptable adverse effect on survival, growth, or reproduction of aquatic organisms due to bioaccumulation. As a result, an objective 'Predicted Outcome' of "Fails to Meet LPC" in this tool may still be modified to a "Meets LPC" determination during further assessment by a subject matter expert (e.g., "ERDC (20

Instructions | MPRSA Sec103 Tier 3 Predictions

Figure 1. Excel-based tool that accepts user input values for the 36 most sensitive Tier I/II 'input' parameters and utilizes Machine Learning (ML) models on the back end to output a 'predicted outcome' and 'confidence in prediction' value for each of the three Tier III 'outputs.'

This research also reveals that only a small subset (36 parameters, or 7.5%) of the 480 possible Tier I and II physical and chemical parameters collected in MPRSA Section 103 evaluations have a significant impact on Tier III outcomes. Reconsidering testing for the least influential input parameters may help to reduce the cost and time associated with compliance testing. The team hopes to conduct future work focused on (1) considering conditions under which the ML model should be incorporated into MPRSA Section 103 guidance, and (2) investigating the use of this prediction method for inland disposal evaluations where Tier III testing is not a firm requirement (i.e., Clean Water Act Section 404). Additionally, the team would like to dedicate further efforts to (1) transforming the ML model developed in this project into a web-based platform to enable continuous learning and improvement, and (2) considering how the results presented in their research paper can support potentially revisiting the regulations for ocean disposal in the future.

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