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MEMORANDUM

To: Scott Pickard, CELRB-TD-EH
Michael Asquith, CELRB-PM-PM

From: Paul R. Schroeder, Ph.D., PE
Earl Hayter, Ph.D.

Date: 14 March 2016

We have reviewed Dr. Nathan Hawley's report on sediment migration at the open-lake placement area CLA-1 (Enclosure 1) which challenges the analysis and conclusions of modeling documented by U.S. Army Engineer Research and Development Center (USAERDC) (2014a, 2014b). We have several substantive concerns with his analysis and conclusion. Our comments are as follows:

1. Dr. Hawley states that "If sediment from the Cleveland Harbor is placed at CLA -1, it will be resuspended and migrate multiple times per year under typical weather conditions. Generally, the sediment will likely migrate miles per year in a largely unpredictable pattern, but eventually will end up in the eastern basin of Lake Erie."

Dr. Hawley does not cite any papers or reports that would support this statement. He only provides a bibliography of studies on the Great Lakes, and he did not provide information specific to CLA-1 and mechanically placed dredged material. If Dr. Hawley could reference such studies, then we will review those to determine whether we should change the conclusions of our focused modeling study on erosion potential under typical annual conditions at the proposed placement sites.

2. Dr. Hawley states that "There is ample evidence that sediment resuspension occurs throughout the central basin of the lake multiple times per year, and that this material may travel considerable distances, and may remain unburied for years to decades before it is finally buried and removed from the ecosystem."

a. As before, Dr. Hawley needs to cite specific published literature that supports his contention.

b. Raw water turbidity data for the Cleveland area potable water intakes show that resuspension does indeed occur about a dozen times per year, almost exclusively in November through April; the larger events occur in November through February. Eighty percent of the dredging occurs in May and June, which allows four months for the dredged material to consolidate and become incorporated within the sediment bed before significant storms occur. During these storms/resuspension events, total suspended solids (TSS) increase in the water column at the deep water intakes (greater than 45 ft) by 25 to 50 mg/L, while the TSS at the water intake in shallower water increases by 50 to 100 mg/L. The data suggests that resuspension is much greater in water depths less than 40 feet where waves contribute significantly to the bottom shear stress. Resuspension events are both greater and more frequent in shallow water. To increase the TSS in the water column by 50 mg/L, only 1 mm of consolidated sediment or 3 mm of unconsolidated sediment would need to be resuspended. After a resuspension event, the TSS will settle out in deeper areas where the sediments tend to be fine-grained such as at CLA-1, and then reestablish the surface with new deposition. This new deposition is resuspended in subsequent resuspension events and the underlying sediment remains in place. Therefore, locations such as CLA-1 in 60 ft of water tend to be slightly net depositional (a few millimeters per year) because sediment will generally be transported from shallow to deeper water. The raw water turbidity data for the Cleveland area water intakes show that the TSS settle in one to two days after the resuspension event ends, suggesting a settling velocity of 0.1 to 0.2 mm/sec, representative of small (10 to 20 microns in diameter) aggregates of fine-grained material rather than discrete clay and fine silt particles. Dr. Hawley's analysis ignores sedimentation occurring at CLA-1. His report does not address whether the site is erosional, but merely states that resuspension will occur multiple times per year. Resuspension occurring at a location is not equivalent to a location being net erosional. Our modeling addresses whether the site is likely to be net erosional and dispersive, as opposed to whether surficial resuspension occurs, which was the focus of Dr. Hawley's report. Neglecting sedimentation is a critical flaw in Dr. Hawley's report and leads to the false conclusion that the dredged material will be transported out of CLA-1 by resuspension.

3. Dr. Hawley states that "The Corps used models similar to those described above, the results of which contain serious flaws because the Corps used unreasonably high critical stresses and unreasonably low bottom stresses in its models. In doing so, the Corps ignored 20 years of Great Lakes research performed by NOAA and others and instead relied on outdated research and data from studies of river and ocean sediments."

No research was ignored during this modeling. It is not true that we "relied on outdated research and data from studies of river and ocean sediments." Since Dr. Hawley does not specify which outdated research and data from other studies he is referring to, we cannot give a specific reply to this comment.

4. Dr. Hawley states that "The Corps reports that it first ran its model to simulate a thirty-day period between 31 May and 30 June of 2002. The Corps asserts that no resuspension was predicted even though the bottom current velocities were as large as 40 cm/s, which are considerably higher than the ambient monthly average velocities (4-9 cm/s) observed by NOAA. However, the Corps presented no information about what, if any, waves were included in its simulation. Furthermore, no values of bottom stresses are given, yet the Corps reports that no resuspension of material was predicted to occur. Without considering information on wave energy during this time period, this model is of little value in predicting future annual sediment resuspension and migration."

Long-term (LT) FATE was used to perform the three-dimensional hydrodynamic and sediment transport modeling for both periods that were modeled. The bottom shear stresses used in performing the sediment transport modeling account for both current and wave generated shear stresses calculated by the SEDZLJ sediment bed model. We did use the wave record from a nearby NOAA buoy to calculate the wave-induced stresses because wave modeling could not be performed under this focused modeling study. The simulated 40 cm/s current velocities during an event that occurred in June 2002 were not bottom currents as stated by Dr. Hawley, but were surface currents. Dr. Hawley further states that "Apparently, the Corps calculated simulated waves and currents using a different model for the first time period, but that model was not provided." The hydrodynamic model and results were documented in a Technical Memorandum entitled "Lake Erie Circulation Modeling Conducted Using the ADCIRC Long-wave Hydrodynamic Model to Evaluate Flow Conditions during Representative Time Periods for Open-Water Dredged Material Placement Operations" prepared for the USACE Buffalo District by the Coastal and Hydraulics Laboratory of the U.S. Army Engineer Research and Development Center and dated 30 July 2013 (USAERDC 2013).

5. Dr. Hawley states: "This first report also briefly describes results for the period during Hurricane Sandy, when, according to the Corps, the calculated bottom stresses approached 0.2 Pa. However, the Corps provided no information regarding what inputs it used to represent waves and currents."

The report did describe the forcings (including the use of wave data at the nearby NOAA buoy) used as boundary conditions for LTFATE.

6. Dr. Hawley offered several other comments. Our responses to those comments are given below.

a. "The Corps has underestimated the potential for sediment resuspension at disposal site CLA-1 for several reasons. First, the Corps significantly underestimated the value of the bottom stress exerted on the sediments by the waves and currents. The Corps' bottom stresses are significantly lower (by up to 10 times) than those measured and/or calculated by other studies in the Great Lakes. In Saginaw Bay, for instance, Hawley et al. (2014) calculated bottom stresses of over 1 Pa when the waves were much smaller than those observed during Hurricane Sandy."

A comparison with bottom shear stresses in Saginaw Bay is inappropriate because nearly all of Saginaw Bay is less than 30 ft deep and most of it is less than 20 ft deep. Additionally, Saginaw Bay is not an open lake environ; rather, it is an embayment subject to additional forcing functions such as the river flow. The water depths at the CLA-1 site, which vary between 60 and 65 ft (18.3 and 19.8 m), are the main reason for the bed shear stresses calculated by SEDZLJ being lower than what Dr. Hawley expected.

b. "My calculations show that using the maximum wave height would produce values of τ_w and τ_{cw} approximately 30% greater than those reported by the Corps, or 0.16-0.21 Pa for τ_w and 0.21-0.26 Pa for τ_{cw} over fine-grained material. These values of τ_{cw} exceed even the unreasonably high values that the Corps used as the critical stress for resuspension for silt (0.2

Pa). Therefore, resuspension of most of the material in composites 2 and 3 would be predicted to occur." Additionally, "However, the most important reason the Corps results are flawed is because the Corps has significantly overestimated the value of the critical stress for the silt-sized material. Apparently the Corps determined this value based on the work of Jepsen et al. (1997) who took bottom samples from the Fox River, the Detroit River, and off of Santa Barbara (Pacific Ocean) and experimentally eroded them. The Corps determined that the critical stress of the silt-sized material was 0.2 Pa. However there are a large number of published studies from the Great Lakes that show that the critical stress value for silt sized material is actually between 0.05 and 0.15 Pa and that resuspension not only occurs frequently in the lakes, but that it also occurs during storms when the conditions were much less severe than during hurricane Sandy."

We strongly disagree that 0.2 Pa is an unreasonably high value of the critical shear stress for resuspension. We did not use this value based on the work of Jepsen *et al*. (1997). The range of critical shear stresses found in numerous SEDFLUME studies performed in lakes, rivers, harbors, and estuaries typically vary between 0.05 to more than 1.0 Pa. A value of 0.2 Pa is a common value measured for sediments in the top 5 cm of the tested sediment cores. The value depends on the degree of cohesiveness of the sediment, which depends on, among other factors, the fraction of clays to larger sediment size classes, the mineralogy of the clay size fraction, and the degree of consolidation of the sediment (Mehta *et al*. 1989). The reported critical shear stress were measured on sediment cores, and not mechanically dredged and placed dredged material that may be denser than surficial sediments formed by sedimentation and disturbed by bioturbation. The Upper Cuyahoga River Channel sediment has a wet bulk density of 1.57 kg/L, liquidity index of 1.85 and toughness index of 1.70, indicating that the sediment is highly resistant to water entrainment and shear. Recent open-lake area sample collection offshore of Ashtabula Harbor for similar dredged material and dredging operations confirms that virtually no entrainment of water or bulking in the surface samples should be expected; three weeks after placement, the dredged material wet bulk density was the same as it was in the barge prior to placement. Most surficial fine-grained sediments would have a wet bulk density of 1.15 to 1.3 kg/L and a liquidity index of 6 to 12, which would yield a critical shear stress approximately an order of magnitude smaller than would exist for the Upper Cuyahoga River Channel sediment. Critical shear stresses of the Upper Cuyahoga River Channel sediment below the top 5 cm are likely to be greater than 1 Pa. Therefore, the critical shear stress of 0.2 Pa used in our modeling study would likely represent a realistic worst-case value. Consequently, our modeling of erosion potential is likely to over predict the erosion potential rather than under predict as Dr. Hawley's report states.

c. "As a final piece of anecdotal evidence to refute the Corps' conclusion that sediment resuspension did not occur during Hurricane Sandy, I have attached a satellite image (Fig. 2) of Lake Erie taken seven days after the storm (the first day that the cloud cover allowed observations to be made). This figure shows a wide band of suspended sediment along the southern shore, even though the waves and currents had decreased considerably after the storm. This demonstrates that the waves and currents produced in Lake Erie during Hurricane Sandy were sufficiently strong to resuspend bottom sediments on the Lake bed near Cleveland."

We agree that the waves and currents during Hurricane Sandy were most likely strong enough to resuspended bottom sediments near Cleveland where the water depths are shallower than they are at the CLA-1 site. USAERDC (2014b) indicates that the Composite #1 fluff layer could be resuspended during Super Storm Sandy, but that its mass and PCB contribution would not be significant compared to resuspension occurring in the shallow water environs.

d. "Additional, anecdotal evidence that bottom sediments and the pollutants adsorbed onto them have been transported from site CLA-1 is presented in a summary of results of a survey conducted by the Ohio EPA (Ohio EPA 2015). Contaminated sediments were deposited at CLA-1 prior to about 1960, and the concentrations of both PCBs and PAHs remain high at the site. However, the data also clearly show that both PAH and PCB concentrations are markedly higher to the south of CLA-1 than to the north, where the concentrations approach the background concentrations. The obvious explanation for this pattern is that contaminated sediments have been transported from the disposal site southward during the period since the sediment was deposited at CLA-1."

The report entitled "Cleveland Harbor (Upper Cuyahoga River Channel) Dredged Sediments with Respect to Suitability for Open-Lake Placement" performed by the USACE Buffalo District (USACE 2016) found that dredged material that had been placed at CLA-1 was still present, but contaminant concentrations on the surface at many locations were comparable or only slightly greater than the surrounding concentrations. The contaminant concentrations at a few locations were significantly higher, particularly to the south as noted by Dr. Hawley. The fact that contamination is still present after more than 45 years and perhaps 500 resuspension events clearly suggests that significant net erosion is not occurring at the site. The lower contaminant concentrations in deeper water within the site and north of the site suggest a net deposition of at least 2 to 3 mm per year occurs at the site as concluded above, while the location south of the site is shallower and therefore less depositional. If sediment were transported to the south by resuspension events, there should be a contaminant concentration gradient with the highest concentration in CLA-1 and decreasing concentrations proceeding south. Existing data fail to suggest any such trend.

7. We will not comment on the Section "Transport and fate of resuspended material" in Dr. Hawley's report since the scope of our modeling study was limited to determining if the sediment resuspended or not during the two simulated time periods.

8. In conclusion, Dr. Hawley's analysis and conclusions are substantively flawed because:

a. His analysis focused only on sediment resuspension and not net sediment erosion.

b. He did not consider the effects of sedimentation in the lake, which replenishes the sediment surface following each resuspension event and limits the exposure and resuspension of the placed dredged material below the deposition.

c. He did not consider the density of mechanically dredged and placed dredged material in estimating critical shear stress. Instead, he relied on natural lake sediment cores formed by sedimentation, which are significantly less dense, more liquid and, therefore, more erodible than mechanically dredged and placed dredged material. Therefore, he overestimates the potential for erosion and resuspension.

d. He has not generated estimates of the bottom shear stress for representative storm events and wave conditions at CLA-1 or provided estimates for comparison with bottom shear stresses used for previous modeling.

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Enclosure

<u>References</u>

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USAERDC. 2014b. Evaluation of NOAA Cleveland-area buoy data for potential resuspension and erosion of open-lake placed dredged material by severe sustained storms. Technical memorandum dated 22 April 2014.