GUIDANCE FOR THIN-LAYER SEDIMENT PLACEMENT AS A STRATEGY TO ENHANCE TIDAL MARSH RESILIENCE TO SEA-LEVEL RISE

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Prepared by:
Researchers from eight National Estuarine Research Reserves (NERRs) collaborated on a two-year NERRS Science Collaborative-funded field experiment investigating thin-layer placement of sediment in tidal marshes, beginning in Fall 2017. An expert Advisory Committee for the two-year project was convened that helped prepare these guidance documents.

For more information:
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The Little River, Wells NERR. Courtesy of the Chesapeake Bay VA NERR.

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CHAPTER 2: THIN-LAYER PLACEMENT OF SEDIMENT FOR TIDAL MARSH RESILIENCE IN THE CONTINENTAL UNITED STATES: A LITERATURE REVIEW

INTRODUCTION

The earliest studies of how tidal marsh responds to sediment addition had little to nothing to do with restoration; instead, TLP had its origins in disposing of dredged sediments from drilling sites, navigation channels, and pipeline canals – documented most thoroughly in Louisiana. To our knowledge, the practice of thin-layer placement is now fully focused on marsh restoration and resilience. Sediments may be sourced from a variety of places, including the proposed "win-win" relationship where dredged sediments are beneficially used to build marsh surface elevations in order to keep pace with accelerating sea-level rise. No matter the source of the sediment, primary attention is given to ecological function and services of tidal marsh. There has been interest in the impact of sediment addition on marsh for 50 years; as one example, the U.S. Army Corps of Engineers initiated a Dredged Materials Research Program in 1973. In early, seminal research, Reimold et al. (1978) explored the effects of sediment addition depths of 8-91 cm on *Spartina alterniflora* (smooth cordgrass).

Across the studies reviewed, results tend to show that a) tidal marsh plants can recover through 5-15 cm of sediment addition (although this depends greatly on marsh geomorphology and integrity, rather than being a rule of thumb); b) plants recover through resprouting in about two years, and through re-seeding in a longer time frame; and c) added sediment may improve marsh re-vegetation (plant cover), and increase marsh biomass, plant stem density, and nutrient uptake into plant tissue, as long as the pitfall of sulfuric acid toxicity is avoided. There are many open questions as to how to avoid conditions which lead to transformation of sulfidic soils to acid sulfate soils, but one factor is that saturated, anaerobic soils (a reducing environment) with a composition of fine-grain sediments that are exposed to air (an oxidizing environment) are more likely to lead to sulfuric acid development. The quality of the sediment certainly comes into play as to whether added nutrients are beneficial or detrimental to marsh resilience; whether there are contaminants or toxicants present; and grain size or sediment type, from coarse sand to fine silt or mud.

A review by the Army Corps of Engineers' Research and Development Center, "Maintaining tidal marshes in the face of sea-level rise," (VanZomeren et al. 2019) states, "Thin-layer placement of dredge material was used as the major restoration technique in ten references (Cahoon and Cowan 1987, Delaune et al. 1990, Wilber 1993, Ford et al. 1999, Cornu and Sadro 2002, Mendelssohn and Kuhn 2003, Croft et al. 2006, Ray 2007, Schrift et al. 2008, Wigand et al. 2017)." This review covers those ten references (substituting the published article by Cahoon and Cowan (1988) for the 1987 report and not listing the Ray 2007 review). In addition, the table includes the following references: Reimold et al. (1978), Frame et al. (2005), Slocum et al. (2005), and La Peyre et al. (2009). Thin-layer placement of sediment has been investigated or applied in Georgia, Louisiana, North Carolina, New York, Oregon, and Rhode Island.

There are various concerns with TLP, especially for those unfamiliar with it as a nature-based adaptation tool. As mentioned, TLP's origin and history is one of dumping dredged sediments for convenience, not restoration: canals were cut through Louisiana marshes for oil and gas extraction, and dredged sediment dumped on the sides. That is the beginning of the literature — although not in the spirit or direction of TLP, which is a restoration tool. The vast majority of papers come from Barataria Bay, Louisiana, and the LA Delta, so geographic variation is limited in terms of scientific results. Second, TLP currently has the same permit process as filling wetlands: legal and policy frameworks do not distinguish between filling wetlands for development and adding sediments to marsh for the purpose of marsh sustainability. Again, in the policy framework, we have not differentiated harm to marsh from restoration of marsh — making it, perhaps, difficult for TLP to have a positive association. Lastly, few designers and engineers are familiar with nature-based techniques for coastal protection (Restore America's Estuaries 2015), so they may not readily look to living shorelines or TLP. It will take more education and awareness about nature-based options, which this guidance document can provide for TLP.

Note: Results of completed studies are presented geographically, starting in the Northeast and proceeding clockwise.

PROJECTS SORTED BY LOCATION: CLOCKWISE AROUND THE U.S. BY STATE, STARTING IN THE NORTHEAST

PROJECT TEAM OR CO-AUTHORS	DATE	LOCATION	PROJECT DESCRIPTION	PLANT COMMUNITY(IES)	SEDIMENT DEPTH (CM) AND TYPE	RESULTS/DID IT RESTORE MARSH VEGETATION AND FUNCTION?
C Wigand, T Ardito, C Chaffee, W Ferguson, S Paton, K Raposa, C Vandemoer, E Watson	2017	Narrow River, RI	A climate change adaptation framework is presented, where one aspect of adaptation is TLP on the Narrow River, RI. Dredged sediment will be added to high marsh to improve habitat for the tidal marsh sparrow.	*Spartina patens* (salt meadow hay) and *Juncus gerardii* (black rush).	Reporting on a stakeholder process; sediment depths still to be decided at time of publication.	Planned project, where results will be monitored using a Before/After/Control/Impact design.
G.W. Frame, M.K. Mellander, D.A. Adamo	2006	Jamaica Bay, NY	Big Egg Marsh, Jamaica Bay, NY restoration through thin-layer placement of sandy sediments, using high-pressure spray.	*Spartina alterniflora*.	20 cm higher than any of the remnant *Spartina alterniflora* tussocks, which meant up to 1.0 m in low-lying areas.	*Spartina alterniflora* survived spray application of sand in the first season if sediment thickness was 20 cm or less. Found that sand was transforming into a silty and organic tidal marsh soil, there was a dense cover of smooth cordgrass, and an appropriate animal community was becoming established on the treatment site.
AL Croft, LA Leonard, TD Alphin, LB Cahoon, MH Posey	2006	Masonboro Island, NC	Examined sediment additions of 0-10 cm; two deteriorated plots and two non-deteriorated plots received sediment additions; control areas did not.	*Spartina alterniflora* marsh, "deteriorating and non-deteriorating," in monospecific stands. Non-deteriorating marsh was defined by >200 stems per m^2 of *S. alterniflora*, and deteriorating marsh had <150 stems per m^2.	Zero (control) to 10 cm: applied as categories of thick, medium, and thin. 50% fine sand; 50% silt and clay.	Stem densities of *S. alterniflora* increased in all sediment addition plots, with the greatest increases in deteriorated plots. Stem heights were not influenced by treatment.

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RJ Reimold, MA Hardisky, PC Adams (US Army Corps of Engineers)	1978	Glynn County, GA	The goal was to examine the spreading of dredged material so that it is both cost effective and environmentally sound.	*Spartina alterniflora* marsh.	8, 15, 23, 30, 61, and 91 cm. Type: 1) coarse sand; 2) mixed sand and clay; 3) clay as experimental treatments.	*S. alterniflora* stems can grow through "overburden" sediment up to 23 cm deep regardless of the sediment type. Plots covered with 60 cm or more of dredged material did not recover.
RD DeLaune, S Pezeshki, JH Pardue, J Whitcomb, H Patrick, Jr.	1990	Barataria Basin, LA	Manual addition of sediment to tidal marsh plots enclosed in plywood boxes: two different sediment heights, with initial sediment addition in July 1986 and second sediment addition in June 1987. Plants sub-sampled in November 1987.	*Spartina alterniflora* marsh, degrading.	Two phases of application: first, thicknesses of 2-3 cm and 4-5 cm; after second application, thicknesses were 4-6 cm and 8-10 cm. Type: 40% fine sand, 28% coarse-fine silt, and 32% clays and organics.	Sediment addition resulted in increases in aboveground biomass (AGB) and density of *S. alterniflora* shoots in both treatments (both levels of sediment application). Increase in AGB was only significant for the deeper sediment treatment; number of plant shoots was significantly greater for both levels of sediment input. Nitrogen uptake in plants in deepest sediment level was twice that of the controls.
MK La Peyre, B Gossman, BP Piazza	2009	Six sites in Barataria Basin, LA	Project examined short-term (< 1 yr) and long-term (1-8 years) response to sediment enhancement in terms of functional response of vegetated brackish marsh and interior open water ponds. Used a chronosequence of sediment addition sites (a space-for-time substitution).	*Spartina patens* (salt meadow hay) and *Schoenoplectus americanus*, dominant species in brackish marsh; previously vegetated open water ponds.	Rather than targeting specific sediment addition levels, targeted elevations ranged from 36 to 54 cm NAVD88.	Vegetation response depended on pre-enhancement conditions, whether it was vegetated marsh or open pond (with an intention of restoring open ponds to marsh). In marsh habitat that was vegetated before enhancement, aboveground vegetation biomass decreased over time and belowground biomass neither increased nor decreased over time. In open water habitat, both above-ground and below-ground vegetation increased over time until they approached the biomass of reference marshes over a 7-year period.

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IA Mendelssohn, NL Kuhn	2003 (work related to Slocum et al. 2005 paper)	near Venice, LA, within the Modern (Birdfoot) Delta of the MS River	Assessed the plant structural and soil physico-chemical responses to different intensities of sediment subsidy in a salt marsh experiencing a high rate of relative sea level rise.	*Spartina alterniflora* tidal marsh, degrading. *S. patens* and *Distichlis spicata* were present, but had low percent cover.	Range of 0 cm to >30 cm.	*S. alterniflora* showed a significant increase in percent cover with sediment subsidy; plant height was 30–60% greater with increasing sediment subsidy (significant); alive+dead biomass increased significantly with sediment addition, but pattern was less clear in alive biomass alone. No change in species composition occurred at the sites with increasing sediment addition. Soil bulk density increased with sediment thickness; interstitial soil salinity was significantly higher with more added sediment.
MG Slocum, IA Mendelssohn, NL Kuhn	2005	near Venice, LA, within the Modern (Birdfoot) Delta of the MS River	Tested how different amounts of sediment ameliorated the effects of sea-level rise and subsidence over 7 years; sediment slurry addition.	*Spartina alterniflora* tidal marsh, degrading.	0-22 cm after compaction (at end of 7-yr. experiment): originally 0-40 cm.	At end of 7-year experiment, areas receiving moderate amounts of sediment (5-12 cm) had better plant vigor (55% plant cover) and soil condition, more than double bulk density and 0 mM hydrogen sulfide (HS) compared to areas not receiving sediment (20% plant cover, lower bulk density, and >1.0 mM HS). Sediments were also high in nutrients, which led to 3-year increase in plant growth.
MA Ford, DR Cahoon, JC Lynch	1999	near Venice, LA, within the Modern (Birdfoot) Delta of the MS River	Investigated high-pressure spray of dredged material onto two habitats: degraded marsh on spoil banks of a canal, and recently-opened shallow water (previously tidal marsh).	*Spartina alterniflora*.	2.3 cm.	Most emergent plants were flattened by the spray application of sediment and then recovered. One year after spray, *Spartina alterniflora* (percent cover) increased significantly.

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AM Schrift, IA Mendelssohn, MD Materne	2008	near Leeville, LA	After 40,000 ha of *Spartina alterniflora* marsh died due to drought, researchers assessed the effectiveness of sediment-slurry application for vegetation recovery to compensate for post-dieback soil consolidation. Researchers added sediment and created high, medium, and low elevation treatments.	*Spartina alterniflora* marsh, with some *Salicornia virginica* (species list in Table 1).	Rather than depth of sediment added, measured surface elevation relative to ambient, healthy marsh (e.g., low elevation/13–18 cm above ambient healthy marsh). Type: semi-fluid, mineral soil.	The addition of sediment slurries increased the rate of recovery (plant cover) following disturbance in a rapidly subsiding tidal marsh. Elevations, averaging 14 and 20 cm above ambient marsh (44 and 50 cm above NAVD 88, respectively), in the low elevation and vegetated treatment levels had rapid plant recruitment and species richness similar to that of the healthy reference marsh sites.
DR Cahoon, JH Cowan	1987, 1988	Lake Coquille and Terrebonne Parish wetlands (Dog Lake), LA	First description of response of LA coastal wetland to TLP by high-pressure spraying.	Lake Coquille: *Spartina alterniflora* marsh.	10-15 cm at Dog Lake; 18-38 cm at Lake Coquille. Type not described: slurry from canal dredging.	14 months after placement, vegetation still smothered at both sites; however, recolonization by tidal marsh plant species was underway.
Wilber	1993	LA and NC	Technical report for Army Corps of Engineers, including review of four studies.		General conclusion that marsh vegetation can survive or recolonize through placement of 5-15 cm of overlying sediment.	Healthy stands of marsh vegetation atop 5 to 15 cm layers of dredged materials. Presents conceptual model for marsh recovery after TLP with two pathways, a) new shoots emerging through sediment, or b) after hypoxia and sulfides kill rhizomes, recolonization through seeds reaching new surface.

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C Cornu, S Sadro	2002	South Slough National Estuarine Research Reserve, OR	Kunz Marsh 5-ha restoration project: originally mature high marsh, then diked and drained in 1900s for agricultural use; restoration created four separate cells and dike material was used as fill to create three intertidal elevations (high, mid, and 2 reps of low marsh).	Competitive dominant, permanent plant species included: *Agrostis alba, Carex lyngbyei, Grindellia integrifolia, Potentilla pacifica, Deschampsia caespitosa, Triglochin maritimum,* and *Salicornia virginica* (pickleweed).	Rather than sediment thickness added to marsh surface, dike material used to create elevations of high, mid, and low marsh.	After project construction there was no vegetation cover in any of the four cells. After three years of monitoring: average of 53% plant cover across all cells, compared with 100% cover at mature (high marsh) reference sites. Marsh elevation and associated tidal inundation did not influence vertical accretion, in contrast to numerous other studies.

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