GUIDANCE FOR SITE ASSESSMENT AND MONITORING OF THIN LAYER PROJECTS IN NORTH CAROLINA TIDAL MARSHES

North Carolina Division of Coastal Management
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Cover photo courtesy of NOAA National Centers for Coastal Ocean Science –application of dredged material onto degraded salt marsh in Camp LeJeune, North Carolina, as part of 2018-2022 NOAA study.

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INTRODUCTION

The following guidance was developed by the N.C. Division of Coastal Management with support from an interagency working group made of representatives from the U.S. Army Corps of Engineers (Wilmington District), National Marine Fisheries Service (Southeast Regional Office), U.S. Fish and Wildlife Service (Raleigh Field Office), N.C. Division of Marine Fisheries, N.C. Division of Water Resources, and the N.C. Wildlife Resources Commission. Each of these agencies plays a key role in permitting coastal projects in North Carolina. The guidance includes a range of site assessment and monitoring protocols that these agencies have identified as important for “thin layer” sediment placement projects on tidal marshes. While not all of the information below will necessarily be required for all project proposals, each item was identified as important or helpful for project scoping, interagency permitting reviews, and future outcome evaluations. Similarly, satisfaction of the below guidance does not guarantee that a specific project will be permitted, and additional permit conditions or information requirements may apply.

Thin-layer placement (TLP), for the purposes of this document, is a coastal wetland restoration or enhancement strategy whereby material (often dredged sediment) is intentionally placed on a wetland to increase its elevation while maintaining hydrology and inundation durations necessary for native (targeted) wetland vegetation to persist. In many cases, the need to complete a dredging project may be the driving force for a proposed project, but the primary purpose of TLP should not be for the ‘convenient disposal’ of dredged material. Rather, the primary goal should be the restoration of impaired or at-risk wetlands with measurable benefits expected from the addition of sediment. At-risk wetlands include, but are not limited to, those with low stem density or stunted vegetation; ditching, channelization; impoundments; fragmented marsh vegetation or conversion of high to low marsh; elevation deficits (relative to local tidal range), and/or expanding ponds or pools with minimal faunal usage. TLP projects may be considered for beneficial use, natural infrastructure, and marsh restoration projects, but are not a creditable mitigation strategy in the regulatory context.

TLP should be considered only if it is suited to the placement location. All projects should establish quantitative objectives, assess the suitability of the site, and develop a monitoring plan with success criteria before proceeding [1,2,3]. It is acknowledged that sediment placement will temporarily impact the existing wetland habitat. The site assessment and monitoring plan should address both temporary impacts and the long-term condition.

SITE ASSESSMENT PROTOCOLS

A site assessment should be used to determine the extent and likely cause of the degradation of a tidal marsh site of interest, and the likelihood that TLP can produce desired results in terms of the specific restoration goals at the selected site. Site assessments should include the following, based largely on best practices reported in the literature [1,3,4]:

1) Map of project's proposed placement site, including project boundaries, access corridors, staging areas, buffers, and site features (e.g., vegetated and unvegetated areas, pools, existing tidal connectivity, etc.), proximity to sensitive habitats (e.g., SAV, oyster reefs), and any special management designations (e.g., Primary or Secondary Nursery Areas; Outstanding Resource Waters; Critical Habitat areas; NC Coastal Reserve, etc.).
2) Placement site characteristics such as fetch and slope. Sites with short fetch and low slopes (1-3 %) are generally exposed to reduced amounts of wave energy and are more likely to retain sediment deposited on the site.
3) Characterization of tidal marsh degradation and apparent causes, such as historical habitat conversion or loss, pond expansion, marsh edge erosion, loss of vegetative cover (e.g., low UVVR score) [5], as well as proportion of tidal marsh below mean high water. Previous investigations have shown that marshes located within the lower end (bottom third) of the tidal range are less likely to be able to keep pace with sea level rise [6]. Remotely sensed data such as historic aerial photographs may be used to assess temporal changes over time. Light Detection and Ranging (LiDAR) data may be used to identify project site(s) (e.g., low-lying tidal marsh). However, a visit to the project site(s) must be conducted for a high-resolution topographical survey (Appendix 1).
4) Identification of nearby control and reference sites for comparing TLP results. Control sites may be equally degraded sites. Reference sites should serve as 'targets' that the TLP project attempts to achieve. Historical aerial imagery (see #3 above) may be used to help with selection of control and reference sites.
5) Identification of tidal datums (e.g., MHW and MLW), vegetation zones based on nearby reference sites (e.g., lowest extent of *Spartina alterniflora* at -1.9m NAVD88, short-form *S. alterniflora* at -1.6m NAVD88, *S. patens* dominated high marsh at -1.2m NAVD 88), and restoration goals of the project (including any plans for planting or seeding with coastal wetlands vegetation).

6) Elevation and topography of the project site and control site to provide necessary information for estimating needed thickness to meet targeted ecological elevations and for more efficient and accurate dredged material placement. In addition, this information is needed to identify low spots that may require a greater fill depth than surrounding (higher) areas.

7) Characterization and survey of flora and fauna, including, but not limited to, distribution and inventory of tidal marsh plant species, invasive species, and threatened and endangered species utilization. At a minimum, a qualitative characterization of fish and bird species utilization should also be provided.

8) Sediment characteristics using metrics such as grain size, bulk density, organic matter content in comparison with native sediment (Appendix 2).

9) Evaluation of potential sediment contaminants (see EPA report: "Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S."). More intensive sediment analysis may be required where the source material is taken from marinas or other potential point source discharges of contaminants.

10) A plan outlining temporary sediment confinement approaches and structures, including a plan for removal of the containment (unless using approved biodegradable materials).

11) Assessment of the project site's surface to determine bearing capacity to support heavy machinery, and how the weight of placed dredged material and/or use of heavy equipment will compact the existing tidal marsh surface. Compaction of the added material and the underlying tidal marsh substrate could affect whether the target ecological elevations can be achieved and whether the tidal marsh can recover from sediment placement. For example, pools in the project site may lose more elevation over time due to compaction than the tidal marsh platform, which may result in shallow pools reforming in pre-existing pool areas. Compaction may generally be estimated using relatively simple techniques, such as adding new material to the existing substrate within small sample plots. However, the potential for compaction of access corridors or other sensitive areas due to the use of heavy equipment should be closely assessed and avoided.

12) Description of potential negative changes to adjacent hydrology and implications for secondary impacts to habitats, tidal creeks, tidal exchange, drainage, or shoreline erosion.

13) Summary of site constraints based on the above assessments, including impacts of site characteristics on alternative disposal methods, confinement methods, and access corridors.

RECOMMENDED MONITORING PLAN

Monitoring associated with TLP projects should align with *a priori* specified objectives (e.g., restoration vs enhancement). It is recommended that development of a TLP monitoring plan be designed to provide the data needed to (1) determine whether the TLP project goals and objectives are met, (2) evaluate whether the project was built as designed (as-built survey), (3) evaluate the effects of the project on populations of interest (e.g., Spartina spp., bird nesting) [1,2]. Monitoring should be conducted following a Before-After-Control-Impact experimental design. At a minimum, this should be conducted at least once before sediment addition and once yearly for a minimum of five to seven years [2]. In addition, initial sediment elevations should be measured immediately following sediment addition and again between 3-6 months later to assess sediment compaction. Project evaluation may also need to occur after hurricanes or other large-scale events.

The following components of a monitoring plan are recommended:

> <u>Site visits</u>: Quarterly site visits to collect qualitative monitoring data through visual observation and repeat photography (from fixed locations) should be conducted following sediment addition. While this is not a substitute for quantitative monitoring, this type of monitoring can identify obvious problems (i.e., die-offs) without the time delay common between quantitative data collection and analysis. During site visits, qualitative observations of fish and bird utilization, as well as the abundance and distribution of any invasive species, must also be documented. The monitoring plan should describe how any invasive species identified during monitoring will be addressed.
>
> <u>Elevation</u>: To ensure desired elevation targets (functional marsh elevation range) are achieved and maintained, it is recommended that RTK-GPS or leveling be conducted along transects or a grid pattern to span the entire elevation range of the TLP site. Density of elevation measurements should be ≥ 30/ha, with the density of elevation measurements increasing with increased topographic complexity of the tidal marsh [8,10,11]. Drones can be used to augment transect surveys until vegetation cover exceeds c. 25-50% [12]. In addition, sediment cores can be taken, during and after construction, to compare the actual depth of the placed sediment (above the native soil) in comparison with the design depth. At a minimum, elevation monitoring should be conducted once prior to sediment addition, once immediately after sediment addition, and once per year for five years. Compaction monitoring, through bulk density measurements or other means, should be conducted concurrently with elevation measurements.

Habitat map: Site habitat maps (e.g., vegetated and unvegetated areas, pools, etc.) should be completed at the end of years 1, 4, and 7 following sediment addition.

Vegetation: To evaluate whether desired vegetative cover and community composition are achieved (relative to reference site or historic conditions) and maintained, it is recommended that vegetation surveys be conducted in m^2 plots in the locations (or a subset of locations) where elevation measurements are concurrently taken. Vegetation monitoring of species-specific percent cover should be conducted during times of peak biomass and standardized across annual sampling events for five years. Repeat photography and/or drone surveys can also be used to complement transect surveys.

Soil characteristics: Plant colonization and survival are often dependent on soil characteristics. It is recommended that soil characteristics including bulk density, organic matter content, grain size composition, sulfide concentration, pH, and salinity be monitored once prior to sediment addition, once immediately after sediment addition, and once per year for five years. Replicate sediment samples spanning the TLP project should be collected.

Where resources permit and *a priori* objectives align, several additional monitoring metrics should be considered. These include the following:

1) Vegetation above and below ground biomass (or stem density and canopy height to estimate aboveground biomass allometrically).
2) Turbidity and sedimentation proximal to adjacent sensitive habitats (e.g., designated critical habitat, shorebird or waterbird nesting areas, oyster reefs and SAV).
3) Water level and tidal creek structure to assess site hydrology and inundation.
4) Animal communities including benthic infauna, fish, and birds.
5) Biogeochemical functions such as Carbon sequestration and denitrification.

A final report should document how the project has, at a minimum, enhanced the project site in comparison with the control site; and how the project site compares with the reference site, targeted elevations, floral and faunal species distributions.

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APPENDIX 1: SURVEY REQUIREMENTS TO GENERATE A DEM

There are multiple approaches for measuring the elevation of tidal marsh and generating digital elevation models (DEM), including LiDAR, RTK-GPS, digital leveling, and Surface Elevation Tables (SETs). Each approach generally offers tradeoffs in spatial coverage and accuracy (see Table 1 below modified from [8]). Additionally, drones with optical sensors, in combination with Structure from Motion processing, offer an option for estimating tidal marsh elevations following thin- layer deposition of sediments when marsh vegetation is scarce [9].

Table 1. Comparison of spatial scales and residual mean square error (RMSW) among different elevation measurement techniques.

Technique	Spatial scale (order of magnitude)	Error (RMSE, mm)	Notes
LiDAR	10–100s km^2	140	Gesch (2009)[12]
RTK	10s ha	20–60	Renschler et al. (2002)[13]
Digital level[a]	1 ha	4.7	Cain and Hensel (2018)[8]
SET[b]	1 m^2	1.5	Cain and Hensel (2018)[8]

[a]Residual mean square error for the average of the four rod measurements taken within a given position of the SET plot across all sites.

[b]Residual mean square error for the pin readings averaged to the level of the SET plot across all sites.

RTK-GPS and Digital leveling. There is no general 'rule of thumb' for the density of RTK or digital leveling points to generate a tidal marsh DEM. Suggest point densities range from 3 to 80 points/1000m^2 (30-800/ha) in the literature densities [8,10,11] with the range of suggested densities due largely to the topographic complexity of the tidal marsh. The orientation of points is most commonly setup in a grid-like structure, but taking elevation measurements in a 'clumped' pattern may be necessary where topographic complexity is greatest. The spatial coverage using RTK or digital leveling is typically on the order of a hectare.

LiDAR and drones. Digital elevation models developed from ground-based RTK or digital leveling surveys are often time consuming, labor intensive and limited by spatial coverage. An alternative that is often used is LiDAR data from crewed flights, and, increasingly, with drones using LiDAR sensors. Vertical accuracy tends to be lower than RTK or digital leveling surveys (10-15cm vs 2-6cm) [8]. Additionally, LiDAR data collected from crewed flights is limited by horizontal resolution (0.5-1m). Drone-based LiDAR data can drastically improve horizontal resolution (<5cm) with sub decimeter vertical accuracy.

Crewed flights and LiDAR sensor for drones are expensive, but optical sensors on drones can be useful for generating DEMs in areas with thin vegetation (i.e., following application of thin-layer deposition), such that vertical accuracies are sub-decimeter [14]. However, where tidal marsh vegetation is dense, elevation estimates can be overestimated by 50-60cm [14].

APPENDIX 2. MEASURING SOIL ORGANIC CONTENT

There are multiple ways to measure soil organic content, including using an elemental analyzer to measure Carbon, Hydrogen and Nitrogen content. More commonly, the loss-on-ignition method is used to measure organic content of soils, whereby replicate sediment samples (c. 5-10ml each) are combusted at 450-550C for 4 hours in a muffle furnace [7]. Loss-on-ignition is a cheaper approach to processing samples than elemental analysis.