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The Use of Native Vegetation for Structural Stability in Dredged Material Placement Areas: A Case Study of Beneficial Use Site 4A, Chocolate Bayou, Brazoria County, Texas

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PURPOSE: This technical note is the third in a series about using native plant communities to enhance dredge material placement areas (DMPAs), confined disposal facilities (CDFs), and projects where dredged sediments are used for various engineering purposes. DMPAs and CDFs occur in numerous locations spanning different geographic locations nationwide. Oftentimes, these containment dikes are constructed using earthen materials. The materials are either barged in from an off-site location or obtained on-site from new or virgin materials, consisting of heavy clay particles and sediments removed from the nearby channel. In the Gulf Coast region of the United States, new or virgin materials are obtained during channel deepening activities using mechanical or hydraulic dredging methods. Examples of these dredging methods include hopper dredge, pipeline dredge, and excavator or bucket dredge. When materials are considered suitable for beneficial use purposes, and following environmental compliance, the materials are often used to construct containment dikes in DMPAs and CDFs. The project site used in this study—Beneficial Use Site 4A (BUS 4A)—used dredged material during its construction and has periodically received dredged material to maintain its target elevation of 2 ft (0.67 m) above the mean lower low water; hence, this site presents an opportunity for use as a demonstration study. Project goals include (1) demonstrating the use of native plant communities to provide structural stability, (2) introducing targeted vegetation establishment on DMPAs and CDFs as a management strategy to improve engineering and environmental outcomes, and (3) providing technology transfer to the U.S. Army Corps of Engineers (USACE) districts through hands-on planting techniques and installation of natural material (in this demonstration, coir logs).

BACKGROUND: DMPAs and CDFs provide temporary or permanent containment of material produced during dredging of navigable channels in the United States, including bays, inland rivers, harbors, and berthing areas. Historically, standard engineering practice used rock, steel, cement, and other hardened structures or allowed non-native and invasive plants (for example, *Triadica sebifera*) to stabilize these areas during repairs. Similarly, historical engineering practice to stabilize shorelines has been the use of rock structures such as stone revetments (USACE 2002). Armored shorelines affect the nearshore ecosystem, altering the fish community and their habitat (Munsch et al. 2017). However, recent advancements in the understanding of the properties of plants and their potential use to supplement or replace rock structures has led to green or *soft* structures. These soft structures provide both stabilization properties and ecological value. An ecological study indicated that wetland plants hold soil in place with their roots, absorb the energy of waves, and slow the flow of stream or river currents along the shore (Mitsch and Gosselink 2000). In addition, vegetation provides important engineering functions including restraining and protecting soil, as well as increasing the strength and competence of the soil mass (Coppin and Richards 1990). Another laboratory study showed that both emergent and near-emergent vegetation can attenuate wave energy from simulated coastal storms (Augustin et al. 2009). Furthermore, created *Sporobolus alterniflorus* salt marshes have been proven to provide value to fisheries and nekton despite not reaching the full functionality of a natural marsh (Minello and Webb Jr. 1997). On the basis of this premise, we used native plant communities to vegetate actively eroding sections of the dike, stabilize the soil, and attenuate waves during a demonstration workshop at BUS 4A.

CASE STUDY: The US Army Engineer Research and Development Center (ERDC) conducted a workshop from March 13–16, 2017. The USACE Galveston District (SWG) hosted the Engineering With Nature® (EWN®) workshop, which took place both in the classroom and in the field-based EWN workshop that demonstrated how the application of native plant species can enhance engineering objectives while maximizing environmental benefits. The addition of vegetation resulted in nature-based features that enhanced the structural integrity of dikes associated with BUS 4A. The project site is in Chocolate Bay, along Chocolate Bayou located along FM 2004, on the southwestern side of Santa Fe, Brazoria County, Texas (Figures 1 and 2). Chocolate Bay connects with Galveston Bay and is adjacent to Brazoria National Wildlife Refuge, an internationally significant shorebird site.

In October 2014, SWG was selected as an EWN *Proving Ground*. This status recognized SWG for its pursuit of EWN principles and practices. ERDC and SWG subsequently explored the use of planting native vegetation on DMPAs as part of an EWN approach to managing disposal areas. In March 2016, USACE and the National Oceanographic and Atmospheric Administration (NOAA)–National Ocean Service conducted a collaborative workshop on natural and nature-based features (NNBF). During this workshop, participants identified several NNBF collaborative projects, and they identified the use of native vegetation on DMPAs as a priority for application of EWN principles and practices on a national scale.

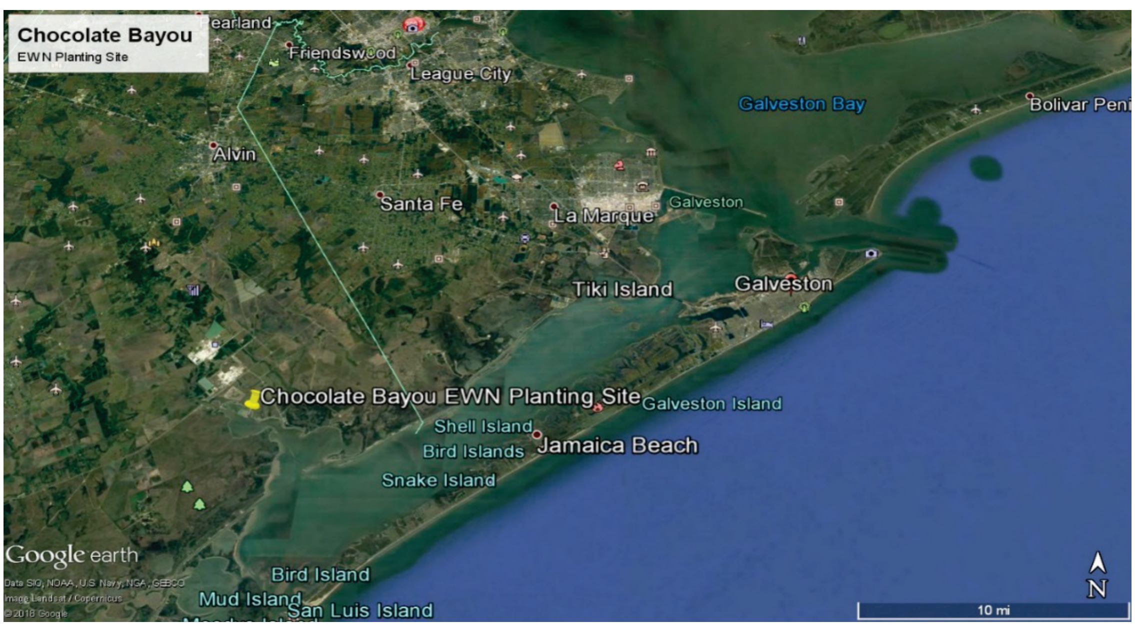

Figure 1. Beneficial Use Site 4A (BUS 4A) adjacent to Chocolate Bayou, near Chocolate Bay located southwest of Galveston, Texas. *Yellow pin* indicates the project site.

Figure 2. Close-up view of BUS 4A, along Chocolate Bayou within Chocolate Bay in Brazoria County, Texas.

The ERDC-SWG EWN workshop included 32 participants from state and federal agencies, academia, and private entities. The workshop offered the interagency group field experience with new planting techniques while also providing additional perspectives and instructions for incorporating EWN principles into coastal projects. This workshop was the first in a series of field-based, EWN workshops facilitated by ERDC to train USACE engineers, scientists, and project managers on new techniques to manage DMPAs using native vegetation. The workshop brought together a diverse group, consisting of engineers, landscape architects, marine biologists, soil scientists, and ecologists, promoting collaboration across multiple disciplines. The EWN demonstration workshop is a platform for technology transfer and should be used by USACE districts to seek ERDC's expertise in real-world application of EWN principles on various projects, whether coastal or inland. During workshop planning and implementation, ERDC identified certain topics relevant to successful EWN projects: vegetative surveys, use of natural materials, ecological considerations, regulatory perspectives, species selection, planting methodology, and monitoring.

Threatened and endangered species considerations included a telephone conference with the US Fish and Wildlife Service (USFWS). The service indicated concerns about the interior least tern (*Sternula antillarum*) nesting population within the project area. The USFWS recommended completing all planting at BUS 4A on or before March 15 to avoid disturbance to the breeding populations. As a result, workshop attendees completed all planting activities before the stipulated date in accordance with USFWS recommendations.

VEGETATIVE SURVEY: A vegetative survey is an inventory of the existing plant species found within a given location, a reconnaissance of the plant communities that make up an ecosystem. Mr. Kevin Philley, research biologist, conducted the vegetative survey of Chocolate Bayou approximately two weeks prior to the workshop (Figure 3). The Chocolate Bayou vegetative survey showed that the dike contained four distinct plant communities: (1) a *Baccharis, Iva*, and *Borrichia* community; (2) a *Batis*, *Suaeda*, *Salicornia*, *Lycium* mix; (3) a *Sporobolus alterniflorus* stand; and (4) a shrub-herbaceous mix.

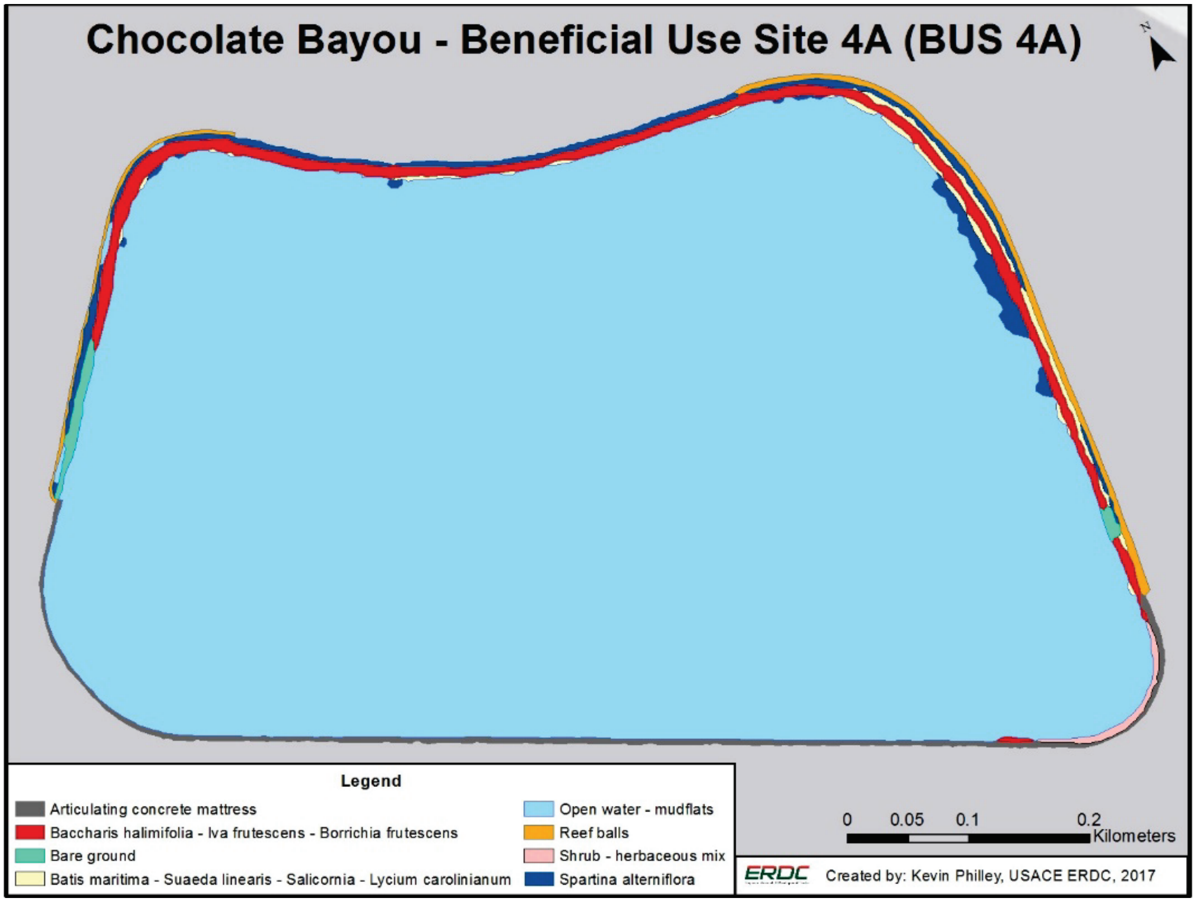

Figure 3. Vegetative survey of BUS 4A showing existing plant communities, reef balls, bare ground, and open water.

USE OF NATURAL MATERIAL: This term means the use of natural materials in lieu of hard structures for erosion control and stability of a confined disposal area. Natural materials included native vegetation, coir logs, and jute or coir mattings. During the workshop, ERDC facilitators used the hands-on application of two 10 ft long, 2 ft diameter coir logs to show proper application of coir log in concert with vegetation for the purpose of securing the top of slope, which was susceptible to erosion (Figure 4). The project area (29.205539, −95.1779789) is a DMPA incorporating a biofriendly marsh toe with reef balls that maintains the water-intertidal continuum. The reef balls on the bay side are encrusted with barnacles, which add weight and help the reef balls adhere together. Bare spots exist behind the reef ball marsh toe where fringing plants are starting to fill in. The soil of the bare intertidal area seems stable and is protected by the marsh toe reef balls, so no further edging is needed. With the marsh toe already in place, the site required additional planting to accelerate the plant establishment process. While reef balls are very effective at dissipating wave energy, they are not very effective at accruing soils. It also appears the *Sporobolus alterniflorus* is spreading into the intertidal zone occupied by the upper layer of reef balls. Removing the upper layer of reef balls and placing a better sediment-accruing material, like coconut fiber logs, behind the remaining reef balls will better manage the BUS 4A site. This action might also aid the spread of *Sporobolus alterniflorus* and allow soil to accrue where the upper reef balls were located, and the removed reef balls could then be used to help stabilize another part of the placement area berm. This technical note recommends implementing this practice.

Figure 4. ERDC staff demonstrates the installation techniques for coir during the Engineering With Nature® (EWN®) workshop.

ECOLOGICAL CONSIDERATIONS: This process involves using ecosystem characterizations such as soil, elevation, slope, plant species, threatened and endangered species, and microclimate, as well as any special aquatic sites (for example, wetlands) and the interactions between these elements to plant the right species and establish the correct plant communities in the right locations. Ecological considerations take into account the right environmental factors that will ensure the establishment of the vegetation.

REGULATORY CONSIDERATIONS: This process includes considering all applicable environmental laws, including the National Environmental Policy Act (NEPA)[1], Clean Water Act[2], Endangered Species Act[3], National Historic Preservation Act[4], and applicable Presidential *executive orders*, which meant evaluating the planting exercise according to the pertinent federal laws and regulations as well as state statutes. The project did not require federal authorizations, because USACE owns this project site, but it did require informal consultation with USFWS because several migratory birds from the Gulf of Mexico use BUS 4A and other offshore and nearshore DMPAs in the Galveston Bay and adjacent ecosystems. Therefore, it was imperative to seek USFWS expertise before embarking on the project. USFWS indicated that interior least tern uses the BUS 4A site for nesting. According to USFWS, the nesting season runs from April 15 to June 15 annually, and disturbance must be avoided according to the Endangered Species Act. Abiding by these dates, we completed planting activity on the dike before April 15, 2017, to avoid disturbance.

The only permit that was required was the aquatic plant introduction permit (AIP) under the Texas Administrative Code Title 31, Part 2, Chapter 57, Subchapter C[5] from the Texas Parks and Wildlife Department, which requires a permit for any plant species that is introduced in the state's waters. This permit was required because *Sporobolus alterniflorus* was planted below the mean lower low water at the project site.

SPECIES SELECTION: We selected species for this site on the basis of their ability to spread quickly and stabilize bare and sparsely vegetated areas of the dike section as well as their habitat value. Species were also selected to tolerate the tidal regime of the site. Species selected for planting were smooth cordgrass (*Sporobolus alterniflorus*), salt meadow cordgrass (*Spartina patens*), seashore paspalum or seashore crown grass (*Paspalum vaginatum*), seashore dropseed (*Sporobolus virginicus*), sea oxeye (*Borrichia fructencens*), wax myrtle (*Morella cerifera*), coral bean (*Erythrina herbacea*), yaupon holly (*Ilex vomitoria*), Carolina desert thorn (*Lycium carolinianum*), and saltgrass (*Distichlis spicata*).

In most EWN and restoration projects, not all species selected are readily available; therefore, selecting a few species that are locally or commercially available is a common practice. For this project, we planted smooth cordgrass (*Sporobolus alterniflorus*), salt meadow cordgrass (*Spartina patens*), seashore paspalum or seashore crown grass (*Paspalum vaginatum*), wax myrtle (*Morella cerifera*), coral bean (*Erythrina herbacea*), yaupon holly (*Ilex vomitoria*), Carolina desert thorn (*Lycium carolinianum*), and salt grass (*Distichlis spicata*) in plugs, sprigs, and potted plants according to their availability. We did not propagate any seeds.

Because of shade tolerance and low tolerance for salinity, seashore paspalum has propagated widely (Lee et al. 2004). Smooth cordgrass and salt meadow cordgrass are adapted to the saltmarshes of the high, low, and brackish marshes in the United States (Blum et al. 1968; Gleason

1. National Environmental Policy Act of 1970, 42 U.S.C. 55 § 4321 et seq. (2010). https://www.govinfo.gov/content/pkg/USCODE-2010-title42/pdf/USCODE-2010-title42-chap55-sec4321.pdf.
2. Federal Water Pollution Control Act of 1948, 33 U.S.C. § 1251 et seq. (2018). https://www.govinfo.gov/content/pkg/USCODE-2018-title33/pdf/USCODE-2018-title33-chap26.pdf.
3. Endangered Species Act of 1973, 16 U.S.C. 35 § 1531 et seq. (2018). https://www.govinfo.gov/content/pkg/USCODE-2018-title16/pdf/USCODE-2018-title16-chap35-sec1533.pdf.
4. National Historic Preservation Act of 1966, 16 U.S.C. § 470 et seq. (2012). https://www.govinfo.gov/content/pkg/USCODE-2012-title16/pdf/USCODE-2012-title16-chap1A-subchapII.pdf.
5. 31 Tex. Admin. Code **§** 57.252 (2005).

and Zieman 1981; Frenkel and Boss 1988). Smooth cordgrass (*Sporobolus alterniflorus*) has developed an adaptation to anoxia as a result of oxygen deficiency in its environment (Mendelson et al. 1981); hence, it is widely encountered in the hypoxic zones of the Gulf Coast. The genus *Juncus* exists in numerous species in the United States on a gradient of salt tolerance. Black needlerush (*Juncus roemerianus*) occurs widely in the brackish marshes, with salinity between 5 and 18 ppt. (Eleuterius 1989; Touchette 2006). Finally, salt grass, (*Distichilis piscata*) is a commonly encountered species in coastal dunes and wetlands.

PLANTING PLAN/METHODOLOGY: We designated the planting area into four distinct zones according to elevation and tidal inundation level (Figure 5). In Zone 1 and Zone 4, the zones that receive the most inundation, we planted with smooth cordgrass (eight plants per quadrat). We planted Zone 2, a transition zone, with the following species: salt meadow cordgrass, wax myrtle, coral bean, yaupon holly, Carolina desert thorn, and salt grass, (eight plants per quadrat of grass species and one plant per quadrat of the shrub species in an alternating fashion). Zone 3 was the top of the slope with the highest elevation and also the zone with the least inundation. We planted this zone with salt meadow cordgrass (eight plants per quadrat) and shrubs such as coral bean, yaupon, *Iva*, *Lycium* and *Morella*.

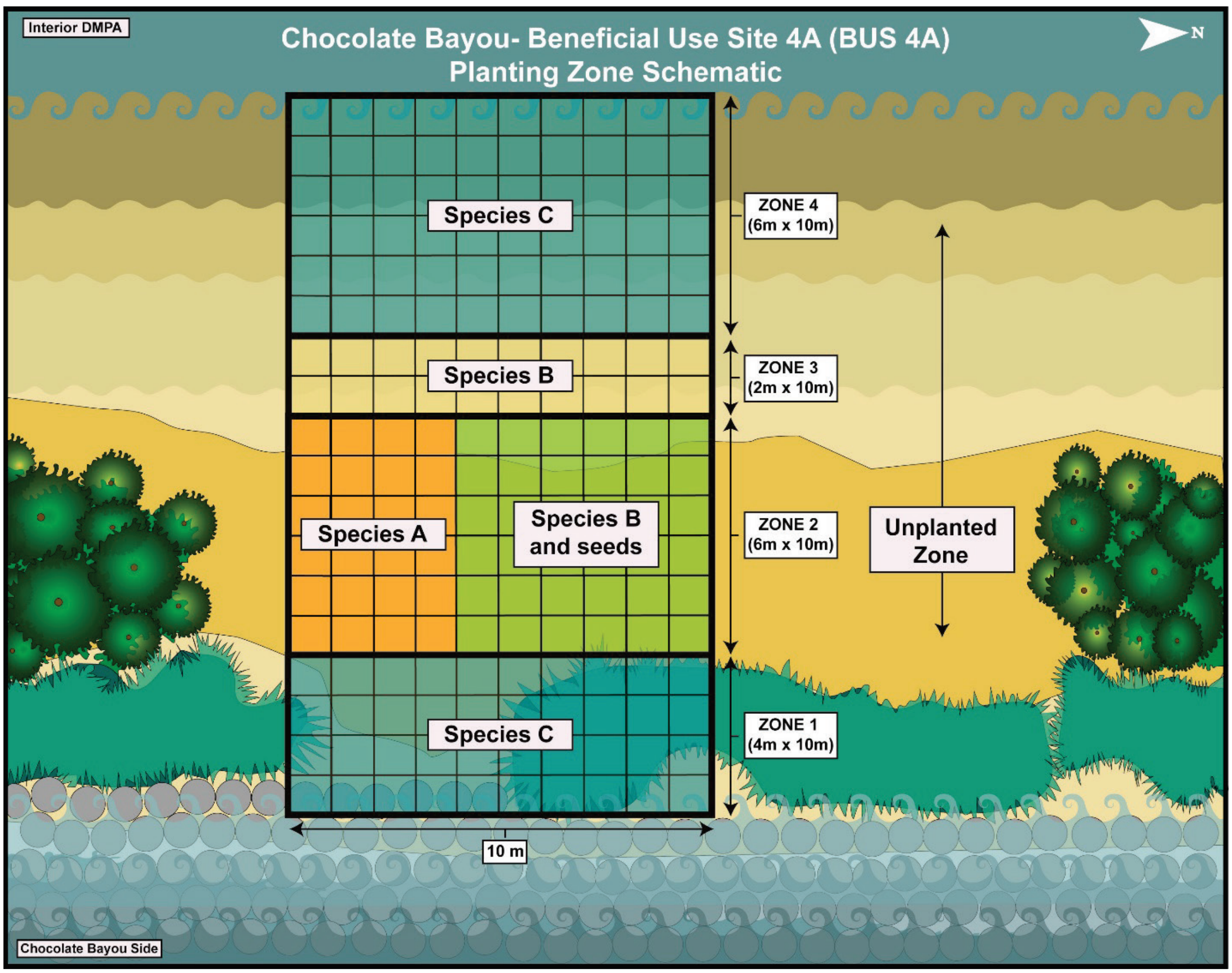

Figure 5. Planting zones for the Chocolate Bayou EWN project.

EWN WORKSHOP: Participants comprised of 32 individuals representing USACE, ERDC, SWG, the NOAA–National Marine Fisheries Service, Texas A&M University at Galveston, the Texas General Land Office, and the private sector: Ecology and Environment and Gahagan and Bryant Associates. The first day consisted of a classroom teaching addressing the key elements of successful vegetation establishment. The topics covered were EWN: potentials and possibilities; vegetative survey; biotechnical planting; and NNBF: coir logs and coconut fiber; ecological and regulatory considerations; and plant selection. This classroom work was followed by a plant-harvesting activity at NRG EcoCenter in Bayown, Texas (Figure 6).

Figure 6. Workshop participants harvested *Sporobolus alterniflorus* and *Spartina patens* at NRG EcoCenter.

The sprigs were stored in containers quarter-filled with water to keep the plants cool and moist and kept in a cool open place overnight. The second day of the workshop was a full day of planting activity. ERDC facilitators introduced each activity, and all participants engaged in the planting and installation activity afterwards (Figure 7).

The conceptual design and planting zonation schematic (Figure 5) was developed prior to the workshop to account for the numbers of plugs and species per quadrat. This planting plan was developed by Mr. Brian Durham of ERDC, who has expertise in landscape architecture and biotechnical planting.

MONITORING: Preliminary monitoring occurred approximately 60 days after planting (Figure 8. Periodic monitoring of Chocolate Bayou will be completed by SWG. Monitoring will include photo documentation of vegetation establishment as well as plant success rate (percent cover), density, and species composition.

Figure 7. Participants planting within 5 m^2 square quadrats at the BUS 4A workshop site.

Figure 8. BUS 4A 60 days after planting the site. (Photo credit: Jantzen Miller.)

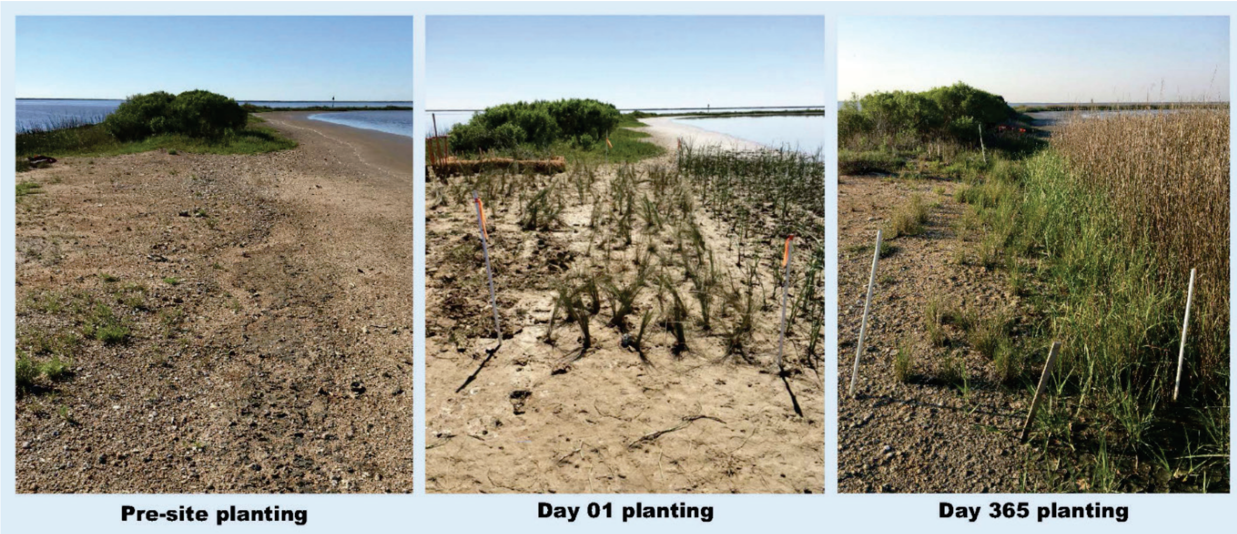

Figure 9. BUS 4A Pre-and post planting photos. (Photo credits: Brian Durham.)

SUMMARY AND LESSONS LEARNED: The planting survival rate for Chocolate Bayou varied depending on the plant species. The most successful plant for potential coverage and expedited growth rate was *Sporobolus alterniflorus.* This grass has stabilized each side of the dike, and we predict it will fill in the area over time because of its aggressive nature. *S. alterniflora* is an excellent toe hold as an emergent plant species, capable of growing at higher elevations on the dyke in pure clay. The major concern with planting *S. alterniflora* is its ability to displace other plant species because of competition. In the East and Gulf coasts, however, this plant species thrives in the coastal and brackish marshes and is considered a desirable native species.

Spartina patens was limited in survival and establishment; this poor survival rate may be due to the dense clay soil on the dike. However, despite the competition with *S. alterniflora*, *S. patens* survived in Zone 3. Records of growth and establishment in the next few years will determine the most suitable species for this site. The heavy dense clay used to construct the dike was not the best medium in which to grow plants. Only a number of the hardiest of plants species can survive in this type of soil environment. *S. patens* was planted above the high tide mark and received very little water through the growing season. In addition, the shrink and swell properties of clay soils may pose additional stress on plant roots. Sandy loam or sandy clay would be better than pure clay soil for *S. patens*'s growth habit according to observation.

Lycium carolinanum is a tough plant capable of tolerating high salinity and dense clay soil. If *S. alterniflora* does not inhibit this plant, then we expect to see substantial growth in future years. *Paspalum distichum* moved beyond its border, suggesting that this plant is highly tolerable of dense clay particles. This habit is a promising one—especially when paired with an aggressive grass species like *S. alterniflora*. Future interspecific interactions and potential competition between *Paspalum*, *Lyceum* and *Spartina* will be monitored and documented in the future.

The majority of the growth in the unplanted areas was due to the encroaching *S. alterniflora* from the neighboring planted zones (1 and 4) and the existing *S. alterniflora* unplanted Zone 1. The unplanted Zones 3 and 4 were not colonized by any plant species. Existing *S. alterniflora* colonized Zone 2 and displaced the existing herbaceous plants after one year. *S. alterniflora* would have been the only growth observed in Zones 1 planted and Zone 1 unplanted if this site had not been planted with other species by the workshop. The extent of spread and colonization of *S. alterniflora* would have been limited across the entire perimeter of the BUS4A site if concerted effort has been made to vegetate the site in past years.

Early indications show that the planted species will continue to establish themselves at BUS 4A. Vegetation at Chocolate Bayou was well established one year after planting and appears to be providing some immediate structural support for the disposal area. Overall, this project helped determine the plant species capable of colonizing a pure clay dike: *Sporobolus alterniflorus, Spartina patens, Paspalum vaginatum, Lycium carolinanum, Salicornia* sp., and *Distichlis spicata*. Elevation and soil type are key factors in selecting the right plant species for the right location. This project has further demonstrated that quick stability is achieved by using the appropriately selected desirable native vegetation.

ADDITIONAL INFORMATION: This technical note was prepared by Dr. Tosin Sekoni, research ecologist; Mark Eberle, biologist; Brian Durham, research biologist; and Dr. Matthew Balazik, research ecologist, US Army Engineer Research and Development Center, and Mark Eberle, biologist, Philadelphia District. The study was conducted as an activity of the Engineering With Nature initiative. For more information, please visit www.EngineeringWithNature.org or contact Dr. Todd Bridges, EWN National Lead, and Dr. Jeff K. King, EWN Deputy National Lead, at Todd.S.Bridges@usace.army.mil and Jeffrey.K.King@usace.army.mil. This technical note should be cited as follows:

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