Capstone Design of Coastal Wetlands

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INTRODUCTION

Natural wetlands are found in many forms throughout the world: as inland salt flats in arid regions; as bogs and tundra in cooler, humid regions; as riparian forests and backwater swamps along rivers and streams. In coastal environs, tidal salt and freshwater marshes and mangrove swamps (mangals) are typical[1].

Although not easily defined, wetlands are often identified as transitional lands between uplands and aquatic systems where the water table is usually at or near the surface or where the land is typically covered by shallow water[1]. Among their distinguishing characteristics is a predominance of hydric soils that are frequently inundated or saturated. Naturally, the prevalent vegetation is hydrophytic, i.e., capable of growing in wet soils. Because wetlands often possess characteristics of both terrestrial and aquatic environments, they offer unique habitats for a variety of wildlife and, biologically, are extremely productive.

Besides habitat provision, wetlands are known to improve water quality, reduce (the potential for) flooding, and control erosion. Their vibrant productivity provides for several commercial harvests including fish, shellfish, timbers and tannin, and offers many recreational opportunities such as birdwatching, fishing, and hunting. For better or worse, natural wetlands have also been used for wastewater discharge. Even so, drainage and filling of wetlands, principally for agricultural use, were common practices[2]. Fortunately, increased public awareness of wetland functions and values led to the "no net loss of wetlands" policies of the Bush and Clinton Administrations. Today, engineers will find it useful and often necessary to include wetlands restoration and conservation among project objectives.

Accordingly, instruction in wetlands function awareness and design procedures has been introduced in the ocean engineering curriculum at the U.S. Naval Academy. Also, capstone design projects have been initiated which include wetlands restoration or creation as a desired design objective. This paper provides a brief overview of wetlands design principles and reviews the specific tasking of three recent capstone projects. Coupled with its complementary reference[3], the paper provides others a convenient means to initiate instruction in this relatively-new coastal design methodology.

PRINCIPLES OF WETLANDS DESIGN

Technical guidelines and procedures concerning various aspects of wetlands design and construction have been published by government agencies and others. Among the more useful for student activities is a design task sequence developed by Palermo[4] at the U.S. Army Engineer

Waterways Experiment Station (WES). In flowchart form, design activities for wetlands restoration projects are identified and their sequence is illustrated. Initial priorities include a thorough understanding of wetlands significance (function and value) as it relates to the proposed project and baseline surveys addressing site hydrologic, vegetative, soil and topographic characteristics. Subsequently, determination of cut and fill requirements, the need for water and erosion control structures, and techniques for vegetation establishment will have a significant influence on the economic and functional success of the project. The WES flowchart is reproduced in the complementary reference[3]. Of special note, under its Wetlands Research Program, WES is pursuing development of a Wetlands Engineering Handbook, similar in form and purpose to its highly-successful Shore Protection Manual[5].

General guidelines for wetland restoration and creation have been proposed by Mitsch and others, and were summarized (in part) as follows[1]:

· Design the wetland for minimum maintenance, i.e., the system of plants, animals, substrate and water flows should be self-sufficient and self-maintaining.

· Design the wetland to use natural energies, e.g., the potential energy of nearby streams.

· Design the wetland to fulfill multiple goals. Whereas the principal objective might be erosion control, secondary objectives might include flood control, or habitat replacement.

· Design the wetland as an ecotone, i.e., a true transition zone between the upland and the aquatic systems that it protects.

· Design the system for function, not form. Be satisfied if the system is functional (meets objectives), though the initial design form may not have survived.

· Consider also . . .
... the landscape: best sites are where wetlands previously existed or currently exist nearby.
... the climate and hydraulic conditions: without water during (part of) the growing season, a wetland is not possible.
... the chemical composition of feed waters: these can limit or enhance wetland productivity.
... the substrata: highly permeable or rocky soils do not support wetland vegetation.
... surrounding lands and future land-use changes: e.g., future agricultural use may prevent or dictate wetland applications.

· Do not over-engineer. Avoid unnatural forms of basins, structures and channels; where possible, mimic natural systems in both form and topography.

· Give the system time. Adequate plant establishment, nutrient removal and wildlife enhancement may require several years.

Other references[6,7] offer both qualitative and quantitative approaches including systematic equations and parameters useful in dimensioning and shaping constructed wetlands.

LOCAL GUIDELINES

Along Maryland's Chesapeake Bay shoreline, both structural and nonstructural techniques have been applied for shore erosion control. Structural measures that have proven successful include bulkheads, revetments and groins. More recently, the State has favored nonstructural techniques such as beach nourishment and tidal marsh creation that provide for better conservation of fish and plant habitat. The Maryland Department of Natural Resources (MDNR) has set forth basic procedures for preparing and planting a tidal marsh site[8]. The recommended vegetation has the potential of trapping sediment from eroding banks and sand moving along the shoreline. A dense buffer of natural vegetation may also be sufficient to stabilize eroding bluffs. Through its Non-Structural Shore Erosion Control Program, MDNR has provided (up to) 50% matching funds to waterfront property owners who use nonstructural techniques to solve their shore erosion problems.

CAPSTONE DESIGN PROJECTS

Among the recent design projects accomplished by student teams in the ocean engineering major are the construction of a saltwater marsh; the restoration of a natural sand spit/island complex, and the protection and environmental enhancement of an eroding shoreline. A brief description of each project follows; a more thorough description including project details and design results can be found in the complementary reference[3].

· *Saltwater Marsh Wetland Creation.* This design project arose from an agreement between the Department of Defense, the Environmental Protection Agency and several states to reduce pollution in the Chesapeake Bay. One part of this agreement required the Navy to identify, control and reduce its nonpoint source pollution discharges into the Bay and its tributaries. The Navy, in turn, chose to create an artificial saltwater marsh wetland to investigate its effectiveness in treatment of stormwater runoff [9]. The site for this treatment wetland was at the Naval Amphibious Base Little Creek, VA.

Four student design teams were provided actual hydraulic data and water-quality characteristics of the stormwater runoff, and the extent and topography of the land area available for use. Desired removal efficiencies of certain pollutants (BOD, TSS, nitrogen and phosphorous) were stipulated and cost data for various site grading and planting activities was also provided. The design task was to decide the appropriate number, size, shape and location of each wetland subarea; to specify and quantify the wetland vegetation; to define and detail required water control structures; to map the final design topography; and, to estimate total project costs.

· *Sand Spit Restoration and Stabilization.* Natural erosion processes have significantly impacted the size and aerial extent of Rooster Island, a natural sand spit extending into the lower Choptank River near Cambridge, MD. This alteration affects the island's ability to shelter points further upstream including Hambrooks Bay, a fishery habitat and local recreation area; the Port of Cambridge; and, the public waterfront and coastline of the Town of Cambridge. MDNR sought an engineering solution to this loss of shelter.

Here, student design teams were required to research the island's erosion history and its impact on the local area. While conducting this research, appropriate hydrologic, geologic, environmental and cost data was to be gathered. The specific design task was to restore Rooster Island to a condition mutually compatible with local and state objectives, and to provide protection or sacrificial fill to reduce near-term (25-yr) affects of erosion processes. Although both structural and nonstructural techniques were considered acceptable, each design was to include provisions for a minimum 0.35 acres of intertidal wetlands to enhance wildlife habitats. The required design effort included preparation of design drawings and specifications, an estimate of total project costs including annual maintenance expenditures, and a cost-benefit assessment (including intangibles) of the recommended design.

· *Shoreline Enhancement and Stabilization.* Arundel Estates is a family housing unit of the Severn River (MD) Naval Complex. At least 80 families are housed in the multi-family dwellings that border a 1200'-long bank of the Severn River and a 600' bank of Shady Lake. Except for a 300'-length of the Severn bank protected by rubble stone, erosion of both shorelines is evident and continues unabated. Given its proximity to the new Naval Academy Bridge, the site is highly visible and supports limited recreational activities including fishing and boating. Provision of shoreline improvements was an excellent opportunity for the Naval Academy to contribute to the environmental restoration of the Chesapeake Bay watershed.

Accordingly, the design teams were tasked to develop plans for the restoration, protection and environmental enhancement of the Arundel Estate shorelines. Creation of an intertidal wetland and a recreational beach was to be given strong consideration. As with the previous capstone project, students were expected to investigate the erosion processes; gather appropriate hydrologic, geologic, environmental, and cost data; and, evaluate alternative protective measures. Design submittals included design drawings and specifications, an estimate of total project costs, and a cost-benefit assessment.

As suggested by the project descriptions, the tasking for each capstone project developed from and incorporated real world requirements. In each case, the design effort culminated in formal oral and written presentations to state and local officials associated with the project and a Review Board consisting of ocean engineering professionals who volunteered to participate in the design evaluations.

CONCLUSION

Among the rewards of teaching engineering is the opportunity to develop student creativity by introducing new technologies in challenging applications. Whereas ocean engineering students have long been exposed to coastal engineering design methods for breakwaters, seawalls, and the beach-fill alternative, only recently has a formal design methodology become available for tidal salt and freshwater marshes and other wetland forms. Basic design guidelines for wetland restoration and creation are appearing in the literature with ever-increasing frequency. A recent conference[10] dedicated to wetland engineering (and river restoration) is further evidence of the importance of this methodology and the ecosystems that it supports.

The ocean engineering capstone design project is opportune for increasing student awareness of the values, design and construction methods for restoring and creating wetlands. Given the ever-increasing public awareness of wetlands functions and values, familiarity - if not proficiency - with the design methodology will serve our students well. Only then can they properly evaluate wetland restoration and creation measures with respect to the more conventional techniques for achieving cost-effective and environmentally-sound shoreline enhancements.

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