POPLAR ISLAND ENVIRONMENTAL RESTORATION PROJECT: ADAPTIVE MANAGEMENT PROCESS FOR ASSESSMENT OF WETLAND CELL DEVELOPMENT AND HABITAT RESTORATION SUCCESS

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ABSTRACT

The Poplar Island Environmental Restoration Project (PIERP) is using clean dredged material from the Chesapeake Bay approach channels to the Port of Baltimore to restore approximately 460 hectares (1,140 acres) of remote island habitat in the Chesapeake Bay, Maryland. Equal areas of tidal marsh and uplands will be created from 32 million cubic meters (42 million cubic yards) of dredged material placed at the island. Inflow of dredged material began in 2001 and is expected to continue for 15-20 years. The Poplar Island Adaptive Management Plan (AMP) provides the framework for managing the habitat restoration goal of the PIERP. The Plan establishes a hierarchy of goals, objective, attributes, criteria, and monitoring plans for the project. Each criterion is expressed as a target with acceptable bounds, recognizing the inherent uncertainty of ecological restoration. For every criterion there is a monitoring plan to collect the data necessary to measure progress toward meeting that criterion. The Adaptive Management Team annually reviews progress toward meeting project criteria and uses the experience gained each year to revise project design and operations or to modify the objectives, attributes, or criteria if they have proved to be unrealistic. An 11-hectare (27-acre) demonstration wetland cell with sand substrate was completed on the island in 2003. Through the adaptive management process, the lessons learned from the demonstration cell were applied to the design and construction of the first full-size, 13-hectare (32-acre) wetland cell, which was constructed with dredged material and completed in 2005. The lessons learned from that cell are being applied to the next two wetland cells, which are scheduled for construction and planting in 2007-2008.

Keywords: Marsh restoration, dredged material management, beneficial uses, adaptive management plan, tern habitat

INTRODUCTION

Poplar Island is located in the upper middle Chesapeake Bay, approximately 63 kilometers (39 miles) southeast of the Port of Baltimore, Maryland (Figure 1). From a size probably exceeding 450 hectares (1,100 acres) in the 1800s, the original natural island eroded down to four separate islands together totaling only 2 hectares (5 acres) in the mid-1990s.

The Poplar Island Environmental Restoration Project (PIERP) will restore Poplar Island to its approximate size in 1847 using clean dredged material from the Chesapeake Bay approach channels to the Port of Baltimore. The plan

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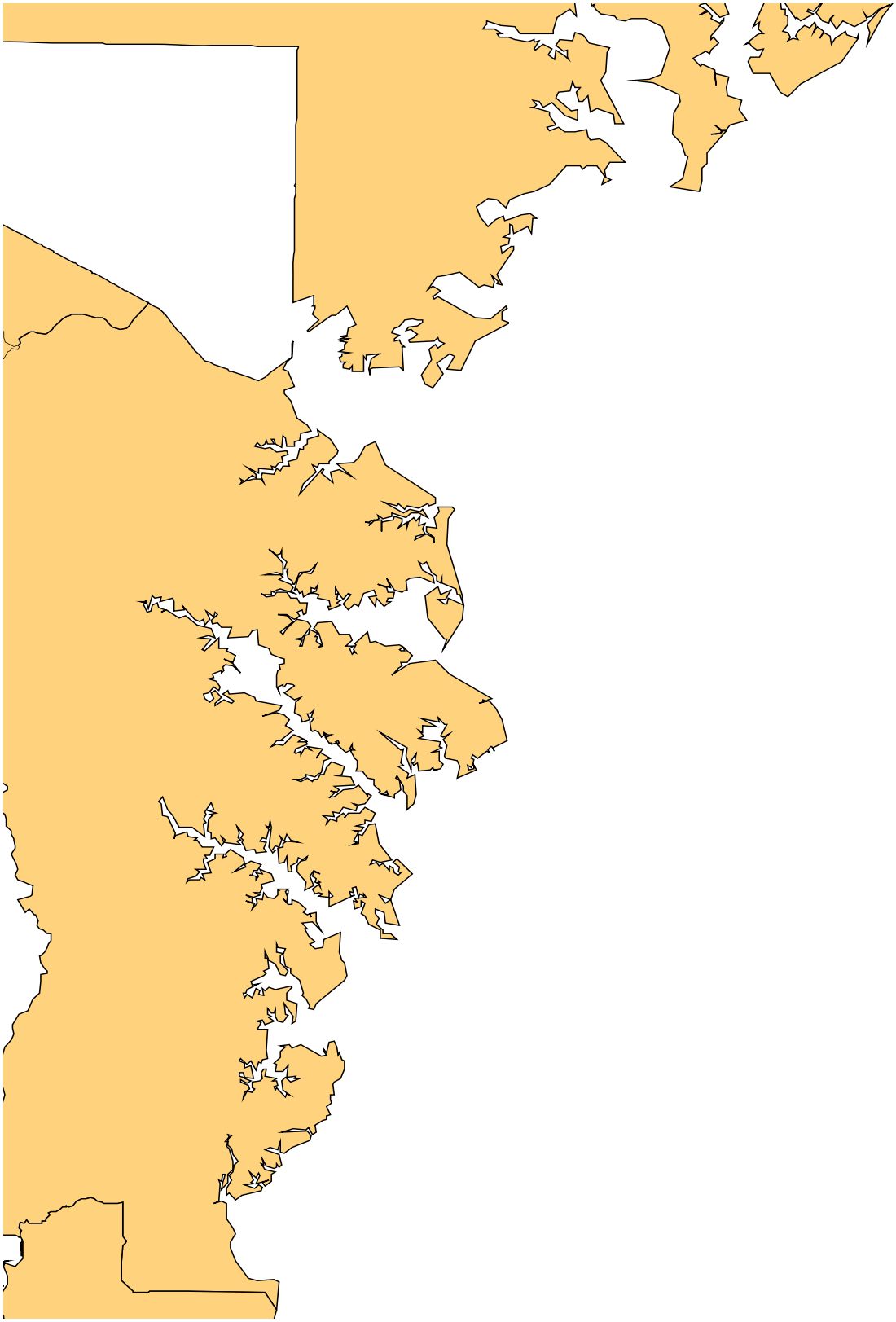

Figure 1. Location map.

for rebuilding of the island was developed through the cooperative efforts of many federal and state agencies, as well as private organizations. The Baltimore District of the U.S. Army Corps of Engineers (Corps) and the Maryland Port Administration (MPA) prepared a Feasibility Report and Environmental Impact Statement, dated February 1996, which the Assistant Secretary of the Army (Civil Works) approved in September 1996.

The restoration of the island involves placing approximately 32 million cubic meters (42 million cubic yards) of dredged material behind 12,000 meters (40,000 feet) of containment dikes to create a 460-hectare (1,140-acre) island with equal portions of tidal marsh and upland habitat (Figure 2). Of the 230 hectares (570 acres) of tidal marsh, 80 percent will be developed as low marsh and 20 percent as high marsh. Small islands, ponds, mudflats, and dendritic guts or channels will be created within the marsh areas to increase habitat diversity. In the 230 hectares (570 acres) of upland, habitat diversity will be increased by constructing small ponds and freshwater wetlands within forest, scrub/shrub, and meadow areas.

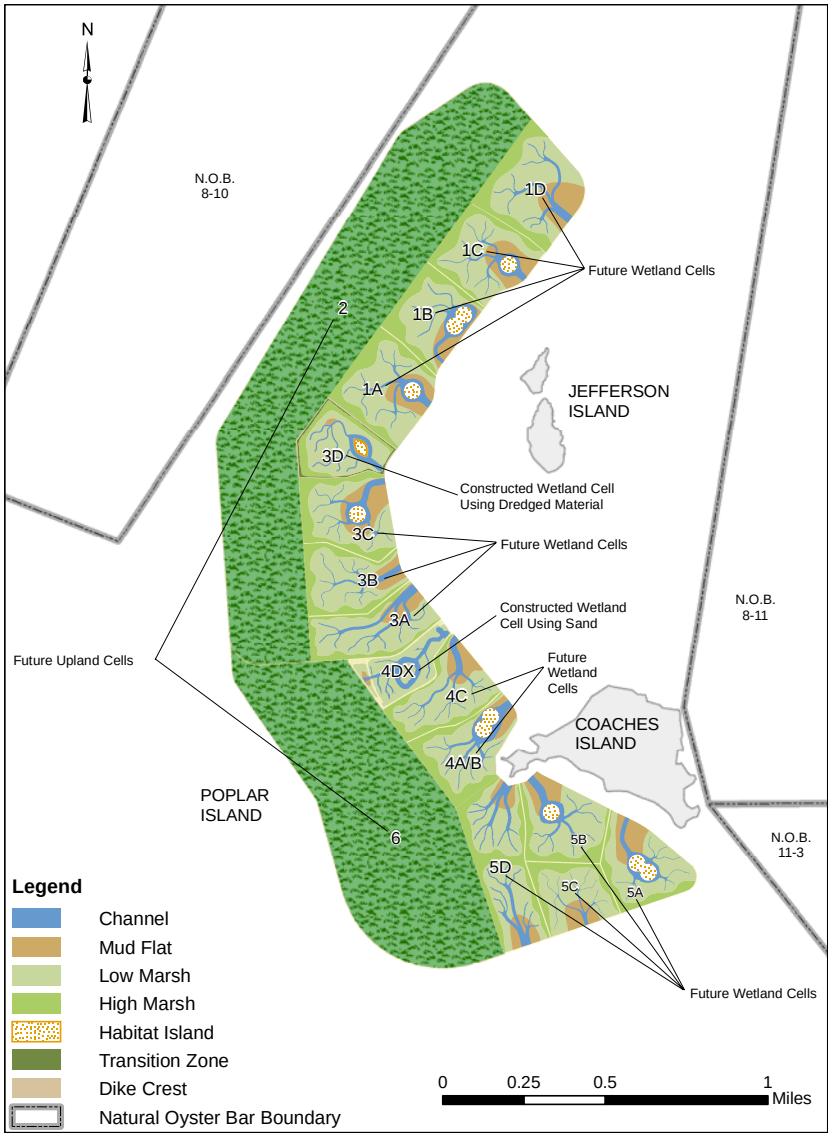

Figure 2. Site plan.

The original containment dikes were completed in February 2002, except for a 300-meter (1,000-foot) gap left in Cell 6 for access to the interior of the island to offload dredged material. Placement of dredged material at Poplar Island began in April 2001 and will continue annually in fall through early spring over the 15-20-year life of the

project. Through the 2006-2007 inflow season, an estimated 12 million cubic meters (16 million cubic yards) of dredged material—38 percent of the island's capacity—has been placed at Poplar Island (Figure 3).

Figure 3. Aerial view (September 2006).

The first habitat development, with wetland and upland components, occurred in a small, 0.8-hectare (2-acre) test cell (4D) in April 2002. In 2002-2003, a larger wetland demonstration cell (4DX) was constructed with sand substrate and a direct tidal connection to Poplar Harbor to test channel hydrodynamics and marsh planting techniques. Cell 4D was connected hydraulically to Cell 4DX, creating a marsh with a combined size of 11 hectares (27 acres). The first full wetland cell constructed of dredged material, 13-hectare (32-acre) Cell 3D, was planted in 2005 and 2006. The wetland cells are connected directly to Poplar Harbor through pipes that pass through the dikes. The pipes will be removed and the dikes will be breached once the wetlands have sufficiently developed and stabilized. Two more wetland cells (1A, 1B; 15 hectares (38 acres) each) are currently in design, with final cell contouring scheduled for 2007 and planting scheduled for 2008. The first upland cell is scheduled for planting in 2012. Specific design criteria for upland restoration have yet to be developed, but the uplands are planned to be 50 percent forest, 20 percent shrub/scrub, 20 percent meadow, and 10 percent freshwater ponds and wetlands.

ADAPTIVE MANAGEMENT TEAM

The management structure for PIERP is illustrated in Figure 4. Responsibility for overall management of PIERP resides in the Ecosystem Restoration Project Coordination Team, which is co-chaired by the project partners: the Corps, representing the Federal Government, and the MPA, representing the State of Maryland. Supporting that team are three primary teams responsible for management of project tasks: Site Development Team, Site Operations Team, and Adaptive Management Team. The Adaptive Management Team is responsible for developing and implementing management plans and guidance documents related to the habitat restoration and environmental monitoring components of the project, including the Adaptive Management Plan. The Adaptive Management Team is co-chaired by the Corps and MPA and includes representatives from those two agencies, the Maryland Environmental Service (MES), and contractors. To benefit from the advice and support of outside technical and regulatory experts, the Adaptive Management Team is advised by the PIERP Working Group, which includes representatives of other federal, state, and local agencies and other interested parties. Federal and state project managers coordinate the PIERP Adaptive Management Plan with the federal and state dredged material management programs, including the interagency Bay Enhancement Working Group.

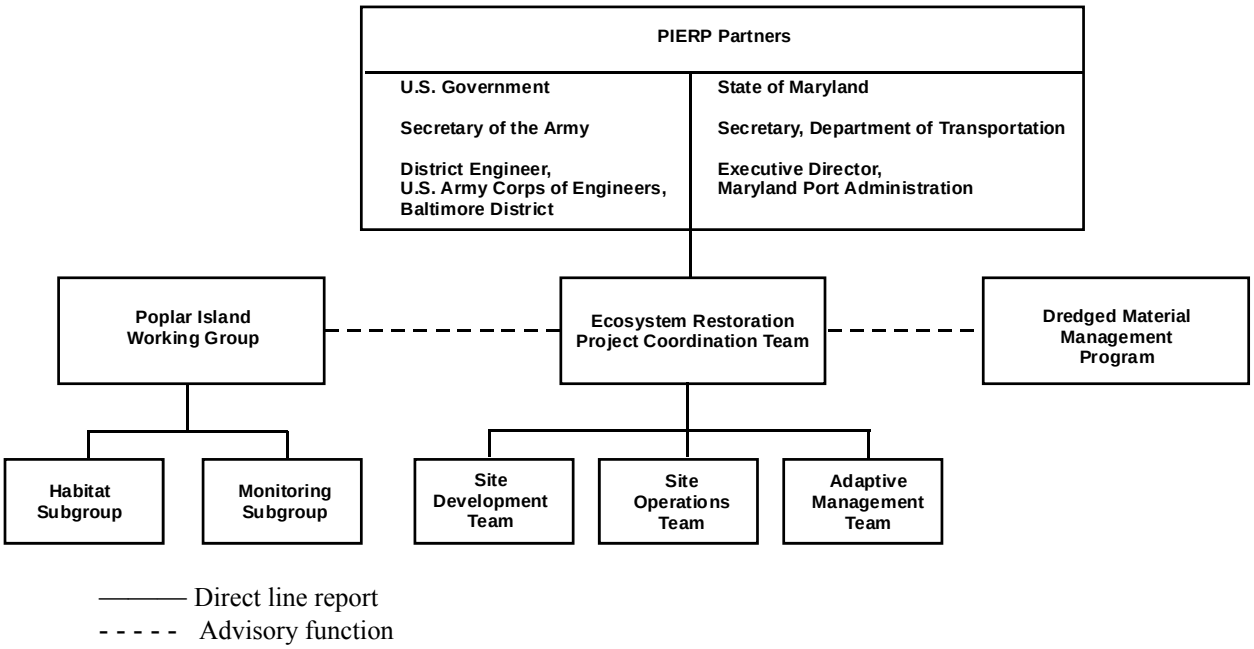

Figure 4. PIERP management structure.

The Site Development and Site Operations Teams meet more frequently than the Adaptive Management Team and are, therefore, better able to adaptively manage individual cell designs and daily site operations. Members of the Adaptive Management Team sit on both of the Site Teams, which ensures that project changes are made within the guidelines of the long-term management strategy developed in the Adaptive Management Plan and that potential long-term management issues are raised to the Adaptive Management Team for consideration during annual updates. Quick feed-back loops are also built into the project through quarterly meetings with the Working Group or Habitat Subgroup, monthly status updates to stakeholders, and extensive electronic discussion among team members on specific issues as they arise.

STRUCTURE OF THE ADAPTIVE MANAGEMENT PLAN

The goals of the Poplar Island Environmental Restoration Plan, as stated in the Project Management Plan, are to

- Restore remote island habitat in mid-Chesapeake Bay using clean dredged material from the Chesapeake Bay approach channels to the Port of Baltimore

- Optimize site capacity for clean dredged material while meeting the environmental restoration purpose of the project
- Protect the environment around the restoration site

To manage the habitat restoration goal, the Adaptive Management Team developed "The Poplar Island Adaptive Management Plan" in 2004. The Adaptive Management Plan provides a tiered approach relating the habitat restoration goal to specific criteria for assessing progress toward attaining that goal. The hierarchy of elements in the Adaptive Management Plan is shown in Table 1.

Table 1. Hierarchy of elements in the PIERP adaptive management plan.

• Goal	Primary project goal
• Subgoal	Secondary goal in support of primary goal
• Objective	Action task to be implemented (e.g., create, improve, achieve)
• Attribute	Specific, measurable aspect of the objective (e.g., size, concentration, species composition)
• Criterion: • Target • Acceptable boundary around the target	Measurable endpoint for each attribute, expressed as: Most probable outcome Acceptable range around that outcome, recognizing environmental variability and the inherent uncertainty of ecological restoration projects
• Monitoring plan: • Approach/methods • Schedule	Plan for measuring progress toward achieving the objective, including: Specific approach to measuring each attribute Frequency for conducting the measurements

The habitat restoration goal for Poplar Island is to create approximately 460 hectares (1,140 acres) of remote island habitat, half uplands and half tidal marsh. The upland areas will contain forest, shrub/scrub, meadow, and wetland/pond habitats, and the marshes will contain low marsh (*Spartina alterniflora*), high marsh (*S. patens*), pond, and mudflat habitats, as well as tidal channels, hummocks, and waterbird nesting islands.

The restoration goal is supported by seven subgoals:

1. Create island nesting habitat for ground-nesting colonial waterbirds (e.g., terns)
2. Create island nesting habitat for colonial wading birds (e.g., herons, egrets)
3. Create tidal marsh habitat
4. Create upland habitat
5. Create a diversity of microhabitats
6. Create quiescent conditions in Poplar Harbor for SAV recovery
7. Minimize and offset loss of benthic habitat

Six of these subgoals are restoration objectives developed by the Corps, MPA, and state and federal resource agencies for the 1996 Feasibility Report/Environmental Impact Statement. A seventh subgoal to address upland habitat was added by the Adaptive Management Team.

EXAMPLE SUBGOALS IN THE ADAPTIVE MANAGEMENT PLAN

Each subgoal is broken down into the adaptive management elements listed above—objectives, attributes, and criteria (targets and acceptable bounds). Examples of the Adaptive Management Plan structure for subgoals 1 and 3 are shown in Tables 2 and 3. In 2005-2006, the Adaptive Management Team reviewed the monitoring data collected in 2004 and 2005 and assessed progress toward meeting the attributes and criteria in the Plan. The Adaptive Management Plan was revised in 2006 to include the annual assessment (see last column in Tables 2 and 3) and to add, delete, or modify objectives and criteria based on the experience gained to date.

Wetland Cell Development

An 11-hectare (27-acre) demonstration wetland (Cell 4DX) with sand substrate was competed on the island in 2003 (Figure 5). Through the adaptive management process, the lessons learned from the demonstration cell about channel construction, hydrodynamics, and planting techniques were applied to the design and construction of the first full size, 13-hectare (32-acre) wetland cell, which was constructed with dredged material and completed in 2006. The lessons learned from constructing that cell, in turn, are being applied to the design of the next two wetland cells, programmed for final construction and planting in 2008. The restoration objectives for the marshes are covered under subgoal #3 of the Adaptive Management Plan: Create tidal marsh habitat. The subgoal has six objectives, two for the creation of physical habitat (create low marsh habitat; create high marsh habitat) and the other four for achieving use of the habitat by fauna (birds, fish, invertebrates, herpetofauna).

Table 2 shows the three attributes and criteria for the objective of creating low marsh habitat: total marsh size, species composition of marsh vegetation, and percent coverage by marsh vegetation. The expected size of the low marsh on Poplar Island—185 hectares (456 acres)—is based on the original goal established in the 1996 Environmental Impact Statement of having 50 percent of the island as marsh and 80 percent of the marsh as low marsh. The acceptable bounds around the target criterion are relatively tight (± 5 percent) because the final size is prescribed by the wetland permit and the water quality certification for the project.

The low marsh areas are being planted with essentially 100 percent *Spartina alterniflora*. Recognizing that other species will appear over time through natural transport mechanisms, the target for *S. alterniflora* in the "mature" low marsh is 80-100 percent of total floral composition. The acceptable bounds, however, are very wide—20-100 percent—based on surveys of reference mainland marshes in mid-Bay, where *S. alterniflora* constitutes 20-80 percent of the marsh. The target for *S. alterniflora* is set high because of the ecological value of this species and the ability to manage the Island marshes more than unmanaged mainland marshes, but the bounds are set much wider to reflect reference marsh composition so that the Project would still be considered a success if species composition is

Figure 5. Cell 4DX in second summer after planting.

Table 2. Excerpts from Adaptive Management Plan for sub-goal 3: Create tidal marsh habitat.

No.	Objective	Attribute	Criterion		Monitoring Plan		Annual Assessment	
			Target	Acceptable Bounds	Approach	Schedule	Data Year	Summary
3-1	Create low marsh habitat	Size	185 ha (456 ac)	175-195 ha (430-480 ac)	Engineering survey OR Infrared aerial photography	Each new wetland cell OR TBD	2005	**In progress** (10 percent complete)—marsh habitat has not been fully developed. Marsh cell 3D planted summer 2005 and 2006 with low marsh = 10.2 ha (25.1 ac) = 78 % of cell. Total low marsh (3D, 4DX) = 18.8 ha (46.5 ac) = 78 % of total developed marsh cells. Note: Total size of marsh cells (1, 3, 4, 5) in final design is 228 ha (564 ac); 80 % of that is 182 ha (451 ac).
							2003	**In progress** (5 percent complete)--marsh habitat has not been fully developed. Marsh cell 4DX planted summer 2003 with low marsh = 8.7 ha (21.4 ac) = 79 % of cell. Note: Total size of marsh cells (1, 3, 4, 5) in final design is 228 ha (564 ac); 80 % of that is 182 ha (451 ac).
3-2		Flora--species comp. --*S. alterniflora* --Other ref. spp. --Nuisance	 ≥ 80 % ≤ 20 % 0 %	 ≥ 20 % ≤ 80 % ≤ 10 %	"Wetland Vegetation Monitoring"	Annually through 2013	2004	**Not applicable yet**--marsh habitat has not fully developed (i.e., at least 3 years) in any cell. (Cell 4DX low marsh = 100 % *S. alterniflora* after 1 year of growth (Guy and Miller 2005).)
							2003	**Not applicable yet**--marsh habitat has not fully developed in any cell. (First marsh cell 4DX planted summer 2003.)
3-3		Flora--% coverage by wetland flora (not including mud flats, channels, islands, ponds)	≥ 90 %	≥ 85 %	"Wetland Vegetation Monitoring"	Annually through 2013	2004	**Not applicable yet**--marsh habitat has not fully developed (i.e., at least 3 years) in any cell. (Cell 4DX low marsh = 89 % coverage in sample plots after 1 year of growth (Guy and Miller 2005).)
					Infrared aerial photography	TBD	2003	**Not applicable yet**--marsh habitat has not fully developed in any cell. (First marsh cell 4DX planted summer 2003.)
Objective "Create high marsh habitat" has Attributes 3-4 to 3-6 that are similar to attributes 3-1 to 3-3.								
3-9	Achieve use of marshes by fish	Use of marshes by resident/forage fish and commercial/ predatory/higher-trophic-level fish	Presence		"Wetlands Use by Fish Monitoring"	Annually through 2009; 2011-12 2014-15	2004	**Not applicable yet**--marsh habitat has not been fully developed. (After 1 year, 4DX had established populations of mummichog, striped killifish, and sheepshead minnow, but low populations of predator fish.)
Similar objectives for use of marshes by birds, invertebrates, and herpetofauna								

similar to that of the reference marshes. The marshes on Poplar Island have not been in existence long enough to see how reasonable the relatively high target for species composition will be over time.

As shown in the last column of Table 2, many of the low-marsh attributes are not applicable yet because only 10 percent of the marsh acreage has been planted and none of it is over 3 years old. Full application of the criteria for the marshes will not occur until all the marsh cells are completed and allowed to mature for 10-20 years.

Bird-Nesting Habitat

When Poplar Island was constructed in 2001, ten 0.4-hectare (1-acre) islands were constructed in the cells designated for future development as wetlands. Five of these islands were covered with shell and are being managed for nesting by colonial waterbirds, primarily common and least terns. None of these tern-nesting islands, however, lies within a completed wetland cell; they all lie in cells still being filled with dredged material. The restoration objectives for these islands are covered under subgoal 1 of the Adaptive Management Plan: Create island nesting habitat for ground-nesting colonial waterbirds. As with the marshes, the objectives for nesting islands relate to constructing the physical habitat (create island nesting habitat) and achieving use of the islands by target species (common terns, least terns, and skimmers) (Figure 6).

Table 3 shows some of the attributes for this subgoal. Several of the attributes and targets—island dimensions and vegetation coverage—are based on the U.S. Fish and Wildlife Service habitat suitability index model for least terns. Attributes for width and depth of a moat around each island (not shown in the table) were added for protection from predators. Vegetation control on the nesting islands has been necessary to prevent the islands from becoming so weedy that adult terns would not nest there. Vegetation control is expensive and time-consuming, however, and studies are underway to determine if the nesting islands could be built with barriers to vegetation growth and still support tern nesting. Preliminary results from the first year of study indicate that terns avoided nesting on portions of the test island with complete vegetation control and suggest that the target of 10 percent vegetation in the Adaptive Management Plan may be valid.

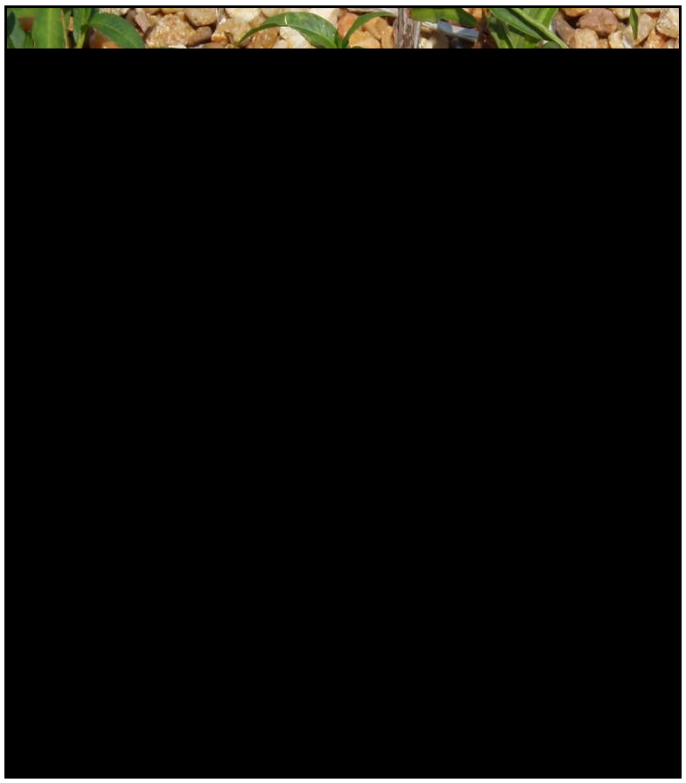

Figure 6. Tern nest with eggs on Poplar Island (MES 2006).

Table 3. Excerpts from Adaptive Management Plan for sub-goal 1: Create island nesting habitat for ground-nesting colonial waterbirds.

			Criterion		Monitoring Plan		Annual Assessment	
No.	**Objective**	**Attribute**	**Target**	**Acceptable Bounds**	**Approach**	**Schedule**	**Data Year**	**Summary**
1-1	Create island nesting habitat for ground-nesting colonial waterbirds	Size—total area above high tide line	3.2 ha (8 ac)	2.4-4.8 ha (6-12 ac)	Engineering survey	Each new island	2001	**In progress** (55 percent complete)--islands have not been fully developed; 5 islands are managed for terns; total area = 1.8 ha (4.4 ac)
1-2		Size—area of each island above high tide line	Rev. 2006: 1.2 ha (3 ac) Original: < 0.8 ha (2 ac)	Rev. 2006: 0.8-2.0 ha (2-5 ac) Original: < 0.8 ha (2 ac)	Engineering survey	Each new island	2005	Original **target met** for 5 islands constructed in 2001; typ. size = 0.36 ha (0.90 ac). Revised target (1.2 ha (3 ac)) not applicable yet--no islands constructed since criterion was changed.
1-3		Size—diameter of each island above high tide	≥ 15 m (50 ft)	≥ 10 m (30 ft)	Engineering survey	Each new island	2001	**Target met** for 5 islands managed for terns; diameters = 70-79 m (230-260 ft).
1-8		Vegetation—% cover	10 %	5 – 20 %	"Photo Documenta-tion" and "Vegetation Monitoring"	Annually, April-Oct.	2005	**Criterion met** (within bounds) for 2 islands (5-25 %). **Criterion not met** for 2 islands (2-4; 40 %). No data for other island. Common terns preferred nesting where there was vegetation (10-35 % coverage). (MES 2006)
1-10	Achieve use of islands as nesting sites by ground-nesting colonial waterbirds	Nesting by terns and skimmers	Presence of nesting birds		"Wetlands Use by Wildlife Monitoring" and "Bird Utilization Monitoring"	Annually	2005	**Target met.** Est. no. of nesting pairs: 477 Common Terns, 12 Least Terns (Erwin 2006).
							2004	**Target met.** Est. no. of nesting pairs: 809 Common Terns, 50-60 Least Terns (Erwin 2004).
							2003	**Target met.** Est. no. of nesting pairs: 827 Common Terns, 62 Least Terns (Erwin 2003).
1-11		Successful fledging by terns (added in 2006)	≥ 1.0 young per nest	≥ 0.5 young per nest	"Wetlands Use by Wildlife Monitoring" and "Bird Utilization Monitoring"	Annually	2005	**Criterion not met.** Est. productivity: Common Tern, 60-70 young = < 0.2 young per nest; Least Tern, 0 young. Low hatching success attributed to Great Horned Owl predation and disturbance. (Erwin 2006)
							2004	**Criterion not met.** No fledged young. Low success attributed to fox or gull predation or insufficient food supply (fish). (Erwin 2004)
							2003	**Criterion not met.** "nearly zero"—1 Common Tern and 1 Least Tern young. Low success attributed to wet weather (greatest precipitation in more than 50 years). (Erwin 2003)

Poplar Island has become the primary nesting area for common terns in the Chesapeake Bay, and predator control has been necessary to protect the colony from foxes and great horned owls. Although the original attribute for use of Poplar Island by waterbirds was simply presence of nesting birds ("If we build it, they will come"), it became apparent through extensive monitoring of bird presence on the Island that large numbers of common terns were nesting on the island, but very few of those nests were successfully producing fledglings (see the Annual Assessments for Attributes 1-10 and 1-11 in Table 3). Therefore, an attribute for monitoring nesting success was added to the Adaptive Management Plan in 2006 (Attribute 1-11 in Table 3) because of the significant management efforts that have become necessary to try to ensure that the nesting islands' habitat will encourage successful tern nesting and to prevent Poplar Island from becoming a population sink.

CONCLUSIONS

Adaptive management has been employed successfully in the design of wetland cells on the Poplar Island Environmental Restoration Project. Lessons learned from the construction and planting of an 11-hectare (27-acre) demonstration cell were used to design and construct the first, 13-hectare (32-acre) cell using dredged material. Lessons learned from that cell are, in turn, being applied to the design of the next two cells scheduled for planting in 2008. The Adaptive Management Plan for Poplar Island was approved by the Adaptive Management Team in 2004 before the first dredged-material cell was developed. Based on the early experience gained from the demonstration cell and the first dredged-material cell, the objectives, attributes, and criteria from the original plan were evaluated in the first re-assessment of the Plan, and a revised Plan was approved by the Team in 2006. In addition to minor adjustments of some of the original criteria based on the early lessons learned, the biggest changes to the Plan were the incorporation of attributes for successful nesting of waterbirds because of the important role Poplar Island has come to play in Bay-wide populations of these birds.

REFERENCES

Erwin, R.M. (2006). *Post Phase I Dike Construction Faunal Component, Surveys of the Poplar Island Environmental Restoration Project, 2005 Field Phase: The 2005 Assessment of Waterbird Nesting*. U.S. Geological Survey Patuxent Wildlife Research Center, and Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia, USA.

Erwin, R.M. (2004). *Post Phase I Dike Construction Faunal Component, Surveys of the Poplar Island Environmental Restoration Project, 2004 Field Phase: The 2004 Assessment of Waterbird Nesting*. U.S. Geological Survey Patuxent Wildlife Research Center, and Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia, USA.

Erwin, R.M. (2003). *Poplar Island Baseline Monitoring Program, MPS Contract # 596920, Final Report: Wetland and Upland Use by Wildlife*. U.S. Geological Survey Patuxent Wildlife Research Center, and Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia, USA.

Maryland Environmental Service (MES) (2006). *Poplar Island Environmental Restoration Project, 2005 Tern Nesting Island Monitoring*. MES, Millersville, Maryland, USA.

Guy, C.P., and Miller, J.K. (2005). *2004 Wetland Vegetation Monitoring for the Poplar Island Restoration Project*. Report No. CBFO-FA05-02. U.S. Fish and Wildlife Service, Annapolis Field Office, Annapolis, Maryland, USA.

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