CLOSURE CONCEPTS FOR HART-MILLER ISLAND DREDGED MATERIAL CONTAINMENT FACILITY

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ABSTRACT

Construction of the Hart-Miller Island (HMI) dredged material containment facility was completed in 1984. The facility was designed to safely contain dredged material from Baltimore Harbor shipping channels and berthing areas. The approximately 445-hectare (1100-acre) site is divided into two cells, the North Cell, 324 hectare (800 acres) and South Cell, 121 hectare (300 acres). In 1990, dredged material placement ceased in the South Cell and it lay idle for about eleven years. From 2002 to 2006, the South Cell underwent an environmental restoration project. Currently, the South Cell serves to provide valuable habitat to a large number of resident and migrating bird species, including some on the Maryland State rare, threatened, and endangered species list.

The State of Maryland passed legislation that requires final closure of HMI with transfer of property and management to the Maryland Department of Natural Resources (DNR). Closure will begin after filling of the site with dredged material ceases at the end of 2009. However, before the HMI facility can be transferred to DNR, the Maryland Port Administration (MPA) intends to close the facility according to the site's master plan, which specifies that HMI shall be restored to provide valuable wildlife habitat and public opportunities for passive recreation.

There are numerous challenges in closing a site like HMI; a relatively large flat site, fine-grained sediments that exhibit low strengths, estuarine sediments high in sulfide that can acidify and mobilize heavy metals and little precedent to use as guidance. Consequently, the MPA commissioned a study team to develop a variety of closure concepts ranging from completely flooded to mostly uplands. This paper summarizes the significant findings and recommendations of the HMI north cell closure study team and provides much insight into the development of a highly complex set of design requirements for closure of this type of facility.

Keywords: Dredged Material Management, Confined Disposal, Site Closure

INTRODUCTION

Hart-Miller Island is a Dredged Material Containment Facility (DMCF) located in Chesapeake Bay and has served as the primary placement site for dredged material from Baltimore Harbor dredging projects over the past twenty years. The site is currently scheduled for closure in a few years.

Project History

HMI was originally constructed (1981-1984) by connecting and encompassing both Hart and Miller Islands with sand-filled dikes and creating a section of sandy beach on the Hawk Cove side of the islands. The primary forms of recreation allowed in the State Park portion of HMI during the summer months (mid-May through September) are boating, camping, and beach use. Approximately, 45,000 to 70,000 people visit the site annually depending on weather conditions. The island is approximately 445-hectares (1100-acres) and is divided into two cells, the North

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Cell and South Cell shown in Figure 1. The first tier perimeter dike was constructed to +5.5m (+18ft) mean lower low water (MLLW).

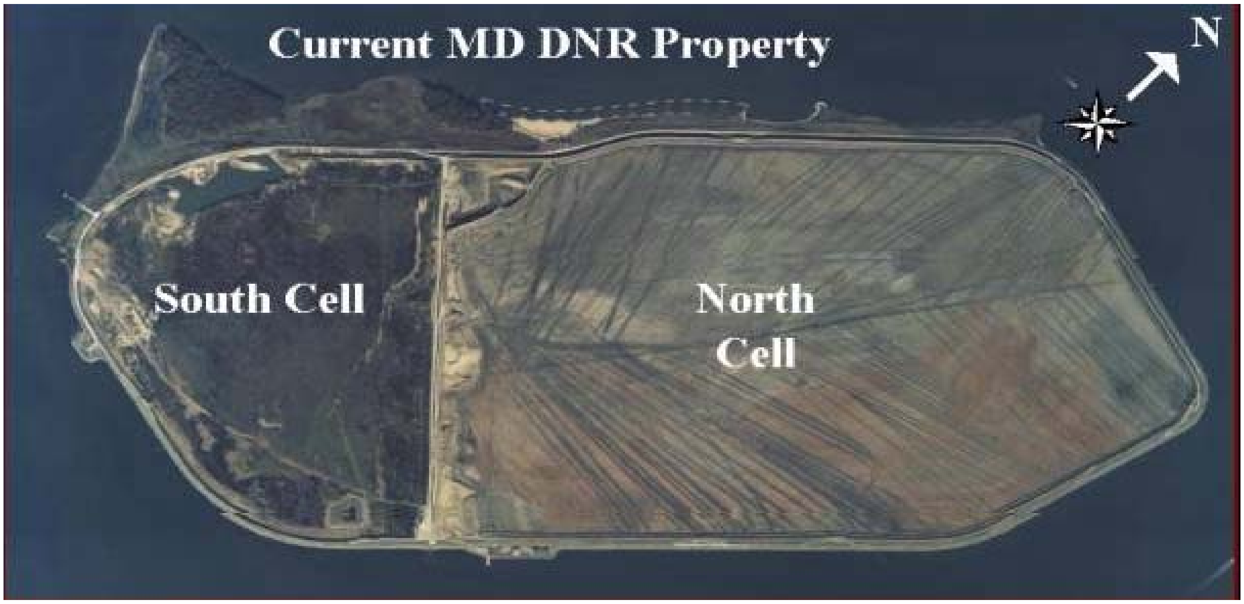

Figure 1. Hart Miller Island dredged material containment facility.

The South Cell began receiving dredged material in 1984, and the North Cell was placed into operation in 1985. A second tier dike was constructed in 1988 and 1989 raising the dike elevation to +8.5m (+28ft) MLLW. During 1996 and 1997, the North Cell dike elevation was raised another 4.9m (16ft) to a final elevation of +13.4m (+44ft) MLLW. The North Cell is approximately 324 hectares (800 acres) in area and the South Cell encompasses around 121 hectares (300 acres). No new material has been placed in the South Cell since 1990. The South Cell, restored under Section 1135 of the Water Resources Development Act of 1986, is currently monitored as a wildlife restoration site. During restoration, the South Cell dike elevation was lowered to achieve an average cell elevation of 5.5m (18ft). MLLW. In 2006, a 1.2m (4ft) temporary berm was constructed on the perimeter dike of the North Cell to +14.6m (+48ft) MLLW to accommodate the final years of inflow into the site.

Maryland State law stipulates that no more dredged material be placed into HMI after December 31, 2009. At the end of 2006, approximately 69 million m^3 (90 million cubic yards) of dredged material had been placed into HMI. The remainder of this paper will present preliminary findings of an ongoing closure study of the North Cell of HMI.

CLOSURE STUDIES AND CONCEPTS

From the inception of the project, the closure of HMI has been the subject of many agreements and meetings. As early as June 6, 1979, a Memorandum of Understanding was prepared by Maryland Department of Transportation, Maryland DNR and other State Agencies that directed development of a master plan for HMI to include fisheries, wildlife, and recreational use of the island. In July 1982, the citizens of Maryland participated in a DNR Recreational Survey, which documented existing and identified potential future uses for HMI after closure. Over the years, the HMI Citizens Oversight Committee has requested that HMI be closed with a final cover constructed from suitable material and the site be developed into a beneficial wildlife habitat. The Maryland Port Administration (MPA) began identifying concepts for the closure of HMI by authorizing the preliminary development of closure and capping options in 2003 (GBA 2003). In addition, MPA authorized the development of a plan of action to address the management of low pH soil conditions that could arise from the final closure operations (OAS 2004, Francingues and Thompson 2005).

In August 2004, the Maryland Port Administration formed the HMI North Cell Closure Team (NCCT) and NCCT Working Group (NCCT-WG) to begin development of conceptual plans for the closure of the facility after 2009. The members of the NCCT and NCCT-WG are listed in Table 1.

Table 1. Members of the HMI North Cell closure team and working group.

NCCT	NCCT Working Group	Name	Organization
√	√	Nathaniel Brown David Bibo	Maryland Port Administration
√	√	Melissa Slatnick Elizabeth Habic Jennifer Harlan Stan Snarski Aimee Warner Al West	Maryland Environmental Service
√	√	Norman Francingues Ron Vann	OA Systems Corporation
√	√	Craig Huntley	Moffatt & Nichol, Inc.
√	√	Jim Runion Marty Snow Dick Thomas	Gahagan & Bryant Assoc, Inc.
	√	Tom Kroen	HMI Citizens Island Oversight Committee
	√	Arnold Norden Dave Brinker Michele Hurt Bob Iman	Maryland Department of Natural Resources
	√	Matthew Rowe Charles Poukish	Maryland Department of Environment
	√	Jeffery McKee	Baltimore District, U.S. Army Corps of Engineers
	√	Gene Scarpulla	Maryland Ornithological Society
	√	Dave Curson	MD-DC Audubon Society

The NCCT was charged with the following closure study goals:

- Environmental and regulatory compliant closure strategy
- Passive recreation and beneficial wildlife habitat end use
- Low maintenance (O&M)
- Capital cost sensitive
- Adaptive management (incorporate lessons learned from the South Cell restoration)

A time line of key events during the life cycle of HMI is presented in Figure 2.

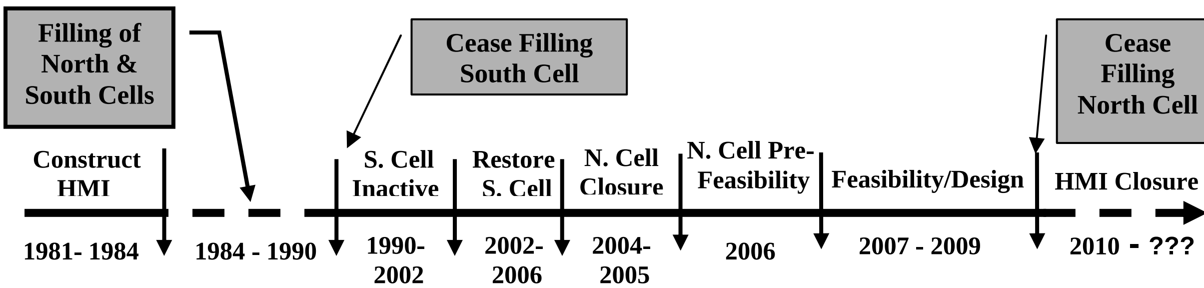

Figure 2. Time line for Hart-Miller Island dredged material containment facility.

With the completed restoration of the South Cell in 2006, future restoration efforts are focused on the much larger North Cell in preparation for completion of dredged material filling at the end of 2009. Much like the South Cell, the primary restoration goal for the North Cell is to establish wildlife habitat with managed public recreational and educational facilities. Habitats that will be created in the North Cell are similar to those found in the South Cell, but will also include the addition of uplands (MPA 2006).

The overall environmental restoration of HMI will provide habitats that are rare in urbanized areas such as uplands, wetlands, mudflats, and shallow water habitat for various bird and waterfowl species. The island location of the habitat will also limit access by both people and natural predators, making the site particularly suited for nesting terns, migratory shorebirds, and waterfowl. HMI will provide an opportunity to reclaim a small portion of the estimated 4,250 hectares (10,500 acres) of island habitat lost in the upper portion of the Bay and help restore a unique part of the Bay (MPA 2006).

Investigation of a Conceptual Closure Cover Design

The NCCT began developing closure cover concepts using dredged material "Filling Option F" developed by Gahagan & Bryant Associates, Inc. (2003). Seven steps were used to develop, evaluate, and screen a variety of upland cover designs (OAS 2005).

1. Identify potential projects and schedules for filling
2. Identify potential cover concepts
3. Level I Screening - Availability for use as cover material based upon volume, types of material, and project schedule
4. Level II Screening – Physical and chemical compatibility as cover materials
5. Develop potential closure cover concepts versus the selected filling option
6. Identify data needs and evaluations
7. Prepare order of magnitude cost comparisons

In addition, there are numerous challenges in closing a facility like HMI. HMI is a relatively large flat site containing fine-grained, unconsolidated sediments that exhibit low bearing strengths making it difficult to use normal construction equipment. Also, the estuarine sediments are high in sulfide that can acidify and mobilize heavy metals, presenting environmental permit issues. And, finally, there is little precedent to use as guidance in a closure of a site like Hart-Miller.

After an exhaustive analysis of several types of upland grass cover systems, the NCCT recommended a conceptual design consisting of a 91cm (36-inch) moisture balance layer with a 30.5cm (12-inch) capillary layer as the preferred upland cover concept that could provide the upland, grassland, and bird habitat, be environmentally compliant, and sustain a low maintenance (O&M) closure cover system (See Figure 3).

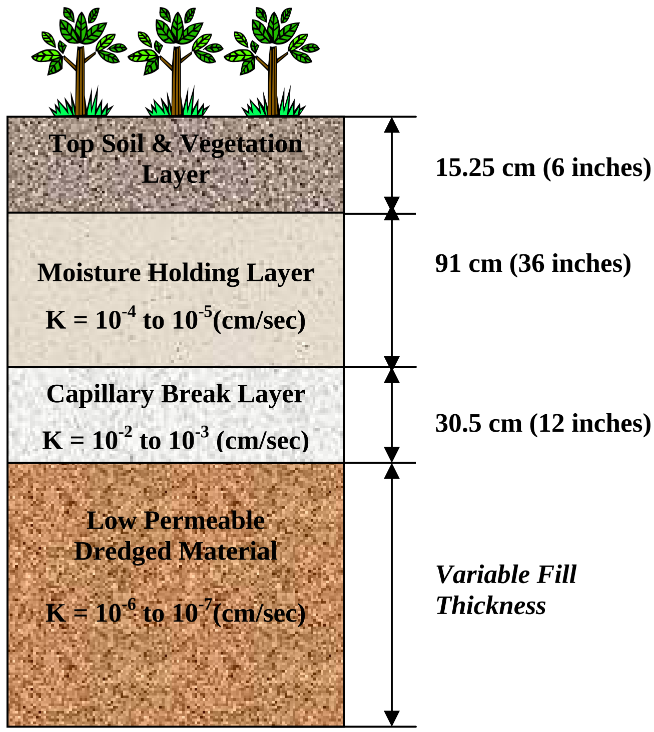

Figure 3. Typical moisture balance soil cover system (not to scale).

However, the concept was not without some drawbacks. Implementation would require about 0.46 million m^3 (0.6 MCY) of topsoil, 01.3 million m^3 (1.7 MCY) of well-graded sand (moisture layer), and 0.84 million m^3 (1.1 MCY) of coarse sand (capillary layer). As OAS noted in their study (OAS 2005), few sources of materials were available onsite (only 0.38 million m^3 (0.5 MCY). Consequently, there appeared to be a shortfall of about 2.2 million m^3 (2.9 MCY) that would require acquisition from offsite sources.

Although most of the study goals were attainable with the concept design, significant capital costs may be seen as prohibitive for this type of closure option. Therefore, a variety of uplands, seasonal wetlands, mudflats, and ponds were investigated to reduce capital cost, while at the same time providing positive environmental benefits and passive recreational opportunities (OAS 2005).

EXPANDED DESIGN CONCEPTS

On September 20, 2005, the NCCT closure study charter was broadened to examine a range of closure concepts based upon the following criteria:

- Closure based on natural succession
- Closure based solely on onsite material availability
- Closure with the lowest capital cost
- Closure with the lowest operations and maintenance costs
- Closures using dredged material "Filling Plan F" (GBA 2003).

During the course of study, the NCCT revised the list slightly to focus on the following five (5) closure objectives:

- Baseline (minimal requirements according to closure agreements)
- Maximum use of onsite material
- Enhancement of onsite material use with stockpiled offsite material
- South Cell closure model (based upon lessons learned from South Cell Restoration)
- Maximum upland model using both onsite and offsite material.

Ultimately, the five closure concepts evolved into the following six design concepts:

- Concept 1 – Baseline or caretaker status
- Concept 2 – Maximum ponding using onsite material for upland
- Concept 3 – Onsite & offsite material stockpiled at HMI
- Concept 4A – South Cell restoration (spray irrigation)
- Concept 4B – South Cell restoration (flooded irrigation)
- Concept 5 – Maximum Upland, using onsite and offsite material

The concept designs were developed to represent a wide range of closure scenarios and habitats by expanding on a few elements common to each design. All designs used "Filling Plan F", incorporated a baseline O&M or caretaker component, and assumed compliance with relevant state permits and local cooperation agreements. Some additional features such as controls for *Phragmites* (an invasive plant) and mosquitoes were also common to each option. The primary differences in the designs were in the type and amounts of habitat provided and the length of time to construct the closure. The South Cell Restoration Concept 4 was divided into two designs 4A and 4B to differentiate between the type of pumping/wetting operations for maintaining seasonal wetlands and mudflats. The above concepts provide a range of development and cost levels, from detailed development with irrigation and pumps to no development. The concepts are summarized in the following sections.

Concept 1– Baseline or Caretaker Status

Concept 1 is shown in Figure 4. This concept provides for the baseline "minimal closure" or "caretaker" status. There are minimal site capital investments but long-term operational requirements. The advantages include no offsite material, minimal site preparation, low capital cost and maximum use of the filling plan. The disadvantages are long-term O&M for *Phragmites*, mosquitoes, pH control, and periodic pond maintenance for solids removal. The site will eventually transition to an unmanaged upland habitat of approximately 295 hectares (728 acres) and a 16.2 hectare (40 acre) pond. This option was eliminated from further consideration because it lacks adequate recreation opportunities, provides poor habitat value, and has high annual O&M costs.

Figure 4. Concept 1– Baseline or caretaker status.

Concept 2 – Maximum Ponding Using Onsite Material for Upland

This Concept (Figure 5) expands upon the baseline or caretaker Concept 1 by incorporating approximately 70 hectares (174 acres) of marginally improved upland habitats, using reclaimable onsite material (i.e., the temporary berm and excess grading materials from the pond) for construction of the upland cover. The remaining 240 hectares

(594 acres) are incorporated in shallow water [0-0.76m (2.5ft)] pond habitat with an outlet structure and pumping station. Apparent advantages are no use of offsite material and control of acid soils with the pond. The major disadvantages are increases in capital and O&M costs (significant grading, upland cover construction, and an added pumping station to comply with the final dike elevation of 13.4m (44ft).

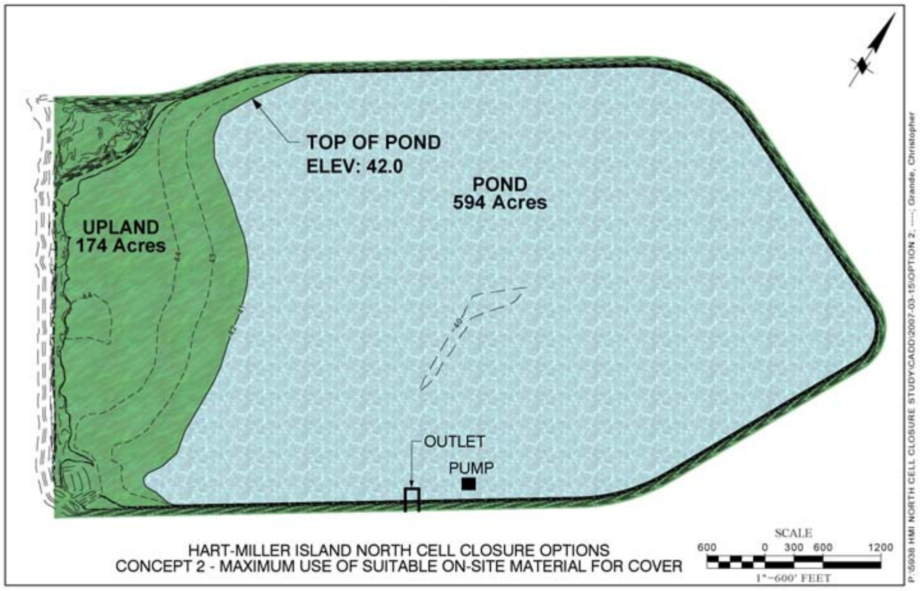

Figure 5. Concept 2– Maximum ponding using onsite material for upland.

Concept 3 – Onsite and Material Stockpile

This concept, shown in Figure 6, is similar to Concept 2; except that it incorporates stockpiling of borrow material from an offsite source for construction of upland cover and makes maximum use of onsite materials. There are approximately 185 hectares (457 acres) of upland, 52 hectares (128 acres) of seasonal wetland and 74 hectares (183 acres) of pond. Approximately 0.76 million m^3 (1.0 MCY) of suitable cover material are required to construct the self-sustaining moisture balance cover system. Apparent advantages are enhanced use of HMI North Cell onsite materials for upland, grassland bird habitat, and less maintenance of the upland habitat (uses a moisture balancing cover). The disadvantages are increases in capital costs (upland cover, pond construction, and pumping station) and O&M costs (pumping), and increases in dewatering costs and time for construction. This option assumes that the final cover will be placed over a considerable period of time (10-15 years) for consolidation of the dredged material to occur before construction can proceed with conventional equipment. This concept results in a significant impact on site capacity, since there is a requirement to use 0.76 million m^3 (1.0 MCY) and to maintain a final dike elevation of 13.4m (44ft).

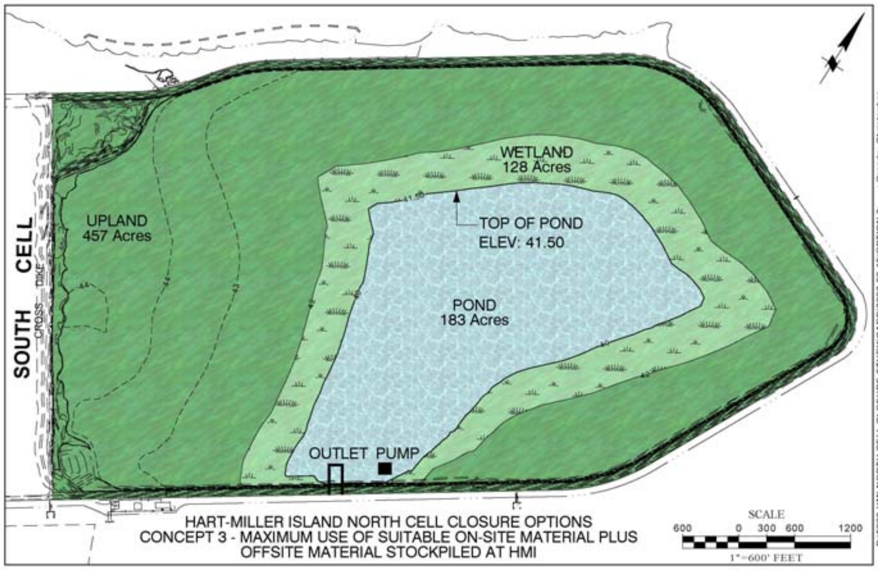

Figure 6. Concept 3– Onsite and material stockpile.

Concept 4A – South Cell Restoration (Spray Irrigation)

Extrapolation of the South Cell restoration model to the North Cell is the premise for Concept 4A as shown in Figure 7. The mix of habitat is about 103 hectares (255 acres) of marginally improved seasonal upland, 98 hectares (242 acres) of seasonal wetlands, 82 hectares (202 acres) of mudflats, and a small pond of 28 hectares (69 acres) to manage the surface water discharges. A spray irrigation pumping system is used to provide the seasonal wetting needed to maintain the wetlands/mudflats. This option uses onsite material (i.e., temporary berm) for the upland area and has minimal impact to the filling capacity. The apparent advantages are increased nesting bird habitat, no use of offsite material, and pH control through simulated seasonal dredging operations. Disadvantages include increases in capital costs, long-term O&M cost for the irrigation system, *Phragmites* and mosquito controls, pH control amendments for uplands and wetlands, and periodic pond maintenance for solids removal.

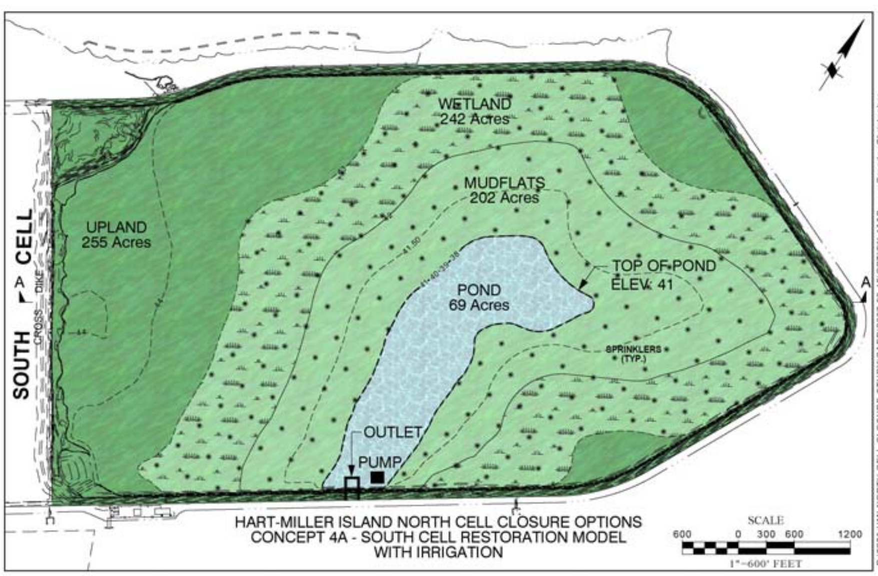

Figure 7. Concept 4A – South cell restoration (spray irrigation).

Concept 4B – South Cell Restoration (Flooded Irrigation)

The mix of habitat for this Concept (Figure 8) is about 103 hectares (255 acres) of marginally improved upland, 98 hectares (242 acres) of seasonal uplands/wetlands, 82 hectares (202 acres) of mudflats, and a small pond of 69 acres to manage the surface water discharges. The basic description, advantages and disadvantages of this Concept 4B are the same as Concept 4A except that the spray irrigation pumping system is replaced with an outlet structure & pumping system designed to provide seasonal flooding of water to maintain the wetlands and mudflats with the proper moisture conditions. This system should be less expensive to construct and maintain than Concept 4A, while providing similar seasonal conditions.

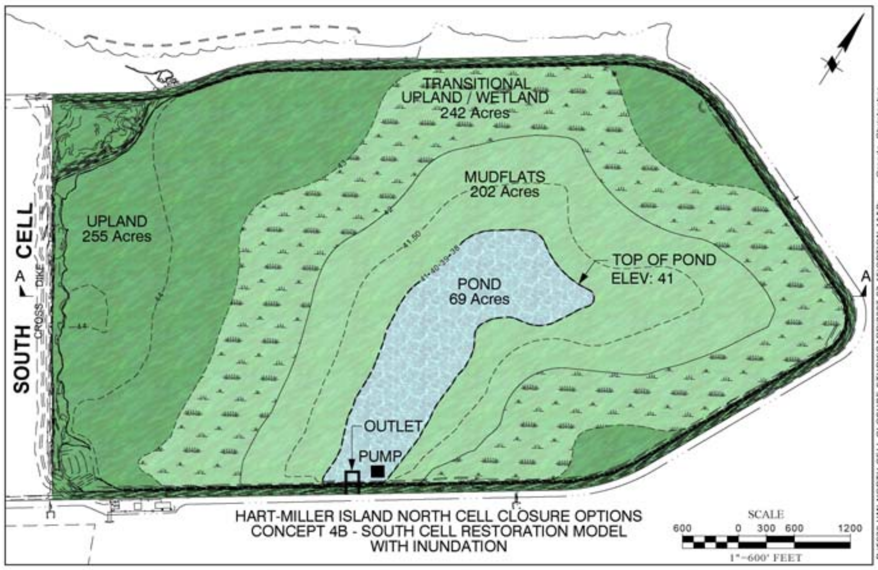

Figure 8. Concept 4B – South cell restoration (flooded irrigation).

Concept 5 – Maximum Upland

The primary feature of Concept 5 shown in Figure 9 is the use of a moisture balancing cover designed specifically to control pH. The result is 295 hectares (728 acres) of upland grassland bird habitat and a 16.2 hectares (40-acre) shallow water pond to manage surface water runoff. The principal advantages are that the concept should be self-sustainable and require lower maintenance (no additional pH control due to use of a moisture balancing cover). The primary disadvantages are the requirement for 2.2 million m^3 (2.9 MCY) of offsite material (high capital costs), an increase in dewatering costs, an increase in time for construction, and a decrease in habitat diversity (mostly upland). This concept assumes that the final cover will take considerable time (> 10 years) for consolidation of the dredged material before construction can proceed with conventional equipment. This concept results in a significant impact on site capacity since there is a requirement to use 2.2 million m^3 (2.9 MCY) of mostly offsite material and to maintain a final dike elevation of 13.4m (44ft).

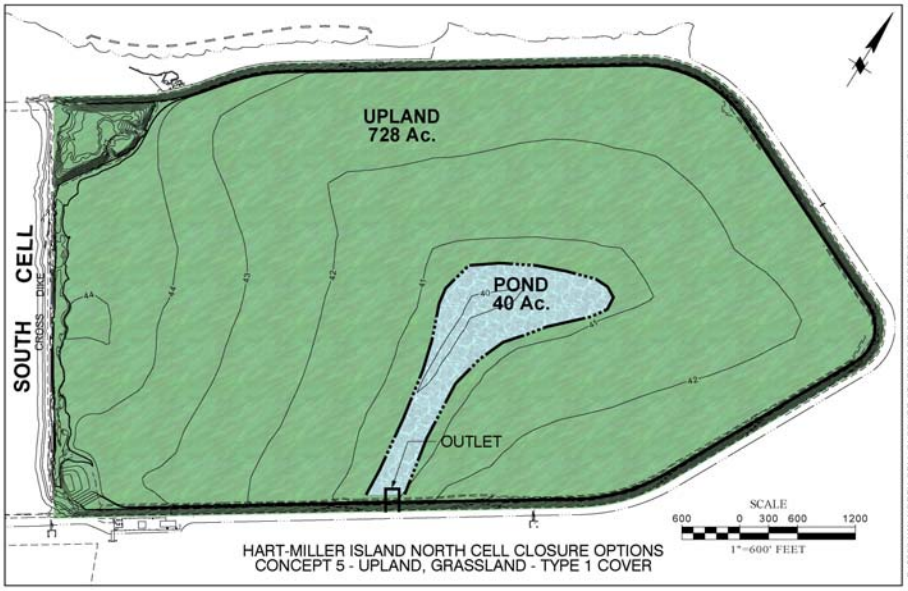

Figure 9. Concept 5 – maximum upland

COSTS AND SCREENING OF CONCEPTS

The costs of the various concepts are summarized in Table 2. Surprisingly, Concept 1, the baseline, represents the fourth highest capital costs and fourth highest annual O&M costs.

Table 2. HMI North Cell closure concept costs with 20% contingency.

	Concept 1	Concept 2	Concept 3	Concept 4A	Concept 4B	Concept 5
Capital Costs, K$	20,012	14,600	62,797	21,092	17,732	98,582
O&M, K$	1,305	1,041	1,281	1,755	1,587	1,312

Extrapolation of the South Cell Spray Irrigation Model (Concept 4A) to the North Cell yields the third highest capital investment and the highest annual O&M cost. The highest capital cost occurs for the maximum upland Concept 5, but this concept represents the third lowest annual O&M cost. The concepts ranked in order of lowest capital costs results in 2, 1, 4B, 4A, 3, & 5 and according to lowest annual O&M costs in 2, 3, 1, 5, 4B, & 4A (approximately a $700,000 spread from lowest to highest). It is clear to see that four concepts (1, 2, 4A & 4B) are similar in capital costs, whereas, the concepts containing the most upland areas (3 & 5) are considerably higher in capital costs and high to moderate in annual O&M costs.

Finally, each of the concepts was re-screened against the goals shown in Table 3. Each concept was assumed to be compliant with site operating permits over the long term. With respect to preferred habitat, the habitat was targeted for priority bird species versus species diversity. With that in mind, the environmental benefits ranking of various habitats in each of the concepts listed in order of priority is:

- Wetlands and mudflats
- Emergent vegetation and scattered shrubs
- Open water pond
- Upland grassland

Concepts 4A & 4B provide the maximum in habitat diversity and passive recreation and are most beneficial for priority bird species. Concept 2 minimizes uplands and maximizes open water and wetlands habitats. Concepts 1, 3 and 5 are the least desirable due to lack of mudflats and wetlands and the predominance of uplands. The most sensitive to capital costs are Concepts 1, 2, 4A & 4B.

Table 3. Screening of concepts against study goals.

Concept	Goals			
	Environmentally Compliant	Passive Recreation & Beneficial Wild Life Habitat	Capital Cost Sensitive	Low (O&M)
1 – Baseline	Yes	Unmanaged	Yes	Moderate
2 – Max Pond	Yes	Minimal	Yes - least	Yes - least
3 – Stockpile	Yes	Marginal (mix)	No	Moderate
4A – Spray Irrigation	Yes	Maximum diversity	Yes	Highest
4B – Flooded Irrigation	Yes	Maximum diversity	Yes	High
5 – Upland	Yes	Minimum	No – Highest	Low

PUBLIC MEETINGS

The MPA hosted two Public Meetings in the Baltimore communities closest in proximity to HMI to present the results of the NCCT pre-feasibility assessment phase of the closure study. These meetings were held during the evenings of October 4, 2006 and October 5, 2006 at Chesapeake High School and the Community College of Baltimore County (CCBC), Dundalk Campus, respectively. The program for the meeting included a poster session following by eight presentations on topics that ranged from an overview of the original master plans, interior and exterior site monitoring, SCERP, current bird utilization, and the pre-feasibility study closure design concepts. Panel participants included representatives from the Maryland Port Administration, HMI Citizens Oversight Committee, Maryland Environmental Service, Maryland Department of Natural Resources, Maryland Department of the Environment, University of Maryland Center for Environmental Studies, Maryland Ornithological Society, and OA Systems Corporation. The purposes of the public meetings were to solicit comments regarding the status and plans for closure of HMI and to encourage any other suggestions and input for future evaluations regarding site closure. During the meetings, the NCCT representative suggested that they were favoring Concepts 4A & 4B for more detailed evaluations. Also, they stated that it would probably take longer than 10 years to implement any closure concept due to the need to condition (consolidate) the soils onsite. There were several members of the audience that openly supported the South Cell Restoration Model concepts based on significant numbers of Maryland State rare, threatened, and endangered bird species presently using HMI either as a resident site or for a stopover during migration.

CONCLUSIONS

Based upon the many favorable comments received during the public meeting about the closure concepts, the MPA has elected to eliminate the baseline or caretaker, Concept 1, from further consideration. Concept 1 lacks adequate recreation opportunities, provides poor habitat value, and has the second highest annual O&M costs. Although Concept 2 (maximum ponding condition) appears attractive due to its low capital and low O&M costs, it does little to provide environmental benefits and recreational opportunities. Conversely, the maximum upland acreage Concepts 3 & 5 are the most expensive to construct, provide marginal to minimal environmental benefits and passive recreational opportunities. Therefore, based upon the screening results presented in Table 3 and Public comments received, Concepts 2, 3, & 5 should also be also eliminated from future evaluations by MPA. Subsequently, the NCCT recommends that MPA should:

- Recognize that final site closure is a long term proposition that will probably be delayed a minimum of 10-15 years after filling is completed in 2009
- Refine engineering feasibility for closure Concepts 4A & 4B
- Select a preferred closure concept for design
- Inform the Public of the preferred closure concept
- Design and implement the preferred closure concept

REFERENCES

Francingues, N. R. and D. W. Thompson. (2005). "Don't Let Your Disposal Site Go Sour On You." *Proceedings of the Western Dredging Association 25th Technical Conference and 37th Annual Texas A&M Dredging Seminar*, June 19-22, 2005, New Orleans, LA, 221-235.

Gahagan & Bryant Associates (GBA), Inc. (2003). "Preliminary Evaluation of Options for the Closure and Capping of Hart-Miller Island Dredged Material Placement Facility, Final Report." Prepared for the Maryland Port Administration by Gahagan & Bryant Associates, Inc.

Maryland Port Administration (MPA). (2006). "Fact Sheet – North Cell Closure Hart-Miller Island, Baltimore, Maryland, Review of North Cell Closure Concepts." Prepared by the Maryland Port Administration, Harbor Development.

OA Systems Corporation (OAS). (2004). "Proposed Plan of Action (POA) Control of Low pH Conditions at Hart-Miller Island Dredged Material Containment Facility Final Report," Prepared for Maryland Port Administration, Maryland Environmental Service, and Moffatt Nichol Engineers by OA Systems Corporation.

OA Systems Corporation (OAS). (2005). "Final WHITE PAPER – Development of Potential Closure Options – North Cell Hart-Miller Island Dredged Material Containment Facility," Prepared for the Maryland Port Administration, Maryland Environmental Service, and Moffatt Nichol Engineers by OA Systems Corporation.

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