APPENDIX A
Engineering Appendix

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APPENDIX A
Engineering Appendix

Section 1 – Civil Design:

1.1. Introduction and Background: The Cat Island Chain of Islands is located in Green Bay, Wisconsin. In the early 1970's the Cat Island Chain was severely eroded leaving a series of shoals mostly below low water datum. The US Army Corps of Engineers, US Fish & Wildlife and Brown County plan to provide dredged material capacity, while restoring the island chain.

The benefits of restoring the islands are threefold:

- Creating the conditions for re-establishment of emergent and submerged aquatic vegetation southwest of the Cat Island Chain;
- Providing capacity for placement of clean dredge material of Green Bay Federal Shipping Channel dredging activities;
- Restoring habitat associated with the islands.

A concept evaluation and initial design development report (Baird, 2002) was performed by Baird & Associates. The 2002 report documents conceptual coastal design of the islands, construction issues, and recommendations for subsequent phases.

The initial goal of the project was to restore the Cat Island Chain to their historic original position under Section 204 Authority . An IPR was conducted in 2008, and as a result the district was directed to convert the study to a DMMP. The historic Cat Island chain perimeter boundaries have been established by the US Fish & Wildlife and Brown County. This boundary is presently being utilized in an application to obtain a Lake Bed Grant. A Lake Bed Grant is required prior to placing any fill materials on the existing lakebed.

In 2002, Baird prepared an "Initial Design Development and Concept Evaluation" report, which included a conceptual island chain restoration design. Detailed plans, cross sections, optional beaches and revised Lake Bed Grant limits are indicated in Figures 10-1 through 10-10 (Attachment B). The revised plan includes beaches and revetments along the northeastern perimeter of the islands. Between the islands a 300-foot wide gap, or circulation channel, has been incorporated to deter predator and pedestrian access between islands and to promote water circulation. Due to flow velocities through these gaps, during storm set-up and surge events, additional stone will be placed on the lake bottom to provide scour protection. The gap between the islands will have a depth below low water in the range of 1 to 2 ft allowing small fishing boats to pass between the islands during low water and larger craft during higher water levels. The ideal and ultimate depth between the islands could be controlled by allowing flows to scour out the existing sediment until sufficient depths are achieved, followed by placement of the stone

bed protection and the island berms. Some of the features (cobble and sand beaches) in the Baird report cannot be implemented under the DMMP authority, however these environmental betterments may be implemented after the islands are constructed under a section 204 authority with a cost sharing partner.

During the construction phase, access between islands will be required. Construction access roads, with circulation culverts, will be constructed though these gap areas. See Attachment B, page 16 for drawings that indicate construction sequencing.

1.2. Storage Capacity:

The following table summarizes the storage capacities. The extent of the jetties is to establish an Island Chain to provide a 20 year dredged material storage capacity. The gravel beaches and sand beaches shown in the conceptual plans could be implemented under a section 204 authority, after the initial islands are fully developed.

Table A.1 displays the storage capacity anticipated for the three islands .

Table A.1 – Island Storage Capacity Summary

Island	Storage Capacity (cubic yards)
West Island	630,000
Central Island	720,000
East Island	1,000,000

1.3. Physical Model Results & Island Design Requirements: Review and analyses of the wave climate, water levels, material availability and physical model study, as well as consideration of construction issues has been undertaken to support preliminary design development for the island perimeter (construction access roads, stone headlands and beaches).

The preliminary designs are based on the estimated 20-year storm event consisting of:

- Hs/Tp = 3.3 ft / 6 s along the “exposed” NE side of the islands; and
- Hs/Tp = 2.0 ft / 4 s along the “sheltered” SW side of the islands.

1.4. Stone Revetment/Headland Cross-Sections: Two alternative revetment and headland cross-sections have been developed, including a “conventional” design concept and a “berm” design concept. The latter allows the use of smaller riprap with a wider gradation, but requires an increase in the overall quantity of riprap. Attachment B, page 14 presents these two alternative cross-sections.

The conventional design has an outer slope of 2:1, while the berm design has an outer slope of 1.3:1 (assumed angle of repose). These steep slopes are intended to minimize quantities and equipment reach requirements. However, flatter slopes could certainly be considered to provide easier access to/from the water for wildlife. With the berm design, the slope will evolve naturally to have milder sections as it is exposed to wave attack at different lake levels.

Both designs have a crest elevation of +8 ft LWD. This elevation has been selected, on the basis of the physical model results, to prevent damage to the structure or erosion of sand dredge material behind the structure due to wave overtopping.

The advantage of developing two stone revetment/headland designs is that it provides the opportunity to bid both alternatives and select the lowest cost solution. It may be possible that the berm concept will be less expensive to construct then the conventional design. Although there is a greater quantity of stone to transport to the site with the berm design, it may be less expensive to produce the stone due to the wider gradation. Stone placement is also less time consuming than the conventional design.

Following the placement of the armor stone on the exposed perimeter slope of the revetment/headland, additional armor stone will be placed on the surface of the construction access road to provide a splash apron. This splash apron has been incorporated to allow the over-all crest height of the revetment to be lowered to reduce cost. During extreme storm events wave overtopping may occur. Excess water from overtopping would be collected in a shallow swale landward of the revetment structure and drain back to the lake. This swale would be bio-engineered during the final design process to withstand overtopping events and reduce erosion of the dredge sand fill. In addition, the splash apron may also be bio-engineered to support plant life during the majority of the time and to regenerate vegetation following extreme storm events.

Both cross-sections show a geotextile filter fabric between the riprap cover layer and the underlying materials. The requirement for a filter layer (geotextile or granular) between the riprap and the quarry run/shot rock core will depend on the gradation of this material, in particular the presence of fines in the rock fill.

1.5. Imported Material Beach Cross-Sections:

Attachment B, page 13 presents cross-sections of beach fill placement profiles and estimated storm beach profiles for three different beaches fill materials, including:

- Coarse gravel/cobbles (well sorted, $D_{50} > 1$")
- Clean fine gravel (well sorted, $D_{50} \sim 3/8$-1")
- Coarse sand or mixed sand-gravel (material with a significant percentage < 3/8" The estimated storm beach profiles are based on the physical model results for a 20-year design event at a 5 to 10-year water level (+6 ft LWD).

1.6. Dredge Sand Beach Sections: Along the southwest side of the proposed islands a flatter slope is anticipated, due to the fine sediments of the dredge sand material. The COSMOS numerical model of coastal processes was applied to investigate the cross-shore stability of fine sand beaches on the lee side of the islands. It is important to evaluate the stability of the dredged sand without protection on the lee side of the island during extreme wave attack. The COSMOS model is a deterministic profile model of coastal processes and simulates: wave transformation (shoaling, refraction, friction losses, breaking, wave decay and reformation, run-up and overtopping), hydrodynamics (long shore and cross-shore steady currents including undertow and non-linear orbital velocities) and erosion/sedimentation (considering bed and suspended load, erosion of glacial sediment and a consideration of erosion resistance surfaces).

1.7. Habitat Considerations for Layout & Sections:

The updated island design development plan includes a variety of different substrates and slopes to provide a variety of habitat opportunities. The beaches shown include a variety of materials and slopes, along with opportunities to create wetland lagoons, deadfall areas, native rock outcrop areas and island berms.

1.8. Alternatives: All of the evaluated alternatives (except the "No Federal Action" alternative), considered for the Cat Island Chain Project, involve restoring the islands to provide capacity for placement of clean dredge spoils and restoring habitat associated with the islands. The following alternatives were evaluated:

1.8.1. Alternative 1- No Action. This alternative involves no action and would approximate the without project condition listed above. It is highly unlikely that the locals could finance the construction of the three islands or wave barrier on their own, therefore the Cat Island chain will not be restored. The remaining island and habitat will continue to be unprotected and deteriorate. The no action alternative forms the baseline for evaluating the environmental impacts of the proposed action.

1.8.2. Alternative 2- Construct a single island (West Island), a partial wave barrier and an access road. This alternative proposes to construct a single island (West Island) and a partial wave barrier located within Green Bay, WI as shown on Attachment B, page 2. This island would re-establish a portion of the deteriorated Cat Island Chain and surrounding shallow water habitat. It is one of three islands being considered for construction and it is the most western island, located closest to the northwest shoreline. An island approximately 74 acres. A temporary access road would be constructed initiating at the shoreline of the mainland and extending into the water approximately 3,600 linear feet to the West Island. A wave barrier (approximately 3,000 linear feet) would be constructed along the northeast side of the constructed West Island to protect the island and the shallow water habitat behind it (Duck Creek delta wetland and Peter's marsh) against wave action from the bay. Construction of the West Island and a partial wave barrier would create a reduction in wave height and restore approximately 420 acres of water habitat and 74 acres of terrestrial habitat for a total restoration of 494 acres.

1.8.3. Alternative 3- Construct a single island (West Island), a complete wave barrier and

an access road. This alternative also proposes to construct a single island (West Island) with a complete wave barrier to extend the length of the original Cat Island Chain located within Green Bay, WI as shown on Attachment B, page 3. It is one of three islands being considered and it is the most western island, located closest to the northwest shoreline. The size and location of this island and the temporary access road would be the same as Alternative 2 above. A complete wave barrier would be constructed along the northeast side of the West Island and extend approximately 8,600 feet eastward to protect the island and the shallow water habitat behind it (Duck Creek delta wetland and Peter's marsh) against wave action from the bay. Construction of the West Island and a complete wave barrier would create a reduction in wave height and restore approximately 1,423 acres of aquatic habitat and 74 acres of terrestrial habitat for a total restoration of 1,497 acres.

1.8.4. Alternative 4 - Construct two islands (West and Middle Islands), a partial wave barrier, and an access road. This alternative proposes to construct two islands (West and Middle Islands) sequentially, and a partial wave barrier located within Green Bay, WI as shown on Attachment B, page 4. These islands would re-establish a portion of the deteriorated Cat Island Chain and surrounding shallow water habitat. The size of the two islands are as follows; West Island (approximately 74 acres) and Middle Island (approximately 92 acres). The two islands would encompass a total of approximately 166 acres. The construction of the two islands and partial wave barrier could be phased-in over a period of time as needed. A temporary access road would be constructed initiating at the shoreline of the mainland and extend into the water 3,600 linear feet, connecting to the starting point of the wave barrier. The wave barrier would extend 5,400 feet eastward along the northeast side of West and Middle Island to protect the two islands and the shallow water habitat behind it (Duck Creek delta wetland and Peter's marsh) against wave action from the bay. Construction of the West Island and Middle Island and a partial wave barrier would create a reduction in wave height and restore approximately 875 acres of water habitat and 166 acres of terrestrial habitat for a total restoration of 1,041 acres.

1.8.5. Alternative 5 - Construct two islands (West and Middle Islands), a complete wave barrier, and an access road. This alternative proposes to construct two islands (West and Middle Islands) sequentially, and a complete wave barrier located within Green Bay, WI as shown on Attachment B, page 5. These islands would be positioned near the deteriorated Cat Island Chain. The size and location of these islands and the access road are the same as discussed in Alternative 4 above. The major difference between this alternative and Alternative 4 above is that the complete wave barrier is constructed prior to the islands versus a partial wave barrier as each island is constructed. A complete wave barrier would extend 8,600 feet eastward along the northeast side of West and Middle Islands to protect the islands and the shallow water habitat behind it (Duck Creek delta wetland and Peter's marsh) against wave action from the bay. Construction of the West and Middle Island alone would create a reduction in wave height and protect approximately 1,200 acres behind it. Construction of the West Island and Middle Island and a complete wave barrier would create a reduction in wave height and restore approximately 1,331 acres of water habitat and 166 acres of terrestrial habitat for a total restoration of 1,497 acres.

1.8.6. Alternative 6 - Construct three islands (West, Middle and East Islands), a partial wave barrier, and an access road. This alternative proposes to construct three islands (West, Middle, and East Islands) and a wave barrier incrementally over time, located within Green Bay, WI as shown on Attachment B, page 6. The three islands are centrally located between the northwest shoreline and the Federal navigation channel. The size of the three island are as follows; West Island (approximately 74 acres), Middle Island (approximately 92 acres) and East Island (approximately 106 acres). The three islands would encompass a total of approximately 272 acres. The construction of the three islands and wave barrier could be phased-in over a period of time as needed. A temporary access road would be constructed initiating at the shoreline of the mainland and extend into the water 3,600 linear feet, connecting to the starting point of the wave barrier. The wave barrier would extend 8,600 feet eastward along the northeast side of the three islands to protect the islands and the shallow water habitat behind it (Duck Creek delta wetland and Peter's marsh) against wave action from the bay. Construction of the West, Middle and East Island and a partial wave barrier would create a reduction in wave height and restore approximately 1,225 acres of water habitat and 272 acres of terrestrial habitat for a total restoration of 1,497 acres.

1.8.7. Alternative 7 - Construct three islands (West, Middle and East Islands), a complete wave barrier, and an access road. This alternative proposes to construct three islands (West, Middle, and East Islands) and a complete wave barrier at one time, located within Green Bay, WI as shown on Attachment B, page 7. The size and location of these islands and the access road are the same as discussed in Alternative 6 above. The major difference between this alternative and Alternative 6 above is that the complete wave barrier is constructed prior to the islands versus a partial wave barrier as each island is constructed. The three islands would encompass a total of approximately 272 acres. The construction of the three islands could be phased-in over a period of time as needed. The wave barrier would extend 8,600 feet eastward along the northeast side of the three islands to protect the islands and the shallow water habitat behind it (Duck Creek delta wetland and Peter's marsh) against wave action from the bay. Construction of the West, Middle and East Island and a complete wave barrier would create a reduction in wave height and restore approximately 1,225 acres of water habitat and 272 acres of terrestrial habitat for a total restoration of 1,497 acres.

1.8.8. Alternative 8 - Construct a single island (East Island), a complete wave barrier, and an access road. This alternative proposes to construct a single island (East Island) and a complete wave barrier located within Green Bay, WI. (See Attachment B, page 8). It is one of three islands being considered and it is the most easterly island, located closest to the federal navigation channel. The size and location of this island and the access road are the same as discussed in Alternative 6 above. The major difference between this alternative and similar alternatives above is that the complete wave barrier is constructed prior to the island and it is nearest the Federal navigation channel. This island would encompass a total of approximately 106 acres. The wave barrier would extend 8,600 feet eastward along the northeast side of the island to protect the island and the shallow water habitat behind it (Duck Creek delta wetland and Peter's marsh) against wave action from the bay. Construction of the East Island and a complete wave barrier would create a reduction in wave height and restore approximately 1,391 acres of water habitat and 106 acres of terrestrial habitat for a total restoration of 1,497

acres.

1.8.9. Alternative 11 - Construct a 36 acre Dredged Material Disposal Facility (DMDF) to expand existing Bayport CDF Facility. This alternative proposes to construct a 36 acre DMDF adjacent to the existing Bayport CDF containing dry cells for stock piling dry dredged material. (See Attachment B, page 9) The existing Bayport CDF will continue to process wet dredged material. The process will consist of temporary storage of the wet dredged material in designated cells until it is dried, then transferring it to the 36 acre expansion site. Taking into consideration, the 400,000 cy for Renard Island, the proposed 36 acre DMDF site will be designed to contain approximately 800,000 cy. This will provide additional placement capacity for years 2020 thru 2031. The Corps will continue to pay a tipping fee for the Operation & Maintenance of the facility.

Section 2 – Survey and Mapping

Survey and Mapping information is provided in Attachment B, Design Plans

Section 3– Construction Procedures and Water Control Plan

All construction work will be accomplished from land; therefore, a water plan is not required.

Section 4 – Operation and Maintenance

Operation and Maintenance responsibilities will be transferred to the local sponsor, Brown County, Wisconsin upon completion of the construction project.

All project features should be periodically inspected. Problems may arise along the islands as related to erosion and/or high water levels which may impact features of the restoration project and/or the environmental benefits. Every effort should be made by the local sponsor to remediate these conditions as soon as possible.

Repair and maintenance of the island structures shall be provided to restore them to the original cross-section and condition.

Annual Operation and Maintenance Costs are estimated to be approximately 3 percent of construction costs.

Alternative	O&M Cost
2	$ 238,800
3	$ 326,820
4	$ 410,730
5	$ 464,850
6	$ 693,240
7	$ 828,840
8	$ 475,200

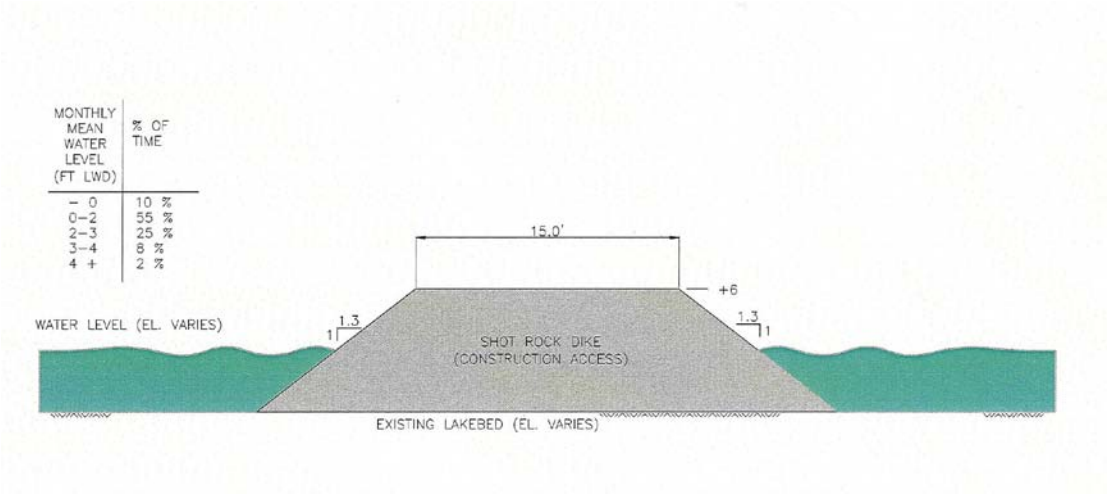
It is anticipated that the following project features and/or conditions will need to be inspected periodically and repaired/replaced as needed.

Section 5 – Access Roads

5.1. Construction Access Road: Depending on the mode of material delivery and construction methodologies adopted, a construction access road may be required. This construction access road would extend from the mainland to Western Island as indicated on Attachment B, page 1. This structure would likely be constructed of quarry run or shot rock, with its crest width established by equipment requirements and a crest height several feet above prevailing lake levels at the time of construction. At this time, a minimum crest width of 15 ft and a crest elevation of +6 ft LWD have been assumed. (See figure 1 below and Attachment B, page 15) The crest width of 15 feet has been selected to allow two-way truck traffic and provide space for loaders and excavators to continuously place stone as delivered by trucks. It is likely that periodic maintenance will be required along this perimeter following significant storm events.

Whether the temporary construction access road is required or not, some form of road will be required to create a series of island berms to significantly reduce the potential for flow between the west island and the shore, restoring a condition that existed before the Cat Island Chain was eroded (i.e. where the area between the west island and the shore consisted of dense emergent vegetation and low flows). This is necessary to achieve the required water clarity conditions, to the southwest of the west island along the shore, for restoration of aquatic vegetation.

A similar cross section will also be utilized to provide access for the construction of the island perimeter stone revetments, headlands and extended jetties. These structures will remain in place and become an integral part of the final island perimeter and beach containment system.



Note: Elevations are in ft, LWD

Figure A.1 – Construction Access Road – Preliminary Design

During the final design phase it may possible to optimize this cross section. If special construction sequencing and material delivery scheduling is utilized there are opportunities to reduce the width and/or crest height of this section and therefore reduce cost. This may be accomplished though the refinement of the revetment design to allow excavators to place stone while trucks maintain delivery of materials and/or the use of a one way roadway system with periodic bump-outs to allow trucks to pass. If the construction road is placed during periods of low water it may be possible to reduce the crest height, which will also reduce stone quantities and costs.

Section 6 – Project Security

Once the islands are complete, Brown County would utilize the existing Bay Shore road to connect to the access road to Cat Island Chain for maintenance activities. However direct access to the Cat Island restoration site may be restricted to protect the habitat. Other access is by water through Green Bay.

<u>References</u>

1) Cat Island Chain Restoration Design Development Report, prepared by W.F. Baird & Associates Ltd. Madison, Wisconsin, April 28, 2005.