UPPER MISSISSIPPI RIVER RESTORATION

ENVIRONMENTAL MANAGEMENT PROGRAM

POST-CONSTRUCTION

PERFORMANCE EVALUATION REPORT

2014

FOR

BERTOM AND McCARTNEY LAKES

HABITAT REHABILITATION AND ENHANCEMENT PROJECT

US Army Corps
of Engineers ®
Rock Island District

MISSISSIPPI RIVER POOL 11

RIVER MILES 599-603

GRANT COUNTY, WISCONSIN

ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

General. The design of the Bertom and McCartney Lakes Habitat Rehabilitation and Enhancement Project (HREP) was to provide the physical conditions necessary to improve and enhance wetland habitat quality. As stated in the 1989 Definite Project Report (DPR), the Bertom and McCartney Lakes HREP was undertaken to address the following primary problem: sedimentation from fluvial processes and upland erosion decreasing the extent and diversity of aquatic habitat in the backwater complex. The project was constructed between January 1990 and October 1991.

Purpose. The purposes of this Performance Evaluation Report (PER) are as follows:

1. Document the pre and post-construction monitoring activities for the Bertom and McCartney Lakes HREP.
2. Summarize and evaluate project performance on the basis of project goals and objectives as stated in the Definite Project Report (DPR).
3. Summarize project operation and maintenance efforts, to date.
4. Provide recommendations concerning future project performance evaluation.
5. Share lessons learned and provide recommendations concerning the planning and design of future HREP projects.

Project Goals and Objectives. The specific goals and objectives as stated in the DPR were to:

1. Enhance Aquatic Habitat
    a. Restore deep (>6 feet) aquatic habitat volume.
    b. Restore lentic-lotic habitat access cross-sectional area.
    c. Increase rock substrate aquatic area.
    d. Establish mussel bed.
    e. Reduce movement of bedload sediment into Bertom Lake.
    f. Improve dissolved oxygen concentrations during critical seasonal stress periods
2. Enhance Migratory Waterfowl Habitat
    a. Establish aquatic vegetation bed.

Project Performance Monitoring. Pre and post-project monitoring, both qualitative and quantitative, was performed in accordance with the Appendix A, Project Evaluation Plan, from the original DPR. Monitoring and performance evaluation was conducted by the U.S. Army Corps of Engineers, and the Wisconsin Department of Natural Resources. The period of data collection covered in this report includes the pre-project monitoring year 1987, quantitative and qualitative post-project monitoring through 2014, and anecdotal information through 2014.

Evaluation of Project Objectives. For the evaluation period of 2003 to 2013, observations were made with regard to the efficacy of the objectives in meeting project goals. In addition, general conclusions were drawn regarding project measures that may affect future project design.

1. RESTORE DEEP AQUATIC HABITAT
    a. Restore deep (6 feet) aquatic habitat
        i. Evaluation Criteria: 200 acre-feet of habitat greater than 6 feet in depth by Year 50.
        ii. Pre-project condition: Zero acre-feet of deep aquatic habitat.
        iii. General Observation: Sedimentation of the McCartney Lake dredge cuts has occurred, but the fish communities are doing well.
        iv. Results: Total habitat volume greater than 6 feet in depth is 35 acre-feet.
        v. Success: The objective for volume of deep aquatic habitat has not been met.
        vi. Conclusion: The project has been successful in terms of biological response, but unsuccessful in maintaining the desired volume of deep aquatic habitat.
        vii. Lessons Learned & Recommendations: The objective of 200 acre-feet is based on apparent miscalculation of as-built deep aquatic habitat volume. The revised as-built volume is 114 acre-feet. The recommended revised objective is 80 acre-feet.

    b. Restore lentic-lotic habitat access cross-sectional area
        i. Evaluation Criteria: 1800 square feet of average cross sectional area by Year 50.
        ii. Pre-project condition: 300 square feet average cross sectional area.
        iii. General Observation: Sedimentation has reduced cross sectional area.
        iv. Results: Average cross-sectional area is 1460 square feet based on 2013 survey.
        v. Success: The evaluation criteria has not been met.
        vi. Conclusion: The project has been unsuccessful at maintaining as-built cross-sectional area, however biological monitoring indicates that fisheries have not been impacted.
        vii. Lessons Learned & Recommendations: Continued surveying of the channel transects is recommended.

    c. Increase rock substrate aquatic habitat
        i. Evaluation Criteria: 10,000 square yards of rock habitat by Year 50
        ii. Pre-project condition: Zero square yards of rock habitat.
        iii. General Observation: Some erosion and sedimentation has occurred within the Habitat Channel. However, fish species diversity has increased over time.
        iv. Results: Last sedimentation survey conducted in 2006, minimal erosion and sedimentation (0.5 to 1 foot) since project construction.

v. Success: Due to a lack of current survey information, the area of rock habitat cannot be determined. The biological response is positive, inferring that sufficient rock habitat is currently present.
vi. Conclusion: The project appears successful in maintaining adequate rock habitat based on biological response.
vii. Lessons Learned & Recommendations: In addition to conducting sedimentation survey, add criteria to survey to determine presence or absence of rock, and conduct concurrently with mussel surveys.

d. Establish mussel bed
    i. Evaluation Criteria: 10 mussels per square yard by Year 50.
    ii. Pre-project condition: Zero mussels per square yard.
    iii. General Observation: Habitat conditions are suitable for mussels, but the effectiveness of the mussel bed has not been assessed.
    iv. Results: 1.6 live mussels per square yard.
    v. Success: Minimally successful.
    vi. Conclusion: Habitat conditions are adequate, but other factors may be influencing.
    vii. Lessons Learned & Recommendations: Continued monitoring to determine if re-colonization is occurring.

e. Reduce movement of bedload sediment into Bertom Lake
    i. Evaluation Criteria: Decrease sedimentation rate to 0.55 inches per year by Year 50.
    ii. Pre-project condition: 0.7 inches per year sedimentation rate.
    iii. General Observation: Sedimentation has occurred at moderate rate.
    iv. Results: Sedimentation rates for the evaluation period (1988-13) are 0.9 inches per year for Bertom Lake and adjacent sloughs.
    v. Success: The sedimentation rate of $\leq$ 0.55 inches per year has not been met.
    vi. Conclusion: The project was unsuccessful in meeting the objective and project goal.
    vii. Lessons Learned & Recommendations: Recommend continued surveying of channel transects.

f. Improve dissolved oxygen (DO) concentration during critical seasonal stress periods
    i. Evaluation Criteria: Dissolved oxygen greater than 5 mg/L by Year 50.
    ii. Pre-project condition: <5.0 mg/L dissolved oxygen.
    iii. General Observation: Project has been effective the majority of the time at providing sufficient DO concentrations.
    iv. Results: Average summer DO concentrations are between 7.8 and 9.4 mg/L. Average winter DO concentrations range from 15.04 to 15.09

mg/L. Average DO concentration for 2006 to 2010 monitoring period is 9.9 mg/L.

v. Success: The goal of DO concentrations > 5 mg/L has been met the majority of the time.

vi. Conclusion: The project has been successful at improving DO concentrations during critical seasonal stress periods, as indicated by pre-project to post-project comparisons.

vii. Lessons Learned & Recommendations: Diurnal fluctuations in DO concentrations in backwaters of the UMR during the summer months are typical. It is not uncommon for nighttime DO concentrations to fall below 5 mg/L. These short-term excursions below 5 mg/L do not appear to significantly impact fish because it is rare for fish kills to be reported. If a numerical DO concentration criterion is used for future HREPs, it is recommended that diurnal DO fluctuations somehow be accounted for in determination of the criterion.

2. ENHANCE MIGRATORY WATERFOWL HABITAT
   a. Establish aquatic vegetation bed
      i. Evaluation Criteria: 10 acres of aquatic vegetation bed.
      ii. Pre-project conditions: Zero acres aquatic vegetation bed.
      iii. General Observation: Semi-aquatic vegetation is prevalent in the project area.
      iv. Results: In the HREP area 40 to 60 percent of sample sites were vegetated compared to 3 to 20 percent of the rest of Pool 11.
      v. Success: Greater than 10 acres of semi-aquatic vegetation is estimated.
      vi. Conclusion: The project was successful in meeting the project goal.
      vii. Lessons Learned & Recommendations: Recommend utilizing UMRCC and LTRMP monitoring data for future assessments instead of aerial photography analysis.

The HREP features have been degraded since construction, particularly since the early 2000's. Sedimentation is the primary reason, impacting the dredged areas, the habitat channel and access. However, DO concentrations have improved and appear fairly stable, fisheries have had a positive biological response, and semi-aquatic vegetation is prevalent.

Evaluation of Project Operation and Maintenance. The O&M manual was completed in March 1996. Periodic maintenance is required on the closing structure. O&M costs through 2012 are approximately $4,820 based on sponsor provided data. Regular site inspections by the USFWS Refuge Manager have resulted in proper coordination and corrective maintenance actions.

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FIGURES

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UPPER MISSISSIPPI RIVER RESTORATION
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1. INTRODUCTION

The Upper Mississippi River Restoration Environmental Management Program (UMRR-EMP) is a Federal-State partnership to manage, restore and monitor the UMR ecosystem. The UMRR-EMP was authorized by Congress in Section 1103 of the Water Resources Development Act of 1986 (Public Law 99-662) and reauthorized in 1999. Subsequent amendments have helped shape the two major components of EMP – the Habitat Rehabilitation and Enhancement Projects (HREPs) and Long Term Resource Monitoring (LTRM). Together, HREPs and LTRM are designed to improve the environmental health of the UMR and increase our understanding of its natural resources.

Habitat Rehabilitation and Enhancement Project (HREP) construction is one element of the UMRR-EMP. In general, the projects provide site-specific ecosystem restoration, and are intended and designed to counteract the adverse ecological effects of impoundment and river regulation through a variety of modifications, including flow introductions, modification of channel training structures, dredging, island construction, and water level management. Interagency, multi-disciplinary teams work together to plan and design these projects.

The Bertom and McCartney Lakes HREP is part of the UMRR-EMP. This project consisted of hydraulic diversions (i.e., partial closing structures), dredging, and island building in a degraded backwater complex to increase dissolved oxygen for overwintering fish. Dredged material created an island with interior wetlands and native vegetation colonization.

1.1 Purpose of Project Evaluation Reports

The purposes of this Project Evaluation Report for the Bertom and McCartney Lakes HREP (known in this report as HREP) are to:

1. Document the pre and post-construction monitoring activities for the HREP
2. Summarize and evaluate project performance on the basis of project goals and objectives as stated in the Definite Project Report (DPR)
3. Summarize project operation and maintenance efforts, to date
4. Provide recommendations concerning future project performance evaluation
5. Share lessons learned and provide recommendations concerning the planning and design of future HREP projects

1.2 Scope

This report summarizes available monitoring data; operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) information; and project observations made by the U.S. Army Corps of Engineers (USACE), the Wisconsin Department of Natural Resources (WDNR), U.S. Fish and Wildlife Service (USFWS), the Upper Mississippi River Conservation Committee (UMRCC), and the Long Term Resource Monitoring Program (LTRMP) Wisconsin Field Station. The period of data collection covered in this report includes the pre-construction monitoring (1987) to post-construction monitoring as of 2014.

1.3 Project References

Published reports which relate to the Bertom McCartney HREP are presented below.

1. Bertom and McCartney Lakes Rehabilitation and Enhancement, Upper Mississippi River System Environmental Management Program, Definite Project Report (R-3) with Integrated Environmental Assessment, Pool 11, Upper Mississippi River, Grant County, WI; Rock Island District USACE. June 1989.
2. Bertom and McCartney Lakes Rehabilitation and Enhancement, Upper Mississippi River System Environmental Management Program, Post Construction Initial Performance Evaluation Report (PER3F), Pool 11, Upper Mississippi River, Grant County, WI; Rock Island District USACE. May 1995.
3. Bertom and McCartney Lakes Rehabilitation and Enhancement, Upper Mississippi River, Environmental Management Program, Operation and Maintenance Manual, Pool 11, River Miles 599-603, Grant County, WI; Rock Island District USACE. March 1996. Contract DACW90-C-0020, March 1996.
4. Bertom and McCartney Lakes, Upper Mississippi River System, Environmental Management Program, 10 Year Post Construction Performance Evaluation Report, Pool 11, River Miles 599-603, Grant County, WI; Rock Island District USACE. May 2002.
5. Bertom and McCartney Lakes, Upper Mississippi River System, Environmental Management Program, 11-Year Post Construction Addendum to the 10-Year Performance Evaluation Report, Pool 11, River Miles 599-603, Grant County, WI; Rock Island District; September 2003.

6. Bertom and McCartney HREP 2009 Annual Inspection Report, Upper Mississippi River National Wildlife Refuge; USFWS. August 2009.

1.4 Project Location

The HREP is located in Grant County, Wisconsin, on the east bank of Pool 11 of the Mississippi River, between river miles 599 and 603, and is three river miles south of Cassville, Wisconsin (Figure 1 – Bertom and McCartney Lakes HREP project area). The project is operated by the USFWS as part of the Upper Mississippi River National Wildlife and Fish Refuge.

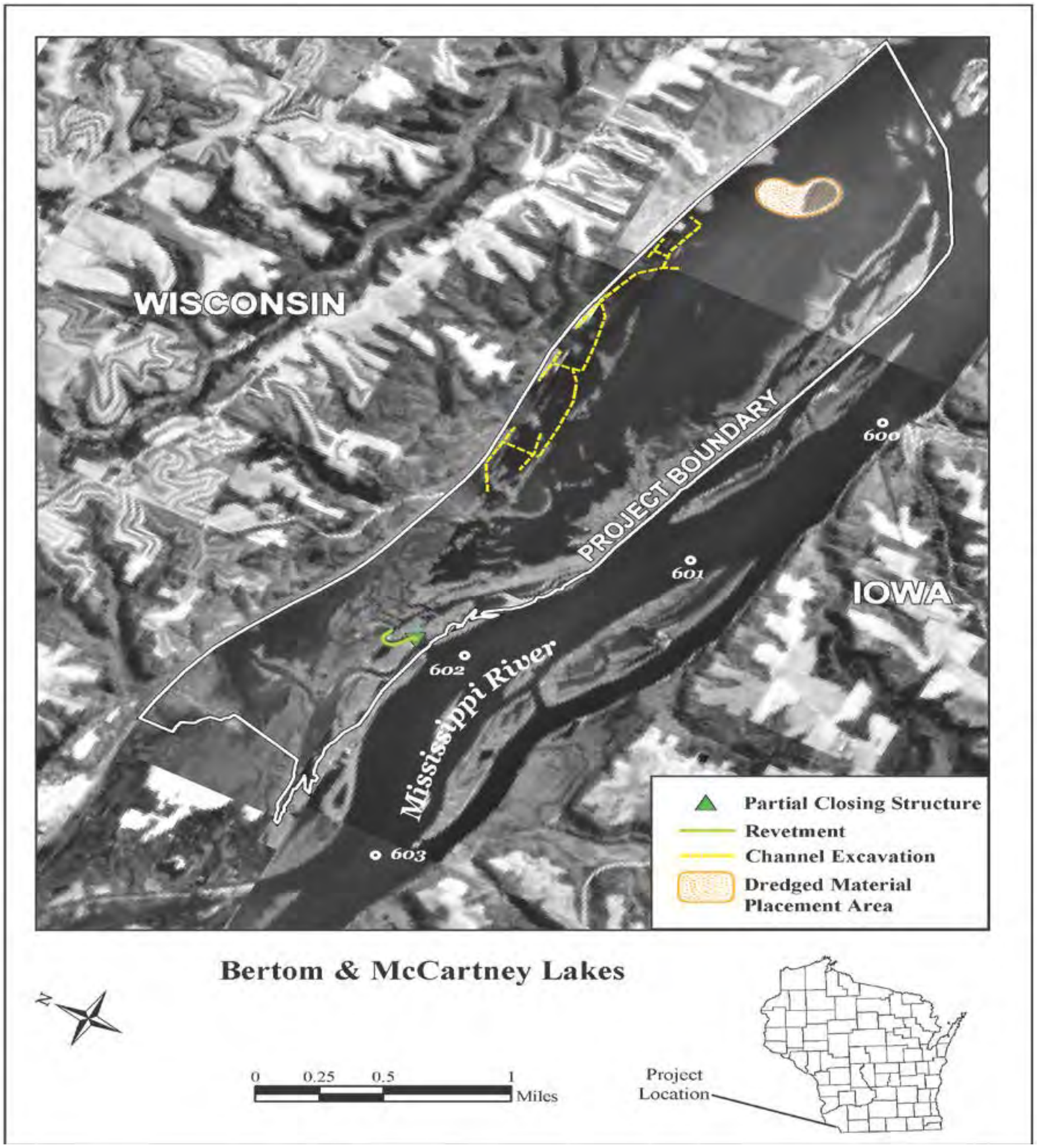


Figure 1. Bertom and McCartney Lakes HREP Project Area

2. PROJECT PURPOSE

2.1 Overview

The Bertom and McCartney Lakes HREP was constructed between 1990 and 1991 using hydro-geomorphic principles to design measures to improve aquatic habitat (Table 1). A partial closing structure was constructed at the head of Coalpit Slough, which is the main side channel leading into the upper end of the Bertom and McCartney Lakes backwater complex. The purpose of the partial closing structure is to reduce flow into the area and also reduce bedload sedimentation rates in the backwaters. Fish and mussel habitat was also enhanced in the upper 1,500 feet of Coalpit Slough using a variety of features.

Backwater dredging was done in isolated backwater bays to improve year-round fisheries habitat. These dredged areas were connected by dredging an 8,200 foot long channel which provides increased side channel flow into the backwater areas. Approximately 375,000 cubic yards of material were hydraulically dredged and placed at a 22 acre confined disposal site (CDF). The CDF was constructed by creating a sand dike around the perimeter of the site. The sand was hydraulically dredged from what would become the interior of the CDF. This was done to increase capacity of the CDF. The CDF island also blocked wind from the south to reduce wind-waves, which increase local turbidity in large, shallow, open-water lakes and impoundments.

Table 1. Problems, goals, objectives, and measures

PROBLEMS	GOALS	OBJECTIVES	RESTORATION MEASURES
Fluvial processes and upland drainage system erosion led to sedimentation and loss of aquatic habitat	Restore Aquatic Habitat	1) Restore deep (6 ft) aquatic habitat 2) Restore lentic-lotic habitat cross-sectional area 3) Increase rock substrate aquatic habitat 4) Establish mussel bed 5)Reduce movement of bedload sediment into Bertom Lake 6) Improve dissolved oxygen concentrations during critical seasonal stress periods	Dredging Side Channel Excavation Fish & mussel rock habitat Fish & mussel rock habitat Partial closure structure Dredging
	Enhance Migratory Waterfowl Habitat	Establish aquatic vegetation bed	In-water confined dredged material placement site

3. PROJECT DESCRIPTION

3.1 Project Measures

The HREP included a combination of hydraulic dredging, habitat construction and dredged material placement (see Figure 2 for general locations of measures). A Site Plan (Sheet C-101) is included in Appendix D. A description of each of these measures is provided below.

1. Submerged Rock Partial Closing Structure. The partial closing structure reduces the movement of Mississippi River bedload sediment directly into the Bertom and McCartney Lakes complex. The structure has 1:1 side slopes with a 5-foot bench on the riverside slope.

2. Deep Aquatic Habitat. Hydraulic dredging of approximately 375,000 cubic yards of fine-grained material from McCartney Lake side channels and sloughs was done to ensure a minimum water depth of 6 feet throughout the project life. The dredging was designed to increase the amount of deep-water habitat and encourage the flow of oxygen-rich main channel water into Bertom and McCartney Lakes.

3. Dredged Material Placement Site. The dredged material was placed in an in-water confined dredged material placement site. A dredged material containment dike surrounds the placement site. The site is approximately 22 acres with a 4,500 foot perimeter shoreline.

4. Fish and Mussel Rock Habitat Channel. A fish and mussel rock Habitat Channel was constructed to improve aquatic habitat in the inlet channel to Bertom Lake by providing a rock substrate channel bottom and installing fish structures. The components consisted of 1,500 linear feet of graded rock, 25 sections of concrete pipe and submerged timber structures.

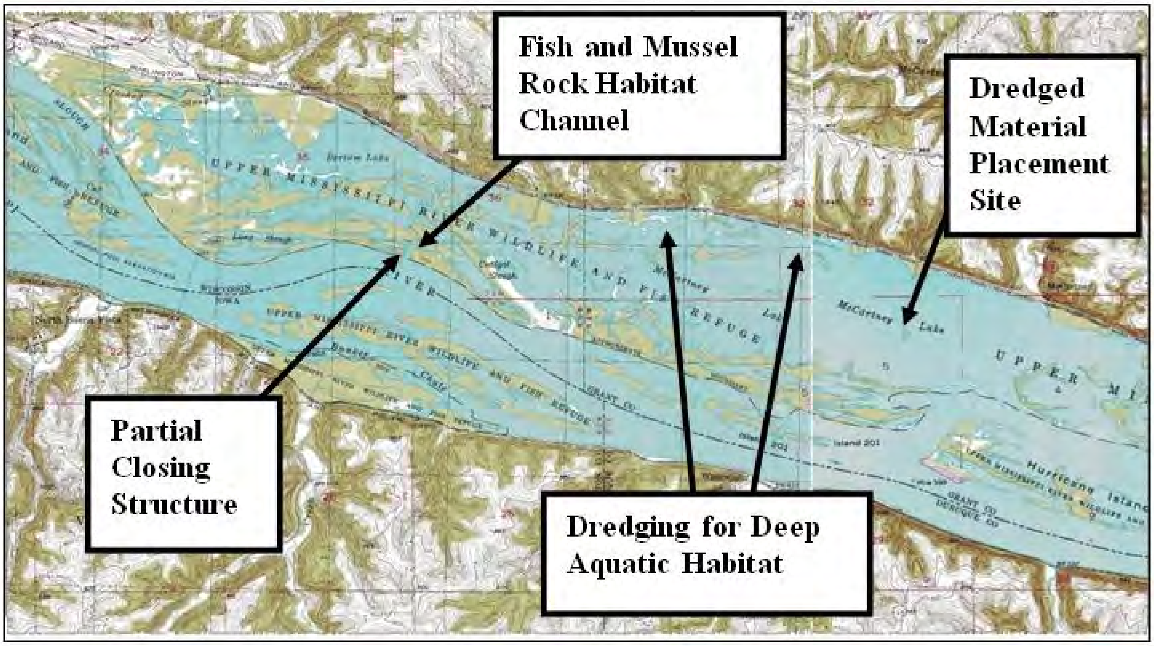


Figure 2. Bertom & McCartney Lakes HREP Project Measures

3.2 Project Construction

The HREP was approved for construction in January 1990 at an estimated cost of $1,866,277 (equivalent to $3,403,000 in FY12). Dredging and confined placement of the dredged material in McCartney Lake began during the late summer of 1990 and was essentially completed in the fall of 1991. The rock substrate and partial closing structure construction also began in the late summer of 1990 and was completed in the fall of 1991. Final Inspection of the project was performed after the vegetation at the dredged material placement site was given a growing season to establish itself. This time was allowed to address concerns that seeding or earthwork would be needed in sandy areas to allow sufficient vegetative growth. Adequate vegetation established itself, and this additional work was not needed. A Final Inspection of the project construction was made in the summer of 1992, indicating overall project completion.

3.3 Project Operation and Maintenance

General. In the original DPR it was estimated that the HREP would require little or no maintenance. Operation and maintenance responsibilities for the HREP were originally outlined in the DPR. The acceptance of these responsibilities was formally recognized by an agreement signed by the USFWS and the Rock Island District, USACE.

A detailed description of all operation and maintenance requirements can be found in the Project Operation, Maintenance, Repair, Replacement, and Rehabilitation Manual (OMRR&R Manual). The OMRR&R Manual for the project delegated responsibilities and procedures for post project activities. Project operation and maintenance generally consists of the following:

1. Advance measures ensuring availability of labor and materials.
2. Project Inspections conducted annually each May.
3. Inspection of partial closure structure during and after periods of high water.
4. Inspections of dredge cut in McCartney Lake visually and with sufficient pole soundings.
5. Inspections of Confined Dredged Material Placement site recording usage of site in accordance with management practices.
6. Periodically inspect fish and mussel rock habitat for serviceability and debris, and conduct corrective action based on inspections.

Project Measures Requiring Operation and Maintenance. Maintenance is required on the partial closure structure on an as needed basis to its structural integrity and continued function in the manner for which it was designed. None of the project features have operational requirements. Regular site inspections by the USFWS overall have resulted in proper coordination and corrective maintenance actions. Remaining areas of concern include thinning bank protection material (rock) in the fish and mussel habitat channel and erosion at the end of the channel.

4. PROJECT PERFORMANCE MONITORING

4.1 General

Performance monitoring of the HREP has been conducted by WDNR, LTRMP, UMRCC, USFWS and USACE to help determine the extent to which the design meets the habitat improvement objectives. Information from this monitoring will also be used, if required, for adaptive management.

The monitoring and performance evaluation matrix is outlined in Table 2. Pre and post-project monitoring, both qualitative and quantitative, by each of the involved agencies is summarized below.

1. U.S. Army Corps of Engineers: The success of the project relative to original project objectives shall be measured utilizing data, field observations, and project inspections provided by USFWS, WDNR, and USACE. The USACE was responsible for post-project analyses of sedimentation, water quality, and vegetation. The Corps of Engineers has overall responsibility to measure and document project performance.
2. U.S. Fish and Wildlife Service: The USFWS is responsible for operating and maintaining the HREP. USFWS was responsible for post-project annual field inspections and post-project analysis of aquatic macroinvertebrates, and fish communities. The USFWS does not have project-specific monitoring responsibilities.

3. Wisconsin Department of Natural Resources: The WDNR is responsible for collection of water quality and fish station data.
4. Upper Mississippi River Conservation Committee: The UMRCC ad-hoc submersed aquatic vegetation sampling occurred in Pool 11 in 2001.
5. Long Term Resource Monitoring Program: The LTRMP Wisconsin Field Station sampled Pool 11 during out-pool sampling in 2009.

Table 2. Monitoring and Performance Evaluation Matrix

Activity	Purpose	Responsible Agency	Implementing Agency	Funding Source	Remarks
Sedimentation Problem Analysis	System-wide problem definition. Evaluates planning assumptions	USGS, USACE	LTRMP, Nav Study	N/A	Leads into pre-project monitoring; defines desired conditions for plan formulation (Theiling et al. 2000; WEST Consultants, Inc., 2000)
Pre-project monitoring	Identifies and defines problems at HREP site. Established need for proposed project feature	Sponsor	Sponsor	Sponsor	Attempts to begin defining baseline. See DPR.
Baseline monitoring	Quantifies criteria for performance evaluation	USACE	sponsor thru Cooperative Agreement	WDNR	See DPR for location and sites for data collection and baseline information. Actual data collection will be accomplished during Plans & Specification phase.
Data Collection for Design	Includes identification of project objectives, design of project, and development of performance evaluation plan	USACE	USACE	HREP	Comes after fact sheet. This data aids in defining the baseline
Construction Monitoring	Assesses construction impacts; assess permit conditions are met	USACE	USACE	HREP	Environmental protection specifications to be included in construction contract documents. Inter-agency field inspections will be accomplished during project construction phase
Performance Evaluation Monitoring	Determine success of project as related to objectives	USACE (quantitative), sponsor (field observations)	WDNR, LTRMP, USFWS USACE	HREP, USFWS	Comes after construction phase of project
Analysis of Biological Responses to Project	Evaluates predictions and assumptions of habitat unit analysis. Determine critical impact levels, cause-effect relationships, and effect on long-term losses of significant habitat	USFWS, USACE	USACE, Sponsor	USACE	Problem Analysis and Trend Analysis studies of habitat projects

4.2 Project-Induced Habitat Changes

The HREP project features restored backwater overwintering habitat in isolated backwater pockets and connecting channels. Improved water movement through dredged channels introduced oxygen to improve fish habitat. The CDF decreased aquatic connectivity to reduce wind fetch in a large, shallow, open water impounded area. Natural succession of wetland habitat supports a variety of wildlife on the CDF. The island supports turtle nesting and other wildlife detected by tracks. Pre-project submersed aquatic vegetation (SAV) was uncommon, but SAV was present at 40 to 60 percent of sites in Bertom-McCartney Lake compared to 15 percent or fewer sites vegetated in the rest of Pool 11.

4.3 Non-Project-Induced Habitat Changes

The interior wetland in the CDF was not anticipated. Dredged material may not have filled the entire CDF, or there was more settling than anticipated, which left a depression in the island. Groundwater seepage filled the depression which was colonized naturally with beneficial aquatic plant communities. Wetland vegetation succession was a positive outcome with little effort expended to achieve an early successional cottonwood-willow community.

5. PROJECT EVALUATION

5.1 Construction and Engineering

Dredging and confined placement of the dredged material in McCartney Lake began during the late summer of 1990 and was essentially completed in the fall of 1991. The rock substrate and partial closing structure construction also began in the late summer of 1990 and was completed in the fall of 1991.

5.2 Costs

In the original DPR, cost estimates for the entirety of the project were $3,092,000. Initial construction costs were $1,866,277. Total cost of the HREP including planning, engineering and design and construction management was $2,244,277.

5.3 Operation and Maintenance

In the original DPR, over the 50-year project life the estimated maintenance cost was $275,000. From the estimate, an average annual operation and maintenance cost was calculated to be $5,500. This amount included annual inspections, debris removal and 150 tons of rock replacement per year. To date, the total documented OMRR&R cost has been $4,620, with the estimated average annual cost to be $660.00. Table 3 provides OMRR&R history and cost for the HREP.

Table 3. Operation and Maintenance History for the Bertom & McCartney Lakes HREP*

Year	Years in O&M	Est. Annual Cost with Inflation	Actual USFWS Costs	Activities
1992	1	$6,222	No Data	No Data
1998	7	$7,229	$350	Inspections, Coal-Pit Chute rock work
FY2003	12	$8,162	$1,011	Inspections, clear/plant trees
FY2004	13	$8,383	$704	Inspections
FY2005	14	$8,668	$0	Inspections
FY2006	15	$8,945	$763	Inspections
FY2007	16	$9,218	$0	Inspections
FY2008	17	$9,554	$192	Inspections
FY2009	18	$9,595	$1,400	Inspections
FY2010	19	$9,856	$0	Inspections
FY2011	20	$10,004	$200	Inspections
FY2012	21	$10,300	$200	Inspections

*Operation and Maintenance data source is USFWS.

5.4 Ecological Effectiveness

The HREP objectives and how they pertain to the ecological effects of the project are discussed below. Table 4 summarizes the performance evaluation plan and schedule for the HREP goals and objectives.

Table 4. Performance Evaluation and Monitoring Schedule

Goal	Objective	Enhancement Measure	Units	Monitoring Target Values					Monitoring Schedule
				Year 0 without project (1990)	Year 1 with project (1991)	Year 7 with project (1998)	Year 22 with project (2012)	Year 50 target (2040)	
Enhance Aquatic Habitat	Restore deep (≥6') aquatic habitat volume	Hydraulic Dredging	Acre-Feet	0	114	111	35	80	Perform hydrographic soundings
	Restore lentic-lotic habitat access cross sectional area	Hydraulic Dredging	Sq. Feet	300	NM[a]	NM	1,460	1,800	Perform hydrographic soundings
	Increase rock substrate aquatic habitat	Rock habitat channel	Sq. Yard	0	NM	NM	NM	10,000	Perform profile of rock substrate
	Establish mussel bed	Rock habitat channel	# Per Sq. Yard	0	NM	NM	1.6	10	Perform area mussel survey
	Reduce sedimentation Bertom Lake	Partial Closing Structure	In. Per Year	0.7	NM	0.46[b]	0.9[c]	0.55	Perform hydrographic soundings

Goal	Objective	Enhancement Measure	Units	Year 0 without project (1990)	Year 1 with project (1991)	Year 7 with project (1998)	Year 22 with project (2012)	Year 50 target (2040)	Monitoring Schedule
	Improve DO concentration during critical stress periods	Hydraulic dredging	mg/L	<5.0	>5.0	9.7 (mean)	9.9 (mean)	>5.0	Perform water quality tests at 5 stations
Enhance Migratory Waterfowl Habitat	Establish aquatic vegetation bed	Aquatic Bed/Perched Wetland	Acre	0	NM	NM	>10	10	Perform aerial surveys

a: Not measured b: For evaluation period 1988-1998 c: For evaluation period 1988-2013

A. Restore deep aquatic habitat volume (≥6')

General. Fish habitat was degraded by sedimentation filling backwater lakes and connecting channels to less than 4 feet deep. Low lake volume, lack of thermal stratification, and lack of circulation led to anoxia during winter and summer. Hydraulic dredging was conducted in McCartney Lake and connecting channels to initially create 290 acre-feet of deep aquatic habitat. Dredging increased the amount of deep water habitat volume and encouraged flow of oxygen rich water from the main channel to the lakes. The Year 50 target is 200 acre-feet of habitat greater than or equal to 6 feet in depth.

Pre- and Post-Project Conditions. Pre-project aquatic habitat was negatively affected by loss of aquatic habitat to sedimentation. Deposition in Bertom Lake consisted predominately of sands, while McCartney Lake experienced predominately clay and silt deposition. Year round habitat depths were primary shallow, less than four feet deep in the majority of the project area. Baseline sedimentation studies were conducted prior to the 1991 construction of the HREP. The average sedimentation rate from the years 1938 to 1998 was 0.39 inch/year, with rates in Bertom Lake averaging 0.70 inch/year.

Pre-project fish communities included small numbers of small bluegill and largemouth bass (Figure 3; Appendix A). Post project fish community size structure of both bluegill and bass responded rapidly to restoration measures (Figures 4 and 5). Larger fish moved into the project area the year after restoration, but fish abundance lagged until local-spawned fish grew into the community and began reproducing to develop larger populations. Variable year class strength detected by larger numbers of fish among years can be seen for both bass and bluegill.

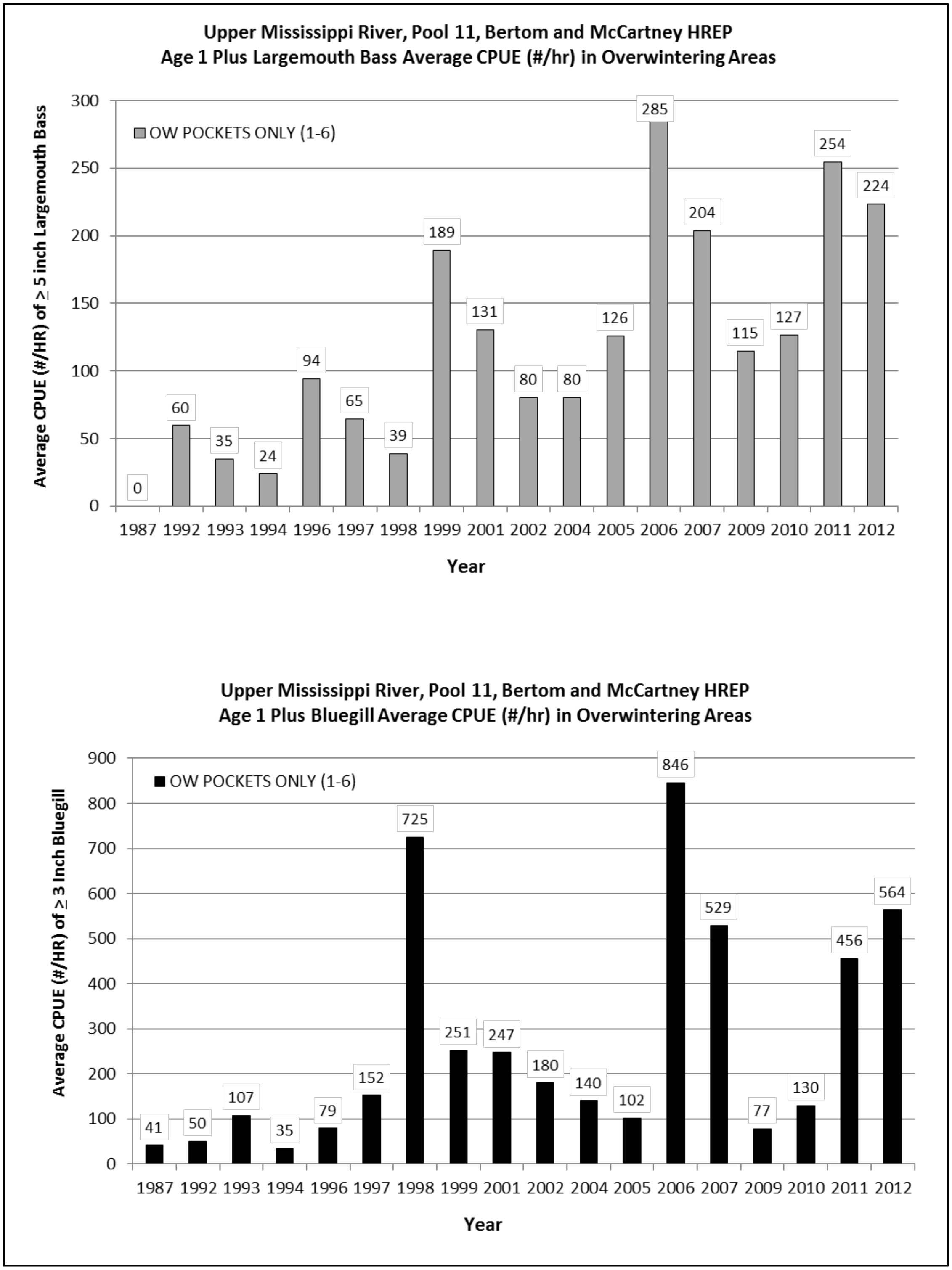


Figure 3. Largemouth bass and bluegill relative abundance from electrofishing samples in Bertom-McCartney Lakes over 15 years (Source: Jeff Janvrin, Wisconsin Department of Natural Resources, unpublished data).

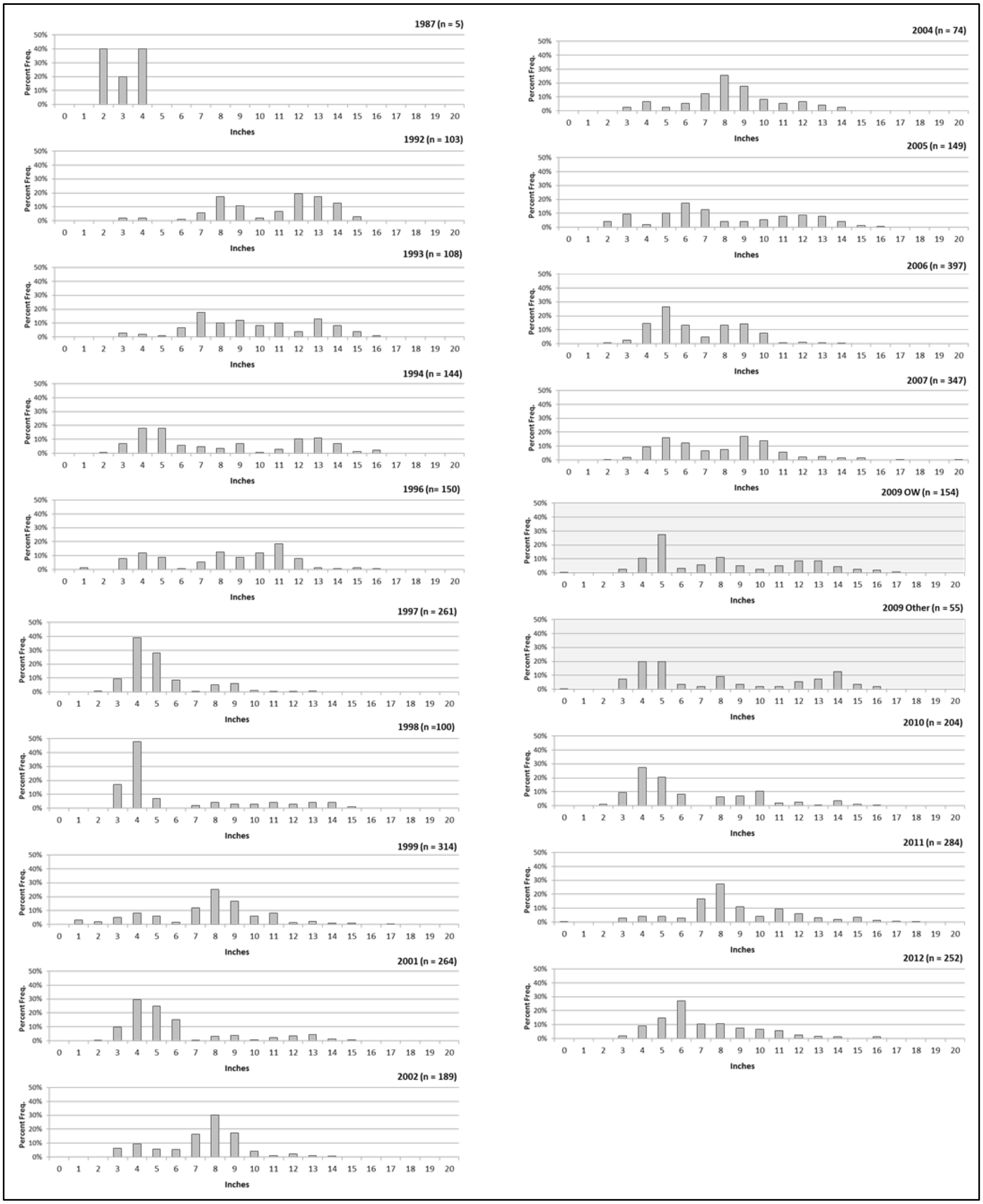


Figure 4. Largemouth bass length frequency at Bertom-McCartney Lakes from electrofishing samples in Bertom-McCartney Lakes over 15 years (Source: Jeff Janvrin, Wisconsin Department of Natural Resources, unpublished data). Left axis is percent frequency, Bottom axis is 1-inch size classes. Changes in year class strength can be observed.

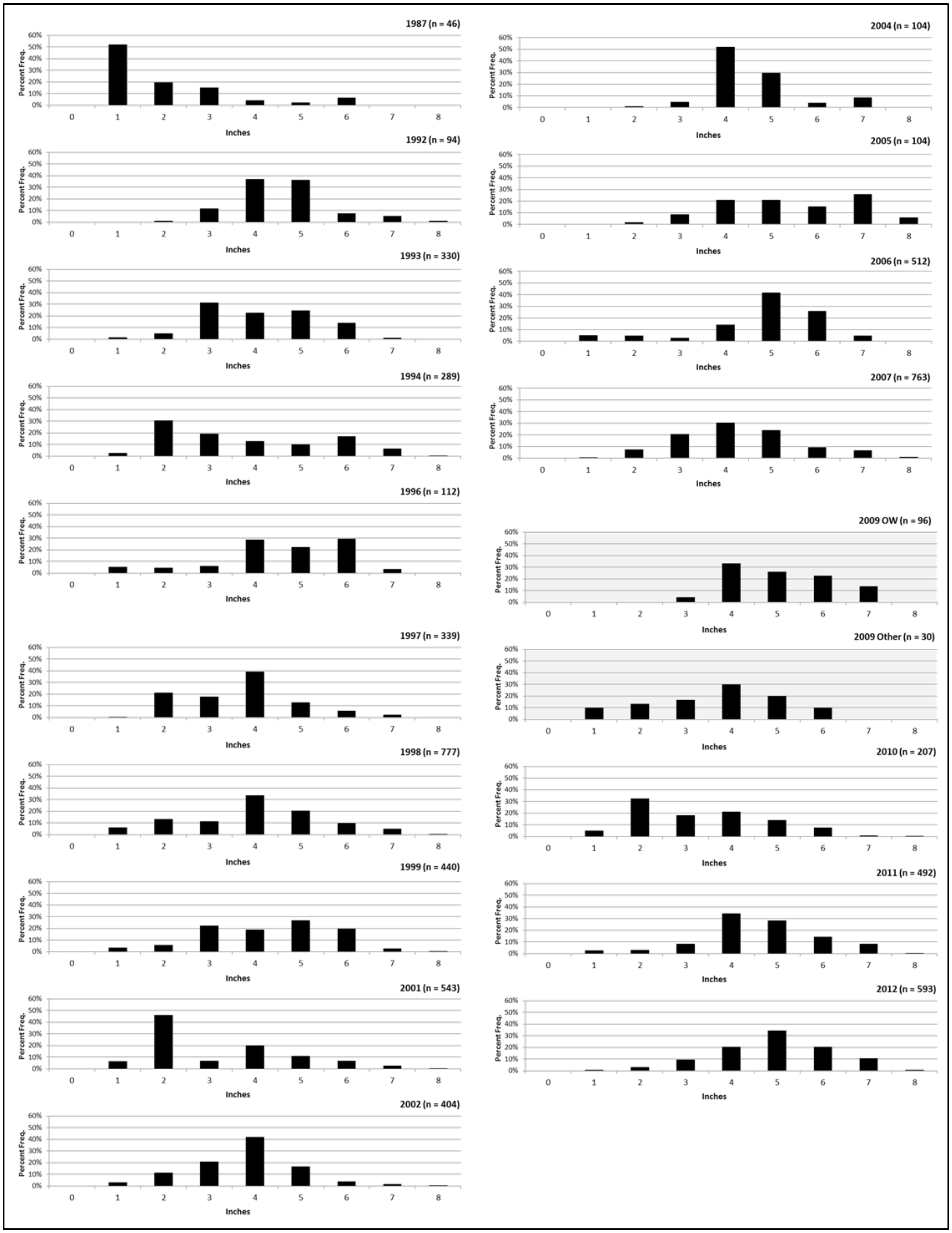


Figure 5. Bluegill length frequency at Bertom-McCartney Lakes from electrofishing samples over 15 years (Source: Jeff Janvrin, Wisconsin Department of Natural Resources, unpublished data). Left axis is percent frequency, Bottom axis is 1-inch size classes. Changes in year class strength can be observed.

Four historical sediment transects are located in the dredged areas of McCartney Lake. These transects are S-M601.2B (located in Channels A and C), S-M600.8B (located in Channels D and F), S-M600.2B (located in Channels G and H) and S-M599.6B (located in Channels I and J). These transects were surveyed in 2013. Transect cross-sections are provided in Appendix D. To determine the volume of deep aquatic habitat, the cross-sectional area was measured for each transect below elevation 597 feet MSL (6 feet below the flat pool elevation of 603 feet MSL). The cross section areas were averaged and applied along the length of the corresponding channels. The total current volume of deep aquatic habitat 6 feet or greater below flat pool was calculated to be 35 acre-feet. This is significantly less than the stated as-built volume of 290 acre-feet or 1998 estimated volume of 263 acre-feet. However, upon further review, it appears the reported volumes for deep aquatic habitat for as-built conditions and for the Year 50 goal are based on the entire volume of the dredged channels below flat pool elevation, not 6 feet below flat pool. A revised measurement of the as-built volume below an elevation of 597 feet MSL gives a total volume of approximately 114 acre-feet. Comparing the ratio of current volume (35 acre-feet) to as-built volume (114 acre-feet) and to the sediment transects, the transects verify that much of the original dredge cut has silted in. Table 5 indicates the change in deep aquatic habitat volume over the 22 year history of the project.

Table 5. Deep Aquatic Habitat Volume, McCartney Lake.

Pre-Project	As-Built (1991)	Year 7 (1998)	Year 15 (2006)	Year 22 (2013)	Year 50 Target (2041)
0	114	111	63	35	80*

* recommended target

Conclusion. Although the sedimentation transects indicate that the physical objective for deep aquatic habitat at has not been met, it appears the project measures were successful based on the biological response. Fish communities responded quite well to improved deepwater winter habitat conditions. The HREP is a popular recreation area that showed improved year-round fishing success. The Year 50 target is recommended to be changed to 80 acre-feet, approximately 70% of the as-built volume.

B. Restore lentic-lotic habitat access cross-sectional area

General. Hydraulic dredging was conducted in McCartney Lake to create deep aquatic habitat as well as lentic-lotic access area. The assessment target for this project objective is an average of 1800 square feet of lentic-lotic access area by Year 50.

Pre- and Post-Project Conditions. Hydraulic connectivity between channels, backwaters, and floodplains is important in large rivers with seasonal flood cycles. The UMRS 9-Ft. Channel Project impounded the river ca. 1940 which increased year-round aquatic habitat connectivity. Impoundment altered river flow and, thus altered, sediment, material, and nutrient transport. Fine sediment load was increased by altered land use basin-wide. Fine sediment settled in backwaters which gradually lost depth, water clarity, aquatic plants, dissolved oxygen, and fish as they became degraded lakes in a process termed "pool aging" (Lubinski, 1998). Connecting channels were transporting excessive flow and bedload that degraded habitat throughout the central flow path in the lake. Backwaters along the Wisconsin bankline were filled with sediment, shallow, and anoxic in winter. A partial closure restricted flow to the project area. The DPR indicated that pre-project lentic-lotic access area was 300 square feet.

Areas with lentic-lotic access issues occur in McCartney Lake. These areas were dredged and labeled Channels A, C, F, H, K and J. Dredged backwater areas create suitable volume for fishes to overwinter; the connecting channels direct a gentle flow of oxygen-rich water to the dredged holes. Historical sedimentation survey transects are located in the channels: S-M601.2B is located in Channels A and C, S-M 600.8B is located in Channel F, S-M 600.2B is located in Channel H and S-M 599.6B is located in Channel J. No survey transect is located in Channel K. The cross sectional area of each channel below flat pool elevation of 603 feet MSL was determined for the 2013 survey data. In addition, the cross sectional area of each channel below flat pool elevation was determined for the as-built conditions.

The average cross-sectional area for Channels A, C, F, H and J is 1,460 square feet for the 2013 survey data. The average as-built cross-sectional area for the same channels is 2,400 square feet.

Conclusion. The project measures were not successful in maintaining the as-built lentic-lotic access area. The Year 50 target of 1800 square feet is not being met. Sedimentation appears to be occurring in the dredged areas of McCartney Lake at a quicker rate than anticipated in the DPR. Although the access area goal has not been met, the biological data for McCartney Lake indicates the habitat is not degraded to a point where the biota is clearly impacted. It is recommended that hydrographic surveys of the transects are completed in the next scheduled PER in FY 2018.

Access to overwintering sites is important for fish migrations and water exchange. Improved connections between the dredged backwaters and connecting channels increased opportunities for fish movement and oxygen exchange. Loss of cross-sectional area in backwater openings is a factor that will need to be monitored in the future and corrected if dissolved oxygen concentrations in the lakes decline.

C. Increase rock substrate aquatic habitat

General. Fish and mussel habitat was enhanced in the Habitat Channel using a variety of features: dredging, lining the bottom with different gradations of rock, bank stabilization with rip-rap, placement of concrete culverts for fisheries habitat and the placement of submerged timber structures (i.e., LUNKER structures) to provide underwater openings. The Year 50 assessment target is 10,000 square feet of substrate habitat suitable for fish and mussels.

Pre- and Post-Project Conditions. Two areas were sampled to determine fisheries response to construction of the Habitat Channel. One area that serves as a control is an unimproved channel that flows “upstream”, to the west, just after the partial closing structure. The other area is the entire length of the Habitat Channel. Prior to the project, the primary species using the both channels were "rough" fish (carp, buffalo, suckers, etc.) with only a few fish considered desirable by anglers (walleye, sauger and catfish; Appendix A).

A comparison of pre and post-project monitoring shows an increase in the number of species and numbers of individuals caught using the Habitat Channel with little to no change in the control (Appendix A). Post project sampling in the Habitat Channel and control channel show higher species numbers in the Habitat Channel after project completion in 1990 (Table 6 and Appendix A). Numbers of popular sportfish, including walleye, largemouth bass, and smallmouth bass have increased. Abundance of carp has declined (Appendix A). Habitat structures within the slough showed little change over time.

Table 6. Number of fish species in Bertom-McCartney Habitat Channel and nearby control site.

Year	Number of Species	
	Habitat Channel	Control Channel
1987	14	21
1988	18	22
1990	17	14
1993	9	7
1994	25	19
1996	5	No Data
1999	15	10
2001	8	No Data
2004	4	1
2005	3	1
2006	7	3
2010	14	No Data

There are two historical sedimentation transects within the Habitat Channel. S-M602.1J is located at the Habitat Channel entrance, and S-M602.1G is located downstream midway through the Channel. Hydrographic soundings were conducted at these transects in 1993, 1998, 2002 and 2006. These transects were not surveyed in 2013. Channel hydrographic transects are provided in Appendix D. Based on the most recent data from 2006, the channel cross sections overall retained the same shape and depths as originally constructed. The west side of the Habitat Channel at S-M602.1J experienced minor erosion (approximately 0.5 feet) from 1993 to 2006. The east side of the channel at S-M602.1J experienced more significant erosion on the order of approximately 2 to 4 feet from 1993 to 2006. The channel retained roughly the same profile in this location. Transect S-M602.1G experienced 0.5 to 1.0 feet of erosion or sedimentation during the 1993 to 2006 monitoring period. Overall the channel shape and depth at this location is very similar to original construction, the most significant change being a shifting of the east bank westward by approximately five feet. The S-M602.1J and S-M602.1G channel hydrographic transects are provided in Appendix D on Sheet C-302. The USFWS noted in a 2009 inspection report that at the Habitat Channel entrance some water is flowing toward an adjacent channel rather than through the Channel, erosion was occurring at the end of the channel rock on the east bank, and that some bank protection rock was thinning.

Conclusion. Biologically, the Habitat Channel is functioning as expected and appears sustainable. Water flow through the area is maintained for sufficient access and oxygen transport, although flow may be diverting to an alternate channel. Fish are using the habitat channel.

Due to the lack of current hydrographic survey data in this location, it cannot be determined with any certainty that the original rock substrate is still exposed. Although no survey data has been collected in the channel since 2006, it can be assumed based on the sedimentation and erosion observations from 1993 to 2006 that the channel has maintained roughly the same profile, and therefore that most of the rock substrate was likely in place in 2006. Based on this and the fisheries data mentioned above, the project measures appear minimally successful in maintaining rock substrate habitat, although no quantitative assessment can be given at this time. It is recommended that hydrographic surveys of the two Habitat Channel transects include a description of the channel bank and bed is completed in the next scheduled PER.

D. Establish mussel bed

General. Graded rock was added to the inlet channel to Bertom Lake. Several gradations of rock were included. The assessment target for this objective is 10 mussels per square yard in the inlet channel by Year 50.

No mussel surveys have been conducted prior to 2014 due to lack of funds, personnel or unsafe diving conditions.

Pre- and Post-Project Conditions. The access channel to Bertom-McCartney side channel-backwater complex was increasing in flow capacity with erosion of a river-side natural levee. Bedload transport created a sand, silt, and clay substrate depending on local flow. Swift flowing areas were sandier and low flow areas accumulate silts. The entire channel was dredged and lined with different graded rock substrates to assess the best substrate for future potential mussel bed rehabilitation.

A mussel survey was conducted by a joint effort of USACE Rock Island District and St. Paul District, Minnesota DNR and Wisconsin DNR staff on October 7th through 9th, 2014. Qualitative and quantitative survey methods were utilized. The survey indicated a density of 1.6 live mussels per square yard. A detailed report of the survey is included in Appendix E.

Conclusion. Habitat conditions are suitable for freshwater mussels, but the assessment target has not been met. Although present mussel community density and diversity are about half of that of healthy mussel beds on the UMR, the data indicate that if habitat conditions are suitable (including adequate host fish habitat) and source populations are nearby, mussels can recolonize habitat that has been created or modified for mussels without being artificially supplemented. Of the additional mussel species that occur in UMR Pool 11 which have not re-colonized, there is potential for additional species to re-colonize the area given more time. Similarly, Kelner and Davis (2002) and Sietman *et. al.* (2001) reported a reduced mussel community than historically occurred in the reaches. It appears populations have remained stable in the past decade and it remains unknown at this time if additional species will naturally re-colonize those reaches. The Bertom and McCartney fish and mussel Habitat Channel should be monitored 5 and 10 years in the future to assess whether the mussel community continues to colonize.

E. Reduce movement of bedload sediment into Bertom Lake

General. Construction of a partial closing structure across Coalpit Slough, originally perceived to be a major access point for river bedload materials to this backwater complex, was eliminated from the selected design following evaluation of soundings which revealed an existing, natural submerged berm at this location. This berm was already providing the bedload impedance that is desired. Dredging in Bertom Lake was removed from the plan due to the potential disruption of existing migratory waterfowl habitat. A submerged partial closure structure was placed in the inlet channel to Bertom Lake. The structure was designed to reduce the amount of bedload sediment moving into Bertom Lake. The Year 50 target for this objective is to reduce the sedimentation rate to 0.55 inches per year.

Pre- and Post-Project Conditions. Pre-project aquatic habitat was negatively affected by loss of aquatic habitat to sedimentation. Deposition in Bertom Lake consisted predominately of sands, while McCartney Lake experienced predominately clay and silt deposition. Year round habitat depths were primary shallow, less than 4 feet deep in the majority of the project area.

Baseline sedimentation studies were conducted prior to the 1991 construction of the HREP. The average sedimentation rate from the years 1938 to 1988 was 0.39 inch/year, with rates in Bertom Lake averaging 0.70 inch/year. For the period 1988 to 1998, the sedimentation rate was calculated as 0.46 inch/year.

Historic sedimentation transects are present at various locations in Bertom Lake and the sloughs connecting the Lake to the main channel. Two transects, S-M602.1J an S-M602.1G, were last surveyed in 2006. These two transects are located the Habitat Channel. Eight transects, S-M602.1D, S-M602.3B, S-M602.2B, S-M602.0B, A, B, E and L were last surveyed in 2013, and are located within Bertom Lake or adjoining sloughs. Channel hydrographic transects are provided in Appendix D. Sedimentation rates between 2002 and 2006 were determined for the Habitat Channel, as those transects only have 2006 survey data. Sedimentation rates between 2006 and 2013 were determined for the remaining transects.

The average sedimentation rate for the Habitat Channel for the time period 2002 to 2006 is 0.85 inches per year. The average sedimentation rate within Bertom Lake for the time period 2006 to 2013 is 1.5 inches per year. The average sedimentation rate in the adjoining sloughs for the time period 2006 to 2013 is 1.5 inches per year.

The average sedimentation rate for the Habitat Channel for the time period 1991 to 2006 is -0.6 inches per year. This negative rate is indicative of significant scouring occurring between 1991 and 1993 (post flood) and during the 1998 to 2002 time period. The average sedimentation rate within Bertom Lake for the time period 1988 to 2013 is 0.9 inches per year. No additional data outside of the 2006-2013 time period is available for the adjoining sloughs.

Conclusion. The project measures were minimally successful in reducing bedload sediment into Bertom Lake. The average sedimentation rates in Bertom Lake and adjoining sloughs exceed the objective of 0.55 inches per year. It is recommended that hydrographic surveys of the transects are completed in the next scheduled PER.

F. Improve dissolved oxygen concentration during critical seasonal stress periods

General. Hydraulic dredging was conducted in McCartney Lake to encourage flow of oxygen rich water from the main channel to the lakes. The Year 50 target for this objective is a dissolved oxygen concentration of 5.0 mg/L in the HREP.

Pre- and Post-Project Conditions. Pre-project water quality was considered adequate for wildlife support during most time periods, but there were occasions during summer and winter where dissolved oxygen concentrations fell to detrimental levels. Because of sediment deposition, some areas within the project site had become isolated from oxygenated, flowing water sources. Groundwater interactions and decaying aquatic vegetation further reduced dissolved oxygen concentrations during critical periods such as under snow and ice cover. By selectively dredging access channels to these isolated areas, it was anticipated that the occurrence of low dissolved oxygen concentrations could be avoided.

Water quality monitoring at this project was suspended after the 2002 PER for several years. Water quality monitoring resumed in December 2006 and continued through March 2010 with a combination of instantaneous and continuous monitoring. During the summer months of June through September, data were collected at sites W-M599.2C, W-M599.5D, W-M599.8B, and W-M600.3C. During the winter months from December through March, data were collected at sites W-M599.8B and W-M600.3C only. Parameters measured included dissolved oxygen, pH, water temperature, water depth, specific conductance, secchi disk depth, wave height, water velocity, air temperature, percent cloud cover, wind speed and direction, total alkalinity, suspended solids, turbidity, chlorophyll a, b, and c, and pheophytin a.

The target minimum dissolved oxygen concentration for this project is 5.0 mg/L during both the winter and summer seasons. The trend of improved dissolved oxygen concentrations following project construction has continued through the most recent monitoring period. The mean DO concentration from all four stations for the 2006 to 2010 monitoring period was 9.9 mg/L. The data are discussed in detail in Appendix C and summarized here. For this monitoring period, no readings were observed below 5.0 mg/L during the winter months. High concentrations were common, with values occasionally supersaturated. The average winter concentrations were 15.09 mg/L at Site W-M600.3C and 15.04 mg/L at Site W-M599.8B. Similar results were observed by WDNR personnel.

During the summer months, continuous monitoring data showed diurnal variations in dissolved oxygen concentrations, with nighttime concentrations sometimes falling below 5.0 mg/L at Site W-M599.2C. The longest observed period of concentrations below 5.0 mg/L occurred over 3 days during August 2007 at Site W-M599.2C. The average grab sample concentrations varied from 7.80 mg/L to 9.44 mg/L between the four sites. Very few instances of low concentrations were observed by instantaneous monitoring. Low dissolved oxygen was detected in grab samples on July 17, 2007 at Sites W-M600.3C (4.26 mg/L), W-M599.8B (3.91 mg/L), and W-M599.2C (4.40 mg/L). The dissolved oxygen concentration fell below 5.0 mg/L at Site W-M600.3C one other time; the concentration was 3.76 mg/L on August 14, 2007.

Conclusion. The project measures were mostly successful in providing the ability to meet the desired concentration of dissolved oxygen in the deepwater habitat areas. The dredging of channels has improved the circulation of water within the backwater complex and in particular to previously isolated areas. Adequate oxygenated water is now available to areas that previously experienced less than desirable concentrations at different times throughout the year.

G. Establish aquatic vegetation bed

General. Aquatic vegetation in Bertom Lake was a diverse mix of emergent and submersed aquatic species beneficial to many wildlife species. No changes were desired in Bertom Lake. The large open area of McCartney Lake was subject to wind-waves that reduced SAV abundance in open water areas. Shallow sheltered backwaters, however, supported emergent and submersed aquatic plant communities similar to Bertom Lake. The objective of the restoration was to increase depth in the backwaters for fish use and use the dredged material to create an island to block wind-waves and promote SAV coverage of 10 acres in open areas of McCartney Lake.

Pre- and Post-Project Conditions. There were two problems with aquatic plants in different parts of the Bertom-McCartney Lakes project area. Dense floating leaved American lotus and mixed aquatic species colonized backwater lakes as they became shallower with sedimentation. Excessive plant debris accumulated in backwaters which depleted dissolved oxygen under ice when decomposing during winter. The plant beds are beneficial to migrating birds and wildlife, but poor winter water quality degrades fish habitat in shallow wetlands.

The large, impounded, open water portion of the backwater complex was similarly affected by sedimentation, and also by wind-generated waves accumulating across open impounded areas. Wave vortices can reach bottom in shallow areas and resuspend fine sediments, which in turn cloud water and reduce light for aquatic plant growth and fish feeding. Aquatic plants initially expanded their distribution and abundance in the impounded UMRS, but “pool aging” (Lubinski, 1998) has altered physical conditions beyond plant suitability in many parts of the river. Sparks et al. (1990) describe threshold effects where plant beds degrade gradually around the edges until they fragment and cannot maintain internal controls maintaining their survival. Wind-waves also create physical wave forces that can sheer plant stems in addition to their ambient turbidity effects.

Pre-project quantitative data were not collected. Post project sampling in 2001 and 2009 identified aquatic vegetation throughout Pool 11 (Appendix B). In the HREP area up to 40 percent of sample sites were vegetated compared to 2 to 18 percent of the rest of Pool 11 (Table 7). Aquatic plant species were distributed by their tolerance of current velocity. Backwater species, coontail and lotus, were most abundant in the HREP area (Figures 6 and 7; Table 7), whereas species adapted to flow, wild celery and sago pondweed, were similar in abundance or more common outside the HREP backwater area (Table 7).

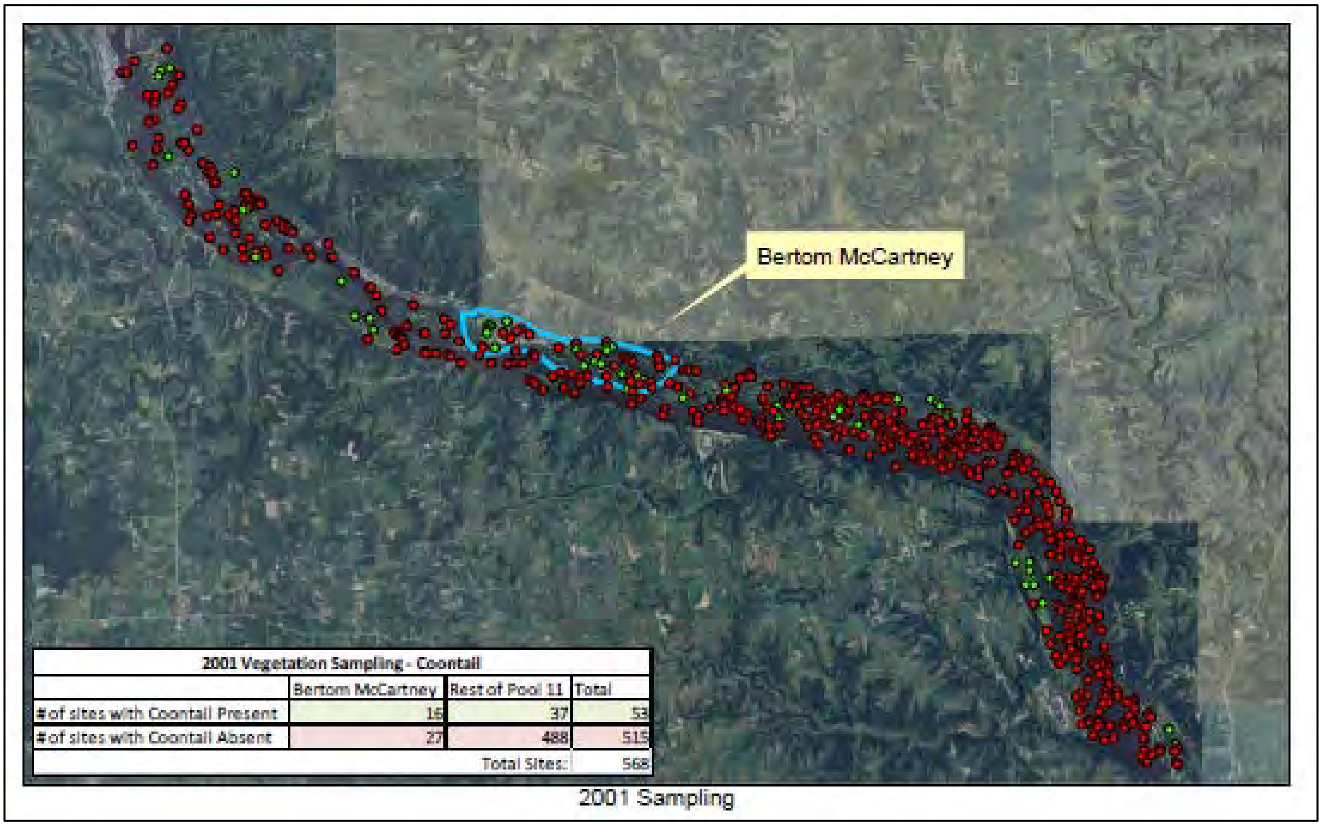
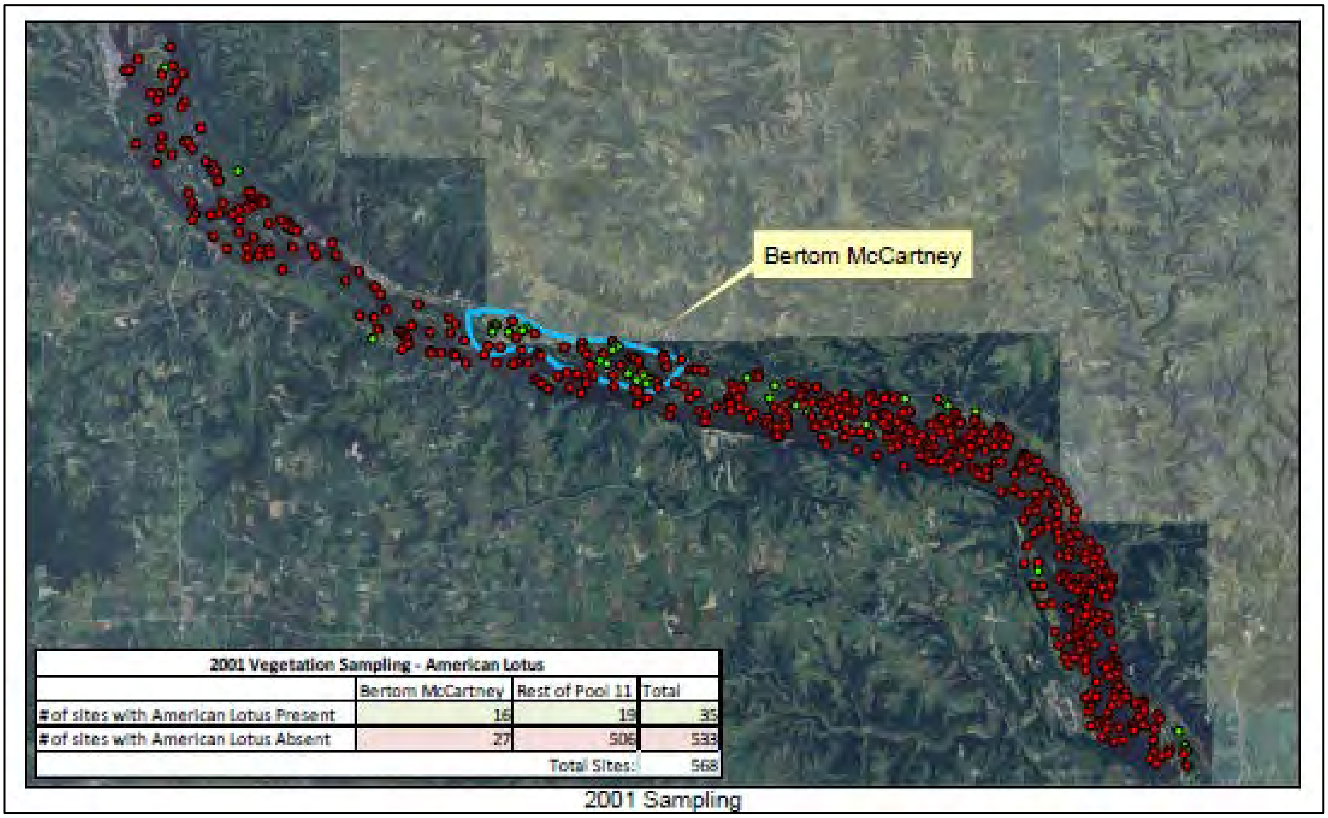


Figure 6. Coontail distribution in Pool 11 and the Bertom-McCartney HREP in 2001.



2001 Vegetation Sampling - American Lotus			
	Bertom McCartney	Rest of Pool 11	Total
#of sites with American Lotus Present	16	19	35
#of sites with American Lotus Absent	27	506	533
		Total Sites:	568

Figure 7. Lotus distribution in Pool 11 and the Bertom-McCartney HREP in 2001.

Table 7. Frequency of abundance of aquatic vegetation species, measured as vegetated sample sites in Pool 11 and the Bertom-McCartney HREP area.

	2001		2009	
Species occurrence	Bertom McCartney sample sites	Rest of Pool 11 sample sites	Bertom McCartney sample sites	Rest of Pool 11 sample sites
Coontail present	16	37	6	37
Coontail absent	27	488	14	231
% present	37.2%	7.0%	30.0%	13.8%
American lotus present	16	19	2	24
American lotus absent	27	506	18	244
% present	37.2%	3.6%	10.0%	9.0%
Wild celery present	1	10	0	48
Wild celery absent	42	515	20	220
% present	2.3%	1.9%	0.0%	17.9%
Sago pondweed present	5	46	2	35
Sago pondweed absent	38	479	18	233
% present	11.6%	8.8%	10.0%	13.1%

Conclusion. Aquatic vegetation was not modified in Bertom Lake because of the existing habitat benefit provided to migratory birds in that portion of the project area. Dredging in McCartney Lake relieved the plant encroachment that was limiting aquatic habitat quality for fish in that portion of the project area. Backwater plant species responded to the structure of the CDF blocking wind-generated waves in a third part of the project. Coontail and lotus were present in almost 60 percent of sites in 2001 and 40 percent of sites in 2009 indicating the objective for 10 acres of aquatic vegetation coverage was met and has persisted for many years.

6. LESSONS LEARNED AND RECOMMENDATIONS FOR FUTURE SIMILAR PROJECTS

6.1 Confined Disposal Facility/Perched Wetland

An unplanned feature of the HREP was the establishment of a perched wetland within the CDF. The perched wetland vegetation was voluntary, as only the CDF berm was seeded. The vegetation was attributed to the initial rich seed bank and clear stable water. It is recommended that he potential for, and/or the creation of perched wetlands be considered in future HREP's in which island CDF's are proposed.

6.2 Dissolved Oxygen Monitoring

Diurnal fluctuations of DO concentrations in backwaters of the UMR during the summer months are typical. It is not uncommon for night time DO concentrations to fall to below 5.0 mg/L. These short episodes below 5.0 mg/L do not appear to significantly impact fish because fish kills are rarely reported here. If a numerical DO concentration criteria is used for future HREPS, it is recommended that diurnal DO fluctuations are taken into account when determining the project criterion.

7. CONCLUSIONS

The HREP features have been degraded since construction, particularly since the early 2000's. Sedimentation is the primary reason, impacting the dredged areas, the habitat channel and access. However, DO concentrations have improved and appear fairly stable, fisheries have had a positive biological response, and semi-aquatic vegetation is prevalent.

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Appendix A

Average number of fish/hour of electrofishing by species in the Bertom-McCartney HREP

(Source: Jeff Janvrin, Wisconsin Department of Natural Resources, La Crosse, Wisconsin).

Appendix A.1. Average number of fish/hour of electrofishing by species during fall sampling in the Bertom-McCartney HREP overwintering habitat. Numeric change in numerous species can be detected.

Avg. #/hr (Sites 1 - 9) All Sizes																		
Specie Common Name	**1987**	**1992**	**1993**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2010**	**2011**	**2012**
bigmouth buffalo	0	0	1.2	2.0	0	0	2.9	0.9	0	0	0	0	0	0	0	0	0	0
black crappie	0	19.5	5.1	4.2	26.1	39.1	40.5	17.1	12.7	11.8	5.6	112.8	41.4	44.6	52.9	16.3	19.2	31.7
bluegill	69.3	50.7	104.0	51.5	86.3	189.3	905.4	278.0	709.0	266.2	41.3	118.8	70.0	641.3	613.2	296.0	408.8	592.8
bowfin	3.0	0	8.0	1.1	0.8	0	6.0	1.7	5.4	0.3	2.2	0	0	0.4	0	2.6	1.2	1.7
brook silverside	1.5	0	0	0	0	0	0	0	4.8	7.7	0	21.0	1.7	10.3	1.3	7.7	6.0	5.1
bullhead minnow	0	0	0	0	0	0	0	0	0	0.9	0	0	0	0	0	0	0	0
carpsucker	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
carpsuckers	1.5	0	6.2	5.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
channel catfish	0	0	0.5	0.7	0	0	1.4	0	0	0	0	0	0	0	0	0	0	0
common carp	4.5	0	21.0	2.7	0	0	21.9	2.6	5.0	0	0	0	0	0	0.6	0	0	0.9
emerald shiner	0	0	5.2	0	0	0	1.8	0	0	1.5	0	6.0	0	0	0	21.4	0	0
freshwater drum	0	0	6.6	3.8	0	0.8	0	0.9	0	0	0	0	0	0	3.5	0	0	0
gilt darter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.0	0
gizzard shad	4.5	0	50.7	93.1	0	0.9	15.2	6.8	1.3	10.1	61.4	99.8	0	3.3	87.2	27.4	1.3	0
golden shiner	3.0	0	0	0	0	0.4	2.4	0	0	1.8	0	8.0	0.8	1.3	0	0.9	0	0
grass pickerel	4.5	0	0	0	0	0	0	0	0	0	0	1.0	0	0	0	0	0.6	0
green sunfish	0	0	0	0	0	1.1	0.9	0.9	0	0.8	0	0	0	0	0.2	0	2.7	3.4
green sunfish x bluegill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0
green sunfish x unknown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0
highfin carpsucker	0	0	0	0	0	0	0	0.9	0	0	0	0	0	0	0	0	1.3	0
largemouth bass	7.5	62.1	38.4	39.0	118.7	123.2	110.4	231.8	217.5	91.2	31.9	76.8	112.8	264.7	199.2	188.2	210.4	230.1
logperch	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
longear sunfish	0	0	0	0	0	0	0	0	0	0	2.2	0	0	0	0	0	0	0
mimic shiner	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	0	0
minnows species	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
northern pike	4.5	0	1.0	0.2	0.6	0.7	1.5	0	0.8	0	0	1.0	0.7	0	0	1.7	0.7	0
orangespotted sunfish	0	1.4	12.9	6.3	0	20.0	27.8	0.9	6.0	15.2	0	0	0	0.7	1.9	18.0	0	0
pirate perch	1.5	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0
pumpkinseed	0	0	0	0.2	0	2.3	0	0	0	0	0	0	0	3.4	0	2.6	5.3	6.8
quillback	0	0	0	0	0	0	0	2.6	0	0	0	0	0	0	0	0	0	0
redhorses	0	0	0.2	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
river carpsucker	1.5	0	0	0	0	0	9.1	0.9	0	0	0	0	0	0	0.6	0	0	0
rock bass	0	0	0	0.3	0	0.4	0	0	0	0	0	0	0	6.7	3.6	0	0	3.4
sand shiner	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.7	0	0	0
sauger	0	0	7.5	5.7	0	0	36.8	0	0	0	0	0	0	0	0	2.6	0	0
shiners species	0	0	0	0	0	0	0	0	1.7	0	0	0	0	0	1.5	1.7	0	0
shorthead redhorse	0	0	1.1	2.5	0	0	0.9	2.6	0	0	0	0	0	0	0	0	0	0
shortnose gar	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
smallmouth buffalo	0	0	1.6	0	0	0	2.9	0.9	0.5	0	0	0	0	1.5	0	0	0	0
spotfin shiner	4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
spottail shiner	0	0	1.5	0	0	0	0	0	0	0.9	0	0	0	0	0	0	0	0
spotted sucker	1.5	0	8.6	6.0	13.7	14.3	21.5	7.7	6.8	40.1	20.7	5.0	13.3	6.7	7.1	7.7	4.0	2.6
sunfishes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.1	0	0	0
tadpole madtom	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0
walleye	0	0	2.1	7.0	0	0	2.7	2.6	0	0	0	0	0	0	1.4	0	0	0
warmouth	7.5	0.5	0.5	0	0	0	13.7	6.8	0	0.8	0	0	0	0	3.0	0	2.4	1.7
white bass	1.5	0.5	0.5	1.2	0	2.9	1.5	1.7	0	1.3	2.2	0	1.5	0	3.1	0	0.7	0
white crappie	1.5	3.0	1.3	1.8	7.5	43.4	6.7	47.9	33.4	4.4	47.2	204.6	18.8	46.0	45.0	17.1	4.0	12.8
white sucker	0	0	0	0.3	0	0	0	0	0	0.4	2.5	0	2.0	0	0	0.9	2.0	0
yellow perch	10.5	0	0.9	1.5	0	0	5.4	0	1.0	0	0	0	0	0	1.5	5.1	0	0
Yearly Number of Species	**19**	**7**	**25**	**25**	**7**	**14**	**23**	**20**	**14**	**19**	**10**	**11**	**10**	**13**	**22**	**18**	**17**	**12**

Appendix A.2. Average number of fish/hour of electrofishing by species in the Bertom-McCartney HREP habitat channel and control channel. Changes in abundance of many species can be detected in the Habitat Channel samples.

Aug. Oct. Nov.

Avg. #/hr All Sizes	Habitat Channel												Control Channel								
Specie Common Name	1987	1988	1990	1993	1994	1996	1999	2001	2004	2005	2006	2010	1987	1988	1990	1993	1994	1999	2004	2005	2006
bigmouth buffalo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.4	0	2.8	0	0	0	0
bigmouth shiner	0	0	0	0	0	0	0	0	0	0	0	0	3.0	0	0	0	0	0	0	0	0
black crappie	3.0	0	9.8	0	0	0	0	0	0	0	0	0	6.0	0	0	0	2.8	0	0	0	0
bluegill	18.1	86.9	84.4	0	5.6	0	74.0	66.7	0	0	323.4	74.9	42.2	112.9	8.2	0	0	5.0	0	0	47.9
bowfin	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	1.1	0	0	0	0
brook silverside	0	0	0	0	0	0	0	0	361.5	84.3	598.8	18.0	0	0	0	0	0	0	0	0	598.8
burbot	0	0	0	0	0.7	2.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
carpsuckers	0	1.5	0	0	3.0	0	0	0	0	0	0	0	0	1.9	0	0	1.1	0	0	0	0
channel catfish	3.0	0	0	1.4	2.7	0	12.3	0	0	0	0	0	12.0	0	0	11.4	14.1	10.0	0	0	0
channel shiner	0	0	0	0	0	0	0	0	0	0	0	110.8	0	0	0	0	0	0	0	0	0
common carp	27.1	8.2	35.8	33.8	21.3	0	74.1	0	0	0	0	0	75.3	8.6	40.4	11.4	36.2	0	0	0	0
darters (Percina spp.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0
emerald shiner	3.0	0	0	0	0	0	0	0	120.5	156.6	598.8	6.0	6.0	0	0	0	0	0	0	0	598.8
flathead catfish	3.0	0	0	1.4	11.9	0	9.2	9.5	0	0	0	0	6.0	1.0	0	0	0	0	0	0	0
freshwater drum	66.3	18.2	34.6	5.7	32.2	0	6.5	9.5	0	0	0	0	144.6	31.0	48.5	0	4.6	20.0	0	0	0
gilt darter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
gizzard shad	153.6	97.8	5.4	0	56.0	2.7	11.5	0	0	0	0	0	75.3	22.6	2.7	0	9.5	0	0	35.9	0
golden redhorse	0	3.7	0	0	0	0	6.2	4.8	0	0	0	0	0	2.9	0	5.7	0	0	0	0	0
golden shiner	0	0	0	0	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
highfin carpsucker	0	1.7	0	0	0	0	0	4.8	0	0	0	0	0	1.7	0	0	2.0	0	0	0	0
largemouth bass	0	7.0	38.2	0	13.7	0	65.3	38.1	0	12.1	6.0	47.9	30.1	6.4	8.2	0	4.1	5.0	0	0	0
logperch	0	0	0	0	1.2	0	0	0	0	0	0	0	0	1.9	0	0	0	0	0	0	0
longnose gar	0	0	0	0	0	0	0	0	0	0	0	0	18.1	0	0	0	1.9	5.0	0	0	0
minnows species	0	0	0	0	0	0	0	0	0	0	0	0	15.1	0	2.7	0	0	0	0	0	0
mooneye	0	0	0	0	0.9	0	0	0	0	0	0	0	0	0	0	2.9	1.1	0	0	0	0
northern pike	0	0	0	0	0.9	0	0	0	0	0	0	6.0	0	0	0	0	1.1	0	0	0	0
orangespotted sunfish	0	3.0	0	5.7	1.2	0	0	0	0	0	0	9.0	0	0	0	0	0	0	0	0	0
pugnose minnow	0	0	0	0	0	0	0	0	0	0	6.0	0	0	0	0	0	0	0	0	0	0
pumpkinseed	0	0	0	0	0	0	0	0	0	0	0	6.0	0	0.7	0	0	0	0	0	0	0
quillback	0	3.0	11.4	0	0	0	0	0	0	0	0	0	0	1.4	8.2	0	0	0	0	0	0
redhorses	0	0	1.5	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0
river carpsucker	3.0	0	0	0	0	0	0	0	0	0	0	0	12.1	0.7	0	0	0	0	0	0	0
river shiner	0	0	0	0	0	0	0	0	120.5	0	0	0	0	0	0	0	0	0	0	0	0
rock bass	12.0	3.0	0.9	0	3.4	0	3.7	0	0	0	0	9.0	3.0	1.9	0	0	0	0	0	0	0
sand shiner	3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sauger	0	0.3	32.8	0	5.3	0	1.0	0	0	0	0	0	3.0	0	5.5	11.4	1.1	5.0	0	0	0
shorthead redhorse	111.4	22.7	34.7	84.1	44.4	10.9	23.3	33.3	0	0	6.0	3.0	57.2	10.2	18.5	28.6	8.0	25.0	0	0	0
shortnose gar	0	0.9	0	0	0	0	0	0	0	0	0	0	3.0	0	0	0	0	10.0	0	0	0
silver chub	0	0	0	0	2.0	0	0	0	0	0	0	0	0	0	3.4	0	0	0	0	0	0
silver redhorse	0	0	3.9	0	2.0	0	0	0	0	0	0	0	0	0	0	0	1.1	0	0	0	0
smallmouth bass	0	0	10.0	5.0	19.3	19.1	28.5	19.1	0	0	6.0	6.0	0	0	0	0	0	0	0	0	0
smallmouth buffalo	0	0	8.4	0	1.8	0	7.0	0	0	0	0	0	3.0	2.6	6.2	0	0.9	0	0	0	0
spotfin shiner	0	0	0	0	0	0	0	0	120.5	0	0	0	0	0	0	0	0	0	0	0	0
spottail shiner	0	0	0	0	0	0	0	0	0	0	0	0	3.0	0	0	0	0	0	0	0	0
spotted sucker	0	5.4	0	1.7	0	0	1.7	0	0	0	0	3.0	0	0	0	2.9	0	0	12.1	0	0
walleye	15.1	3.6	15.0	5.2	4.6	0	0	0	0	0	0	0	0	6.4	3.4	0	1.1	5.0	0	0	0
warmouth	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white bass	87.4	11.7	2.4	0	7.3	2.7	13.1	0	0	0	0	0	117.5	58.3	64.2	0	4.1	5.0	0	0	0
white crappie	0	0	0	0	0	0	0	0	0	0	0	0	6.0	3.3	0	0	0	0	0	0	0
white sucker	0	0	0	0	0	0	0	0	0	0	0	3.0	0	0	0	0	0	0	0	0	0
yellow bullhead	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
yellow perch	0	3.0	3.0	0	0.9	0	0	0	0	0	0	12.0	0	0	0	0	0	0	0	0	0
Yearly Number of Specie	14	18	17	9	25	5	15	8	4	3	7	14	21	22	14	7	19	10	1	1	3

Appendix B

Aquatic plant species in Pool 11 pool wide aquatic plant surveys

(Source: UMRCC 2001 and LTRMP 2009)

Aquatic plant species in Pool 11 pool wide aquatic plant surveys

Species Code	Scientific Name	Common Name	2001 (Number of sites)	2009 (Number of sites)	2001 (Percent of sites)	2009 (Percent of sites)
CEDE4	Ceratophyllum demersum	coontail	53	43	10%	16%
POPE6	Potamogeton pectinatus	sago pondweed	51	37	10%	14%
NELU	Nelumbo lutea	American lotus	35	26	7%	10%
NYTU	Nymphaea tuberosa (aka N. odorata)	American white waterlily	26	15	5%	6%
LEMI3	Lemna minor	small or common duckweed	24	29	5%	11%
SPPO	Spirodela polyrhiza	greater duckweed	24	20	5%	7%
SALA2	Sagittaria latifolia	broad-leaved arrowhead	16	10	3%	4%
MYSP2	Myriophyllum spicatum	Eurasian watermilfoil	13	12	2%	4%
WOCO	Wolffia columbiana	Columbian watermeal	12	0	2%	0%
VAAM3	Vallisneria americana	wild celery	11	48	2%	18%
NAGU	Najas guadalupensis	southern waternymph	8	1	2%	0%
NLPW	Potamogeton foliosus, P. pusillus, or other unidentified narrow-leaved pondweeds	narrow-leaved pondweeds	7	14	1%	5%

Species Code	Scientific Name	Common Name	2001 (Number of sites)	2009 (Number of sites)	2001 (Percent of sites)	2009 (Percent of sites)
	Any species of filamentous alga (including Spyrogyra, Cladophora, Hydrodictyon)				0%	0%
PONO2	Potamogeton nodosus (aka P. americanus)	American pondweed	5	4	1%	1%
POCR3	Potamogeton crispus	curly-leaf pondweed	5	11	1%	4%
NI?TE	Nitella sp.	a nitella species	5	0	1%	0%
ELCA7	Elodea canadensis	Canadian waterweed	5	20	1%	7%
POZO	Potemogeton zosteriformis	flat-stem pondweed	4	0	1%	0%
ZODU	Zosterella dubia (aka Heteranthera dubia)	water stargrass	3	14	1%	5%
SARI	Sagittaria rigida	stiff arrowhead	3	2	1%	1%
NAFL	Najas flexilis	slender naiad	2	1	0%	0%
SCFL	Scirpus fluviatilis	river bulrush	2	0	0%	0%
PHAR3	Phalaris arundinaceae	reed canary grass	2	0	0%	0%
LEOR	Lemnaceae oryzoides	rice-cut grass	2	3	0%	1%
CHAR	Chara sp.	a chara species	2	1	0%	0%

Species Code	Scientific Name	Common Name	2001 (Number of sites)	2009 (Number of sites)	2001 (Percent of sites)	2009 (Percent of sites)
NULU	Nuphar variegata (aka N. luteum)	yellow pond-lily	1	0	0%	0%
TYLA	Typha latifolia	broad-leaved cattail	1	0	0%	0%
SPEU	Sparganium eurycarpum	giant bur reed	1	0	0%	0%
SCVA	Scirpus validus	bulrush	1	0	0%	0%
NAGU	Najas guadalupensis	southern waternymph	1	0	0%	0%
NAMI	Najas minor	brittle waternymph	1	0	0%	0%
NAFL	Najas flexilis	slender naiad	1	0	0%	0%

Appendix C

Water Quality Analysis

APPENDIX C

BERTOM AND McCARTNEY LAKES WATER QUALITY SUMMARY

1. INTRODUCTION

Prior to project construction and intermittently throughout the post-project period, water quality monitoring has been performed. This report primarily discusses water quality monitoring performed by EC-HQ and WDNR personnel after the 2002 PER was published. Data collected prior to that time is discussed in the 2002 PER (USACE, 2002). Due to the cyclical nature of the EC-HQ HREP water quality monitoring program, monitoring at this project was suspended after the 2002 PER for several years and resumed in December 2006. This monitoring cycle continued through March 2010, and the next cycle will commence in December 2013. Budget constraints preclude annual water quality monitoring at all completed HREPs.

Available data show that several positive trends in water quality that emerged immediately post construction and were documented in previous PERs have continued. These include improved flow through the project area as a result of the dredged channels, improved dissolved oxygen concentrations at specific locations, and the establishment of aquatic vegetation in the vicinity of the island created from dredged material even though a reduction of sediment resuspension during the growing season attributable to this island has not been seen. The 2002 PER concluded that the island orientation and configuration do not effectively shelter the target area from wind-induced wave action, and for that reason improvements in water clarity on the east side of the island have not been observed. In general, however, it appears that the water quality objectives related to aquatic habitat are still being met.

2. PROJECT OBJECTIVES

Specific water quality objectives were established as part of the general goals of enhancing the aquatic habitat and the migratory waterfowl habitat within the backwater complex. These included increasing water exchange between lotic and lentic areas, improving dissolved oxygen concentrations during critical seasonal stress periods, and reducing resuspension of fine-grained bottom sediments to promote growth of aquatic vegetation. Because of sediment deposition, areas within the project along the Wisconsin bankline had become isolated from oxygenated, flowing water sources. As those areas lost depth, they became choked with aquatic vegetation, which caused dissolved oxygen concentrations to become depleted as the plants decayed during the winter months. Groundwater interactions further reduced dissolved oxygen concentrations during critical periods such as under snow and ice cover. By selectively dredging access channels to these isolated areas, it was anticipated that the occurrence of low dissolved oxygen concentrations could be avoided.

Much of the sediment deposited in the backwater complex is very fine-grained and easily resuspended by wind-induced wave action. This resuspension greatly reduces water clarity and makes for an unsuitable substrate in which aquatic plants can become established. It was anticipated that constructing and strategically orienting an island would realize some wind-sheltering effect in the large open-water area of McCartney Lake. This would potentially reduce sediment resuspension, improve light penetration, and promote aquatic plant growth. Once aquatic plants become established, the bottom would be stabilized and thus be less subject to resuspension.

3. MONITORING METHODS

A. Instantaneous Monitoring. During the summer months of June 2007 – September 2009, samples were collected approximately bi-weekly on 24 occurrences at sites W-M599.2C, W-M599.5D, W-M599.8B, and W-M600.3C. Site locations are shown on the Monitoring Plan, Sheet C-101, Appendix D. During the winter months from December 2006 – March 2010, samples were collected approximately monthly on 12 occasions at sites W-M599.8B and W-M600.3C only.

Sampling consisted of taking grab samples from just below the water surface at the 4 sites. In addition, field determinations of dissolved oxygen and temperature were routinely made at the approximate mid-depth of the water column. Field analyses were performed for ephemeral parameters. Parameters measured in this fashion included dissolved oxygen, pH, water temperature, water depth, specific conductance, secchi disk depth, wave height, water velocity, air temperature, percent cloud cover, wind speed and direction, total alkalinity, suspended solids, turbidity, chlorophyll a, b, and c, and pheophytin a. Dissolved oxygen measurements were made in the field using a membrane electrode or optical probe. Water samples were shipped to a commercial laboratory for solids and pigment analyses. Alkalinity and turbidity analyses were performed in-house. EC-HQ instantaneous monitoring results are presented in Figures C-1 through C-3 and discussed in Section 4.a.

Wisconsin Department of Natural Resources (WDNR) staff performed field measurements of dissolved oxygen, water temperature, water depth, specific conductance, and water velocity at several sites throughout the project area on February 8, 1999, February 19, 2003, and February 26, 2004. The parameters were measured at the water surface, at the approximate mid-depth of the water column, and near the bottom. Results are presented in Figure C-4 and discussed in Section 4.a. In 1999 and 2003, flow in the backwater channels of McCartney Lake was also measured at several locations. The water quality monitoring sites and discharge measurement locations are depicted in Figure C-5.

B. Continuous Monitoring. In-situ continuous monitoring has been performed for short periods during both the summer and winter since project completion. Monitoring equipment consisted of Yellow Springs Instrument model 6000, 6600, or 6600-V2 series and Hach DS5X series data sondes. Calibration was performed in the laboratory prior to field deployment. A single monitoring event typically lasted for a period of 2 weeks during summer months and approximately 6 weeks during winter months. Data sondes were suspended approximately 5 to 7 feet above the bottom at site W-M599.8B and 2 to 3 feet above the bottom at the remaining sites. Upon retrieval, the sondes were recalibrated in the laboratory and adjustments for instrument drift were made to the data where necessary.

Continuous monitoring events have been performed at sites W-M599.8B and W-M600.3C during the winter months and at sites W-M599.2C and W-M599.5D during the summer months. Sampling locations are shown on the Monitoring Plan, Sheet C-101, Appendix D. Parameters measured with data sondes include dissolved oxygen, pH, water temperature, depth, specific conductance, and turbidity.

In addition to data sondes, Onset Stowaway temperature loggers were suspended 1 foot and 8 feet above the bottom at site W-M599.8B during the winter of 2006-2007 to determine if temperature stratification was present. Results of temperature logger and sonde data are discussed in Section 4.b.

4. RESULTS AND DISCUSSION

A. Instantaneous Monitoring.

(1) <u>Discharge and Velocity.</u> One purpose of the dredging project was to allow fresh water from the main channel to flow into isolated backwater areas. The 1995 PER compares discharge measurements that were made pre- and post-project construction in the backwater complex. The post-construction measurements were also compared to the total river flow at Lock and Dam 10 to estimate the percentage of flow through the project area. The report indicated that flow was good throughout the complex, allowing oxygenated water to reach previously deprived areas (USACE, 1995). Three flow measurements have been made by the WDNR since the 1995 PER. The results are documented in Table C-1. Only the "Above Rock" site can be compared to previously documented measurements in the 1995 PER. Assuming that the measurements were made at the same cross-section, it appears that the maximum depth and cross-sectional area have decreased over time, probably due to sedimentation. Flow may also have decreased slightly, but the maximum velocity is similar to other measurements at this cross-section.

Table C-1. Discharge Measurement Summary.						
Location	**Date**	**Cross-Sectional Area (sq ft)**	**Maximum Depth (ft)**	**Maximum Velocity**	**Discharge (cfs)**	**Discharge at L/D 10 (cfs)**
Site 02BMCL9DIS	8 Feb 99	607	8.0	0.01 ft/s 0.30 cm/s	3.7	29,900
Site BMCL10	19 Feb 03	15.8	0.7	0.10 ft/s 3.05 cm/s	0.9	23,000
Above Rock (Near Site 08WQBMCLCAR)	19 Feb 03	636	7.5	0.24 ft/s 7.32 cm/s	113	23,000

The optimum current velocity for bluegill over-wintering habitat is 0 cm/sec. The habitat suitability index decreases to 40% as velocity increases to 1 cm/sec, and it further declines to 10% as velocity increases to 3 cm/sec (Palesh & Anderson, 1990). Surface measurements made by EC-HQ personnel at Site W-M600.3C (in the dredged channel in Area G) and Site W-M599.8B (dredged backwater bay in Area K) continue to indicate that velocity in the channel is consistently higher. During the winter months of December-March, velocity within the channel averaged 8.25 cm/sec compared to 1.09 cm/sec at Site W-M599.8B. Even though the average velocity at the off-channel site is greater than ideal, 8 out of 9 measurements were less than 3 cm/sec, and 6 of those were below 1 cm/sec. Thus, in terms of water velocity, Site W-M599.8B is providing a somewhat suitable over-wintering location for fish, especially compared to Site W-M600.3C, but velocity could be a limiting factor for fish in that area. WDNR monitoring results show velocities along the dredged channel in Area G similar to the average at Site W-M600.3C. Velocities were either not detected or less than 1 cm/sec at all other sites in the dredge cuts where measurements were made.

During the summer months, optimal current velocities for bluegill are less than 5 cm/sec for juvenile and fry, less than 7.5 cm/sec in spawning areas, and less than 10 cm/sec for adults (Stuber, Gebhart, & Maughan, 1982). Velocity measurements met the most limiting of these criteria (less than 5 cm/sec) 95% of the time at all sites except Site W-M600.3C. At that location in the dredged channel, the average velocity was 7.37 cm/sec, and only 2 out of 16 measurements were above 10 cm/sec. Those two observations occurred during periods of high river flow.

(2) Depth. Water depth of 4 ft or greater relative to the normal pool elevation is considered optimum for bluegill in the winter, when this depth condition is achieved in more than 50% of the backwater complex (Palesh & Anderson, 1990). Winter water depth averaged 7.8 ft at Site W-M600.3C and 9.8 ft at Site W-M599.8B. (Note that these measurements have not been compared to flat pool or normal pool elevations.)

WDNR personnel have measured depth at a number of sites throughout McCartney Lake. They noted in February 2003 that many of the dredge cuts appeared to have lost depth and that substantial sedimentation had occurred in the area near Site 9. They concluded that the small channel below Bertom Landing, which passes through Site 10 and leads to the dredge cut beginning just upstream of Site 9, conveys a great deal of sediment during periods of high water. Depths in all dredge cuts were greater than 4 feet, except those measured at Sites 07BMCL (in Area L) and 9b/01BMCL9B (in Area C) in February 2004. These depths are more than adequate for fish cover at these sites, but the bathymetric survey results must be used to check for suitable depths and determine sedimentation rates throughout the entire backwater complex.

Average depth in the summer months had similar values as those discussed in the previous paragraphs for Sites W-M600.3C and W-M599.8B. For Sites W-M599.2C and W-M599.5D, the average depths were 3.7 ft and 3.9 ft, respectively.

(3) Water Temperature. The optimum winter water temperature for bluegill is 4°C, with the habitat suitability index dropping from 50% down to zero between 1°C and 0°C (Palesh & Anderson, 1990). During the winter months, the surface water temperature (just below ice cover, if present) averaged 0.55 °C at site W-M599.8B. In fact, 9 out of the 12 measurements were below 1°C, and 8 of those were 0.2°C or below. Water temperature readings taken 3-5 ft below the surface were typically only a few tenths of a degree higher than the surface temperature at site W-M599.8B. Similar observations were made at Site W-M600.3C. The average surface water temperature there was 0.58°C; however, the temperatures did not appear to vary with depth at that site.

WDNR personnel also observed relatively cold temperatures in the dredged areas. Temperatures increased with depth except in the flowing channels in Areas E and G and in the shallow Area L, where temperatures ranged from 0.4°C to 0.6°C throughout the water column. Areas A, B, and C were the warmest, with bottom temperatures ranging from 1.5°C to 2.5°C. Bottom temperatures above 1°C were also recorded in Areas F, H, and K. Although there was slight variation between sites and slight thermal stratification at some sites, the observed temperatures are generally much less than the optimum and could be a limiting factor for fish utilization of these backwater areas.

Optimum maximum midsummer temperature is 27°C for adults and 30°C for juveniles (Stuber, Gebhart, & Maughan, 1982). In the summer months, water temperature ranged from 17.7°C to 34.5°C at all four sites with the average between sites ranging 25.0-25.6°C. Temperatures above 30°C were observed at all four sites on July 31, 2007 and June 23, 2009. On these occasions, thermal stratification was present at Sites W-M600.3C and W-M599.8B, where the water was cooler, approximately 26.8°C, at a depth of approximately 5 ft. Sites W-M599.2C and W-M599.5D are much shallower, and there was no thermal stratification present.

(4) Dissolved Oxygen. The target minimum dissolved oxygen concentration for this project is 5.0 mg/l during both the winter and summer seasons (USACE, 1989). The trend of

improved dissolved oxygen concentrations following project construction has continued through the most recent monitoring period. A summary and comparison of pre- and post-construction monitoring of surface dissolved oxygen concentrations from six locations are presented in Table C-2. For this monitoring period, no readings were observed below 5.0 mg/l during the winter months. High concentrations were common, with values occasionally supersaturated. The average concentrations were 15.09 mg/l at Site W-M600.3C and 15.04 mg/l at Site W-M599.8B. Similar observations were made by WDNR personnel on their sampling trips.

During the summer months, the average concentrations varied from 7.80 mg/l to 9.44 mg/l between the four sites. Low dissolved oxygen was detected on July 17, 2007 at Sites W-M600.3C (4.26 mg/l), W-M599.8B (3.91 mg/l), and W-M599.2C (4.40 mg/l). The dissolved oxygen concentration fell below 5.0 mg/l at Site W-M600.3C one other time; the concentration was 3.76 mg/l on August 14, 2007.

Table C-2. Surface Dissolved Oxygen Summary.

Dissolved Oxygen (mg/l)	W-M600.3C	W-M599.8B	W-M598.9E	W-M599.5D	W-M599.2C	W-M600.8B
Total samples collected	141	119	56	79	79	6
			N/A	N/A	N/A	N/A
Pre-project samples collected	34	12	N/A	N/A	N/A	N/A
Range (mg/l)	1.0 – 15.8	1.1 – 16.0	N/A	N/A	N/A	N/A
Mean (mg/l)	7.9	10.7	N/A	N/A	N/A	N/A
Percent of samples < 5.0 mg/l (%)	21	8	N/A	N/A	N/A	N/A
Post-project samples collected (through 2002)	71	71	56	55	55	6
Range (mg/l)	3.7 – 18.9	3.7 – 19.0	5.1 – 18.3	4.2 – 14.3	4.2 – 15.9	10.1 – 12.34
Mean (mg/l)	9.96	10.1	9.3	8.8	8.8	11.6
Percent of samples < 5.0 mg/l (%)	3	4	0	4	4	0
Post-project samples collected (2006-2010)	36	36	N/A	24	24	N/A
Range (mg/l)	3.8 – 19.4	3.9 – 19.8	N/A	5.2 – 13.4	4.4 – 16.2	N/A
Mean (mg/l)	10.2	11.3	N/A	8.7	9.3	N/A
Percent of samples < 5.0 mg/l (%)	6	3	N/A	0	4	N/A

(5) pH. The optimum pH range during the growing season is 6.5-8.5 (Stuber, Gebhart, & Maughan, 1982). During the summer months, pH measurements were typically in the upper half of this range, sometimes exceeding the upper limit of the range. A summary of pH readings is presented in Table C-3.

Table C-3. Summer Monitoring pH Summary.

pH (SU)	W-M600.3C	W-M599.8B	W-M599.5D	W-M599.2C
Number of Samples	22	22	22	21
Maximum	9.0	9.1	9.2	9.1
Minimum	7.5	7.7	7.7	7.7
Percent of Samples > 8.5 (%)	9	23	27	38

(6) Water Clarity. At Sites W-M599.5D and W-M599.2C, water clarity measurements were taken in an attempt to identify any "shadow effect" and subsequent reduction in resuspension of bottom sediments and establishment of aquatic vegetation that might be attributable to the presence of the constructed island. In order for the island to have any beneficial impacts in this regard, the predominate wind direction must be from a westerly direction. Continuous wind data collection was performed prior to the 2002 PER in order to determine how much of the time the wind came from a westerly direction. The 2002 PER concluded that wind direction allowed the island to produce a shadow effect for the leeward side (in the vicinity of Site W-M599.2C) approximately 30-60 percent of the time. The 2002 PER also stated that the island is more effective at higher wind speeds (USACE, 2002). Instantaneous wind speed and direction were measured at each site during this monitoring period, but continuous monitoring was discontinued. Also, aquatic plants would only benefit from improved water clarity during the growing season, so only data gathered during the summer months were analyzed with respect to this goal.

Total Suspended Solids (TSS) and Turbidity samples were taken at four locations. A summary of the TSS results is presented in Table C-4, and turbidity data is presented in Table C-5. Field Secchi disk depth measurements were made at four sites following project construction during the growing season. Results of these measurements are presented in Table C-6.

Table C-4. TSS Summary.

TSS (mg/l)	W-M600.3C	W-M599.8B	W-M599.5D	W-M599.2C
Number of Samples	29	29	24	24
Mean	24	19	31	28
Maximum	55	56	70	59
Minimum	2	3	16	16
Percent of Samples > 25 mg/l (Summer only)	58	25	58	54

Table C-5. Turbidity Summary.				
Turbidity (NTU)	**W-M600.3C**	**W-M599.8B**	**W-M599.5D**	**W-M599.2C**
Number of Samples	36	36	24	24
Mean	24.3	20.3	29.1	27.0
Maximum	92.1	80.4	85.8	90.8
Minimum	3.4	3.0	13.1	11.2
Percent of Samples > 20 NTU (Summer only)	71	50	79	67

Table C-6. Summary of Secchi Disk Depth Measurements (Summer Only).				
Secchi Disk Depth (feet)	**W-M600.3C**	**W-M599.8B**	**W-M599.5D**	**W-M599.2C**
Number of Measurements	24	24	24	24
Mean	1.14	1.40	1.09	1.13
Maximum	1.64	2.17	1.53	1.46
Minimum	0.70	0.86	0.70	0.73
Percent of Samples < 1.64 ft	96	71	100	100

Average turbidities increased slightly for the current monitoring period compared to the results in the 2002 PER. The maximum turbidity at all four sites occurred on June 3, 2008 during high river flow. In general, turbidity values were closer to the average value. As in the 2002 PER, no obvious differences in turbidity values exist between sites.

Secchi disk depth appears to be slightly better at Site W-M599.8B. There does not appear to be any difference between the remaining three sites. Compared to the 2002 PER, average Secchi depth has slightly decreased at Site W-M600.3C but has not significantly changed at the other sites.

The optimum TSS level is less than 50 mg/l for bluegill (Stuber, Gebhart, & Maughan, 1982). TSS was greater than or equal to 50 mg/l at all four sites on June 3, 2008, during a period of high water. TSS exceeded 50 mg/l one other time at Site W-M599.5D, reaching 70 mg/l on September 11, 2007. As that site is located on the windward side of the constructed island, the high TSS measurement on that occasion could be due to wind/wave action. On that day, the wind was from the NW at 15 mph, and the wave height was nearly 1 foot, the highest measured during this monitoring period. The TSS concentration on that day at Site W-M599.2C on the leeward side of the island was only half that of Site W-M599.5D, which supports the conclusions made in the 2002 PER regarding the sheltering effect of the island.

Although water clarity conditions appear to be adequate for bluegills to be able to see to find their food, the light-related criteria necessary to support and sustain the submersed aquatic vegetation (SAV) that serves as a food source for fish, migratory waterfowl, and other wildlife that utilize the project area are stricter. The Upper Mississippi River Conservation Committee (UMRCC) Water Quality Technical Section recommends Secchi Disk Depths greater than 0.5 m (1.64 ft), TSS concentrations less than 25 mg/l, and turbidities less than 20 NTU (2003). As shown in Tables C-4 through C-6, most of the time none of these criteria are met at the water quality monitoring sites in the project area. Also, no significant differences in average TSS concentration, turbidity, or Secchi disk depth were observed between Sites W-M599.5D and W-M599.2C.

Even though water clarity conditions are generally not ideal at the monitoring sites for SAV growth and survival, it appears that the constructed island still provides some benefit to the open-water area on its leeward side. A cursory review of historical aerial imagery in Google Earth Pro shows some aquatic vegetation near Site W-M599.2C at times when it is present in other parts of the project area. For example, an image from June 2007 shows approximately 4 acres of aquatic vegetation on the leeward side of the constructed island and none on the windward side (Figure C-6). EC-HQ field notes from August 2007 confirm the presence of lotus at Site W-M599.2C.

(7) Wave Height. Wave height determinations were routinely made at two locations, one on either side of the dredged material placement island. As was the case with TSS, turbidity, and secchi disk depth, wind-sheltering effects were anticipated as a result of the presence of the dredged material placement island. Estimates of wave height were based on visual observations by comparing to objects of known height. Results of the wave height data are summarized in Table C-7.

Table C-7. Summary of Wave Height Measurements.

Wave Height (feet)	W-M599.5D	W-M599.2C
Number of Measurements	24	24
Mean	0.33	0.14
Maximum	0.98	0.69
Minimum	0	0

Wave height results are similar to those in the 2002 PER. There still appears to be a slight sheltering effect from the island that results in lower maximum wave height and average wave height on the leeward side of the island.

B. Continuous Monitoring. Continuous monitoring results are consistent with grab sample data. During the winter months of December 2006 – March 2007, sondes were deployed at Sites W-M600.3C and W-M599.8B. Following that season, continuous monitoring during the winter months was suspended at Site W-M600.3C, but winter monitoring continued through March 2010 at Site W-M599.8B. Unfortunately, collection of dissolved oxygen data was not very successful, but consistently low temperatures were observed by the sondes at both sites during most deployments. Results of two deployments containing useful dissolved oxygen data are shown in Figures C-7 and C-8. Adequate dissolved oxygen concentrations were observed most of the time, but Figure C-8 shows that the concentration dropped slightly below 5.0 mg/l for several hours on February 28, 2010 at Site W-M599.8B. This event is the only occurrence of low dissolved oxygen observed by the sondes during the winter months. It constitutes a mere 0.4% of the total observation time for the December 2009 – March 2010 winter season.

The temperature probe data from Site W-M599.8B for the winter months of December 2006 – March 2007 is consistent with the instantaneous measurements and sonde observations at that time and location. The data further support the grab sample observations in that there was only a slight difference between surface temperatures and bottom temperatures. The average temperature difference was 0.19°C. A graph of the results is presented in Figure C-9.

During the summer months from June 2007 to September 2009, continuous monitoring was performed at sites W-M599.5D and W-M599.2C. Obvious trends in the data are apparent for several parameters. Diurnal variations in water temperature, pH, and dissolved oxygen can be seen during most monitoring events. Nighttime dissolved oxygen concentrations periodically fell below 5.0 mg/l at Site W-M599.2C in the summers of 2007 and 2009. The data shown in Figure C-10 represents these typical conditions. The longest observed period of low dissolved oxygen concentrations lasted three days in August 2007 at Site W-M599.2C (Figure C-11). Although a comparison between sites could not be made for the same date range with valid data, turbidity values measured by the sondes were consistent with grab sample observations.

5. CONCLUSIONS.

Overall, it is clear that many of the original water quality objectives of this project were achieved following construction and continue to be achieved during critical seasonal stress periods. The dredging of channels improved the circulation of water within the backwater complex and in particular flow to previously isolated areas. Adequate oxygenated water is available the majority of the time to areas that had previously experienced less than desirable concentrations at different times throughout the year. Although the dredge cuts have lost some depth since they were constructed, water depths are still better than pre-project conditions at both flowing water and slack-water locations. The depths are adequate for fish cover, allow access and movement between lentic and lotic areas, and in the slack-water areas the deeper water allows for thermal stratification (although minimal during the winter), providing areas with less critical temperatures for fish. Winter water temperatures have improved from pre-project conditions but are still colder than optimum.

The water quality impacts of the dredged material placement island are subtle, and although the observed water clarity criteria generally do not meet the thresholds recommended by the UMRCC, some evidence exists for improvement in conditions conducive to aquatic plant growth on the leeward side of the island. Finally, no negative water quality impacts resulting from any project feature have been observed.

6. REFERENCES.

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Summer Instantaneous Monitoring Results at Site W-M599.2C

Date	Water Depth (m)	Velocity (cm/sec)	Wave Height (cm)	Air Temp. (°C)	Cloud Cover (%)	Wind Speed (MPH)	Wind Direction	Water Temp. (°C)	Dissolved Oxygen (mg/l)	pH (SU)	Total Alkalinity (mg/l as CaCO3)	Specific Conductance (µmhos/cm @ 25°C)	Secchi Disk Depth (cm)	Turbidity (NTU)	Suspendid Solids (mg/l)	Chlorophyll a (mg/m^3)	Chlorophyll b (mg/m^3)	Chlorophyll c (mg/m^3)	Pheophytin a (mg/m^3)
6/5/2007	1.440	**	6	20	30	11	NW	23.3	5.63		142	465	44.5	17.90	17.0	11.0	<1	<1	1.9
6/19/2007	1.220	*	10	24	10	12	NW	25.9	5.87	8.00	163	468	41.5	21.20	21.0	7.9	<1	<1	<1
7/3/2007	1.140	*	1	30	80	6	SW	27.5	9.64	8.40	171	471	41.0	18.40	18.0	40.0	<1	<1	<1
7/17/2007	1.250	*	5	22	75	2	SE	24.0	4.40	8.10	169	432	37.0	21.20	28.0	39.0	<1	1.7	<1
7/31/2007	1.250	3.58	0	33	10	0	-	31.5	12.48	8.80	159	414	44.0	12.80	22.0	40.0	1.5	<1	<1
8/14/2007	1.270	0.25	0	27	80	5	NW	28.4	9.05	8.30	148	396	39.0	11.90	27.0	39.0	1.9	2.3	<1
8/28/2007	1.665	0.07	0	33	15	6	SW	24.9	5.72	7.70	143	345	34.0	37.80	34.0	17.0	1.7	2.0	5.6
9/11/2007	1.120	*	10	19	15	13	NW	20.0	7.43	8.00	184	467	32.0	27.80	36.0	13.0	<1	<1	<1
6/3/2008	1.475	-	21	15	98	10	NE	19.5	12.07	8.60	157	423	31.0	90.80	59.0	59.0	<1	2.0	<1
6/24/2008	1.750	-	12	27	40	7	SE	24.7	8.10	8.00	147	384	37.5	28.30	36.0	22.0	<1	1.8	3.7
7/8/2008	1.285	1.17	1	23	90	4	W	25.5	6.65	7.90	164	448	31.0	37.60	32.0	16.0	<1	1.3	5.0
7/22/2008	1.090	1.73	3	27	10	5	SE	29.7	16.18	8.60	159	420	30.5	31.30	24.0	19.0	1.2	<1	2.9
8/5/2008	1.100	2.10	8	27	30	7	NW	28.6	12.83	9.00	172	431	32.0	24.40	25.0	39.0	<1	<1	<1
8/19/2008	0.980	2.98	10	28	30	8	SE	27.4	12.28	9.10	192	444	26.0	30.60	30.0	45.0	<1	<1	6.1
9/5/2008	0.870	-	1	16	20	3	W	20.8	6.54	-	181	432	25.0	32.60	25.0	12.0	<1	<1	3.6
9/16/2008	1.020	1.54	0	13	0	2	NW	18.1	6.30	-	181	456	26.0	38.70	30.0	55.0	<1	<1	3.5
6/4/2009	1.000	1.37	1	22	15	3	SW	25.5	8.20	7.90	139	385	25.0	24.10	24.0	17.0	1.0	2.0	3.0
6/23/2009	0.944	*	0	32	75	2	N	33.4	8.48	8.45	136	348	26.2	26.40	28.0	94.0	21.0	2.0	0.0
7/7/2009	0.840	0.42	2	20	90	7	SE	24.0	6.82	8.04	162	405	22.2	32.70	37.0	29.0	1.0	2.0	7.0
7/21/2009	0.810	0.43	8	18	100	7	SE	21.8	9.98	8.70	179	406	38.8	15.10	22.0	32.0	0.0	2.0	3.0
8/4/2009	0.828	0.790	1	29	30	7	W	27.5	15.18	9.00	169	406	41.0	13.60	16.0	58.0	3.0	2.0	0.0
8/18/2009	0.910	1.24	2	24	50	7	NW	26.2	11.86	8.60	177	411	43.4	15.90	25.0	54.0	0.0	3.0	3.0
9/1/2009	0.902	0.500	2	21	30	4	SE	23.6	12.01	8.50	157	384	34.0	24.90	27.0	35.0	1.0	3.0	4.0
9/15/2009	0.750	0.700	1	27	35	3	SE	25.1	10.07	8.50	168	400	41.2	11.20	26.0	31.0	2.0	2.0	5.0
MIN.	0.750	0.07	0	13	0	0	-	18.1	4.40	7.7	136	345	22.2	11.2	16.0	7.9	0.0	1.3	0.0
MAX.	1.750	3.58	21	33	100	13	-	33.4	16.18	9.1	192	471	44.5	90.8	59.0	94.0	21.0	3.0	7.0
AVG.	1.121	1.26	4	24	44	6	-	25.3	9.32	-	163	418	34.3	27.0	27.9	34.3	2.9	2.1	3.6

Summer Instantaneous Monitoring Results at Site W-M599.5D

Date	Water Depth (m)	Velocity (cm/sec)	Wave Height (cm)	Air Temp. (°C)	Cloud Cover (%)	Wind Speed (MPH)	Wind Direction	Water Temp. (°C)	Dissolved Oxygen (mg/l)	pH (SU)	Total Alkalinity (mg/l as CaCO3)	Specific Conductance (µmhos/cm @ 25°C)	Secchi Disk Depth (cm)	Turbidity (NTU)	Suspended Solids (mg/l)	Chlorophyll a (mg/m^3)	Chlorophyll b (mg/m^3)	Chlorophyll c (mg/m^3)	Pheophytin a (mg/m^3)
6/5/2007	1.350	**	15	20	30	11	NW	22.4	6.22	7.90	140	464	41.0	21.00	25.0	18.0	<1	<1	<1
6/19/2007	1.090	*	22	24	10	15	NW	25.1	5.86	8.00	158	464	36.5	35.30	44.0	12.0	<1	<1	2.0
7/3/2007	0.980	*	13	30	80	9	SW	27.4	8.35	8.30	170	474	37.0	21.80	20.0	27.0	1.9	<1	<1
7/17/2007	1.110	*	8	21	80	5	S	23.9	5.16	8.30	160	427	38.5	23.20	35.0	45.0	<1	1.8	<1
7/31/2007	1.155	2.92	10	33	10	5	SW	31.5	13.30	8.90	158	410	42.0	13.10	27.0	30.0	1.1	1.1	<1
8/14/2007	1.145	2.71	10	27	80	5	NW	28.4	7.11	8.00	143	396	46.5	17.50	26.0	21.0	2.4	2.4	2.1
8/28/2007	1.560	1.71	15	33	10	9	SW	25.1	6.51	7.70	139	348	30.0	21.20	30.0	12.0	1.5	2.1	2.2
9/11/2007	0.960	*	30	19	15	15	NW	20.0	7.63	8.00	179	467	25.0	44.10	70.0	12.0	<1	<1	3.0
6/3/2008	1.515	-	6	14	98	6	E	19.5	11.82	8.40	152	426	27.6	85.80	50.0	58.0	<1	2.2	<1
6/24/2008	2.270	-	15	26	40	8	SE	24.5	7.44	7.80	156	390	34.5	30.10	31.0	24.0	<1	2.2	2.5
7/8/2008	1.400	4.63	7	23	90	7	W	25.0	6.75	8.00	161	449	30.5	27.50	28.0	19.0	1.1	1.1	2.4
7/22/2008	1.620		4	27	15	5	E	28.5	13.25	8.30	154	418	29.0	30.40	23.0	13.0	1.5	1.4	2.5
8/5/2008	0.980	5.40	15	27	35	11	NW	28.2	10.59	8.80	178	435	31.0	34.20	25.0	26.0	<1	<1	2.6
8/19/2008	0.960	-	6	28	30	3	SE	28.0	13.38	9.20	190	438	28.5	31.20	22.0	61.0	1.4	1.9	8.2
9/5/2008	1.000	-	8	16	20	3	W	20.2	6.44	-	176	432	22.0	43.60	35.0	13.0	<1	<1	3.2
9/16/2008	0.960	2.23	0	12	0	0	-	17.7	5.56	-	178	462	26.0	41.40	37.0	10.0	1.8	<1	1.8
6/4/2009	1.150	1.49	9	22	20	3	W	26.7	6.53	7.70	129	378	29.0	23.60	23.0	5.0	0.0	1.0	2.0
6/23/2009	1.202	*	3	33	75	4	S	32.4	7.55	8.19	132	349	23.0	29.30	28.0	53.0	10.0	2.0	4.0
7/7/2009	0.954	2.61	3	20	90	4	E	23.8	7.20	8.02	164	406	21.2	35.10	36.0	37.0	2.0	2.0	2.0
7/21/2009	1.128	2.25	5	18	100	6	E	21.8	9.74	8.63	169	409	46.0	13.70	23.0	33.0	0.0	3.0	6.0
8/4/2009	0.980	2.28	10	29	20	6	NW	25.9	9.77	8.60	165	416	36.6	22.50	38.0	34.0	0.0	2.0	2.0
8/18/2009	1.148	1.83	15	24	45	10	NW	25.8	8.52	8.20	176	418	38.4	17.70	20.0	23.0	0.0	1.0	3.0
9/1/2009	1.032	1.99	3	21	30	6	SE	22.9	12.38	8.60	159	383	31.0	21.10	21.0	35.0	1.0	2.0	2.0
9/15/2009	0.996	1.46	6	26	35	5	SE	24.8	11.52	8.50	170	398	43.6	14.40	16.0	56.0	5.0	3.0	0.0
MIN.	0.954	1.46	0	12	0	0	-	17.7	5.16	7.7	129	348	21.2	13.1	16.0	5.0	0.0	1.0	0.0
MAX.	2.270	5.40	30	33	100	15	-	32.4	13.38	9.2	190	474	46.5	85.8	70.0	61.0	10.0	3.0	8.2
AVG.	1.194	2.58	10	24	44	7	-	25.0	8.69	-	161	419	33.1	29.1	30.5	28.2	1.9	1.9	2.8

* Meter malfunction
** Not applicable, ice cover
*** Too windy to take measurement
**** Field/Laboratory accident

Summer Instantaneous Monitoring Results at Site W-M599.8B

Date	Water Depth (m)	Velocity (cm/sec)	Wave Height (cm)	Air Temp. (°C)	Cloud Cover (%)	Wind Speed (MPH)	Wind Direction	Water Temp. (°C)	Dissolved Oxygen (mg/l)	pH (SU)	Total Alkalinity (mg/l as CaCO3)	Specific Conductance (µmhos/cm @ 25°C)	Secchi Disk Depth (cm)	Turbidity (NTU)	Suspended Solids (mg/l)	Chlorophyll a (mg/m^3)	Chlorophyll b (mg/m^3)	Chlorophyll c (mg/m^3)	Pheophytin a (mg/m^3)
6/5/2007	3.140	-	12	20	30	6	NW	23.5	6.70	7.70	139	467	66.0	12.90	12.0	17.0	<1	<1	<1
6/19/2007	3.020	-	18	24	20	7	W	26.9	7.13	8.30	167	477	63.0	12.20	15.0	9.4	<1	<1	<1
7/3/2007	2.785	-	5	30	85	5	SW	28.0	14.20	8.80	176	468	61.5	8.28	6.0	54.0	<1	<1	<1
7/17/2007	2.950	-	1	21	80	3	S	24.2	3.91	7.90	174	441	58.5	10.30	17.0	34.0	<1	1.3	<1
7/31/2007	2.980	1.20	0	33	10	1	W	31.1	10.44	8.50	155	418	47.5	10.50	15.0	20.0	<1	<1	<1
8/14/2007	3.050	1.00	0	27	80	1	W	27.0	8.37	8.10	147	403	49.0	8.32	20.0	79.0	<1	<1	<1
8/28/2007	3.380	-	10	33	10	5	SW	26.9	7.65	7.90	137	343	39.0	22.10	30.0	11.0	1.1	<1	<1
9/11/2007	2.900	-	10	19	15	14	W	21.1	5.79	7.80	182	468	32.0	27.20	27.0	11.0	<1	<1	2.8
6/3/2008	3.210	-	12	14	98	10	SE	19.6	9.65	8.40	146	429	26.2	80.40	56.0	58.0	<1	1.7	<1
6/24/2008	3.900	-	8	26	40	0	-	25.0	7.72	7.80	144	385	32.0	31.20	27.0	21.0	<1	1.4	5.2
7/8/2008	3.130	1.04	1	23	90	3	W	25.6	6.48	7.90	157	452	33.0	25.30	27.0	19.0	<1	1.4	5.2
7/22/2008	2.885	0.730	3	27	15	2	S	30.0	16.12	8.40	155	419	28.0	25.20	24.0	18.0	2.1	1.2	<1
8/5/2008	2.800	2.56	8	27	40	7	W	29.8	14.13	9.00	178	433	41.0	13.40	12.0	23.0	1.3	1.2	1.2
8/19/2008	2.850	5.320	2	27	20	5	SW	27.3	11.08	9.00	194	442	33.0	31.10	24.0	31.0	1.5	<1	7.1
9/5/2008	2.720	-	2	17	20	0	-	21.1	5.09	-	185	443	32.0	29.60	24.0	18.0	<1	<1	2.2
9/16/2008	2.710	3.350	1	13	0	0	-	18.4	5.68	-	184	462	28.5	27.50	23.0	9.3	<1	<1	6.8
6/4/2009	2.880	1.220	6	22	20	5	SW	26.0	7.82	7.90	133	382	29.0	25.50	25.0	11.0	2.0	2.0	3.0
6/23/2009	2.962	*	0	34	60	1	N	34.5	9.16	8.42	132	350	27.2	29.40	32.0	72.0	16.0	2.0	2.0
7/7/2009	2.742	0.640	1	20	90	0	-	23.9	8.57	8.22	170	411	35.0	14.90	18.0	73.0	5.0	3.0	9.0
7/21/2009	2.818	0.830	3	18	100	3	E	21.7	10.07	8.65	171	415	61.8	10.70	13.0	34.0	0.0	2.0	7.0
8/4/2009	2.720	1.16	8	29	20	7	W	27.5	18.30	9.10	168	403	52.0	45.00	16.0	55.0	2.0	3.0	0.0
8/18/2009	2.950	3.20	9	24	40	6	W	26.5	9.61	8.20	177	422	56.8	12.10	15.0	31.0	1.0	2.0	3.0
9/1/2009	2.848	2.43	1	21	30	3	SE	23.1	11.88	8.40	161	391	47.2	10.80	14.0	32.0	1.0	2.0	2.0
9/15/2009	2.690	1.62	2	26	35	3	E	24.7	10.95	8.50	181	409	46.4	13.90	19.0	83.0	4.0	4.0	7.0
MIN.	2.690	0.64	0	13	0	0	-	18.4	3.91	7.7	132	343	26.2	8.3	6	9.3	0.0	1.2	0.0
MAX.	3.900	5.32	18	34	100	14	-	34.5	18.30	9.1	194	477	66.0	80.4	56	83.0	16.0	4.0	9.0
AVG.	2.959	1.88	5	24	44	4	-	25.6	9.44	-	163	422	42.7	22.4	21	34.3	3.1	2.0	4.2

Summer Instantaneous Monitoring Results at Site W-M600.3C

Date	Water Depth (m)	Velocity (cm/sec)	Wave Height (cm)	Air Temp. (°C)	Cloud Cover (%)	Wind Speed (MPH)	Wind Direction	Water Temp. (°C)	Dissolved Oxygen (mg/l)	pH (SU)	Total Alkalinity (mg/l as CaCO3)	Specific Conductance (µmhos/cm @ 25°C)	Secchi Disk Depth (cm)	Turbidity (NTU)	Suspended Solids (mg/l)	Chlorophyll a (mg/m^3)	Chlorophyll b (mg/m^3)	Chlorophyll c (mg/m^3)	Pheophytin a (mg/m^3)
6/5/2007	2.585	-	3.0	19	30	7	N	22.2	6.73	7.60	143	467	31.50	43.60	38.0	26.0	<1	1.4	<1
6/19/2007	2.295	-	8.0	24	20	5	W	26.9	5.53	8.10	159	465	39.00	23.70	27.0	11.0	<1	<1	<1
7/3/2007	2.290	-	6.0	30	85	5	SW	27.8	9.66	8.40	170	471	42.00	15.30	15.0	23.0	<1	<1	<1
7/17/2007	1.340	-	0.0	21	85	1	SW	24.1	4.26	8.20	161	424	35.50	21.30	36.0	46.0	<1	<1	<1
7/31/2007	2.335	3.14	0.0	33	10	4	SW	30.2	7.34	8.10	148	422	48.00	10.10	7.0	13.0	<1	<1	<1
8/14/2007	2.385	3.79	1.0	27	85	3	NW	28.0	3.76	7.70	142	401	50.00	10.70	20.0	12.0	2.1	2.4	1.4
8/28/2007	2.870	22.42	5.0	33	10	2	SW	25.0	5.59	7.50	135	347	28.00	27.80	36.0	12.0	<1	<1	8.7
9/11/2007	2.350	-	12.0	19	20	5	SW	21.3	6.61	7.90	184	471	32.00	27.20	38.0	11.0	<1	<1	2.2
6/3/2008	2.525	-	10.0	14	98	9	SE	19.6	9.98	8.40	150	422	31.20	92.10	55.0	57.0	<1	1.2	<1
6/24/2008	3.450	19.51	4.0	26	40	1	S	24.5	7.48	7.80	165	387	31.50	34.70	38.0	22.0	<1	1.6	3.6
7/8/2008	2.660	8.29	1.0	23	90	3	SW	25.1	6.14	7.80	145	448	28.00	43.40	33.0	14.0	<1	1.1	4.8
7/22/2008	2.530	9.85	2.0	26	20	5	SE	29.2	14.39	8.30	158	417	35.00	31.00	28.0	12.0	<1	<1	3.1
8/5/2008	2.420	3.93	6.0	27	45	4	W	29.4	12.09	8.80	174	438	40.00	21.80	19.0	19.0	1.7	2.2	2.5
8/19/2008	2.250	6.98	0.0	27	20	1	NE	27.1	10.64	9.00	179	441	33.00	32.70	27.0	23.0	<1	<1	5.8
9/5/2008	2.060	-	5.0	17	20	4	SW	21.4	6.48	-	185	439	26.00	50.00	38.0	14.0	<1	<1	2.2
9/16/2008	2.280	4.55	1	12	0	1	NE	17.7	6.87	-	183	460	28.0	33.20	28.0	11.0	<1	<1	3.2
6/4/2009	2.440	4.54	3.0	22	25	6	SW	24.4	6.67	7.70	134	375	26.00	29.00	23.0	5.0	0.0	1.0	2.0
6/23/2009	2.540	*	0.0	34	55	2	NW	33.0	6.29	7.86	139	355	23.80	31.10	35.0	16.0	2.0	2.0	4.0
7/7/2009	2.560	7.97	1.0	19	90	2	N	23.4	6.48	7.96	170	405	21.20	29.80	35.0	15.0	1.0	2.0	4.0
7/21/2009	2.324	9.36	3.0	18	100	4	E	21.5	8.31	8.37	170	412	49.60	13.50	19.0	20.0	0.0	2.0	5.0
8/4/2009	2.102	2.56	1.0	29	20	2	SW	27.1	10.15	8.50	168	422	39.60	17.90	21.0	23.0	0.0	1.0	2.0
8/18/2009	2.334	2.53	4.0	24	40	3	W	25.9	7.86	8.10	172	420	41.20	16.50	20.0	18.0	1.0	1.0	4.0
9/1/2009	2.320	5.26	1.0	21	30	5	E	22.8	10.55	8.30	160	387	33.60	20.10	21.0	21.0	0.0	2.0	3.0
9/15/2009	2.210	3.27	1.0	26	35	4	NE	24.4	7.42	8.10	168	406	43.80	14.60	18.0	16.0	0.0	1.0	3.0
MIN.	1.340	2.53	0	12	0	1	-	17.7	3.76	7.5	134	347	21.2	10.1	7	5.0	0.0	1.0	1.4
MAX.	3.450	22.42	12	34	100	9	-	33.0	14.39	9.0	185	471	50.0	92.1	55	57.0	2.1	2.4	8.7
AVG.	2.394	7.37	3	24	45	4	-	25.1	7.80	-	161	421	34.9	28.8	28	19.2	0.8	1.6	3.6

* Meter malfunction
** Not applicable, ice cover
*** Too windy to take measurement
**** Field/Laboratory accident

Winter Instantaneous Monitoring Results at Site W-M599.8B

DATE	WATER DEPTH (M)	VELOCITY (CM/SEC)	AIR TEMP. (°C)	CLOUD COVER (%)	SURFACE WATER TEMP. (°C)	MID-DEPTH WATER TEMP. (°C)	DISSOLVED OXYGEN (MG/L)	pH (SU)	TOTAL ALKALINITY (MG/L as CaCO3)	SPECIFIC CONDUCTANCE (µMHOS/CM @ 25°C)	TURBIDITY (NTU)	SUSPENDED SOLIDS (MG/L)
12/19/2006	2.970	0.38	-4	5	1.7	1.8	19.80	8.80	155	340	5.44	14.0
1/25/2007	3.010	-	-7	15	0.2	0.4	15.17	7.80	151	335	3.00	7.0
3/15/2007	3.360	1.89	-1	40	0.6	0.9	14.28	7.70	136	309	57.40	-
12/14/2007	3.110	-	-12	10	0.1	0.3	14.10	7.80	181	370	7.49	3.0
1/31/2008	2.940	0.45	-15	75	0.0	0.2	14.79	7.80	179	378	9.60	7.0
3/13/2008	2.980	0.43	2	20	0.1	1.0	13.87	7.50	167	354	15.40	12.0
12/9/2008	2.780	1.160	-3	100	0.2	0.5	17.48	8.30	190	358	5.56	
1/21/2009	2.900	-	-8	20	0.1	0.2	14.35	7.80	195	377	5.99	
3/6/2009	2.790	0.530	2	20	1.8	2.3	16.86	8.00	152	330	24.40	
12/14/2009	2.700	0.28	-4	98	0.1	0.5	14.79	8.20	202	415	10.30	
1/25/2010	2.870	0.82	-7	100	0.2	0.3	12.38	7.60	185	396	6.80	
3/12/2010	3.280	3.88	8	100	1.5	1.6	12.58	7.80	-	349	40.60	
MIN.	2.700	0.28	-15	5	0.0	0.2	12.38	7.50	136	309	3.000	3.0
MAX.	3.360	3.88	8	100	1.8	2.3	19.80	8.80	202	415	57.40	14.0
AVG.	2.974	1.09	-4	50	0.55	0.83	15.04	-	172	359	16.00	8.6

Winter Instantaneous Monitoring Results at Site W-M600.3C

DATE	WATER DEPTH (M)	VELOCITY (CM/SEC)	AIR TEMP. (°C)	CLOUD COVER (%)	SURFACE WATER TEMP. (°C)	MID-DEPTH WATER TEMP. (°C)	DISSOLVED OXYGEN (MG/L)	pH (SU)	TOTAL ALKALINITY (MG/L as CaCO3)	SPECIFIC CONDUCTANCE (µMHOS/CM @ 25°C)	TURBIDITY (NTU)	SUSPENDED SOLIDS (MG/L)
12/19/2006	2.200	5.13	-3	5	1.2	1.5	19.37	8.80	148	334	6.13	13.0
1/25/2007	2.400	-	-10	80	0.1	0.1	16.56	7.80	146	329	3.40	7.0
3/15/2007	2.650	10.52	-2	25	0.4	0.4	14.59	7.70	135	307	62.00	-
12/14/2007	0.820	7.18	-13	10	0.1	-	14.43	7.80	185	368	8.75	2.0
1/31/2008	2.370	9.27	-15	85	0.0	-	14.19	7.70	179	370	8.57	5.0
3/13/2008	2.500	8.15	2	20	0.8	-	13.89	7.50	167	361	7.78	3.0
12/9/2008	1.920	5.78	-3	100	0.2	-	17.43	8.20	180	356	6.03	
1/21/2009	2.480	-	-8	20	0.1	-	14.12	7.70	183	376	4.65	
3/6/2009	2.280		2	20	2.1	2.0	16.61	8.00	164	436	9.95	
12/14/2009	2.220	4.26	-4	98	0.0	-	14.49	8.30	184	409	5.20	
1/25/2010	2.320	11.40	-7	100	0.2	-	12.79	7.50	186	399	5.00	
3/12/2010	2.760	12.520	8	100	1.7	1.7	12.62	7.70	-	348	54.50	
MIN.	0.820	4.26	-15	5	0.0	0.1	12.62	7.50	135	307	3.400	2.0
MAX.	2.760	12.52	8	100	2.1	2	19.37	8.80	186	436	62.00	13.0
AVG.	2.243	8.25	-4	55	0.58	-	15.09	-	169	366	15.16	6.0

* Meter malfunction
** Not applicable, ice cover
*** Too windy to take measurement
**** Field/Laboratory accident

Date	Dredged Area	Site Name	Ice Depth (ft)	Max Depth (ft)	Sample Depth (ft)	Water Column Location	Dissolved Oxygen (mg/l)	Water Temp. (°C)	Velocity (ft/sec)	Current Direction	Specific Conductance (µmhos/cm @ 25°C)
2/8/1999		Bertom Landing	1	4	2		13.2	0.8	-		240
2/8/1999	A	02BMCL9	1	8.3	8	BOTTOM	11.6	1.5	ND		255
2/8/1999	A	02BMCL9	1	8.3	6	MIDBOTTOM	11.6	1.5	0.01	W	255
2/8/1999	A	02BMCL9	1	8.3	4	MIDDLE	11.8	1.4	0.01	W	255
2/8/1999	A	02BMCL9	1	8.3	1.5	TOP	12.9	0.6	0.03	W	240
2/8/1999	C	01BMCL9B	0.9	8.6	8	BOTTOM	9.3	1.5	ND		255
2/8/1999	C	01BMCL9B	0.9	8.6	6	MIDBOTTOM	9.4	1.5	ND		255
2/8/1999	C	01BMCL9B	0.9	8.6	4	MIDDLE	9.6	1.5	ND		255
2/8/1999	C	01BMCL9B	0.9	8.6	1.5	TOP	9.5	1.3	ND		250
2/8/1999	C	BMCL9C	0.8	9	8.5	BOTTOM	7.2	1.7	ND		250
2/8/1999	C	BMCL9C	0.8	9	6	MIDBOTTOM	7.2	1.7	ND		250
2/8/1999	C	BMCL9C	0.8	9	3	MIDDLE	7.3	1.7	0.02	S	250
2/8/1999	C	BMCL9C	0.8	9	1	TOP	8.2	1.1	0.01	S	250
2/19/2003		Bertom Landing	1.6	3.5	2.5		16.5	0	0.08	W	225
2/19/2003		BMCL10	0.6	1.2	1		17.2	0.3	0.04	W	225
2/19/2003	A	02BMCL9	1.3	7.5	7	BOTTOM	18	2	-		265
2/19/2003	A	02BMCL9	1.3	7.5	4	MIDDLE	20	1.9	ND		250
2/19/2003	A	02BMCL9	1.3	7.5	2	TOP	>20	1.7	ND		235
2/19/2003	C	01BMCL9B	1.7	7.4	7	BOTTOM	19.4	1.8	-		255
2/19/2003	C	01BMCL9B	1.7	7.4	4	MIDDLE	>20	1.6	ND		240
2/19/2003	C	01BMCL9B	1.7	7.4	2	TOP	18	0.9	ND		230
2/19/2003	F	03BMCL5	1.8	8.1	7.5	BOTTOM	14	1	-		240
2/19/2003	F	03BMCL5	1.8	8.1	5	MIDDLE	19.8	0.6	-		230
2/19/2003	F	03BMCL5	1.8	8.1	2	TOP	19.8	0.4	ND		230
2/19/2003	F	03BMCL6	1.8	7.3	7	BOTTOM	17.8	1	-		235
2/19/2003	F	03BMCL6	1.8	7.3	4	MIDDLE	19.8	0.8	-		230
2/19/2003	F	03BMCL6	1.8	7.3	2	TOP	19.6	0.7	ND		230
2/19/2003	G	09BMCL8	0.9	9.3	9	BOTTOM	17.9	0.4	0.22	W	230
2/19/2003	G	09BMCL8	0.9	9.3	5	MIDDLE	17.9	0.4	0.25	W	230
2/19/2003	G	09BMCL8	0.9	9.3	2	TOP	17.8	0.4	0.19	W	230
2/19/2003	H	04BMCL7	1.7	7.8	7.5	BOTTOM	16.6	1.2	-		250
2/19/2003	H	04BMCL7	1.7	7.8	4	MIDDLE	19	0.6	-		230
2/19/2003	H	04BMCL7	1.7	7.8	2	TOP	18.5	0.4	ND		230
2/19/2003		small stream above rock	0	0.2	0.1		12.3	6	0.3	N	410
2/26/2004		BMCL1	0.6	10.8	8	BOTTOM	12.4	0.4			216
2/26/2004		BMCL1	0.6	10.8	4	MIDDLE	12.4	0.4			217
2/26/2004		BMCL1	0.6	10.8	2	TOP	12.4	0.4	0.17	NW	217
2/26/2004		BMCL2	0.8	4.3	4	BOTTOM	12.4	0.4			217
2/26/2004		BMCL2	0.8	4.3	2	TOP	12.4	0.4	0.14	NW	217
2/26/2004		BMCL3	0.8	4.9	4	BOTTOM	12.5	0.5			220
2/26/2004		BMCL3	0.8	4.9	2	TOP	12.4	0.6	0.22	W	217
2/26/2004		BMCL10	0.8	1.6	1.3	MIDDLE	12.1	0.5	0.14	NW	217
2/26/2004	A	02BMCL9	1	6.6	6	BOTTOM	7.9	2.5			257
2/26/2004	A	02BMCL9	1	6.6	4	MIDDLE	11.3	1.7			234
2/26/2004	A	02BMCL9	1	6.6	2	TOP	12.6	1.6	ND		226
2/26/2004	B	02BMCL9DIS	0.8	7.6	7	BOTTOM	6.2	2.5			268
2/26/2004	B	02BMCL9DIS	0.8	7.6	4	MIDDLE	11.1	1.8			233
2/26/2004	B	02BMCL9DIS	0.8	7.6	2	TOP	11.8	1.6	ND		228
2/26/2004	C	01BMCL9B	1	3.5	3	BOTTOM	11.9	1.7			226
2/26/2004	C	01BMCL9B	1	3.5	2	TOP	12.4	1.3			222
2/26/2004	E	BMCL4	0.8	6.6	6	BOTTOM	12.4	0.4			217
2/26/2004	E	BMCL4	0.8	6.6	4	MIDDLE	12.4	0.4			217
2/26/2004	E	BMCL4	0.8	6.6	2	TOP	12.4	0.4	0.02	W	216
2/26/2004	F	03BMCL5	1.4	8.4	8	BOTTOM	5.5	1.6			242
2/26/2004	F	03BMCL5	1.4	8.4	5	MIDDLE	12.1	0.8			222
2/26/2004	F	03BMCL5	1.4	8.4	2	TOP	12.5	0.7			220
2/26/2004	F	03BMCL6	1.3	7.3	7	BOTTOM	11.5	1.2			222
2/26/2004	F	03BMCL6	1.3	7.3	4	MIDDLE	12.6	0.7			217
2/26/2004	G	08WQBMLCAR	0.3	6.8	6	BOTTOM	12.2	0.4			217
2/26/2004	G	08WQBMLCAR	0.3	6.8	4	MIDDLE	12.4	0.4			217
2/26/2004	G	08WQBMLCAR	0.3	6.8	2	TOP	12.4	0.4	0.27	W	217
2/26/2004	G	09BMCL8	0.3	5	4	BOTTOM	12.4	0.4			217
2/26/2004	G	09BMCL8	0.3	5	2	TOP	12.4	0.4	0.24	W	217
2/26/2004	G	09BMCL8.1	0.3	8	1	TOP	12.6	0.4	0.29	W	216
2/26/2004	H	04BMCL7	1.3	6.7	6	BOTTOM	12.5	0.8			218
2/26/2004	H	04BMCL7	1.3	6.7	4	MIDDLE	12.6	0.6			217
2/26/2004	H	04BMCL7	1.3	6.7	2	TOP	12.6	0.6	ND		215
2/26/2004	I	06BMCL12	1.5	6.9	6	BOTTOM	12.2	0.8			219
2/26/2004	I	06BMCL12	1.5	6.9	4	MIDDLE	12.5	0.5			218
2/26/2004	I	06BMCL12	1.5	6.9	2	TOP	12.5	0.4	ND		217
2/26/2004	K	05BMCL11	1.3	9.7	9	BOTTOM	9.1	1.4			224
2/26/2004	K	05BMCL11	1.3	9.7	7	MIDBOTTOM	12.1	0.8			222
2/26/2004	K	05BMCL11	1.3	9.7	5	MIDDLE	12.3	0.7			218
2/26/2004	K	05BMCL11	1.3	9.7	2	TOP	12.7	0.5	ND		215
2/26/2004	L	07BMCL	1.3	3.7	3	BOTTOM	12.5	0.6			215
2/26/2004	L	07BMCL	1.3	3.7	2	TOP	12.6	0.6			215

Figure C-4. WDNR Instantaneous Monitoring Results.

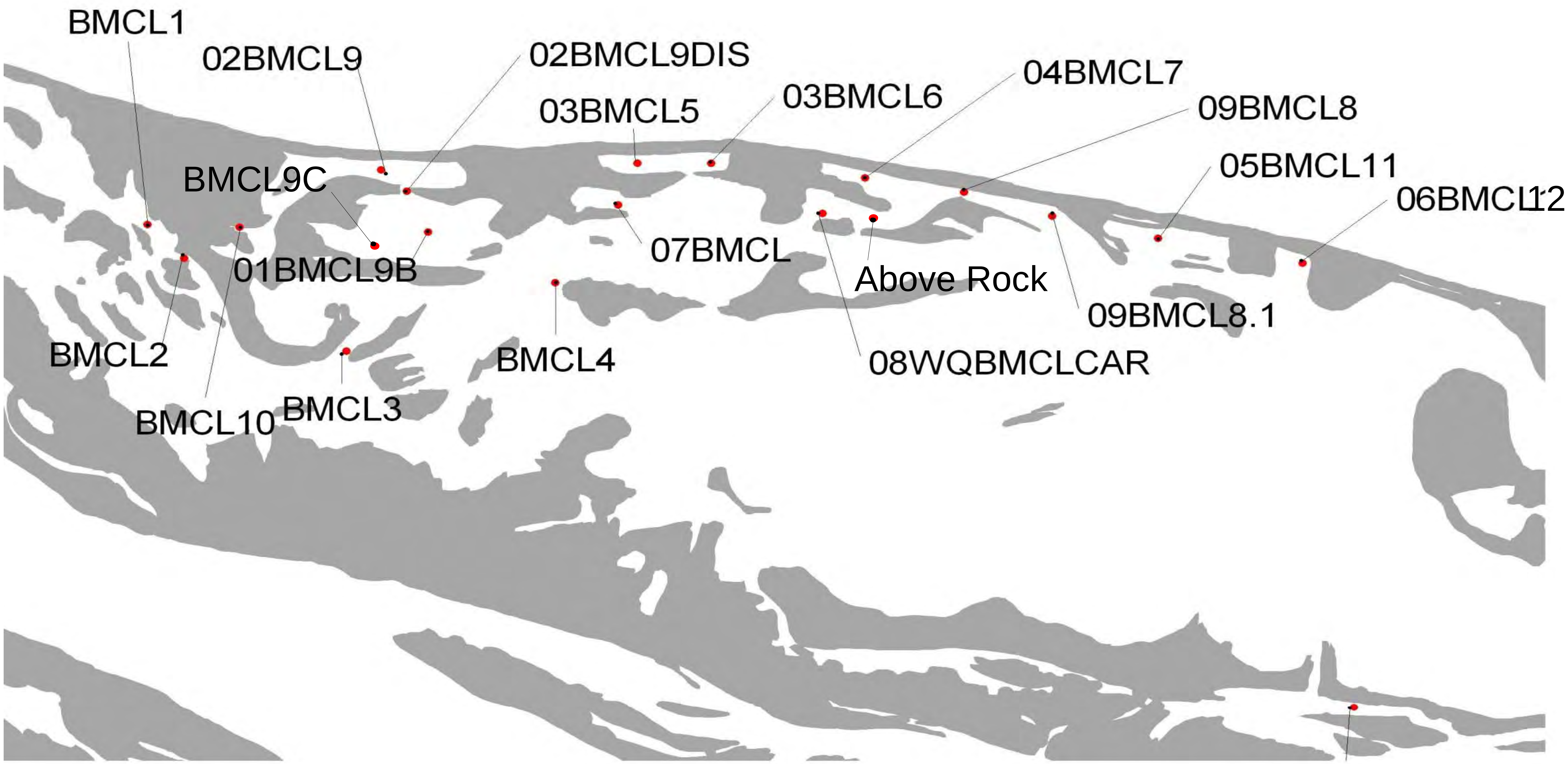
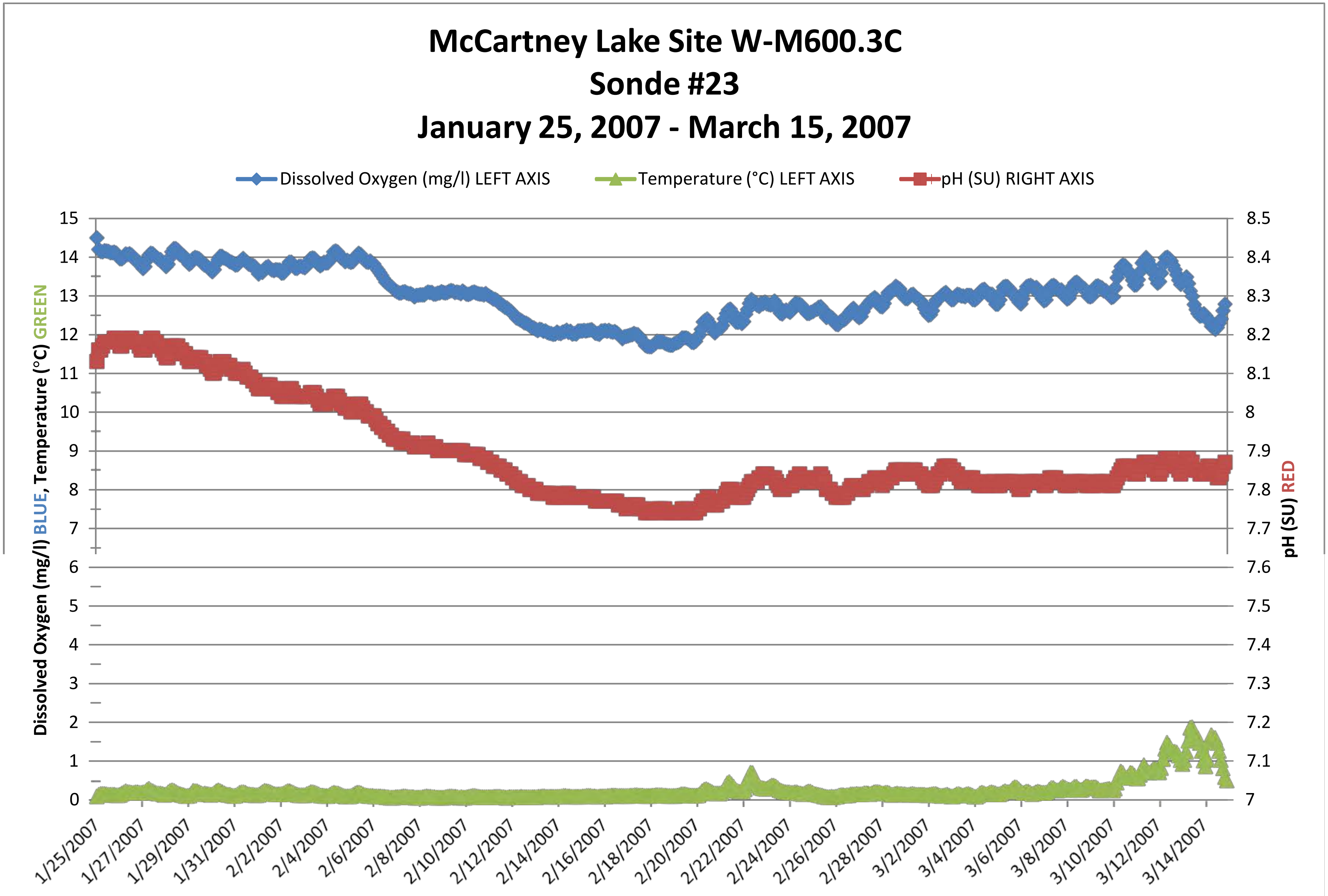


Figure C-5. Map of WDNR Sampling Locations and Discharge Measurements.

Figure C-6. Aquatic Vegetation on Leeward Side of Constructed Island, June 2007 (Google Earth Pro)


McCartney Lake Site W-M600.3C
Sonde #23
January 25, 2007 - March 15, 2007
Dissolved Oxygen (mg/l) LEFT AXIS
Temperature (°C) LEFT AXIS
pH (SU) RIGHT AXIS
Dissolved Oxygen (mg/l) BLUE, Temperature (°C) GREEN
pH (SU) RED
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
8.5
8.4
8.3
8.2
8.1
8
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7
1/25/2007
1/27/2007
1/29/2007
1/31/2007
2/2/2007
2/4/2007
2/6/2007
2/8/2007
2/10/2007
2/12/2007
2/14/2007
2/16/2007
2/18/2007
2/20/2007
2/22/2007
2/24/2007
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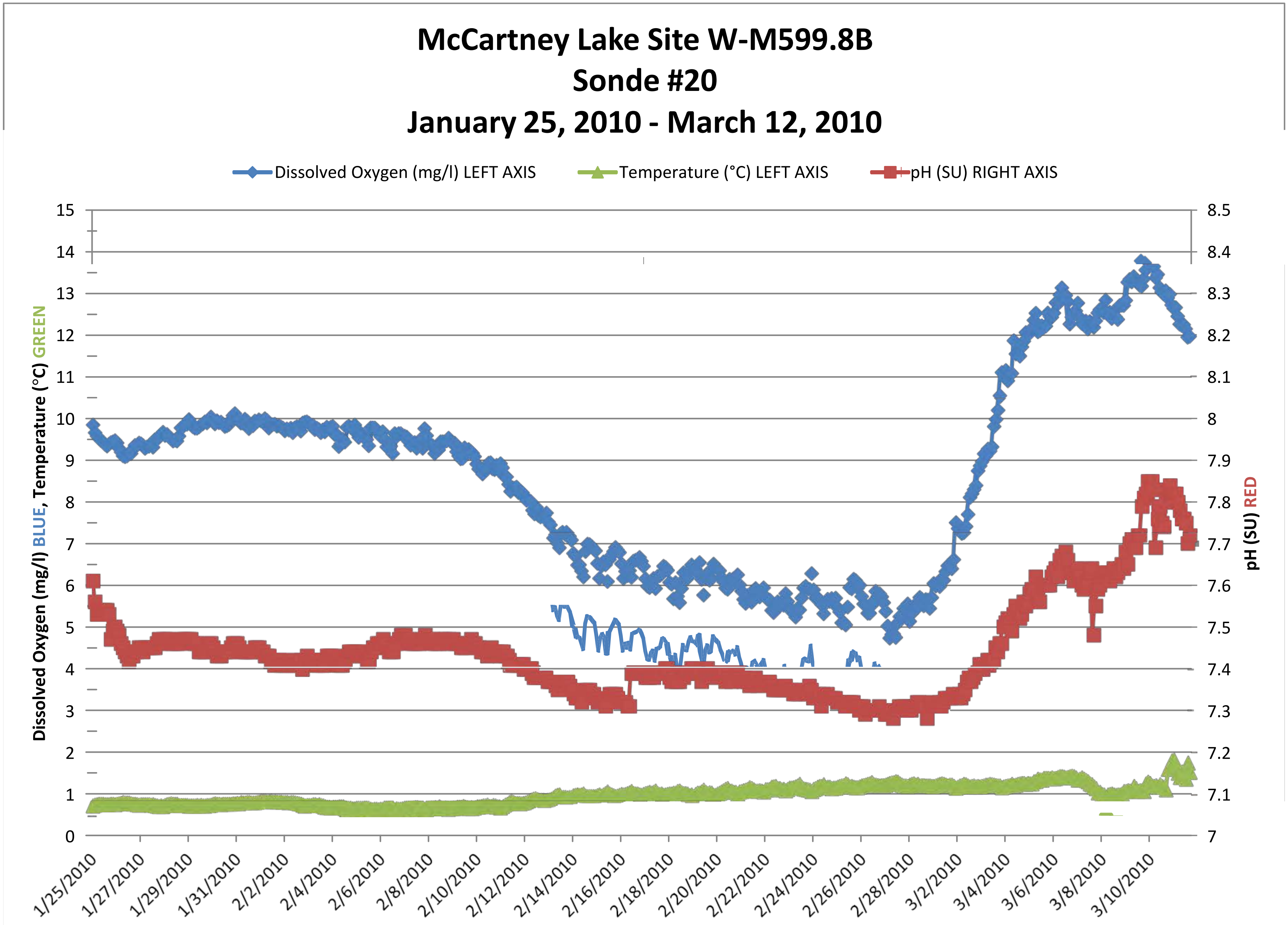
3/12/2007
3/14/2007


McCartney Lake Site W-M599.8B
Sonde #20
January 25, 2010 - March 12, 2010
Dissolved Oxygen (mg/l) LEFT AXIS
Temperature (°C) LEFT AXIS
pH (SU) RIGHT AXIS
Dissolved Oxygen (mg/l) BLUE, Temperature (°C) GREEN
pH (SU) RED
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
8.5
8.4
8.3
8.2
8.1
8
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7
1/25/2010
1/27/2010
1/29/2010
1/31/2010
2/2/2010
2/4/2010
2/6/2010
2/8/2010
2/10/2010
2/12/2010
2/14/2010
2/16/2010
2/18/2010
2/20/2010
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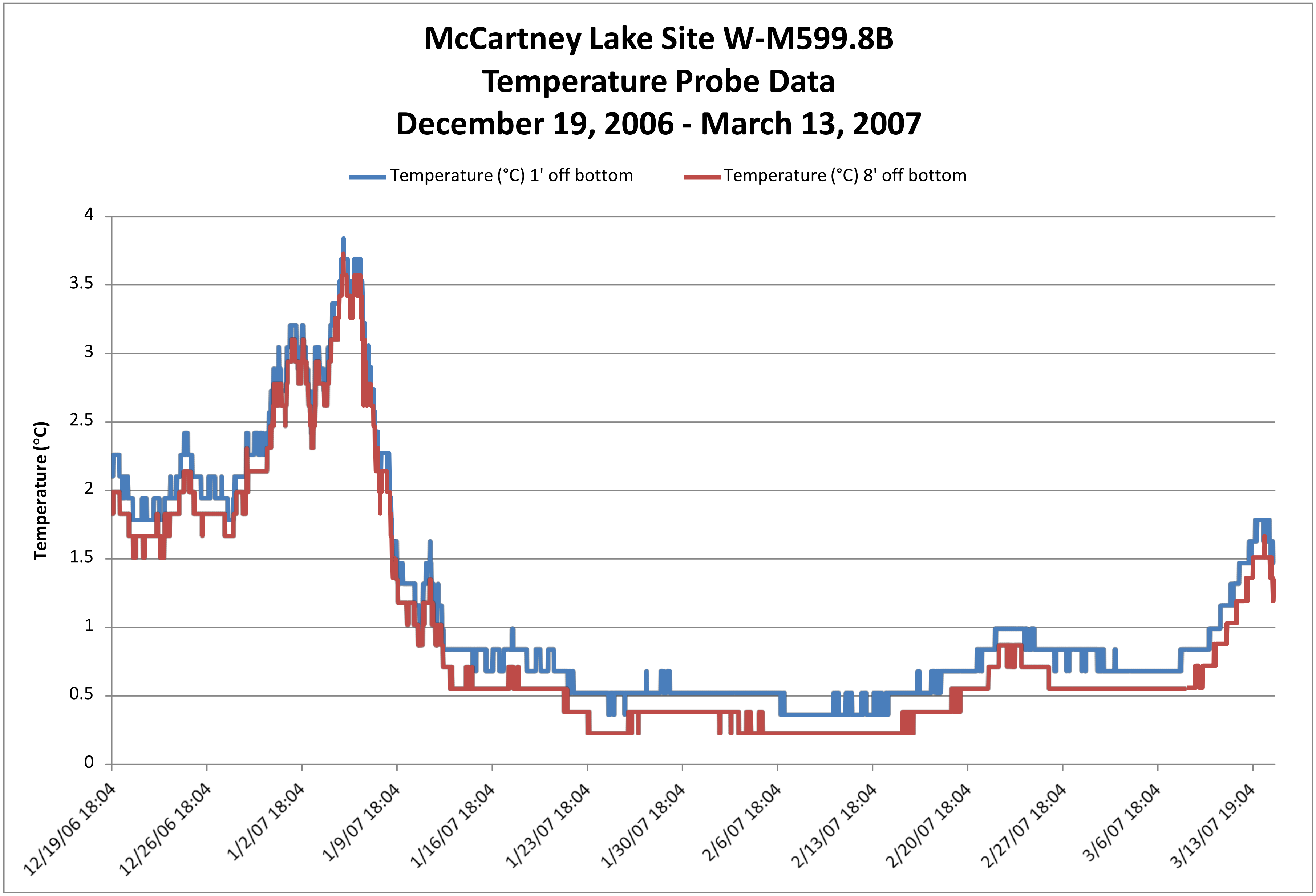
3/8/2010
3/10/2010


McCartney Lake Site W-M599.8B
Temperature Probe Data
December 19, 2006 - March 13, 2007
Temperature (°C) 1' off bottom
Temperature (°C) 8' off bottom
Temperature (°C)
4
3.5
3
2.5
2
1.5
1
0.5
0
12/19/06 18:04
12/26/06 18:04
1/2/07 18:04
1/9/07 18:04
1/16/07 18:04
1/23/07 18:04
1/30/07 18:04
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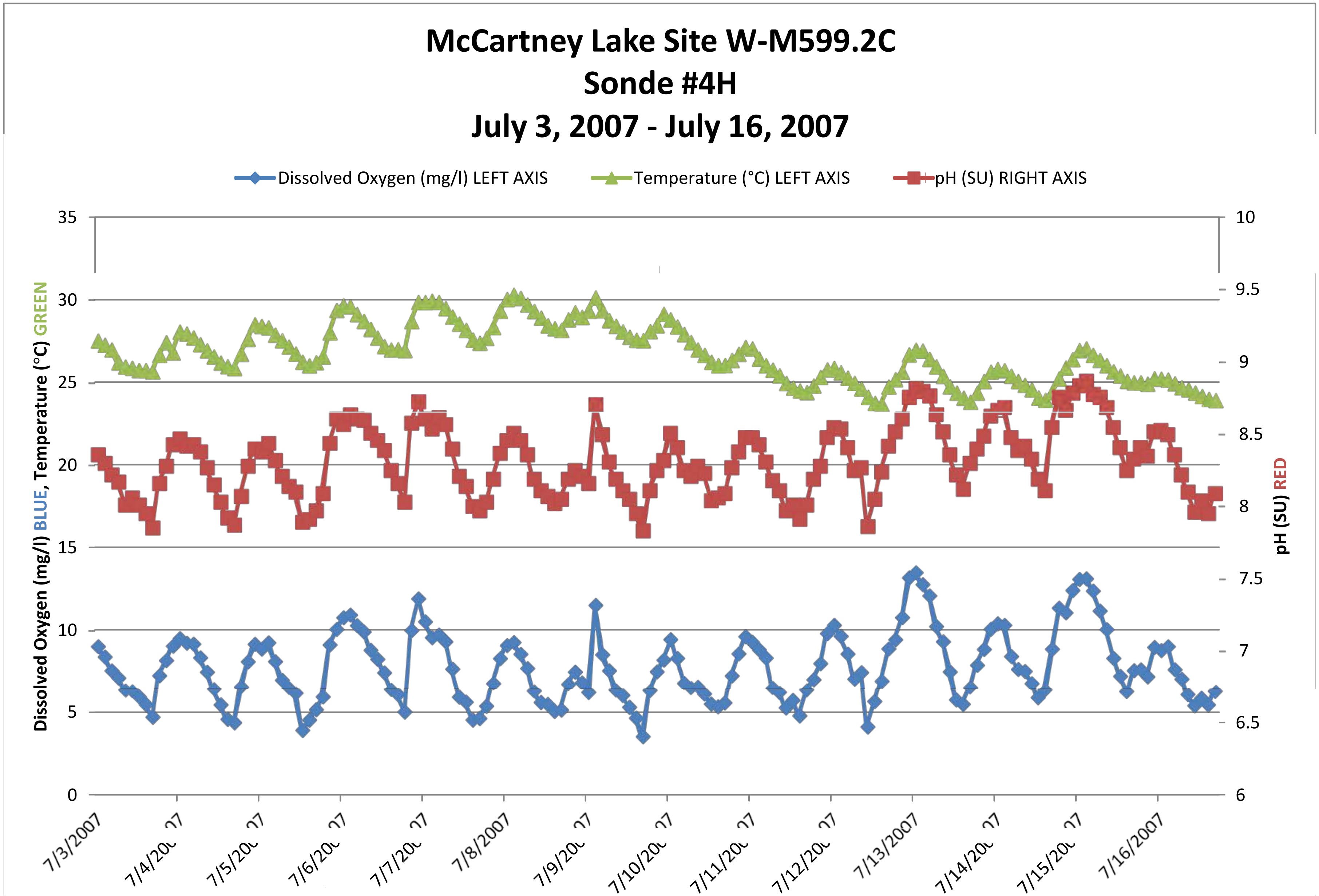
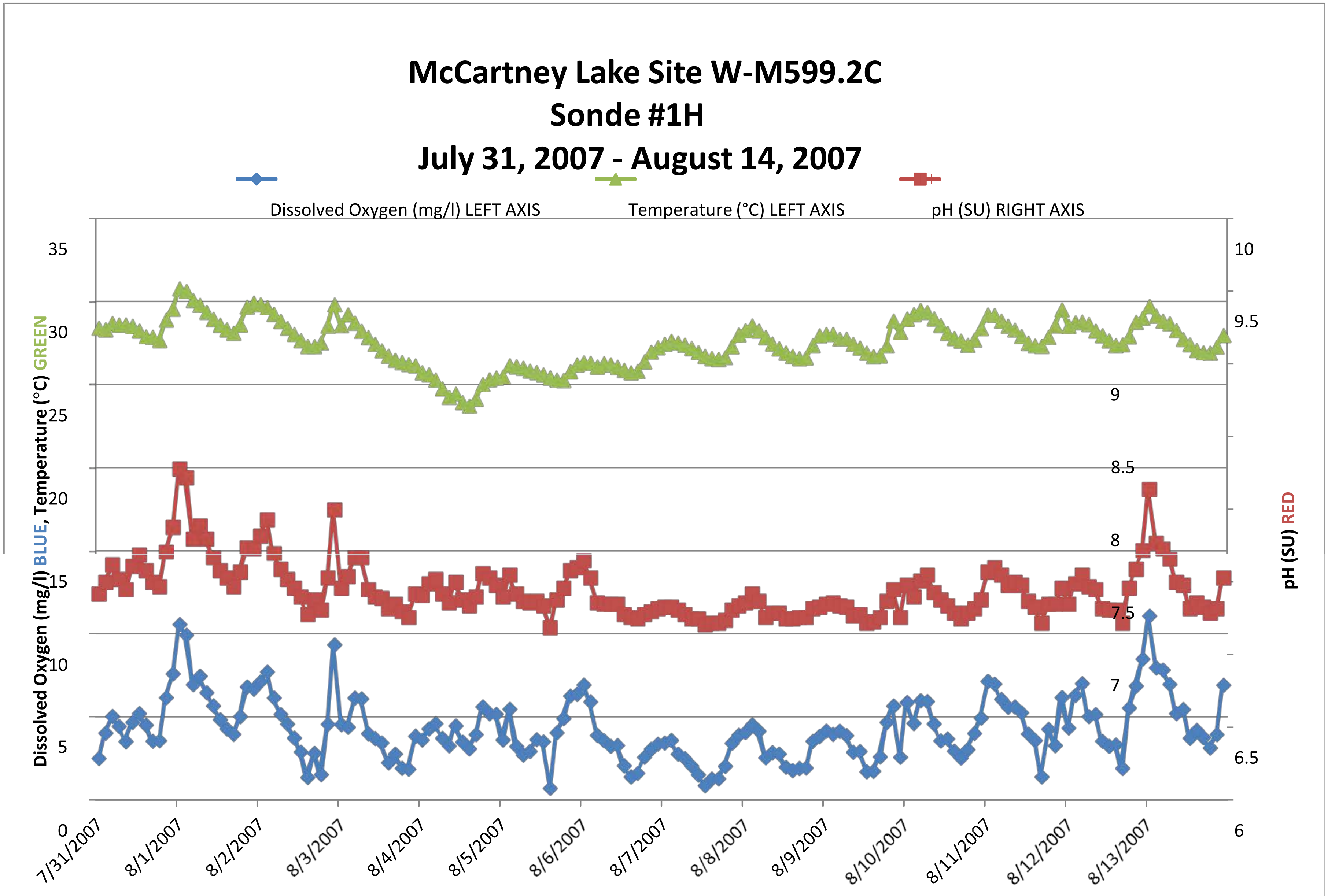
3/13/07 19:04



McCartney Lake Site W-M599.2C
Sonde #4H
July 3, 2007 - July 16, 2007
Dissolved Oxygen (mg/l) LEFT AXIS
Temperature (°C) LEFT AXIS
pH (SU) RIGHT AXIS
Dissolved Oxygen (mg/l) BLUE, Temperature (°C) GREEN
pH (SU) RED
35
30
25
20
15
10
5
0
10
9.5
9
8.5
8
7.5
7
6.5
6
7/3/2007
7/8/2007
7/13/2007
7/16/2007


McCartney Lake Site W-M599.2C
Sonde #1H
July 31, 2007 - August 14, 2007
Dissolved Oxygen (mg/l) LEFT AXIS
Temperature (°C) LEFT AXIS
pH (SU) RIGHT AXIS
Dissolved Oxygen (mg/l) BLUE, Temperature (°C) GREEN
pH (SU) RED
0
5
10
15
20
25
30
35
6
6.5
7
7.5
8
8.5
9
9.5
10
7/31/2007
8/1/2007
8/2/2007
8/3/2007
8/4/2007
8/5/2007
8/6/2007
8/7/2007
8/8/2007
8/9/2007
8/10/2007
8/11/2007
8/12/2007
8/13/2007

Appendix D

2013 Sediment Transect Plates

POINT ID	DESCRIPTION	NORTHING	EASTING	ELEV
CLAYTON CO. IA. GPS PT. 186	ALUM. BENCH MARK DISC	2192504.22	2085880.92	611.74
CLAYTON CO. IA. GPS PT. 202	REBAR W/ RPC (AERIAL TARGET)	2195156.77	2098499.80	616.81
13-161-100	CHISLED SQUARE UPSTREAM SIDE RAMP AT BERTOM BOAT LANDING 12" SPIKE W/ USACE WASHER	2194353.23	2098120.01	607.54

GENERAL NOTES

1. SURVEY FIELD WORK COMPLETED JUNE 10TH, 11TH AND 12TH, 2013. FIELD BK FC-06-2 PAGES 52 TO 76.
2. VERTICAL DATUM: MSL 1912, GEIOD 09 US
   HORIZONTAL DATUM: NAD83 (CONUS) ILLINOIS WEST-1202
   UNITS ARE US SURVEY FEET.
   TO CONVERT MSL 1912 TO NAVD 88 ADD 0.67 FEET

DWG REF(s) : ____________

A1 SURVEY CONTROL PLAN

SCALE : 1"=1000'-0" 0 1000' 2000'

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

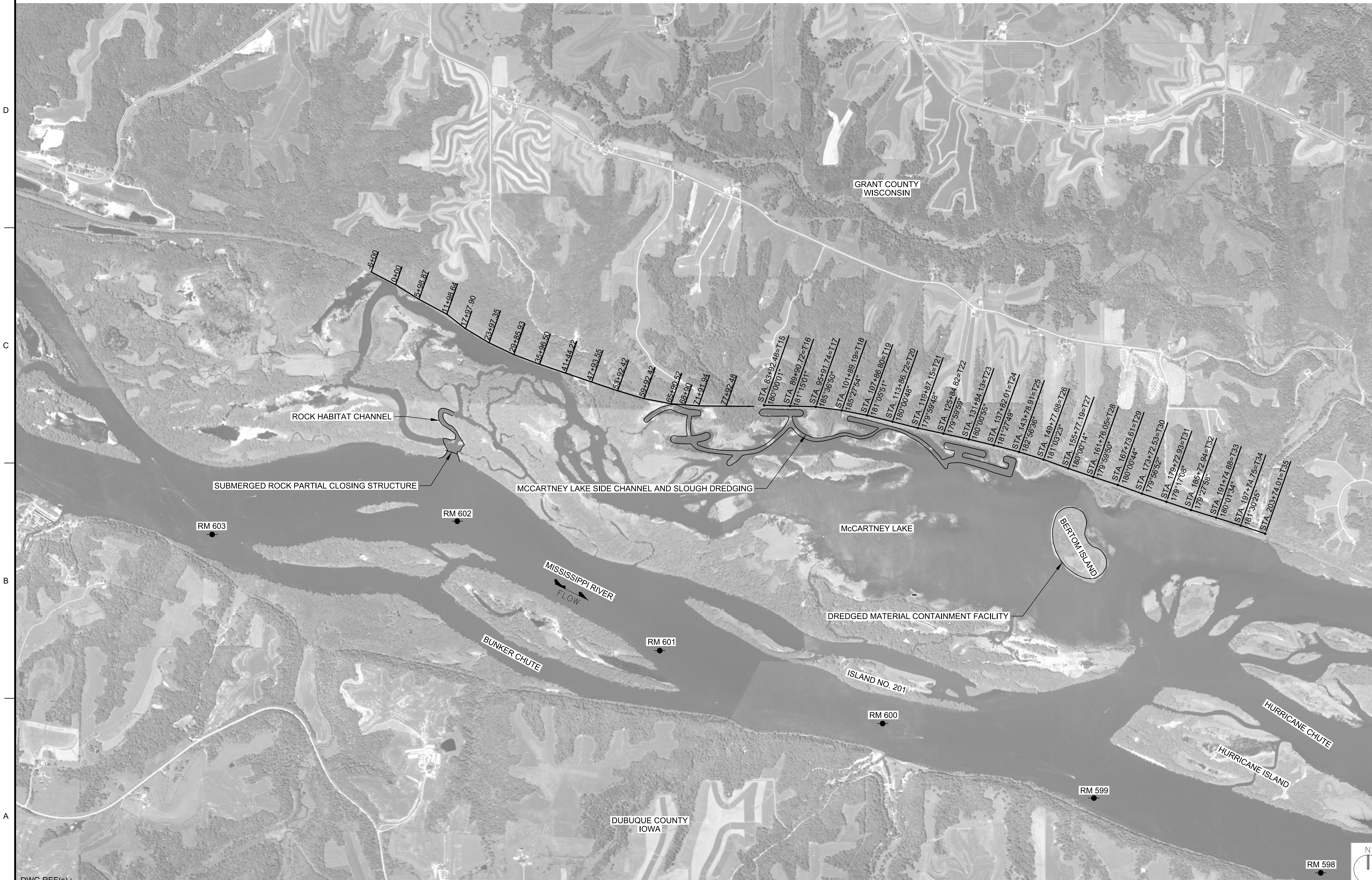
U.S. ARMY CORPS OF ENGINEERS
ROCK ISLAND DISTRICT
ROCK ISLAND, ILLINOIS

DESIGNED BY: SJG		DATE:
DWN BY: MLS	CKD BY:	SOLICITATION NO.:
SUBMITTED BY: HLA		CONTRACT NO.:
PLOT SCALE: AS SHOWN	PLOT DATE:	PROJECT CODE: PER
SIZE: ANSI D	FILE NAME: PERV-101xxx.dgn	

MISSISSIPPI RIVER
RIVER MILES 599.0 - 602.8
GRANT COUNTY, WI
BETROM AND MCCARTNEY LAKES HREP
PERFORMANCE EVALUATION REPORT

SURVEY CONTROL PLAN

Sheet ID
V-101



DWG REF(s) :

A1 SITE PLAN

SCALE : 1"=1000'-0"

0 1000' 2000'

US Army Corps of Engineers

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: SJG | CKD BY: | DATE:
DWN BY: JMF | SOLICITATION NO.:
SUBMITTED BY: HLA | CONTRACT NO.:
PLOT SCALE: AS SHOWN | PLOT DATE: | PROJECT CODE: PER
SIZE: ANSI D | FILE NAME: PERC-101xxx.dgn

U.S. ARMY CORPS OF ENGINEERS
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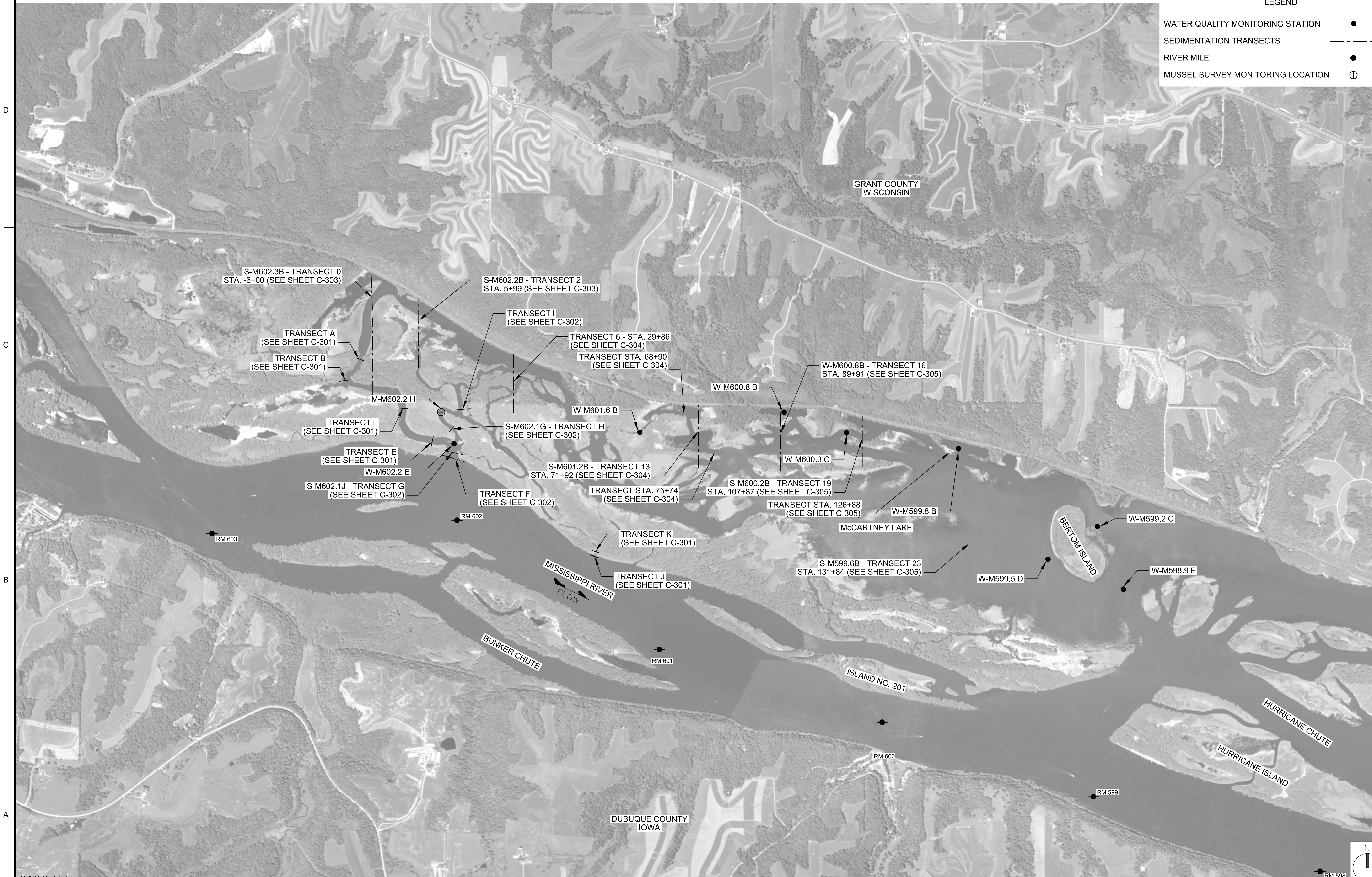
ROCK ISLAND, ILLINOIS

MISSISSIPPI RIVER
RIVER MILES 599.0 - 602.8
GRANT COUNTY, WI
BERTOM AND MCCARTNEY LAKES HREP
PERFORMANCE EVALUATION REPORT
SITE PLAN

Sheet ID
C-101



A1 MONITORING PLAN

SCALE : 1"=1000'-0"

0 1000' 2000'

US Army Corps of Engineers®

MARK	DATE	DESCRIPTION	APPR.

U.S. ARMY CORPS OF ENGINEERS
ROCK ISLAND DISTRICT
ROCK ISLAND, ILLINOIS

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DWN BY: JMF	CKD BY:	SOLICITATION NO.:	
SUBMITTED BY: HLA		CONTRACT NO.:	
PLOT SCALE: AS SHOWN	PLOT DATE:	PROJECT CODE: PER	
SIZE: ANSI D	FILE NAME: PERC-102xxx.dgn		

MISSISSIPPI RIVER
RIVER MILES 599.0 - 602.8
GRANT COUNTY, WI
BERTOM AND MCCARTNEY LAKES HREP
PERFORMANCE EVALUATION REPORT

MONITORING PLAN

Sheet ID
C-102

LEGEND

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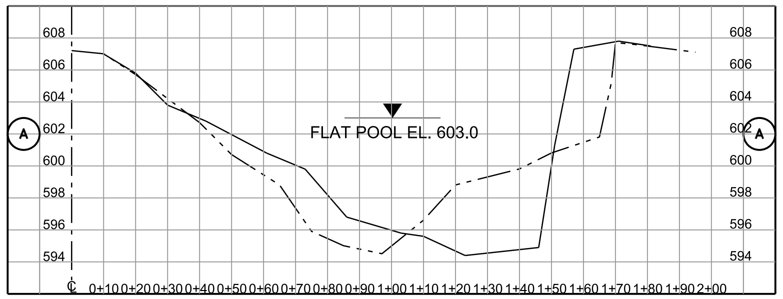
- RANGE - 1998
- RANGE - 2002
- RANGE - 2006
- RANGE - 2013
- ORIGINAL DESIGN



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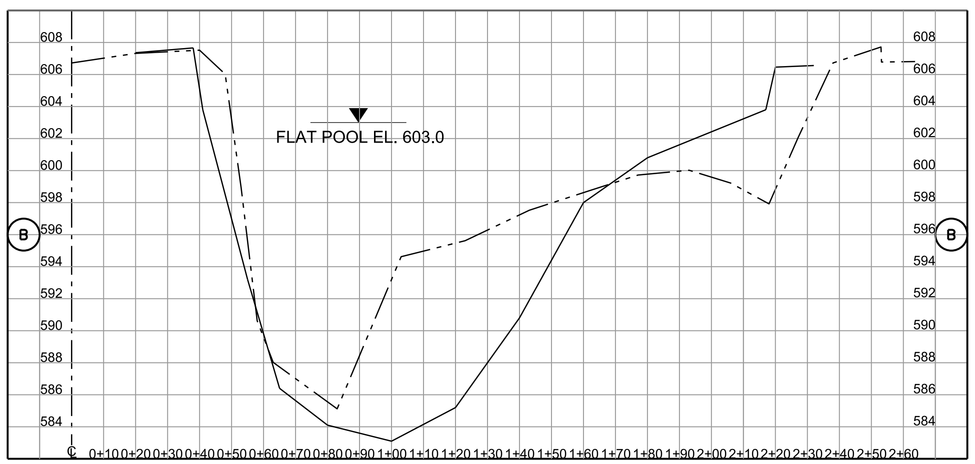

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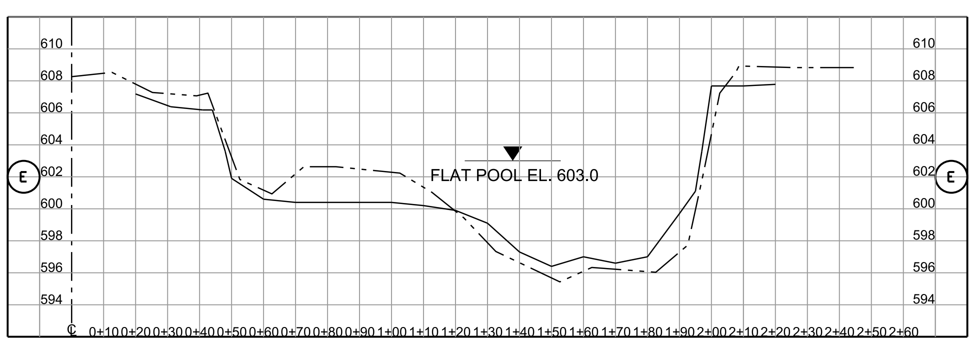

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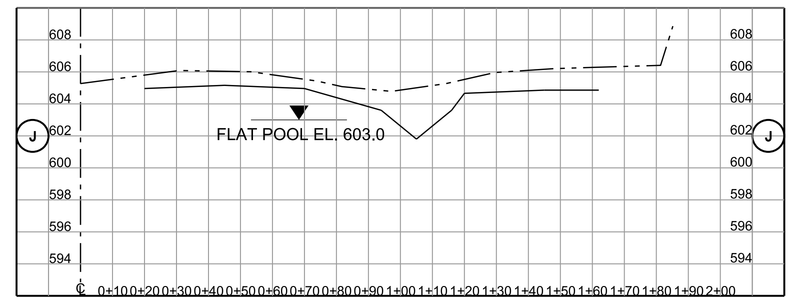

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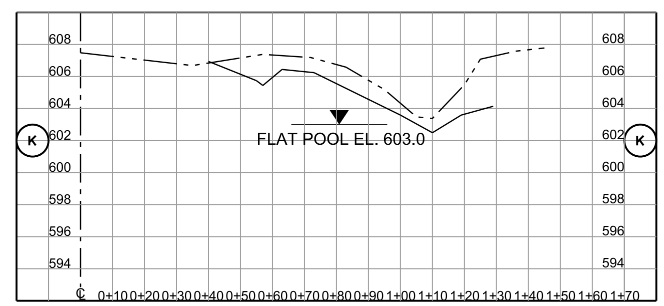

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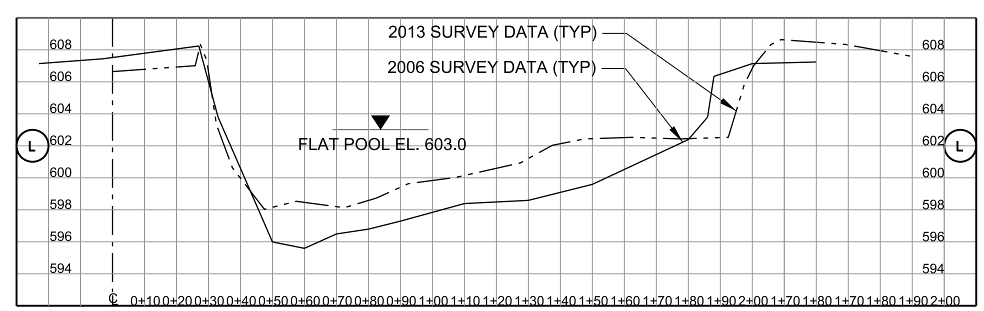

TRANSECT L (BERTOM LAKE)

DWG REF(s) : ____________

A1 TRANSECT CROSS SECTIONS - A, B, E, J, K, AND L

SCALE : 1"=30'-0"

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SIZE: ANSI D | FILE NAME: PERC-301xxx.dgn

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BERTOM AND MCCARTNEY LAKES HREP
PERFORMANCE EVALUATION REPORT
TRANSECT CROSS SECTIONS
A, B, E, J, K, AND L

Sheet ID
C-301

LEGEND

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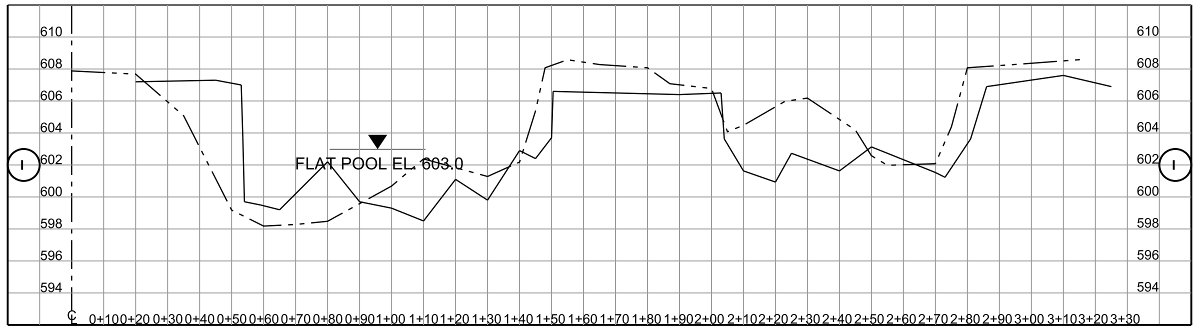
RANGE - 1998
RANGE - 2002
RANGE - 2006
RANGE - 2013
ORIGINAL DESIGN



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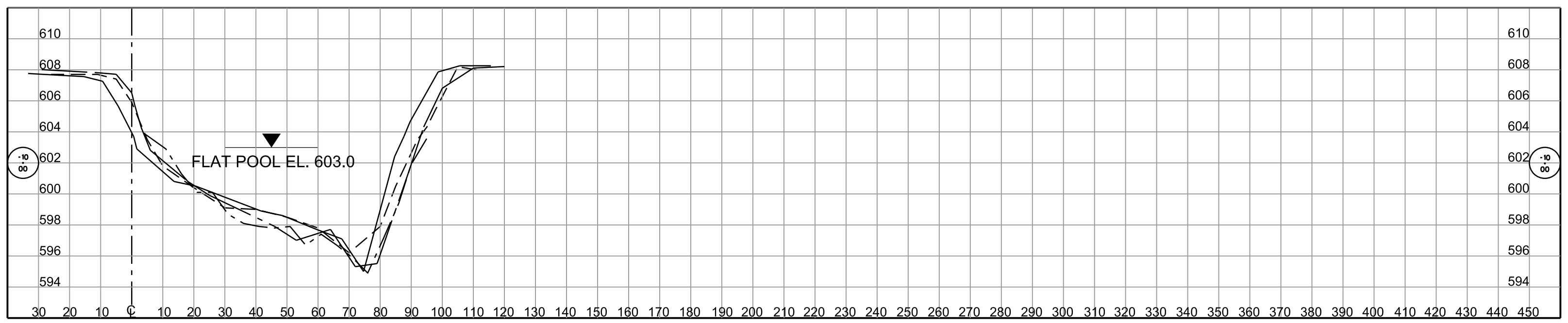
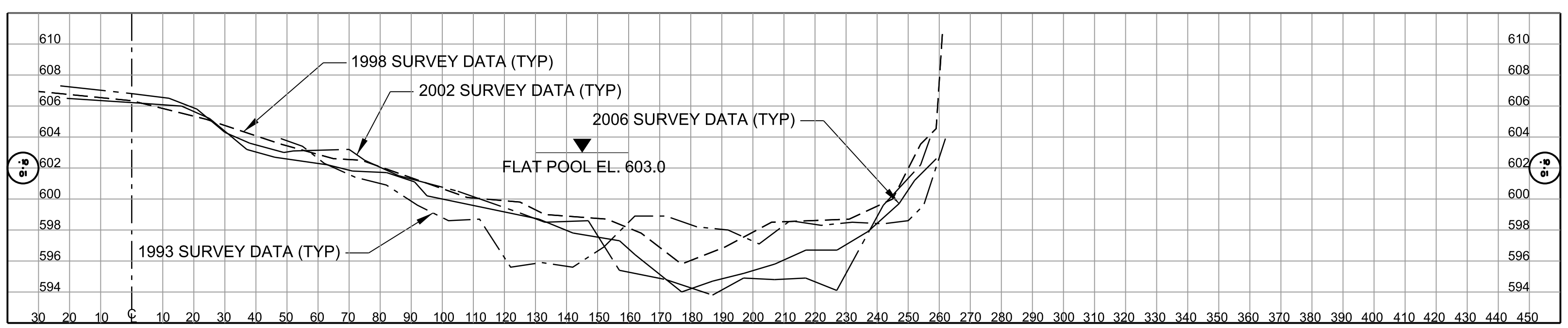


S-M602.1G - TRANSECT H (STATION -10+00, ROCK HABITAT CHANNEL)



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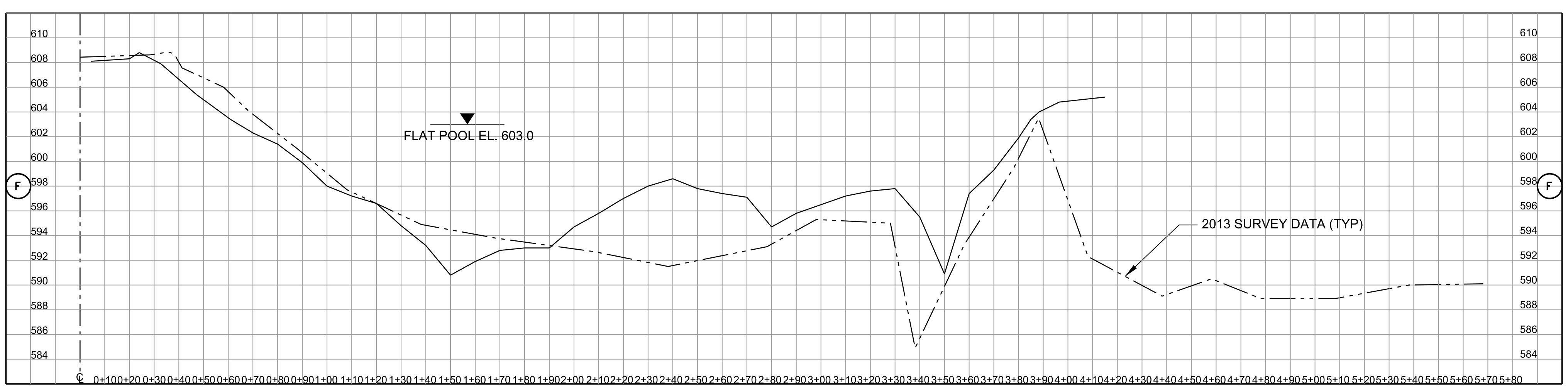

TRANSECT F (ROCK HABITAT CHANNEL INLET, MISSISSIPPI RIVER)

DWG REF(s) : ____________

A1 TRANSECT CROSS SECTIONS - F, G, H, AND I

SCALE : 1"=30'-0"

0 30' 60'

US Army Corps of Engineers®

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SUBMITTED BY: HLA
PLOT SCALE: N.T.S.
PLOT DATE:
SIZE: ANSI D
FILE NAME: PERC-302xxx.dgn
DATE:
SOLICITATION NO.:
CONTRACT NO.:
PROJECT CODE: PER

MISSISSIPPI RIVER
RIVER MILES 599.0 - 602.8
GRANT COUNTY, WI
BERTOM AND MCCARTNEY LAKES HREP
PERFORMANCE EVALUATION REPORT
TRANSECT CROSS SECTIONS
F, G, H, AND I

Sheet ID
C-302

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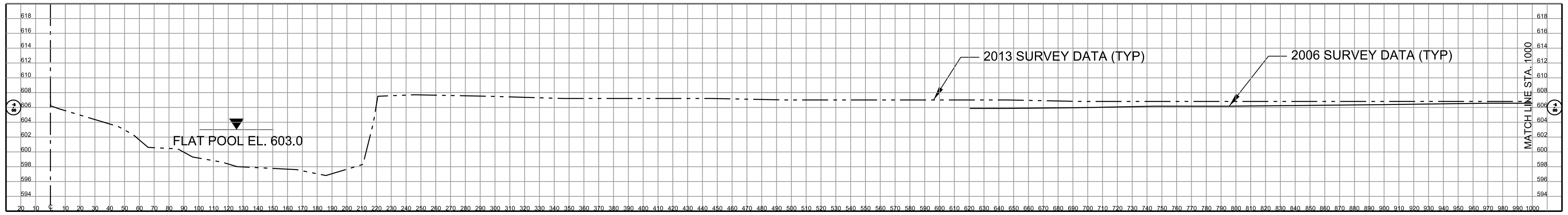
RANGE - 2013
ORIGINAL DESIGN



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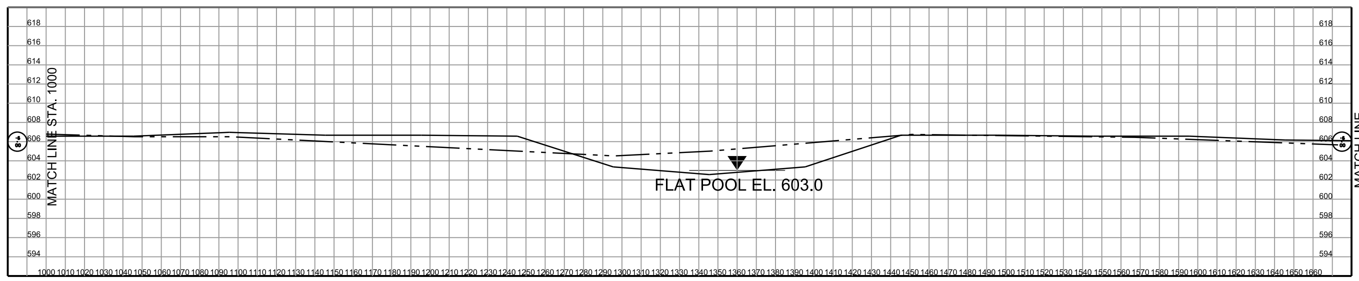

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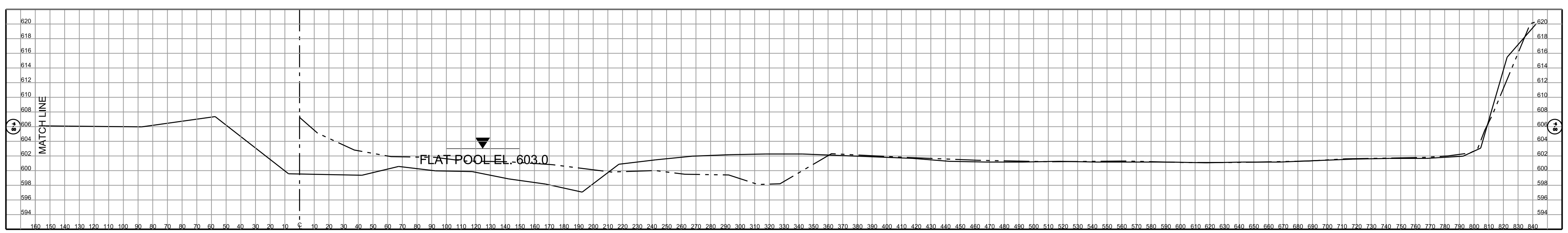

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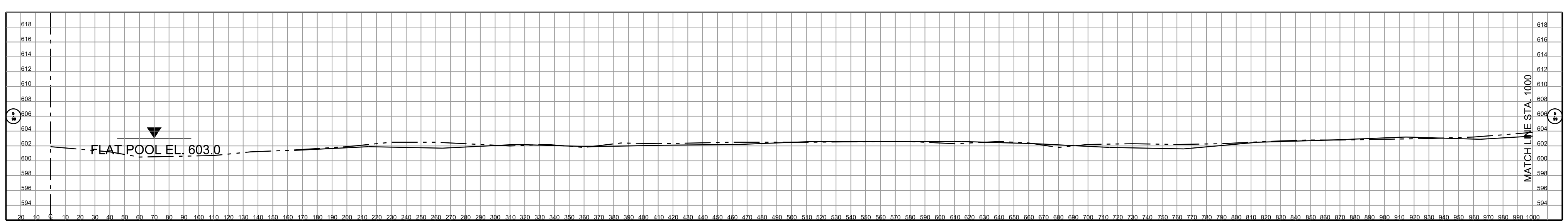

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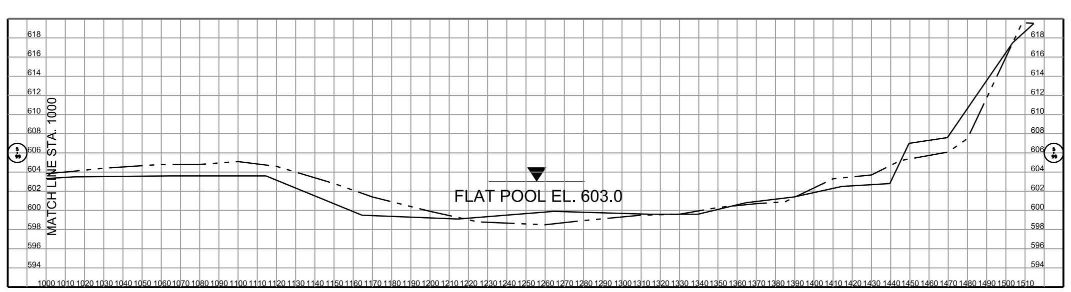

S-M602.2B - TRANSECT 2 STATION 5+99 (BERTOM LAKE)

DWG REF(s) : ____________

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SCALE : 1"=50'-0"

0 50' 100'

US Army Corps of Engineers

MARK | DATE | DESCRIPTION | APPR.

U.S. ARMY CORPS OF ENGINEERS
ROCK ISLAND DISTRICT
ROCK ISLAND, ILLINOIS

DESIGNED BY: SJG
DWN BY: JMF
CKD BY:
SUBMITTED BY: HLA
PLOT SCALE: N.T.S.
PLOT DATE:
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CONTRACT NO.:
PROJECT CODE: PER

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RIVER MILES 599.0 - 602.8
GRANT COUNTY, WI
BERTOM AND MCCARTNEY LAKES HREP
PERFORMANCE EVALUATION REPORT
TRANSECT CROSS SECTIONS
S-M602.3B, T0, STA. -6+00 AND
S-M602.2B, T2, STA. 5+99

Sheet ID
C-303

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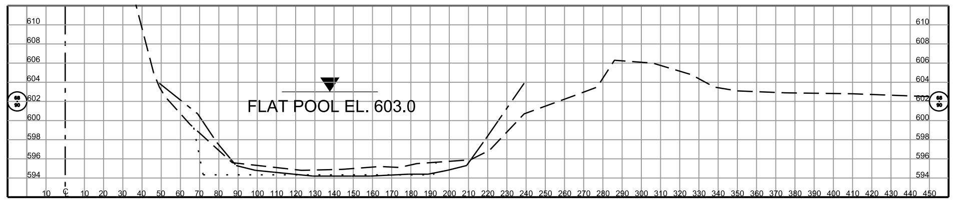

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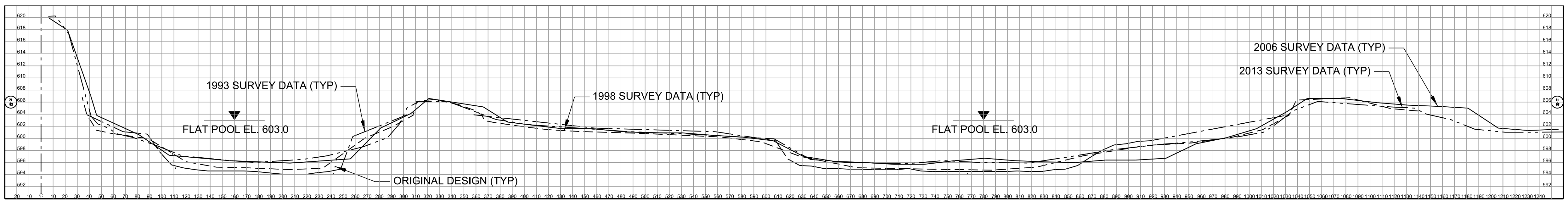

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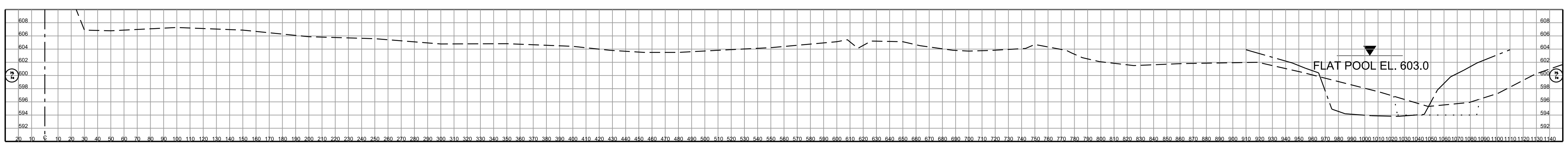

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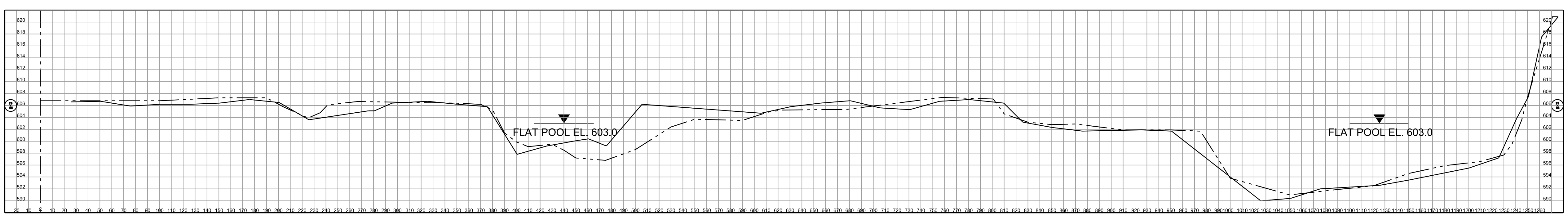

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D-8

US Army Corps of Engineers®

MARK | DESCRIPTION | DATE | APPR.

U.S. ARMY CORPS OF ENGINEERS
ROCK ISLAND DISTRICT
ROCK ISLAND, ILLINOIS

DESIGNED BY: SJG | DWN BY: JMF | CKD BY: | SUBMITTED BY: HJL | DATE: | SOLICITATION NO.: | CONTRACT NO.: | PLOT SCALE: N.T.S. | PLOT DATE: | PROJECT CODE: PER | SIZE: ANSI D | FILE NAME: PERC-304xxx.dgn

MISSISSIPPI RIVER
RIVER MILES 599.0 - 602.8
GRANT COUNTY, WI
BERTOM AND MCCARTNEY LAKES HREP
PERFORMANCE EVALUATION REPORT
TRANSECT CROSS SECTIONS
T6, STA. 29+86, STA. 68+90,
STA. 71+92, AND STA. 75+74

Sheet ID
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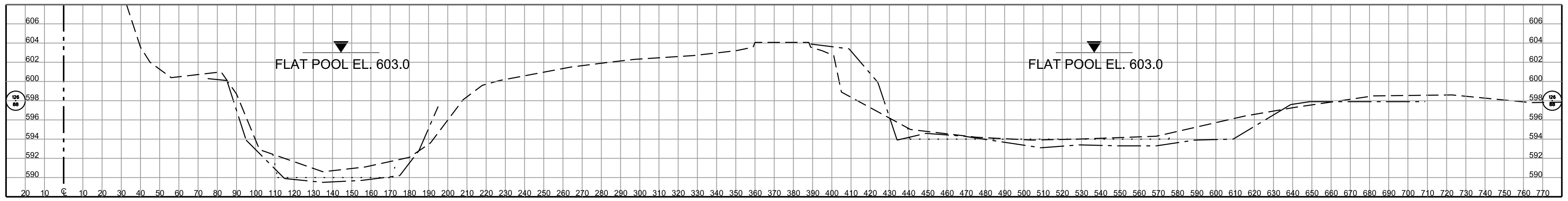

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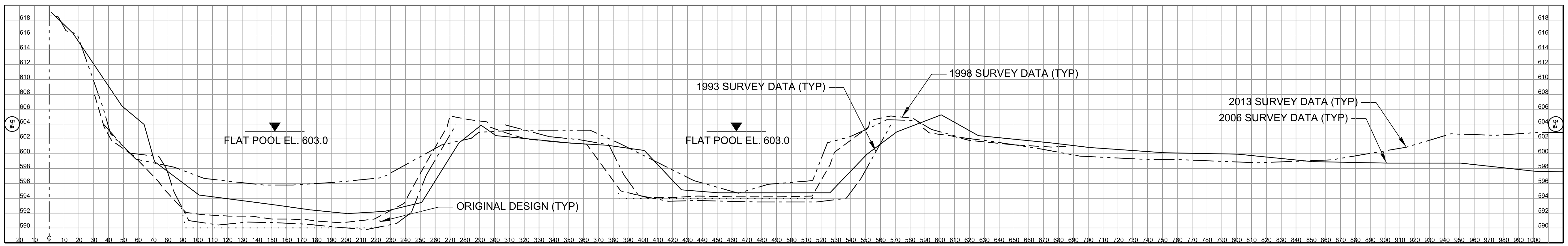

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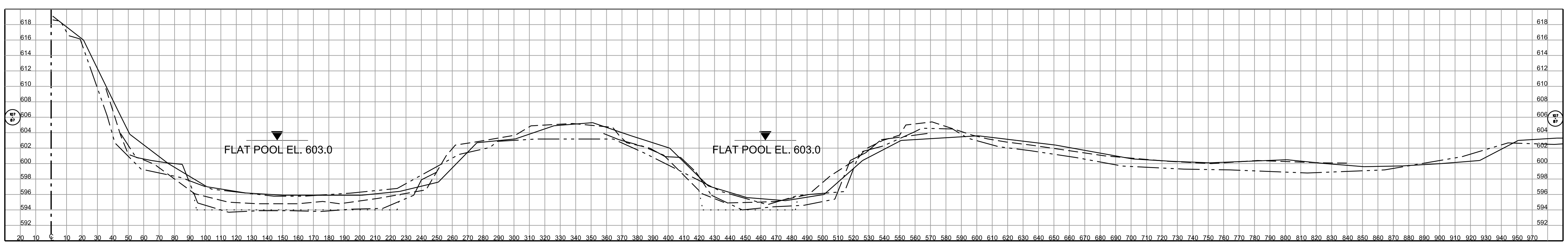

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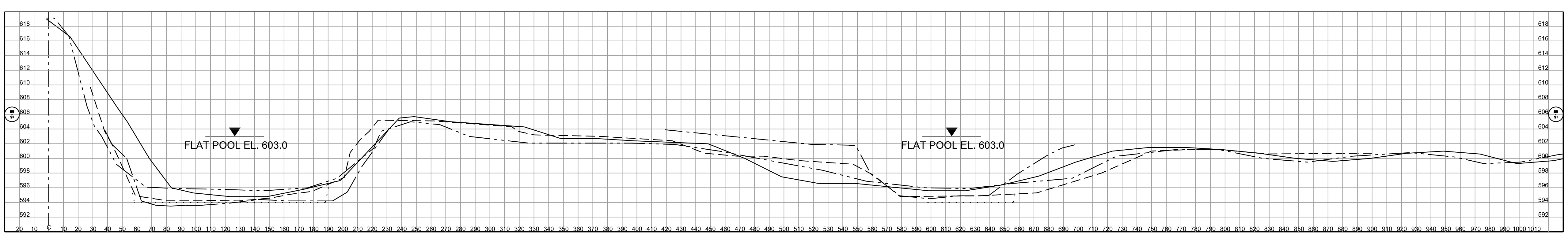

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DESIGNED BY: SJG | DATE: | SOLICITATION NO.:
DWN BY: JMF | CKD BY: | CONTRACT NO.:
SUBMITTED BY: HLA | PROJECT CODE: PER
PLOT SCALE: N.T.S. | PLOT DATE: | FILE NAME: PERC-305xxx.dgn
SIZE: ANSI D

U.S. ARMY CORPS OF ENGINEERS
ROCK ISLAND DISTRICT
ROCK ISLAND, ILLINOIS

MISSISSIPPI RIVER
RIVER MILES 599.0 - 602.8
GRANT COUNTY, WI
BERTOM AND McCARTNEY LAKES HREP
PERFORMANCE EVALUATION REPORT
TRANSECT CROSS SECTIONS
T16, STA. 89+91, STA. 107+87,
STA. 126+88, AND STA. 131+84

Sheet ID
C-305

Appendix E

2014 Mussel Habitat Enhancement Monitoring

Final Report

Mussel Habitat Enhancement Monitoring
Upper Mississippi River Pool 11
Bertom and McCartney Lakes Upper Mississippi River Restoration
Habitat Restoration Enhancement Project
October 2014.

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January 2015

Acknowledgements

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Introduction

The Corps is interested in developing a greater understanding of native mussel mussel habitat requirements within its waterways and whether habitat can be enhanced or created. In particular, the three Corps districts in the Upper Mississippi River (UMR), St. Louis, Rock Island, and St. Paul are evaluating whether mussel habitat enhancement can be incorporated into the Upper Mississippi River Restoration (UMRR) program (Environmental Management Program) and into routine UMR channel maintenance activities. Few projects have attempted to create physical mussel habitat. From a literature search by ESI (2014) only four projects have been identified, only one of which has been attempted on the UMR, the current Bertom and McCartney Lakes UMRR-Habitat Restoration and Enhancement Project (HREP) that this report addresses.

The Bertom and McCartney Lake HREP occurs near Cassville, Grant County, Wisconsin in UMR Pool 11 near River Mile 602 (Figure 1). The features of the fish and mussel enhancement features of the HREP were constructed from 1990-92. The project consisted of creating a high velocity run (Habitat Channel) connected to another secondary channel with no modifications (Control Channel) for comparison (Figure 2). The high velocity run contained a gradation of substrate sizes and fish LUNKERS (Little Underwater Neighborhood Keepers Encompassing Rheotactic Salmonids). Conceptual drawings are provided in Figure 3. The project goal was to establish a mussel bed by creating both fish and mussel habitat as a means of introducing mussels via fish host life history requirement and eventual self sustained mussel recruitment.

Overall, UMR Pool 11 contains a diverse assemblage of native mussels with 32 species including two federally endangered species, sheepnose (*Plethobasus cyphyus*) and Higgins eye (*Lampsilis higginsii*), and several additional state listed species in Wisconsin and Iowa (Table 1). One of fourteen Higgins eye Essential Habitat Areas (EHA) occurs in the pool near Cassville, WI, approximately five river miles upstream of the Bertom and McCartney Lakes HREP. Mussels are patchily distributed throughout the pool and mussel species richness and abundance is relatively low within the Bertom and McCartney HREP fish and mussel enhancement area. Given the close proximity and potential for mussel colonization from the Cassville Higgins eye EHA and elsewhere in the pool, the Bertom and McCartney HREP fish and mussel enhancement project provides an excellent opportunity for mussel habitat creation. Lucchesi and Thiel (1988) conducted brail surveys in the area and reported a total of 10 live species (see Table 1). They reported very few mussels in the Habitat Channel area pre-project with only eleven individual juvenile mussels of five species recorded. In the Control Channel they reported 16 juvenile mussels of the same five species as in the Habitat Channel. It was assumed that no mussels occurred in the Habitat Channel immediately post construction as mussels would have been removed by dredging or buried by rock placement.

Fish and mussel habitat was enhanced by lining approximately 1,500 ft (457 m) of an existing side channel adjacent to the main channel and upstream of Coalpit Slough (see Figure 3). The channel was designed as a high velocity area to deter *Dreissena polymorpha* (zebra mussel) colonization while favoring riverine native mussels. The selected side channel had a minimum bottom width of 50 ft (15 m). Rock of several different sizes, gradations, and types was used to further diversify the habitat. Side slopes were constructed as 1:2, rock depth averaged 2 ft (0.6 m), and minimum depth over the rock was 4 ft (1.2 m). A total of 9,000 tons (5,625 CY) of quarry rock of different sizes were used. The channel was divided into seven discrete sections. The first section immediately following the partial closing structure was 300 ft (91 m) long; the remaining sections were 200 ft (61 m) long. The existing channel was excavated by dragline or clamshell as required to achieve the minimum bottom width and to provide for unrestricted channel flow. The excavated material was placed on the right bank of the channel and spread to prevent the creation of a berm. Each channel section had a different rock substrate material placed in generally placed in descending order by size such that Segment 1, immediately adjacent to the main navigation channel will have the largest graded stone. Table 2 shows gradation, size, and type of rock placed.

The Habitat Channel had stable banks pre-project and did not show signs of active erosion. Since bank armoring was required in the vicinity of the fish structures, bank protection was provided for the entire Habitat Channel to prevent migration of the channel. Conventional barge-mounted equipment was used for the construction of partial closing structure, fish and mussel rock habitat, and containment levee. The fish and mussel rock habitat also included habitat structures such as sections of reinforced concrete pipe and LUNKERS. These structures, originally designed as part of a trout habitat improvement program initiated by the Wisconsin Department of Natural Resources (WIDNR), consisted of a submerged system of planking that was installed into a stream bank to provide resting, feeding, and escape cover for fish.

Mussel surveys were planned every five years but never conducted until 2014. The objective of the 2014 monitoring project was to collect information on mussel habitat, native mussel density, relative abundance, community composition, population demographics in the Habitat Channel, Control Channel, and downstream of the Control Channel and Habitat Channel. This study will assist the Corps in evaluating whether the project succeeded in enhancing mussel habitat and guide future attempts in enhancing native mussel habitat.

Methods

The survey was conducted 7-9 October, 2014 by the Corps St. Paul District and MNDNR biologists. Both quantitative and qualitative survey methods were used to evaluate habitat conditions and collect mussels. The goal was to collected both quantitative and qualitative samples within each rock substrate segment and at each sample point within the Control Channel and downstream of the Control Channel and Habitat Channel. Within Segments 1, 3, 4 rock substrate gradations sizes where too large to effectively collect whole substrate quantitative samples so only timed qualitative dive searches where done. Also at a site downstream of the Habitat Channel, water depths where only a few inches deep and no mussels were observed during a timed qualitative search so quantitative sampling was not done. Conversely, within Segment 6 substrate was small (2-4" diameter) and extremely consolidated and very difficult for divers to collect mussels tactually or visually under near zero visibility conditions that only whole substrate quadrat samples were collected.

Quantitative sampling was necessary to accurately estimate density, age/length structure, and relative abundance. Five quadrat samples of 0.25 square meters (m^2) were collected from at each sample point by throwing the quadrat in a semicircle around the downstream side of the anchored boat. At each quadrat collection, a diver hand placed the quadrat on the river bottom and excavated all the material to approximately a depth of 10 centimeters (cm). The excavated material was placed into a ¼ inch mesh collection bag attached to the quadrat frame and sent to the surface for processing. The contents of the mesh bag were evaluated for mussels and substrate composition. Sampled substrate was additionally described as observed by the diver, and water depth was recorded to the nearest 0.5 ft. Mussels were identified and enumerated, aged (external annuli count), and measured for length in millimeters (mm); shells were recorded as fresh dead (FD) or weathered dead (WD). Zebra mussel infestation on native live mussels was also recorded if present. Native mussels were then placed back to near their collected area after processing.

Size and age were analyzed for the quantitative data to assess recent recruitment and age/size class demography in the mussel community. Mussel length (mm) and age (number of annuli) were recorded for each live specimen. The mean, minimum, and maximum were then calculated for each species as well as the mussel community as a whole. Data were summarized in three categories; % individuals less than 30 mm and having ≤ 3 and ≤ 5 external annuli (years old).

Qualitative sampling (visual and tactual searching by diver) was used to estimate the species composition and relative abundance within the sites. Timed searches at each site averaged 20 minutes total (10 min. x two divers). Mussels collected in qualitative samples were identified, enumerated, and classified as young (≤ 3 and ≤ 5 years, ≤ 30mm) or mature (> 5 years, > 30mm) based on age and length. The presence and quantity of zebra mussels was also recorded. Substrate type as well as minimum and maximum depths were also recorded at each of the qualitative dive sites

Results

Habitat

Surveys were conducted 7-9 October, water temperature was 53°F (11.6°C), and flows were typical for fall and lower than typical spring and summer flows. Discharge at Lock and Dam 10, approximately 13 river miles upstream, ranged from 46,000 – 50,000 cfs. Within the Habitat Channel where the higher velocity run was constructed, flows were near or exceeded 3ft/sec, a velocity near the maximum extent in which a boat can anchor and divers can safely work. In mid September the site was visited to assess conditions, discharge at Lock and Dam 10 was 105,000 cfs and current velocity was extremely high and exceeded 6 ft/sec. in the Habitat Channel. Not surprisingly, there is a positive correlation with discharge at Lock and Dam 10 and flows at the Habitat Channel and Control Channel. Since the project was constructed in 1992, spring to fall discharge rarely dropped below 40,000 cfs. Only in winter months did discharge drop below 30,000 cfs. It's safe to assume that flows near or exceeding 3 ft/sec occur in the Habitat Channel the majority of the year deterring zebra mussel settlement while albeit on the high end of optimal current velocity for riverine mussels, potentially providing conditions for most native riverine mussel species.

Habitat Channel - For the most part the rock substrate that was placed remained in placed with a few exceptions (Table 2). Larger angular rip rap rock placed in Segments 1, 3, and 4 was observed during 2014 and was clean and silt free. The 2-4" rounded river stone placed in Segment 5 remained during 2014 and was also silt free. However, the 2-4" crushed angular rock placed in Segment 6 contained approximately a 50/50% mix of the 2-4" rounded river stone, undoubtedly washed in from Segment 5. There appeared a fine layer of silt/sand within Segment 2 over the smaller crushed angular fragments by the island protected from higher flows of the main channel. Also, a depositional back eddy area within Segment 7 had accumulated sand with some empty zebra mussel shells, again protected from higher flows. As previously mentioned, flows were near or exceeded 3 ft/sec through most of the channel. Water depths at sites sampled ranged from 2-8 ft. For the most past rip rap rock placed along the bank remained in place except for an area along Segment 3 the bank was exposed and rock appeared to have disappeared (see Appendix photo documentation, photo of Segment 3).

Downstream of Habitat Channel (Coalpit Slough) – Flow velocity downstream of the Habitat Channel was considerably less to non-existent (see Table 2). Substrate consisted of silt/sand/clay, most of which probably deposited from the bed load passing through the Habitat Channel when flows decrease. Water depths ranged from 1 to 3 ft. Immediately downstream of the Habitat Channel was a scour hole 20-25' deep, the results of high velocity flows exiting the stable rock lined Habitat Channel into softer unprotected substrates.

Control Channel - Flows were slightly less than the Habitat Channel ranging from 2-3 ft/sec. Substrate consisted of 100% sand and was loose shifting in nature at all four sites; 10, 12, 13, 14, a substrate not conducive to native mussels (see Table 2). Water depth ranged from 3-6 ft.

Downstream of Control Channel - Flows were less than in the Control Channel ranging from 1-2 ft/sec. Substrate consisted of compact and stable silt and sand mixture, a substrate more conducive to native mussels than was observed in the Control Channel (see Table 2). Water depth was 3.5 ft.

Main Channel Border – Flows along the Main Channel Border site was 1-2 ft/sec and substrate consisted of 100% sand. Water depth ranged from 8-12 ft. (see Table 2).

Mussels

A total of 17 sites were sampled (eight in the Habitat Channel, three in Coalpit Slough, four in the Control, and one each downstream of the Control Channel and along the Main Channel Border) (Figure 3). Overall, 209 live native mussels representing 14 live species were collected in the areas from this study (Table 3). An additional five species were represented with empty shells only. Overall, *Amblema plicata* (threeridge) (34.0%) and *Obliquaria reflexa* (threehorn wartyback) (31.1%) dominated the collection(s) and within each study area (see Table 3 and Table 4). Two species listed for protection in either Iowa or Wisconsin were collected live but were rare (*Quadrula nodulata* [wartyback] and *Truncilla donaciformis* [fawnsfoot]). No live federally endangered mussels were collected however, a relatively fresh dead Higgins eye shell was collected in Segment 5 of the Habitat Channel (see Table 3 and 4 and Appendix photo documentation) and a weather dead specimen was collected downstream of the Control Channel at Site 15. No live zebra mussels were collected in the entire study, only empty shell were observed at a few sites. In addition, byssal threads attached to native shells (indicative of recent attachment) were not observed.

Habitat Channel – Forty (40) live mussels were collected representing eleven species. However, no mussels were collected in Segments 1, 3, 4, areas where larger rip rap rock was placed (see Table 4). At Sites 2a, 5, 6, 7 densities were $0.8/m^2$, $4.8/m^2$, $4.0/m^2$, and $1.6m^2$, respectively (see Table 4). In addition to Sites 5 and 6 having the highest density they contained the most species (five) (see Table 4 and Figure 5). Average age of mussels was 6.8 years old and all individuals were ≤ 10 years old which indicates all individuals collected colonized the area within the past 10 years but > 10 years post construction of the Habitat Channel. There's no evidence of colonization from 1-12 years post construction.

Downstream (Coalpit Slough) – Forty one (41) live mussels were collected at two of the three sites representing nine species (see Table 3 and 4). No live mussels were collected at Site 17. Density at Site 8 was $1.6/m^2$ and no mussels were collected in quadrats at Site 9, however Site 9 contained more live species (seven) when timed searches are included. Average age was 5.0 years old with all mussels ≤ 7 years old (see Table 5).

Control Channel - A total of only 11 live mussels were collected representing six live species (see Table 3). No live mussels were collected in quadrats at three of the four sites ($0/m^2$). Density at Site 13 was $0.8/m^2$ (see Table 4). Only one live mussel was collected in quadrats (*Utterbackia imbecillis* [paper pondshell]) and was one year old and 27mm in length. It was not included on Table 5.

Downstream of Control Channel - A total of 108 live mussels were collected representing eleven species (see Table 3 and Figure 5). Density was $6.8/m^2$ at Site 15 (see Table 4). Average age was 3.2 years old and ranged from 0 to 10 years old (see Table 5).

Main Channel Border – A total of nine live mussels representing five live species were collected (see Table 3 and 4). Mussels were not aged or measured as no quantitative samples were collected.

Discussion

From this study, it's inconclusive as to whether improved fish habitat conditions and colonization of mussels in the Habitat Channel had any impact on Coalpit Slough downstream. It was thought that perhaps downstream drift of juvenile mussels dropping from fish in the Habitat Channel may populate areas in Coalpit Slough. Species composition and richness are similar between the Habitat Channel and Coalpit Slough but without pre-project data from Coalpit Slough it's difficult to assess affects.

Mussel habitat within the Control Channel was not conducive to native mussels. The Habitat Channel was more stable and harbored more mussels in some areas than the Control Channel. There appears to be a large amount of sand entering from the main channel as evidenced by the large exposed sand bar at the head of the Control Channel and substrate consisted of a moving bedload of 100% shifting sand (see Appendix photo documentation). In addition, there was considerable erosion along the banks. As a result, very few mussels were found. Downstream of the Control Channel habitat conditions were more favorable for mussels (compact silt and sand with moderate flow) and contained a species rich and fairly abundant mussel community.

Albeit at low levels, it appears that native mussels have colonized the Habitat Channel in areas where substrate consisted of 2-4" river washed stone (Segment 5), 2-4" river washed stone mixed with 2-4"angular stone (Site 6), and areas protected from higher flows (Segments 2 and 7). Segments 1, 3, and 4, which contained larger rip rap rock probably didn't provide ideal mussel habitat due to the lack of softer substrate and interstitial space for mussels to burrow into. Smaller rounded river stone provides interstitial space for mussels but is not as stable as angular rock. Angular rip rap by design locks tight together for stability, rounded stone is prone to move under high flows. However, the benefit of providing stability upstream and along the banks of the Habitat Channel is that it stabilized the channel and the preferred substrate. Segments 1, 3, and 4 may have also provided fish habitat in which fish infested with mussel glochidia would occupy those areas and release juvenile mussels which would drift downstream to favorable habitat. Similarly, the fish LUNKERS may have assisted with mussel colonization in a similar manner.

Segments 5 and 6 had similar densities ($4.8/m^2$ and $4.0/m^2$, respectively) and species richness (five each) but substrate slightly differed. It appears the river washed stone in Segment 5 being less stable than angular stone, washed downstream into Segment 6 to mix with the angular stone. This suggests that perhaps a combination of smaller rounded river stone providing interstitial habitat mixed with smaller angular stone providing stability may prove to be excellent mussel habitat. A variation and recommendation to consider for use in a future project design could also be a substrate containing fewer but larger angular stone mixed with a majority smaller rounded river stone which would provide more interstitial space for mussels to burrow and stability and hydrodynamic diversity from the larger angular rock.

Flow conditions and water depth within the Habitat Channel appear to support native mussels given the proper substrate. Depth in Segments 5 and 6 was 6-7 feet and velocity was >3ft/sec and probably comparable for most of the year and among years since the project was constructed. Water depth of 6-7 feet has been targeted for mussel habitat enhancement in other mussel habitat studies (ESI 2014). The fast flowing run habitat likely limited settling of zebra mussel juveniles which typically settle in flows <0.3 ft/sec. (Hunter 1992). Other mussel habitat enhancement studies and field measurements suggest that ideal flows for native riverine mussels range from approximately 0.7 to 2.6ft/sec. (Hornbach 2010 and ESI 2014). In this study, flow velocities may be at the upper threshold within the Habitat Channel for ideal mussel habitat and may explain the relative low density ($<5/m^2$) and species diversity (11 species) observed compared to other UMR mussel bed densities which routinely exceed $>10.m^2$ and contain >20 species (Kelner unpubl. data.). Another explanation for the relatively low mussel densities and diversity may be explained by the relatively slow recolonization rate of native mussels into areas either previously disturbed or into newly created habitat. The rate of recovery of certain macroinvertebrates (MacKay 1992, Matthaei et. al. 1996) and fish (Peterson and Bayley, 1993, Sheldon and Meffe 1994) following a disturbance can be rapid due to their greater mobility and short generation times. Freshwater mussels on the other hand are not very mobile as adults, are long lived with a complex life cycle, and depend on fish to disperse their larvae. These characteristics can inhibit mussels from recolonizing rapidly if a community is decimated (Neves 1993).

Estimating age of mussels post-disturbance or habitat creation projects can be used to predict when mussels began to recolonize such areas. Kelner and Davis (2002) and Sietman *et. al* (2001) report native mussels colonizing areas following near extirpation of fish and mussels in reaches of the Upper Mississippi River and the upper Illinois River after conditions improved, respectively. With the passing of the Clean Water Act in 1972 and the addition of other environmental laws and regulations in the 1970s, water quality dramatically improved in these areas, fish populations improved and mussels began to colonize both reaches in about 1980 - 1985. This is supported by Kelner and Davis (2002) in that estimated ages of live mussels collected during 2000-01 suggest colonization began 15-20 years prior (1980-85). Similarly, Sietman *et al.* (2001) surveys were conducted during 1994, 1995, and 1999 and age data suggest colonization began about 1980. This study shows a similar trend in that mussels began to recolonize the Habitat Channel approximately 10 -12 years post Habitat Channel construction (or post disturbance).

Although present mussel community density and diversity are about half of that of healthy mussel beds on the UMR, the data indicate that if habitat conditions are suitable (including adequate host fish habitat) and source populations are nearby, mussels can recolonize habitat that has been created or modified for mussels without being artificially supplemented. Of the additional mussel species that occur in UMR Pool 11which have not re-colonized, there is potential for additional species to recolonize the area given more time. Similarly, Kelner and Davis (2002) and Sietman *et. al.* (2001) reported a reduced mussel community than historically occurred in the reaches. It appears populations have remained stable in the past decade and it remains unknown at this time if additional species will naturally recolonize those reaches. The Bertom and McCartney fish and mussel Habitat Channel should be monitored 5 and 10 years in the future to assess whether the mussel community continues to colonize.

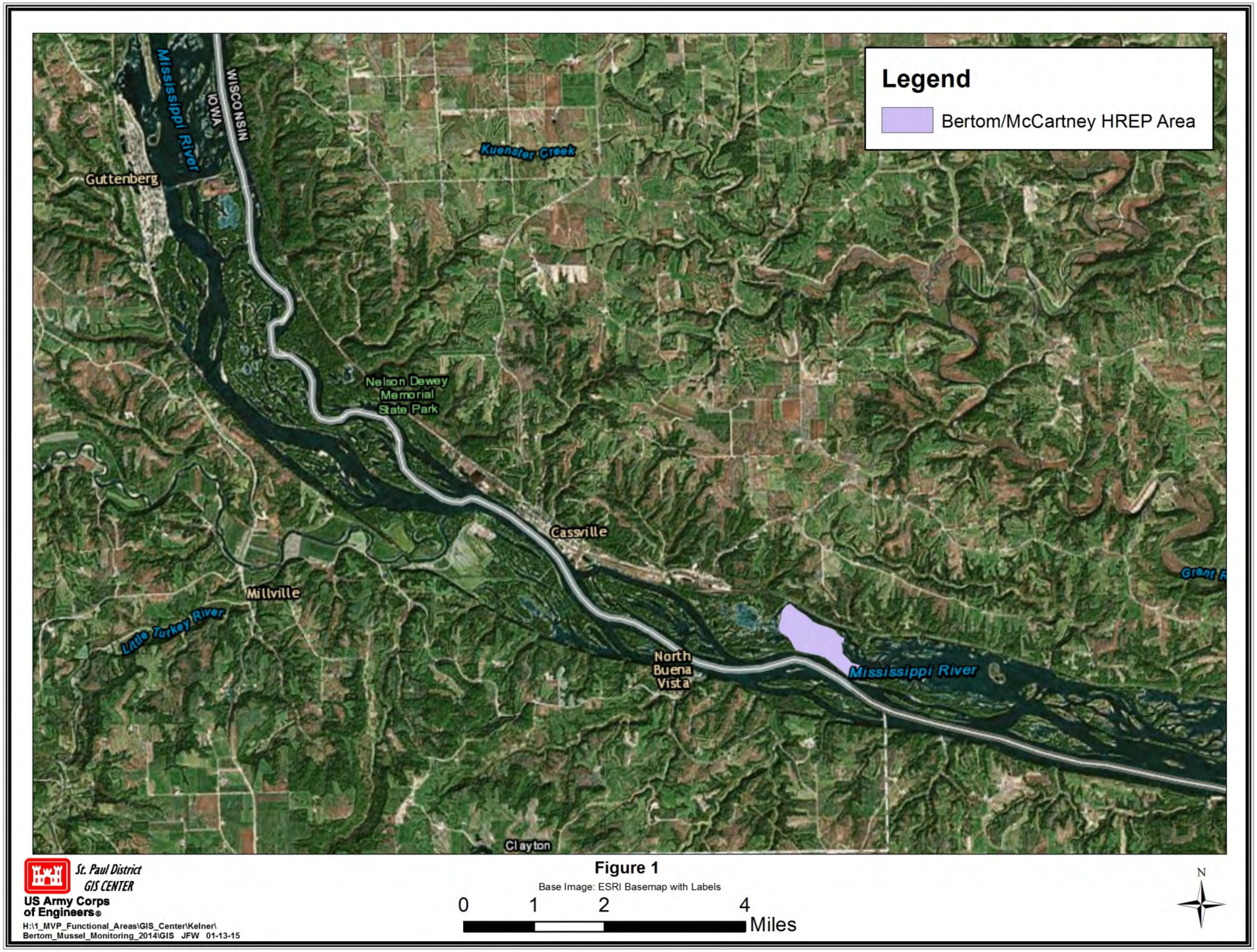

Figure 1

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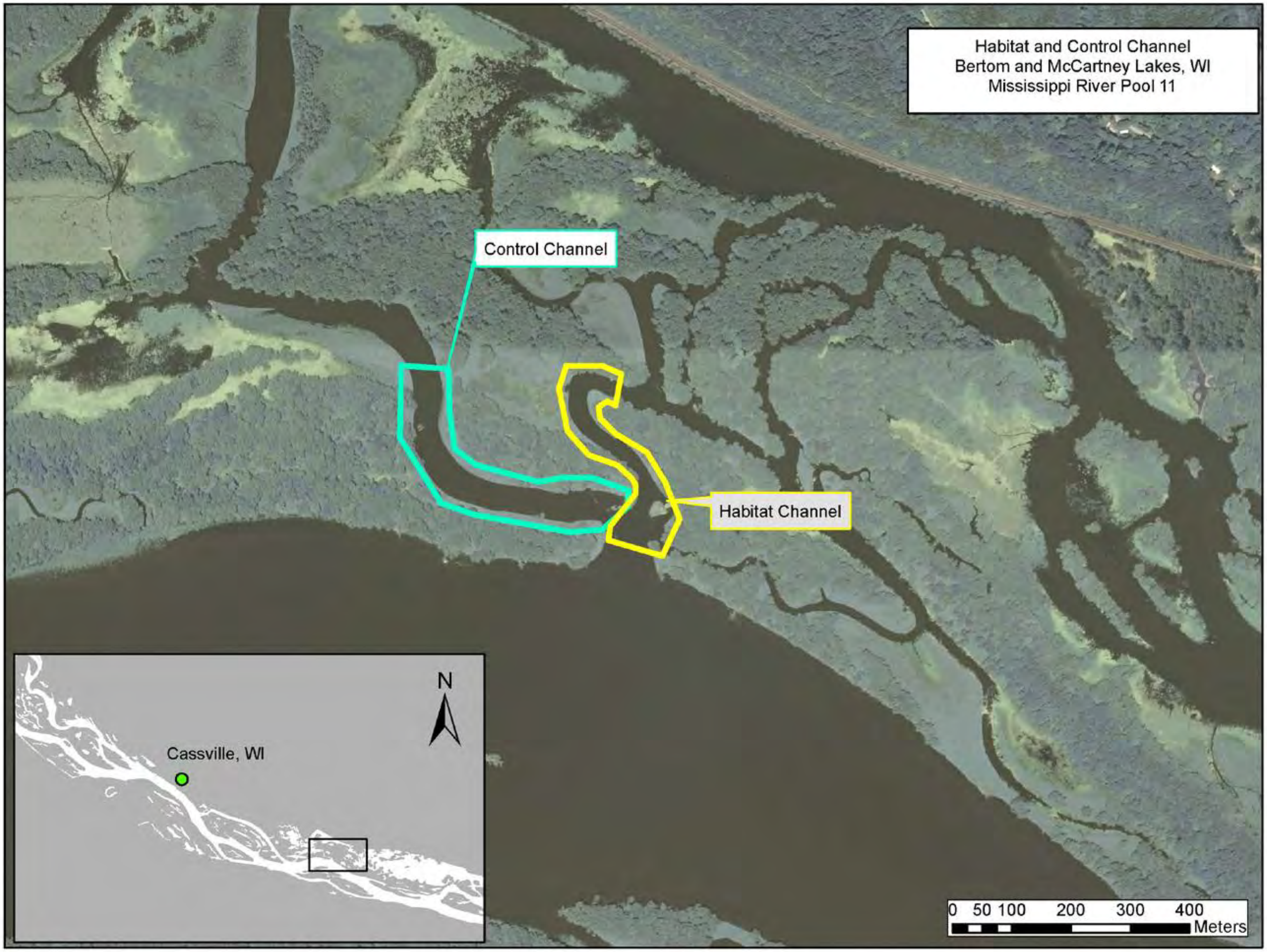

Figure 2. Bertom McCartney HREP fish and mussel enhancement project secondary control and habitat channels.

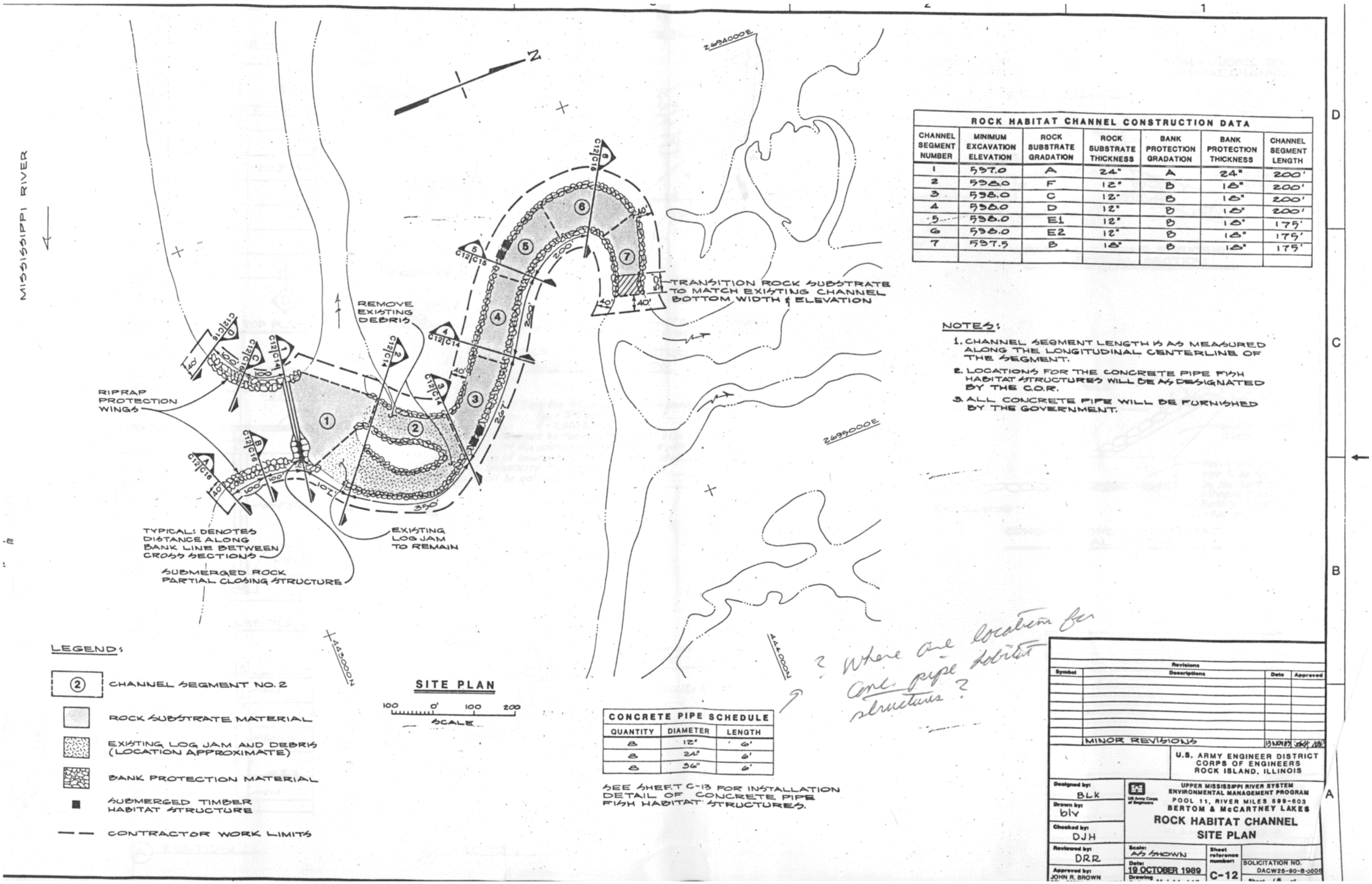

Figure 3. Bertom McCartney HREP fish and mussel enhancement project.

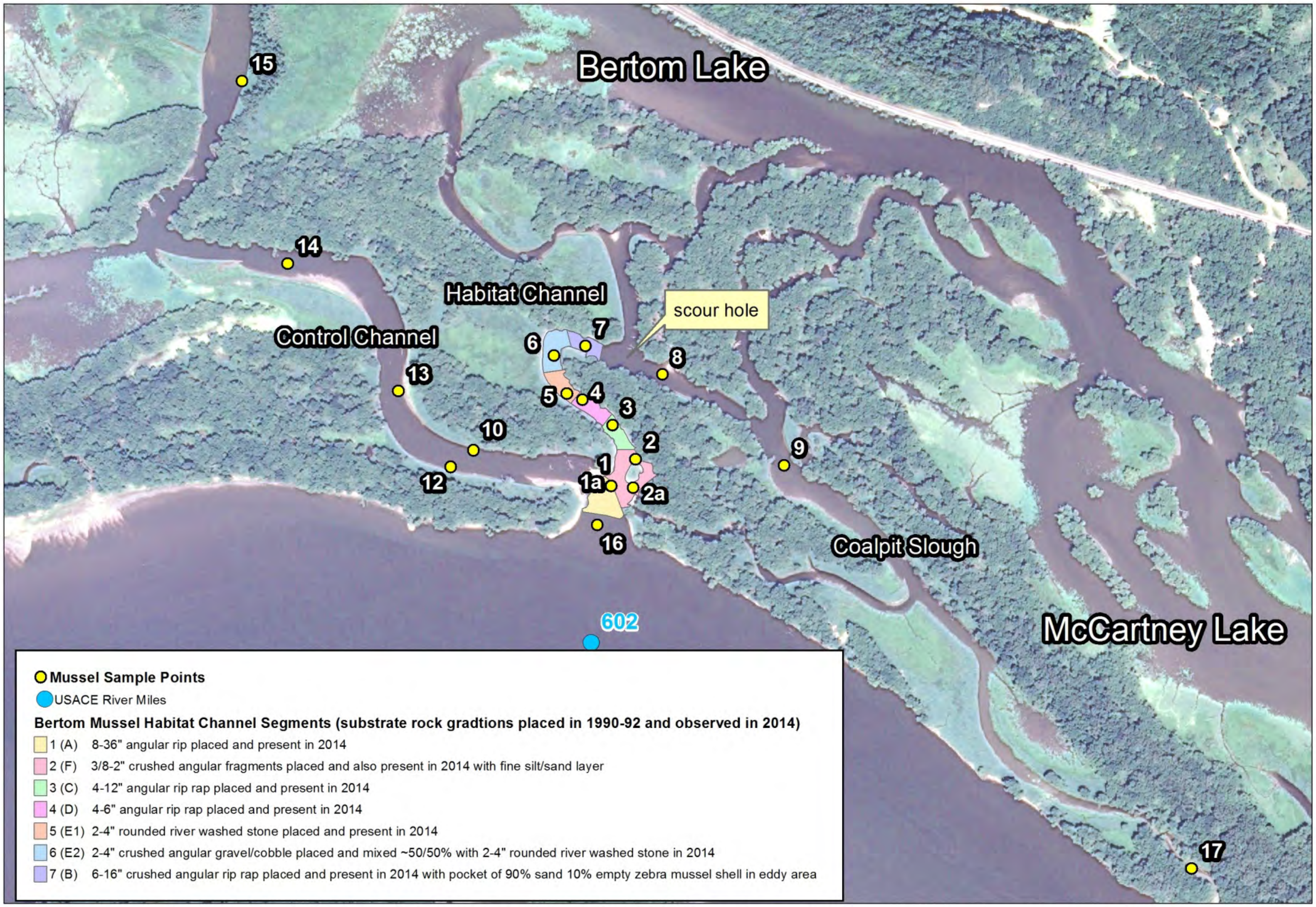

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Figure 4. Mussel sample sites at Bertom McCartney HREP fish and mussel enhancement project, October 2014.

Base Image: 2008 WI FSA Imagery

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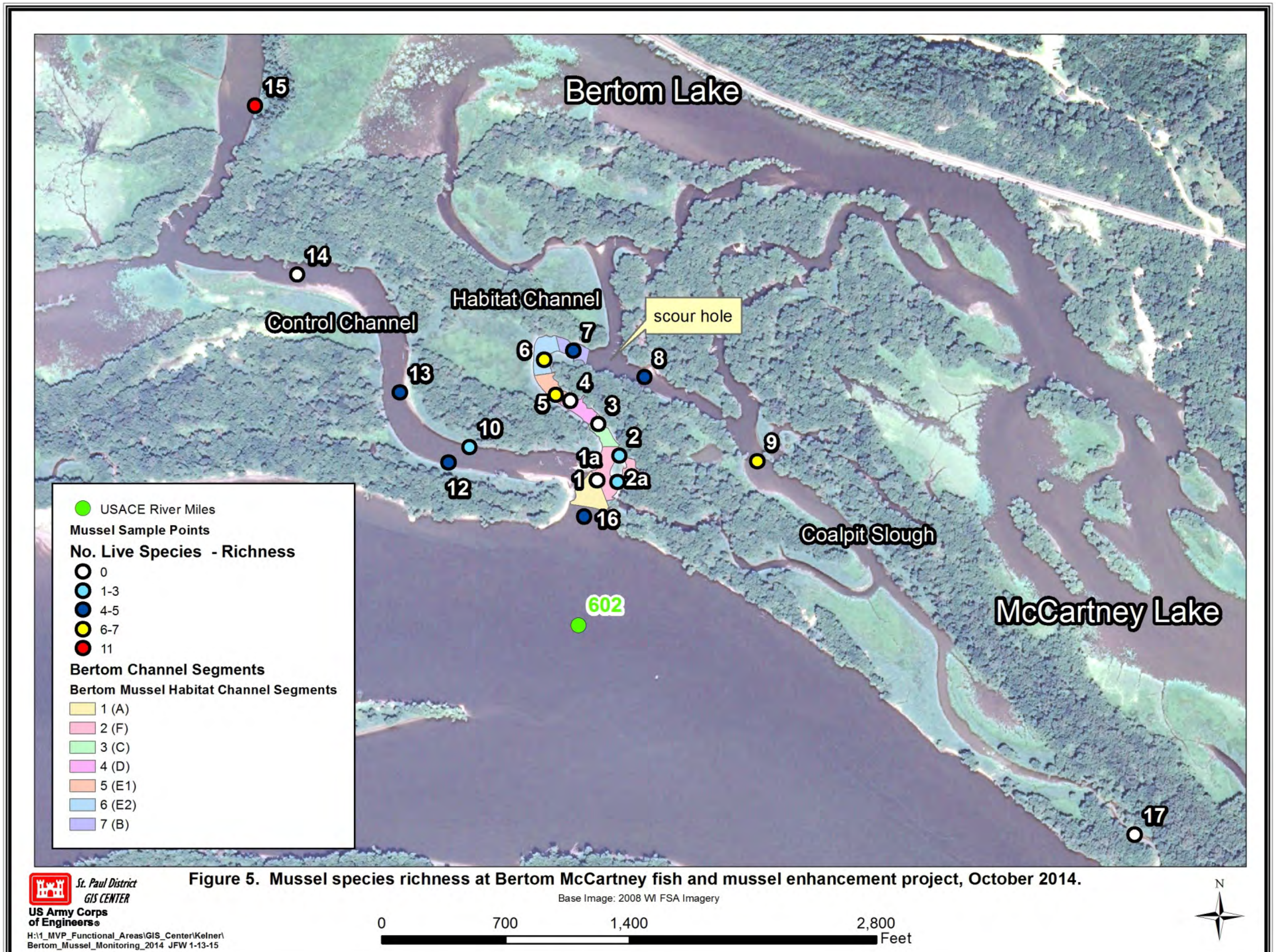

Figure 5. Mussel species richness at Bertom McCartney fish and mussel enhancement project, October 2014.

Base Image: 2008 WI FSA Imagery

Table 1. Historical and recent occurrence of native mussels in UMR Pool 11 and at the Bertom McCartney HREP.

Subfamily	Species	Common name	Historically in UMR Pool 11***	Bertom McCartney Mussel Habitat Area	
				Lucchensi and Thiel 1987	This study 2014
Ambleminae	*Amblema plicata*	threeridge	L		L
	*Cyclonaias tuberculata**	purple wartyback	H		
	*Elliptio crassidens**	elephant ear*	H		
	Elliptio dilatata	spike	L		
	*Fusconaia ebena**	ebonyshell*	L		
	Fusconaia flava	Wabash pigtoe	L		L
	Megalonaias nervosa	washboard	L		
	*Plethobasus cyphyus***	sheepnose**	L		
	*Pleurobema sintoxia**	round pigtoe*	L		
	*Quadrula metanevra**	monkeyface*	L		
	*Quadrula nodulata**	wartyback*	L	L	L
	Quadrula pustulosa	pimpleback	L		L
	Quadrula quadrula	mapleleaf	L	L	L
	*Tritogonia verrucosa**	pistolgrip*	H		
Anodontinae	*Alasmidonta marginata*	elktoe	L		
	*Arcidens confragosus**	rock pocketbook*	L		
	Lasmigona complanata	white heelsplitter	L		L
	Pyganodon grandis	giant floater	L		L
	*Strophitus undulatus**	strange floater*	L		D
	Utterbackia imbecillis	paper pondshell	L		L
Lampsilinae	*Actinonaias ligamentina*	mucket	L		
	*Ellipsaria lineolata**	butterfly*	L		
	Lampsilis cardium	plain pocketbook	L	L	L
	*Lampsilis higginsii***	Higgins eye**	L		D
	Lampsilis siliquoidea	fatmucket	L		
	*Lampsilis teres**	yellow sandshell*	L		
	Leptodea fragilis	fragile papershell	L	L	L
	Ligumia recta	black sandshell	L		L
	Obliquaria reflexa	threehorn wartyback	L		L
	Obovaria olivaria	hickorynut	L	L	L
	Potamilus alatus	pink heelsplitter	L	L	
	Potamilus ohiensis	pink papershell	L	L	D
	Toxolasma parvus	lilliput	L	L	D
	*Truncilla donaciformis**	fawnsfoot*	L	L	L
	Truncilla truncata	deertoe	L	L	D
Live species			32	10	14
Total species			35	10	19

L = live H = historic D = Dead

*Iowa or Wisconsin threatened or endangered; **state and federally endangered.

***Historical information of native mussels found in the UMR (Kelner, 2011 unpublished data).

Table 2. Habitat conditions at Bertom and McCartney HREP fish and mussel habitat enhancement project, October 2014.

	Habitat Channel (Sample Site within respective Segment)						
	1	2 & 2a	3	4	5	6	7
Substrate placed rock gradation	A	F	C	D	E1	E2	B
Substrate placed diameter/type	8-36" angular rip rap	3/8 - 2" crushed angular fragments	4-12" angular rip rap	4-6" angular rip rap	2-4" rounded river stone	2-4" crushed angular gravel/cobble	6-16"angular rip rock
Substrate observed in 2014	8-36" angular rip rap	Silt/Sand/ 3/8 - 2" crushed angular fragments	4-12" angular rip rap	4-6" angular rip rap	2-4" rounded river stone	2-4" 50% rounded river stone and 50% crushed angular gravel/cobble	6-16"angular rip rock w/pocket (eddy) of 90% sand/10% empty zebra mussel shells
Water depth (ft.)	8	2-3	6	6-7	6-7	6-7	6-7
~Current Velocity (ft./sec)	>3ft sec	>3ft/sec	>3ft sec	>3ft/sec	>3ft sec	>3ft/sec	1-2ft/sec

	Downstream Habitat Channel (Coalpit Slough Sample Site)			Control Channel (Sample site)				Downstream Control Channel	Main Channel Border
	8	9	17	10	12	13	14	15	16
Substrate observed in 2014	Silt/Sand/Clay	Silt/Sand/Clay	Silt/ Sand	100% Sand Dunes	100% Sand Dunes	100% Sand Dunes	100% Sand Dunes	Silt/Sand compact - stable	100% Sand
Water depth (ft.)	3	3	1	5.5	3-6	3-6	3-6	3.5	8-12
~Current velocity (~ft./sec)	1ft/sec	0.5ft/sec	0 ft/sec	2-3ft/sec	2-3ft/sec	2-3ft/sec	2-3ft/sec	1-2ft/sec	1-2ft/sec

Table 3. Total mussel species richness and relative abundance from qualitative and quantitative samples at Bertom and McCartney HREP fish and mussel habitat enhancement project, October 2014.

Species	**Habitat Channel** No.	**Habitat Channel** %	**Downstream Habitat Channel (Coalpit Slough)** No.	**Downstream Habitat Channel (Coalpit Slough)** %	**Control Channel** No.	**Control Channel** %	**Downstream (Control Channel)** No.	**Downstream (Control Channel)** %	**Main Channel Border** No.	**Main Channel Border** %	**Total** No.	**Total** %
Ambleminae												
Amblema plicata	10	25.0	13	31.7	3	27.3	42	38.9	3	33.3	71	34.0
Fusconaia flava	1	2.5	3	7.3			5	4.6	2	22.2	11	5.3
*Quadrula nodulata**	1	2.5	1	2.4			8	7.4	1	11.1	5	2.4
Quadrula pustulosa	2	5.0	1	2.4			2	1.9	1	11.1	12	5.7
Quadrula quadrula	2	5.0	1	2.4			2	1.9			5	2.4
Anodontinae												
Lasmigona complanata	2	5.0	2	4.9							4	1.9
Pyganodon grandis	D		1	2.4	2	18.2					3	1.4
*Strophitus undulatus***	D										D	
Utterbackia imbecillis			2	4.9	2	18.2	2	1.9			6	2.9
Lampsilinae												
Lampsilis cardium	3	7.5	D		1	9.1	7	6.5			11	5.3
*Lampsilis higginsii****	D						D				D	
Leptodea fragilis	1	2.5	D		1	9.1	2	1.9			4	1.9
Ligumia recta	3	7.5									3	1.4
Obliquartia reflexa	13	32.5	17	41.5			33	30.6	2	22.2	65	31.1
Obovaria olivaria	2	5.0			2	18.2	1	0.9			5	2.4
Potamilus ohiensis			D								D	
Toxolasma parvus					D						D	
*Truncilla donaciformis**			D				4	3.7			4	1.9
Truncilla truncata			D								D	
No. live	40		41		11		108		9		209	
Live species	11		9		6		11		5		14	
Total species	14		14		7		12		5		19	
No. sites qual. and quant.	8		3		4		1		1		17	

*Wisconsin threatened ; ** Iowa threatened; *** Federally, Iowa, Wisconsin endangered

Table 4. Native mussel abundance at each sample site, Bertom and McCartney HREP fish and mussel habitat enhancement project, October 2014.

	Habitat Channel (Sample Site within respective Segment)											Downstream (Coalpit Slough)				
	1	2	2a		3	4	5		6	7		8		9		17
Species	Qual.	Qual.	Qual.	Quant.	Qual.	Qual.	Qual.	Quant.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Ambleminae																
Amblema plicata		9						1				6		7		
Fusconaia flava									1			1		2		
Quadrula pustulosa								1	1				1			
quadrula nodulata		1												1		
quadrula quadrula								2						1		
Anodontinae																
Lasmigona complanata									1		1	2				
Pyganodon grandis		D								D				1	D	
Strophitus undulatus									D							
Utterbackia imbecillis														2		
Lampsilinae																
Lampsilis cardium									1	2			D			
Lampsilis higginsii								D								
Leptodea fragilis		D		1						D				D		
Ligumia recta							1	1			1					
Obliquaria reflexa		11					D	1	1			8	1	8		
Obovaria olivaria							D			2						
Potamilus ohiensis														D		
Toxolasma parvus																
Truncilla donaciformis														D		
Truncilla truncata													D			
No. Live	0	21	0	1	0	0	1	6	5	4	2	17	2	22	0	0
Live species	0	3	0	1	0	0	1	5	5	2	2	4	2	7	0	0
Total species	0	5	0	1	0	0	3	6	6	4	2	4	4	10	1	0
(n) 0.25m^2 samples				5				5	5		5		5		5	
Density (No. live/m^2) [2SE]				0.8 [1.6]				4.8 [5.9]	4.0 [3.6]		1.6 [2.0]		1.6 [2.0]		0.0 [0.0]	
Estimated population size*	NA			<500	NA	NA		7,050	8,736		<500		NA		NA	

*Approximation - based on density x area. Statistical comparisons on density were not done due to the small sample sizes (5) and variability of the data.

Table 4 (cont). Native mussel abundance at each sampling station, Bertom and McCartney HREP fish and mussel habitat enhancement project, October 2014.

	Control Channel								**Downstream (Control Channel)**		**Main Channel Border**
	10		12		13		14		15		16
Species	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Ambleminae											
Amblema plicata			2		1				40	2	3
Fusconaia flava									5		2
Quadrula pustulosa									8		1
quadrula nodulata									2		1
quadrula quadrula									2		
Anodontinae											
Lasmigona complanata											
Pyganodon grandis			2								
Strophitus undulatus											
Utterbackia imbecillus			1			1				2	
Lampsilinae											
Lampsilis cardium			1						7	D	
Lampsilis higginsii									D		
Leptodea fragilis					1				2	D	
Ligumia recta											
Obliquaria reflexa									31	2	2
Obovaria olivaria		1			1				1		
Toxolasma parvus			D								
Truncilla donaciformis									2	2	
Truncilla truncata											
No. Live	0	1	6	0	3	1	0	0	100	8	9
Live species	0	1	4	0	3	1	0	0	10	4	5
Total species	0	1	5	0	3	1	0	0	11	6	5
(n) 0.25m^2 samples		5		5		5		5		5	
Density (No. live/m^2) [2SE]		0.0 [0.0]		0.0 [0.0]		0.8 [1.6]		0.0 [0.0]		6.4 [7.4]	
Estimated population size		NA				NA				NA	NA

Table 5. Mussel community characteristics from quantitative samples from the Bertom McCartney HREP fish and mussel habitat enhancement project, October 2014.*

		Age - Years (external annuli count)			Length mm (maximum anterior to posterior)		
Species	(n)	Mean	Min.	Max.	Mean	Min.	Max.
Habitat Channel							
Ligumia recta	2	6.5	4	9	115.0	101	129
Leptodea fragilis	1	2.0	2	2	46.0	46	46
*Lampsilis higginsii***	FD	6.0	6	6			
Quadrula quadrula	2	5.5	2	9	36.5	20	53
Quadrula pustulosa	2	8.0	8	8	56.0	56	56
Lampsilis cardium	1	8.0	8	8	105.0	105	105
Obliquaria reflexa	2	4.0	2	6	33.0	20	46
Amblema plicata	1	10.0	10	10	79.0	79	79
Fusconaia flava	1	10.0	10	10	57.0	57	57
Lasmigona complanata	2	9.0	8	10	145.0	140	150
Total	15	6.8	2	10	75.6	20	150
% ≤ 3 years old		21.4					
% ≤ 5 years old		28.6					
% ≤ 30 mm					14.3		
Downstream Habitat Channel							
Obliquaria reflexa	1	7.0	7	7	34.0	34	34
Quadrula pustulosa	1	3.0	3	3	20.0	20	20
Total	2	5.0	3	7	27.0	20	34
% ≤ 3 years old		50.0					
% ≤ 5 years old		50.0					
% ≤ 30 mm					50.0		
Downstream Control Channel*							
Amblema plicata	2	6.0	2	10	48.5	22	75
Obliquaria reflexa	2	4.0	4	4	37.5	35	40
Truncilla donaciformis	2	1.0	1	1	15.5	14	17
Utterbackia imbecillis	2	0	0	0	21.5	20	23
Total	8	3.2	0	10	34.0	14	75
% ≤ 3 years old		75.0					
% ≤ 5 years old		87.5					
% ≤ 30 mm					60.0		

*Only one live *U. imbecillis* was aged and measured from the Control Channel and was not include in table. Individual was 1 year old and 27mm in length

***L. higginsii* (Higgins eye collected was fresh dead and was aged and included (but not measured for length)

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Appendix

GPS Photo Documentation

Site 16. Main Channel Border facing Habitat Channel. 100% sand.

W 90° 55' 01"
N 42° 41' 12"

10/9/2014
11:50:10 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 2 - facing northwest downstream of Island looking downstream into Habitat Channel. Segment 2.

W 90° 54' 58"
N 42° 41' 15"

10/8/2014
10:10:40 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

At head of Control Channel facing Site 1 a 2a on n left between head of island and log jam).
Main Channel on right.

W 90° 55' 02"
N 42° 41' 14"

10/9/2014
11:04:55 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 3, Segment 3. Large quarry rock - no mussels.

W 90° 54' 60"
N 42° 41' 17"

10/8/2014
10:31:17 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 2a Crushed quarry gravel near log jam at head of island. no mussels - poor habitat.

W 90° 54' 58"
N 42° 41' 14"

10/8/2014
3:07:54 PM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 5 Segment 5. Clean river washed gravel - excellent mussel subtrate.

W 90° 55' 03"
N 42° 41' 19"

10/8/2014
11:01:52 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 5 Segment 5. Higgins eye 1/2 shell semi-fresh <3years ago. Six when it died.

W 90° 55' 03"
N 42° 41' 19"

10/8/2014
10:54:33 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 5 , Segment 5. Mike Davis (MNDNR).

W 90° 55' 02" 10/8/2014
N 42° 41' 19" 10:54:20 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 5 Segment 5. River washed gravel/cobble with some crushed quarry rock. 2-6" diameter rock. Ligumia recta (black sandshell)

W 90° 55' 03"
N 42° 41' 19"

10/8/2014
10:47:12 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 8. Downstream of Habitat Channel looking downstream.

W 90° 54' 55"
N 42° 41' 20"

10/8/2014
1:17:48 PM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 8 facing west. Downstream of Habitat Channel facing upstream. Deep scour hole immediately downstream of Habitat Channel
Depositional area at Site 8, ~2.5 ft. deep, ~100% sand a few mussels.

W 90° 54' 56"
N 42° 41' 20"

10/8/2014
1:16:38 PM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 9. Below Habitat Channel. Facing north. 3ft deep, silt, sand some mussels. no flow.

W 90° 54' 47"
N 42° 41' 15"

10/8/2014
2:02:38 PM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 9. Below Habitat Channel. Facing south. 3ft deep, silt, sand some mussels. no flow.

W 90° 54' 47"
N 42° 41' 15"

10/8/2014
2:02:38 PM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 17 downstream of Habitat Channel near outlet to Main Channel
Flow actually coming in from main channel flowing towards McCartney.

W 90° 54' 20"
N 42° 40' 54"

10/9/2014
11:20:35 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 17 downstream of Habitat Channel near outlet to Main Channel
Flow actually coming in from main channel flowing towards McCartney.

W 90° 54' 19" 10/9/2014
N 42° 40' 54" 11:20:20 AM
Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Sand Bar at head of Control Channel facing downstream.

W 90° 55' 04" 10/9/2014
N 42° 41' 15" 11:03:04 AM
Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Sand Bar at head of Control Channel facing Habitat Channel.

W 90° 55' 04"
N 42° 41' 15"

10/9/2014
11:02:57 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 12. Control Channel. Facing downstream. Eroding shoreline, loose shifting sand dune substrate.

W 90° 55' 15"
N 42° 41' 19"

10/9/2014
9:37:45 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 12. Control Channel. Facing downstream. Eroding shoreline, loose shifting sand dune substrate.

W 90° 55' 11" 10/9/2014
N 42° 41' 15" 9:29:19 AM
Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Control Channel immediately downstream backwater lake.

W 90° 55' 30" 10/9/2014
N 42° 41' 29" 10:14:41 AM
Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Downstream of Control Channel Site 15 Facing downstream. Site on right bank. mussels along bank.
Loose shifting sand mid-channel - poor.

W 90° 55' 25"
N 42° 41' 36"
10/9/2014
10:35:31 AM
Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Downstream of Control Channel Site 15 Directly on site facing upstream. Mussels along bank.

W 90° 55' 25"
N 42° 41' 35"
10/9/2014
10:35:51 AM
Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR