POST-CONSTRUCTION
10-YEAR PERFORMANCE EVALUATION REPORT

POOL 11 ISLANDS (MUD AND SUNFISH LAKES)
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

2016

US Army Corps of Engineers
Rock Island District

POOL 11 ISLANDS

RIVER MILES 583.3-593.0

DUBUQUE COUNTY, IA, AND GRANT COUNTY, WI

ACKNOWLEDGEMENTS
&
POINTS OF CONTACT

Many individuals of the Rock Island District, U.S. Army Corps of Engineers; the Iowa Department of Natural Resources; the Wisconsin Department of Natural Resources; and the U.S. Fish and Wildlife Service contributed to the development of this Post-Construction Performance Evaluation for the Pool 11 Islands Habitat Rehabilitation and Enhancement Project. These individuals are listed below:

U.S. Army Corps of Engineers, Rock Island and St. Paul District				
T. Leo Keller (MVR)	Hydrologist	Clock Tower Building 1500 Rock Island Ave Rock Island, IL 61201	309-794-5720	thomas.l.keller@usace.army.mil
Steve Gustafson P.G. (MVR)	Report Preparer	Clock Tower Building 1500 Rock Island Ave Rock Island, IL 61201	309-794-5202	stephen.j.gustafson@usace.army.mil
Charles Theiling, PhD (MVP)	Large River Ecologist/ Report Preparer	Clock Tower Building 1500 Rock Island Ave Rock Island, IL 61201	309-794-5636	charles.h.theiling@usace.army.mil
U.S. Fish and Wildlife Service				
Richard King	McGregor District Manager	470 Cliffhaven Road Prairie du Chien, WI 53821	608-326-0515	richard_king@fws.gov
Wendy Woyczik	McGregor District Assistant Manager	470 Cliffhaven Road Prairie du Chien, WI 53821	608-326-0515	Wendy_woyczik@fws.gov
Clyde Male (retired)	McGregor District Assistant Manager			
Sharonne Baylor	Environmental Engineer	51 E. Fourth St, Room 101, Winona, MN 55897	507-494-6207	Sharonne_baylor@fws.gov
Jon Duyvejonck (retired)	Fish and Wildlife Biologist			
Kraig McPeek	Field Office Supervisor	Rock Island Field Office 1511 47th Ave Moline, IL 61265	309-757-5800 x 202	Kraig_mcpeek@fws.gov
Sara Schmuecker	Fish and Wildlife Biologist	Rock Island Field Office 1511 47th Ave Moline, IL 61265	309-757-5800 x 203	Sara_schmuecker@fws.gov
Aleshia Kenney	Fish and Wildlife Biologist	Rock Island Field Office 1511 47th Ave Moline, IL 61265	309-757-5800 x 218	Aleshia_kenney@fws.gov
Iowa Department of Natural Resources				
Scott Gritters	Fisheries Biologist	24143 Hwy 52 Bellevue, IA 52031	563-252-1156	Scott.Gritters@dnr.iowa.gov
Kirk Hansen	Fisheries Biologist	24143 Hwy 52 Bellevue, IA 52031	563-872-4976	Kirk.Hansen@dnr.iowa.gov
Michael Steuck	Fisheries Biologist	22693 205th Ave, Manchester, IA 52057	563-927-3276	Michael.steuck@dnr.iowa.gov
Mike Griffin	Wildlife Biologist	206 Rose St Bellevue, IA 52031	563-872-5700	Michael.griffin@dnr.iowa.gov
Wisconsin Department of Natural Resources				
Jeff Janvrin	Habitat Products Coordinator	2550 Mormon Coulee Rd La Crosse, WI 54601	608-785-9005	Jeff.janvrin@wisconsin.gov

POST-CONSTRUCTION
PERFORMANCE EVALUATION REPORT

POOL 11 ISLANDS (MUD AND SUNFISH LAKES)
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

2016

EXECUTIVE SUMMARY

General. The design of the Pool 11 Islands (Mud Lake and Sunfish Lake) project was to provide the physical conditions necessary to improve and enhance wetland habitat quality habitat by reducing resuspension of sediments, creating areas with flow and depth diversity, reducing sedimentation, increasing the abundance and diversity of aquatic plants, providing reliable food sources for migratory birds and resident wildlife and creating off-channel deep-water areas to provide year-round habitat for centrarchids and associated species. As stated in the Definite Project Report (DPR), the Pool 11 Islands Habitat Rehabilitation and Enhancement Project (HREP) was undertaken to address the following primary problems: lack of protected off-channel fisheries and decreased diversity of habitats in off-channel areas. These problems were contributing to the direct loss of feeding, spawning, nursery and overwintering habitat for fish, especially centarchids, as well as habitat for waterfowl and other wildlife.

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

1. Document the pre- and post-construction monitoring activities for the Pool 11 Islands HREP.
2. Summarize and evaluate project performance on the basis of project goals and objectives as stated in the 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. Restore and Protect Aquatic Habitat
   a. Reduce resuspension of sediments.
   b. Create areas with flow and depth diversity.
   c. Increase abundance and diversity of aquatic plants.
   d. Enhance nesting and brooding habitat for migratory birds.

2. Reduce Island Erosion (to include constructed embankments)
3. Restore and Protect Backwater Habitat
    a. Create off-channel deepwater areas to provide year-round habitat for centrarchids and associated species.
    b. Reduce sedimentation in backwaters.
    c. Provide reliable food resources for migratory birds and resident wildlife.

Project Performance Monitoring. Pre- and post-project monitoring, both qualitative and quantitative, was performed in accordance with the monitoring and performance evaluation matrix and post construction monitoring plan from the original DPR. Monitoring and performance evaluation was conducted by the U.S. Army Corps of Engineers and the Iowa Department of Natural Resources. The period of data collection covered in this report includes the pre-project monitoring (1991-2004), quantitative and qualitative post-project monitoring through 2012, and anecdotal information through 2012.

Evaluation of Project Objectives. For the evaluation period of 2005 to 2012, 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 and Protect Aquatic Habitat

a. Reduce Resuspension of Sediments

i. Evaluation Criteria: The monitoring plan did not clearly establish a measurement to evaluate resuspension of sediments, but water quality samples that have been taken since 1991 routinely analyze total suspended solids (TSS) and turbidity in NTUs.

ii. General Observation: In general resuspension appears to have been reduced. In some locations, the reduction is greater than 50%.

iii. Results: At sample location 583.4P, average total suspended sediment was reduced by 50% during the winter months and nearly 70% during the summer months. At location 588.0B, average TSS was reduced by 33% in the winter months and 28% during the summer months. At location 589.0C, average TSS was reduced by 38% during the summer months. At the remaining locations, there were no preconstruction samples to compare to, but post construction TSS values were similar to the other locations.

iv. Success: Sedimentation resuspension appears to have been reduced significantly by construction of the project.

v. Conclusion: The project was successful in reducing overall suspended solids, however, based on similar preconstruction and post construction values of turbidity, it would appear that most of the reduction in TSS was for larger particle sizes.

vi. Lessons Learned & Recommendations: Measuring TSS is a good way to determine the effectiveness of the project on reducing resuspension of sediments; however, this is not a requirement in the O&M manual.

b. Create Areas With Flow Diversity

i. Evaluation Criteria: The DPR stated that channel current velocity should be 0.3 cm/sec after 50 years. Backwater current velocity was to be 0.0 cm/sec after 50 years.

ii. General Observation: The project has been successful at modifying velocity diversity.

iii. Results: Overall post construction average velocity in the dredged channels was 2.7 cm/sec. Overall post construction average velocity in backwater areas was 1.8 cm/sec.

iv. Success: The HREP measures were not successful at reducing velocities to the desired target levels.

v. Conclusion: The notches appear to be successful at modifying and reducing velocities, but not to the desired target levels.

vi. Lessons Learned & Recommendations: Continued monitoring should be done to ensure that the notched weirs are performing as designed.

c. Create Areas With Depth Diversity

i. Evaluation Criteria: The DPR evaluation plan identifies the presence of water depth greater than 1.2m for evaluation of excavated channels. Criteria for ranges of depth was not established.

ii. General Observation: Sedimentation has occurred since construction.

iii. Results: Both Mud Lake and Sunfish Lake dredge channels depths and areas have been reduced from as-built conditions.

iv. Success: No measurement criteria.

v. Conclusion: Depth diversity is present at the HREP. To determine success of this objective in future PERs, the team should look at the survey data and compare that to observed presence of vegetation and fish.

vi. Lessons Learned & Recommendations: Sedimentation in dredged channels may occur faster than historical rates. Determination of depth diversity success, in spite of sedimentation rates should be better defined for future projects. In order to evaluate the success of dredging efforts to achieve depth diversity and the associated longevity of that action, future PERs should look at survey data and get input from refuge manager regarding the adequacy of the diversity based on the presence of diverse vegetation and fish. It may be beneficial to create mapping

d. Increase Abundance and Diversity Of Aquatic Plants

i. Evaluation Criteria: Observe presence of and types of vegetation.

ii. General Observation: Aquatic vegetation increased in Sunfish Lake.

iii. Results: Wild celery, coontail, sago pondweed and lotus observed.

iv. Success: No measurement criteria. However, the presence of diverse vegetation exists and therefore to date, it can be determined that the project was successful in providing diverse aquatic vegetation.

v. Conclusion: The HREP appears to have created correct conditions aquatic vegetation growth.

vi. Lessons Learned & Recommendations: Continued monitoring of Mud Lake and Sunfish Lake. Future PERs should consider obtaining vegetation survey data for analysis to include analysis of aerial photography per DPR and obtaining information from refuge manager during growing season site visits.

e. Enhance Nesting and Brooding Habitat for Migratory Birds

i. Evaluation Criteria: The DPR did not identify any measurements.

ii. General Observation: Migratory birds present.

iii. Results: Wood Duck, Canada Goose and Mallards observed on Sunfish Lake.

iv. Success: No measurement criteria. However, future monitoring could provide a basis for establishing criteria for future PERs.

v. Conclusion: Informal observation indicates migratory birds present.

vi. Lessons Learned & Recommendations: Formal bird monitoring should be conducted for future PERs. These results should be compared to prior year observations to determine the reliability of the project area for nesting and brooding habitat.

f. Reduce Sedimentation in Backwaters

i. Evaluation Criteria: Sediment trap bottom elevation of 183.0 meters (m) MSL by Year 50.

ii. General Observation: Sediment trap bottom elevation has risen.

iii. Results: Average elevation of sediment trap bottom is 180.5 meters, with ranges of 179.98 m to 182.79 m. The as-built elevation was 179.8 m MSL.

iv. Success: Although the sediment trap has experienced sediment deposition, whether or not the sediment trap reduced sediment deposition in the backwater area is unknown. If the sediment trap has accreted at a faster rate than the backwater, this is a positive indicator that the sediment trap performing its function, but to what degree cannot be determined.

v. Conclusion: The sediment trap is collecting sediment. However, the data available is not adequate to determine its impact on the reduction of sediment in the backwater area.

vi. Lessons Learned & Recommendations: Conduct hydrographic surveys of the sediment trap and backwater area in future monitoring events to determine if the trap is accreting at a faster rate. Consideration should be given to sediment bed samples of deposited sediment. These samples could be compared – sediment trap vs dredged channels.

g. Provide Reliable Food Resources for Migratory Birds and Resident Wildlife

i. Evaluation Criteria: The DPR and O&M manual do not identify any measurements.

ii. General Observation: Food resources present in Sunfish Lake.

iii. Results: Wild Celery relative abundance increased by 13%.

iv. Success: HREP was successful in establishing a food resource.

v. Conclusion: Conditions exist for development of reliable food resources

vi. Lessons Learned & Recommendations: Further monitoring is needed to fully assess the food resources at the HREP.

h. Create Off-Channel Deep Water Areas To Provide Year Round Habitat for Sunfish and Associated Species

i. Evaluation Criteria: The DPR stated that 24.3 hectares (as built was 23.1 hectares) of water with a depth of greater than 1.2 meters should be available after 50 years.

ii. General Observation: Sedimentation has occurred since construction.

iii. Results: Mud Lake dredge channel contains 6.4 hectares of water at the desired depth. A full determination of Sunfish Lake dredge channel suitable deepwater habitat was not made due to lack of adequate survey data.

iv. Success: The HREP has not maintained the as built 23.1 hectares of deepwater channel habitat. However, the remaining hectares are functioning as intended.

v. Conclusion: Deepwater channel habitat is present at the HREP but has been reduced.

vi. Lessons Learned & Recommendations: conduct surveys for future PERs to compare to as built and subsequent PER survey to determine remaining hectares at 1.2 meters.

Evaluation of Project Operation and Maintenance. The operation and maintenance manual was completed for this project in 2012. While this project is designed to have no operational costs, it does require a yearly inspection of the embankments, mowing and spraying, debris removal and assumes that approximately 5% of the project will need to be repaired every 10 years.

POST-CONSTRUCTION
PERFORMANCE EVALUATION REPORT

POOL 11 ISLANDS (MUD AND SUNFISH LAKES)
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

2016

TABLE OF CONTENTS

TABLES

APPENDICES

POST-CONSTRUCTION
PERFORMANCE EVALUATION REPORT

POOL 11 ISLANDS (MUD AND SUNFISH LAKES)
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

2016

INTRODUCTION

The Upper Mississippi River Restoration Program (UMRR) is a Federal-State partnership to manage, restore and monitor the UMR ecosystem. The UMRR 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 the Environmental Management Program (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.

HREP construction is one element of the UMRR Program. 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 Pool 11 Islands HREP is part of the UMRR. This project consisted of water control structures, deflection levees and dredging that were designed to improve and enhance backwater aquatic habitat reducing sedimentation and resuspension of sediment in backwaters and creating off-channel deep water areas with flow and depth diversity.

1. Purpose of Project Evaluation Reports. The purposes of this Project Evaluation Report (PER) for the Pool 11 Island HREP are to:

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

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); U.S. Fish and Wildlife Service (USFWS); Iowa Department of Natural Resources (IDNR); and the Wisconsin Department of Natural Resources (WDNR). The period of data collection covered in this report includes the pre-construction monitoring 1991 to post-construction monitoring as of 2014.

3. Project References. Published reports which relate to the Pool 11 Islands HREP include:

a. Definite Project Report with Integrated Environmental Assessment, Pool 11 Islands, Sunfish Lake and Mud Lake Habitat Rehabilitation and Enhancement Project, Rock Island District Corps of Engineers, September 2001.

b. Pool 11 Islands, Sunfish Lake and Mud Lake, Habitat Rehabilitation and Enhancement Project Operation and Maintenance Manual, Rock Island District Corps of Engineers, August 2012.

c. An Evaluation of Winter Habitats used by Bluegill, Black Crappie, and White Crappie in Pools 11-14 of the Upper Mississippi River, Iowa Department of Natural Resources, December, 2010.

4. Project Location The Pool 11 Islands HREP is located on the Upper Mississippi River National Wildlife and Fish Refuge in Dubuque County, Iowa and Grant County, Wisconsin on the right and left descending banks of the Mississippi River, respectively, in Pool 11, 2.3 miles upstream of Dubuque, Iowa and 17 miles downstream of Cassville, Wisconsin. The Pool 11 Islands HREP extends from Mississippi River Miles (RM) 583.3 to 593.0, and is in a rural setting. The constructed features of the HREP lie within Sections 10, 11, 14, 15 and 23 of Township 90 North, Range 2 East, Dubuque County, Iowa and Sections 17, 18, 19 and 20 of Township 1 North, Range 2 West, Grant County, Wisconsin. Sunfish Lake consists of 426 acres of aquatic habitat. Mud Lake consists of 493 acres of aquatic habitat. Detailed maps of the Pool 11 Islands HREP are shown in Figure 1. All Pool 11 Islands HREP lands are in Federal ownership and are managed by the USFWS as part of the Upper Mississippi River National Wildlife and Fish Refuge.

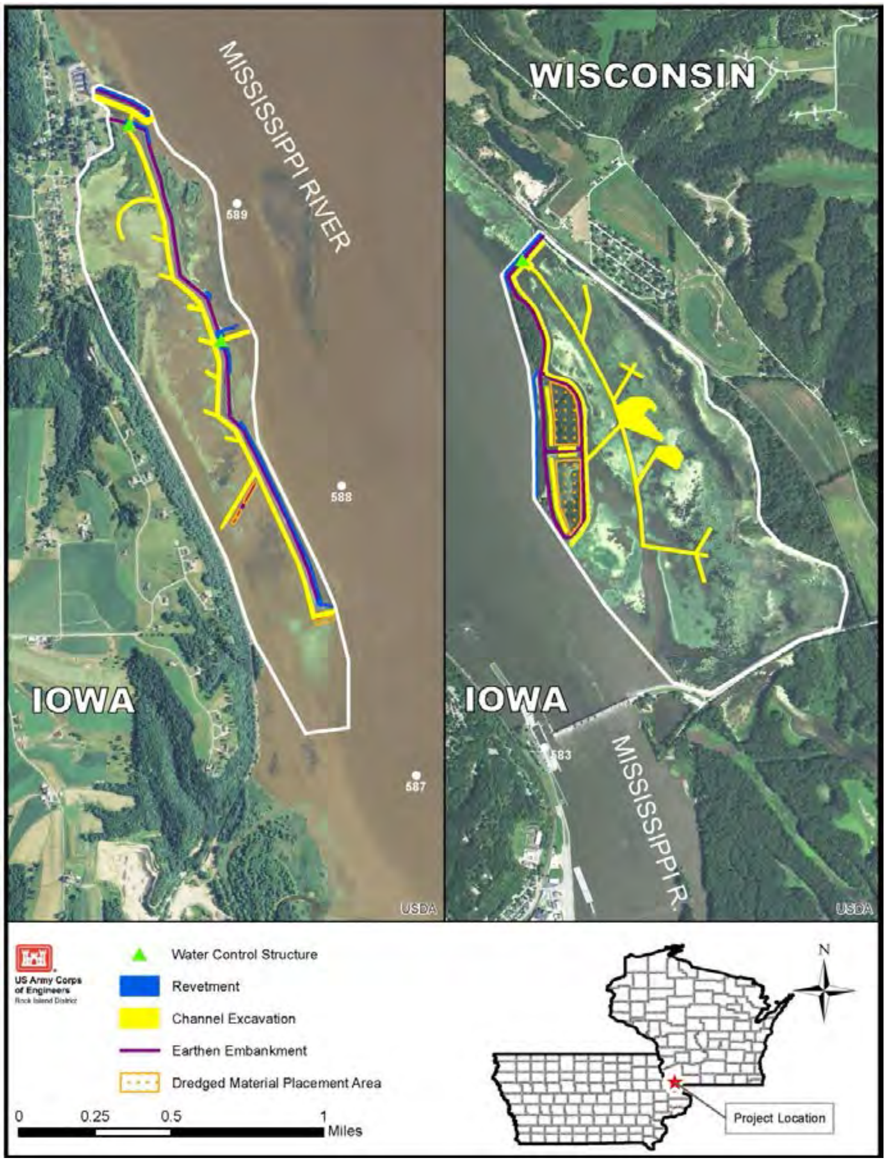


Figure 1. Pool 11 Islands HREP Project Area

PROJECT PURPOSE

The design of the Pool 11 Islands HREP was to provide the physical conditions necessary to improve and enhance wetland habitat quality. The specific goals as stated in the Definite Project Report (DPR) were to: Restore and Protect Aquatic and Backwater Habitat. In order to achieve these goals, the lack of protected off-channel fisheries habitat, and the decreased diversity of habitats in off-channel areas at the site needed to be addressed. These problems were contributing to the direct loss of fish habitat for feeding, spawning and nursery, overwintering, loss of diving duck habitat, loss of micro-invertebrate habitat and overall lack of habitat diversity. The problems, opportunities, goal, objectives and measures implemented to address the goals and objectives are listed in Table 1.

Table 1. Problems, Opportunities, Goals, Objectives, and Measures

Problems	Opportunities	Goals	Objectives	Restoration Measures
Lack of Protected Off-Channel Fisheries Habitat	Reduce re-sedimentation	Restore and Protect Aquatic/Backwater Habitat	Create off –channel deepwater areas to provide year around habitat for centrarchids and associated species Create areas with flow and depth diversity	Excavate channels in backwater areas
Decreased Diversity of Habitats in Off-Channel Areas	Control diversity of flow	Restore and Protect Aquatic/Backwater Habitat	Reduce sedimentation in backwaters Reduce island erosion[1] Reduce resuspension of sediments Enhance nesting/brooding habitat for migratory birds Increase abundance/diversity of aquatic plans Provide reliable food resources for migratory birds and resident wildlife	Construct deflection embankments Construct flow control structure Construct sediment trap

[1] Mid channel islands not constructed, objective eliminated after mid channel islands removed from DPR Recommend Plan.

PROJECT DESCRIPTION

1 Project Measures. The Pool 11 Islands HREP included a combination of excavated channels, deflection berms and flow control structures. See Figure 1 for locations of measures. A detailed description of each of these measures is as follows:

a. Excavate Channels in Backwater Areas. Off-channel dredging was used at both sites. The purpose of the dredging was to increase the depths in off-channel habitats, provide access between shallow and deep aquatic areas, and increase overwintering fish habitat for centrarchids and associated species.

b. Construct Deflection Berms. In both stages, deflection embankments were constructed and exposed surfaces were either vegetated or riprapped. The embankments were created from the borrow material created by dredging the deep water fish habitat. In Stage I, Sunfish Lake, the material was hydraulically dredged, with some mechanically dredging due to high clay content. In Stage II, Mud Lake, the material was mechanically dredged. The embankments are used to divert main channel flow around the project sites and allow for lower velocities, reduced sedimentation and increased amounts of aquatic vegetation.

c. Construct Flow Control Structure. To maintain a fresh inflow of dissolved oxygen, a notched rock weir was constructed at the upstream end of the Mud Lake and Sunfish Lake deflection embankments. The weir crest elevation is 0.6 m (1.9 ft) below flat pool elevation at Mud Lake, and 0.79 m (2.59 ft) below flat pool at Sunfish Lake. Downstream of the Sunfish Lake weir, a sediment trap was constructed to reduce sedimentation in the newly dredged channels. The trap was sized to retain the majority of the expected sediment load through the weir for a 50-year period. A midpoint weir was placed at Station 14+30 of the Mud Lake deflection embankment. This weir is set at flat pool elevation.

2. Project Construction. In the 2001 DPR, cost estimates for the entirety of the project were $9,431,617. Actual total construction costs (completed in 2005) were $7,615,148.87. Nearly another $1,000,000 was spent on the DPR, real estate, plans and specifications, engineering and design and construction management for a total of $8,510,538.

The Pool 11 Islands HREP project was approved for construction in two stages. Stage I included the construction of Sunfish Lake. Stage II included the construction of Mud Lake. Stage I was approved in July 2002 at a cost of $4,132,228.85. Stage II was approved in 2004 at a cost of $3,482,920.02. The Sunfish Lake section of the Pool 11 Islands project was completed in June of 2004, and the Mud Lake portion of the project was completed in July of 2005. Specific details about the items constructed and modifications are listed below.

In both stages, deflection embankments were constructed and exposed surfaces were either vegetated or riprapped. The embankments were constructed with the material dredged from the river bottom to create the deep water channel. In Sunfish Lake, the material was mechanically dredged due to high clay content. Additional channels and the sediment trap were hydraulically dredged. In Mud Lake, the material was only mechanically dredged. The embankments are used to divert main channel flow around the project sites and allow for lower velocities, reduced sedimentation and increased amounts of aquatic vegetation. The embankments also protect shallow water areas from wind fetch and sediment resuspension to improve environmental conditions for the growth of aquatic vegetation.

The Sunfish Lake HREP included a 1,568 m (5,145 ft) embankment that ties in to the Wisconsin shore at the upstream end (RM 584.1) and extends out toward the main channel, terminating near RM 583.5 (Figure 2). The embankment's top elevation was constructed to 185.60 m (608.92 ft). This elevation is 0.3 m (1 ft) above the 20 percent chance exceedance flood elevation plus an additional 0.3 m (1 ft) for potential settling. The top width is 3 m (10 ft) with side slopes of 4H:1V or shallower. A 3 m (10 ft) bench on the river side of the embankment is planted with willow stakes to protect against wind, wave, and current erosion. The borrow for this embankment was mechanically dredged from the river bottom, downstream and adjacent to the embankment alignment using a 275 ton crane with a 3 and 4 cubic yard bucket. Some of the material was obtained from within the confined disposal facility (CDF) to increase the capacity for hydraulically dredged material from the habitat channels. In some areas, the embankment is protected against wind, wave and current erosion by a 0.5 m (1.6 ft)-thick layer of Iowa Class E riprap and a 0.25 m (10 inch)-thick layer of bedding stone. An 8-inch hydraulic pipeline dredge was used to dredge channels. The hydraulically dredged material was placed in the CDF. The effluent from the CDF was further processed by a barge-mounted settling system in order to meet water quality standards. The west side of the island experienced severe erosion during construction. The construction contract was modified to add an offshore riprap dike from Stations 7+70.37A to 13+50A on an old road bed (this resulted in abundant vegetation growth in the protected area between riprap and embankment).

To maintain a fresh inflow of dissolved oxygen, a notched rock weir was constructed at the upstream end of the embankment. The weir crest elevation is 0.79 m (2.6 ft) below flat pool elevation. Downstream of the weir, a sediment trap was constructed to reduce sedimentation in the newly dredged channels. The trap was sized to retain the majority of the expected sediment load through the weir for a 50-year period. The design discharge of the notch is 1.1 cubic meters per second (cms) [40 cubic feet per second (cfs)] during average January conditions with no ice cover.

Figure 2. Sunfish Lake Aerial Photo At High Water (Left), the Inlet Notch (Center), and Inside the Confined Containment Facility Emergent Marsh During Low Water Condition (Right)

The 2005 Mud Lake portion of the HREP (Figure 3) created a protected backwater behind a 2,822 m (9,259 ft) embankment that ties into the Iowa shore at the upstream end near RM 589.4 and extends out toward the main channel and then angles downstream paralleling the main channel, ending near RM 587.7. The embankment's top elevation was constructed to 185.60 m (608.92 ft), 0.3 m (1 ft) above the 20 percent chance exceedance flood elevation plus 0.3 m (1 ft) for potential settling. A second 302 m (991 ft) embankment was constructed upstream of the primary embankment. This secondary embankment was designed to deflect sediment and debris that naturally accumulate at the head of Mud Lake, thereby decreasing maintenance of the upstream notched rock weir and decreasing sediment loads into Mud Lake. The embankment top width is 10 m (33 ft) [except for the secondary embankment width at 3 m (10 ft)] with side slopes no steeper than 6H:1V. The embankments were created by mechanical dredging using 275 ton crane with 3 and 4 cubic yard buckets. Some areas of the embankment are protected against wind, wave, and current erosion with a 0.25 m (10 inch)-thick layer of bedding stone and a 0.5 m (1.6 ft)-thick layer of Iowa Class E riprap. At the lower end channel entrance, the contractor was allowed to side cast a small amount of material for their convenience. This created a small berm at the downstream end of the embankment and channel. There are no maintenance requirements for the side cast berm as it is not part of the project design.

Two notched rock weir structures were constructed to maintain a fresh inflow of dissolved oxygen into Mud Lake, one near the embankment's midpoint at station 14+30 and one near the upstream end at station 2+10. The weir crest elevation was 0.60 m (2 ft) below flat pool elevation for the upper inlet and directly at flat pool elevation for the lower inlet. The design flow rates of the notches are roughly 0.57 cms (20 cfs), each during low flow winter conditions. The crest elevation of the notches were narrowed with additional rock, August 2006, at the request of the IADNR after their monitoring measured high flows in the excavated channel that would discourage overwintering fish use. The weir crest elevations previously stated reflect this change.

Figure 3. LEFT: Mud Lake Aerial Photo, CENTER: Mud Lake (Left), RIGHT: the Lower Part of the Project (Zollicoffer Slough), and Looking Toward The River Through A Notch.

3. Off-Channel Dredging. Off-channel dredging was also used at both sites. The purpose of the dredging was to increase the depths in off-channel habitats, provide access between shallow and deep aquatic areas, and increase overwintering fish habitat for centrarchids and associated species. Sunfish Lake included a series of deep-water channels totaling 13.1 ha (32.4 acres) dredged in the backwater area protected by the deflection embankment. A two-cell containment area was constructed as part of the embankment to hold the hydraulically dredged material. Both the hydraulically and mechanically dredged channels were excavated to a bottom elevation of 181.31 m (594.85 ft), a bottom width of 10 m (33 ft), and side slopes of approximately 3H:1V. The hydraulically dredged channels were dredged by an 8 inch hydraulic pipeline dredge. The mechanical dredging was accomplished utilizing a 275 ton crane with 3 and 4 cubic yard buckets. Dredging depths were based on historic sedimentation rates and are discussed in detail in the DPR. Two channel alignments (A & B) parallel the embankment alignment. The additional channels (D through M) connect to the first channel alignments and extend east and south towards the shoreline. Additionally, Option Areas "A" and "C" were either partially or fully dredged to elevation 182.0 meters as part of the Project.

Borrow material for the Mud Lake embankment was mechanically dredged from the river bottom, landward and adjacent to the embankment alignment. The resulting deep-water channel was excavated to a bottom elevation of 181.45 m (595.31 ft), a minimum bottom width of 10 m (33 ft), side slopes of approximately 3H:1V, and a total 11.2 hectares (ha) (27.6 acres) of bottom area. Several high spots (depth diversity structures) were left in the dredged channel to retain the warmer bottom water during overwintering periods.

4. Project Construction Modifications. Six recorded modifications to the Pool 11 Islands HREP have been completed.

1.) Per USFWS request, a second access gate was added to the Project at Mud Lake. This gate is located northwest of the planned gate at the far northwest end of Embankment B.

2.) Riprap was also added along embankment areas of Mud Lake to prevent erosion and to minimize future maintenance costs. . A riprap dike was added to the existing submerged road bed at Sunfish Lake. Although this was not originally thought to be necessary during the planning phase, excessive erosion was observed during construction, which warranted the addition of the rock protection for the CDF.

3.) Rock was placed at the southeast tip of Sunfish Lake during the Mud Lake contract.

4.) The sediment trap was lengthened to compensate for the road bed at Sunfish Lake.

5.) A 50 megagram (MG) (55 ton) riprap stockpile was left at Mud Lake.

6.) Additional riprap was added to the inlets at Mud Lake. The upper inlet was raised from 182.90 to 183.19 meters (599.91 to 600.86 ft). The lower inlet was raised from 182.90 to 183.80 meters (599.91 to 601.22 ft). The additional riprap was added to reduce the winter flow velocities to the backwater areas, which were found to be too high for overwintering fish.

5. Project Operation and Maintenance. A detailed description of all operation and maintenance requirements can be found in the HREP OMRR&R Manual dated August 2012.

In the original DPR, over the 50-year project life the estimated cost was $498,000. From the estimate, an average annual operation and maintenance cost was calculated to be $9,960. This amount included embankment inspection, riprap, erosion control, debris removal, weirs and planting maintenance. To date, the total OMRR&R cost has been $14,678, with the estimated average annual cost to be $1,630. Table 2 provides OMRR&R history and cost for the Pool 11 Islands HREP.

Table 2. Operation and Maintenance History for the Pool 11 Islands HREP

Year	Years in O&M	Estimated Annual Cost with Inflation	Actual USFWS Costs	Activities
2004	1	$9,960	$3,018	Tree Planting
2005	2	$10,300	$0	Inspection
2006	3	$10,650	$1,560	Inspection, placed “Slow-No-Wake” buoys
2007	4	$10,900	$2,950	Inspection, placed “Slow-No-Wake” buoys
2008	5	$11,350	$350	Inspection, placed “Slow-No-Wake” buoys
2009	6	$11,310	$1,800	Inspection, placed “Slow-No-Wake” buoys
2010	7	$11,500	$2,700	Inspection, placed “Slow-No-Wake” buoys
2011	8	$11,850	$1,200	Inspection
2012	9	$12,105	$1,100	Inspection
2013	10	$12,283	$1,700	Inspection, placed “Slow-No-Wake” buoys

PROJECT PERFORMANCE MONITORING

Performance monitoring of the Pool 11 Islands HREP has been conducted by the Corps, IA DNR, WDNR and LTRMP 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 if project features do not function as desired or in response to field conditions.

The monitoring and performance evaluation matrix is outlined in Table 3. Pre- and post-project monitoring, both qualitative and quantitative by each of the involved agencies is summarized as follows.

> **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, IADNR, WDNR, and USACE. USACE was responsible for post-project analyses of water quality, sedimentation and vegetation. USACE has overall responsibility to measure and document project performance.
>
> Corps of Engineers monitoring to assess off-channel aquatic habitat included water quality monitoring and bathymetric surveys. Water temperature, dissolved oxygen, and current velocity were evaluated to assess habitat suitability for centrarchids and associated fish species. Bathymetry surveys periodically inspect depths in the dredged channels and in the Sunfish Lake sediment trap. Wisconsin DNR sampled pre- and post-project water quality in Sunfish Lake. Iowa DNR evaluated current velocity in Mud Lake and fish movement throughout the reach. Upper Mississippi River Conservation Committee volunteers sampled aquatic vegetation in 2001 and the LTRMP Wisconsin Field Station sampled aquatic vegetation in 2009.
>
> **U.S. Fish and Wildlife Service:** The USFWS is responsible for operating and maintaining the Pool 11 Islands HREP.

ECOLOGICAL EFFECTIVENESS

Table 4 summarizes the performance evaluation plan and schedule for the Pool 11 Island HREP goals and objectives. Appendix A of this PER discusses the ecological effectiveness of the HREP measures in detail. Water quality analysis of the HREP is included in Appendix B.

Table 3. Monitoring and Performance Evaluation Matrix

Activity	Purpose	Responsible Agency	Implementing Agency	Funding Source	Remarks
Sedimentation Problem Analysis	System-wide problem definition. Evaluates planning assumptions	USFWS	USGS (UMESC)	LTRMP	Leads into pre-project monitoring; defines desired conditions for plan formulation
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	Establishes baselines for performance evaluation	USACE	Field station or sponsor thru Cooperative Agreements or Corps	LTRMP	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)	Field station or sponsor thru Cooperative Agreements or Corps	LTRMP Cooperative	Comes after construction phase of project
Analysis of Biological Responses to Project[1]	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	USGS (UMESC)	LTRMP	Problem Analysis and Trend Analysis studies of habitat projects

[1] This row was added during the PER process

Table 4. Performance Evaluation and Monitoring Schedule

				Monitoring Results						
Goal	**Objective**	**Enhancement Measure**	**Units**	**Year 0 W/out Project**	**Year 1 W/ Project: Actual Conditions**	**Year 1 DPR Target**	**Year 10 W/ Project: Actual Conditions**	**Year 10 DPR Target**	**Year 50 Target W/ Project- DPR Target**	**Monitoring Schedule**
Restore & Protect Aquatic & Backwater Habitat	Create off-channel deep-water areas to provide year-round habitat for centrarchids and associated species	Excavate channels in backwater areas	Winter water temperature. [^{O}C(^{O}F)] - Avg of all stations	0.5 (32.9)	0.7 (33.2)	1.0(33.8)	1.2 (34.2)	1.0(33.8)	1.0 (33.8)	Perform water quality tests
			Channel water depth [ha >1.2 m (acre >3.9 ft)]	0	23.1 (57)	23.1 (57.0)[1]	14.1 (34.8)	23.1 (57.0)[1]	23.1(57.0)[1]	Transect Surveys
			Channel velocity [cm/sec (ft/sec)] Summer & Winter Channel stations only: avg	>3.0 (>0.1)	6.7 (0.2)	0	2.7 (0.09)	0	0.3 (0.001)	Perform water quality tests
			Catch Per Unit Effort	See Appendix A						
	Reduce sedimentation in backwater	Construct Deflection Embankments	Current velocity in backwater areas [cm/sec (ft/sec)] Summer & Winter Stations 583.4P & 588.0B	>3.0 (>0.1)	1.1 (0.04)	0	1.8 (0.06)	0	0	Perform water quality tests
		Construct flow control structure	Dissolved Oxygen (mg/L) Summer & Winter Avg all stations	3.0-5.0 (M*) 13.1 (S*)	12.2 (M) 12.1 (S)	$\geq$5.0	10.3 (M) 10.3 (S)	$\geq$5.0	$\geq$5.0	Perform water quality tests
			Total Suspended Solids (mg/L)[2] range of avgs all stations	11.3-28.5 (M) 16.5-60.1 (S)	Not measured		6.2-34.6 (M) 8.2-22.75 (S)		***Not established***	Perform water quality tests
		Sediment Trap	Bottom Elevation (M)	183.0	179.8	Not established	Avg. 180.5	***Not established***	183.0	Transect Surveys

M=Mud Lake
S= Sunfish Lake
[1] DPR intent for target was the as built condition. DPR projected 24.3 hectares for as built condition. Actual as built condition was 23.1 hectares
[2] Not a monitoring plan parameter in DPR

1. Reduce Suspension of Sediments. The monitoring plan did not clearly establish a measurement to evaluate resuspension of sediments, but water quality samples that have been taken since 1991 routinely analyze total suspended solids (TSS) and turbidity in NTUs.

At sample location 583.4P, average total suspended sediment was reduced by 50% during the winter months and nearly 70% during the summer months. At location 588.0B, average TSS was reduced by 33% in the winter months and 28% during the summer months. At location 589.0C, average TSS was reduced by 38% during the summer months. At the remaining locations, there were no preconstruction samples to compare to, but post construction TSS values were similar to the other locations. Further discussion of TSS is included in Appendix B.

The project was successful in reducing overall suspended solids, however, based on similar preconstruction and post construction values of turbidity, it would appear that most of the reduction in TSS was for larger particle sizes.

Measuring TSS is a good way to determine the effectiveness of the project on reducing resuspension of sediments. Monitoring of TSS should be continued to better understand the success of the project.

2. Create Areas With Flow and Depth Diversity. The DPR stated that channel current velocity should be 0.3 cm/sec after 50 years. The project has been successful at modifying velocity diversity, but has not achieved the desired velocity target.

Three locations had preconstruction data. 589.0C had an average velocity before the project of 0.23 cm/sec, 588.0B had an average velocity of 5.65 cm/sec and 583.4P had an average velocity of 11.18 cm/sec. The post construction velocity for these three sites is 1.06 cm/sec, 2.04 cm/sec and 2.26 cm/sec, respectively. Average velocity at 584.2X was 3.06 cm/sec, 588.1D was 2.74 cm/sec and 589.3D was 6.20 cm/sec. Overall post construction average velocity in the dredged channels was 2.7 cm/sec. Overall post construction average velocity in backwater areas was 1.8 cm/sec. See Appendix B for further discussion on channel and backwater velocities. Continued monitoring should be done to ensure that the notched weirs are performing as designed.

Prior to construction, no suitable deepwater habitat existed in the HREP Project area, so deep channels were dredged in Mud and Sunfish Lakes to provide depth diversity. Success of this feature is discussed in the *Ecological Effectiveness* Section, #7. In addition to deep dredging, a number of high spots were left in the main Mud Lake dredged channel to create separate deepwater sections in the channel with the assumption they would hold denser and warmer water in an effort to achieve the target temperature of 1.0 °C. Temperature monitoring revealed the sections between high spots retained warmer water at low current velocity, but became well mixed with cold water as flows increased. It was determined that distance from main excavated channel had a stronger influence on temperature. If the velocities in the channel had been lower and nearer to the target of 0.3 cm/sec, the deepwater sections between the high spots may have been able to achieve temperature stratification and hold warmer water. Unfortunately, survey data shown in the Plates indicates that the channel bottom has become more uniform as the deeper areas between high spots have filled with sediment. Therefore, the opportunity to monitor the performance of the high spots features no longer exists at this project.

3. Increase Abundance and Diversity of Aquatic Plants. Aquatic vegetation abundance increased behind the deflection dike in Sunfish Lake. Current velocity dropped, wind generated waves were reduced, and water cleared. Wild celery, a valued wildlife food, occurred in the project area during post project sampling. Sago pondweed, coontail, and lotus were detected in pre-project sampling but wild celery was absent. All species showed increased abundance in post project sampling. See Appendix A for details.

4. Enhance Nesting and Brooding Habitat for Migratory Birds. Informal wildlife monitoring has been conducted by Iowa DNR personnel. Observations on Sunfish Lake have determined that the HREP is being used for migratory bird nesting and brooding, as Canada Goose, Wood Duck and Mallard broods have been seen. Further field formal monitoring is recommended to determine the impact of the HREP on migratory birds.

5. Reduce Sediment Deposition in Backwaters. One function of the embankments at Mud Lake and Sunfish Lake were to reduce sediment deposition in the area protected by the embankments, especially the dredged channels. After the construction of the Locks and Dam project, the Mud and Sunfish Lakes areas have experienced sediment deposition rates of 2.58 and 1.95 cm/yr, respectively.

As part of the water quality monitoring program, data is collected at four sites in Mud Lake and three sites in Sunfish Lake. One parameter collected is depth. These data were compiled, converted to elevation, and plotted to show bed elevation trends in the dredged channel. These should be considered a complement to (and not a substitute for) survey data. These data are presented in Appendix B-3. It shows that the three sites in Sunfish Lake have accreted at about the same rate (3.8 cm/yr). The four sites at Mud Lake show that the sites nearer the notch have accreted at a faster rate (5-10 cm/yr) while the sites farther removed from the notch have accreted less (2.5-3.8 cm/yr).

A sediment trap was constructed downstream of the Sunfish Lake weir. The purpose is to capture sediment inflowing into the complex, lessening sediment deposition in the dredged channels. As Sunfish Lake is closer to the dam, and farther from the main channel, as compared to Mud Lake, it would be expected that there would be less suspended sediment traveling through the opening. This has been the case, as discussed in the previous paragraph. However, the lower sediment deposition rate may also be a function (partially) of the sediment trap. If the sediment trap is accreting at a rate faster than the dredged channels, this is an indicator of that. However, it is difficult with available data to determine the effectiveness of the sediment trap. The as-built bottom elevation of the sediment trap was 179.8 m. The Year 50 target for the sediment trap bottom elevation is 183.0 m. A bathymetric survey was conducted in the area of the sediment trap in 2014. See Appendix C for Survey Drawing Set. Analysis of the surveyed sediment trap indicated that average elevation was

180.5 m, with elevations ranging from 179.98 m to 182.79 m. Over the 10 year period since construction, the sediment trap appears to be performing as designed, and has not exceeded the Year 50 target. Based on the sediment deposition rate observed since construction, it is estimated that the sediment trap bottom elevation will slightly exceed the Year 50 target (183.3 m) by Year 50.

The sediment deposition occurring in the dredged areas for Mud Lake and Sunfish Lake is from sediment passing through the respective weirs. More flow and sediment passes through the weir during flooding events, however these flooding events are short in duration. Total suspended solids (TSS) concentrations have decreased significantly compared to preconstruction levels (see *Ecological Effectiveness* Section, #7). This indicates that the HREP is adequately reducing siltation during normal flow regimes. There have been five flood events since construction (two in 2008, 2010, 2011, 2013), with 2011 exceeding the embankment elevations. In April 2011, the embankments were overtopped by a high water event for the first time since construction was completed. The water rose nearly one meter above the top of the embankments. There was no major damage from this event.

6. Provide Reliable Food Resources for Migratory Birds and Resident Wildlife. Based on the aquatic vegetation surveys, reliable food resources are present in Sunfish Lake. Further details on aquatic vegetation are included in Appendix A. Additional formal surveys are recommended to determine the impact of the HREP on food resources prior to the next PER.

7. Create Off Channel Deepwater Areas To Provide Year-Round Habitat for Centrarchids and Associated Species. The HREP was constructed with 23.1 hectares (57 acres) of deepwater channel habitat that was greater than or equal to 1.2 m (3.9 ft) deep from a flat pool elevation of 183.79 m MSL (602.83 ft ASL). Prior to construction zero acres of such suitable deepwater habitat existed in the HREP project area. Bathymetric surveys were conducted at Mud Lake and Sunfish Lake in 2014 along the dredged areas. See Appendix C for Survey Drawing Set. The bathymetric survey for Sunfish Lake did not include the deepwater channels Alignment B, Options A or C, and did not include a portion of Alignment D. The survey data was utilized to determine the area of dredged channels at Mud Lake that were at or deeper than an elevation of 182.59 m ASL (equivalent to ≥ 1.2 m). Mud Lake currently has 6.4 hectares (15.7 acres) of suitable deepwater habitat, down from an as-built condition of 10 hectares (25 acres). Due to the missing data at Sunfish Lake, a full determination of the current suitable deepwater habitat area could not be made. However, the Sunfish bathymetric data was utilized to create cross sections along Alignment E (the main deepwater channel).

The cross sections are provided in Appendix C. The cross sections indicate relatively uniform sediment deposition; however some areas show signs of possible sloughing. The Year 50 target for deepwater channel habitat is 23.1 hectares (57 acres) which represents the actual as built condition. DPR states the Year 50 target as 24.3 hectares (60 acres), which represents the projected as built condition. Based on the limited bathymetric survey data, and water quality station depth measurements, it appears that the amount of deepwater channel habitat has decreased since HREP construction. Full bathymetric surveys of all deepwater channels will need to be conducted in order to completely determine the amount of habitat reduction.

Dissolved oxygen levels and overwintering water temperatures are indicators of centrarchid habitat quality. Dissolved oxygen concentrations in Mud Lake on average were 10.23 mg/L during the post construction measurement period, and averaged 10.33 mg/L in Sunfish Lake over the same period. There where however select times during the summer seasons when the dissolved oxygen levels decreased below the 5 mg/L threshold. The DPR calls for average overwintering water temperatures above 1.0° Celsius. Post construction monitoring indicates the average temperature at Mud Lake is 1.4° Celsius, and the average at Sunfish Lake is 0.77° Celsius. The average of the HREP overall is 1.2° Celsius. In depth discussion of dissolved oxygen and water temperatures is included on Appendix B.

LESSONS LEARNED AND RECOMMENDATIONS FOR FUTURE SIMILAR PROJECTS

The Pool 11 Islands HREP is two distinct project areas using similar restoration techniques. They both use a barrier island to separate open water impounded areas to create backwater habitats. Long linear islands or larger contained disposal facility islands separate the project areas from most flows from the channel. Very high flow can overtop the structures and openings (notches) in the dikes allow prescribed flow into the project area.

The dimensions of the openings in the dikes were an element of uncertainty in the project design, so an adaptive management approach was used to determine the effect of notch size on habitat conditions. The initial notches in Mud Lake were left open and flows in the channels greatly exceeded objectives. A RMA-2 Hydraulic model was used to estimate the notch size required to deliver 20 cubic feet per second flow. Current velocity in dredged channels dropped when rock was installed to restrict the upper notch and close the middle notch in Mud Lake. Fish tracking showed fish used more of the Mud Lake project area after the flow reduction, but the fish still did not use the upper project area where current velocities were high.

Available current velocity meters are not sensitive at the range of flows determining winter habitat quality so a dye tracking study was used to better understand water movement in the project area. The dye study detected high current velocity in Mud Lake's dredged channels that prevented fish from using the upper project area during winter. Oxygen was abundant in most of the project area. The dye study results were used to re-calibrate the RMA-2 model which identified an incorrect assumption in the prior model and accounted for the oversized notch.

Further flow reductions can be achieved by utilizing the excess rock which was left on site for such purposes. Closing the gap with rock is one simple option which also can be easily reversed. Rocks can be loosely placed in the notches to further restrict flow, while still allowing some oxygen rich water intrusion.

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. 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.

REFERENCES

Definite Project Report with Integrated Environmental Assessment, Pool 11 Islands, Sunfish Lake and Mud Lake Habitat Rehabilitation and Enhancement Project, USACE, Rock Island District, September 2001.

Pool 11 Islands, Sunfish Lake and Mud Lake, Habitat Rehabilitation and Enhancement Project Operation and Maintenance Manual, USACE, Rock Island District, August 2012.

Pool 11 Islands (Stage 2) Mud Lake HREP, 2010 HREP Annual Inspection Report, USFWS, May 2010.

Pool 11 Islands (Stage 2) Mud Lake HREP, 2011 HREP Annual Inspection Report, USFWS, Dec 2012.

Pool 11 Islands (Stage 2) Mud Lake HREP, 2007 HREP Annual Inspection Report, USFWS, Sep 2007.

Pool 11 Islands (Stage 1) Sunfish Lake HREP, 2010 HREP Annual Inspection Report, USFWS, May 2010.

*Pool 11 Islands (Stage 1) Sunfish Lake HREP, 2011 HREP Annual Inspection Repor*t, USFWS, Dec 2012.

Pool 11 Islands (Stage 1) Sunfish Lake HREP, 2007 HREP Annual Inspection Report, USFWS, Sept 2012.

Bertom McCartney Lakes HREP, 2014 Performance Evaluation Report, USACE, Rock Island District, Rock Island, Illinois, Sep 2014.

Janvrin, J., Sullivan, J., Stuhr, B., Laube, J., *Sunfish Lake-Summary of 1991-2010 Pre and Post Project Winter Water Quality.*, Wisconsin DNR, La Crosse, WI, Mar 2012 (not published).

Steuck, Michael J., *An evaluation of winter habitats used by bluegill, black crappie and white crappie in Pools 11-14 of the Upper Mississippi River, Study 7021 Completion Report,* Fisheries Research Project No. F-160-R, Iowa DNR, Dec 2010.

Lubinski, K.S. 1999. *Floodplain river ecology and the concept of river ecological health*. Chapter 2 *in* USGS *ed.* Ecological status and trends of the Upper Mississippi River System 1998: A report of the Long-Term Resource Monitoring Program, Report Number LTRMP 99-T001, U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. 236pp.

Palesh, G. and D. Anderson. 1990. *Modification of the habitat suitability index model for the bluegill* (Lepomis macrochirus) *for winter conditions for the Upper Mississippi River backwater habitats,* USACE, 9 pp.

POST-CONSTRUCTION
10-YEAR PERFORMANCE EVALUATION REPORT

POOL 11 ISLANDS (MUD AND SUNFISH LAKES)
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

APPENDIX A

ECOLOGICAL EFFECTIVENESS

WINTER WATER CIRCULATION PATTERNS IN MUD LAKE - AN ADAPTIVE MANAGEMENT STUDY OF A BACKWATER HABITAT RESTORATION PROJECT IN POOL 11 OF THE MISSISSIPPI RIVER.

Abstract

U.S. Army Corps of Engineers, Rock Island District (USACE) personnel performed a dye study during March 2014 in a backwater of the Mississippi River, Pool 11, near Dubuque, Iowa. The study was conducted in response to Iowa Department of Natural Resources (IDNR) fish telemetry data which indicated that newly created dredge channels were underutilized by overwintering fish; and velocity data that indicated Mississippi River main channel flow was entering the backwater area from the dredge channel outlet. A habitat restoration project for the backwater was completed in 2005 as part of the Upper Mississippi River Restoration program. The project included creation of deep water dredge channels in the backwater adjacent to the navigation channel to provide overwintering habitat for centrarchids and associated species.

The primary purposes of the study were to determine how inflowing water disperses, both temporally and spatially, throughout the backwater complex during winter under ice cover; and to measure velocity, a critical factor in the selection of overwintering areas utilized by centrarchids. A single slug injection of Rhodamine WT dye was dispensed immediately downstream from the inlet structure to the backwater and was tracked for more than 24 hours as it dispersed throughout the area. When initial results indicated the dye was not traversing the full length of the main dredge channel, a second injection was dispensed in the dredge channel outlet. The results of the study suggest that implementation of adaptive management measures is necessary in order to reduce dredge channel velocities to acceptable levels for overwintering fish. The results also substantiated velocity data collected by IDNR and Wisconsin Department of Natural Resources (WDNR) personnel which indicated Mississippi River main channel flow enters the backwater area from the dredge channel outlet.

Introduction

The Pool 11 Islands Habitat Rehabilitation and Enhancement Project (HREP) under the Upper Mississippi River Restoration program included two distinct backwater enhancement areas: Mud Lake and Sunfish Lake. All work related to this study was performed in the Mud Lake area. Construction of the Mud Lake project commenced in August 2004 and was completed in July 2005 (USACE, 2014). The Mud Lake HREP is located on the Mississippi River (river miles 587.6 to 589.4), approximately five miles upstream from L/D 11 and the City of Dubuque, Iowa. A site map is included in Figure 1. The HREP consists of Mud Lake at the upstream portion of the backwater area and Zollicoffer Slough at the downstream portion, with the mouth of Leisure Creek forming a depositional area between the two water bodies. The recommended plan for the HREP included construction of a 3,038 m sediment deflection embankment to protect the backwater complex from sediment accretion /resuspension and mechanically dredging 8.8 ha of deep channels for fish overwintering habitat (USACE, 2001). Dredge material was used to construct the deflection embankment and an island near the lower portion of the project that was constructed from material removed to create a channel connecting Zollicoffer Slough with the main dredge channel. As part of the original design process for the Mud Lake HREP, a two dimensional hydrodynamic model (RMA-2) was utilized to evaluate various alternatives for the project. The recommended alternative included two notched rock weirs in the deflection embankment: one at the upper end and one near the middle. The primary purpose of the weirs was to allow oxygenated main channel flow into the backwater area during the winter months to help assure sufficient DO concentrations to support overwintering fish. A DO mass balance performed during project design indicated an inflow of 1.09 cm/sec would be necessary to maintain a DO of 5 mg/L in the backwater. The RMA-2 model was used to size the inlets for the required inflow. Following project construction, both USACE and IDNR personnel measured velocities in the dredge channels that were excessive for overwintering centrarchids. In 2006, adaptive management measures were incorporated to reduce the inflow. The opening in the middle of the deflection embankment was completely filled with rock, while the opening at the upper end was partially filled. This resulted in a significant reduction in velocity in the dredge channels during ensuing winters; however, IDNR fish telemetry studies have indicated the HREP is still underutilized by overwintering centrarchids and velocities continue to be excessive. According to Scott Gritters (IDNR, personal communication, April 2, 2014) at the start of winter, centrarchids in the HREP prefer to stage in areas with zero flow.

In addition to issues involving velocity magnitude, velocity direction has also been a concern. A study performed jointly by IDNR and WDNR staff on February 22, 2008 indicated Mississippi River main channel flow enters the backwater area from the dredge channel outlet. The present study was performed in order to better define velocities and circulation patterns in the backwater complex in an effort to explain the underutilization of Mud Lake by overwintering fish.

Methods

As part of the district's HREP performance evaluation monitoring program, USACE personnel performed water quality sampling at Mud Lake on March 6, 2014. This trip provided the opportunity to gather reconnaissance data for the upcoming dye study. The inlet structure was investigated in order to determine ice coverage and an appropriate method for dispensing the dye, and velocity measurements were taken in order to estimate dye travel times. Ice condition and thickness were also determined at several sites in order to assess the level of effort that would be required for completing the dye study.

Sample site locations were determined prior to performing the dye study by utilizing Google Earth Pro software. Historical imagery was viewed in order to select a recent image (September 22, 2011) that provided the best view of the dredge channels and other deep areas in the backwater complex, which were readily recognized as areas devoid of emergent vegetation. The software pointer was placed on the location of each proposed sampling site and the geographical coordinates were recorded. Most of the sampling sites were located in dredge channels, while some were located in Zollicoffer Slough and other areas throughout the backwater. In this initial exercise, 21 sampling points were identified (see Figure 2).

The fluorescent dye used for the study was a 20 percent solution of Rhodamine WT manufactured by Crompton and Knowles. To determine the amount of dye required for the study, the area of the backwater was estimated using the ruler function in Google Earth Pro. Average water depths were estimated for the dredge channels (1.5 m), Zollicoffer Slough (2.7 m) and the remainder of the backwater complex (0.3 m). The depth for each stratum was multiplied by the area to calculate water volume. The three volumes were added to determine the total water volume of the backwater complex (534,128 m^3). This value was compared to the volume calculated for Spring Lake (11,280,000 m^3), where a previous dye study was conducted. In the Spring Lake study, it was estimated that 3.5 liters of dye would be required to dye the lake to a concentration of 100 ppt (Bierl, 2002), the approximate level of detection. The volume of Spring Lake is considerably greater than Mud Lake; however, to account for dye fluorescence decay which may have occurred during storage, it was conservatively estimated that 3.75 liters of dye would be sufficient for the Mud Lake study.

Waypoints stored on a GPS (Trimble TSC1 datalogger/Pro XR receiver) were used to locate the 21 sampling sites on the first day of the study (March 10, 2014). The sites were marked with orange spray paint, holes were drilled through the ice and measurements were taken. Sites 2, 8, 9, 10 and 19 were found to have insufficient water depth to allow for collection of a representative water sample; thus, these sites were eliminated from further study. Site 12, located on the river side of the rock-filled notch in the deflection embankment, was also dropped from further study when water was observed flowing from the river side of the notch to the backwater side (this site was initially considered due to the possibility of dye exiting the backwater area here). At the remaining sites, water depth, ice thickness, snow depth, dissolved oxygen (DO), water temperature and velocity were recorded. DO and water temperature values were measured at the surface (10 cm below the bottom of the ice), mid-depth (1/2 the water depth) and bottom (10 cm above the bottom) with a YSI Pro ODO Meter. A Sontek FlowTracker ADV was used for taking velocity measurements at the surface. At selected sites, pH was measured at the surface with an Extech Instruments pH100 meter and a depth integrated water sample was collected and analyzed for background fluorescence with a Turner Designs Model 10-AU fluorometer.

On the morning of March 11, 2014, water collected from the inlet channel of the backwater area was mixed with Rhodamine WT dye in a 151 liter plastic drum fitted with a spigot and a one meter discharge tube (see Figure 3). In order to facilitate assimilation of the dye with the inflow, 3.75 liters of dye were mixed with 121 liters of river water. This helped reduce the viscosity of the dye and equilibrate the temperature of the dye with that of the inflowing river water in order to allow for more complete mixing. A single slug injection of the dye commenced at 0830 hours and was completed by 0900 hours. The dye was then tracked.

A water sample was collected at each site with a 2.8 m length of ½-inch diameter EMT conduit with back-to-back #0 conduit hangers fastened near one end (see Figure 4). A 40 ml, amber glass vial with silicon septum screw cap was snapped into place in the conduit hanger. The narrow opening of the cap (following removal of the silicon septum) allowed the bottle to fill relatively slowly; thus, allowing for sample collection throughout the depth profile. The sampling apparatus was lowered into the hole until it approached the bottom and was then raised at the same rate. This allowed for a depth integrated sample. Following collection, a portion of the sample was poured into a 13 mm cuvette and immediately analyzed for the presence of dye with the fluorometer. This process helped assure the temperature of all samples was similar; thus, minimizing the impact of temperature variation on dye concentration. According to Johnson (1984), Rhodamine WT fluorescence decreases approximately five percent for every 2°C increase in temperature. In order to prevent cross-contamination, the sampling apparatus and ice auger/chisel were rinsed with non-dye tainted river water after each sample containing dye was collected. DO, water temperature and velocity measurements were taken at selected sites to determine if these parameters changed significantly from day one of the study.

Once dye tracking commenced, additional sampling sites were identified (see Figure 5) in order to locate the leading edge of the dye at various times. When the sampling results indicated dye had not reached site 18 at the predicted time, a second dye injection was made in the dredge channel outlet to validate velocity data collected by IDNR and WDNR personnel in 2008 which indicated Mississippi River main channel flow enters the backwater area from the dredge channel outlet. The second slug injection of dye commenced at 1214 hours and was completed by 1224 hours on March 12, 2014. This injection was administered in a similar fashion as the first injection; however, approximately one-half the amount of dye and river water was mixed in the drum. Water samples were collected at the three sampling sites located near the outlet (see Figure 5) in order to verify the dye's direction of travel.

Results and Discussion

The Mississippi River elevation during the study was close to the long-term historic average as measured at the Lock and Dam 11 gage (see Figure 6). Over the course of the study, the river rose approximately 0.5 feet. The 6:00 a.m. river elevations on March 10, 2014 and March 12, 2014 were 605.61' and 606.07' upstream at the Guttenberg, Iowa gage and 593.62' and 594.15' downstream at the Lock and Dam 11 gage, respectively. Field data collected on March 10, 2014 are given in Table 1. The winter of 2013/2014 was one of the coldest on record; thus, ice thickness was much greater than during a typical winter, with values ranging from 27.9 cm at site 16 to 66.0 cm at site 17. The combination of thick ice and shallow water depth at sites 2, 8, 9, 10 and 19 precluded collection of a representative water sample; therefore, these sites were eliminated from further study. Site 12, which was initially considered due to the possibility of dye exiting the backwater area here, was also dropped from further study when water was observed flowing from the river side of the rock-filled deflection embankment notch into the backwater side. The remaining sites, all located within dredge channels or in Zollicoffer Slough, had water depths ranging from 1.49 m at the upper end of Zollicoffer Slough (site 14), to 2.74 m at the lower end of Zollicoffer Slough (site 21). The average depth of sites located in dredge channels was 1.89 m, with the deepest area (> 2.0 m) located in the middle of the main dredge channel (sites 11, 13 and 15) and the shallowest area (1.50 m) at site 20, near the dredge channel outlet. Snow was present at all sites with depths ranging from 2.5 cm at several locations to 10.2 cm at site 17. All surface DO values in the backwater area were below saturation, but were more than sufficient to support aquatic life. Concentrations varied little, ranging from 11.34 to 12.34 mg/L. Mid-depth and bottom DO concentrations were similar to surface values, except for sites 4, 5, 14 and 21, where bottom concentrations were lower. The most prominent stratification occurred in the curved dredge channel in Mud Lake (sites 4 and 5). Here, in addition to low bottom DO concentrations (3.66 and 1.92 mg/L, respectively), velocity was also low (0.32 and 0.35 cm/s, respectively). Stratification was less prominent at sites 14 and 21 located in Zollicoffer Slough (bottom DO concentrations of 9.08 and 8.57 mg/L, respectively). A similar stratification pattern was seen with water temperature, where most values changed little throughout the depth profile and surface values ranged from 0.3 to 0.7°C. Again, sites 4, 5, 14 and 21 showed some stratification, with bottom temperatures ranging from 0.7 to 1.6°C. Another parameter which showed a narrow range of variance throughout the backwater area was pH: surface values ranged from 7.46 to 7.62. Sample blanks were collected at sites 1, 5, 13, 14, 16, 20 and 21 in order to determine background fluorescence. These values ranged from 0.731 to 0.953 µg/L.

All velocity readings in the main dredge channel exceeded 3.00 cm/s, ranging from 3.02 cm/s at site 18 to 6.17 cm/s near the inlet (site 1). Surprisingly, the highest velocity measured was 6.55 cm/s at site 16, in the angled channel that connects the main dredge channel with Zollicoffer Slough. Velocity measurements at sites 18 and 20 validated the findings of a 2008 IDNR/WDNR study which indicated Mississippi River main channel flow enters the backwater area from the dredge channel outlet. During the present study, it is surmised that flow from the outlet continued up the main dredge channel past site 18 until the vicinity of the dredge material island, where it either joined the flow coming from above and was routed through the angled dredge channel to Zollicoffer Slough, or was deflected toward Zollicoffer Slough just below the island, or perhaps some combination of the two scenarios. Upon entering Zollicoffer Slough, the flow split with the majority coursing downstream. Figure 7 displays the general direction and velocity of flow in the backwater complex on March 10, 2014. Lower velocities were measured in the dredge channel in Mud Lake (0.32 and 0.35 cm/s at sites 4 and 5, respectively), in a short dredge cut off of the main dredge channel (0.41 cm/s at site 7) and at sites 14 and 17 in Zollicoffer Slough (0.24 and 0.64 cm/s, respectively).

Following injection of dye at the inlet on the morning of March 11, 2014, tracking commenced. Sampling sites were added as needed in an effort to locate the leading edge of the dye before it arrived at the next established sampling point. Based on the background fluorescence concentrations and several initial fluorometer readings, it was determined a positive "hit" for dye would be a concentration ≥1.00 µg/L. Fluorescence concentration results for each site, including the date and time of measurement are included in Table 2. The dye had reached site 1 before there was an opportunity to collect a sample. At most sites, at least one measurement was taken before the dye was detected; thus, giving a good indication as to when the leading edge of the dye plume had arrived. At others, dye was detected on the first measurement; therefore, it was difficult to estimate how much time had lapsed since the leading edge of the dye plume had passed. No samples were collected between 2134 hours on March 11, 2014 and 0822 hours on March 12, 2014; thus, at sites 4 and 5 the dye had likely already passed before it could be detected. Dye was detected at site 5.5 at 0846 hours on March 12, 2014; however, this may have been the trailing edge of the dye plume. The dye transited the main dredge channel until it reached the dredge material island, where flow traveling up from the outlet essentially deflected the dye to the southwest. This was substantiated because the dye arrived at site 16 at 2003 hours but did not arrive at site 15.5, at the northeast tip of the dredge material island, until approximately 2107 hours. The delay in arrival of dye at site 15.5, coupled with the non-arrival of dye at site 18, indicates an upstream movement of flow in the main dredge channel below the island. It is surmised that site 15.5 is located in an eddy where the two flow paths meet; however, lacking additional data it is difficult to determine if the majority of the flow from the outlet was deflected along the upstream or downstream side of the island.

Once the dye passed site 16, it entered Zollicoffer Slough. Here, a majority of the dye flowed downstream, while a small portion traveled upstream. The approximate elapsed time the dye took to reach selected sampling sites is given in Figure 8. The leading edge of the dye reached the farthest downstream Zollicoffer Slough site (23.75) in 25.4 hours, while it took approximately 30.3 hours to arrive at site 14.6, which was located in Zollicoffer Slough, just upstream of the dredge material island.

A second dye injection took place midday on March 12, 2014 in order to verify the upstream direction of flow from the outlet. Dye was injected in the outlet at 1214 hours and after 0.5 hour had arrived at site 26 and following 2.2 hours was detected at site 28; thus, confirming the upstream direction flow.

Conclusions and Recommendation

A Rhodamine WT dye study was performed during March 2014 in Mud Lake, a backwater of the Mississippi River, Pool 11, near Dubuque, Iowa. The study was conducted in response to the underutilization by overwintering fish of newly created dredge channels, and velocity data that indicated Mississippi River main channel flow was entering the backwater area from the dredge channel outlet.

The results from the study indicate velocities in Mud Lake still exceed the level preferred by centrarchids in early winter. The results also confirmed the upstream travel of flow from the dredge channel outlet.

It is imperative that additional adaptive management measures be investigated in order to reduce velocities in Mud Lake so the area provides a viable overwintering site. It is recommended the initial RMA-2 model be revised to reflect as-built conditions and utilize data collected in the present study for model calibration. The updated model could be utilized to evaluate new adaptive management strategies for reducing/redirecting flow.

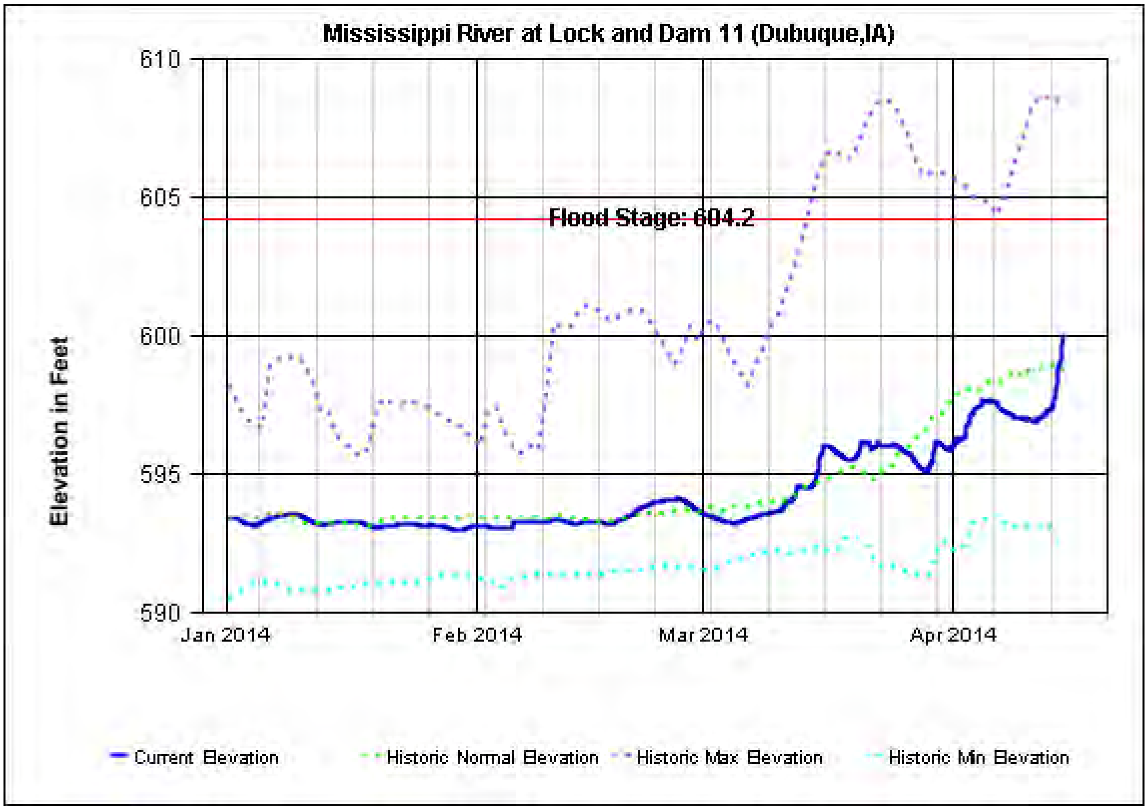
References

Bierl, D. P. 2002. *Dye Dispersion Under Ice at Spring Lake, a Backwater of the Mississippi River.* U.S. Army Corps of Engineers, Rock Island District.

Johnson, M. C. 1984. Fluorometric Techniques for Tracing Reservoir Inflows. U. S. Army Corps of Engineers, Environmental and Water Quality Operational Studies, Instruction Report E-84-1, 46 pp.
USACE. 2014.

U.S. Army Corps of Engineers. "Pool 11 Islands Habitat Rehabilitation and Enhancement Project." U.S. Army Corps of Engineers, Rock Island District. Web. May 21, 2014. http://www.mvr.usace.army.mil/Missions/EnvironmentalProtectionandRestoration/UpperMississippiRiverRestoration/HabitatRestoration/RockIslandDistrict/Pool11Islands.aspx

U.S. Army Corps of Engineers. 2001. Upper Mississippi River System Environmental Management Program, Definite Project Report with Integrated Environmental Assessment (R-13F), Pool 11 Islands Habitat Rehabilitation and Enhancement. U.S. Army Corps of Engineers, Rock Island District.


Mississippi River at Lock and Dam 11 (Dubuque,IA)
Elevation in Feet
610
605
600
595
590
Flood Stage: 604.2
Jan 2014
Feb 2014
Mar 2014
Apr 2014
Current Elevation
Historic Normal Elevation
Historic Max Elevation
Historic Min Elevation


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
Image USDA Farm Service Agency


3.5
3.75
5.5
6.5
13.5
Image USDA Farm Service Agency
14.5
14.6
14.7
14.75
15.5
28
27
26
22
23
23.5
23.75
24

Table 1. Field Data Collected on March 10, 2014 prior to Dye Dispersal

Site*	Time	Water Depth (m)	Ice Thickness (cm)	Snow Depth (cm)	D.O. (mg/L)	Water Temp. (°C)	Velocity (cm/s)	pH	Dye Blank (µg/L)
1S	1708	1.89	35.6	2.5	12.34	0.5	6.17	7.62	0.770
M					12.37	0.4			
B					12.38	0.3			
2	Too shallow.								
3S	1640	1.78	45.7	2.5	12.21	0.5	5.37		
M					12.24	0.4			
B					12.21	0.4			
4S	1653	1.88	53.3	7.6	11.97	0.7	0.32		
M					12.00	0.7			
B					3.66	1.4			
5S	1550	1.98	58.4	5.1	11.58	0.7	0.35	7.48	0.953
M					11.88	0.8			
B					1.92	1.6			
6S	1627	1.85	48.3	7.6	11.98	0.6	5.20		
M					12.03	0.4			
B					12.04	0.4			
7S	1608	1.74	61.0	5.1	11.70	0.6	0.41		
M					11.68	0.5			
B					11.62	0.7			
8	Too shallow.								

9	Too shallow.								
10	Too shallow.								
11S	1519	2.23	50.8	5.1	11.71	0.5	3.94		
M					11.64	0.4			
B					11.55	0.4			
12	1506	0.46	43.2	2.5	15.43	0.6			
13S	1449	2.19	50.8	5.1	11.42	0.6	3.56	7.50	0.848
M					11.45	0.5			
B					11.43	0.5			
14S	1238	1.49	55.9	5.1	11.34	0.5	0.24	7.49	0.731
M					11.25	0.4			
B					9.08	0.7			
15S	1225	2.20	43.2	7.6	11.55	0.5	4.03		
M					11.60	0.3			
B					11.50	0.2			
16S	1213	1.70	27.9	7.6	11.93	0.3	6.55	7.48	0.737
M					11.83	0.3			
B					11.72	0.2			
17S	1150	2.46	66.0	10.2	11.63	0.4	0.64		
M					11.55	0.4			
B					11.35	0.4			
18S	1127	1.68	55.9	5.1	11.68	0.5	3.02	7.52	
M					11.72	0.4			
B					11.77	0.3			

19	Too shallow.								
20S	1049	1.50	53.3	7.6	11.62	0.6	3.60	7.46	0.754
M					11.76	0.2			
B					11.77	0.2			
21S	1024	2.74	53.3	7.6	11.84	0.4	2.10	7.49	0.853
M					11.88	0.3			
B					8.57	1.0			

* "S" readings taken at 10 cm under the ice, "M" at 1/2 water depth, "B" at 10 cm off of bottom.

Table 2. Fluorescence (Dye) Concentrations on March 11 and 12, 2014

Site	Date	Time	Dye (µg/L)*
3	3/11/2014	9:33	0.557
3	3/11/2014	9:40	0.540
3	3/11/2014	9:45	0.732
3	3/11/2014	9:48	0.748
3	3/11/2014	9:50	0.763
3	3/11/2014	9:53	0.800
3	3/11/2014	9:57	0.775
3	3/11/2014	10:02	0.757
3	3/11/2014	10:07	1.09
3	3/11/2014	10:13	19.2
3.5	3/11/2014	13:30	0.504
3.5	3/11/2014	15:51	1.54
3.75	3/11/2014	17:13	0.833
3.75	3/11/2014	17:20	1.61
3.75	3/11/2014	21:34	0.688
4	3/11/2014	13:25	0.774
4	3/11/2014	15:56	0.681
4	3/11/2014	16:38	0.502
4	3/11/2014	16:57	0.678
4	3/11/2014	18:34	0.573
4	3/11/2014	18:46	0.539
4	3/11/2014	18:56	0.563

Site	Date	Time	Dye (µg/L)*
11	3/11/2014	14:03	0.836
11	3/11/2014	14:08	1.03
11	3/11/2014	14:13	2.18
13	3/11/2014	14:46	0.787
13	3/11/2014	14:52	0.726
13	3/11/2014	14:58	0.767
13	3/11/2014	15:04	0.865
13	3/11/2014	15:09	0.803
13	3/11/2014	15:14	0.970
13	3/11/2014	15:19	1.39
14.5	3/12/2014	10:31	0.584
14.5	3/12/2014	14:53	0.684
14.6	3/12/2014	10:37	0.782
14.6	3/12/2014	14:49	2.33
14.7	3/12/2014	10:12	3.60
14.75	3/12/2014	10:25	4.43
15	3/11/2014	19:08	3.08
15.5	3/11/2014	21:07	6.12
16	3/11/2014	19:20	0.503
16	3/11/2014	19:30	0.485
16	3/11/2014	19:41	0.479
16	3/11/2014	19:51	0.637

4	3/11/2014	21:33	0.671
5	3/12/2014	8:22	0.965
5	3/12/2014	8:32	0.781
5.5	3/12/2014	8:46	1.58
6	3/11/2014	10:47	0.629
6	3/11/2014	10:54	0.685
6	3/11/2014	10:59	0.717
6	3/11/2014	11:04	0.714
6	3/11/2014	11:09	0.757
6	3/11/2014	11:14	0.766
6	3/11/2014	11:19	0.708
6	3/11/2014	11:24	3.67
6.5	3/11/2014	12:24	1.04
6.5	3/11/2014	13:13	6.92
6.5	3/11/2014	15:31	15.5
7	3/11/2014	11:42	0.518
7	3/11/2014	11:49	0.455
7	3/11/2014	11:59	0.634
7	3/11/2014	12:09	0.678
7	3/11/2014	12:17	0.649
7	3/11/2014	13:11	0.469
7	3/11/2014	13:36	0.696

16	3/11/2014	20:03	1.12
17	3/11/2014	21:18	0.471
17	3/12/2014	9:04	3.61
18	3/11/2014	20:11	0.495
18	3/11/2014	20:24	0.462
18	3/11/2014	20:36	0.461
18	3/12/2014	10:08	0.626
21	3/12/2014	9:13	3.13
22	3/12/2014	9:21	14.3
23	3/12/2014	9:31	12.3
23.5	3/12/2014	9:47	3.44
23.75	3/12/2014	9:52	1.82
24	3/12/2014	9:38	0.885
Sites tracked as part of second dye			
injection.			
20	3/12/2014	13:23	0.760
20	3/12/2014	13:36	0.648
20	3/12/2014	13:46	77.5
26	3/12/2014	12:36	0.844

7	3/11/2014	14:17	0.635
7	3/11/2014	14:23	0.693
7	3/11/2014	14:28	0.728
7	3/11/2014	14:33	0.569
7	3/11/2014	14:38	0.594
7	3/11/2014	15:25	0.713
7	3/11/2014	15:33	0.643
7	3/11/2014	15:43	0.728
7	3/11/2014	16:44	5.37
11	3/11/2014	13:51	0.571
11	3/11/2014	13:58	0.841
26	3/12/2014	12:42	>100
27	3/12/2014	12:49	0.915
27	3/12/2014	12:51	0.974
27	3/12/2014	12:54	1.11
27	3/12/2014	12:58	0.977
27	3/12/2014	13:05	0.959
27	3/12/2014	13:16	18.1
28	3/12/2014	13:56	0.705
28	3/12/2014	14:03	0.697
28	3/12/2014	14:13	0.754
28	3/12/2014	14:27	>100

* Shaded concentrations indicate dye was detected.


velocity (cm/second)
0.24 - 0.35
0.41 - 0.64
2.10 - 3.02
3.56 - 4.03
5.20 - 5.37
6.17 - 6.55
N
RM 589
Mississippi
River
RM 588
300
Meters

RMA-2 Update

The hydraulics of the project was principally designed with the Two-Dimensional flow model, RMA-2. This model computes water surface elevations and velocity magnitude and direction in the horizontal plane. The velocities are depth-averaged. There were adjustments to the project alignment after the final model simulations were made (which are what is reflected in the DPR).

Because of the dye study, the model was brought out of mothballs, and adjustments made to the alignment and bathymetry to reflect as built conditions. Model runs were made for boundary conditions (inflow to the backwater area and water elevation) during the time of the dye study tests. The general flow patterns were reflected in model results, especially the dye movement from the downstream end of the project upstream. However, the velocities in the dredged channels from the model were far lower than measured in the prototype.

Ice conditions in the prototype were not reflected in the model, as much of the off channel areas were ~1-2 feet deep in the model, but totally iced over in the field. Therefore, the model was further adjusted to essentially block out all of the non-channel areas. The resultant model runs shows velocities and dye travel times matching the measurements rather well.

Figures and videos of model results can be provide if desired.

POST-CONSTRUCTION
10-YEAR PERFORMANCE EVALUATION REPORT

POOL 11 ISLANDS (MUD AND SUNFISH LAKES)
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

APPENDIX B

WATER QUALITY ANALYSIS

POST-CONSTRUCTION
10-YEAR PERFORMANCE EVALUATION REPORT

POOL 11 ISLANDS (MUD AND SUNFISH LAKES)
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

APPENDIX B
WATER QUALITY ANALYSIS

APPENDICES

POST-CONSTRUCTION
10-YEAR PERFORMANCE EVALUATION REPORT

POOL 11 ISLANDS (MUD AND SUNFISH LAKES) HABITAT REHABILITATION AND ENHANCEMENT PROJECT

APPENDIX B WATER QUALITY ANALYSIS

1. GOAL

Improve and enhance backwater aquatic habitat

2. OBJECTIVE

Improve water quality by reducing sedimentation and resuspension of sediment in backwaters and creating off-channel deep water areas with flow and depth diversity

3. ENHANCEMENT FEATURES

Water control structure, dredging, deflection levee

4. BACKGROUND

The water quality objectives of the Pool 11 Islands project are to decrease sediment input and resuspension of sediment, increase winter dissolved oxygen (DO) concentrations, and provide more off-channel deep water areas with flow and depth diversity within Sunfish Lake and Mud Lake (See project map on Plate B-1 of Appendix B1). Observed high turbidity values due in part to wind generated waves across the wide expanse above Lock and Dam 11 and unstable bottom sediments, in conjunction with concerns of low DO concentrations during the winter season, helped to drive the water quality baseline monitoring performed in lower Pool 11 from June 1991 to July 1997 in Sunfish Lake and from August 1997 to March 2005 in Mud Lake. Results of the baseline monitoring can be found in Appendix F Water Quality of the Definite Project Report (DPR) with Integrated Environmental Assessment for Pool 11 Islands Habitat Rehabilitation and Enhancement. This baseline data was used to calculate DO mass balances for Sunfish and Mud Lakes, which denotes required inflow to maintain sufficient DO concentrations to support aquatic biota, typically 5.0 mg/L.

Furthermore, water quality baseline data was used to identify potential problem areas and impacts to water quality due to proposed dredging activity. In an effort to meet project objectives while utilizing monitoring data, the preferred project alternative included the following features: construction of a deflection embankment with mechanical and hydraulic dredging at Sunfish Lake, and construction of a full deflection embankment with mechanical dredging at Mud Lake. A notched weir was placed in the deflection embankment near the Wisconsin shore to allow inflow of oxygenated water into Sunfish Lake.

In the same fashion, two notched weirs were built in the deflection embankment of Mud Lake, one near the upper end and another at the midpoint. The Sunfish Lake section of the Pool 11 Islands project was completed in June of 2004, and the Mud Lake portion of the project was completed in July of 2005.

This water quality performance evaluation report discusses post project construction water quality monitoring data collected by USACE Water Quality and Sedimentation Section (EC-HQ) personnel from December 2004 through March 2010 for Sunfish Lake and from December 2005 to March 2010 for Mud Lake. Due to the cyclical nature of Rock Island District's EMP water quality monitoring program, sampling was not continuous for each site during the whole observation period.

During the study period noted above for Sunfish Lake, EC-HQ personnel performed water quality monitoring at three sites: 583.4P, 583.5R, and 584.2X. Sunfish Lake monitoring site locations are shown on Plate B-2 of Appendix B1. Data gathered by EC-HQ staff included a combination of both periodic grab samples and in-situ continuous monitors (YSI model 6000, 6600, or 6600-V2 series and Hach DS5X series sondes). Grab samples were gathered near the surface. The sites were usually visited biweekly during the summer season of June through September and 3 or 4 times total per winter season of December through March. The following variables were typically measured: water depth, velocity, wave height, air and water temperature, cloud cover, wind speed and direction, DO, pH, total alkalinity, specific conductance, Secchi disk depth, turbidity, total suspended solids (TSS), chlorophyll (a, b and c) and pheophytin a.

Likewise, EC-HQ personnel performed water quality monitoring at four sites in Mud Lake: 588.0B, 588.1D, 589.0C, and 589.3D. Mud Lake monitoring site locations are illustrated in Plate B-3 of Appendix B1. Sampling type, frequency, and water quality parameters were performed in the same fashion as Sunfish Lake, though sampling for Mud Lake was initiated one year after Sunfish Lake.

5. MONITORING RESULTS

The results from water quality monitoring performed after project completion at all sites in both locations are found in Appendix B1. For pre-project baseline monitoring, refer to Appendix F Water Quality of the Definite Project Report (DPR) with Integrated Environmental Assessment for Pool 11 Islands Habitat Rehabilitation and Enhancement. The following tables provide a summary of grab sample results for each lake during both pre- and post-construction.

SUNFISH LAKE

	Summer Samples		
	Pre-Construction	**Post-Construction**	**Change**
Total Times Sampled:	56	120	
Samples DO Below 5.0 mg/L :	0	8	
Ave DO (mg/L):			
583.4P	-	9.91	-
583.5R	9.18	8.69	-5%
584.2X	-	8.48	-
Ave Velocity (cm/s):			
583.4P	-	1.87	-
583.5R	11.43	2.67	-77%
584.2X	-	3.07	-
Ave TSS (mg/L):			
583.4P	-	22.75	-
583.5R	60.13	18.73	-69%
584.2X	-	20.45	-
Ave Temperature (°C):			
583.4P	-	24.9	-
583.5R	20.93	24.74	+15%
584.2X	-	24.52	-

	Winter Samples		
	Pre-Construction	**Post-Construction**	**Change**
Total Times Sampled:	7	49	
Samples DO Below 5.0 mg/L :	0	0	
Ave DO (mg/L):			
583.4P	-	16.12	-
583.5R	14.12	15.97	+12%
584.2X	-	15.24	-
Ave Velocity (cm/s):			
583.4P	-	1.65	-
583.5R	8.89	1.45	-84%
584.2X	-	2.81	-
Ave TSS (mg/L):			
583.4P	-	22.75	-
583.5R	16.50	8.20	-50%
584.2X	-	10.13	-
Ave Temperature (°C):			
583.4P	-	0.54	-
583.5R	2.03	0.77	-62%
584.2X	-	0.69	-

MUD LAKE

	Summer Samples		
	Pre-Construction	**Post-Construction**	**Change**
Total Times Sampled:	116	128	
Samples DO Below 5.0 mg/L :	18	14	
Ave DO (mg/L):			
588.0B	8.13	8.34	+3%
588.1D	-	9.05	-
589.0C	7.86	7.74	-2%
589.3D	-	8.59	-
Ave Velocity (cm/s):			
588.0B	6.78	2.39	-64%
588.1D	-	2.55	-
589.0C	0.23	1.29	+83%
589.3D	-	5.33	-
Ave TSS (mg/L):			
588.0B	19.03	13.38	-30%
588.1D	-	21.50	-
589.0C	38.07	22.66	-40%
589.3D	-	34.63	-
Ave Temperature (°C):			
588.0B	25.29	25.09	-1%
588.1D	-	25.12	-
589.0C	23.97	24.71	+3%
589.3D	-	24.81	-

	Winter Samples		
	Pre-Construction	**Post-Construction**	**Change**
Total Times Sampled:	25	57	
Samples DO Below 5.0 mg/L :	0	0	
Ave DO (mg/L):		Pre / Post Rock	
588.0B	16.40	17.73, 14.00	-15%
588.1D	-	16.72 / 15.10	-
589.0C	-	16.71 / 14.61	-
589.3D	-	17.35 / 14.93	-
Ave Velocity (cm/s):			
588.0B	2.57	2.15 / 1.44	-44%
588.1D	-	6.19 / 2.26	-
589.0C	-	1.15 / 0.60	-
589.3D	-	17.75 / 5.19	-
Ave TSS (mg/L):			
588.0B	11.33	3.00 / 7.40	-35%
588.1D	-	2.67 / 9.50	-
589.0C	-	3.33 / 6.20	-
589.3D	-	2.33 / 9.00	-

Sunfish Lake water quality data was gathered from December 2004 through March 2010 at sites 583.4P, 583.5R, and 584.2X. Summer samples were typically collected biweekly from June through September and 3 or 4 times per winter season from December through March.

Mud Lake water quality data was gathered from December 2005 through March 2010 at 588.0B, 588.1D, 589.0C, and 589.3D. Summer samples were typically collected June through September, and winter samples were typically collected December through March. For winter post construction velocity measurements listed in the table above, values are broken out by pre and post addition of rock, which occurred early in the summer of 2006 to both openings of Mud Lake to reduce the opening's width and depth, thereby decreasing flows through the area and allowing for more favorable overwintering conditions for centrarchids. There are no summer current velocity readings for the post project construction time frame that were before the rock addition at the Mud Lake opening, thus all summer measurements were post project modification.

It should be noted that pre-construction winter water sampling was limited in both Sunfish Lake and Mud Lake, with only 7 grab samples in Sunfish Lake and 25 in Mud Lake. The lack of available data could lead to less certain conclusions on baseline conditions. Another condition that could lead to performance assessment uncertainty was the overall decrease in average daily Mississippi River discharge between pre-construction and post construction. Prior to project construction, the average daily discharge of the Mississippi River at Lock and Dam 11 was 52,996 cfs, which dropped to 47,273 cfs during the time frame after project construction (See Graphs B-5 and B-6 in Appendix B1). Although a flow decrease through the whole pool must be taken into consideration for all water quality comparisons between pre- and post-construction, conclusions and trends can still be analyzed in regards to measuring performance against project objectives.

As identified in Table 10-3 of the Pool 11 Islands DPR, water quality related post construction evaluation criteria includes winter water temperature, current velocity, and dissolved oxygen. The standard value to measure project success for winter water temperature post construction was set at a minimum of 1°C for all out-years 1 to 50. Current velocity had a standard of 0 cm/sec for all out-years. The minimum dissolved oxygen standard, particularly during winter months, was set at 5.0 mg/L for all out-years. Another important water quality parameter not identified in Table 10-3 of the DPR evaluation plan that needs to be discussed as an overall project objective is the reduction in sediment input and sediment resuspension in backwaters. Although there is no identified numerical standard to measure against, the project objective to reduce sedimentation in backwaters can be evaluated by comparing pre and post project construction TSS concentrations.

6. DISSOLVED OXYGEN

Results from DO grab sample measurements taken at Sunfish Lake show no measurements below 5.0 mg/L through the critical winter months for aquatic biota during both pre and post construction, but post construction during the summer there were 4 occurrences each where DO was low at sites 583.5R and 584.2X (1 week in September 2006 and 3 weeks from late August into early September 2007). The pre-construction average summer DO concentration for site 583.5R at Sunfish Lake is 9.18 mg/L and the winter average increases to 14.12 mg/L. Since only site 583.5R was sampled prior to project completion, DO values for that site are considered to represent Sunfish Lake. Post construction average summer DO concentrations ranged from 8.48 mg/L to 9.91 mg/L at the 3 sampling sites, while post construction winter averages ranged from 9.91 to 15.97 mg/L. Due to the lack of available pre-construction sampling data at the other 2 sites, only site 583.5R can be used for a direct comparison of pre- and post-construction DO concentrations. A comparison of average DO values at this site indicate a 5% or 0.49 mg/L decrease during the summer, while the winter DO values increased by 12% or 1.85 mg/L after project construction.

Winter grab sample monitoring of DO concentrations at Mud Lake show no occurrence of values below 5.0 mg/L during pre and post construction. Yet low DO values were observed during the summer season at sites 588.0B (4 grab samples) and 589.0C (14 grab samples) during pre-construction. Pre-construction summer average DO concentrations were 8.13 mg/L and 7.86 mg/L at sites 588.0B and 589.0C, respectively. Even though continuous monitoring and some grab samples indicated occasional low DO values, typically low concentrations were observed during the night when photosynthesis was not occurring and concentrations most often recovered to above 5.0 mg/L the following day (See Graph B-1in Appendix B1 for a typical low DO event). Prior to project completion, winter sampling was performed at site 588.0B only, with the 16.40 mg/L reading for this site representing the average Mud Lake pre-construction DO concentration. Following project construction, a combined 14 low DO concentrations were observed across all 4 sampling sites in Mud Lake, with all occurrences during the summer. Overall, grab samples collected during the summer after construction showed a slight increase in average DO for Mud Lake with values ranging from 7.74 mg/L to 9.05 mg/L. However, sites 588.0B and 589.0C still had 6 low DO readings each, with at least one per year during the 4 years of summer sampling. When reviewing the post construction continuous monitoring data collected at sites 588.0B and 589.0C, summer DO concentrations could be an issue. For example, results from in-situ continuous monitors deployed at site 588.0B on July 31st, August 14th and August 28th and from September 3rd to 16th in 2008 measured DO concentrations below 5.0 mg/L for extended periods of time. See Graph B-2 in Appendix B1 for an example of a worst case summer monitoring session with low DO concentrations at site 588.0B, where values never reached 5.0 mg/L during the entire monitoring session of August 14th to 28th of 2007. Both sites 588.0B and 589.0C are removed from the main flow path of the project area.

Winter sampling post construction at Mud Lake requires consideration of modifications to the lake's upstream and lateral openings in the early summer of 2006. This project modification of decreasing the openings' depth and width resulted in changes to the flow and dissolved oxygen through all of Mud Lake. Prior to the project modification, average winter DO concentrations ranged from 16.71

mg/L to 17.73 mg/L, but after the rock addition average DO values dropped to between 14.00 mg/L and 15.10 mg/L. This resulted in an average DO decrease of 15% at site 588.0B.

In summary, Sunfish Lake DO values showed an increase during the critical winter season post construction with values averaging 15.78 mg/L, yet average summer DO concentrations decreased by an average of 5%. This decrease is likely a result of reduced flow, increased average water temperatures, and reduced wave action induced aeration in Sunfish Lake during the summer season. Average DO values at Mud Lake showed a small increase during the summer after project construction, while the average winter DO concentration post construction decreased by 15% at site 588.0B. Average winter DO values decreased post construction at Mud Lake. Yet, there was little potential for negative impacts to aquatic biota, as average values over the entire post construction winter monitoring period still remained at approximately 15.32 mg/L, more than triple the standard value of 5.0 mg/L required to sustain healthy aquatic habitat. However, low summer DO concentrations can occasionally be an issue at Mud Lake, particularly at sampling locations 588.0B and 589.0C, which are removed from the main dredge channel flow path.

7. CURRENT VELOCITY

Review of the Pool 11 Islands Post-Construction Project Evaluation Plan from the DPR shows a goal of reducing current velocities from over 3 cm/sec without project to 0 cm/sec post construction. Yet when considering project objectives of creating quality year round habitat for centrarchids and other associated fish species, which require a DO concentration of 5.0 mg/L to be maintained during worst case winter conditions, the estimated inflow required is 0.67 m^3/sec at Sunfish Lake and 1.09 m^3/sec at Mud Lake. This indicates that at least some flow is desired into the backwater areas to maintain desirable DO concentrations. Additionally, an evaluation of winter habitat used by centrarchids performed by M.J. Steuck of the Iowa Department of Natural Resources showed that these fish preferred current velocities between 0.0 to 1.2 cm/sec. Another equally important desired project feature is the creation of flow diversity in the backwater area, so flows were examined at each of the sampling sites separately.

Sunfish Lake pre-construction average current velocities during winter sampling seasons were only measured at site 583.5R. The average for the small number of winter samples measured at this site was 8.89 cm/s. Using that winter baseline, the average current velocity during the winter decreased from 8.89 cm/sec to 1.65 cm/sec at site 583.4P, 1.45 cm/sec at site 583.5R, and 2.81 for site 584.2X after the project was completed. These values are close to the IA DNR upper range of 1.2 cm/sec for centrarchid habitat preferences. Though current velocities are not as critical to centrarchids during the summer as during winter, post construction monitoring in Sunfish Lake showed a decrease in average values as well. Summer pre construction current velocities were measured at site 583.5R only, with an average of 11.43 cm/sec, which is considered the summer baseline flow for all Sunfish

Lake sites pre construction. Following project construction, average current velocities decreased from 11.43 cm/sec to 1.87cm/sec at site 583.4P, 2.17 cm/sec at site 583.5R, and 3.07 cm/sec at site 584.2X. Graphs B-3 and B-4 of Appendix B1 illustrate the decrease in current velocity going from pre- to post construction.

As discussed earlier, when examining current velocities for Mud Lake, a comparison of velocity values must be made not only between pre and post construction, but also to the 2 periods of pre and post addition of rock in early summer of 2006 to the upstream and lateral openings of Mud Lake. This project modification was done in response to findings of high flows through Mud Lake and low fish use after project construction during winter months. Summer current velocity data is limited during the time frame after the project was construction but before modifications were completed, so the only summer current velocity comparison that can be made is between post modification/construction data and pre-project construction current velocity values.

During the summer sampling season, current velocity averages in Mud Lake were 6.78 cm/sec at site 588.0B and 0.22 cm/sec at 589.0C before project construction. Post construction and opening modification, summer current velocities changed to 2.39 cm/sec at site 588.0B, 2.55 cm/sec at 588.1D, 1.28 cm/sec at 589.0C, and 5.33 cm/sec at site 589.3D. When comparing these pre- and post-construction summer velocity values, a 65% decrease or 4.39 cm/sec was observed at site 588.0B and an 83% or 1.06 cm/sec flow increase at site 589.0C.

Before project completion, winter current velocity values were sampled at site 588.0B, with results showing an average flow of 3.33 cm/sec. This value is considered the baseline for Mud Lake winter pre construction average current velocity. Once the project was completed in July of 2005, velocity values in Mud Lake averaged 2.15 cm/sec at site 588.0B, 6.19 cm/sec at 588.1D, 1.20 cm/sec at 589.0C, and 17.75 at site 589.3D. With monitoring data illustrating that project objectives were not being met, the Mud Lake upstream and lateral openings were modified by decreasing the opening depth and width in the early summer of 2006. Once the modification was complete, average current velocities decreased at all sites during the winter sampling season, with decreases ranging from 64% or 3.93 cm/sec at site 588.1D to 35% or 0.75 cm/sec at site 588.0B.

8. WINTER WATER TEMPERATURE

Based on a project objective of providing quality year round habitat for aquatic biota, winter water temperature is a critical water quality parameter. During the winter, centrarchids prefer backwater habitats where the water temperature can be 2-5°F warmer than main or side channel areas. So, a desired outcome of the project is an increase in winter water temperature from the without project average temperature of 0.5°C to a temperature of 1.0°C with project for all out-years.

The results of winter water temperature measurements taken at Sunfish Lake pre-construction at site 583.5R shows an average of 2.03°C. After project construction, the average water temperature at this site decreased to 0.77°C, a drop of 62%, which is below the project goal of a minimum of 1.0°C. At all sites in Sunfish Lake after project construction, the average winter water temperature was below 1.0°C , with values ranging from 0.54°C to 0.77°C.

In Mud Lake, the average winter water temperature also decreased post project. Water temperatures at site 588.0B dropped from 1.88°C to 0.6°C. This drastic decrease in winter water temperature was measured prior to the lake's modification of 2006 to the openings. After the modification, the average water temperature during winter increased to 1.7 °C at site 588.0C, above the goal of 1.0°C. Additionally, average temperatures at other sites in Mud Lake also were above 1.0°C, ranging from 1.2°C to 1.6°C. Thus, the decrease in winter flows through Mud Lake had a positive benefit on average winter water temperatures. Despite the positive impact of the project modifications to winter water temperatures post construction, all average winter values decreased when compared to the pre-project average temperature of 1.88°C of site 588.0B.

A design feature added to the construction of the main dredge channel in Mud Lake is the fluctuation of elevation, or high spots. The high spots were intended to provide varied depth and water temperatures, which are of particular interest during the winter season. These features did not appear to achieve their goal, with results indicating that a site's location relative to the main dredge channel flow has more impact to the flow and winter water temperature than the site's position between high spots. See Appendix B2 for a more detailed analysis of the high spots project feature.

9. TOTAL SUSPENDED SOLIDS

Loss of quality backwater habitat, due primarily to sediment input and resuspension of unstable bottom sediment led to the Pool 11 Islands project goal of reducing adverse impacts of sedimentation by construction of diversion embankments at both Sunfish and Mud Lake. Loss of water depth and increased bed uniformity is particularly detrimental to aquatic biota such as centrarchids during the winter, when it is critical for these species to find areas that do not freeze to the bottom, have suitable DO levels, slightly warmer waters, and provide protection from the current.

For the whole Pool 11 Islands project area, average total suspended solids (TSS) decreased during both the summer and winter following project implementation. Sunfish Lake saw the most dramatic decrease in TSS, with average values going from 60.1 mg/L to 18.73 mg/L at site 583.5R during the summer, a 69% decrease, and from 16.5 mg/L to 8.2 mg/L during the winter, a decrease of 52%. Average TSS values for sites583.4P and 584.2X in Sunfish Lake were 22.75 and 20.45 mg/L during the summer post construction and 22.75 and 10.13 mg/l during the winter post construction, respectively.

Mud Lake realized a similar trend, though not as pronounced as at Sunfish Lake. Summer sampling of Mud Lake prior to project construction revealed average TSS values of 19.03 mg/L at site 588.0B and 38.07 mg/L at site 589.0C. Once Mud Lake was completed, TSS values dropped to 13.38 mg/L at 588.0B, a decrease of 30%, and at site 589.0C values decreased by 40% down to 22.66 mg/L. Average post construction summer TSS values at the other 2 sites in Mud Lake were 21.50 mg/L at site 588.1D and 34.63 mg/L at site 589.3D. Winter sampling events allow for analysis of the effect of the modifications to the opening structures on the average TSS in Mud Lake. Site 588.0B, the only site with winter monitoring data prior to project construction, showed an average TSS value of 11.33 mg/L. Once the project was built, TSS at this site dropped dramatically to 3.00 mg/L. However, once the modifications were made to the openings at Mud Lake, the average TSS went from 3.00 mg/L to 7.40 mg/L. The trend of increasing TSS values post project modification versus pre-modification was seen at all 4 monitoring sites in Mud Lake during the winter. Overall, Mud Lake winter TSS values, post project construction and modification, increased from an average of 2.83 mg/L to 8.02 mg/L. While all post project TSS values show improvement when compared to pre-project values, the project modification to the closing structures had a negative effect on the project's ability to decrease average TSS values.

10. DEPTH

In addition to TSS, depth measurements are also taken at the water quality monitoring sites and may provide some information to assess post-construction sedimentation impacts. These data were compiled, converted to elevation, and plotted to show bed elevation trends in the dredged channels. These should be considered a complement to (and not a substitute for) survey data. These data are presented in Appendix B3. It shows that the three sites in Sunfish Lake have accreted at about the same rate (1.5"/year). The four sites at Mud Lake show that the sites nearer the notch have accreted at a faster rate (2-4"/yr) while the sites farther removed from the notch have accreted less (1-1.5"/yr).

11. DISCUSSION AND CONCLUSIONS

The water quality objectives of the Pool 11 Islands project are to decrease sediment input and resuspension of sediment, increase winter dissolved oxygen (DO) concentrations, and provide more off-channel deep water areas with flow and depth diversity within Sunfish Lake and Mud Lake. The project was designed to maintain a minimum average winter water temperature of 1°C, a current velocity of 0 cm/sec (though literature suggests a rate between 0.0 to 1.2 cm/sec), and dissolved oxygen of at least 5.0 mg/L. Another important water quality objective is the reduction in sediment input and sediment resuspension in backwaters. Although there is no identified numerical standard to measure results against, the project objective was met if total suspended solids decreased post project construction. Results from water quality data gathered during this initial 5 year post construction period indicate that the Pool 11 Islands project has a positive impact on water quality overall.

Sunfish Lake DO values showed an increase during the critical winter season post construction, yet summer DO concentrations decreased on average by 5%. This decrease is likely a result of reduced flow, increased average water temperatures, and reduced wave action induced aeration in Sunfish Lake during the summer season. Winter DO value decreases in Mud Lake after the project was completed in 2005 and modified in 2006 are unlikely to have negative impacts to aquatic biota since average values still remain at approximately 14.66 mg/L, almost triple the standard value of 5.0 mg/L required to sustain healthy aquatic habitat. Low summer DO concentrations at Mud Lake continue to be an issue, particularly at sampling locations 588.0B and 589.0C. Impacts to aquatic biota are limited due to the season in which the low DO events occurred. During the summer, fish in low DO areas will move to water with a higher DO concentration, such as the main or side channel, thus fish kills due to low DO concentrations were not observed.

Current velocity is a critical factor for centrarchid overwintering habitat and flow diversity in this backwater area is an overall project objective. Post construction winter values at both Sunfish and Mud Lake indicate the desired results of decreased and varied flows through both backwater areas. The addition of rock at the upstream and lateral openings at Mud Lake in the summer of 2006 achieved a decrease in winter flows by as much as 66% versus the wider and deeper openings of the original project design. Though not as vital as winter flows to centrarchids, summer values for current velocity also decreased through both locations and provided centrarchids habitat with varied current velocities.

Winter water temperature is a critical water quality parameter for meeting the objective of providing quality over wintering centrarchid habitat. The results of winter water temperature measurements taken at Sunfish Lake pre-construction at site 583.5R shows an average of 2.03°C. After project construction, the average water temperature at this site decreased to 0.77°C, a drop of 62%, which is below the project goal of a minimum of 1.0°C. At all sites in Sunfish Lake after project construction, the average winter water temperature was below 1.0°C , with values ranging from 0.54°C to 0.77°C. In Mud Lake, the average winter water temperature also decreased post project. This decrease in winter water temperature was measured prior to the lake's modification in 2006 to the openings. After the modification, the average water temperature during winter increased to 1.7 °C at site 588.0C, above the goal of 1.0°C. Additionally, average temperatures at other sites in Mud Lake also were above 1.0°C, ranging from 1.2°C to 1.6°C. Thus, the decrease in winter flows through Mud Lake had a positive benefit on average winter water temperatures. Despite the positive impact of the project modifications to winter water temperatures post construction, all average winter values decreased when compared to the pre-project average temperature of 1.88°C at site 588.0B.

Based on the recommended plan outlined in Chapter 6 of the Pool 11 Islands Habitat Rehabilitation and Enhancement Definite Project Report (DPR), several high spots were intentionally left in the main dredged channels of Mud Lake to retain warmer bottom water during the wintering period. These project features did not appear to achieve their goal, with results indicating that a site's location relative to the main dredge channel flow had more of an impact to a site's winter water temperature than the site's position between high spots.

Observed high TSS values, due in part to wind generated waves across the wide expanse above Lock and Dam 11 and unstable bottom sediments, led to the project objectives of decreasing sediment input and resuspension of sediment. Based on water monitoring data, TSS decreased at both Sunfish and Mud Lake during both the winter and summer sampling seasons. Sunfish Lake saw the most dramatic drop in TSS values after project construction, but Sunfish Lake's pre construction TSS levels were nearly twice that of Mud Lake. After the marked decrease at Sunfish Lake and the less pronounced reduction at Mud Lake, TSS levels at the 2 lakes became comparable. The modifications to the openings at Mud Lake led to an increase in average winter TSS values of 65%, going from 2.83 mg/L to 8.02 mg/L. While all Mud Lake post project TSS values showed an improvement when compared to pre-project values, the project modification to the closing structures had a negative effect on the project's ability to decrease average TSS values.

Overall, results from the current evaluation period indicate that the Pool 11 Islands project was able to introduce oxygenated water into, and exclude sediment laden water from backwater areas, thus providing year round quality backwater aquatic habitat for native fisheries.

12. REFERENCES

Steuck, M. J. 2010. *An evaluation of winter habitats used by bluegill, black crappie and white crappie in Pools 11-14 of the Upper Mississippi River*. Iowa Department of Natural Resources, Federal Aid in Sport Fish Restoration, Project F-160-R, Study 7021 Completion Report, Des Moines, Iowa.

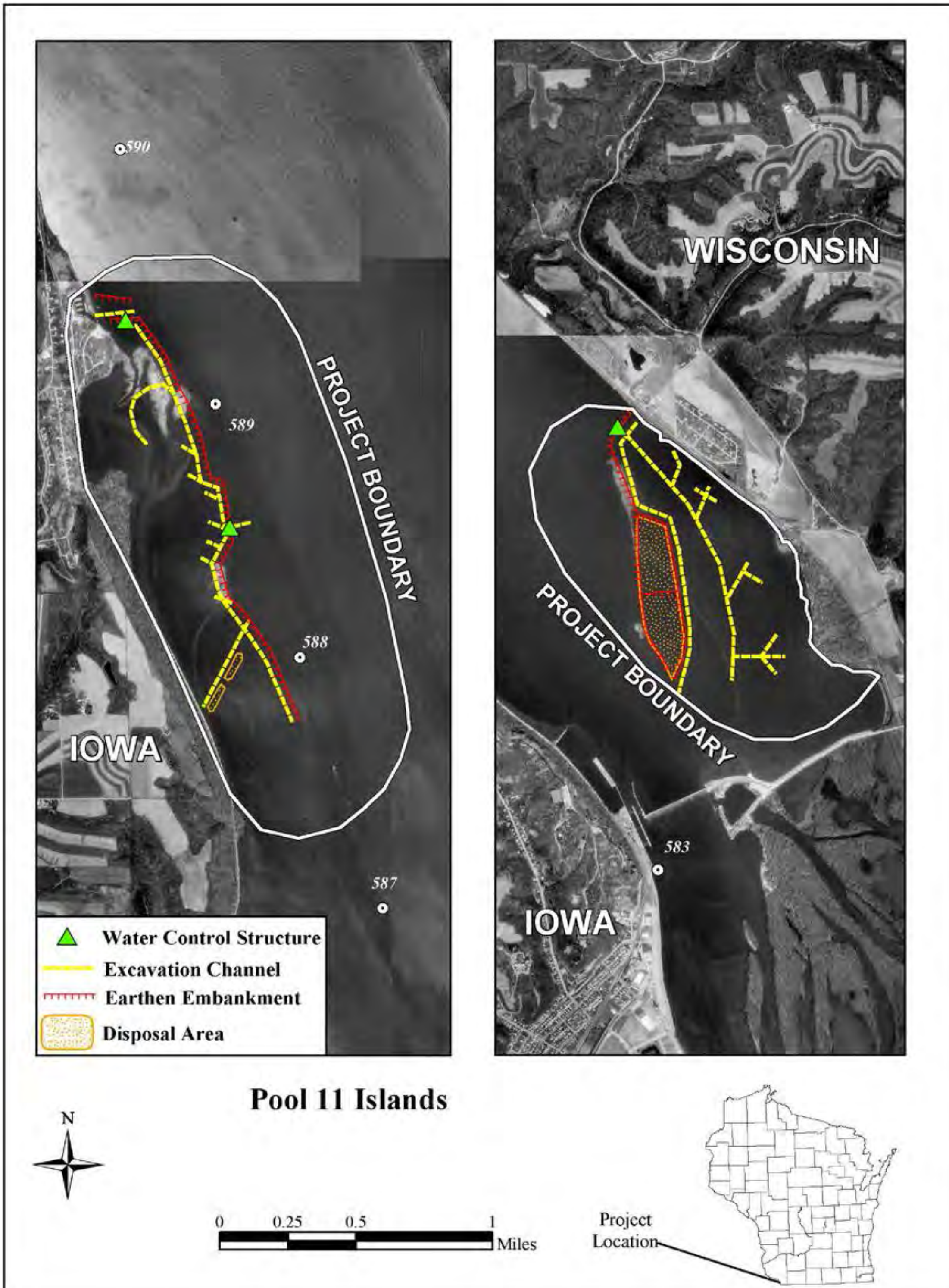
US Army Corps of Engineers, Rock Island District. September 2001. *Upper Mississippi River System Environmental Management Program Definite Project Report with Integrated Environmental Assessment (R-13F) Pool 11 Islands Habitat Rehabilitation And Enhancement Project, Pool 11, Mississippi River Miles 583.3 – 593.0, Dubuque County, Iowa and Grant County, Wisconsin.*

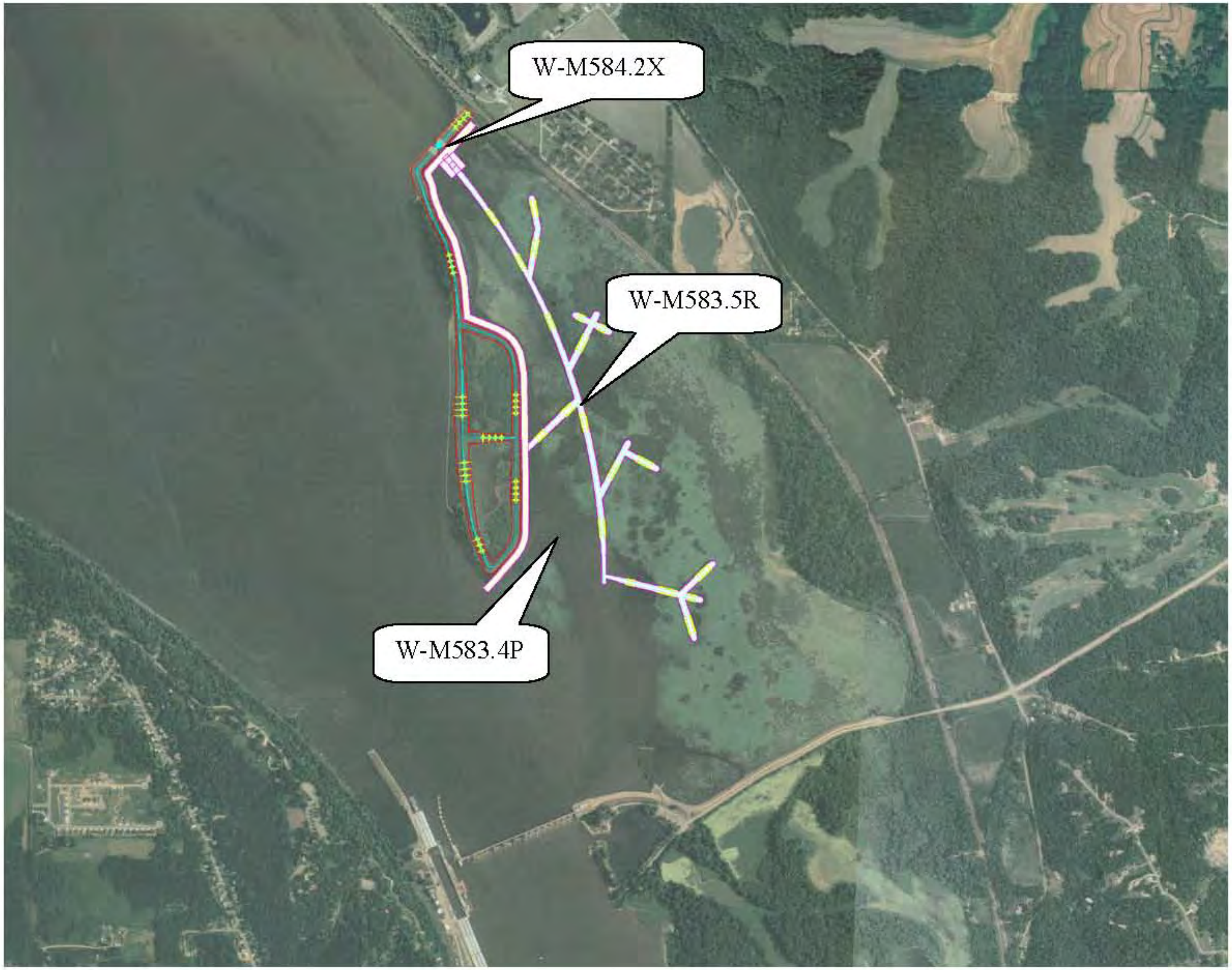
US Army Corps of Engineers, Rock Island District. *Rivergages.com*. March 2012. Web. http://www2.mvr.usace.army.mil/WaterControl/new/layout.cfm

POST-CONSTRUCTION
10-YEAR PERFORMANCE EVALUATION REPORT

POOL 11 ISLANDS (MUD AND SUNFISH LAKES)
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

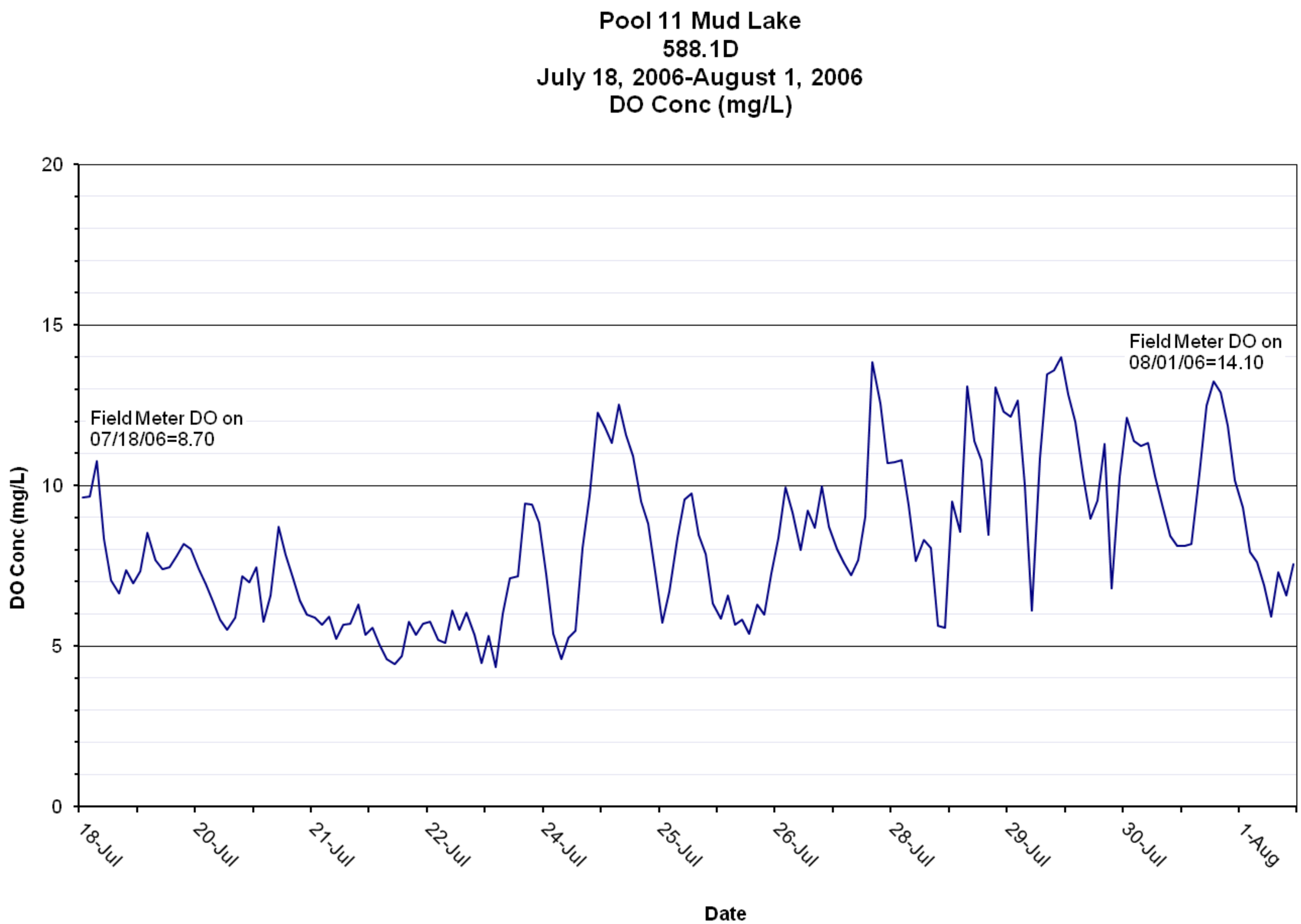
APPENDIX B-1
WATER QUALITY PLATES, GRAPHS, AND TABLES


590
589
588
587
583
PROJECT BOUNDARY
PROJECT BOUNDARY
WISCONSIN
IOWA
IOWA
Water Control Structure
Excavation Channel
Earthen Embankment
Disposal Area
Pool 11 Islands
N
0
0.25
0.5
1
Miles
Project Location

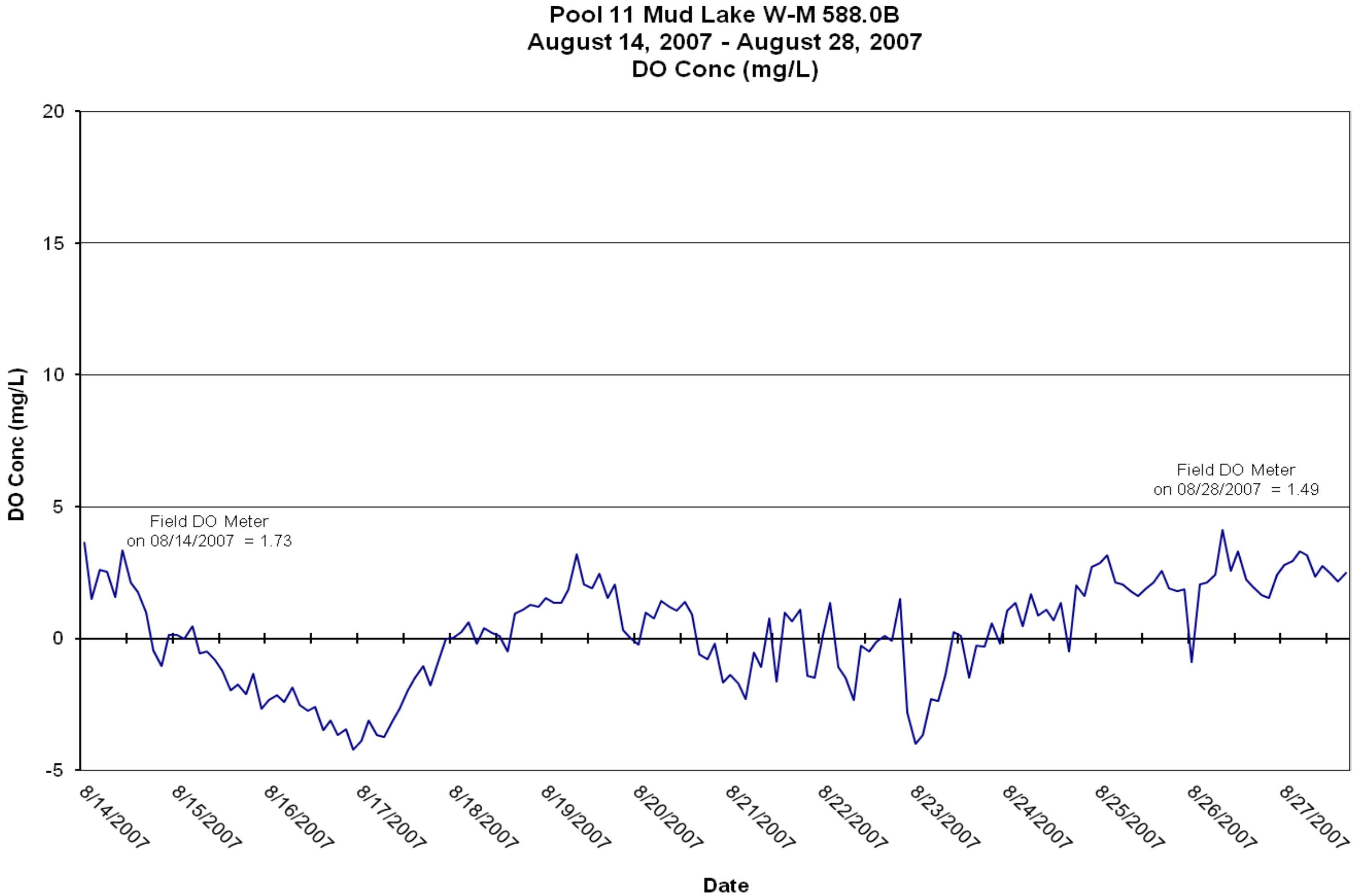


Sunfish Lake Water Quality
Sampling Locations

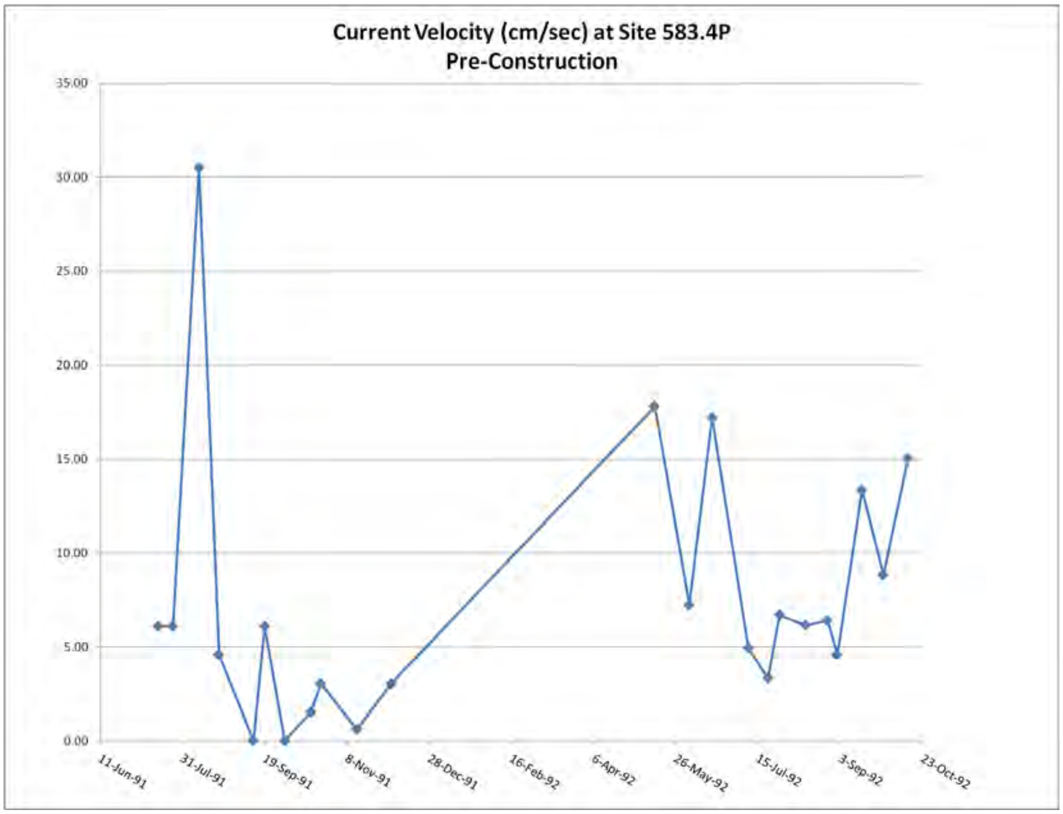
Mud Lake Water Quality
Sampling Locations



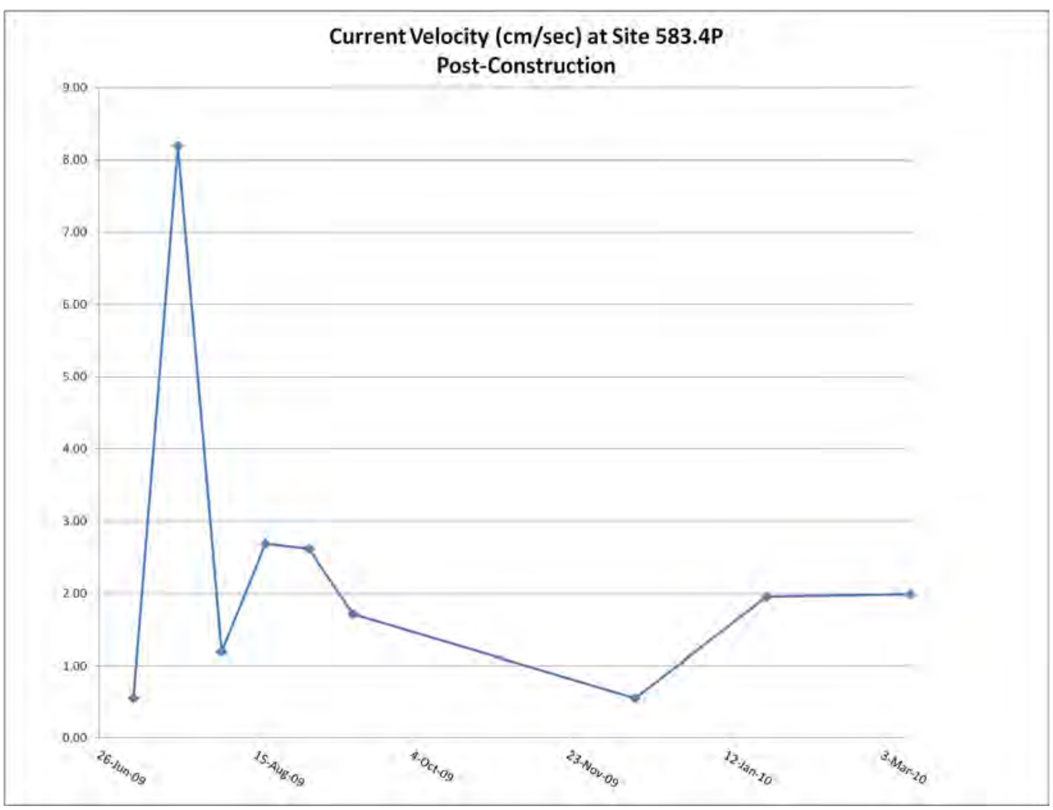
Graph B-1 illustrates a typical summer continuous data monitoring session for dissolved oxygen at Mud Lake. Field DO concentration grab samples were gathered upon deployment and retrieval of the continuous monitoring sondes.



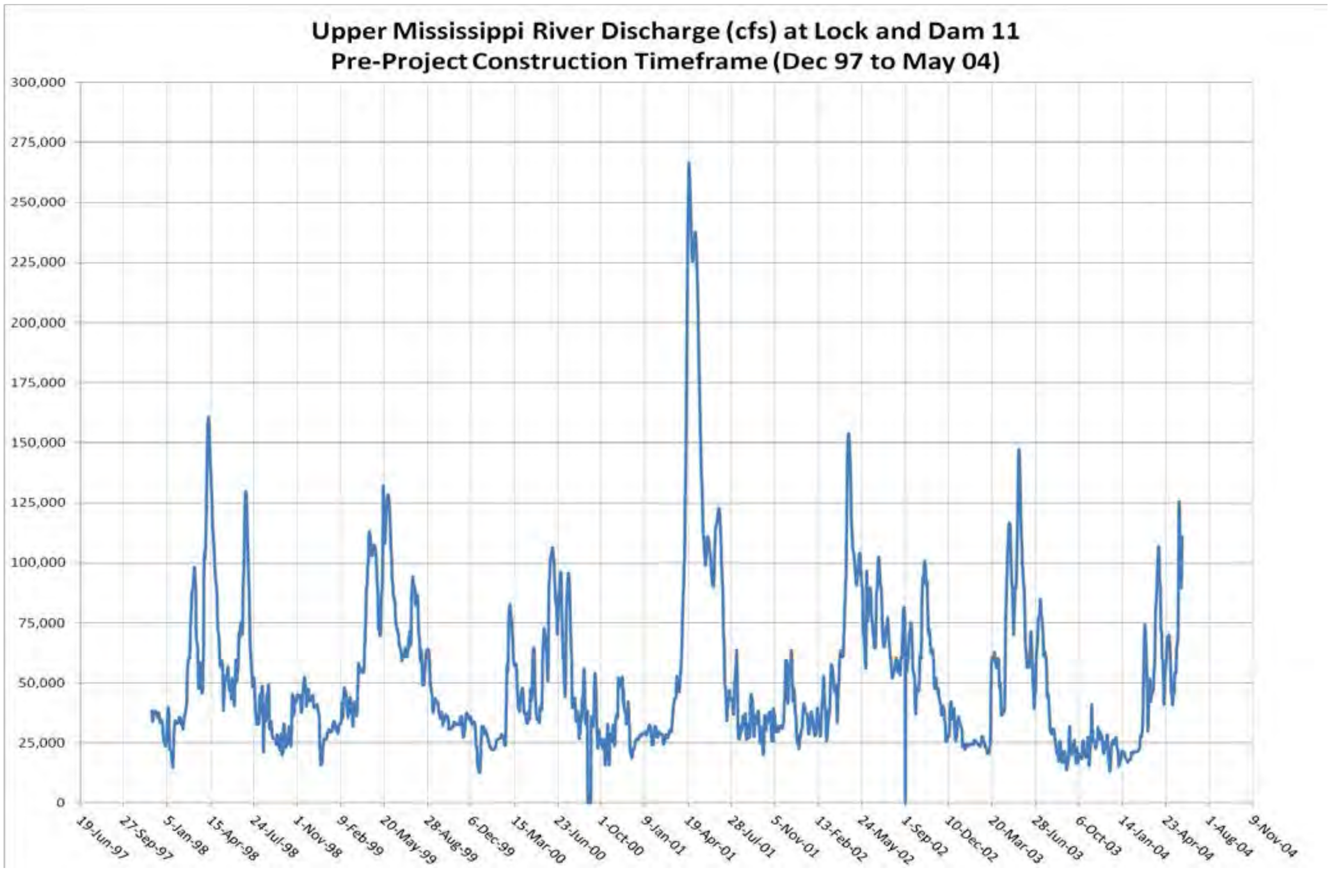
Graph B-2 demonstrates a worst case scenario for low dissolved oxygen concentrations in Mud Lake. Field DO concentration grab samples were gathered upon deployment and retrieval of the continuous monitoring sondes. Values below 0 mg/L are not valid and should not to be taken into consideration, but grab samples collected on August 14th and 28th provide credibility to the observed trend of continued low DO during the monitoring period.



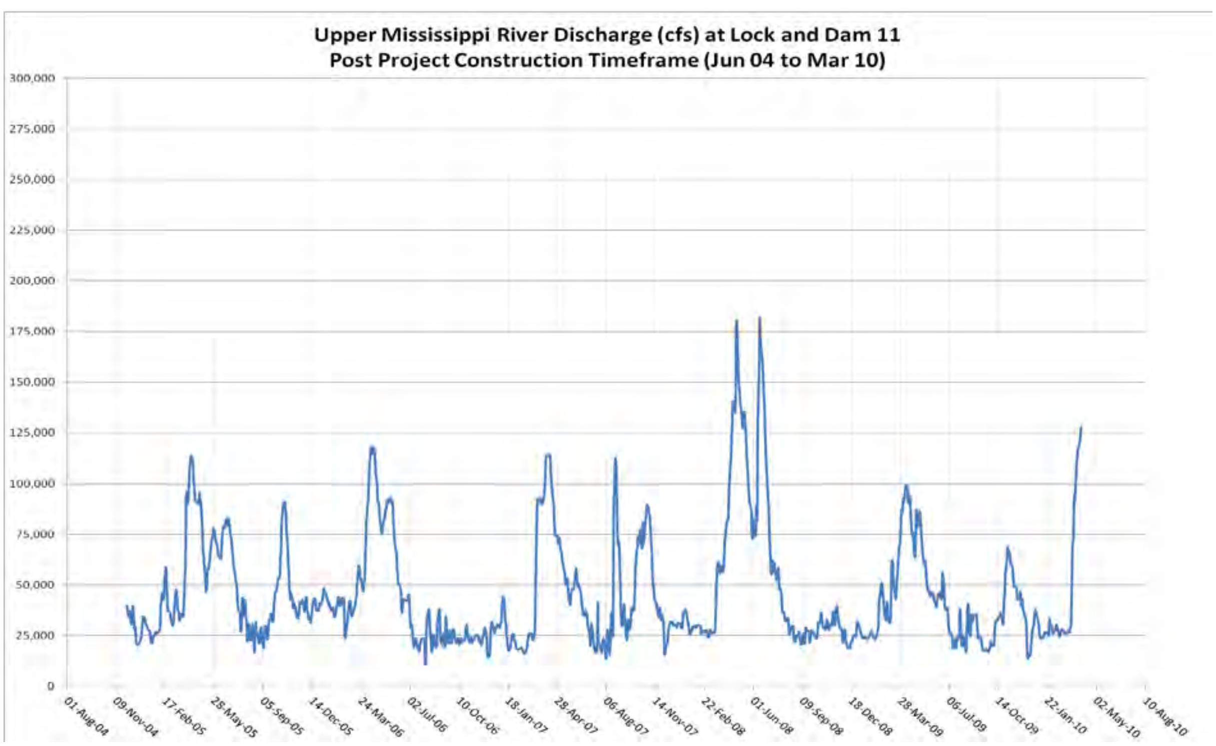
Graph B-3 shows typical current velocities at Site 583.4P during 2 years of pre-construction monitoring.



Graph B-4 shows typical current velocities at Site 583.4P during a year following project construction.



Graph B-5 shows Lock and Dam 11 discharge (cfs) from December 1997 to May 2004.



Graph B-6 illustrates Lock and Dam 11 discharge (cfs) from June 2004 to March 2010.

Site 583.4P Grab Sample Results: Post-Construction

DATE	WATER DEPTH (M)	VELOCITY (CM/SEC)	WATER TEMP. (°C)	DISSOLVED OXYGEN (MG/L)	pH (SU)	TURBIDITY (NTU)	SUSPENDED SOLIDS (MG/L)
12/29/2004	2.680		0.3	17.60	8.20		2.0
2/16/2005	2.790	1.91	0.6	10.62	7.80	74.0	45.0
3/17/2005	2.580	1.39	2.6	25.70	9.30	7.0	4.0
6/1/2005	2.940	6.27	23.0	14.59	9.00	14.1	13.0
6/14/2005	2.340		25.2	8.73	8.50	26.6	32.0
6/28/2005	2.870	2.91	27.3	6.63	8.10	16.7	13.0
7/13/2005	2.220		29.0	10.46	8.60	7.6	5.0
7/26/2005	2.810	1.30	26.4	6.84	8.30	15.6	25.0
8/9/2005	2.800	1.70	30.3	13.82	8.80	8.4	9.0
8/23/2005	2.820		24.5	7.07	7.90	13.1	9.0
9/7/2005	2.400		25.1	9.87	8.70	12.6	16.0
12/13/2005	2.600	1.23	0.3	14.04	7.90	3.8	<1
1/19/2006	2.530		0.8	16.96	8.20	3.5	2.0
3/2/2006	2.375	2.54	0.4	21.44	8.50	3.2	1.0
6/6/2006	2.900	1.99	23.7	9.69	8.60	14.0	19.0
6/20/2006	2.700		24.7	7.52	8.40	12.3	13.0
7/5/2006	2.790	2.87	27.3	10.48	8.80	6.1	16.0
7/18/2006	2.870	0.04	29.0	7.78	8.50	8.7	13.0
8/1/2006	2.780	2.21	31.8	10.40	9.10	8.7	7.0
8/15/2006	2.880	1.12	25.6	10.19	8.60	9.1	8.0
8/29/2006	2.850	1.67	23.9	5.72	8.30	10.7	12.0
9/12/2006	2.740	0.97	17.4	4.07	7.20	10.8	10.0
12/19/2006	2.710	1.00	2.5	19.38	8.80	3.9	10.0
1/25/2007	2.870	1.76	0.4	15.68	7.80	2.4	5.0
3/15/2007	2.670	1.55	0.5	11.60	7.70	36.7	-
6/5/2007	2.790	**	22.0	7.80	8.50	18.1	19.0
6/19/2007	2.760	*	24.8	5.77	8.00	15.6	16.0
7/3/2007	2.700	*	24.8	8.38	8.30	10.2	9.0
7/17/2007	2.735	*	23.6	5.01	8.00	6.6	18.0
7/31/2007	2.700	1.02	27.0	5.79	8.10	4.1	7.0
8/14/2007	2.700	0.36	26.3	3.49	7.60	12.6	24.0
8/28/2007	2.680	1.74	23.1	3.41	7.60	11.8	23.0
9/11/2007	2.300	*	19.5	1.57	7.20	23.1	27.0
12/14/2007	2.810	1.79	0.2	13.36	7.90	4.6	1.0
1/31/2008	2.570	1.07	0.7	15.23	7.90	4.5	4.0
3/13/2008	2.500	0.75	0.5	15.39	7.60	14.1	8.0
6/3/2008	2.290		19.2	15.23	8.50	60.6	36.0
6/24/2008	2.500	3.76	23.2	5.93	7.70	69.3	50.0
7/8/2008	2.290	3.17	26.1	6.44	8.20	37.8	32.0
7/22/2008	2.095	3.55	26.9	9.79	8.00	44.9	38.0
8/5/2008	2.220	1.51	27.5	11.83	8.80	25.6	23.0
8/19/2008	2.340	1.49	25.0	10.25	8.70	20.8	19.0
9/3/2008	2.050	11.58	23.9	7.50	8.60	21.1	25.0
9/16/2008	2.220	4.20	19.2	8.00		21.0	22.0
12/10/2008	2.570	0.77	0.4	19.72	8.50	4.5	
1/22/2009	2.620	-	0.1	13.00	7.70	4.5	
3/6/2009	2.570		1.6	17.70	8.20	10.8	
6/4/2009	2.600	2.42	23.3	12.30	8.50	14.3	16.0
6/23/2009	2.514	*	29.5	10.89	8.41	13.8	15.0
7/7/2009	2.422	0.55	23.9	10.55	8.61	22.0	28.0
7/21/2009	2.480	8.19	21.9	14.99	8.99	11.6	18.0
8/4/2009	2.474	1.19	25.2	13.31	8.80	12.1	16.0
8/18/2009	2.462	2.69	24.8	7.34	8.20	14.4	19.0
9/1/2009	2.418	2.62	21.1	11.72	8.30	9.6	12.0
9/15/2009	2.268	1.72	23.6	6.59	7.90	12.6	17.0
12/14/2009	2.430	0.55	1.1	16.48	8.30	3.8	
1/25/2010	2.430	1.96	0.4	11.28	7.70	28.3	
3/12/2010	2.620	1.99	0.4	12.31	8.00	25.6	

Site 583.5R Grab Sample Results: Post-Construction

DATE	WATER DEPTH (M)	VELOCITY (CM/SEC)	WATER TEMP. (°C)	DISSOLVED OXYGEN (MG/L)	pH (SU)	TURBIDITY (NTU)	SUSPENDED SOLIDS (MG/L)
12/29/2004	2.680		0.3	17.60	8.20		2.0
2/16/2005	2.790	1.91	0.6	10.62	7.80	74.0	45.0
3/17/2005	2.580	1.39	2.6	25.70	9.30	7.0	4.0
6/1/2005	2.940	6.27	23.0	14.59	9.00	14.1	13.0
6/14/2005	2.340		25.2	8.73	8.50	26.6	32.0
6/28/2005	2.870	2.91	27.3	6.63	8.10	16.7	13.0
7/13/2005	2.220		29.0	10.46	8.60	7.6	5.0
7/26/2005	2.810	1.30	26.4	6.84	8.30	15.6	25.0
8/9/2005	2.800	1.70	30.3	13.82	8.80	8.4	9.0
8/23/2005	2.820		24.5	7.07	7.90	13.1	9.0
9/7/2005	2.400		25.1	9.87	8.70	12.6	16.0
12/13/2005	2.600	1.23	0.3	14.04	7.90	3.8	<1
1/19/2006	2.530		0.8	16.96	8.20	3.5	2.0
3/2/2006	2.375	2.54	0.4	21.44	8.50	3.2	1.0
6/6/2006	2.900	1.99	23.7	9.69	8.60	14.0	19.0
6/20/2006	2.700		24.7	7.52	8.40	12.3	13.0
7/5/2006	2.790	2.87	27.3	10.48	8.80	6.1	16.0
7/18/2006	2.870	0.04	29.0	7.78	8.50	8.7	13.0
8/1/2006	2.780	2.21	31.8	10.40	9.10	8.7	7.0
8/15/2006	2.880	1.12	25.6	10.19	8.60	9.1	8.0
8/29/2006	2.850	1.67	23.9	5.72	8.30	10.7	12.0
9/12/2006	2.740	0.97	17.4	4.07	7.20	10.8	10.0
12/19/2006	2.710	1.00	2.5	19.38	8.80	3.9	10.0
1/25/2007	2.870	1.76	0.4	15.68	7.80	2.4	5.0
3/15/2007	2.670	1.55	0.5	11.60	7.70	36.7	-
6/5/2007	2.790	**	22.0	7.80	8.50	18.1	19.0
6/19/2007	2.760	*	24.8	5.77	8.00	15.6	16.0
7/3/2007	2.700	*	24.8	8.38	8.30	10.2	9.0
7/17/2007	2.735	*	23.6	5.01	8.00	6.6	18.0
7/31/2007	2.700	1.02	27.0	5.79	8.10	4.1	7.0
8/14/2007	2.700	0.36	26.3	3.49	7.60	12.6	24.0
8/28/2007	2.680	1.74	23.1	3.41	7.60	11.8	23.0
9/11/2007	2.300	*	19.5	1.57	7.20	23.1	27.0
12/14/2007	2.810	1.79	0.2	13.36	7.90	4.6	1.0
1/31/2008	2.570	1.07	0.7	15.23	7.90	4.5	4.0
3/13/2008	2.500	0.75	0.5	15.39	7.60	14.1	8.0
6/3/2008	2.290		19.2	15.23	8.50	60.6	36.0
6/24/2008	2.500	3.76	23.2	5.93	7.70	69.3	50.0
7/8/2008	2.290	3.17	26.1	6.44	8.20	37.8	32.0
7/22/2008	2.095	3.55	26.9	9.79	8.00	44.9	38.0
8/5/2008	2.220	1.51	27.5	11.83	8.80	25.6	23.0
8/19/2008	2.340	1.49	25.0	10.25	8.70	20.8	19.0
9/3/2008	2.050	11.58	23.9	7.50	8.60	21.1	25.0
9/16/2008	2.220	4.20	19.2	8.00		21.0	22.0
12/10/2008	2.570	0.77	0.4	19.72	8.50	4.5	
1/22/2009	2.620	-	0.1	13.00	7.70	4.5	
3/6/2009	2.570		1.6	17.70	8.20	10.8	
6/4/2009	2.600	2.42	23.3	12.30	8.50	14.3	16.0
6/23/2009	2.514	*	29.5	10.89	8.41	13.8	15.0
7/7/2009	2.422	0.55	23.9	10.55	8.61	22.0	28.0
7/21/2009	2.480	8.19	21.9	14.99	8.99	11.6	18.0
8/4/2009	2.474	1.19	25.2	13.31	8.80	12.1	16.0
8/18/2009	2.462	2.69	24.8	7.34	8.20	14.4	19.0
9/1/2009	2.418	2.62	21.1	11.72	8.30	9.6	12.0
9/15/2009	2.268	1.72	23.6	6.59	7.90	12.6	17.0
12/14/2009	2.430	0.55	1.1	16.48	8.30	3.8	
1/25/2010	2.430	1.96	0.4	11.28	7.70	28.3	
3/12/2010	2.620	1.99	0.4	12.31	8.00	25.6	

Site 584.2X Grab Sample Results: Post-Construction

DATE	WATER DEPTH (M)	VELOCITY (CM/SEC)	WATER TEMP. (°C)	DISSOLVED OXYGEN (MG/L)	pH (SU)	TURBIDITY (NTU)	SUSPENDED SOLIDS (MG/L)
12/29/2004	0.200		0.2	17.6	8.1		
2/16/2005	0.840	9.83	0.2	11.86	7.9	65.7	47
3/17/2005	0.770	6.89	3.6	17.25	8.5	9.47	7
6/1/2005	0.820	4.04	23.4	13.79	8.8	21.57	30
6/14/2005	0.890		24.9	6.63	8	86.23	52
6/28/2005	0.825	5.94	27.3	5.46	7.8	36.167	31
7/13/2005	0.750	3.42	30	11.93	8.5	16.57	22
7/26/2005	0.700	0.91	25.4	10.2	8.6	15.933	25
8/9/2005	0.800		31	11.86	9	4.93	15
8/23/2005	0.720	0.46	25.8	13.02	8.9	8.203	9
9/7/2005	0.810	1.07	27.1	11.53	8.7	10.4	16
12/13/2005	0.780	1.18	0.3	14.85	7.9	3.76	<1
1/19/2006	0.730		0.6	19.2	8.4	3	2
3/2/2006	0.715	0.99	0.1	18.88	8.4	4.3	<1
6/6/2006	0.810	2.84	23.1	7.48	8.1	13.2	21
6/20/2006	0.750		23.8	8.53	8.4	6.97	10
7/5/2006	0.780	0.35	27.3	14.78	9.4	3.2	7
7/18/2006	2.200		29.4	10.59	8.9	1.59	2
8/1/2006	1.220	2.55	32.6	7.78	9.2	5.14	1
8/15/2006	2.085	1.22	24.6	6.95	9	3.75	1
8/29/2006	1.790	2.5	23.9	7.76	8.9	5.1	9
9/12/2006	2.090	4.42	17.3	4.95	7.8	4.07	5
12/19/2006	1.060	4.27	2.1	19.98	8.8	5.26	13
1/25/2007	1.070	1.61	0.3	16.09	7.7	3.1	1
3/15/2007	0.900	0.94	0.5	10.56	7.7	36.4	-
6/5/2007	1.130	3.18	22.1	5.8	8.1	20.4	19
6/19/2007	1.710	*	23.6	6.8	8.1	25.2	34
7/3/2007	1.430	*	25	9.42	8.6	10.5	8
7/17/2007	1.225	*	24	6.67	8.8	8.42	14
7/31/2007	1.160	4.42	26.7	8.88	9	2.1	6
8/14/2007	1.120	0.42	26	4.12	8.1	4.35	11
8/28/2007	1.150	8.89	22.9	4.46	7.7	4.98	10
9/11/2007	1.000	6.63	17.9	3.07	7.4	2.82	3
12/14/2007	0.940	2.29	0.3	15.49	7.9	5.56	7
1/31/2008	0.950	1.01	0.4	13.59	7.7	4.5	3
3/13/2008	0.950	1.94	0.5	14.58	7.6	7.35	1
6/3/2008	1.090		19.3	16.19	8.6	86.6	61
6/24/2008	0.970	5.58	23.1	6.32	7.7	64.9	62
7/8/2008	1.090	0.43	25.2	6.1	7.9	54	55
7/22/2008	1.595	4.4	27.2	11.08	7.9	31.5	36
8/5/2008	1.050	4.68	26.4	9.9	8.7	60.3	39
8/19/2008	1.050	4.49	24.8	9.6	8.7	15.6	20
9/3/2008	0.990	2.53	23.9	7.29	8.6	16.6	23
9/16/2008	1.100	4.86	18.7	8.3		20	23
6/4/2009	1.260	3.28	22.1	10.3	8.2	14.4	18
6/23/2009	1.376	*	27.8	5.1	7.7	27	44
7/7/2009	1.352	2.31	23.5	7.7	8.04	18.2	21
7/21/2009	1.190	0.29	21.4	10.41	8.64	6.6	13
8/4/2009	1.146	4.78	24.5	7.66	8.2	6.5	8
8/18/2009	1.210	0.94	24.4	5.77	7.9	6.73	8
9/1/2009	0.880	1.94	20.9	9.37	8	9.3	15
9/15/2009	1.524	1.28	22.6	5.66	7.7	7.4	10
12/14/2009	1.160	1.12	0.3	15.04	8.1	5.1	
1/25/2010	1.220	1.51	0.3	11.43	7.7	21.3	
3/12/2010	1.130	5.83	0.7	12.14	8	37.4	

Site 588.0B Grab Sample Results: Post-Construction

DATE	WATER DEPTH (M)	VELOCITY (CM/SEC)	WATER TEMP. (°C)	DISSOLVED OXYGEN (MG/L)	pH (SU)	TURBIDITY (NTU)	SUSPENDED SOLIDS (MG/L)
12/13/2005	2.770	0.31	0.1	13.33	8.00	3.25	1.0
1/19/2006	2.680	0.82	0.3	16.75	8.20	4.40	5.0
3/2/2006	2.675	0.78	0.4	28.63	8.90	2.40	<1
6/6/2006	2.840	1.28	24.2	6.39	8.20	8.21	8.0
6/20/2006	2.650		24.4	4.81	7.50	7.50	8.0
7/5/2006	2.720	0.87	26.4	8.69	8.10	6.02	12.0
7/18/2006	2.740	0.03	30.3	13.86	8.80	5.93	10.0
8/1/2006	2.580	2.40	32.1	12.91	9.20	8.55	11.0
8/15/2006	2.565	0.55	26.3	11.00	8.40	9.42	11.0
8/29/2006	2.700	0.72	24.8	6.21	8.00	7.41	12.0
9/12/2006	2.730	0.97	17.3	3.62	7.20	7.08	3.0
12/19/2006	2.630	0.54	1.7	19.66	8.80	5.06	12.0
1/25/2007	2.680		0.8	17.18	7.90	3.20	6.0
3/28/2007	2.920	6.68	12.0	9.23	7.60	42.30	-
6/5/2007	2.675	2.88	20.8	4.73	7.20	14.10	15.0
6/19/2007	2.640	*	25.7	5.85	7.80	6.76	9.0
7/3/2007	2.735	*	26.4	10.27	8.40	7.59	4.0
7/17/2007	2.730	*	23.9	4.78	7.80	7.59	15.0
7/31/2007	2.680	0.80	29.8	8.19	8.00	5.18	6.0
8/14/2007	2.710	0.70	28.1	6.57	7.80	5.18	13.0
8/28/2007	2.785	6.19	23.8	2.32	7.30	6.63	11.0
9/11/2007	2.680	0.92	19.7	3.87	7.40	7.03	7.0
12/14/2007	2.570	0.58	0.1	14.09	7.90	7.37	8.0
1/31/2008	2.420	0.50	0.1	13.81	7.70	5.70	5.0
3/13/2008	2.450	0.48	0.0	13.82	7.50	8.65	6.0
6/3/2008	2.700		19.9	7.31	7.70	44.90	28.0
6/24/2008	2.470	2.80	25.7	8.47	8.00	40.70	30.0
7/8/2008	2.460	4.20	25.9	5.32	7.70	29.30	25.0
7/22/2008	2.360	5.22	28.0	9.02	7.60	21.70	23.0
8/5/2008	2.500	4.44	27.1	8.06	8.00	12.60	9.0
8/19/2008	2.450	0.69	26.7	12.76	9.00	8.43	9.0
9/3/2008	2.480	3.33	24.3	6.83	8.10	22.20	29.0
9/16/2008	2.640	7.79	18.3	6.62		18.20	18.0
6/4/2009	2.480	2.68	25.1	15.15	8.90	14.40	16.0
6/23/2009	2.422	*	31.8	14.33	8.75	11.60	19.0
7/7/2009	2.300	1.48	23.9	9.75	8.20	10.90	13.0
7/21/2009	2.478	1.190	22.1	9.92	8.42	11.10	15.0
8/4/2009	2.370	3.83	26.4	12.68	8.40	8.49	9.0
8/18/2009	2.720	4.15	25.7	7.51	7.70	8.22	10.0
9/1/2009	2.560	1.75	22.6	10.80	8.40	10.70	12.0
9/15/2009	2.320	0.37	25.4	8.19	7.80	6.10	8.0
12/14/2009	2.240	0.86	0.1	14.96	8.20	3.70	
1/25/2010	2.510	1.08	0.3	12.51	7.50	12.50	
3/12/2010	2.785	0.780	0.5	10.80	7.50	10.90	

Site 588.1D Grab Sample Results: Post-Construction

DATE	WATER DEPTH (M)	VELOCITY (CM/SEC)	WATER TEMP. (°C)	DISSOLVED OXYGEN (MG/L)	pH (SU)	TURBIDITY (NTU)	SUSPENDED SOLIDS (MG/L)
12/13/2005	2.7	8.84	0.1	14.45	7.9	3.88	3
1/19/2006	2.58	8.63	0.3	16.65	8.2	2.9	3
3/2/2006	2.28	1.11	0.1	19.07	8.4	3	2
6/6/2006	2.33	0.54	24.8	6.24	7.9	30.7	40
6/20/2006	2.07	-	24.2	6.03	8	19.8	21
7/5/2006	2.49	1.23	27.5	10.34	8.8	6.54	14
7/18/2006	2.49	0.099	30	14.22	8.9	6.01	13
8/1/2006	2.26	0.22	32.2	15.09	9.5	12.5	16
8/15/2006	2.43	1.77	27.9	15.86	9.1	14.3	14
8/29/2006	2.51	4.25	24.9	9.47	8.5	12.2	25
9/12/2006	2.43	2.87	17.7	5.89	7.5	10.5	6
12/19/2006	2.45	0.83	1.7	20.36	8.8	5.53	10
1/25/2007	2.42	1.28	0.3	17.04	8	2.8	5
3/28/2007	2.56	3.45	11.7	9.8	7.6	33.4	-
6/5/2007	2.4	0.15	20.6	5.11	7.2	22.9	24
6/19/2007	2.32	*	25.9	5.53	8	13.6	12
7/3/2007	2.245	*	26.8	10.74	8.6	9.65	7
7/17/2007	2.375	*	24.3	3.37	8	6.82	18
7/31/2007	2.4	1.35	28.7	10.67	8.3	6.09	13
8/14/2007	2.38	1.38	28.5	7.22	8.1	6.73	16
8/28/2007	2.34	11.18	24	6.37	7.7	21.5	27
9/11/2007	1.9	*	21.2	7.5	8.1	16.1	20
12/14/2007	2.375	3.25	0.1	14.46	8	5.48	<1
1/31/2008	2.19	3.65	0	14.32	7.8	5.7	6
3/13/2008	2.3	2.96	0	14.28	7.6	19.8	17
6/3/2008	2.13		19	11.46	8	101	47
6/24/2008	2.3	5.04	25.6	7.46	8	60.4	41
7/8/2008	2.31	1.74	24.9	6.9	7.9	40.9	34
7/22/2008	2.145	0.35	27.6	12.93	8.3	27	22
8/5/2008	2.23	4.29	28.3	10.55	8.7	23.3	20
8/19/2008	2.17	0.94	26.5	12.67	9.1	20.7	14
9/3/2008	2.07	4.15	24.2	9.33	8.85	24.1	25
9/16/2008	2.15		18.91	8.61		21.8	21
12/10/2008	2.1	1.45	0.3	18.43	8.4	5.2	
1/21/2009	2.135	2.14	-0.1	14.39	7.7	7.02	
3/6/2009	2.05	0.97	1.2	17.35	8.1	14.8	
6/4/2009	2.13	2.06	24.6	11.49	8.5	25.6	34
6/23/2009	2.094	*	30.4	6.1	7.9	33.5	47
7/7/2009	1.97	3.01	23.5	7.76	8.07	18.3	35
7/21/2009	2	0.6	21.5	7.72	8.2	11.6	18
8/4/2009	2.078	2	25.7	9.76	8.3	8.74	11
8/18/2009	2.062	3.54	25.6	6.93	7.8	9.53	13
9/1/2009	2.134	6.54	22.8	13.13	8.7	12.6	14
9/15/2009	2	1.9	25.6	7.01	7.9	5.7	6
12/14/2009	1.96	1.05	0.2	14.57	8.2	2.8	
1/25/2010	1.96	2.78	0.2	12.77	7.7	18.0	
3/12/2010	2.25	3.28	0.4	13.45	7.9	13.7	

Site 589.0C Grab Sample Results: Post-Construction

DATE	WATER DEPTH (M)	VELOCITY (CM/SEC)	WATER TEMP. (°C)	DISSOLVED OXYGEN (MG/L)	pH (SU)	TURBIDITY (NTU)	SUSPENDED SOLIDS (MG/L)
12/13/2005	2.600	1.26	0.1	14.18	7.90	3.33	3
1/19/2006	2.560	1.57	0.4	16.42	8.20	3.40	5
3/2/2006	2.510	0.62	0.2	19.52	8.40	3.90	2
6/6/2006	2.520	2.96	24.6	5.66	7.80	24.30	25
6/20/2006	2.600	-	23.3	3.14	7.50	17.70	24
7/5/2006	2.520	-	27.5	9.73	8.60	5.10	13
7/18/2006	2.480	0.01	30.2	10.60	8.70	5.41	13
8/1/2006	2.370	0.32	31.6	14.57	9.30	11.00	13
8/15/2006	2.395	0.29	28.5	14.46	9.10	10.80	12
8/29/2006	2.500	2.36	24.0	8.05	8.60	10.90	18
9/12/2006	2.470	0.57	17.7	6.48	7.50	9.04	7
12/19/2006	2.450	0.69	1.4	19.83	8.80	5.87	14
1/25/2007	2.510	-	0.2	16.98	7.90	2.80	6
3/28/2007	2.540	1.58	11.3	9.87	7.70	32.60	-
6/5/2007	2.330	2.31	20.7	5.07	7.30	29.00	31
6/19/2007	2.310	*	25.9	7.30	8.00	16.10	20
7/3/2007	2.270	*	25.3	10.98	8.40	14.40	21
7/17/2007	2.320	*	24.0	3.28	7.80	4.74	13
7/31/2007	2.395	0.98	28.3	5.98	7.90	8.23	21
8/14/2007	2.220	0.40	28.0	5.48	7.60	6.59	18
8/28/2007	2.335	*	22.0	0.25	7.00	17.60	27
9/11/2007	2.280	*	20.1	6.86	7.80	10.10	14
12/14/2007	2.490	0.82	0.1	14.49	8.00	6.02	2
1/31/2008	2.300	0.33	0.2	14.38	7.80	6.60	3
3/13/2008	2.350	0.17	0.3	13.86	7.60	12.70	6
6/3/2008	2.260	-	18.5	11.70	8.00	86.30	41
6/24/2008	2.430	-	24.1	6.94	7.90	87.80	44
7/8/2008	2.330	1.39	24.7	4.42	7.70	50.30	31
7/22/2008	2.125	-	28.1	10.05	7.50	24.70	32
8/5/2008	2.240	1.46	28.7	11.78	8.70	20.30	16
8/19/2008	2.230	1.18	27.9	12.51	9.10	31.40	42
9/3/2008	2.200	1.67	23.3	6.21	7.40	17.40	21
9/16/2008	1.900	2.54	16.2	2.46	-	5.15	10
12/10/2008	2.230	0.73	0.3	17.84	8.30	5.73	
1/21/2009	2.220	0.44	0.1	14.22	7.80	8.00	
3/6/2009	2.260	0.36	1.7	18.85	8.90	25.90	
6/4/2009	2.230	1.72	24.2	9.68	8.10	48.30	52
6/23/2009	2.226	*	30.8	9.87	8.26	33.60	40
7/7/2009	2.118	0.23	23.2	8.35	7.60	25.20	37
7/21/2009	2.300	0.13	20.8	4.96	7.75	21.70	32
8/4/2009	2.150	4.07	25.6	8.31	7.70	9.72	11
8/18/2009	2.164	0.85	25.5	5.88	7.50	5.94	8
9/1/2009	2.228	0.27	21.9	8.78	7.90	7.30	9
9/15/2009	2.132	1.27	25.5	7.86	8.20	6.60	9
12/14/2009	2.080	0.36	0.3	14.67	8.20	3.30	
1/25/2010	2.100	0.40	0.2	7.85	7.30	33.30	
3/12/2010	2.380	0.76	0.5	12.44	7.80	25.70	

Site 589.3D Grab Sample Results: Post-Construction

DATE	WATER DEPTH (M)	VELOCITY (CM/SEC)	WATER TEMP. (°C)	DISSOLVED OXYGEN (MG/L)	pH (SU)	TURBIDITY (NTU)	SUSPENDED SOLIDS (MG/L)
12/13/2005	2.27	7.54	0.1	14.32	8	3.07	1
1/19/2006		27.03	0.2	17.9	8.4	2.8	3
3/2/2006	1.82	18.68	0.2	19.83		3	3
6/6/2006	2.25	18.73	25.1	6.36	8	14.7	19
6/20/2006	2.15	4.57	24.5	6.02	8.1	16.8	22
7/5/2006	2.12	4.44	27.1	8.91	8.5	4.62	12
7/18/2006	2.16	0.145	29.9	10.95	8.8	7.32	12
8/1/2006	1.87	1.52	33.1	17.48	9.6	15.9	16
8/15/2006	2.11	3.56	26.4	12.1	9	16	20
8/29/2006	2.23	7.41	24.4	7.89	8.4	15	37
9/12/2006	1.97	8.8	19	7.08	7.9	15.2	24
12/19/2006	2.09	6.76	1.2	19.51	8.8	6.17	17
1/25/2007	2.13	9.14	0.2	17.64	8	3.1	8
3/28/2007	2.3	8.3	11.2	10.83	7.8	47.6	-
6/5/2007	2.02	11.46	20.7	6.67	7.6	39	52
6/19/2007	1.925	*	26.5	6.45	8.3	26.2	41
7/3/2007	2.01	*	27.2	10.95	8.6	9.75	12
7/17/2007	2.16	*	25	5.71	8.6	10.2	20
7/31/2007	2.125	2.99	29.1	8.86	8.3	7.39	11
8/14/2007	2.085	4.93	28.4	6.08	7.9	8.46	21
8/28/2007	2.02	2.34	23.7	6.08	7.7	43.3	60
9/11/2007	1.75	4.24	21.7	7.71	8.2	30.8	39
12/14/2007	1.73	8.71	0.1	14.38	8	5.58	<1
1/31/2008	1.69	3.81	0.2	14.36	7.8	4	4
3/13/2008	1.96	4	0.1	14.02	7.6	8.13	7
6/3/2008	2.13		19	13.41	8.3	347	150
6/24/2008	2.2	12.81	24.4	6.72	7.8	60.9	100
7/8/2008	2.1	8.87	24.9	6.04	7.8	70.9	62
7/22/2008	1.96	9.65	27.8	12.37	8.3	39.7	45
8/5/2008	2.03	5.33	27.3	9.35	8.6	29.3	25
8/19/2008	2.14	5.36	25.8	12.01	9	24	18
9/3/2008	1.88	1.66	24.1	9.46	9.2	25.3	32
9/16/2008	1.71	1.33	18.23	8.33		23.3	21
12/10/2008	1.98	5.64	0.3	16.66	8.3	5.45	
1/21/2009	1.995	-	0.1	14.75	7.8	6.74	
3/6/2009	1.94	6.31	0.6	16.23	8	6.44	
6/4/2009	1.9	4.58	18.2	6.57	7.7	65.9	73
6/23/2009	2.08	*	29.8	4.62	7.66	55.7	66
7/7/2009	1.924	1.56	23.6	7.22	8.04	28.6	34
7/21/2009	1.948	0.77	21.3	7.67	8.31	10.9	16
8/4/2009	1.888	5.45	24.9	7.48	8.1	8.81	10
8/18/2009	2.052	5.75	25.6	7.89	8.1	11.2	15
9/1/2009	1.876	1.65	22.4	11.93	8.6	10.4	12
9/15/2009	1.918	3.87	24.8	8.64	8.4	8.6	11
12/14/2009	1.66	0.81	0.1	14.57	8.2	3.8	
1/25/2010	1.78	3.39	0.3	13.35	7.7	11.5	
3/12/2010	2.03	0.32	0.5	12.82	7.9	36.4	

POST-CONSTRUCTION
10-YEAR PERFORMANCE EVALUATION REPORT

POOL 11 ISLANDS (MUD AND SUNFISH LAKES)
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

APPENDIX B-2
TEMPERATURE MONITORING OF HIGH SPOTS

POST-CONSTRUCTION
10-YEAR PERFORMANCE EVALUATION REPORT

POOL 11 ISLANDS (MUD AND SUNFISH LAKES)
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

APPENDIX B-2
TEMPERATURE MONITORING OF HIGH SPOTS

In accordance to the recommended plan outlined in Chapter 6 of the Pool 11 Islands Habitat Rehabilitation and Enhancement Definite Project Report (DPR), several high spots, or depth diversity structures, were intentionally left in the main dredged channel of Mud Lake to retain warmer water near the channel bottom during the wintering period. Water is most dense when at the temperature of 4°C, thus water closest to this temperature would sink into the deeper areas between high spots. In order to assess the success of these features, continuous monitoring temperature probes were deployed at several sites at 2 different depths in the water column; one was positioned 1’ off the bottom within the deeper area between high spots and the other at 4’ or 5’ off the bottom and out of the depression. See Figures B2-1 and B2-2 for sampling site maps.

The first deployments occurred December 13, 2005 to March 2, 2006 at several locations between high spots in the main dredge channel of Mud Lake (sites 589.3D, 589.1D, 588.6D, 588.1D, and 587.6D). Although instrumentation at site 589.1D was lost, data from the remaining sites revealed no temperature stratification along the channel, similar to site 588.1D as shown in Graph B2-1. Changes in flow did not seem to affect this lack of temperature variance. Table B2-1, a summary of data collected over several winter seasons, lists the median of the absolute value of the difference between lower and upper probes at a site. The table shows very little difference between sites for winter 05-06.

Due to the uniformity observed in the main dredged channel in Mud Lake, the next deployments occurred from December 10, 2008 to March 6, 2009 and December 14, 2009 to March 12, 2010 at site 583.5R in the main dredge channel of Sunfish Lake, where no high spots were constructed, site 588.1D in the main dredge channel between high spots in Mud Lake, and site 589.0C in the off-main channel fish hook dredge cut of Mud Lake, where no high spots were constructed. Site 589.0C is also less influenced by flow variances than the main dredge channel.

In examining the temperature monitoring results from 2009 to 2010, stratification is evident at sites 583.5R and 589.0C. Site 583.5R had a 22% higher temperature at the deeper sampling depth versus the shallower depth, and site 589.0C saw a 40% increase in temperature at greater depth. Their ability to produce a temperature difference was constant even as river flow increased, as illustrated in Graphs B2-2 and B2-4 below. Neither site has high spots. Results of temperature monitoring at site 588.1D show stratification between sampling depths until river flows increased. As the river stage increased during

December 15th to 25th, the bottom temperature value decreased and became close to the near-surface value, as seen in Graph B2-3. Of the 3 sampling sites during the winter season of 09 to 10, site 588.1D was the only one that had water temperature readings fall below the project goal of 1°C at the sampling depth of 1' off the bottom. Even though site 588.1D is between high spots, it had the least amount of difference between the 2 sampling depths.

During the previous winter season of 2008 to 2009, results mirrored those of the 09 to 10 season, but the median temperature differences were less pronounced. Site 583.5R of Sunfish Lake and site 588.1D of Mud Lake saw little stratification when flows increased through Pool 11, as seen in Graphs B2-5 and B2-6. As flows increased, the bottom depth temperature dipped to nearly the same value as the upper depth. This trend was not seen, however, at site 589.0C, where there remained a constant difference between the deep and shallow depth temperatures (see Graph B2-7). This difference can be explained by looking at Pool 11 Islands winter water quality monitoring data gathered from 2005 to 2010 included in the Pool 11 Performance Evaluation Report, where site 589.0C has the lowest average current velocity of any site in Mud Lake due to its location away from the main dredge channel and flow path.

When comparing temperature values for the site between high spots in Mud Lake versus the Mud Lake off-main dredge channel site and the main channel site in Sunfish Lake that do not have high spots, it appears that being located off the main channel produced a more pronounced water column temperature stratification. The high spots produced only a minimal amount of desired effect, to provide a low area for warmer water to settle. This effect was only realized when river flows were not high. Yet at site 589.0C in Mud Lake, off the main dredge channel, average water temperatures remained warmer at increased depth, regardless of river stage. So, data would indicate that the more important factor in the presence of warmer winter water temperatures is the sites location relative to the main dredge channel and flow path, not the existence of high spots.

The above conclusion was confirmed during a follow up deployment that occurred December 19, 2013 to March 18, 2014. Monitoring was conducted between high spots in the southern end of the main dredged channel of Mud Lake at sites 587.8D and 587.6D. The results were similar to what was previously observed in the main channel sites in that there was little difference between the lower and upper temperature readings. These sites also experienced average temperatures much colder than the other deployments, indicating the likelihood of fresh cold water from the Mississippi River main channel was entering the project area from this location.

Figure B-2-1. Pool 11 Islands Temperature Monitoring Sites in Mud Lake

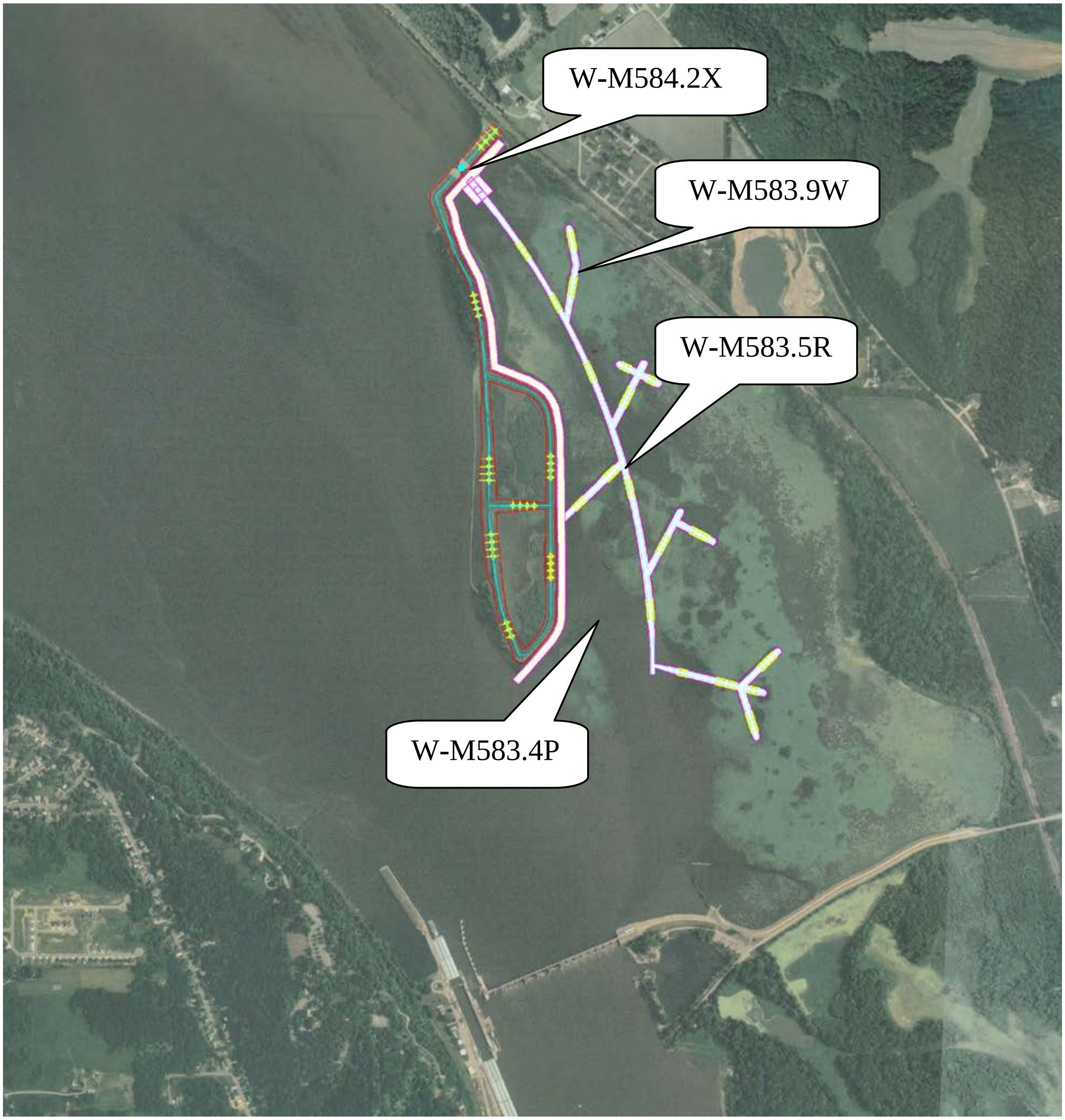
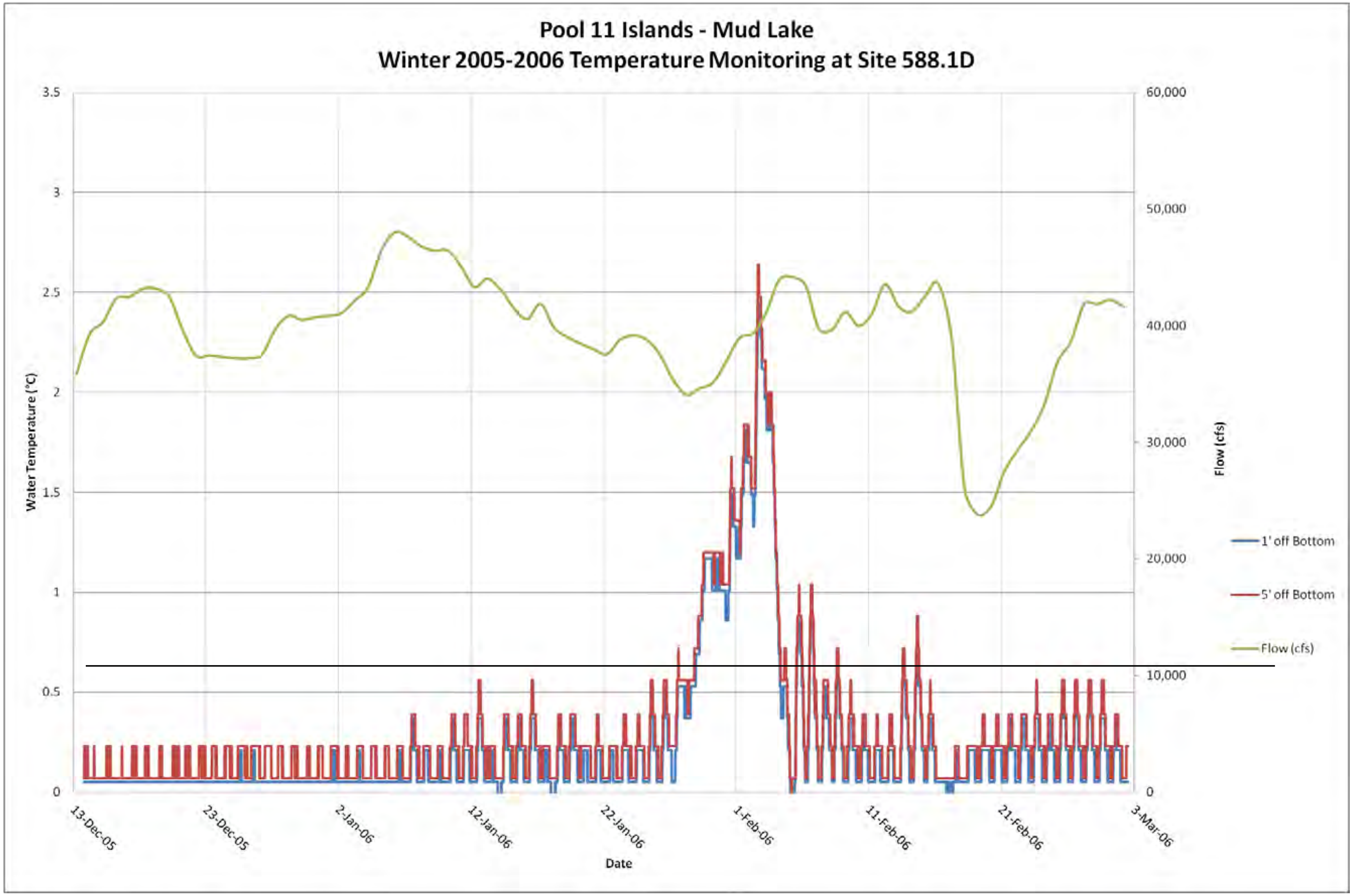
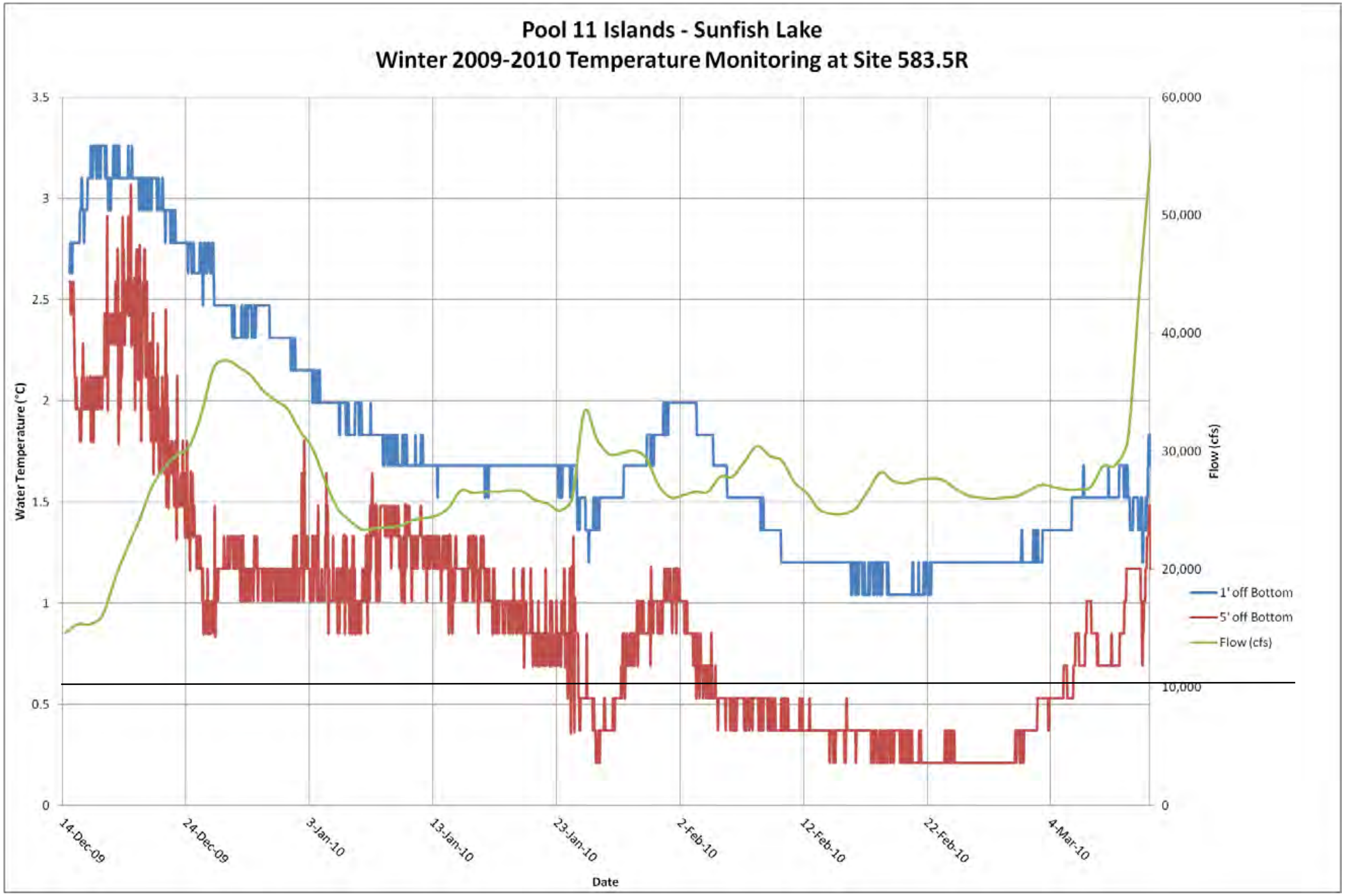


Figure B-2-2. Pool 11 Islands Water Quality Sampling Sites in Sunfish Lake*
*Note: Temperature Monitoring only performed at Site W-M583.5R

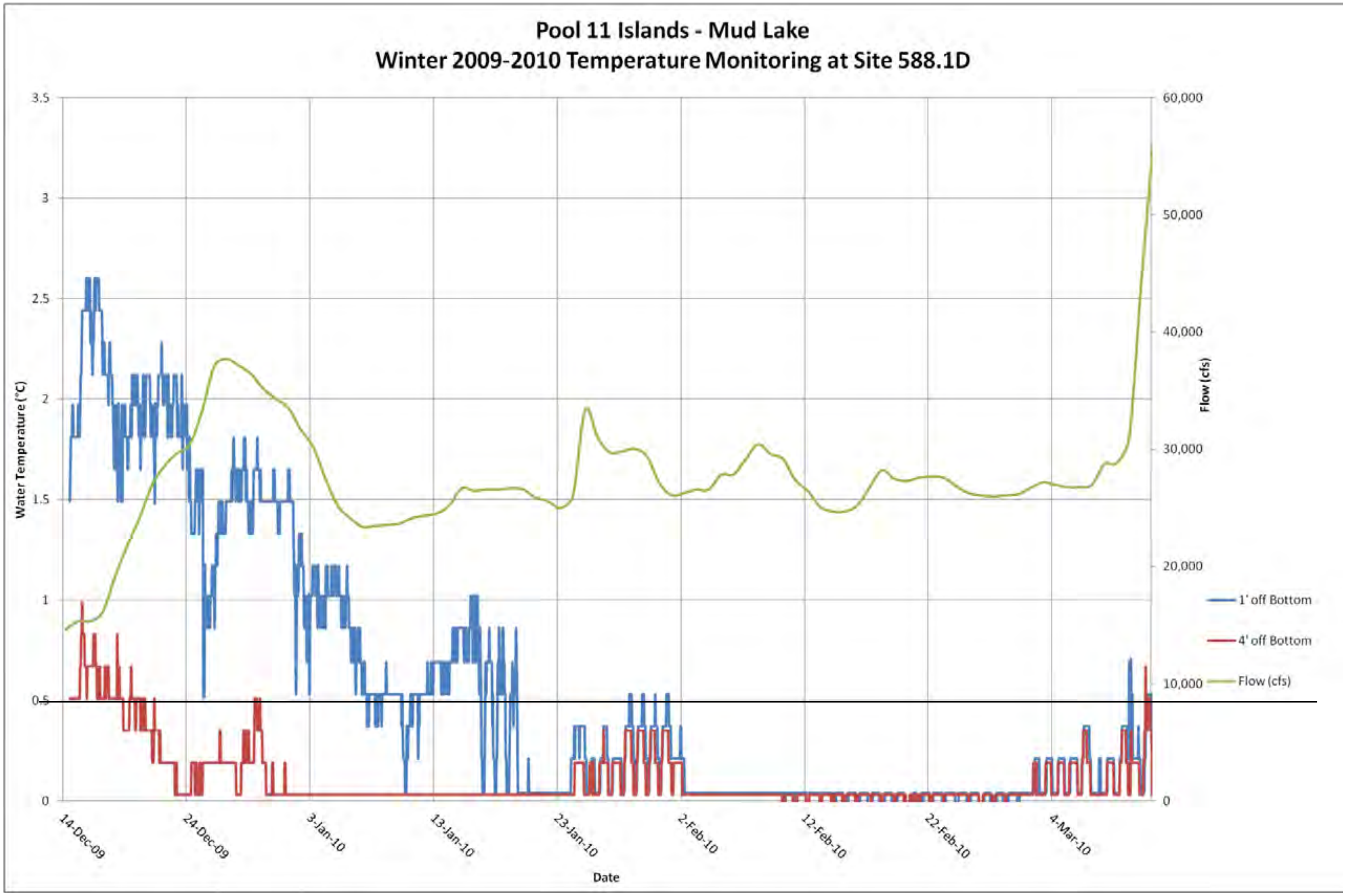
Table B-2-1. Summary of Temperature Monitoring Results				
Year	Site	Depth	Average Temperature (°C)	Median Temperature Difference Between Bottom and Top of Water Column
05 to 06	589.3D	1' off Bottom	0.11	0.14
		5' off Bottom	0.21	
	588.6D	1' off Bottom	0.27	0.02
		5' off Bottom	0.19	
	588.1D	1' off Bottom	0.24	0.02
		5' off Bottom	0.31	
	587.6D	1' off Bottom	0.46	0.17
		5' off Bottom	0.19	
08 to 09	583.5R	1' off Bottom	1.96	0.35
		5' off Bottom	1.34	
	588.1D	1' off Bottom	0.53	0.33
		5' off Bottom	0.11	
	589.0C	1' off Bottom	1.32	0.62
		5' off Bottom	0.65	
09 to 10	583.5R	1' off Bottom	1.77	0.83
		5' off Bottom	0.91	
	588.1D	1' off Bottom	0.63	0.18
		4' off Bottom	0.10	
	589.0C	1' off Bottom	2.35	1.89
		4' off Bottom	0.43	
13 to 14	587.8D	1' off Bottom	0.36	0.17
		4' off Bottom	0.05	
	587.6D	1' off Bottom	-0.03	0.14
		4' off Bottom	-0.52	



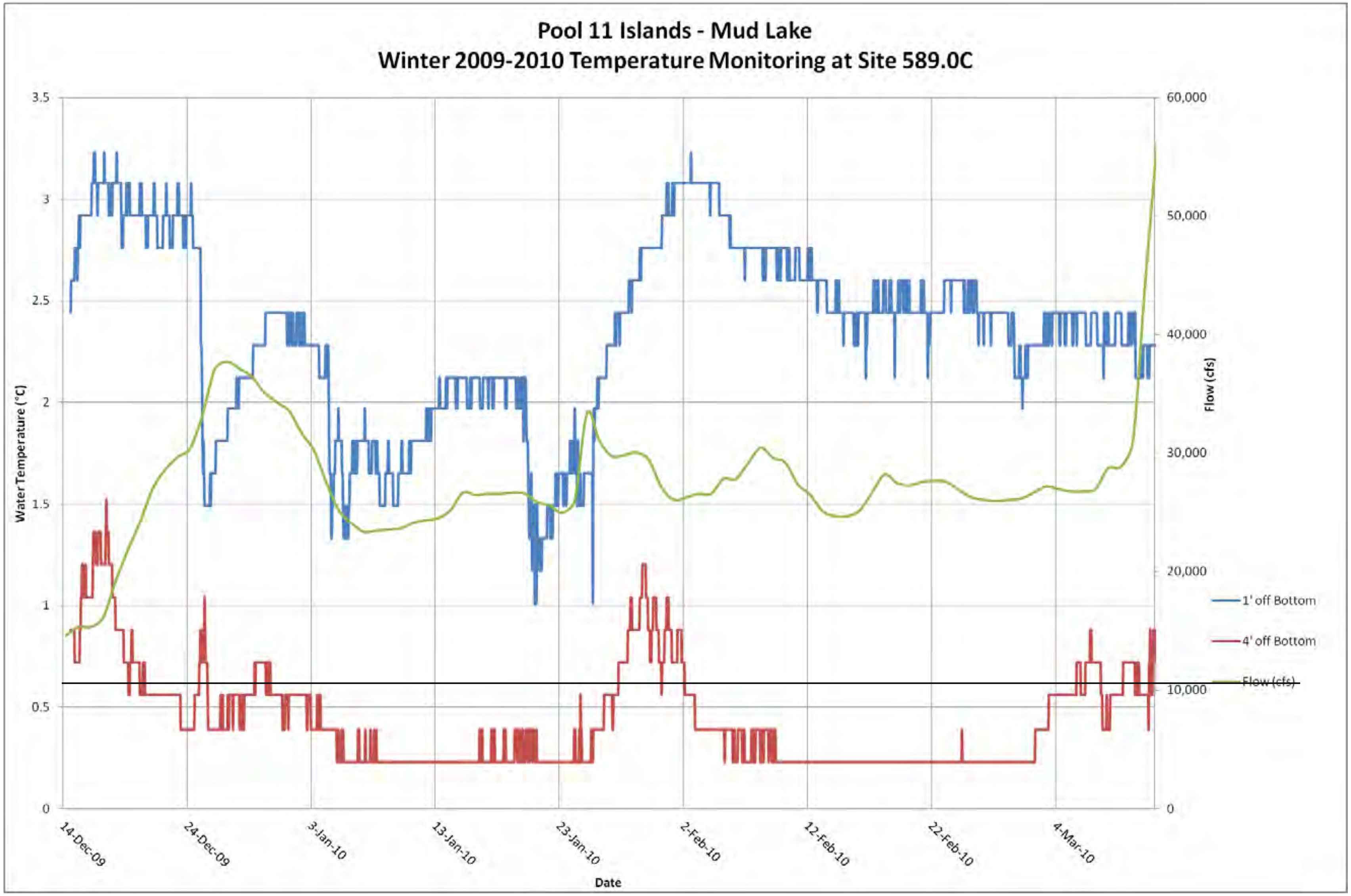
Graph B-2-1. Temperature Monitoring at Site 588.1D in Mud Lake from 13 Dec 2005 to 02 Mar 2006



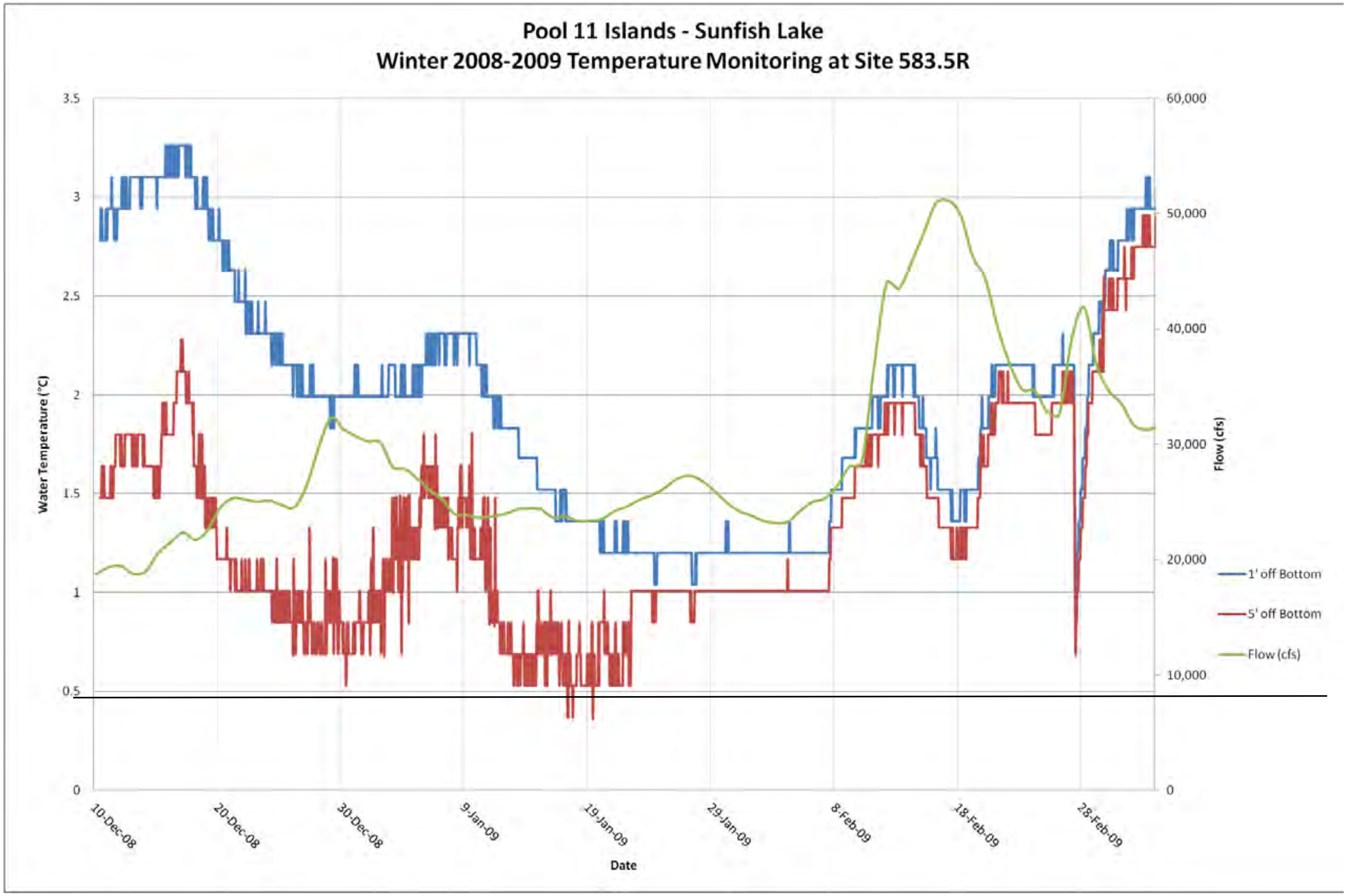
Graph B-2-2. Temperature Monitoring at Site 583.5R in Sunfish Lake from 15 Dec 2009 to 12 Mar 2010



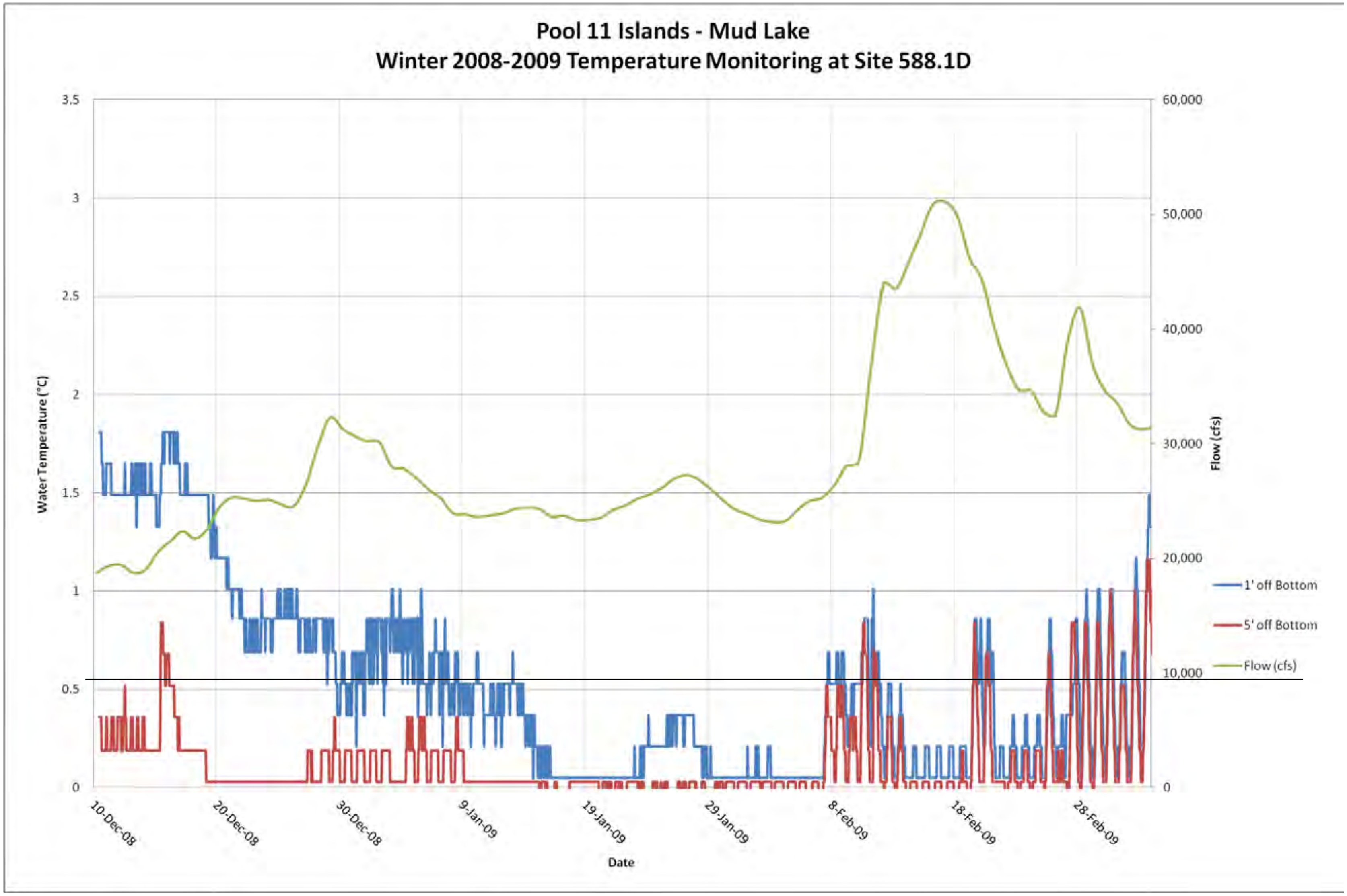
Graph B-2-3. Temperature Monitoring at Site 588.1D in Mud Lake from 15 Dec 2009 to 06 Mar 2010



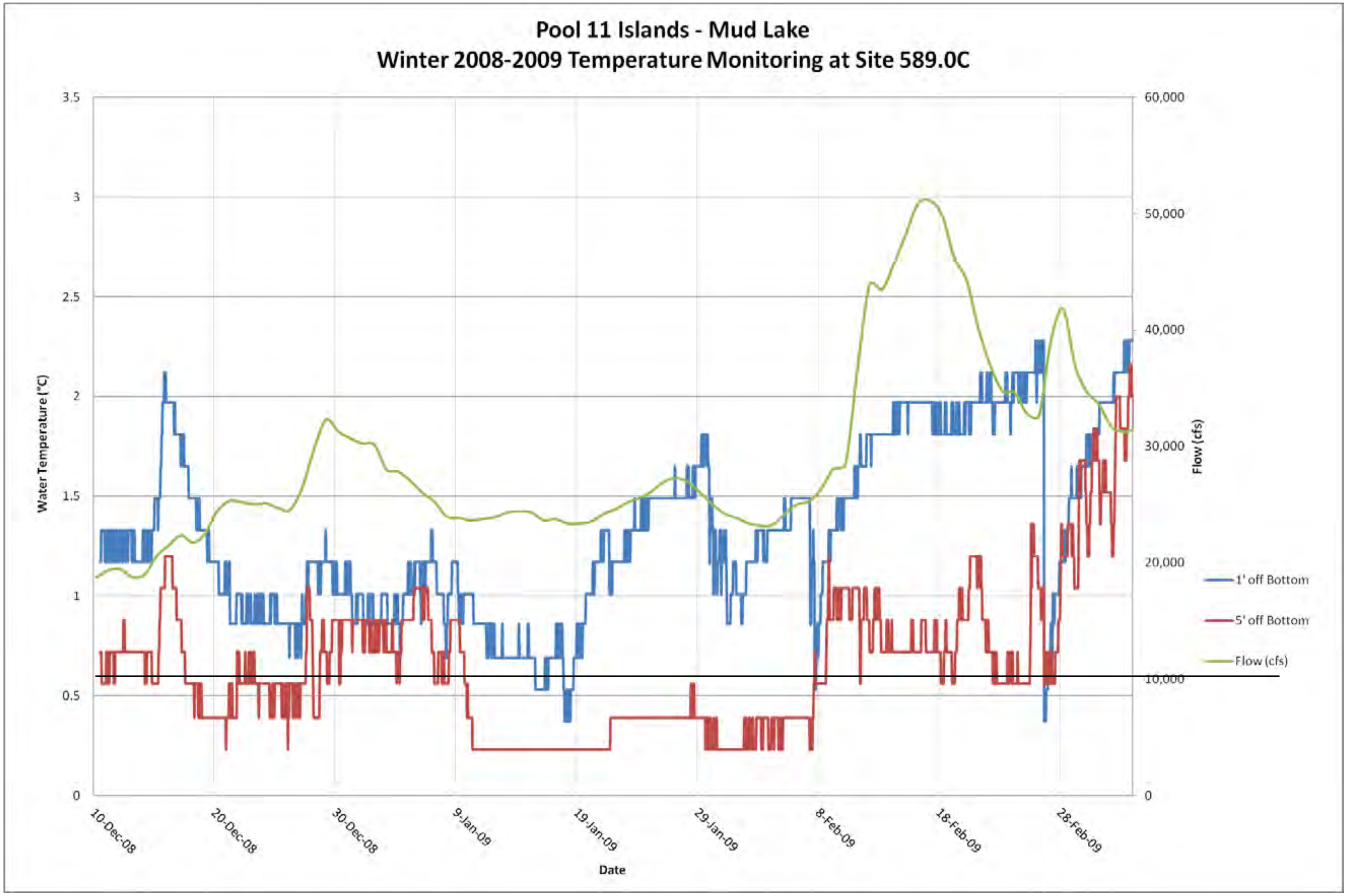
Graph B-2-4. Temperature Monitoring at Site 589.0C in Mud Lake from 15 Dec 2009 to 06 Mar 2010



Graph B-2-5. Temperature Monitoring at Site 583.5R in Sunfish Lake from 10 Dec 2008 to 06 Mar 2009.



Graph B-2-6. Temperature Monitoring at Site 588.1D in Mud Lake from 10 Dec 2008 to 06 Mar 2009.



Graph B-2-7. Temperature Monitoring at Site 589.0C in Mud Lake from 10 Dec 2008 to 06 Mar 2009.

POST-CONSTRUCTION

10-YEAR PERFORMANCE EVALUATION REPORT

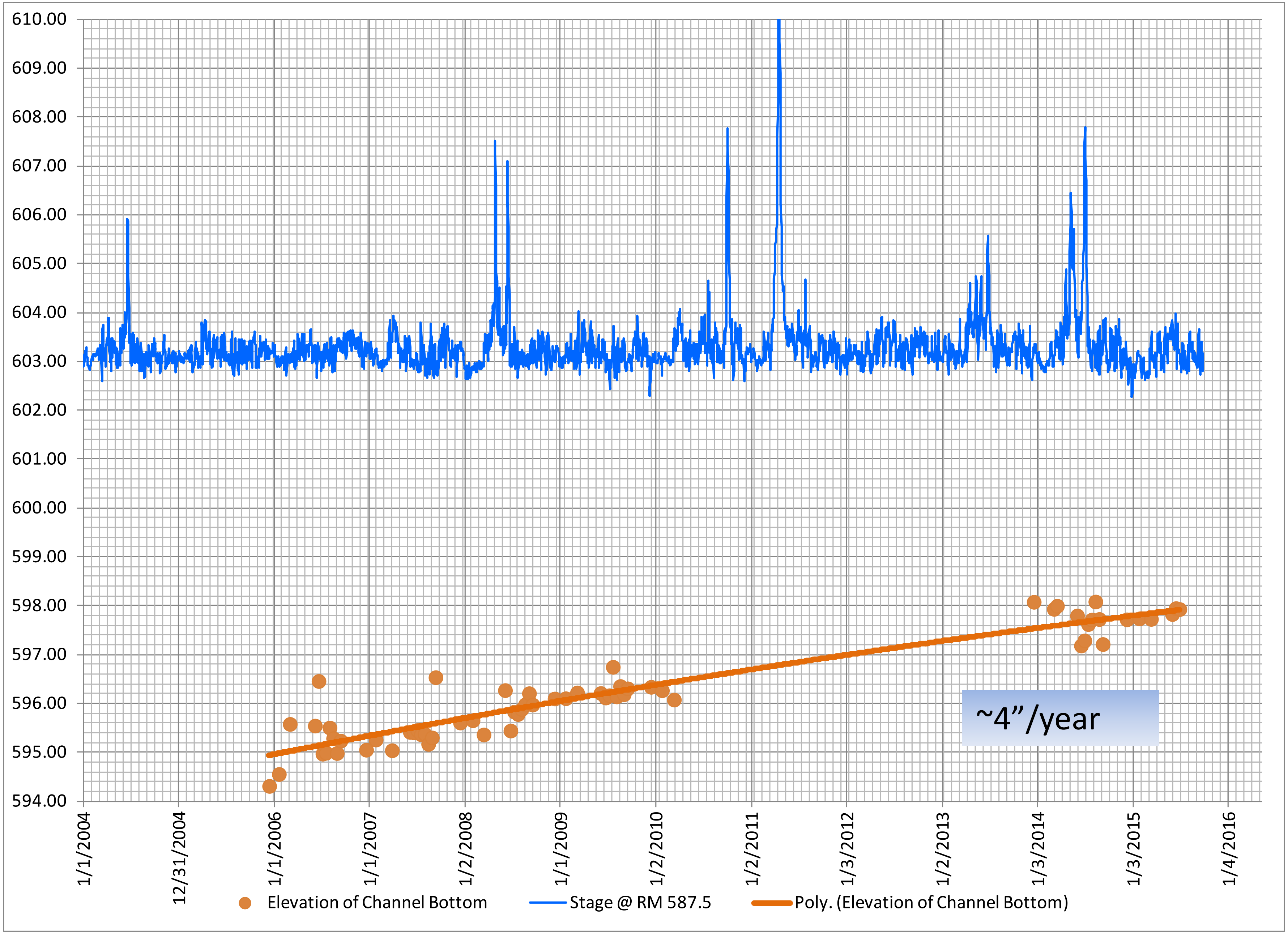
POOL 11 ISLANDS (MUD AND SUNFISH LAKES)
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

APPENDIX B-3

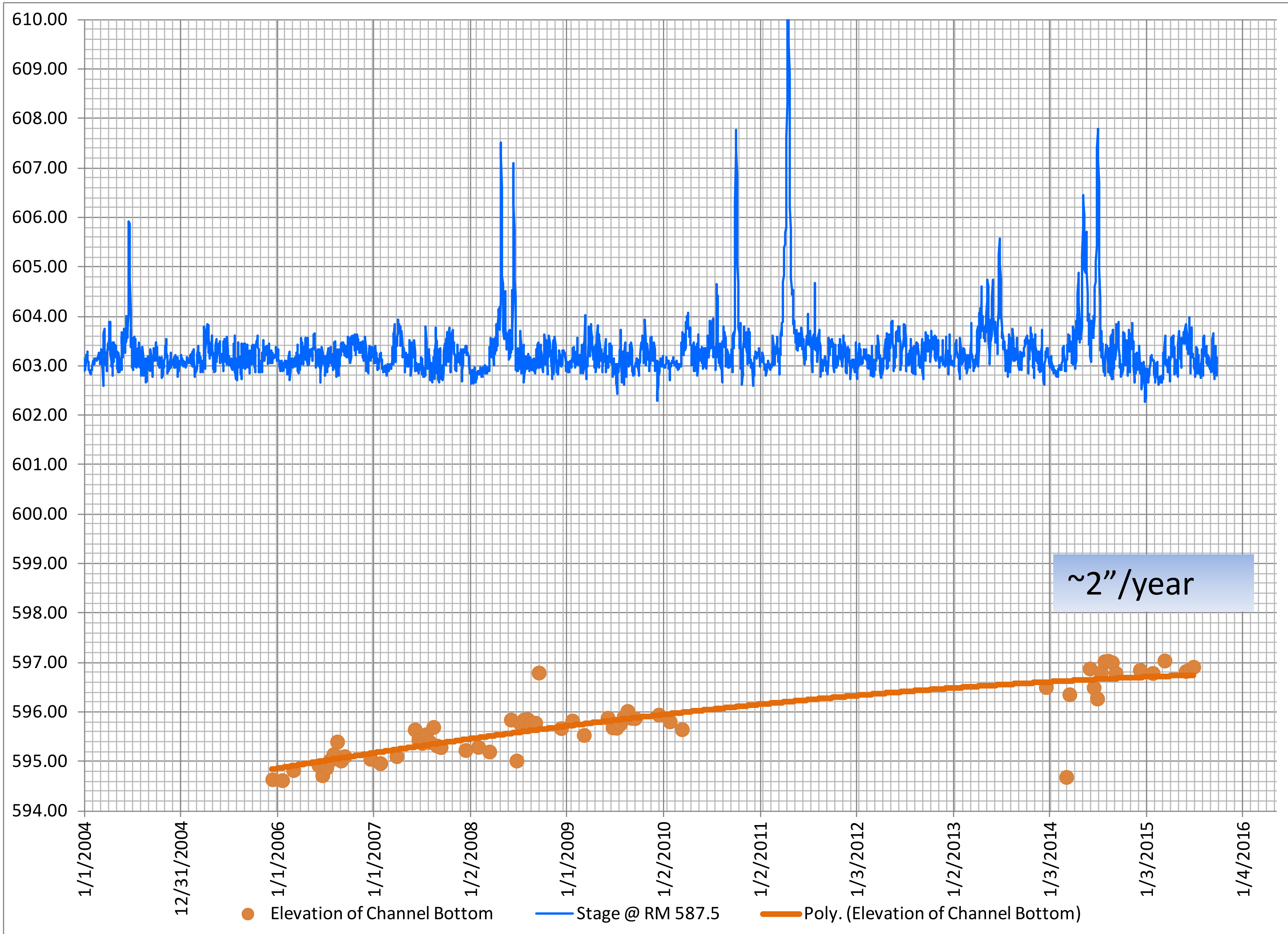
SEDIMENT DEPOSITION TRENDS AT WATER QUALITY MONITORING SITES

Mud Lake Sampling Locations

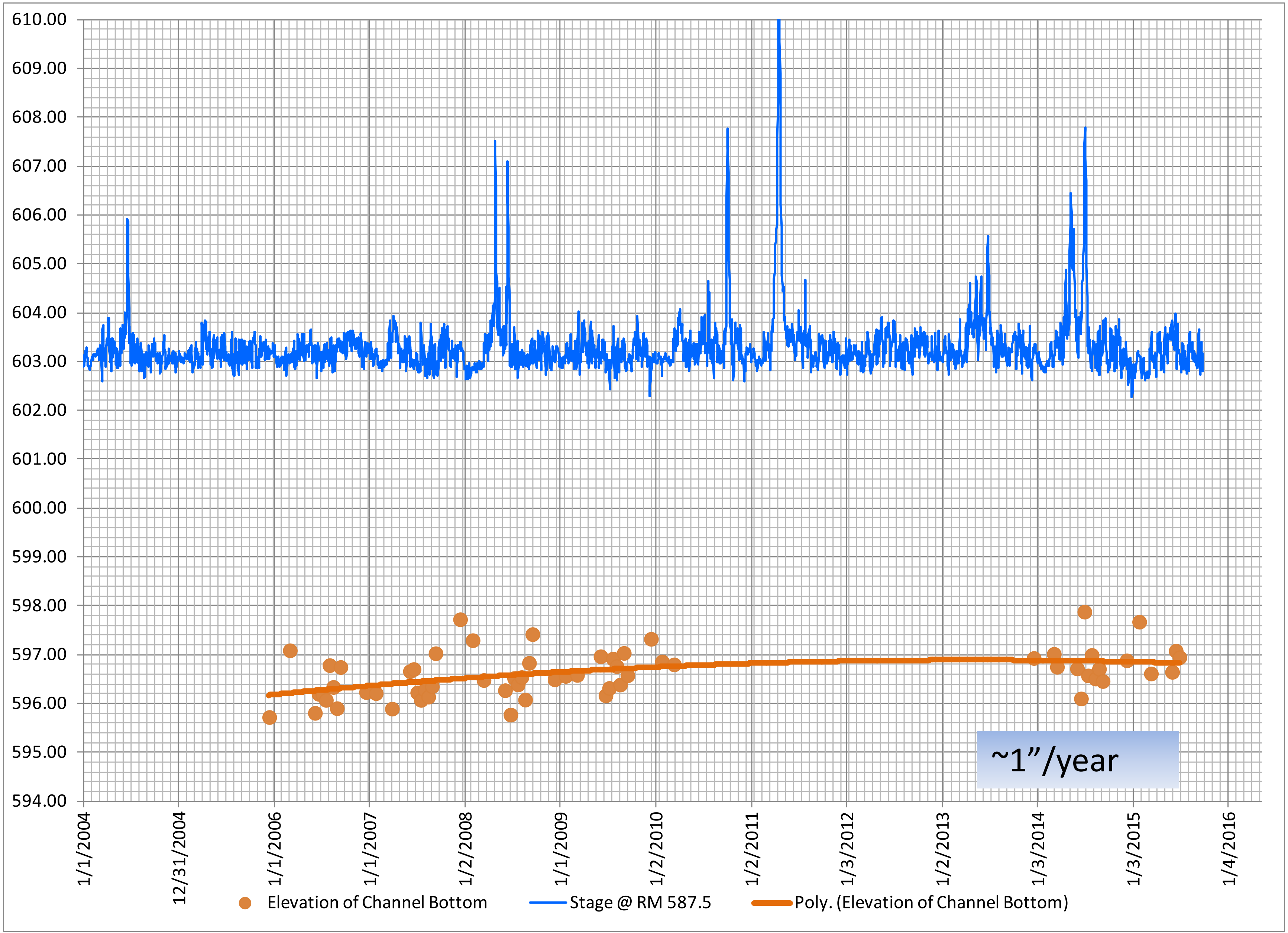
Mud Lake 588.1D



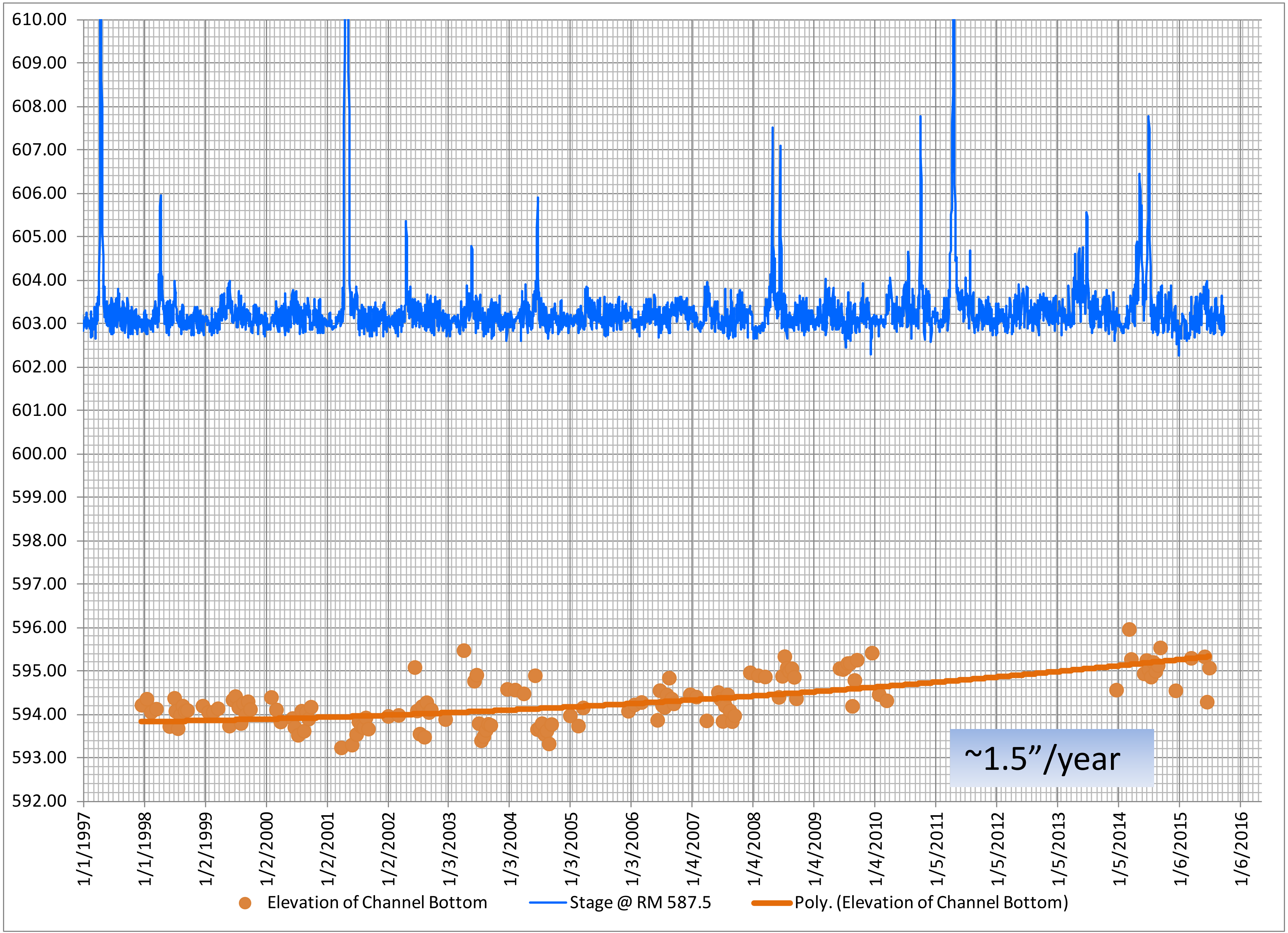
Mud Lake 589.0C



Mud Lake 589.3D

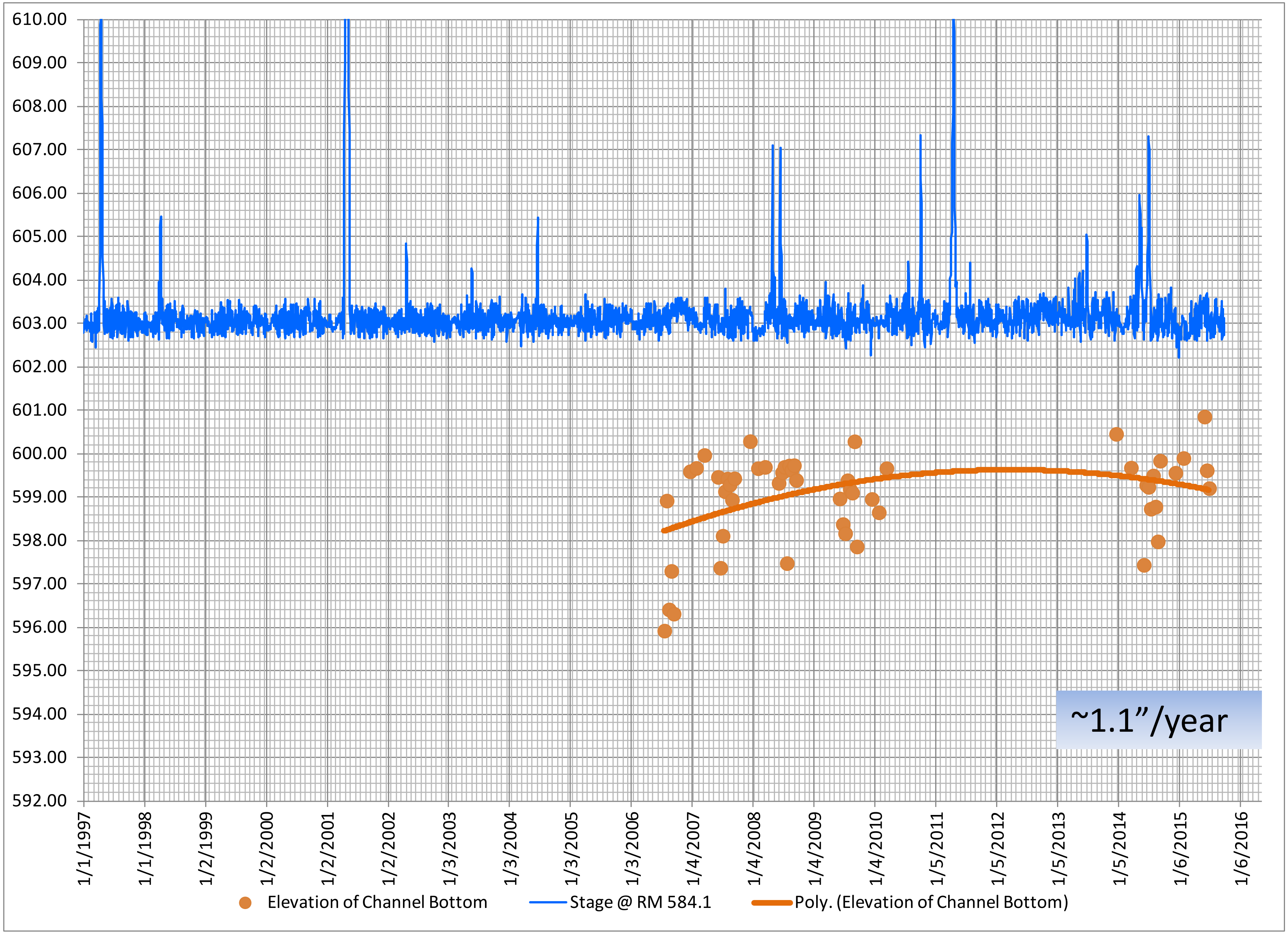


Mud Lake 588.0B

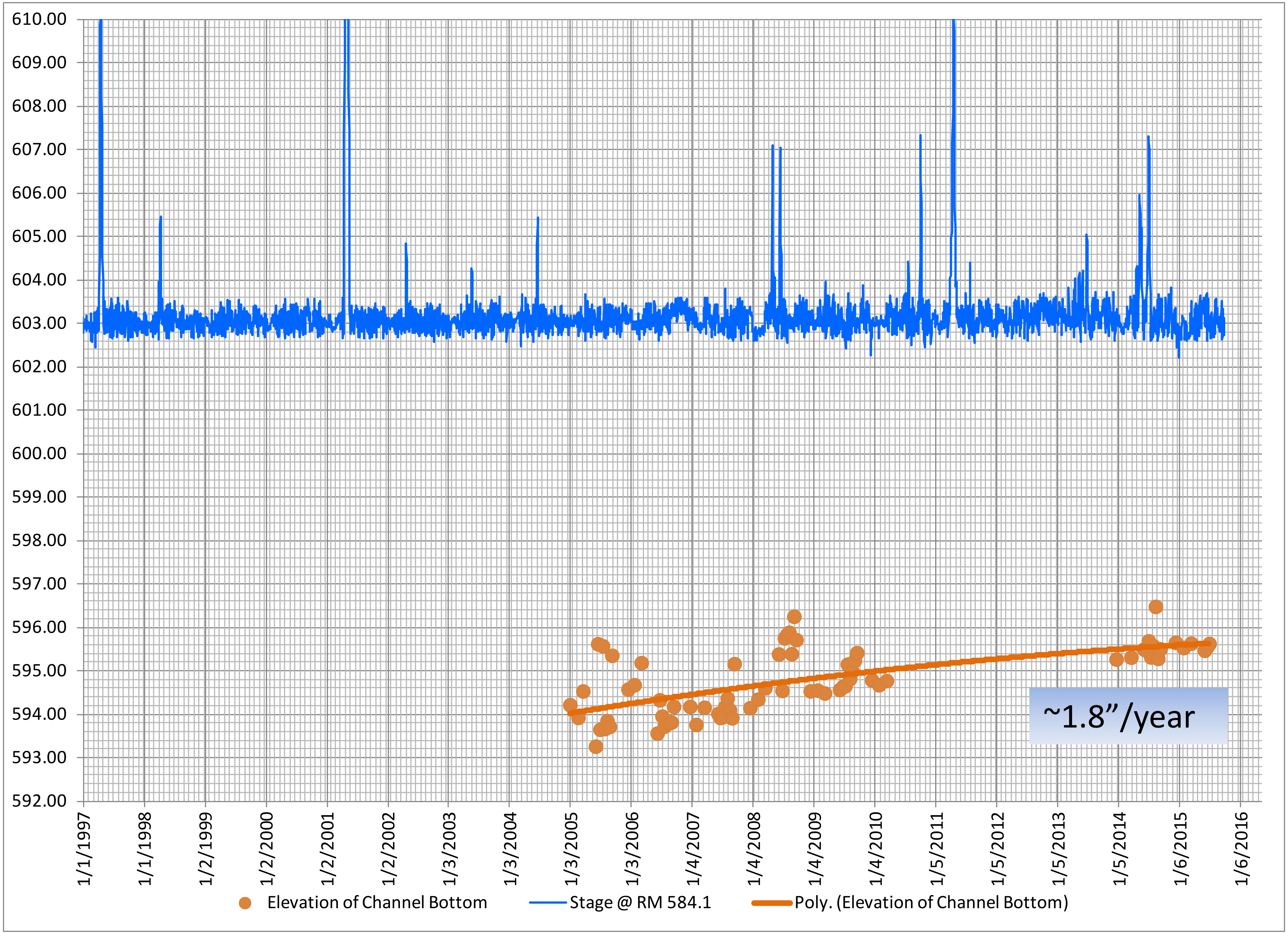


Sunfish Lake Sampling Locations

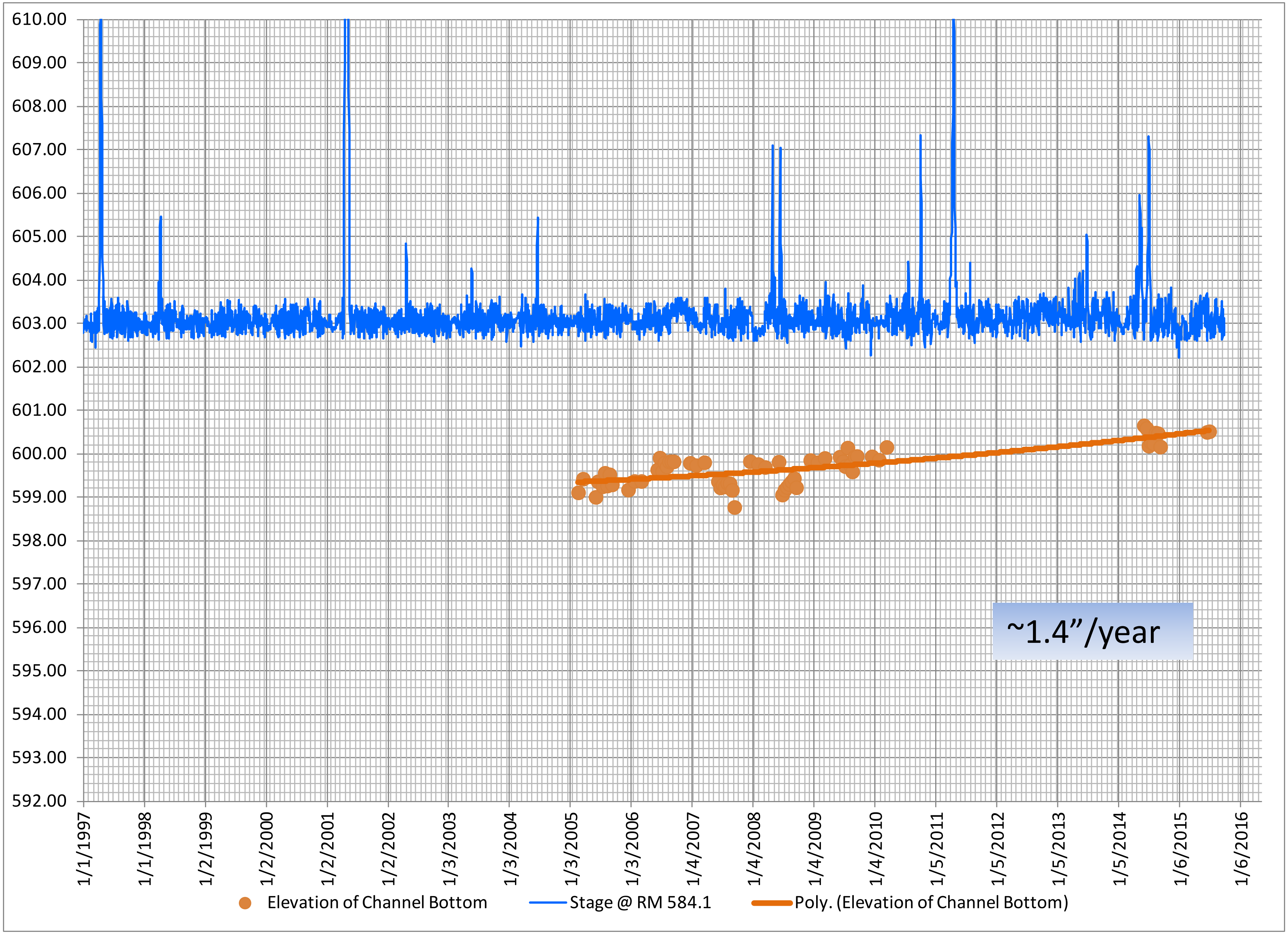
Sunfish 584.2X



Sunfish Lake 583.5R



Sunfish Lake 583.4P

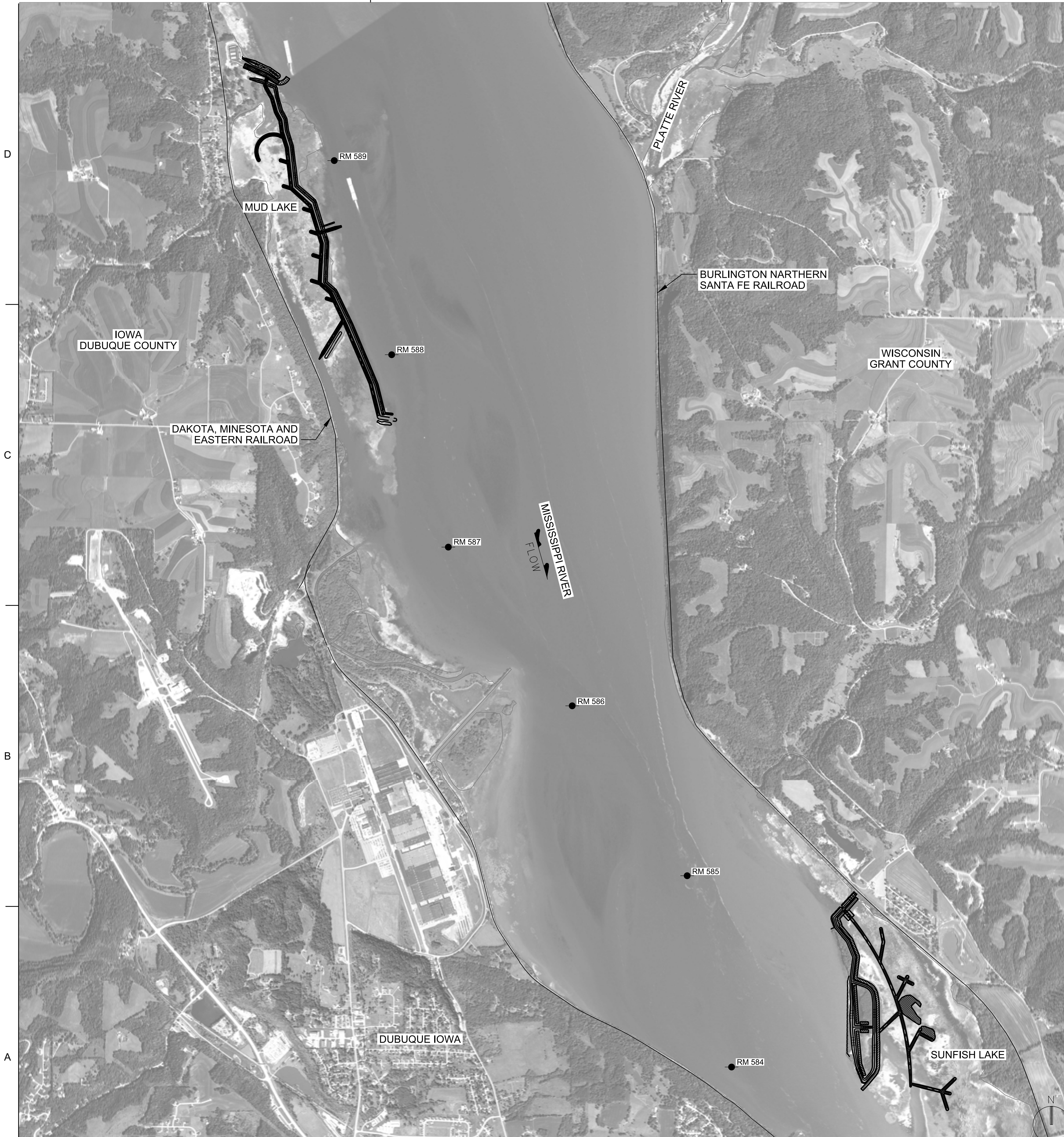


POST-CONSTRUCTION
10-YEAR PERFORMANCE EVALUATION REPORT

POOL 11 ISLANDS (MUD AND SUNFISH LAKES)
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

APPENDIX C

PROJECT PLATES: 2014 BATHYMETRIC SURVEY



A1 SITE PLAN

SCALE: 1:180M 0 360 720

GENERAL NOTES

1. ALL DISTANCES, MEASUREMENTS AND ELEVATIONS SHOWN ARE IN METERS UNLESS OTHERWISE NOTED.
2. SURVEY DATA:
   HORIZONTAL: STATE PLANE NAD83 ILLINOIS WEST METERS
   VERTICAL: NAVD1912 METERS
3. SURVEYS PREFORMED IN NAD83 AND NAVD88 USING GEIOD 12A AND CONVERTED TO THE HISTORIC NAVD1912 ELEVATIONS BY ADDITION OF 0.66 FEET, AND THEN CONVERTED TO METERS BY DIVISION BY 3.28083 FT/M.
4. PHOTOGRAPHY FLOWN IN 2014.

LEGEND

1. POINT:
   - ● - A = WIND MONITORING STATION
   - ● - F = FISH
   - ● - W = WATER QUALITY STATION
2. LOCATION CODE:
   - M ------ = MISSISSIPPI RIVER
   - 545.8 = RIVER MILE
   - ----- H = ALPHA DESIGNATOR
     Z = LEFT DESCENDING BANK
     A = RIGHT DESCENDING BANK

TRANSECT
RIVERMILE
EXISTING EMBANKMENT
EXISTING CHANNEL

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

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

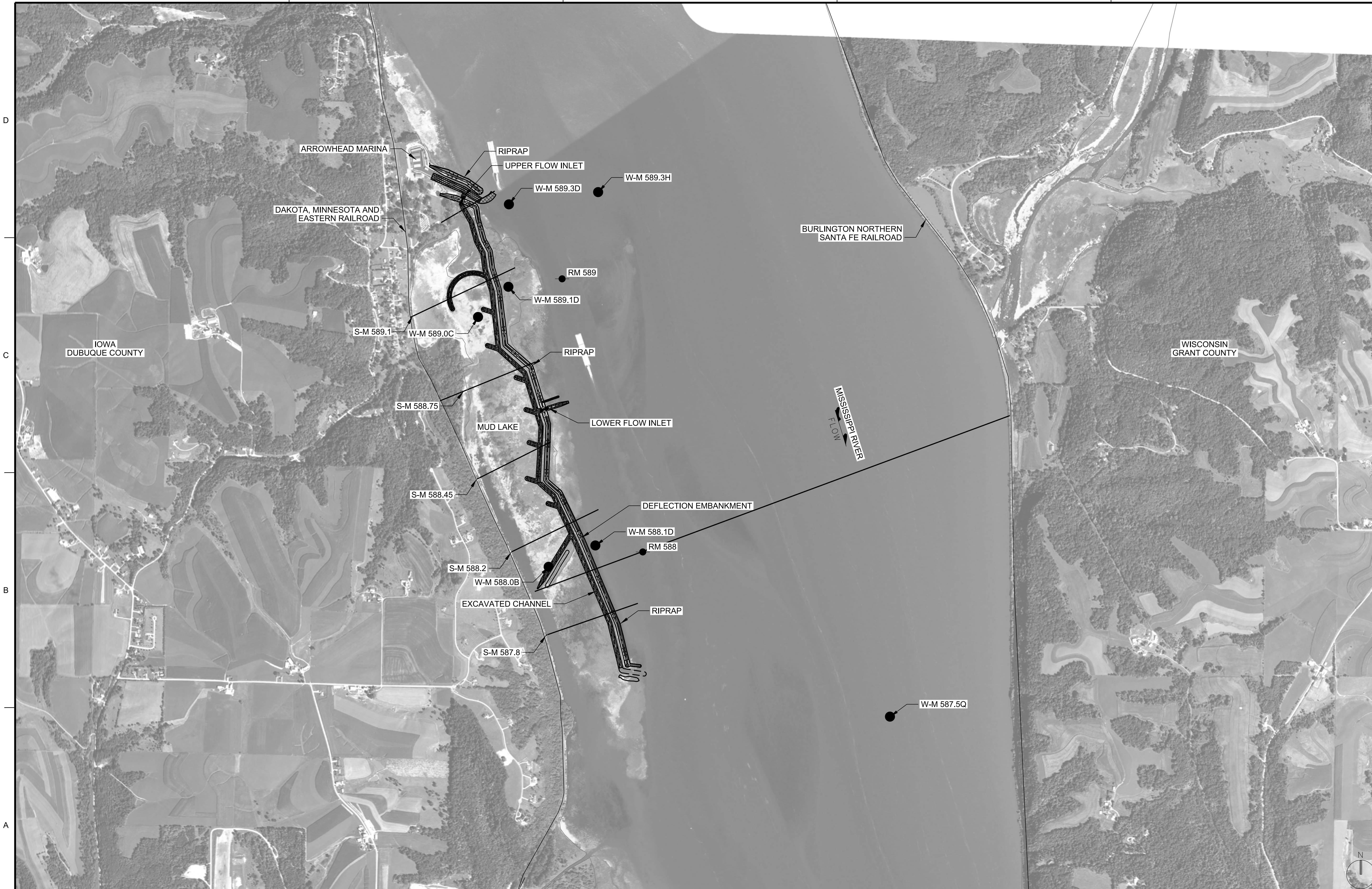
DESIGNED BY: ADH
DWN BY: LLH
CKD BY:
SUBMITTED BY: HLA
PLOT SCALE: AS SHOWN
PLOT DATE:
SIZE: ANSI D
FILE NAME: PER_G-002xxx.dgn
DATE:
SOLICITATION NO.:
CONTRACT NO.:
PROJECT CODE: PER

MISSISSIPPI RIVER
POOL 11 ISLAND
DUBUQUE CO. IA/GRANT CO. WI
POOL 11 ISLAND PERFORMANCE EVALUATION REPORT

SITE PLAN AND GENERAL NOTES

PLATE 01

Sheet ID
G-002



A1 MUD LAKE PLAN

SCALE: 1:100M 0 200 400

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

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

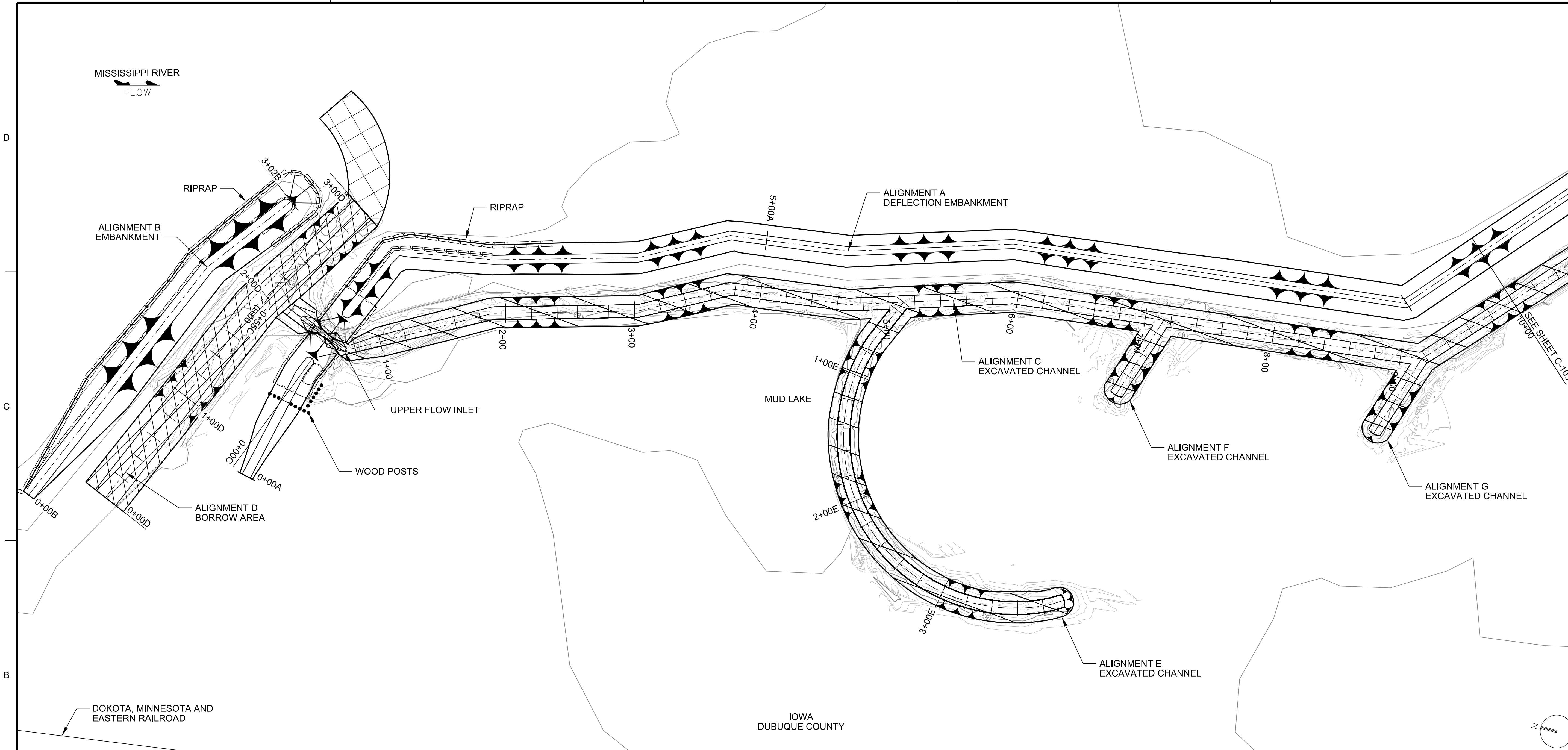
DESIGNED BY: ADH		DATE:
DWN BY: LLH	CKD BY:	SOLICITATION NO.:
SUBMITTED BY: HLA		CONTRACT NO.:
PLOT SCALE: AS SHOWN	PLOT DATE:	PROJECT CODE: PER
SIZE: ANSI D	FILE NAME: PER_C-101xxx.dgn	

MISSISSIPPI RIVER
POOL 11 ISLAND
DUBUQUE CO, IA/GRANT CO, WI
POOL 11 ISLAND PERFORMANCE EVALUATION REPORT

MUD LAKE PLAN

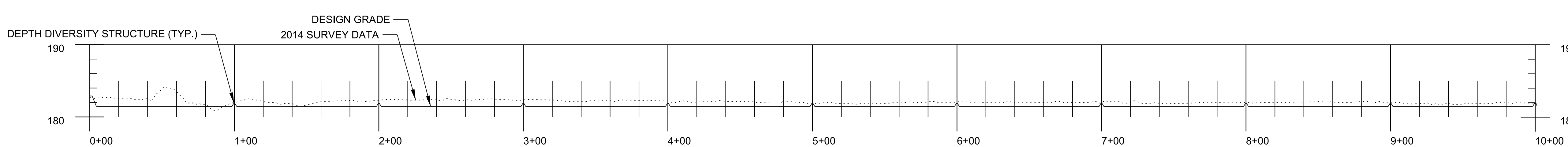
PLATE 02

Sheet ID
C-101



B1 MUD LAKE PLAN STA. 0+00 TO STA. 10+00

SCALE: 1:16M 0 32 64



A1 MUD LAKE PROFILE STA. 0+00 TO STA. 10+00

SCALE: 1:16M 0 32 64

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

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

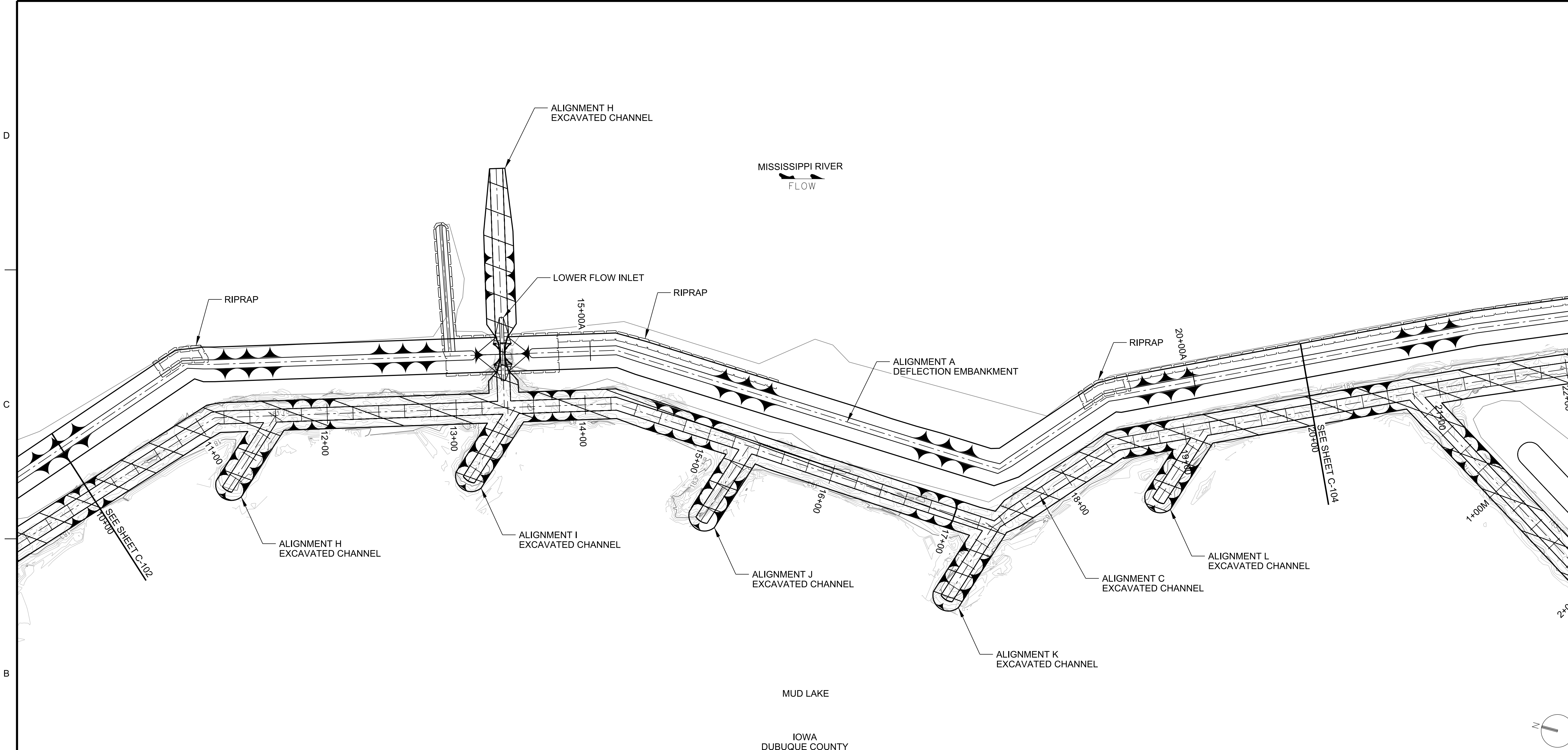
DESIGNED BY: ADH | DATE:
DWN BY: LLH | CKD BY: | SOLICITATION NO.:
SUBMITTED BY: HLA | CONTRACT NO.:
PLOT SCALE: AS SHOWN | PLOT DATE: | PROJECT CODE: PER
SIZE: ANSI D | FILE NAME: PER_C-102xxx.dgn

MISSISSIPPI RIVER
POOL 11 ISLAND
DUBUQUE CO, IA/GRANT CO, WI
POOL 11 ISLAND PERFORMANCE EVALUATION REPORT

MUD LAKE PLAN
STA. 0+00 TO STA. 10+00

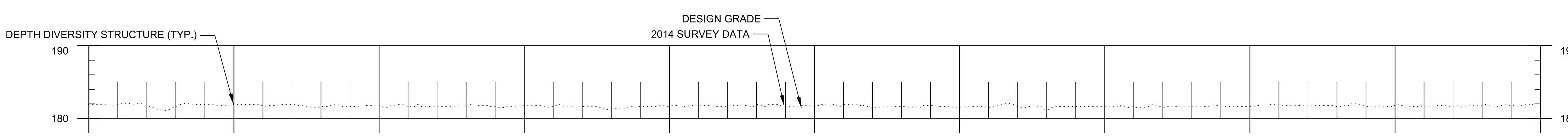
PLATE 03

Sheet ID
C-102



B1 MUD LAKE PLAN STA. 10+00 TO STA. 20+00

SCALE: 1:16M 0 32 64



A1 MUD LAKE PROFILE STA. 10+00 TO STA. 20+00

SCALE: 1:16M 0 32 64

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

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

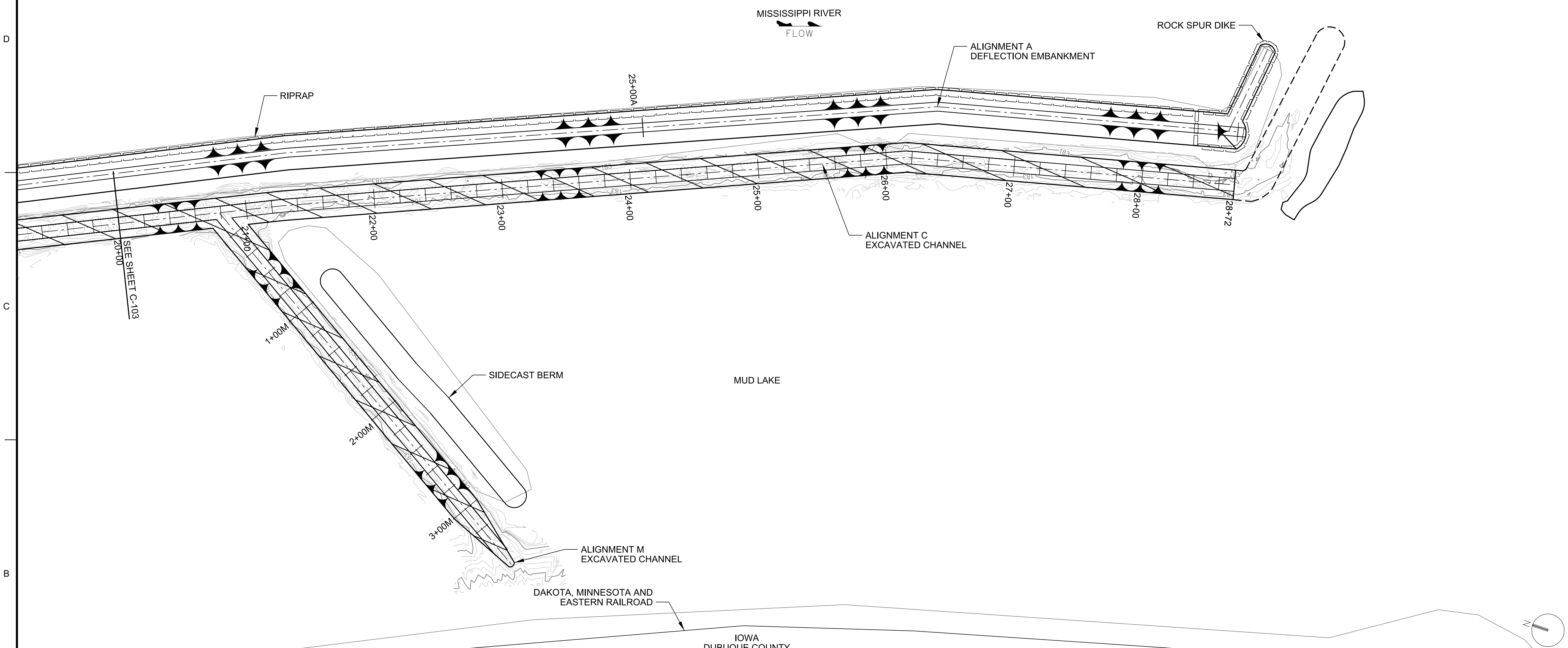
DESIGNED BY: ADH | DATE: | SOLICITATION NO.: | CONTRACT NO.: | PROJECT CODE: PER
DWN BY: LLH | CKD BY:
SUBMITTED BY: HLA
PLOT SCALE: AS SHOWN | PLOT DATE: | FILE NAME: PER_C-103xxx.dgn
SIZE: ANSI D

MISSISSIPPI RIVER
POOL 11 ISLAND
DUBUQUE CO, IA/GRANT CO, WI
POOL 11 ISLAND PERFORMANCE EVALUATION REPORT

MUD LAKE PLAN
STA. 10+00 TO STA. 20+00

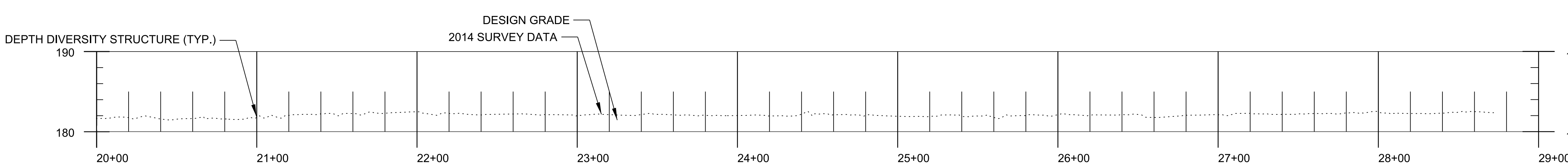
PLATE 04

Sheet ID
C-103



B1 MUD LAKE PLAN STA. 20+00 TO STA. 28+72

SCALE: 1:16M 0 32 64



A1 MUD LAKE PROFILE STA. 20+00 TO STA. 28+72

SCALE: 1:16M 0 32 64

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: ADH
DWN BY: LLH
CKD BY:
SUBMITTED BY: HLA
DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOT SCALE: AS SHOWN
PLOT DATE:
PROJECT CODE: PER
SIZE: ANSI D
FILE NAME: PER_C-104xxx.dgn

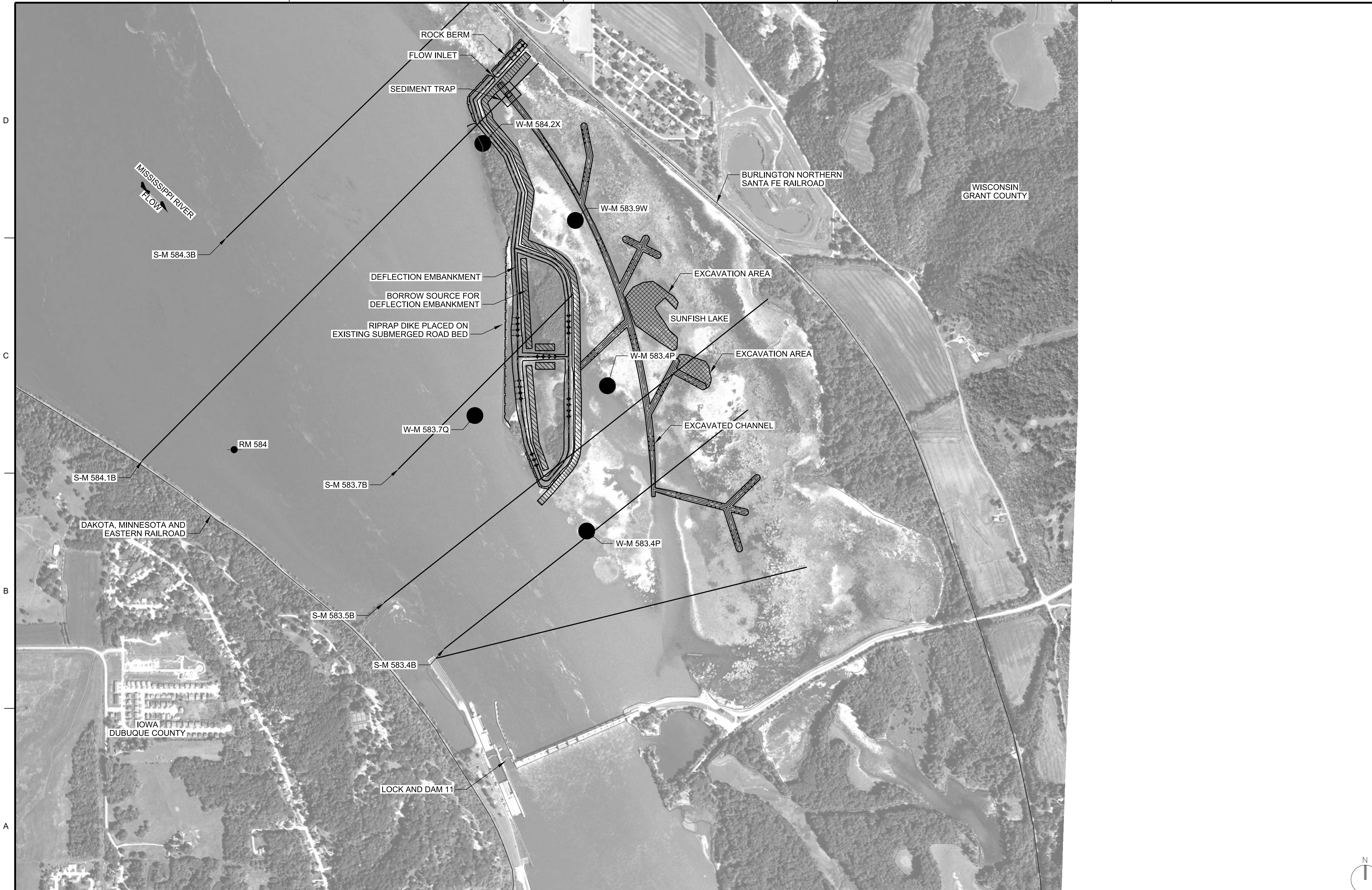
U.S. ARMY CORPS OF ENGINEERS
ROCK ISLAND DISTRICT
ROCK ISLAND, ILLINOIS

MISSISSIPPI RIVER
POOL 11 ISLAND
DUBUQUE CO, IA/GRANT CO, WI
POOL 11 ISLAND PERFORMANCE EVALUATION REPORT

MUD LAKE PLAN
STA. 20+00 TO STA. 28+72

PLATE 05

Sheet ID
C-104



A1 SUNFISH LAKE PLAN

SCALE: 1:60M 0 120 240

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

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

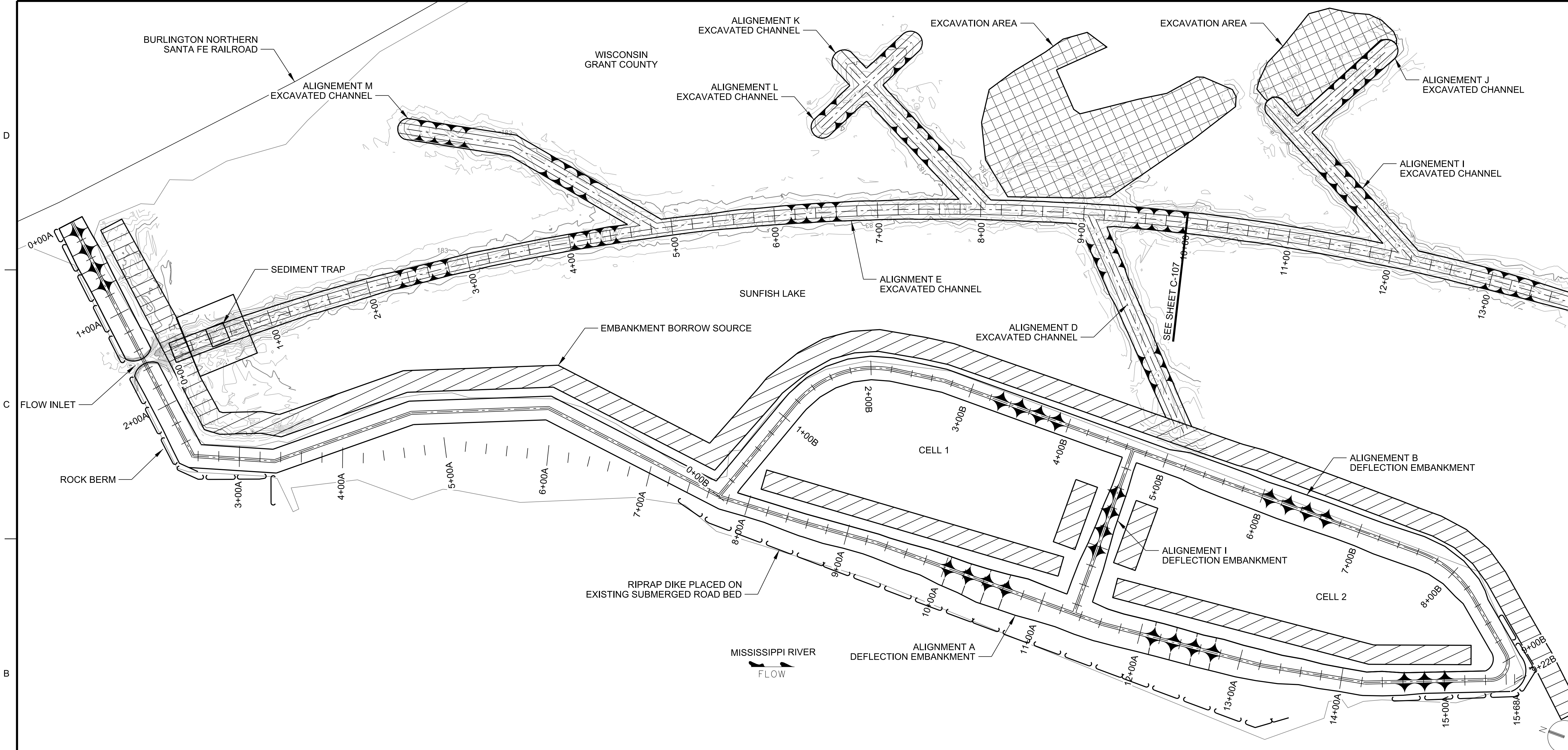
DESIGNED BY: ADH		DATE:
DWN BY: LLH	CKD BY:	SOLICITATION NO.:
SUBMITTED BY: HLA		CONTRACT NO.:
PLOT SCALE: AS SHOWN	PLOT DATE:	PROJECT CODE: PER
SIZE: ANSI D	FILE NAME: PER_C-105xxx.dgn	

MISSISSIPPI RIVER
POOL 11 ISLAND
DUBUQUE CO, IA/GRANT CO, WI
POOL 11 ISLAND PERFORMANCE EVALUATION REPORT

SUNFISH LAKE PLAN

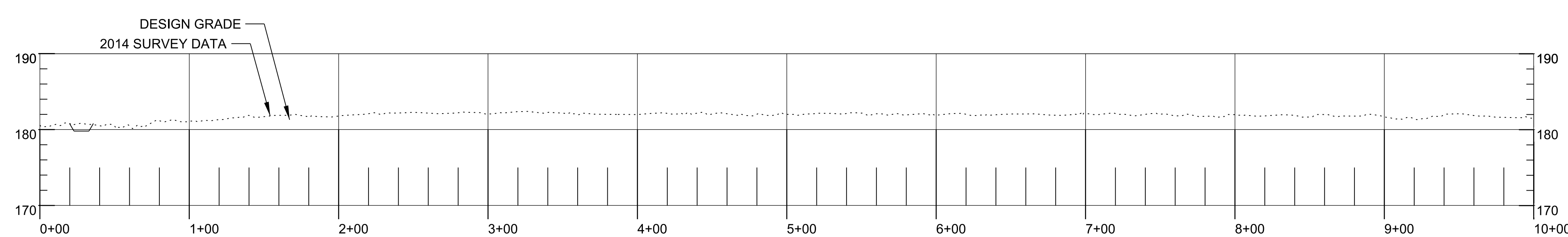
PLATE 06

Sheet ID
C-105



B1 SUNFISH LAKE PLAN STA. 0+00 TO STA. 10+00

SCALE: 1:20M 0 40 80



A1 SUNFISH LAKE PROFILE STA. 0+00 TO STA. 10+00

SCALE: 1:20M 0 40 80

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

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

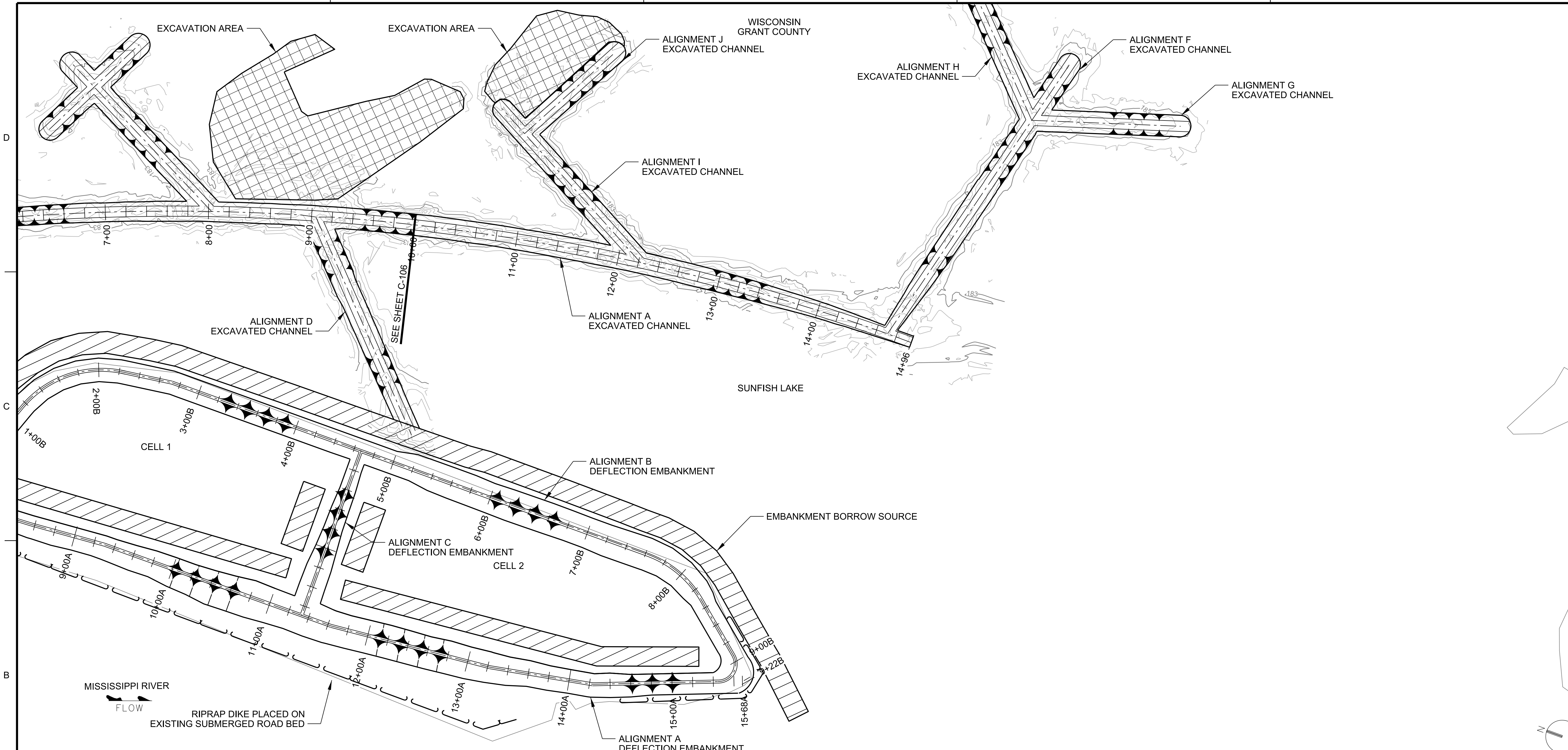
DESIGNED BY: ADH	DWN BY: LLH	SUBMITTED BY: HLA	PLOT SCALE: AS SHOWN
SIZE: ANSI D	CKD BY:	PLOT DATE:	FILE NAME: PER_C-106xxx.dgn
DATE:	SOLICITATION NO.:	CONTRACT NO.:	PROJECT CODE: PER

MISSISSIPPI RIVER
POOL 11 ISLAND
DUBUQUE CO, IA/GRANT CO, WI
POOL 11 ISLAND PERFORMANCE EVALUATION REPORT

SUNFISH LAKE PLAN
STA. 0+00 TO STA. 10+00

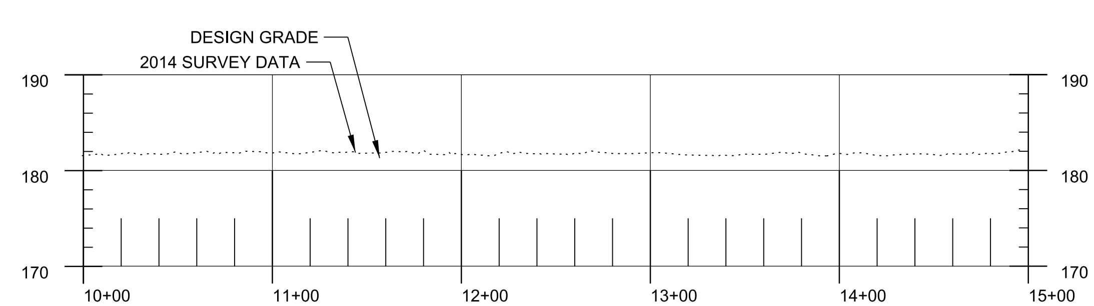
PLATE 07

Sheet ID
C-106



B1 SUNFISH LAKE PLAN STA. 10+00 TO STA. 14+96

SCALE: 1:20M 0 40 80



A1 SUNFISH LAKE PROFILE STA. 10+00 TO STA. 14+96

SCALE: 1:20M 0 40 80

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

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

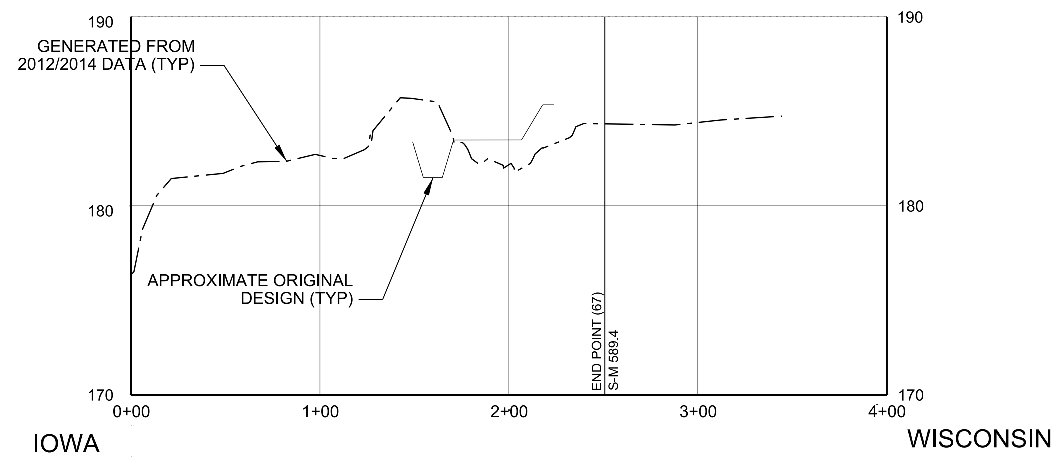
DESIGNED BY: ADH | DATE: | SOLICITATION NO.:
DWN BY: LLH | CKD BY: | CONTRACT NO.:
SUBMITTED BY: HLA | PLOT SCALE: AS SHOWN | PLOT DATE: | PROJECT CODE: PER
SIZE: ANSI D | FILE NAME: PER_C-107xxx.dgn

MISSISSIPPI RIVER
POOL 11 ISLAND
DUBUQUE CO. IA/GRANT CO. WI
POOL 11 ISLAND PERFORMANCE EVALUATION REPORT

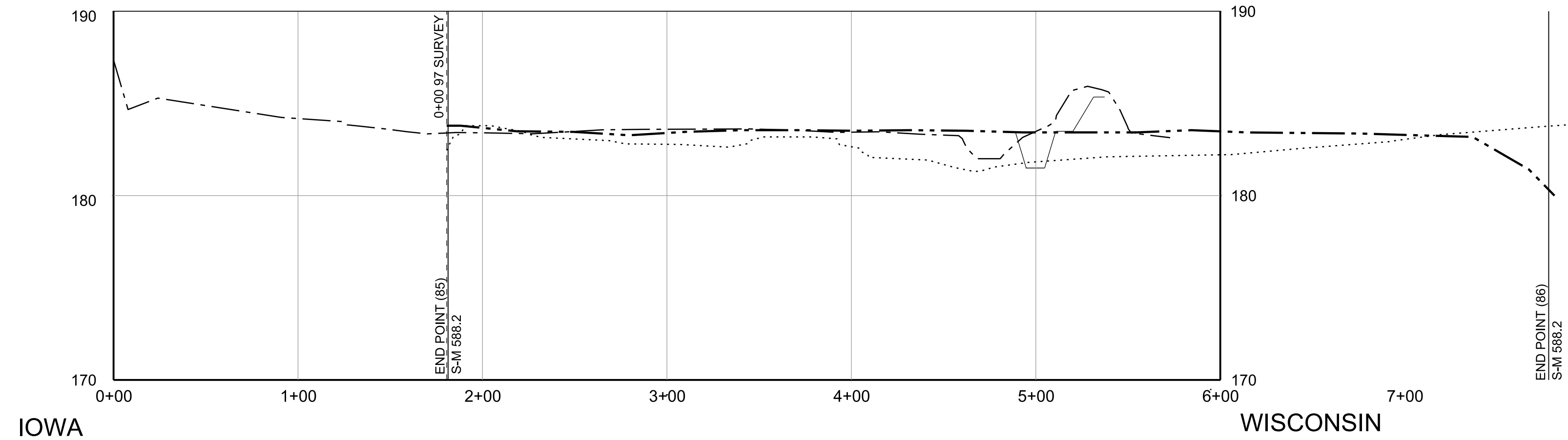
SUNFISH LAKE PLAN
STA. 10+00 TO STA. 14+96

PLATE 08

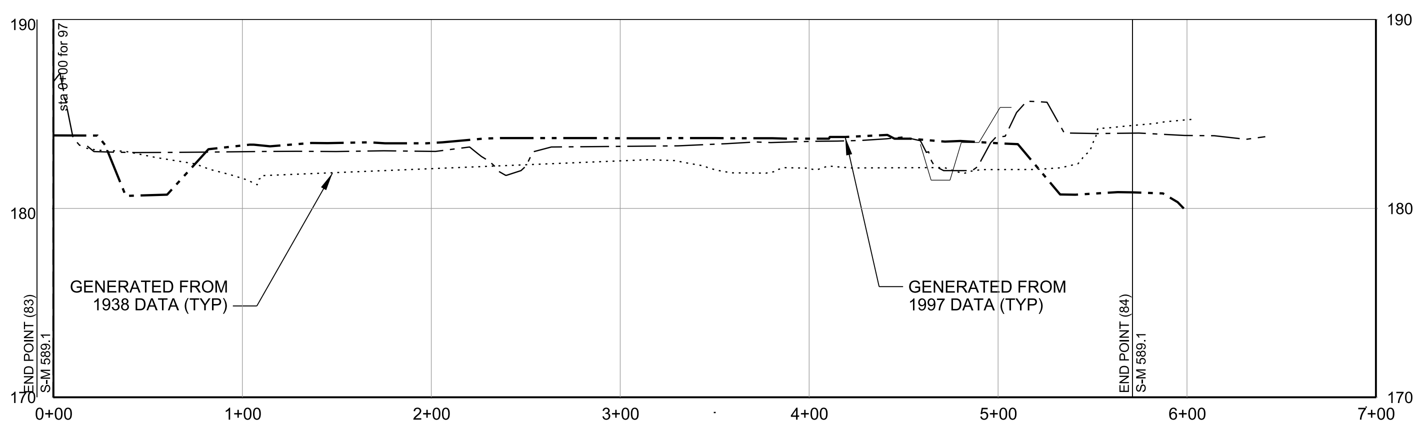
Sheet ID
C-107



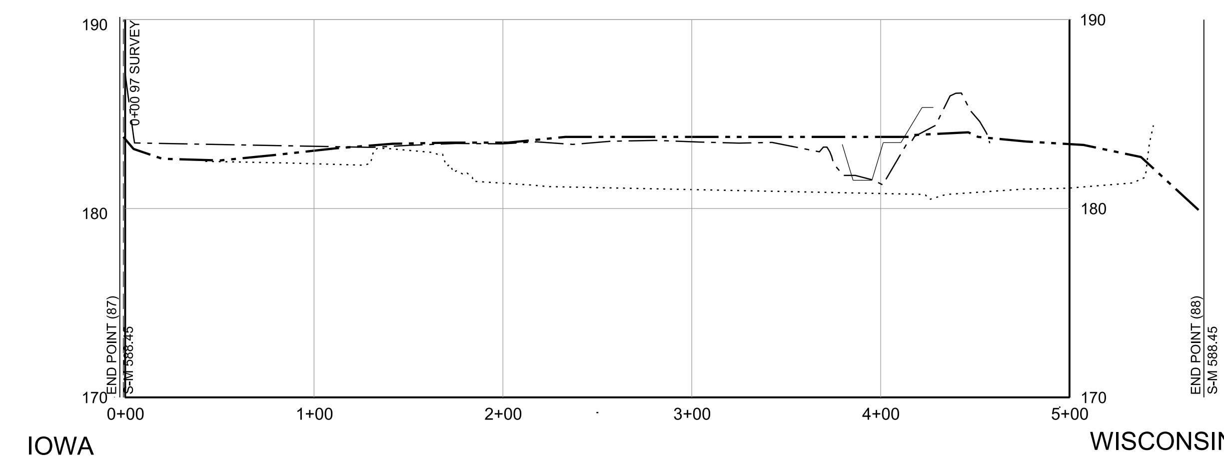
PART TRANSECT 67-68 @ RM 589.4



PART TRANSECT 85-86 @ RM 588.2



PART TRANSECT 83-84 @ RM 589.1



PART TRANSECT 87-88 @ RM 588.4

APPROXIMATE ORIGINAL DESIGN
GENERATED FROM 2012/2014 DATA
GENERATED FROM 1997 DATA
GENERATED FROM 1938 DATA

A1 MUD LAKE TRANSECTS

SCALE: 1:10M 0 20 40

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: ADH
DWN BY: LLH
CKD BY:
SUBMITTED BY: HLA
PLOT SCALE: AS SHOWN
SIZE: ANSI D
PLOT DATE:
FILE NAME: PER_C-301xxx.dgn
DATE:
SOLICITATION NO.:
CONTRACT NO.:
PROJECT CODE: PER

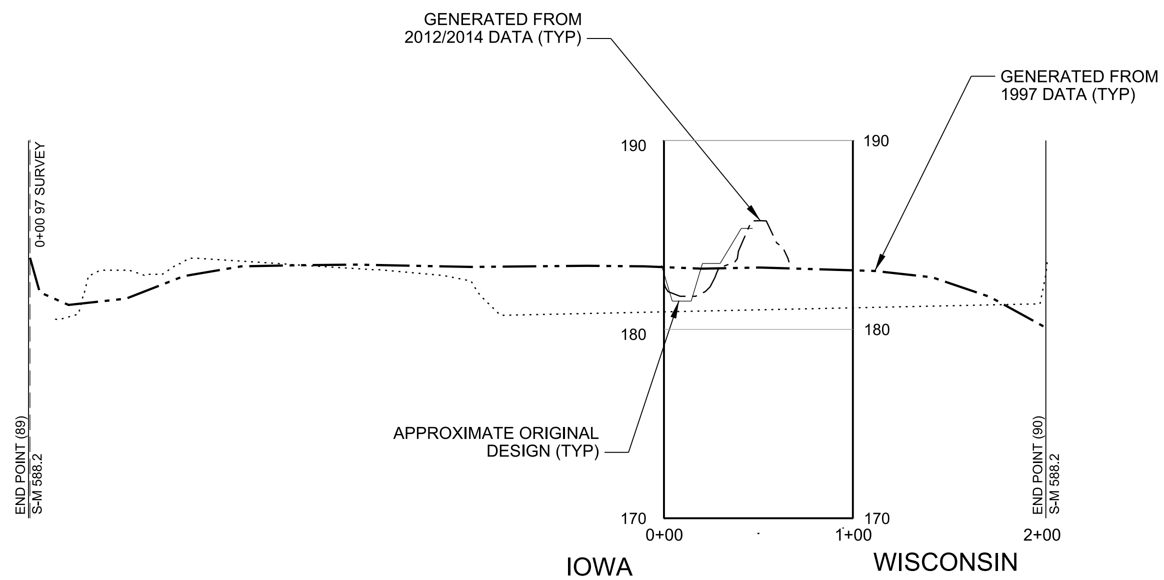
U.S. ARMY CORPS OF ENGINEERS
ROCK ISLAND DISTRICT
ROCK ISLAND, ILLINOIS

MISSISSIPPI RIVER
POOL 11 ISLAND
DUBUQUE CO, IA/GRANT CO, WI
POOL 11 ISLAND PERFORMANCE EVALUATION REPORT

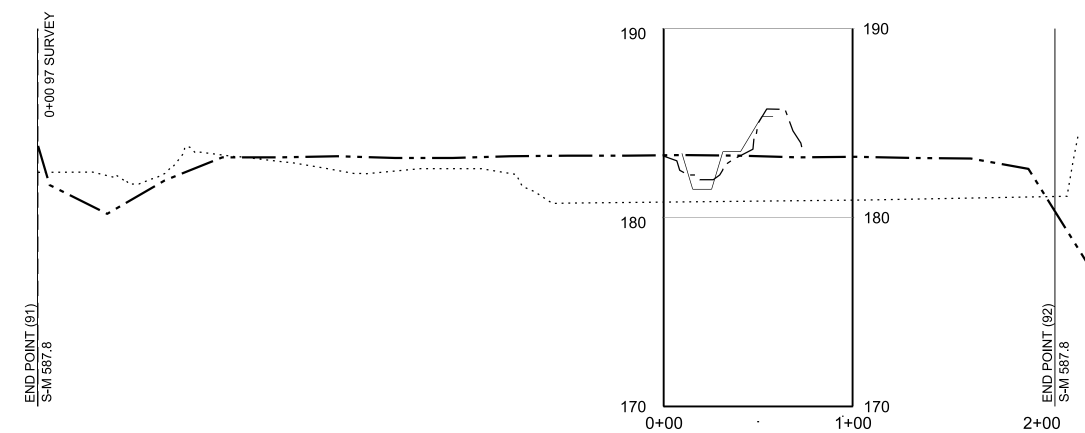
MUD LAKE TRANSECTS

PLATE 09

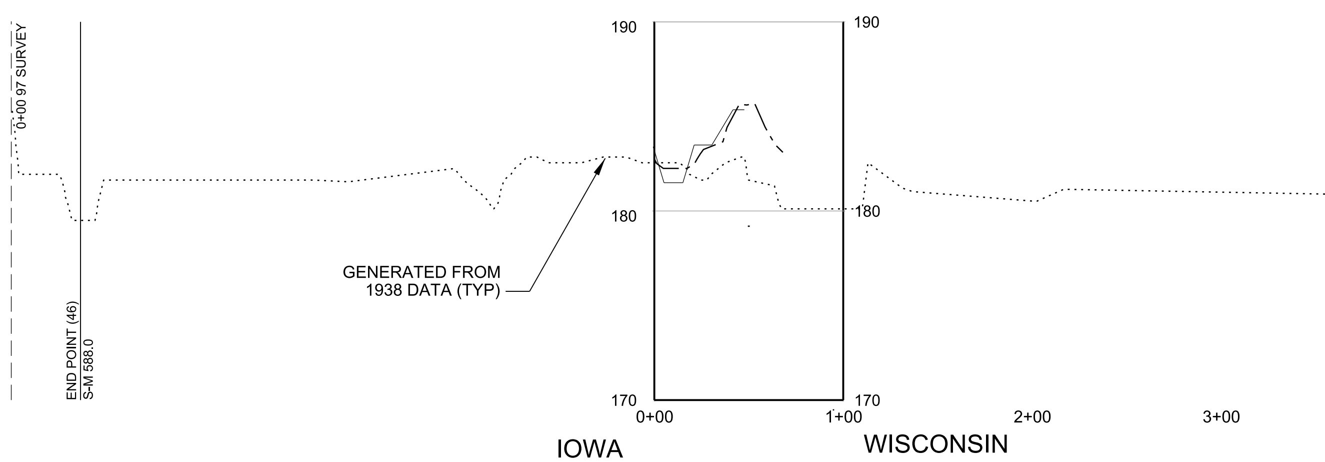
Sheet ID
C-301



PART OF TRANSECT 89-90 @ RM 588.2



PART OF TRANSECT 91-92 @ RM 587.8



PART OF TRANSECT 46-45 @ RM 588.0

APPROXIMATE ORIGINAL DESIGN
GENERATED FROM 2012/2014 DATA
GENERATED FROM 1997 DATA
GENERATED FROM 1938 DATA

A1 MUD LAKE TRANSECTS

SCALE: 1:10M 0 20 40

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

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

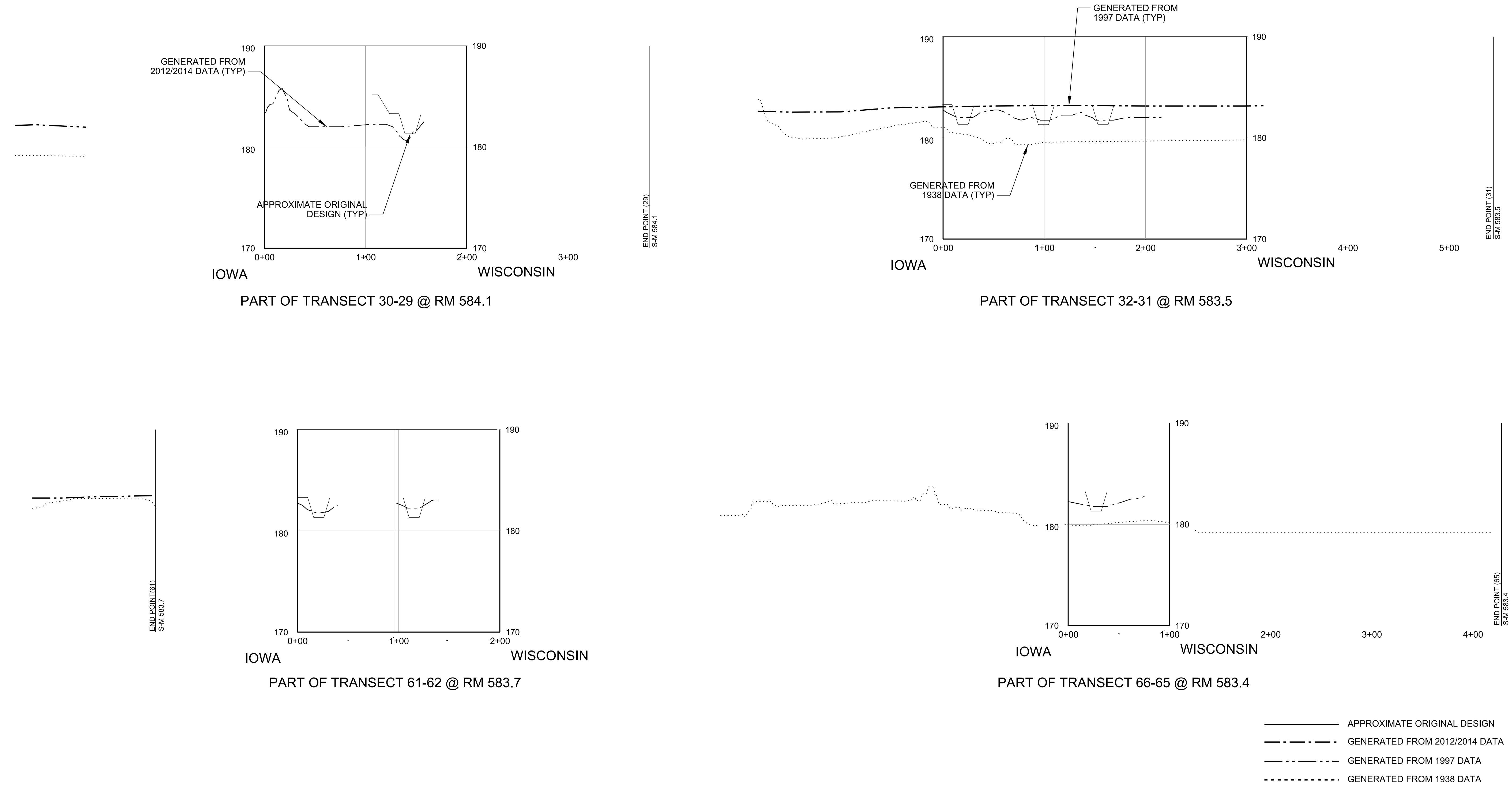
DESIGNED BY: ADH | DATE: | DWN BY: LLH | CKD BY: | SOLICITATION NO.: | SUBMITTED BY: HLA | CONTRACT NO.: | PLOT SCALE: AS SHOWN | PLOT DATE: | PROJECT CODE: PER | SIZE: ANSI D | FILE NAME: PER_C-302xxx.dgn

MISSISSIPPI RIVER
POOL 11 ISLAND
DUBUQUE CO, IA/GRANT CO, WI
POOL 11 ISLAND PERFORMANCE EVALUATION REPORT

MUD LAKE TRANSECTS

PLATE 10

Sheet ID
C-302



A1 SUNFISH LAKE TRANSECTS

SCALE: 1:10M

US Army Corps of Engineers®

MARK | DATE | APPR. | DESCRIPTION

DESIGNED BY: ADH | DATE: | SOLICITATION NO.: | CONTRACT NO.: | PROJECT CODE: PER

DWN BY: LLH | CKD BY: | SUBMITTED BY: HLA | PLOT SCALE: AS SHOWN | PLOT DATE: | SIZE: ANSI D | FILE NAME: PER_C-303xxx.dgn

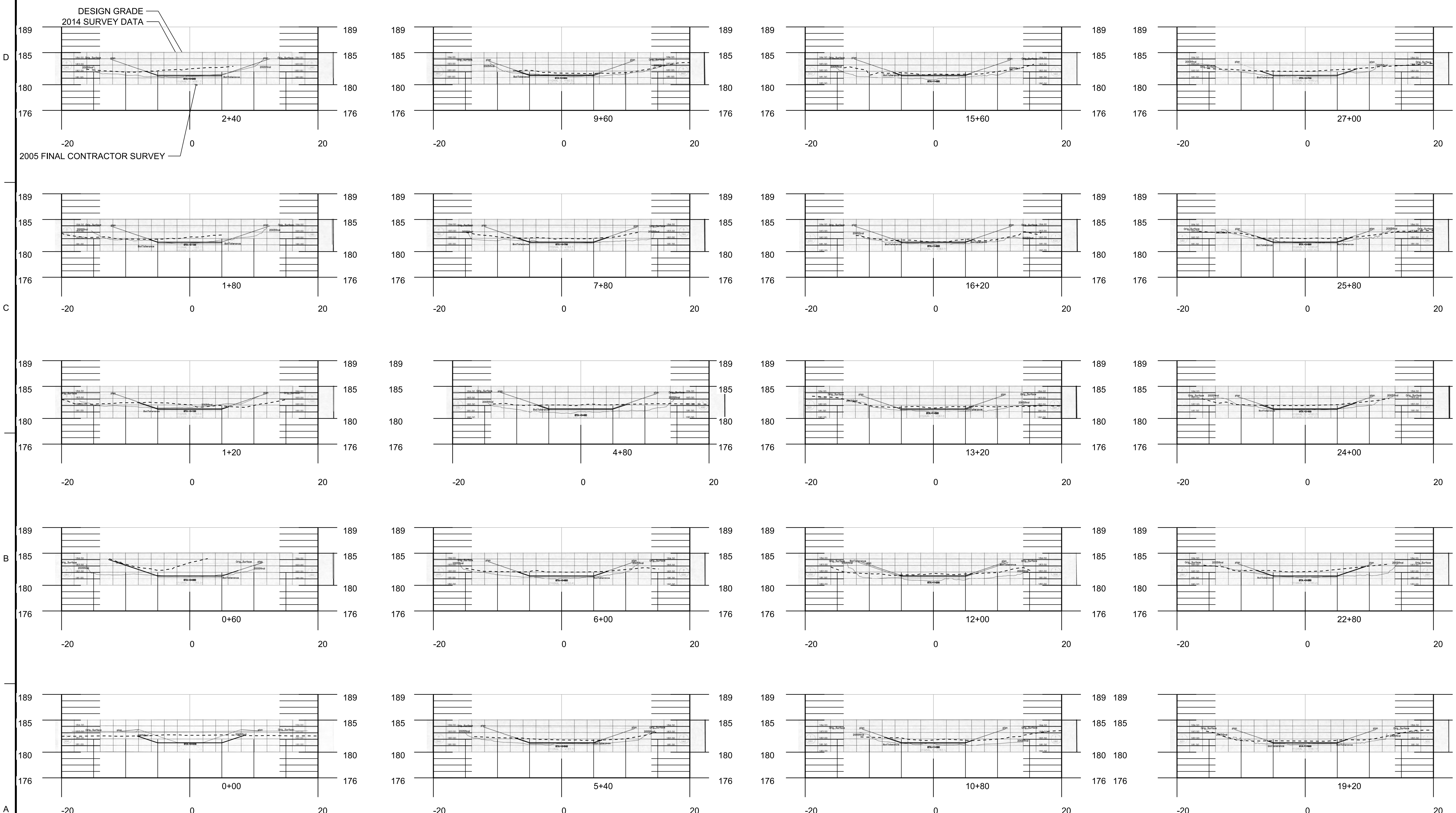
U.S. ARMY CORPS OF ENGINEERS
ROCK ISLAND DISTRICT
ROCK ISLAND, ILLINOIS

MISSISSIPPI RIVER
POOL 11 ISLAND
DUBUQUE CO, IA/GRANT CO, WI
POOL 11 ISLAND PERFORMANCE EVALUATION REPORT

SUNFISH LAKE TRANSECTS

PLATE 11

Sheet ID
C-303



A1 MUD LAKE CROSS SECTIONS

SCALE: 1:3M 0 6 12

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

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

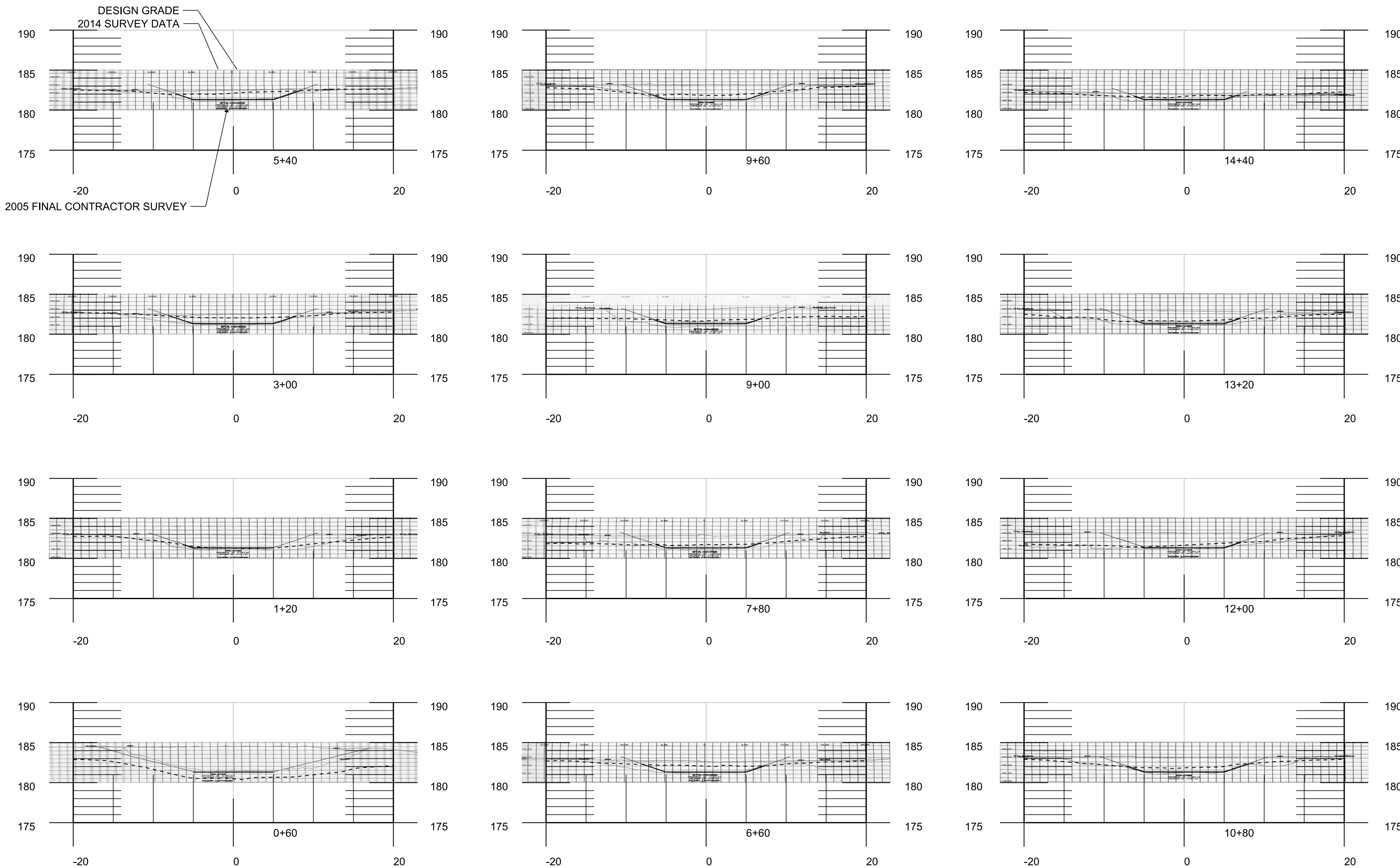
DESIGNED BY: ADH
DWN BY: LLH
CKD BY:
SUBMITTED BY: HLA
DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOT SCALE: AS SHOWN
PLOT DATE:
PROJECT CODE: PER
SIZE: ANSI D
FILE NAME: PER_C-304xxx.dgn

MISSISSIPPI RIVER
POOL 11 ISLAND
DUBUQUE CO, IA/GRANT CO, WI
POOL 11 ISLAND PERFORMANCE EVALUATION REPORT

MUD LAKE CROSS SECTIONS

PLATE 12

Sheet ID
C-304



A1 SUNFISH LAKE CROSS SECTIONS

SCALE: 1:3M

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

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

DESIGNED BY: ADH	DATE:		
DWN BY: LLH	CKD BY:	SOLICITATION NO.:	
SUBMITTED BY: HLA		CONTRACT NO.:	
PLOT SCALE: AS SHOWN	PLOT DATE:	PROJECT CODE: PER	
SIZE: ANSI D	FILE NAME: PER_C-305xxx.dgn		

MISSISSIPPI RIVER
POOL 11 ISLAND
DUBUQUE CO, IA/GRANT CO, WI
POOL 11 ISLAND PERFORMANCE EVALUATION REPORT

SUNFISH LAKE CROSS SECTIONS

PLATE 13

Sheet ID
C-305