Advancing Lake Red Rock Reservoir Management Practices to Maximize Ecological Benefits: From Planning to Monitoring

Chuck Theiling[1], Alyssa Calomeni[1], Nicole Bosco[2], Steve Dinsmore[2], Hugh Howe[3], Todd Gosselink[4], Keith Schilling[5], Matthew Streeter[5], and Perry Thostenson[3]

INTRODUCTION

The Upper Midwest USA has highly developed agricultural landscapes with significant alterations to land cover and hydrology. Landscape conversion eliminated 89 percent of the wetlands and up to 99 percent in the shallow prairie pothole wetlands in Iowa (Bishop et al. 1998). Two flood control dams, Saylorville Lake and Lake Red Rock situated on the Des Moines River above and below Des Moines, Iowa, support extensive wetlands and are managed for multiple uses including flood risk management, low flow augmentation, fish and wildlife management, and recreation, and additionally for hydropower at Lake Red Rock. The Des Moines River reservoir tributary deltas are deemed "Important Bird Areas" by the National Audubon Society that cited its values of rare or unique habitats and significant species concentrations. Waterbirds are consistently attracted to these reservoirs during fall migration when declining water levels expose vast mudflats that are colonized by annual plants (Vanausdall and Dinsmore 2021). This heterogeneous habitat is especially attractive to shorebirds (July through September) and waterfowl (August through November). In addition, river nitrate loads were reduced by 4.9 percent, on average, within Saylorville Lake reservoir, with greater nitrate loss occurring in low flow years with greater retention time compared to high flow years with rapid flushing (Stenback et al. 2014). Overall, water quality, wetland, and wildlife benefits occur during the regular, routine management of water levels to maintain the reservoir's designated uses.

Recognition of the passive environmental benefits achieved in these Iowa reservoirs led US Army Corps of Engineers lake managers and stakeholders to consider actions to increase the ecosystem services derived from Des Moines River flood control dams, including decreasing nitrate concentrations and increasing wetland distribution and waterbird habitat benefits. A Sustainable Rivers Program (SRP) environmental flows workshop (Warner et al. 2014) was held in 2016 to consider water management measures to increase ecosystem benefits derived from Saylorville Lake and Lake Red Rock. Where the SRP had previously focused primarily on downstream reservoir releases for riverine habitat improvements, the Des Moines River workshop also considered Environmental Pool Management (EPM) which was first implemented on the Mississippi River in 1994. EPM is the modification of reservoir and navigation pool water management to better mimic natural flows while remaining consistent with project authorizations.

The objective of this article is to describe the Des Moines River environmental flows evaluations and recommendations, their codification in new water control regulations, and to introduce the ecological benefits monitoring being conducted at Lake Red Rock.

LAKE RED ROCK

Lake Red Rock is a 6,171 ha (15,507 ac) reservoir formed following the completion of the Red Rock dam on the Des Moines River in 1969; it is the largest lake in Iowa. Flood management activities generally occur only 20 percent of the time during April to May which means water can be managed for environmental purposes the remainder of the year. The Lake Red Rock delta does not replace the dispersed small wetlands of the pre-settlement landscape (now lost), but it does provide approximately 2,800 ha (7,000 ac) of riverine delta habitat with extensive wetlands and mudflats. The "large manmade reservoir" wetland habitat class increased by ~4,000 ha (~10,000 ac) between 1980 to 1997 (Bishop et al. 1998), likely due to delta growth from sedimentation in Saylorville Lake and Lake Red Rock. There has not been any substantial reduction in sedimentation, so delta expansion continues (Figure 1) which is typical of many US reservoirs.

Prior environmental considerations for Lake Red Rock water management were limited to conservation pool maintenance, low flow releases, and a 0.6 m (2 ft) fall reservoir rise to support migratory waterfowl and hunter access to the delta region. In 2018, several environmental and operational needs necessitated a review of the Des Moines River Basin Master Reservoir Regulation Manual (RRM). Key indicators of a need for modifications to the RRM were: 1) significant increases in the magnitude and frequency of flooding events, 2) sedimentation rates within Saylorville Lake, and 3) the need to codify environmental deviations in water-control plans (i.e., EPM) approved from 2016 to 2018 (USACE Rock Island District 2019).

1 US Army Corps of Engineers, Engineer Research and Development Center, Vicksburg, MS, Corresponding author contact: Charles.h.theilng@usace.army.mil
2 Iowa State University, Ames, IA
3 Lake Red Rock, Knoxville, IA
4 Iowa Department of Natural Resources, Knoxville, IA ,
5 University of Iowa, Iowa City, IA

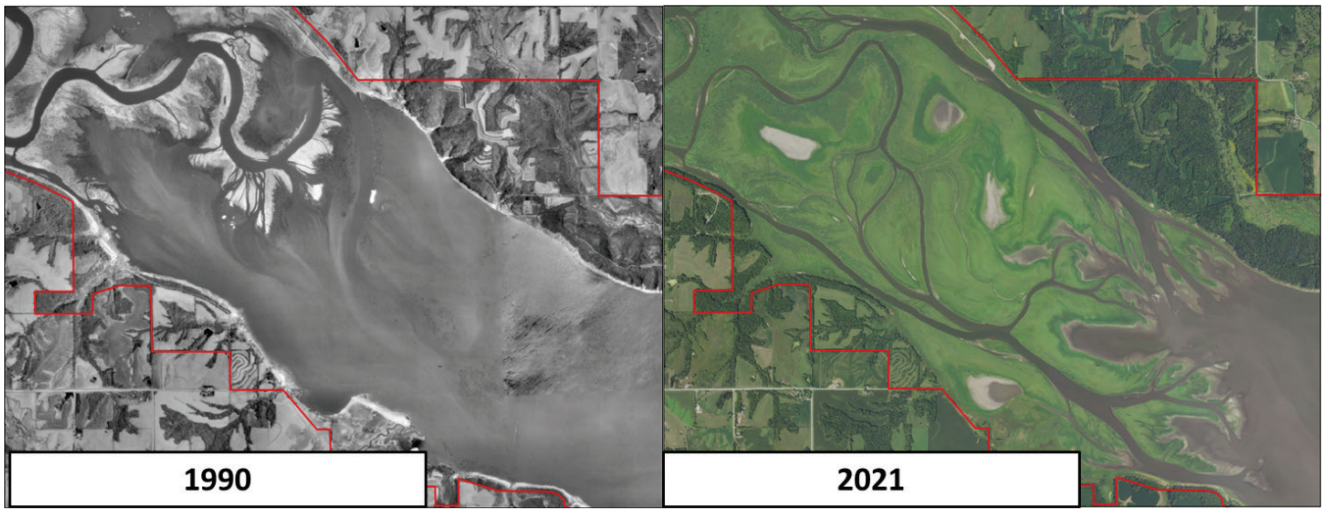


Figure 1. Lake Red Rock delta expansion due to sedimentation from 1990–2021 (Source: Todd Gosselink, Iowa Department of Natural Resources)

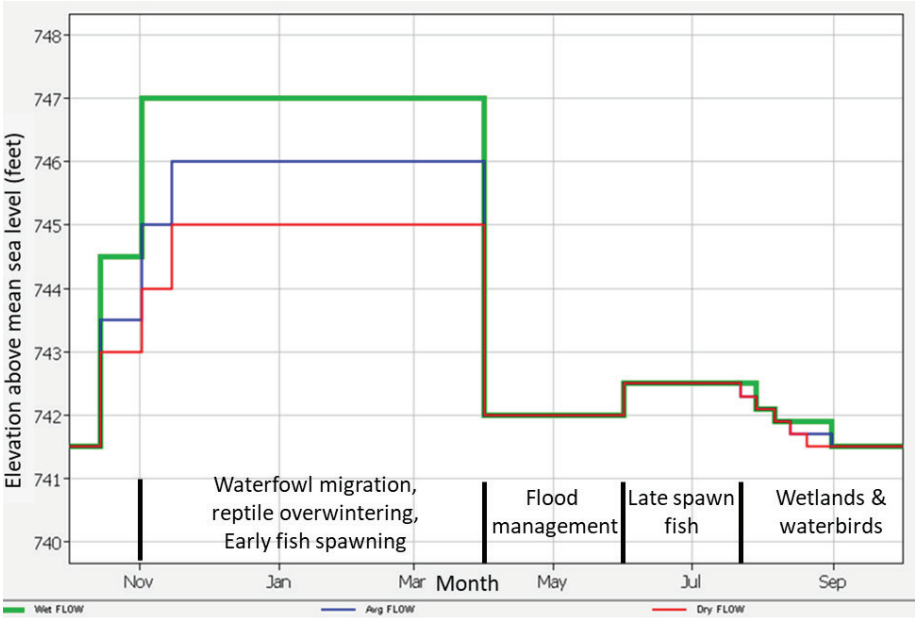


Figure 2. Lake Red Rock environmental pool management plan for a year.

ENVIRONMENTAL FLOWS WORKSHOP

Opportunities to adapt dam operations for increased environmental benefits at Des Moines River flood risk management projects were explored in 2016 using the SRP environmental-flows assessment process developed by USACE and The Nature Conservancy (Warner et al. 2014). This process incorporates collaboration workshops to identify water-management recommendations using stakeholder input from federal (i.e., USACE and U.S. Fish and Wildlife Service), state (e.g., Iowa Department of Natural Resources), and local agencies (e.g., Polk County Conservation), a nongovernmental organization (i.e., TNC), and academic institutions (i.e., University of Iowa and Iowa State University). Environmental flow requirements for specific taxonomic groups (for example, waterbirds, reptiles, fish), wetland habitats, and water quality were key components of reservoir management alterations.

Lake Red Rock environmental flow recommendations (i.e., targeted elevations, durations, and timing) were based on expert hypotheses regarding water level management to positively impact environmental outcomes (Warner et al. 2014). Workshop topics included nitrate concentrations, conditions needed for waterbird migration, and habitat for reptiles. EPM considerations are anticipated to drive the water plan during 80% of a typical operating year. Water levels are held higher in the spring to support fish spawning, they are slowly lowered during summer to promote wetland expansion, they are raised higher during fall waterfowl migration, and held high through winter to support reptile overwintering (Figure 2). The water management plan differs for wet, average, and dry years in anticipation of variable annual hydrology.

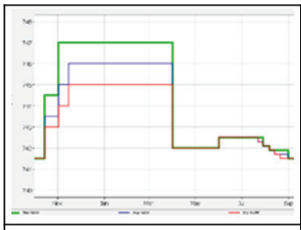
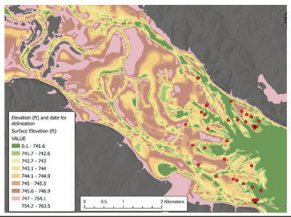
	Water Management Plan	• What ecological processes can be promoted by modifying reservoir pool levels?
	Delta Topographic Delineation	• How will lake levels be impacted? • What areas will potentially form wetlands, shallow and open water?
	Sediment Characteristics and Denitrification	• What was the denitrification potential before EPM? • What are the characteristics of sediments? • What is the denitrification potential?
	Vegetation and Macroinvertebrate Monitoring	• What plant are present? • How fast are plants colonizing new areas? • What macroinvertebrates are present?
	Bird and Reptile Monitoring	• What birds are present? • How are birds using new areas? • What reptiles are present?

Figure 3. Lake Red Rock environmental benefit assessment questions.

ENVIRONMENTAL BENEFITS MONITORING

Environmental benefits of EPM are being monitored by several researchers. Interdisciplinary research is necessary to consider the full range of environmental effects on water, sediment, plants, and animals for which lake levels can be adaptively managed to optimize outcomes (Figure 3). Ongoing and future monitoring efforts include an assessment of historical reservoir nitrate biogeochemistry data and literature review to document declines in nitrate concentrations prior to implementation of the new EPM plan (Schilling et al. 2023). A delta geomorphic assessment with topographic delineation, sediment mapping, and denitrification analyses to characterize inundation patterns in the delta is underway. Surface water-quality (i.e., temperature, specific conductivity, pH, and dissolved oxygen concentration) and nitrate concentrations will be evaluated using a boat-mounted spatial analysis system to map water quality conditions throughout the delta (Meulemans et al. 2020). Wetland, waterbird, and macroinvertebrate monitoring are ongoing to quantify these environmental benefits. Reptile overwintering monitoring is using remote radio transmitters deployed at Lake Red Rock.

Geomorphology and Water Quality

The data and literature review included 42 years of long-term upstream and downstream nitrate monitoring records. Lake Red Rock removed approximately 7,000 Mg nitrate per year, representing 12.4% of the nitrate inputs to the reservoir. Estimated annual nitrate removal rates varied considerably based on flow. This study supports that during periods of high nitrate concentrations and loads, reservoir water levels could be manipulated to achieve longer water

Figure 4. Lake Red Rock delta habitat progression July to September 2021.

retention times achieving greater nitrate removal rates (Schilling et al. 2023).

Lake Red Rock has lost substantial volume over time due to delta progradation which encroached 2.5 miles into the lake between 1994 to 2021 as estimated from National Agricultural Imagery Program imagery (see Figure 2). Sediment physical and chemical characteristics can impact the rate of removal of nitrate within aquatic systems. Field observations identified substantial variation and layering in the delta alluvium related to historical floods that influence surface and hyporheic flow throughout the delta sediment. Altogether, the geomorphic mapping, sedimentology, and nutrient processing rates will be used to further refine models that can predict nitrate removal for water operations within Lake Red Rock. Monthly boat surveys of nitrate concentrations in the reservoir are being conducted to understand how surface water nitrate concentrations are impacted by seasonal connectivity,

Wetlands

EPM exposes mudflats, promotes vegetation growth, and allows it to seed (Figure 4). These wetland areas serve as an important wildlife food source and provide habitat for migratory waterbirds during fall migration. One objective of wetland vegetation monitoring is to measure vegetation responses (e.g., species diversity and cover) to lower water levels in late summer. Another objective is to link vegetation responses with wildlife benefits.

Vegetation monitoring conducted during summer 2021 and 2022 quantified plant species, diversity, and cover. As water levels dropped and exposed mudflats, approximately two weeks were needed for vegetation to be observed. Within slightly more than a month, 100% vegetation cover

was observed. Across both survey years, 19 plant species were identified and included important wildlife foods (Table 1). Thirteen plant species within the mudflat area came to seed and this typically occurred within a month. Vegetation growth slowed in late August indicating that EPM drawdowns should begin in July to ensure a 30-day window for plants to come to seed.

Waterbirds

The Des Moines River corridor, which meanders through the Prairie Pothole Region (PPR) of Iowa, is a major migratory corridor for waterbirds. In particular, the region hosts millions of migratory waterfowl and shorebirds, two groups of birds that are the focus of many management and conservation efforts. Wetlands with diverse habitat conditions (e.g., differing water depths and healthy aquatic plant communities) are critical stopover sites for migratory waterbirds to refuel for the next step in migration. Identifying these stopover sites and understanding how individuals use a site, are critical for future conservation and management efforts (Vanausdall and Dinsmore 2021). Bird use of Lake Red Rock stopover sites is being evaluated by regular visual surveys of the site during fall migration.

A total of 49 waterbird species were documented in 2021 and 44 in 2022 (Table 2). The most prominent subgroups identified included shorebirds (27 spp.) and waterfowl (9 spp.); and all other waterbird groups totaled 14 species (e.g., gulls, terns, and pelicans). On average there were 30 and 26 species recorded per visit in 2021 and 2022, respectively, with species diversity peaking during late August and early September. There were >335,600 individuals counted across all surveys during the fall 2021 and 2022 migration period. American White Pelican (*Pelecanus* erythrorhynchos) was the most numerous species (approximately 40%), Pectoral Sandpiper (*Calidris* melanotos) was the most abundant shorebird species (12% in 2021 and 17% in 2022) followed by the Least Sandpiper (*Calidris minutilla*) (Table 2). The most abundant waterfowl species observed were the Blue (*Spatula* discors) and Green-winged teal (*Anas carolinensis*). Unusual species included

Table 1. Plant species found on the Lake Red Rock delta in 2021 and 2022.

Scientific name	Common name
Echinochloa crus-galli	Barnyardgrass
Xanthium strumarium	Rough cocklebur
Phalaris arundinacea	Reed canarygrass
Leersia oryzoides	Rice cutgrass
Cyperus spp.	Flatsedges
Amaranthus palmeri	Palmer's amaranth
Ammania coccinea	Scarlet toothcup
Lindernia dubia	Yellowseed false pimpernel
Polygonum pensylvanicum	Pennsylvania smartweed
Sagittaria latifolia	Broadleaf arrowhead
Bidens cernua	Nodding beggartics
Mimulus ringens	Allegheny monkeyflower
Bidens frondosa	Devil's beggarticks
Sinapis arvensis	Wild mustard
Phyla lanceolata	Lanceleaf fogfruit
Rorippa palustris	Bog yellowcress
Salix spp.	Willows
Acer saccharinum	Silver maple
Populus deltoides	Eastern cottonwood

Table 2. Lake Red Rock waterbird survey results listing the six most numerous species in each year.

2021		2022	
49 spp.; ~175,000 ind.		44 spp.; ~160,300 ind.	
American White Pelican	73,200 (42%)	American White Pelican	65,000 (41%)
Franklin's Gull	30,700 (18%)	Pectoral Sandpiper	27,800 (17%)
Ring-billed Gull	21,300 (12%)	Franklin's Gull	27,000 (17%)
Pectoral Sandpiper	20,200 (12%)	Ring-billed Gull	16,500 (10)
Green-winged Teal	5,300 (3%)	Killdeer	5,600 (4%)
Least Sandpiper	4,500 (3%)	Least Sandpiper	4,600 (3%)

Piping Plover (*Charadrius melodus*), Red Knot (*Calidris canutus*), Ruddy Turnstone (*Arenaria interpres*), Marbled Godwit (*Limosa feoa*), Western Sandpiper (*Calidris mauri*), Common Gallinule (*Gallinula galeata*) and other species of greatest conservation need (Table 3).

Least Sandpiper Telemetry

Radio telemetry studies of Least Sandpipers were conducted in 2021 and 2022 to estimate residency times and characterize site use for this species (Figure 5). A total of sixty (2021) and eighty (2022) transmitters were deployed on Least Sandpipers between July and August, there were 106 adults and 34 juveniles. The last resight of a tagged individual was on September 13, 2021 and September 1, 2022. This provides evidence for when water management can shift from shorebird to waterfowl management which raises fall water levels to allow access to wetland plant foods to feed migrating waterfowl.

DISCUSSION AND CONCLUSIONS

Lake Red Rock EPM began with experimental water level management in 2016 to 2018 and will continue for the foreseeable future under the new water regulation plan. The EPM adaptive management is suited for a range of flows and operated through a drought in 2022 with excellent outcomes and suitable flow to inundate the delta for fall migrating waterfowl and hunters. The practice is applicable to a subset of dams with specific operating conditions. Neipert et al. (2023) designed an approach for a nationwide, ecoregion spatial analysis of USACE Flood Risk Management dams suitable for EPM. Completing the tool would support a rapid identification and prioritization of projects that can benefit from EPM. It would also support developing regional avian management plans (Jung et al. 2022, Neipert et al. 2023).

Lake Red Rock research is demonstrating that EPM is a cost-effective management practice. Typical costs for large Corps of Engineers restoration construction projects such as island building, river wetland enhancement, backwater dredging coupled with forest plantings, and combinations of features on projects up to 1,000 ha in size on the Upper Mississippi River range from $2,000 - $5,000/average annual habitat unit (AAHU). Pool scale water level management can improve habitat over thousands of ha and is much more cost-effective at <$1,000/AAHU or much lower for most Upper Mississippi River dams (WLM Regional Coordinating Committee 2022). Pre-project dredging is the only construction activity required, and many only need to be done once to support multiple drawdown events. Water level adjustments are daily operations at most dams and the mode of operating EPM requires the same level of effort but delivers greater environmental benefits that will be documented by our research. The environmental flows planning and implementation also created social benefits by forming the collaboration teams that have worked together for several years of shared planning and field work that will continue for the foreseeable future.

Table 3. Lake Red Rock bird species of conservation need observed during 2021 and 2022 monitoring periods.

Federal Threatened	State Endangered
Piping Plover	Piping Plover
Red Knot	
Species of Greatest Conservation Need	
Blue-winged Teal	White-rumped Sandpiper
American Wigeon	Buff-breasted Sandpiper
Northern Pintail	Pectoral Sandpipier
Redhead	Semipalmated sandpiper
Common Gallinule	Short-billed Dowitcher
Black-bellied Plover	Lesser Yellowlegs
American Golden Plover	Wilson's Phalarope
Hudsonian Godwit	Franklin's Gull
Marbled Godwit	Black Tern
Ruddy Turnstone	Forster's Tern
Sanderling	American white Pelican

Figure 5. Least sandpiper telemetry.

ACKNOWLEDGEMENTS

Wetland and waterbird, delta elevation characterization, and historic denitrification research was funded by USACE Sustainable Rivers Program.

REFERENCES

Bishop, R.A., J. Joens, and J. Zohrer. 1998. Iowa's wetlands, present and future with a focus on Prairie potholes. *Journal of the Iowa Academy of Science* 105: 89-93. Available from https://scholarworks.uni.edu/jias/vol105/iss3/3

Jung, J.F., R.A. Fischer, C. McConnell, and P. Bates. 2022. The Use of US Army Corps of Engineers Reservoirs as Stopover Sites for the Aransas-Wood Buffalo Population of Whooping Crane. Technical Report ERDC/EL TR-22-8. US Army Corps of Engineers, Engineer Research and Development Center Environmental Laboratory, Vicksburg, MS 30pp. Available from https://apps.dtic.mil/sti/pdfs/AD1176388.pdf

Meulemans, M.J., C.S. Jones, K.E. Schilling, N.C. Young, and L.J. Weber. 2020. Assessment of spatial nitrate patterns in an Eastern Iowa watershed using boat-deployed sensors. *Water* 12: 146. https://doi.org/10.3390/w12010146

Neipert, E.S., T.E. Steissberg, and C. Theiling. 2023. Spatial Screening for Environmental Pool Management Opportunities. Technical Report ERDC/EL TR-23-9. US Army Corps of Engineers, Engineer Research and Development Center Environmental Laboratory, Vicksburg, MS.

Schilling, K.E., E. Anderson, M.T. Streeter, and C. Theiling. 2023. Long-term nitrate-nitrogen reductions in a large flood control reservoir. *Journal of Hydrology* 620: 129533. https://doi.org/10.1016/j.jhydrol.2023.129533

Stenback, G.A., W.G. Crumpton, and K.E. Schilling. 2014. Nitrate loss in Saylorville Lake Reservoir in Iowa. *Journal of Hydrology* 513: 1-6. https://doi.org/10.1016/j.jhydrol.2014.03.037

US Army Corps of Engineers – Rock Island District (USACE Rock Island District). 2019. Des Moines River Master Reservoir Regulation Manual Feasibility Report with Integrated Environmental Assessment. U.S. Army Corps of Engineers, Rock Island District, Rock Island, IL. 107 pp. Available from https://hdl.handle.net/11681/39939

Vanausdall, R.A., and S.J. Dinsmore. 2021. Stopover ecology of the least sandpiper (*Calidrilis minutilla*) in Iowa: Implications for reservoir management. *Lake and Reservoir Management* 37: 300-312. https://doi.org/10.1080/10402381.2021.1920071

Warner, A.T., L.B. Bach, and J.T. Hickey. 2014. Restoring environmental flows through adaptive reservoir management: planning, science, and implementation through the Sustainable Rivers Project. *Hydrological Sciences Journal* 59: 3-4, 770-785.https://doi.org/10.1080/02626667.2013.843777

WLM Regional Coordinating Committee. 2022. Water Level Management Opportunities for Ecosystem Restoration on the Upper Mississippi River and Illinois Waterway: An update to the NESP Environmental Report 53. Upper Mississippi River Basin Association, Bloomington, MN. 40 pp. Available from https://umrba.org/sites/default/files/documents/Water%20Level%20Management%20Opportunities%20for%20Ecosystem%20Restoration%20on%20the%20UMRS%20-%20July%202022.pdf