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Planning and Implementation of Environmental Pool Management at Lake Red Rock, Des Moines River, Iowa

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PURPOSE: This technical note complements "Environmental Pool Management: The 25-Year Evolution of an Engineering With Nature® Practice," an ArcGIS Story Map available for public access on the Engineering With Nature (EWN) website (EWN 2021b), and communicates the planning and implementation of environmental pool management (EPM) at Lake Red Rock located along the Des Moines River in Iowa.

BACKGROUND: The US Army Corps of Engineers (USACE) operates more than 700 dam and reservoir projects for navigation and flood risk management (USACE 2021). Conventional means of regulating pool levels alters sediment dynamics and floodplain and riparian communities (TNC and USACE 2017). EPM, or modification of reservoir and navigation pools to better mimic natural flows while remaining consistent with project authorizations, has resulted in observed benefits to floodplain and riparian communities. However, data are necessary to quantify biological benefits that EPM provides so that these benefits can be incorporated into dam operation decision-making. Using a 2016 report from the Institute for Water Resources (IWR) that captured 356 reservoir projects owned and operated by USACE, 14% of operating changes were conducted to incorporate seasonal patterns of rising and falling pool levels to support environmental benefits (IWR 2016). Currently EPM is not a frequent driver for managing dam operations, so data quantifying the environmental, social, and economic benefits of this approach will empower districts to make informed decisions regarding operating changes.

Multiple programs and projects value the development of data to quantify environmental and ecological benefits of EPM, and therefore this project leveraged the combined interests of several USACE civil works research programs. This project was initiated by the Sustainable Rivers Program (SRP), which funded waterbird research, sediment delta mapping, and the denitrification literature review for the current EWN research. EWN funded denitrification analyses, water-quality sampling, and external communication opportunities. The Ecosystem Management and Restoration Research Program (EMRRP) funded a reptile overwintering study and the scoping for a spatial-analysis tool to prioritize sites suitable for EPM.* Collaboration is identified as one of the key elements of EWN, which is the "intentional alignment of natural and engineering processes to

* Elizabeth S. Neipert, Todd E. Steissberg, and Charles H. Theiling. 2022. "Spatial Screening for Environmental Pool Management Opportunities." ERDC Technical Note Collection. ERDC TN-EMRRP-22-DRAFT. Vicksburg, MS: US Army Engineer Research and Development Center. In press.

efficiently and sustainably deliver economic, environmental, and social benefits through collaboration" (Bridges et al. 2018, 2; 2021, 5; EWN 2021a). Projects funded through EMRRP include those that focus on understanding the risks and benefits of ecosystem-restoration management strategies (EMRRP 2021). The SRP, formerly the Sustainable Rivers Project, was initiated in 2002 as a collaborative effort between The Nature Conservancy (TNC) and USACE. Within SRP, environmental-flow assessments are conducted to evaluate opportunities for implementation of EPM and downstream-management alternatives. TNC defines environmental flows as "scientific prescriptions for the timing, quality and quantity of water flow that must occur downstream and upstream of dams to revive and sustain critical ecological functions and habitat for species" (TNC 2020). These assessments were conducted within 8 rivers by 2015 and 16 rivers by 2019 (TNC 2020). A 2016 environmental-flow assessment supported by SRP focused on the Des Moines River, where EPM for flood-control reservoirs was introduced at Lake Red Rock and was the impetus for the current research.

The aim of this three-year project is to communicate and quantify the environmental, social, and economic benefits of EPM at Lake Red Rock along the Des Moines River in Iowa. Environmental benefits of EPM will be quantified through wetland, waterbird, and reptile monitoring, a biogeochemistry literature review, sediment delta mapping to identify areas for potential wetland development, denitrification analyses, and spatial water-quality analysis during the growing season. This technical note outlines the history of this project at Lake Red Rock and provides a summary of progress on quantifying environmental benefits to date.

INTRODUCTION: Red Rock dam, located along the Des Moines River, was completed in 1969 (TNC and USACE 2017) and formed the 6,171 ha (15,250 ac)* reservoir, Lake Red Rock (Figure 1). Lake Red Rock's primary purpose is flood-risk management, with other purposes that include low-flow augmentation, fish and wildlife management, and recreation. Lake Red Rock drains an area of 31,916 square km (12,323 mi^2) (TNC and USACE 2017) and provides critical flood-storage capacity, with 1,804,889,610 m^3 (1,463,250 ac-ft) of flood-risk-management storage (approximately 89% of total storage; USACE–Rock Island District, n.d.).

Since the 1980s, water management raised water levels to promote fall waterbird habitat in Lake Red Rock and other Iowa reservoirs. In 2016 additional environmental benefits of Lake Red Rock pool management were explored through the SRP environmental-flows assessment process. This process incorporates workshops to identify water-management recommendations using stakeholder input. An updated reservoir regulation manual was completed in 2019 that incorporated stakeholder recommendations into updated reservoir-operation plans (USACE–Rock Island District 2021). Implementation of EPM in Lake Red Rock provides the opportunity to capture data focused on environmental and other benefits of this approach in a USACE reservoir with the potential for application to other reservoirs. A workshop was subsequently held to take advantage of such an opportunity.

* For a full list of the spelled-out forms of the units of measure and the unit conversions used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office, 2016), 248–52 and 345–47, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

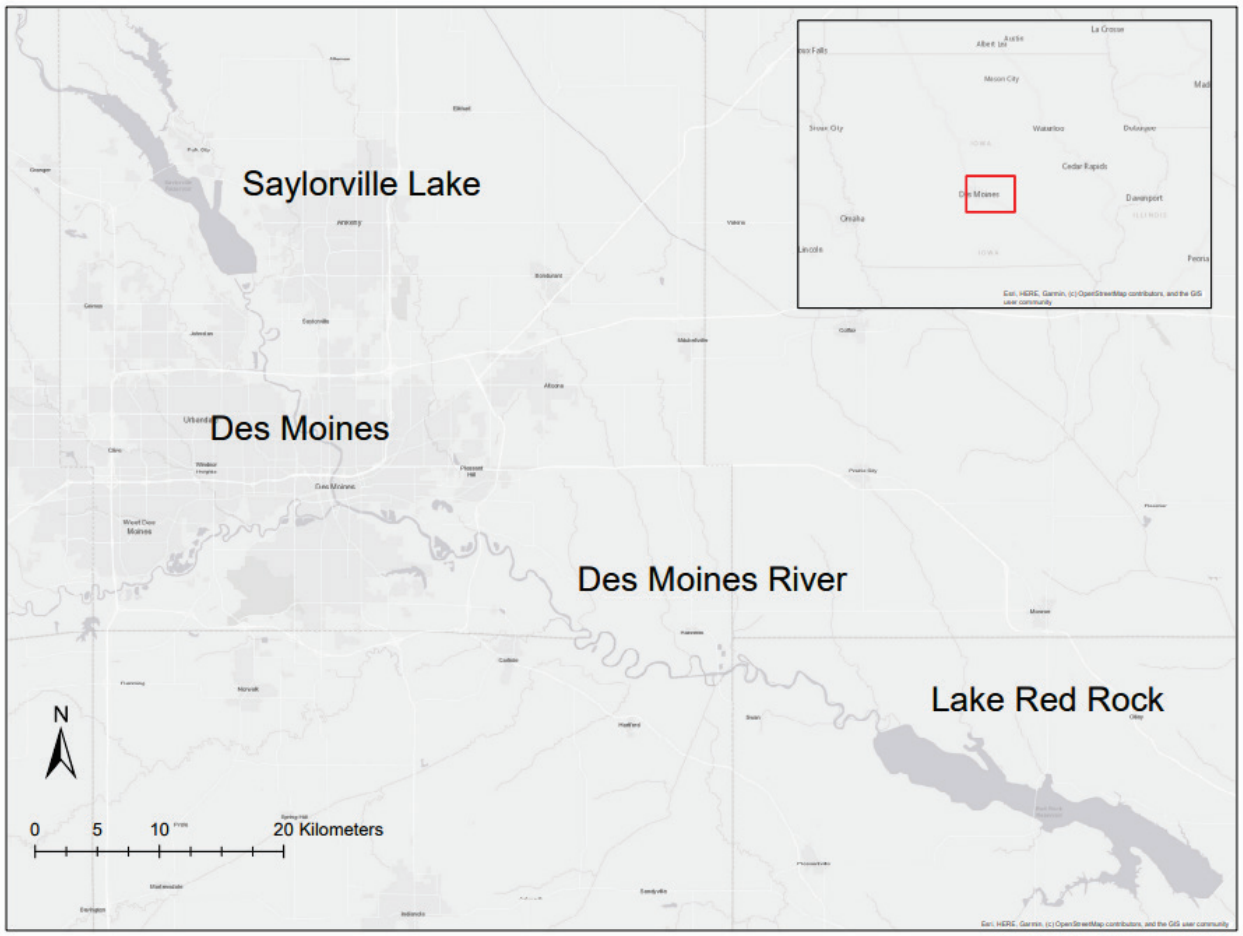


Figure 1. Saylorville Lake and Lake Red Rock near Des Moines, Iowa. *Inset*, the state of Iowa with Des Moines shown in *red rectangle*.

ENVIRONMENTAL FLOWS WORKSHOP SUMMARY: An SRP-funded workshop was held in Pella, Iowa, in October 2016. It brought together stakeholders from federal (for example, USACE), state (for example, Iowa Department of Natural Resources), and local (for example, Polk County Conservation) agencies; a nongovernmental organization (that is, TNC); and academic institutions (for example, University of Iowa, Iowa State University) (USACE and TNC 2016). Workshop attendees explored opportunities for USACE to adapt dam operations to increase wetland habitat benefits using the Red Rock dam. The purpose of the workshop was to provide specific recommendations in terms of magnitude, timing, duration, and frequency of flows as well as rates of change between different flow conditions. These recommendations are based on expert hypotheses regarding water levels that are anticipated to positively affect specific taxonomic groups (for example, waterbirds, reptiles, fish), wetland habitats, and water quality. The goal was for these recommendations to be integrated into an updated reservoir-regulation manual that would guide decisions regarding pool levels.

Topics discussed during the workshop included nitrate concentrations, mussel and sturgeon mortalities, gas-bubble trauma to fish from dams, conditions needed for waterbird migration, habitat for reptiles, stream-bank erosion, and conditions for river recreation. Specific flow

recommendations for pool operations were made to support fish spawning, promote vegetation growth, provide food resources for birds and wildlife, and maintain water quality (Figure 2). Key uncertainties and research needs identified by the stakeholders focused on uncertainties related to denitrification, conditions triggering harmful algal blooms (HABs), and bird habitat.

Workshop questions included the following:

- Under what conditions does denitrification occur?
- How is the rate of denitrification altered by water level?
- What is the impact of the flow recommendations on shorebird habitat and consequently population response?
- What conditions trigger HABs?
- Would increasing residence time to enhance denitrification result in increased HABs, which are often observed in slow-flowing waters?

Reservoir control manual. Recommendations from the environmental flows workshop provided the basis for modifications to the Des Moines River Basin Master Reservoir Regulation Manual (DMRBRRM) related to environmental flows. The DMRBRRM is the guidance document for water managers of the Des Moines River, Lake Red Rock, and Saylorville Lake (upstream of Lake Red Rock). This guidance details how water is to be stored and released given a specific set of scenarios (for example, flash flood, large-magnitude flood, low inflow [less than 300 cfs; 1 cfs = 0.0283 m^3/s]; USACE–Rock Island District 2021). Key indicators of a need for modifications to the DMRBRRM were (1) significant increases in the magnitude and frequency of flooding events, (2) sedimentation rates within Saylorville Lake and (3) the need to implement approved deviations in water-control plans from 2016 to 2018 (USACE–Rock Island District 2019).

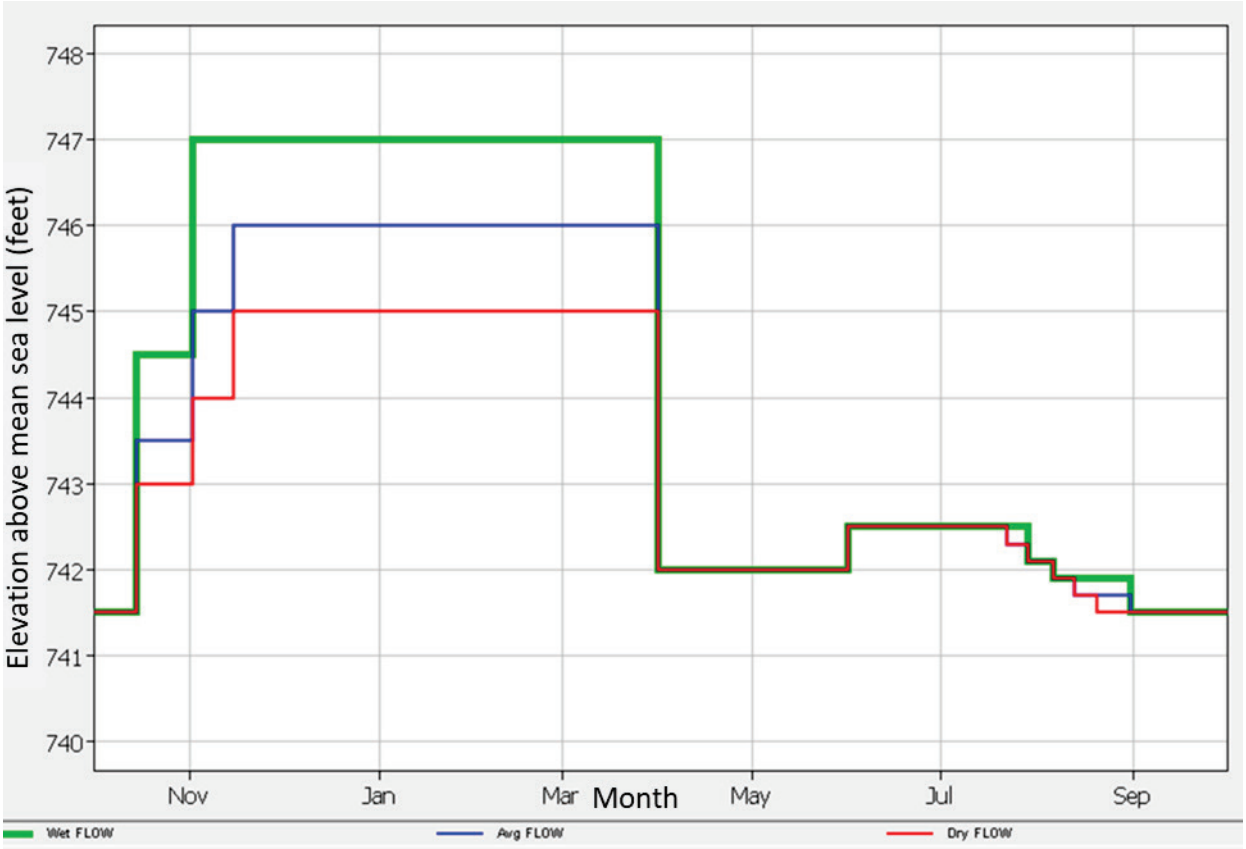


Figure 2. Recommended water levels during wet, average, and dry flows developed during the environmental flows workshop (TNC and USACE 2017, 41).

In 2017 a two-year planning process was initiated to revise the DMRBRRM, which involved the evaluation of 12 alternative plans (including the operation plan then in effect, termed *no action*). A series of workshops (including the environmental flows workshop described above) were held to organize and focus project goals. In addition to the primary congressionally authorized purpose of flood-risk management, project goals were to (1) reduce future flood risk, (2) increase and re-establish water-supply reliability, (3) promote fish and wildlife sustainability, (4) promote enhancement of recreational features, and (5) accommodate other stakeholder interests (for example, Red Rock hydropower operations). These alternatives were initially screened by workshop participants relative to the no-action plan for their ability to maintain, improve, or negatively affect project goals. Following the screening, three alternative plans (including the no-action plan) were carried forward for further economic evaluation, and one alternative was recommended (Figure 3). In February 2019 USACE–Rock Island District began operating under the new plan (USACE–Rock Island District 2019).

Lake Red Rock – Growing Season (May 1 – Dec 15) Water Control Plan

Current Plan Overview

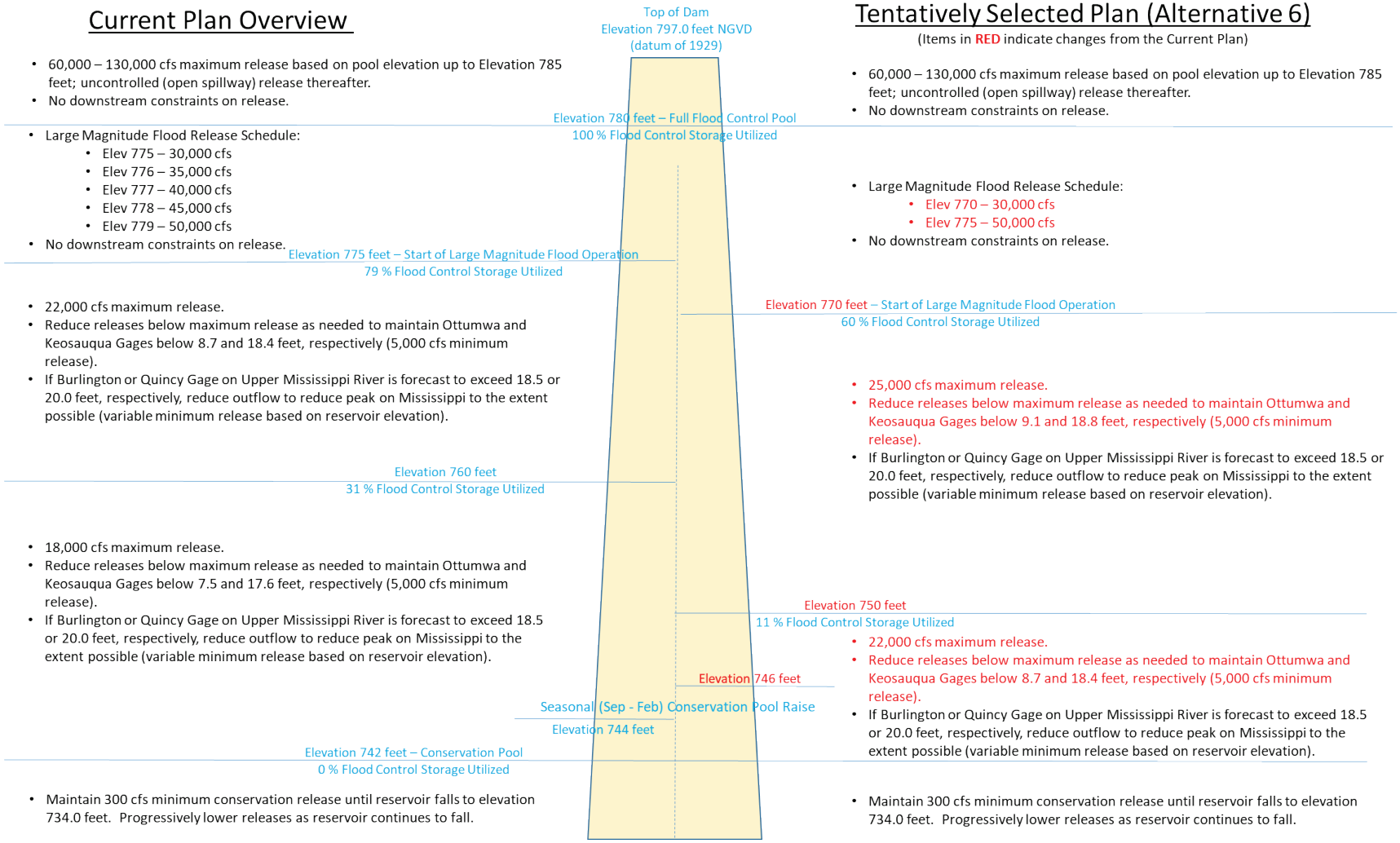
- 60,000 – 130,000 cfs maximum release based on pool elevation up to Elevation 785 feet; uncontrolled (open spillway) release thereafter.
- No downstream constraints on release.

- Large Magnitude Flood Release Schedule:
  - Elev 775 – 30,000 cfs
  - Elev 776 – 35,000 cfs
  - Elev 777 – 40,000 cfs
  - Elev 778 – 45,000 cfs
  - Elev 779 – 50,000 cfs
- No downstream constraints on release.

- 22,000 cfs maximum release.
- Reduce releases below maximum release as needed to maintain Ottumwa and Keosauqua Gages below 8.7 and 18.4 feet, respectively (5,000 cfs minimum release).
- If Burlington or Quincy Gage on Upper Mississippi River is forecast to exceed 18.5 or 20.0 feet, respectively, reduce outflow to reduce peak on Mississippi to the extent possible (variable minimum release based on reservoir elevation).

- 18,000 cfs maximum release.
- Reduce releases below maximum release as needed to maintain Ottumwa and Keosauqua Gages below 7.5 and 17.6 feet, respectively (5,000 cfs minimum release).
- If Burlington or Quincy Gage on Upper Mississippi River is forecast to exceed 18.5 or 20.0 feet, respectively, reduce outflow to reduce peak on Mississippi to the extent possible (variable minimum release based on reservoir elevation).

- Maintain 300 cfs minimum conservation release until reservoir falls to elevation 734.0 feet. Progressively lower releases as reservoir continues to fall.



Tentatively Selected Plan (Alternative 6)

(Items in **RED** indicate changes from the Current Plan)

- 60,000 – 130,000 cfs maximum release based on pool elevation up to Elevation 785 feet; uncontrolled (open spillway) release thereafter.
- No downstream constraints on release.

- Large Magnitude Flood Release Schedule:
  - Elev 770 – 30,000 cfs
  - Elev 775 – 50,000 cfs
- No downstream constraints on release.

Elevation 770 feet – Start of Large Magnitude Flood Operation
60 % Flood Control Storage Utilized

- 25,000 cfs maximum release.
- Reduce releases below maximum release as needed to maintain Ottumwa and Keosauqua Gages below 9.1 and 18.8 feet, respectively (5,000 cfs minimum release).
- If Burlington or Quincy Gage on Upper Mississippi River is forecast to exceed 18.5 or 20.0 feet, respectively, reduce outflow to reduce peak on Mississippi to the extent possible (variable minimum release based on reservoir elevation).

Elevation 750 feet
11 % Flood Control Storage Utilized

- 22,000 cfs maximum release.
- Reduce releases below maximum release as needed to maintain Ottumwa and Keosauqua Gages below 8.7 and 18.4 feet, respectively (5,000 cfs minimum release).
- If Burlington or Quincy Gage on Upper Mississippi River is forecast to exceed 18.5 or 20.0 feet, respectively, reduce outflow to reduce peak on Mississippi to the extent possible (variable minimum release based on reservoir elevation).

- Maintain 300 cfs minimum conservation release until reservoir falls to elevation 734.0 feet. Progressively lower releases as reservoir continues to fall.

Figure 3. Recommended plan (Alternative 6) for Lake Red Rock growing-season water management (USACE–Rock Island District 2018). (Accessible version available in the Appendix.)

The new plan allows for the implementation of water operations within a *conservation band*. The conservation band is a range of pool elevations that can be adjusted during nonflood periods to provide the stated environmental benefits. Conservation bands allow for the implementation of EPM within Lake Red Rock. EPM at Lake Red Rock was informed by the Iowa Department of Natural Resources, county wildlife, fisheries, and water-quality managers, university researchers, and federal agency staff to provide four seasons of benefits (Figure 4), above and beyond the current flood management, environmental, and recreation benefits already provided (*top*, Figure 4). The strategy starts in the early growing season as flood risk decreases, then the summer conservation-pool elevation is raised to support late-spawning fishes before it is gradually lowered during July and August to expose mudflats and the rich invertebrate fauna they support for shorebird feeding (*middle*, Figure 4). Wetland plants rapidly and prolifically colonize mudflats on the expanded wetland areas. Pool levels are raised in the fall to flood reservoir-delta wetlands, which then support waterfowl migration (*bottom*, Figure 4). Past practices would drop the flood-control pool in December (prior to ice over), but the new plan allows for the maintenance of water high through the winter to support reptile, amphibian, and mussel overwintering. Lake levels are held high as long as possible (that is, to not affect the primary authorized purpose of flood storage) to support early-spring-spawning fish, before they are lowered in March or April to accommodate spring floods.

Environmental pool management (EPM) story map. Communication is a key component of the current project and is a part of the 2018–2023 EWN Strategic Plan by "increasing the number and diversity of EWN applications while communicating effectively about accomplishments and future opportunities" (EWN 2018, 5) (available at https://ewn.erdc.dren.mil/). Communication is needed to inform stakeholders of the successes of EPM. One of the stakeholders for this project is the public, and visual communication tools can be effective for this audience. Therefore, an ArcGIS Story Map, which provides an interactive, visual representation of the history, issues, solutions, and background for this current project, was used and published in September 2021 (EWN 2021b).

Engineering With Nature (EWN) monitoring activities. Developing data to quantify the environmental and other benefits of the new EPM plan will aid decision-making regarding different alternatives for water-level management. According to specific uncertainties and research needs identified during the environmental flows workshop (for example, related to waterbirds, reptiles, and denitrification), monitoring is needed to reduce these uncertainties.

Waterbird and vegetation responses to water-level changes. As the new plan for EPM at Lake Red Rock is implemented, it has become an increasingly important stopover area for migrating waterbirds to regain energy and nutrient stores because of its midcontinental location. Different species use a range of habitats during this stopover period. The least sandpiper is a relatively common, summer-migrating shorebird in the area, and its diet consists of invertebrates buried in exposed mudflats (Davis and Smith 1998), while fall-migrating waterfowl rely on plants and invertebrates in the flooded wetland areas for food (Straub et al. 2012). Therefore, EPM can affect waterbird habitats by exposing mudflats or promoting conditions for the growth of wetland plants that are flooded for the fall migration.

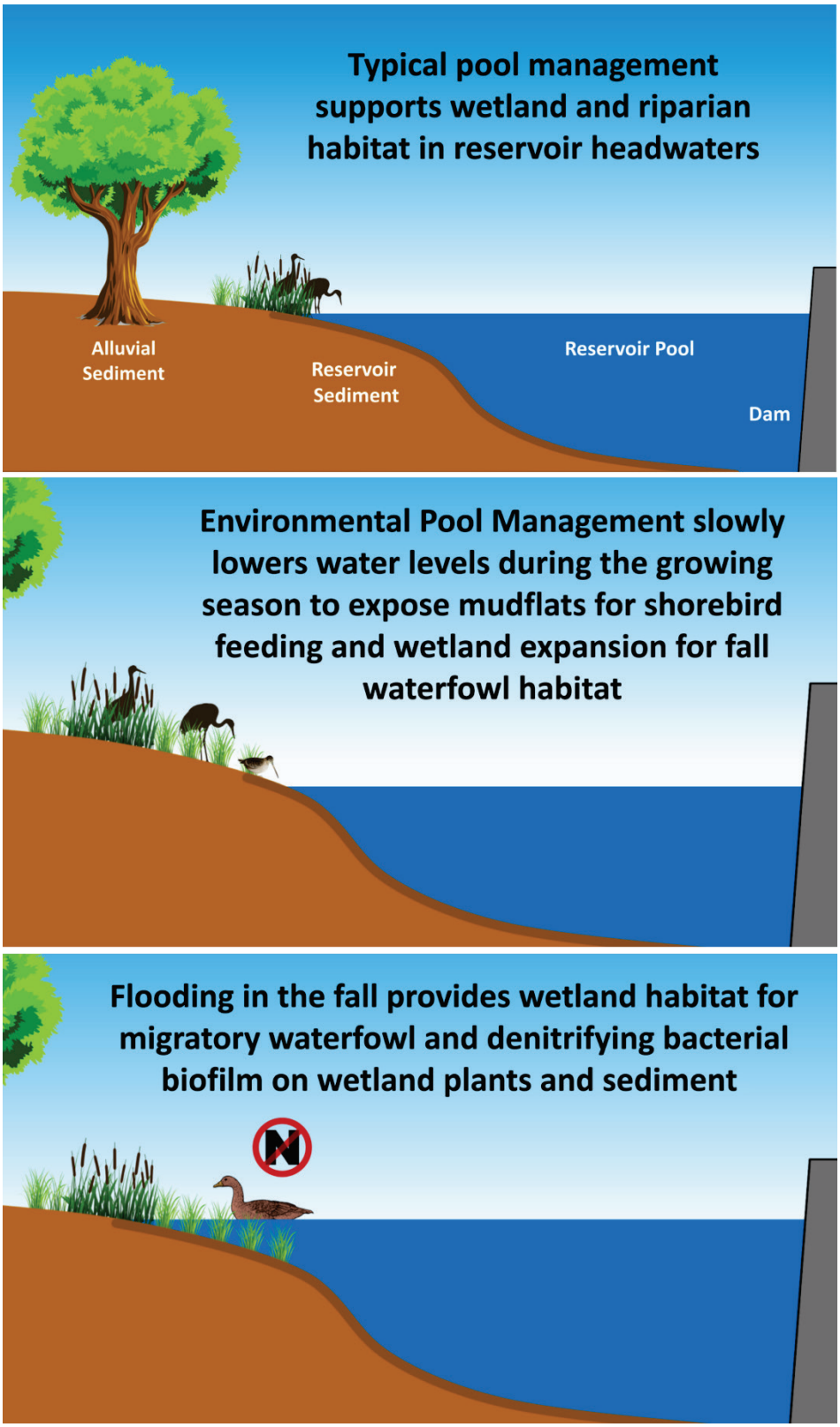


Figure 4. Environmental pool management (EPM) seasonal conceptual model.

Dr. Stephen Dinsmore from the Iowa State University Department of Natural Resource Ecology and Management has studied shorebirds in Lake Red Rock since the 1990s and can draw from his knowledge, experience, and data to support this research. A collaborative research agreement was initiated between Iowa State University and USACE in 2021 to support monitoring waterbirds for this project, which will (1) monitor waterbird responses to water-level management during fall migration, (2) monitor vegetation responses to water-level management, and (3) estimate residency time for a shorebird species (for example, least sandpiper) during migration. Monitoring will include waterbird surveys, line-transect vegetation sampling, and transmitter tracking of least sandpipers (Figure 5). Waterbird and vegetation monitoring began in summer 2021.

Figure 5. Least sandpiper collected in summer 2021 and fitted with a transmitter to document its use of Lake Red Rock mudflats.

Reptile response to water levels. Prior water management had the potential to expose hibernating reptiles and other aquatic inhabitants to excessive cold if they were located at one elevation relative to water levels that were then lowered in December to make room for floods. There is adequate flood storage to eliminate the winter drawdown to hold water levels stable to protect reptiles and other aquatic species. However, little is known about reptile overwintering relative to reservoir management; therefore, monitoring of turtle and snake overwintering environments will be undertaken. A reconnaissance visit to Lake Red Rock was conducted in summer 2021, and sampling methods were tested at another site for effectiveness; refined sampling methods will be implemented at Lake Red Rock in 2022.

Denitrification changes in response to water levels. A collaborative research agreement was initiated with the University of Iowa in March 2021 to conduct monitoring for denitrification within Lake Red Rock. Denitrification is the microbially mediated process in which nitrate is

reduced to gaseous N_2,* resulting in a decrease in aqueous nitrate concentrations. Considerable interest in aqueous nitrate concentrations from the Des Moines River stems from hypotheses that the river and watershed contribute substantially to nitrate concentrations in the Mississippi River and consequent dead zones from nutrient enrichment in the Gulf of Mexico (Loken et al. 2018). Efforts to decrease aqueous nitrate concentrations have explored the possibility of using wetland areas along rivers that promote nitrate removal through denitrification, although uncertainty remains regarding the effectiveness of this approach (Loken et al. 2018). The environmental flows workshop identified an interest in using water operations to target conditions that may decrease nitrate concentrations within and downstream of Lake Red Rock. The overall purpose of the denitrification monitoring study is to determine whether a net reduction in contributions of nitrate from the outflow of Lake Red Rock can be achieved through reservoir operations optimized for nitrate reduction. This monitoring approach will be conducted in two phases, funded by SRP and EWN, respectively.

During the first phase, the wetland area of the delta will be delineated, and a literature review will be conducted to identify available data on the denitrification potential in reservoirs, and water-quality data from areas upstream, downstream, and within Lake Red Rock will be analyzed. The literature review began in the winter of 2021. The second phase will assess sediment denitrification potential in the laboratory during winter 2021 and conduct long-term (three years) water-quality monitoring to include boat surveys of the delta area to measure nitrate concentrations in the water column.

SUMMARY: Lake Red Rock is a critically important reservoir for achieving USACE flood-risk management objectives along the Des Moines River. From 2016 to 2018, increases in severity of flood events required approved deviations in the water-control plan, triggering the need to assess and update the guidance document for operating the Red Rock dam. Stakeholder input regarding project goals in addition to the authorized purpose of flood-risk management were provided through a series of workshops. An environmental flows workshop consisting of federal, state, and local agencies; nongovernmental organizations; and academic institutions provided recommendations for the updated reservoir-regulation plan, which included potential enhanced environmental benefits from EPM (for example, waterbirds, aquatic species, denitrification, and water-quality improvement). As a result of these efforts, a new EPM plan was implemented in the form of a conservation band to allow flexibility to incorporate environmental and other benefits during nonflood events, as captured in the updated operating guidance document. Changes to reservoir operations optimized for EPM provide the opportunity to monitor the impacts of altered pool levels on anticipated environmental and other social and economic benefits consistent with EWN principles. These data will fill critical data gaps identified by USACE staff in collaboration with stakeholders to better inform decisions regarding dam operations at Lake Red Rock and in other watersheds. Further research to monitor waterbird, vegetation, and denitrification has been initiated in Lake Red Rock to fill information gaps identified by stakeholders.

* For a full list of the spelled-out forms of the chemical elements used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office, 2016), 265, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

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APPENDIX: CURRENT AND TENTATIVELY SELECTED PLAN OVERVIEWS

The table below provides a plaintext version of Figure 3.

Table A-1. Overview of water-management plans.

Current plan overview		**Tentatively selected plan (Alternative 6)**	
60,000–130,000 cfs maximum release using pool elevation up to elevation 785 ft • uncontrolled (open spillway) release thereafter • no downstream constraints on release	Top of dam elevation 797.0 ft NGVD (datum of 1929)	60,000–130,000 cfs maximum release using pool elevation up to elevation 785 ft • uncontrolled (open spillway) release thereafter • No downstream constraints on release	Top of dam elevation 797.0 ft NGVD (datum of 1929)
Large magnitude flood release schedule • elevation 775 ft—30,000 cfs • elevation 776 ft—35,000 cfs • elevation 777 ft—40,000 cfs • elevation 778 ft—45,000 cfs • elevation 779 ft—50,000 cfs • no downstream constraints on release	• elevation 780 ft • full flood-control pool • 100% flood control storage used	Large magnitude flood release schedule • elevation 770 ft—30,000 cfs • elevation 775 ft—50,000 cfs • no downstream constraints on release	• elevation 780 ft • full flood-control pool • 100% flood control storage used
22,000 cfs maximum release • reduce releases below maximum release as needed to maintain Ottumwa and Keosauqua Gages below 8.7 and 18.4 ft, respectively (5,000 cfs minimum release) • If Burlington or Quincy Gage on Upper Mississippi River is forecast to exceed 18.5 or 20.0 ft, respectively, reduce outflow to reduce peak on Mississippi to the extent possible (variable minimum release using reservoir elevation).	• elevation 775 ft • start of large-magnitude flood operation • 79% flood control storage used	25,000 cfs maximum release • reduce releases below maximum release as needed to maintain Ottumwa and Keosauqua Gages below 9.1 and 18.8 ft, respectively (5,000 cfs minimum release) • If Burlington or Quincy Gage on Upper Mississippi River is forecast to exceed 18.5 or 20.0 ft, respectively, reduce outflow to reduce peak on Mississippi to the extent possible (variable minimum release using reservoir elevation).	• elevation 770 ft • start of large-magnitude flood operation • 60% flood control storage used
18,000 cfs maximum release • reduce releases below maximum release as needed to maintain Ottumwa and Keosauqua Gages below 7.5 and 17.6 ft, respectively (5,000 cfs minimum release)	• elevation 760 ft • 31% flood control storage used	22,000 cfs maximum release. • reduce releases below maximum release as needed to maintain Ottumwa and Keosauqua Gages below 8.7 and 18.4 ft, respectively (5,000 cfs minimum release)	• elevation 750 ft • 11% flood control storage used

Current plan overview		Tentatively selected plan (Alternative 6)	
• If Burlington or Quincy Gage on Upper Mississippi River is forecast to exceed 18.5 or 20.0 ft, respectively, reduce outflow to reduce peak on Mississippi to the extent possible (variable minimum release using reservoir elevation).		• If Burlington or Quincy Gage on Upper Mississippi River is forecast to exceed 18.5 or 20.0 ft, respectively, reduce outflow to reduce peak on Mississippi to the extent possible (variable minimum release based on reservoir elevation).	
	• elevation 744 ft • seasonal (September to February) • conservation pool raise		• elevation 746 ft • Seasonal (September to February) • conservation pool raise
Maintain 300 cfs minimum conservation release until reservoir falls to elevation 734.0 ft; progressively lower releases as reservoir continues to fall	• elevation 742 ft • conservation pool raise • 0% flood control storage used	Maintain 300 cfs minimum conservation release until reservoir falls to elevation 734.0 ft; progressively lower releases as reservoir continues to fall.	• elevation 742 ft • conservation pool raise • 0% flood control storage used