# Environmental Flows Workshop Summary
## Des Moines River Sustainable Rivers Project


**Central College, Maytag Student Center**
**Pella, Iowa**
**October 25-26, 2016**

## Acknowledgments

This project was made possible with funding from the Iowa Chapter of The Nature Conservancy, in part through funding from the Anne Ray Charitable Trust. Kristen Blann, Freshwater ecologist with The Nature Conservancy in MN, ND, and SD, prepared the bulk of the report. Dave DeGeus, The Nature Conservancy, and Hugh Howe, U.S. Army Corps of Engineers, Red Rock District, initiated the project as well as provided essential input, guidance, and feedback throughout this initial phase (literature review and summary). John Hickey, U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC) and Andrew Warner, USACE Institute for Water Resources affiliate, facilitated and ran the workshop and trained participants on the use and applications of the RPT and software. Multiple staff at the U.S. Army Corps of Engineers, Rock Island, Illinois, have also contributed time, expertise, information and resources. Stakeholders and partners listed in the Appendix also provided the input, expertise and hypotheses on current and historical conditions as well as issues and needs. We are grateful to everyone who has participated for their interest and contribution to improving the health of the Des Moines River.

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## Workshop Agenda and Purpose

The Des Moines River Sustainable Rivers Project environmental flows workshop was held 25-26 October at Central College in Pella, Iowa, with the purpose of exploring whether management changes related to flow could improve the long-term ecological health of the Des Moines River. The workshop was co-organized and sponsored by The Nature Conservancy in Iowa and the U.S. Army Corps of Engineers, Rock Island District, and was attended by over fifty scientists, fisheries, water and natural resource managers from government agencies, universities and non-government organizations. A copy of the final workshop agenda and participant list is included as Appendix A.

The workshop opened with a welcome and opening remarks by Hugh Howe (Natural Resource Specialist, Lake Red Rock, U.S. Army Corps of Engineers). Howe presented an introduction to the Des Moines River Sustainable Rivers Project (SRP), the purpose and structure of the workshop, workshop goals and expected products. David DeGeus (The Nature Conservancy) and Andy Warner (USACE - IWR Affiliate) provided additional overview of the Sustainable Rivers Partnership process, Des Moines River SRP, and how the products and process might be used to influence management decisions.

Opening presentations were followed by an overview of history, authorized purpose and existing operating rules for the Lake Red Rock and Saylorville projects; design considerations underlying existing operating prescriptions; and current operating constraints, presented by Chris Trefry, USACE.

For the last presentation of the morning session of the workshop, Kristen Blann, freshwater ecologist with The Nature Conservancy and primary author of the literature review, highlighted key sections of the Literature Review and summary document that was disseminated to all participants prior to the workshop. This presentation included preliminary hydrologic analyses for the period of record on the Des Moines River (1919-2015) and changes that have occurred in conjunction with and/or in response to construction and operation of the two USACE dams and reservoirs at Lake Red Rock and Saylorville. The presentation also covered background on theory and concepts for understanding flow ecology and developing environmental flow definitions.

After lunch, John Hickey, US Army Corps of Engineers Hydrologic Engineering Center (HEC), provided an overview of the format for the remainder of the workshop, which involved breaking into working groups to develop specific environmental flow definitions and hypotheses. Hickey also introduced the Regime

Prescription Tool, a software tool specifically designed to help capture environmental flow recommendations in an SRP workshop setting, provided an overview of how it has been used to support other SRP projects, and explained how the tool would be used for the remainder of the workshop.

Following the introduction to RPT, workshop participants were organized into three groups, organized based on a mix of expertise designed to address different relevant issues identified in the stakeholder scoping document or literature review:

1. Fish & Mussels
2. Water Quality & other considerations (reservoir focused: shorebirds, waterfowl, pool levels)
3. Floodplain habitat, riverine waterfowl and wildlife

Breakout groups were given the charge to focus on defining flow requirements designed to enhance ecosystem health on the river, and attempt to articulate ecosystem flow needs as unaffected as possible by existing constraints. Each group was charged with the following tasks:

1. Clarify hypotheses for each focus reach regarding flow-related issues and potential flow changes or enhancements that could be made, i.e. identify where current flow prescriptions may be in conflict, or where there is greatest opportunity to enhance benefits via pool-level or flow manipulations
2. Develop environmental flow hypotheses based on specific Environmental Flow Components (low flows, flood pulses, small floods and large floods), understanding of the existing flow prescriptions, and how existing flows could be modified.
3. Identify significant knowledge and information gaps and potential monitoring needs.

Each group was charged with addressing flow needs for 3 distinct geographic reaches on the Des Moines River:

1. Below Red Rock
2. Between Saylorville and Red Rock
3. Saylorville and upstream

After dividing into breakout groups, each with a group facilitator and an RPT operator (consisting of several Corps staff who had been trained on the RPT software functionality prior to the workshop), the first item of business was that participants were asked to confidentially write down their initial questions, hypotheses, and recommendations on notepads at each table. These initial recommendations were collected and compiled into an electronic document that was printed and distributed back to the group on the morning of Day 2, included here as Appendix B.

When defining environmental flow needs , participants were encouraged to consider, at a minimum, high and low flow components in terms of their ecological function. They were encouraged to define baseflows and flood events in terms of *magnitude, timing, duration*, and *frequency* of flows, as well as *rates of change* between different flow conditions. They were also encouraged to consider "contingencies" and "uncertainties", or knowledge gaps. Example environmental flow components for which groups were encouraged to develop flow recommendations included: a) Low flows (seasonal, annual and extreme low flows; b) High flow pulses (up to bank full discharge); c) Small Floods (overbank flows, approximately 2- to 10-year return period); d) Large Floods (floodplain maintenance flows, > approximately 10-year return period). (See Table 1 for examples of ecological functions performed by specific environmental flow components)

Breakout groups were encouraged to explore the significance of environmental flow components in relation to the following:

- Hydrogeomorphic processes – including channel formation, sediment dynamics and gravel movement.
- Floodplain processes and functions – including functions such as vegetation establishment, seed dispersal, riparian community structure and function, seasonal access for fish, habitat for species such as amphibians and birds, etc.
- Water quality – including temperature, DO and nutrients.
- Key indicator species – including a range of species with different life histories, with flow requirements identified for specific life-history stages.
- Implications for population dynamics of non-native species and their interactions with native species and communities.

Breakout groups were challenged to consider the following questions when defining environmental flow components:

- How have dam operations changed river hydrology, morphology, and habitat?
- How does current and pre-dam channel morphology in the Des Moines River compare from the upper limits of Saylorville to the Mississippi River?
- What opportunities exist in the Des Moines River to develop structure or off-channel habitat for aquatic and bird life (e.g. reconnection of old ox-bows)?
- When considering birds, herps, mussels and fish species of greatest conservation need, are there flow management strategies that would benefit all?

Breakout groups continued their work for the remainder of the first day of the workshop. On Day 2, based on the fact that breakout groups were functioning well but had either not completely entered their e-flow definitions into the RPT software, and/or had not completed discussion for all three reaches, the groups were reconvened as originally formed to finish their work (i.e., complete environmental flow definitions for relevant environmental flow components and reaches). Following a break for lunch, participants came back together in plenary for the integration of flow recommendations from Working Groups into a single unified set of environmental flow definitions for each reach. Each of the working group facilitators and RPT operators presented the results of their working groups to the group. The expert findings from the 3 different RPT projects were then integrated and displayed in a single RPT project.

The workshop concluded with a summary of results and discussion of next steps, facilitated by Andy Warner.

**Table 1. Ecological Functions Performed by Different River Flow Levels**
**Flow Component Ecological Roles**

**Base flows and seasonal flows**
• Provide adequate habitat space for aquatic organisms
• Maintain suitable water temperatures, dissolved oxygen, and water chemistry
• Maintain water table levels in floodplain, soil moisture for plants
• Provide drinking water for terrestrial animals
• Keep fish and amphibian eggs suspended
• Enable fish to move to feeding and spawning areas
• Support hyporheic organisms (living in saturated sediments)

**Low flows (drought)**:
• Enable recruitment of certain floodplain plants
• Purge invasive, introduced species from aquatic and riparian communities
• Concentrate prey into limited areas to benefit predators

**High pulse flows**
• Shape physical character of river channel including pools, riffles
(channel forming flows)
• Promotes movement and redistribution of stream bed substrates (sand, gravel, cobble)
• Bankfull discharges
• Prevent riparian vegetation from encroaching into channel
• Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants
• Aerate eggs in spawning gravels, prevents siltation
•

**Floods**
• Provide migration and spawning cues for fish
• Trigger new phase in life cycle (e.g., insects)
• Enable fish to spawn on floodplain, provide nursery area for juvenile fish
• Provide new feeding opportunities for fish, waterfowl
• Recharge floodplain water table
• Maintain diversity in floodplain forest types through prolonged inundation (i.e., different plant species have different tolerances)
• Control distribution and abundance of plants on floodplain
• Deposit nutrients on floodplain
• Maintain balance of species in aquatic and riparian communities
• Create sites for recruitment of colonizing plants
• Shape physical habitats of floodplain
• Deposit gravel and cobbles in spawning areas
• Flush organic materials (food) and woody debris (habitat structures) into channel
• Purge invasive, introduced species from aquatic and riparian communities
• Disburse seeds and fruits of riparian plants
• Drive lateral movement of river channel, forming new habitats (secondary channels, oxbow lakes)
• Provide plant seedlings with prolonged access to soil moisture

*(based on Richter et al., 2006)*

## Summary of unified set of flow requirements and expert findings for the Des Moines River

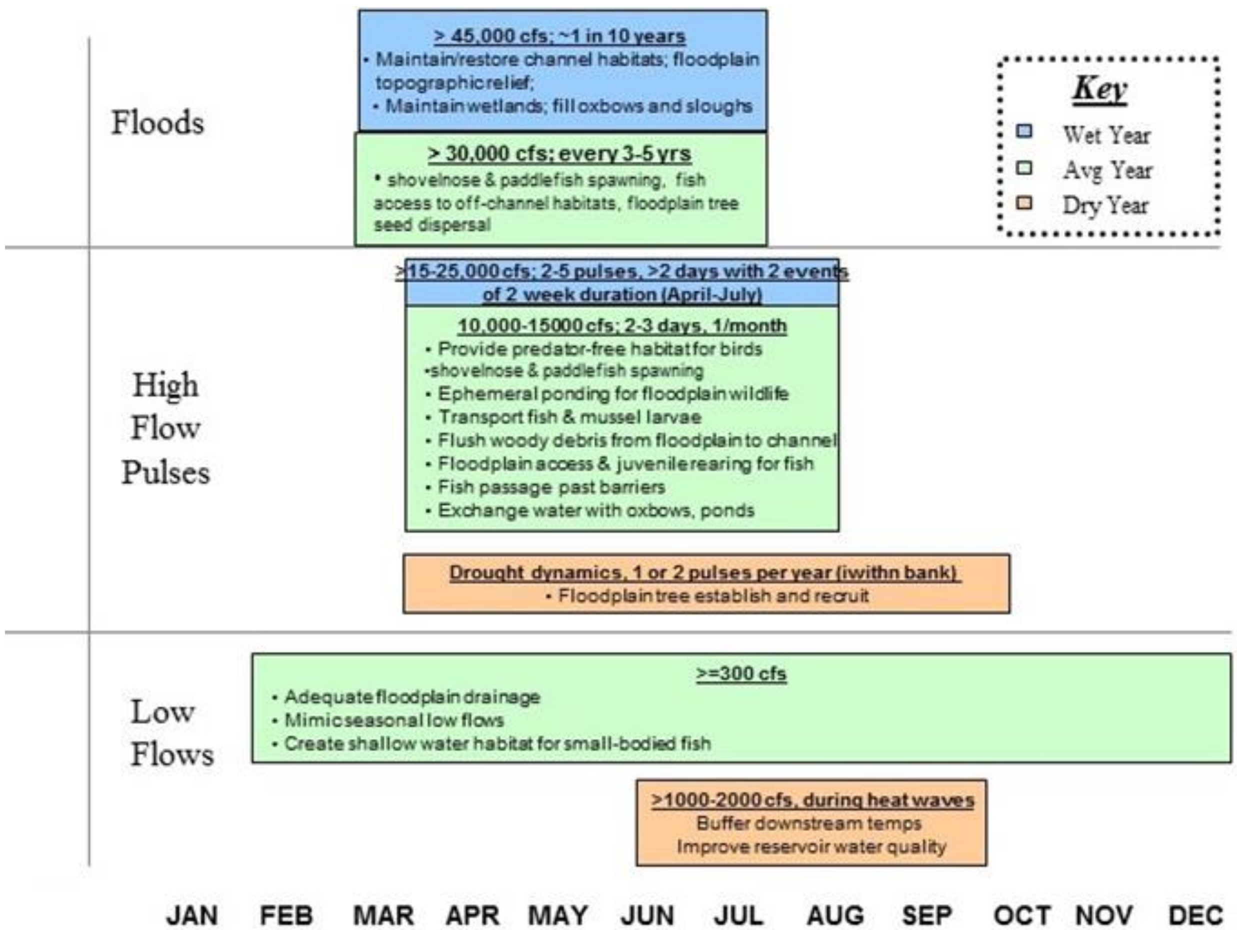


**Figure 1.** Red Rock Environmental Flow Expert Findings. Workshop participants found that flows for Saylorville were not substantially different than current operations, because outflows under current operations resemble natural inflows, except when flows are ratcheted back during Raccoon River flooding. Implications of hypothesized pool level modifications on river flows will need to be further explored in reservoir simulation models.

## BOX 1: The Hydrologic Engineering Center's Regime Prescription Tool (HEC RPT)

The Hydrologic Engineering Center's Regime Prescription Tool (HEC RPT) is a software program to help teams reach agreements on managing the flow regime of a river.[1] Development of HEC RPT was sponsored by the Hydrologic Engineering Center, Portland District and The Nature Conservancy in support of the Sustainable Rivers Program. Sustainable Rivers is an ongoing nationwide partnership between the Corps and The Nature Conservancy to improve the rivers by changing the operations of Corps dams, while maintaining or enhancing project benefits. HEC RPT was designed to provide an easy way to capture and present evolving flow recommendations in a workshop context. HEC RPT meets these needs by facilitating entry, display and documentation of flow recommendations and justifications in real-time public settings--rapidly displaying, adjusting and documenting hydrographs, accessing and plotting historical hydrologic data to guide scientists and managers in developing flow recommendations. It is a visualization tool and not intended to perform the quantitative analyses already performed by other software packages. Instead, HEC RPT seeks to complement those packages by making it easier to create flow times series that other software can import and use in analyses. Based on the successful contributions of RPT in previous SRP workshops, including the Bill Williams and the Willamette River, we decided it would be valuable to bring to the Des Moines River.

During the Des Moines River workshop, the three working groups used RPT to identify and capture suggestions for environmental flow improvements to sustain species and ecological processes on the three key reaches. Three groups were formed to define the river flows or pool levels needed to keep specific aspects of the ecosystem healthy and functioning: (1) floodplain fish, wildlife, and habitats; (2) fish and mussels; and (3) water quality, reservoirs, and waterfowl.

Each group began by capturing hypotheses about flow needs, discussing life history of key species and taxa in relation to the "natural" (unregulated) versus regulated flow pattern. Connections between the species and flows were identified and incorporated into a set of environmental flow recommendations.

A strength of HEC RPT is its ability to display and navigate hydrologic data sets. For the workshop, scientists imported data to HEC RPT that showed how the river has been managed since construction of the dams, as well as how the river would have flowed if there were no reservoirs. During the workshop, HEC RPT was used to build and display the flow recommendations, in real-time. Ideally, when a flow component was proposed, its magnitude, duration and timing were entered into text fields. Plots in HEC RPT update automatically with new entries, which allowed the groups to review and revise their findings.

Recognizing the inherent variability of flows in response to climate, the RPT software is designed to allow for flow prescriptions to be tailored to wet, dry, and average years. Given that "natural" flows on the Des Moines River have been altered by climate change and land use, RPT operators and workshop facilitators defined "reference flow conditions" for the purposes of the workshop project based on flow conditions since 1970. The regulated and unregulated flow series water year data were used to divide the historical flow record into thirds: wet, average, and dry. This analysis was completed prior to the workshop in setting up the software "project" for full functionality during the workshop.

The final step in the workshop was to unify the environmental flow recommendations from each separate group. The merging feature in HEC RPT allowed expert findings to be brought into the same project and plotted together.

[1] HEC RPT is available free of charge at http://www.hec.usace.army.mil/software/hec-rpt/.

## Background on the Saylorville and Red Rock Lake Projects

Following a series of floods on the Des Moines River, Congress authorized construction of two major flood control dams and reservoirs on the Des Moines River at Red Rock (finished in 1969) and Saylorville Lake (placed in operation in 1977). Although the primary purpose of both reservoirs is flood risk management, operation and management also provides other benefits including recreational opportunities, water supply, fish and wildlife habitat, etc. Current operations at Saylorville Lake and Lake Red Rock focus on the congressionally authorized purposes of flood risk reduction, water conservation/low flow augmentation, water supply, fish and wildlife, and recreation.

Construction and operation of both dam and reservoir projects has resulted in potentially significant implications for fish and wildlife habitat, water quality, and other natural resource issues. Operation of these dams results in alterations to the flow regimes of the river and its tributaries, specifically reduced peak flows, lower spring flows, increased summer flows and substantially modified/reduced floodplain inundation. Significant impacts have occurred to resident and migratory fish and mussels, in addition to wildlife that depends on aquatic, riparian and floodplain habitat. At the same time, the natural flow regime of the river has been significantly altered by upstream land use and drainage modifications as well as significant climate change trends over the past 100 years that have resulted in increased annual and seasonal flows.

The Des Moines River Sustainable Rivers project was designed to identify environmental flow requirements for the River, and develop hypotheses for alternative flow releases from the U.S. Army Corps of Engineer dams that might establish more natural flow regimes while providing enhanced multiple benefits within the project area (Figure 1). The Nature Conservancy in Iowa and the U.S. Army Corps of Engineers—working closely with other partners including subject area experts—have led the project using a process for identifying and refining environmental flow objectives developed and tested by The Nature Conservancy and the Army Corps of Engineers at a number of sites across the United States, including the Green River in Kentucky, the Savannah River in Georgia and the Bill Williams River in Arizona. The SRP process utilizes a series of steps to define environmental flow recommendations, implement changes in operation of dams to meet those flow objectives, monitor and model the effects of those changes on both the river ecosystem and the operation of the dams, and refine over time.

The goal of the project is to explore whether it is possible to modify Corps of Engineers' dam operations to benefit fish and wildlife populations, ecosystem function, river and floodplain habitat, recreation and water quality. Meeting environmental flow targets or restoration of more natural flow regimes would be expected to benefit numerous species, including several ancient river fishes such as paddlefish, shovelnose and lake sturgeon as well as floodplain plant communities and terrestrial wildlife. The flow restoration project may be linked to a larger Des Moines River watershed project. The project is designed to develop literature review and experts to define environmental flow adjustments, as well as identify whether proposed modifications are within current guidelines allowed by the Corp's water regulation manual, or might require adjustments to the operations regulations in the course of updates to the water regulation manuals the Corps' is scheduled to explore over the next 2-5 years. Ultimately, the goal is to identify and integrate understanding of flow needs into real-time decisions about how and when water is released from the reservoirs to achieve more environmentally beneficial flow regimes, and to adjust operations as needed in response to monitoring and modeled responses.

The first several phases of the Des Moines River SRP have involved identifying issues of concern expressed by stakeholders and experts; as well as conducting a literature review/summary report identifying key aspects of flow regimes that are important in sustaining the ecological health of the river-floodplain systems on the Des Moines River. The stakeholder workshops and interviews led to identifying 8 key issues of concern. The literature review focused on compiling existing data and literature on the flow requirements of native species and communities and the natural flow regimes of the river system. The report also addressed the 8 issues identified by stakeholders listed below.

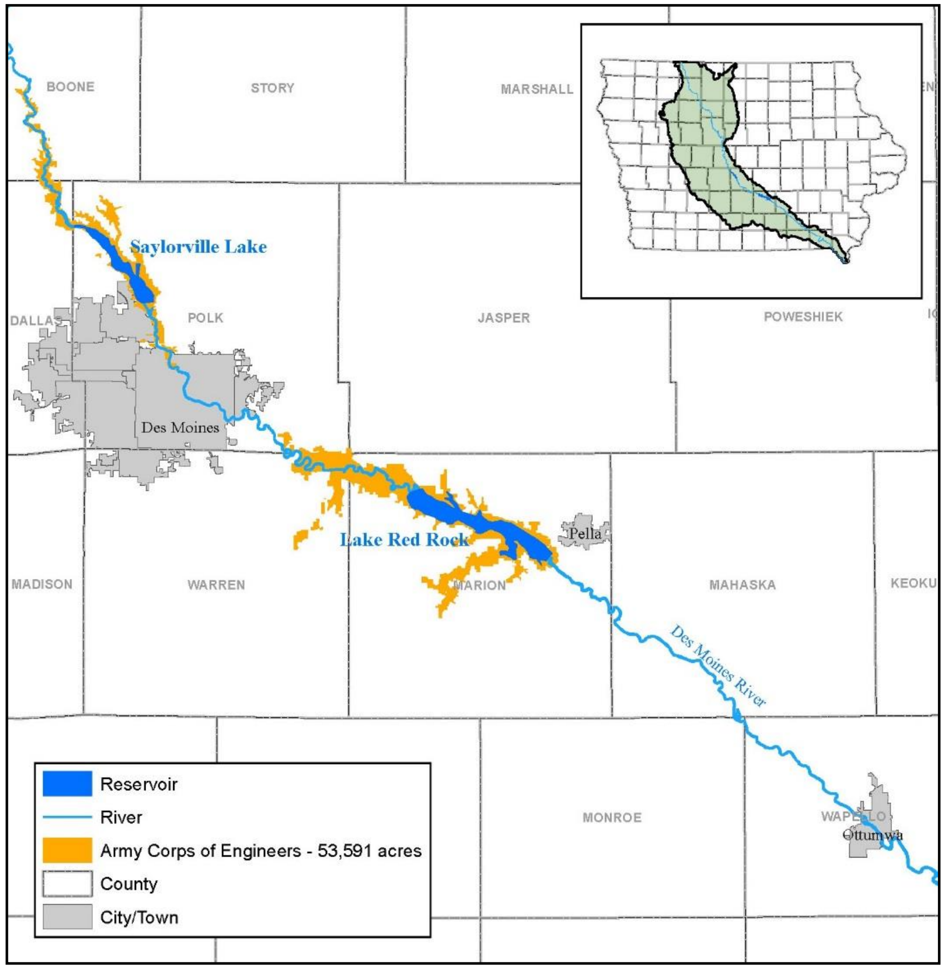


**Figure 2.** Project geographic scope

For the purposes of designing discussion at the workshop, the literature review and summary developed hypotheses regarding environmental flow components; summarized natural and current range of variation in low flow, high flow and flood pulses, duration and frequency of each, and the rate of change from one condition to another. The report also proposed initial flow hypotheses about the potential for modified flow regimes to produce benefits related to the 8 stakeholder issues, and possible flow alternatives to be explored in the e-flow workshop.

## Summary of Existing Operations

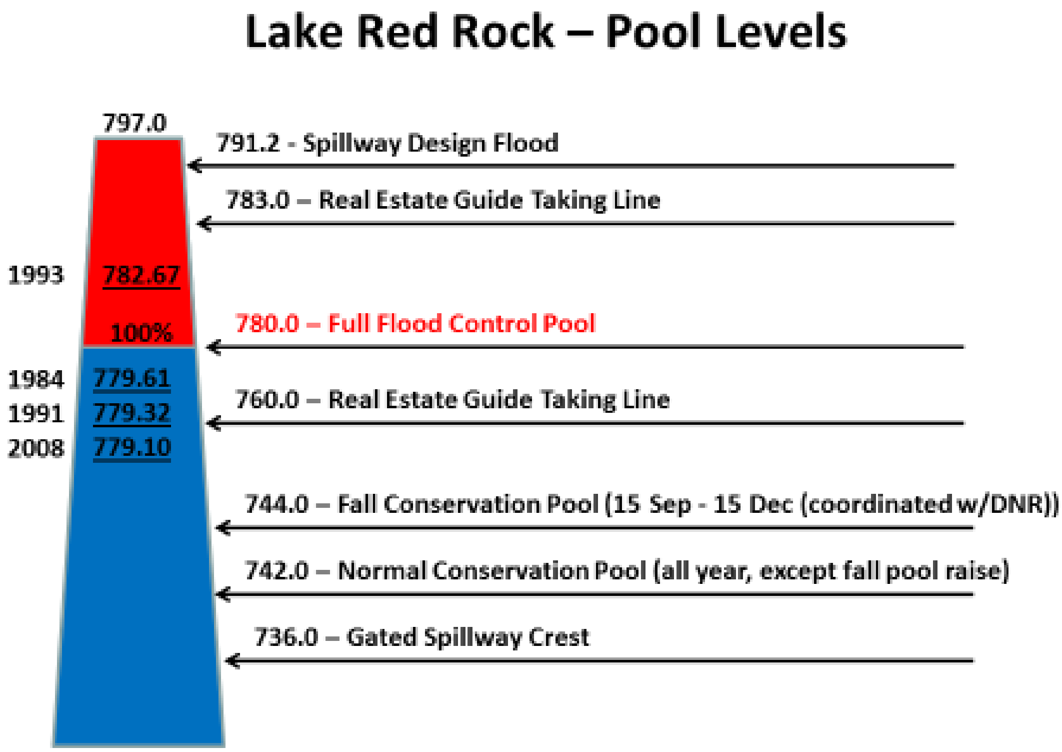


**Figure 3.** Red Rock Pool elevations under current regulations plan. In recent years, the pool has rarely gone below 742 feet, dipping to a low of 741.75 during the relatively dry year of 2012. The current normal conservation pool for Red Rock is set at 742 feet NGVD. The initial conservation pool target elevation was established at 725feet NGVD , and has been raised three times: 1979 (raised to 728 feet); 1988 (raised from 728 feet to 734 feet), and 1992, when the pool was raised from 734 feet to 742 feet. Other modifications to the regulations occurred in 1982, when Flash Flood operation was Implemented (10.8 feet at Ottumwa); 1988, when, in conjunction with the pool raise, the maximum growing season release was raised to 22,000 cfs when pool exceeds 760 feet; and the start of the growing season changed from 21 April to 01 May.

## Box 2. Lake Red Rock Flood Control Regulation Schedule

**Conservation Pool Schedule**

| Date | Elevation (feet) | |
|---|---|---|
| December - Fall | Hold 742 | |
| Fall - 15 December | 742 - 744 | (Fall Pool Raise) |

**Normal Flood Control Operation: Pool elevation at or forecast between 742 and 775 feet**

**15 December - 30 April**

Stage at, above, or forecast to exceed:
Ottumwa: 10.8 feet (or 30,000 cfs release)
Keosauqua: 19.6 feet
Mississippi River at Burlington: 18.5 feet
Mississippi River at Quincy: 20.0 feet

Maximum Release: 30,000 cfs
Minimum Release: 5,000 cfs

**1 May - 15 December**

If lake elevation is below 760 feet:
Stage at, above, or forecast to exceed:
Ottumwa: 7.5 feet (or 18,000 cfs release)
Keosauqua: 17.6 feet

If lake elevation is above 760 feet:
Stage at, above, or forecast to exceed:
Ottumwa: 8.7 feet (or 22,000 cfs release)
Keosauqua: 18.4 feet

Mississippi River at Burlington: 18.5 feet
Mississippi River at Quincy: 20.0 feet

Max Release if lake above 760 feet: 22,000 cfs
Max Release if lake below 760 feet: 18,000 cfs
Minimum Release: 5,000 cfs

**Large Magnitude Flood Operation: Pool elevation at, above, or forecast to exceed 775 feet:**

**Any Date**

| Elevation (feet) | Release (cfs) |
|---|---|
| 775 | 30,000 |
| 776 | 35,000 |
| 777 | 40,000 |
| 778 | 45,000 |
| 779 | 50,000 |
| 780 | 60,000 |
| 780.5 | 80,000 |
| 781 | 100,000 |
| 781.5 | 115,000 |
| 782 | 130,000 |
| 783 | 130,000 |
| 784 | 130,000 |
| 785 | Open spillway gates as necessary to maintain lake elevation 785 until uncontrolled spillway and outlet conduit release prevails. |

Lake Red Rock drains an area of 12,321 sq. mi., and has 1.4 million acre feet of storage (equivalent to 2.18" of runoff). At full flood control pool, the conduit capacity is 37,700 cfs, and spillway capacity is 225,000 cfs. Conduit capacity through the spillway consists of 14 sluice gates, each 5 ft wide x 9 ft tall. The gated spillway consists of 5 tainter gates, each 41 ft wide x 46 ft high (crest at 736' elevation). Peak inflows of 130,000 cfs and 130,800 cfs, and 134,000 cfs have occurred in 2010, 2008, and 1993 respectively. Corresponding peak outflows in those years were 53,500 cfs, 100,000 cfs, and 104,500 cfs. Hedging rules apply at low flows.

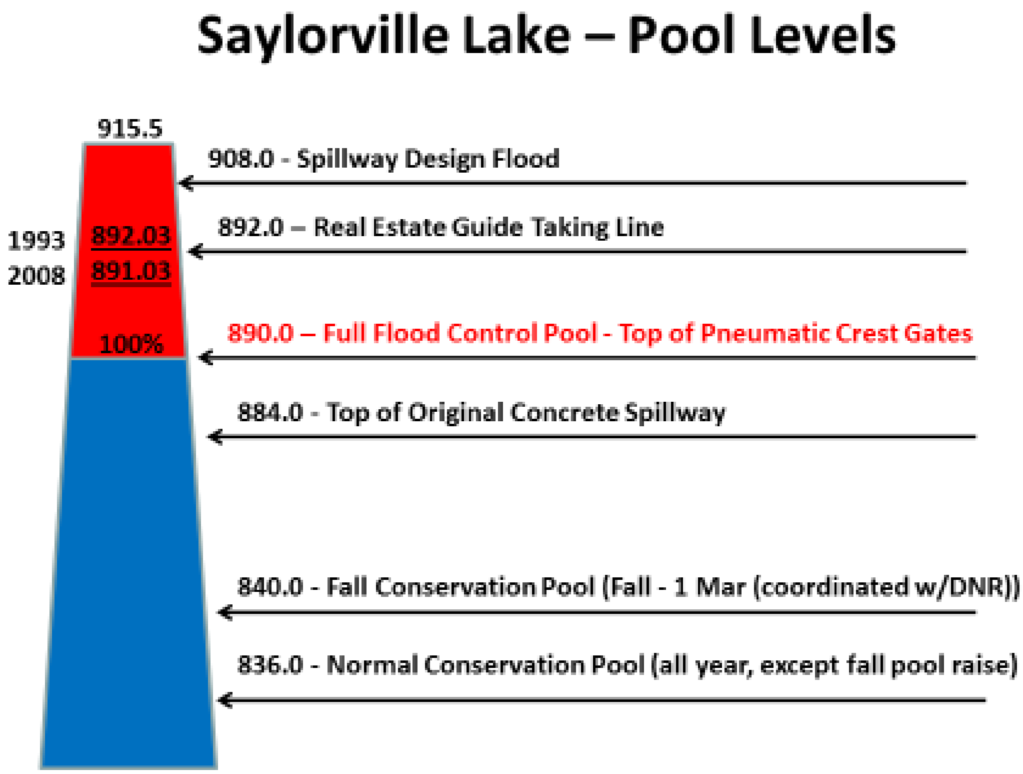


**Figure 4.** Saylorville Lake project was authorized by Congress in 1958. Construction began in 1965 and the conservation pool was reached in September 1977. The initial conservation pool target elevation was established at 833 feet. It was raised from 833 ft to 836 ft in 1982 as part of the Water Supply Contract with the state of Iowa. In 1994, pneumatic crest gates were installed on the overflow spillway section. Saylorville Lake drains an upstream area of 5823 sq. mi., and provides 567,000 acre-feet of storage, equivalent to 1.83" of runoff. At full flood control pool, the conduit and spillway capacity are 21,000 cfs.

In 1982 Iowa purchased storage in Saylorville Lake for consumptive water supply – 18.86% of conservation storage. This storage was determined to provide a continuous flow of 75 cfs with 99% reliability. The conservation pool was raised 3 feet to accommodate the contract. The state has authority to withdraw water from the lake or to order releases through the outlet works. Iowa has subcontracted 2/3 of the water to the Des Moines Water Works and 1/3 to the Iowa Southern Utilities. However, to date, water has never been requested by the state.

**Box 3.**

## Saylorville Lake Flood Control Regulation Schedule

**Conservation Pool Schedule**

| Date | Elevation (feet) | |
|---|---|---|
| December - Fall | Hold 836 | |
| Fall - 1 March | Hold 836 - 840 | (Fall Pool Raise - Variable) |

**Normal Flood Control Operation: Pool elevation at or forecast between 836 and 875 feet**

| 16 December - 20 April | 21 April - 15 December |
|---|---|
| Stage at, above, or forecast to exceed: SE 6th Street, Des Moines: 24 feet | Stage at, above, or forecast to exceed: SE 6th Street, Des Moines: 24 feet |
| Balance storage with Lake Red Rock if lake elevation is below 860 feet. | Balance storage with Lake Red Rock if lake elevation is below 860 feet. |
| Maximum Release: 16,000 cfs | Max Release: 12,000 cfs (Lake Red Rock > 758 feet) |
| Minimum Release: 2,000 cfs | Max Release: 16,000 cfs (Lake Red Rock < 758 feet) |
| | Minimum Release: 2,000 cfs |

**Large Magnitude Flood Operation: Pool elevation at or above 875, or forecast to exceed 884 feet**

| 16 December - 20 April | | 21 April - 15 December | |
|---|---|---|---|
| Elevation (feet) | Release (cfs) | Elevation (feet) | Release (cfs) |
| 875 | 16,000 | 875 | 12,000 |
| 876 | 16,000 | 876 | 13,000 |
| 877 | 16,000 | 877 | 14,000 |
| 878 | 16,000 | 878 | 15,000 |
| 879 | 16,000 | 879 | 16,000 |
| 880 | 17,000 | 880 | 17,000 |
| 881 | 18,000 | 881 | 18,000 |
| 882 | 19,000 | 882 | 19,000 |
| 883 | 20,000 | 883 | 20,000 |
| 884[1] | 21,000 | 884[1] | 21,000 |
| 885 | 21,000 | 885 | 21,000 |
| 886 | 21,000 | 886 | 21,000 |
| 887 | 21,000 | 887 | 21,000 |
| 888 | 21,000 | 888 | 21,000 |
| 889[2] | Fully Open | 889[2] | Fully Open |
| 890 | Fully Open | 890 | Fully Open |
| above 890 | Fully Open + Spillway | above 890 | Fully Open + Spillway |

1. 884 feet is the concrete spillway crest, and is the trigger for raising the pneumatic crest gates.
2. If the lake level is forecast to exceed 890 feet, the pneumatic crest gates are lowered at 889 feet.

An additional constraint on Saylorville operations that does not apply to Lake Red Rock is the 3000 cfs limit on the maximum rate of change in daily releases.

## Summary of Literature Review and Preliminary Flow Hypotheses

The natural flow regime provides a range of specific parameters (timing and magnitude of high and low flows pulses and floods, duration of high and low flow pulses, rate of rise and fall) that can be used to design managed flow regimes designed to mimic natural flows (Richter et al., 1996, 1997; The Nature Conservancy, 2005). A key concept in riverine ecology is that to maintain the ecological integrity of floodplain ecosystems, connectivity to the mainstem river environment is critical—to the point that this idea is considered an overarching theme in river restoration water management (Sparks, 1995). The central concept in the River Pulse Floodplain model and similar models (Junk et al. 1989) is that flow events that connect floodplain and mainstem systems on regular (usually annual) intervals promotes connectivity between the floodplain and river, thus increasing the exchange of nutrients, sediments, lateral connectivity and fish between the two systems that directly affects community composition. When connectivity between these systems is lost, changes in floodplain depth, surface area and shape have been found to lead to additional alterations to a suite of abiotic and biotic characteristics that directly and indirectly affected fish communities. Direct effects included loss of habitat via increased sedimentation that results in unsuitable spawning habitat for many fish species and loss of woody structure that provides attachment sites for many macroinvertebrate species. As floodplain systems become more isolated, they often become shallower, leading to increased temperatures and susceptibility to hypoxic conditions during warm weather conditions, thus allowing for the dominance of species with higher tolerances for poor water quality.

In the Des Moines River Basin, native fish and aquatic communities and species historically depended on a mosaic of riverine habitats and fluvial processes to complete their life cycles. To define the flows needed to support this complex ecosystem, we organized species into groups that share a sensitivity to one or more aspects of the flow regime. Biological and ecological traits are commonly used to describe groups of species with similar life histories, physiological and morphological requirements and adaptations, thereby providing a mechanistic link to understanding or predicting responses to varying hydrologic conditions (Poff et al. 2006, Merritt et al. 2010, Mims and Olden 2012; Parks 2013). Quantitative and qualitative information about how species respond in other river systems can help set expectations about the potential mechanisms and taxa response of species with similar functional traits. Below, we further elaborate on the link between flow-dependent taxa and physical and chemical processes within the basin. For each taxa group, we summarize flow needs and key hydro-ecological relationships identified through literature review (Tables 2-3). For species within each group, we attempt to synthesize known information on critical life history stages and timing for species within each group, as well as to associate groups with habitat types. By overlaying key life history requirements for each group on representative hydrographs for each habitat type, we highlight relationships between species groups and seasonal and interannual streamflow patterns (Figure 5).

Table 2.

| Group | Life history |
|---|---|
| **Aquatic-lotic species**<br>*Smooth softshell, spiny softshell turtles, map turtles, mudpuppy (lungless salamanders)* | • some depend on specific hydraulic conditions, depth, velocity, width<br>• use specialized stream-dependent feeding habits<br>• sensitive to changes in water quality<br>• require aquatic connectivity |
| **Semi-aquatic lotic species**<br><br>*wood turtle, northern water snake, northern leopard frog* | • rely on flowing waters within the active channel or groundwater dependent backwaters for one or more life stages, typically hibernation<br>• depend on access to and quality of floodplain and riparian habitats for migration, feeding, and reproduction |
| **Riparian and floodplain-terrestrial and vernal habitat species**<br>*bog turtle, northern cricket frog, blue spotted salamander* | • mating, egg and larval development may occur in vernal pools within the floodplain or in intermittent streambeds<br>• terrestrial connectivity within riparian and floodplain habitats |

Table 3.

| Group | Description | Examples |
|---|---|---|
| **Large river species (wide ranging)** | • occur in tributaries and large rivers<br>• spring spawners with migration typically cued by temperature and rising water levels<br>• require connectivity to floodplain and backwater habitats as well as to upstream tributaries<br>• long-lived, large-bodied, pelagic feeders requiring maintenance of deep, open waters | Shovelnose Sturgeon<br>Paddlefish<br>Longnose Gar<br>Skipjack Herring<br>Channel Catfish<br>Flathead Catfish |
| **Migratory residents** | • spring spawners requiring connectivity between tributary and small river habitats during spawning migrations<br>• medium body size requiring moderately deep habitats esp. during overwinter period | Lamprey, Sauger, Walleye, American Eel |
| **Backwater dependent/ specialist species** | • Species that utilize or depend upon backwater habitats preferentially for at least part of their life cycle | Golden Shiner, Longnose Gar, Tadpole Madtom, Brook Silverside, Red Shiner, Mississippi Silvery Minnow, Blackchin and Blacknose Shiner, Weed Shiner and Topeka Shiner |
| **Fluvial specialists** | • Almost always found only in lotic systems, i.e. streams and rivers; described as needing flowing water habitats throughout their life cycle | Black Redhorse, Blacknose Dace, Longnose Dace, Common Shiner, Hornyhead Chub, Northern Hogsucker, most Darters |
| **Fluvial dependent** | • Found in a variety of habitats but require access or use of stream habitats or flowing waters at some point in their life cycle, such as for tributary spawning. May have significant lake or reservoir populations that use tributary streams for some life requirement | White Sucker, Golden and Shorthead Redhorse, Paddlefish, Mud Darter, Tadpole Madtom, Topeka shiner |

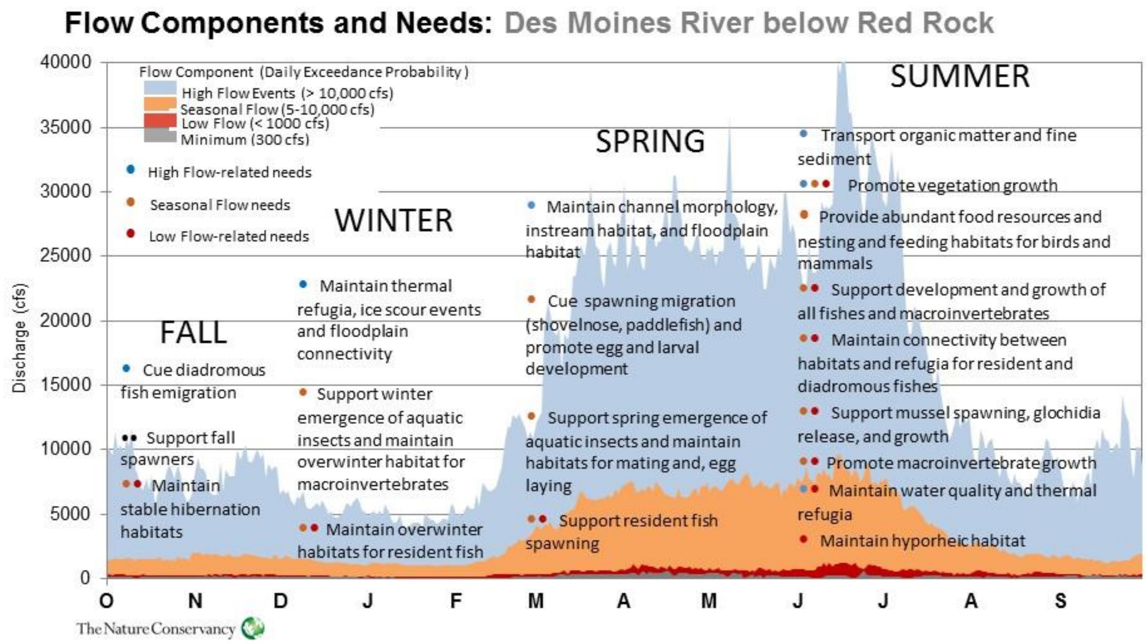


**Figure 5.** Preliminary hypotheses of flow components and needs for the Des Moines River downstream of Red Rock Dam.

As noted in the literature review, the most dramatic changes to hydrology in the Des Moines River Basin have occurred due to the extensive conversion of tallgrass prairie to annual row crops, shallow-rooted pasture/lawn grasses, impervious surface and other non-native land cover; combined with extensive drainage modifications and significantly increased rainfall in the 2nd half of the 20th century. All of these changes have dramatically altered the magnitude, timing, and frequency of a range of environmental flow components. Understanding the impacts of the USACE flood control projects at Saylorville and Red Rock therefore requires teasing out changes due to the dams versus these larger scale changes in basin hydrology. Although the historical flow record is extensive, many changes to the Iowa landscape were already significant by the time gages were installed in 1918. We assume that complete restoration of presettlement natural hydrology is at this point not feasible, and that the goals of this project are to understand ecological flow needs and move towards restoring a more ecologically beneficial hydrology within the constraints of the modern context. Therefore, for the purposes of the workshop, hydrograph changes were explored in relation to flows after 1970. Analyses of hydrologic changes in RPT were based on comparing historical flow time series (1970-2015) for the regulated versus unregulated (simulated flows without either of the projects) generated by the U.S. Army Corps of Engineers (Landwehr, pers. communication).[2]

[2] For the literature review, daily flow statistics were summarized for regulated and unregulated flows over the entire period of record (1918-2015) at each location provided (i.e., below Saylorville and below Red Rock). The literature review also included two-period comparisons (pre- and post- project) using the Indicators of Hydrologic Alteration software (TNC, 2007), flow time series were analyzed as follows:

**Summary of the Effect of the Projects on Environmental Flow Components.**

Wet years. The literature review, comparing daily flow statistics for the $10^{th}$ percentile, median, and 90th percentile flows, showed significant differences in the frequency distributions of daily and seasonal flows (TNC 2016). However, using RPT to compare wet, average, and dry year flows by water year allowed breakout groups to view how the projects have impacted flows across individual water years. Examples are shown in Figures 6-8 for wet, average, and dry year flows from Red Rock and Saylorville. Both projects generally operate according to the seasonal pattern of inflows, but tend to capture and store the highest flows and then release higher flows later in the season. Regulated flows are typically lower and flatter than unregulated flows would be from April to July, but higher and flatter from August through December. During wet years, Red Rock significantly elevates and prolongs fall and winter flows.

Dry years. Red Rock dam operations do not appear in general to substantially impact flows in dry years. However, unregulated low flows are typically higher in the fall (when inflows are being stored to accomplish the fall rise), and the pattern is reversed in mid to late December for the fall pool drop. Flows between 400-2000 cfs in December are significantly more frequent post-dam. Extreme low flows have been completely eliminated by the 300 cfs minimum flow requirement, and in general, low flows are more consistent across years than prior to the project. Dam operations do not seem to significantly impact low flows at Saylorville.

Average years. Relative to the “unregulated” flows, Red Rock reservoir operations have increased seasonal (median) daily flows significantly in December, when the conservation pool is being restored to the lower level after the fall pool raise. Median flows are especially elevated relative to the unregulated flow regime from May through September. Only October flows are lower under the regulated scenario. A similar pattern is observed for Saylorville.

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for the flow releases below Red Rock, using the pre-dam unregulated flow series prior to 1969, and the regulated flow series data for water year 1969 and after and (b) for flow releases below Saylorville, using the pre-dam unregulated flow series prior to 1977, and the regulated flow series data for water year 1977 and after.

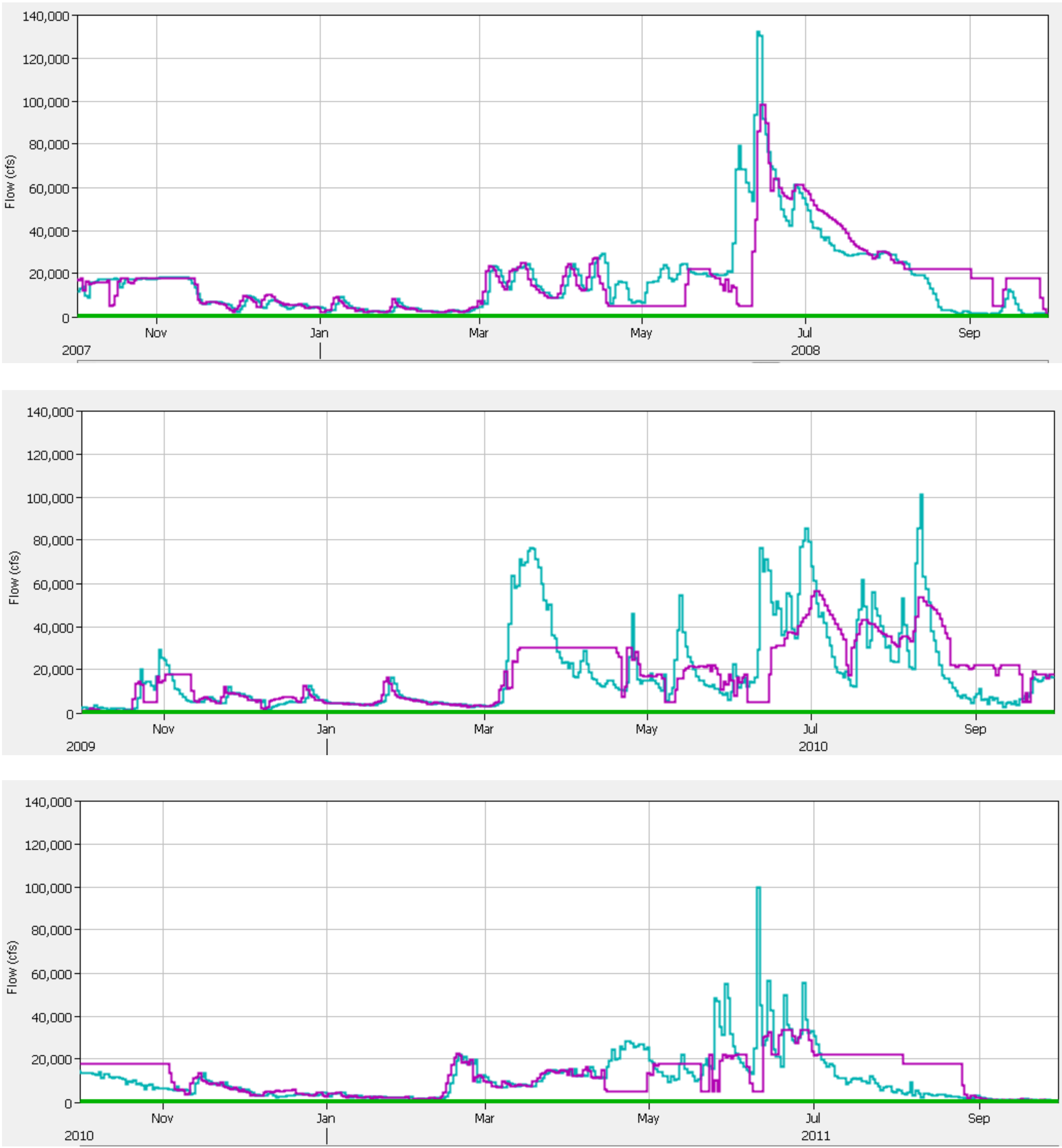



**Figure 6.** RPT time series for example water years for the reach below Red Rock, comparing regulated (purple) to unregulated (turquoise) flows, using "wet" year examples: (a) 2008, (b) 2010, and (c) 2011. The main effect of the project is to reduce the frequency and the number of years during which flows exceed 30,000-40,000 cfs, corresponding to overbank flows and floodplain inundation, and prolong and extend the intermediate flow releases of 18-30,000 cfs. However, in the very wettest years, high flows still do occur.

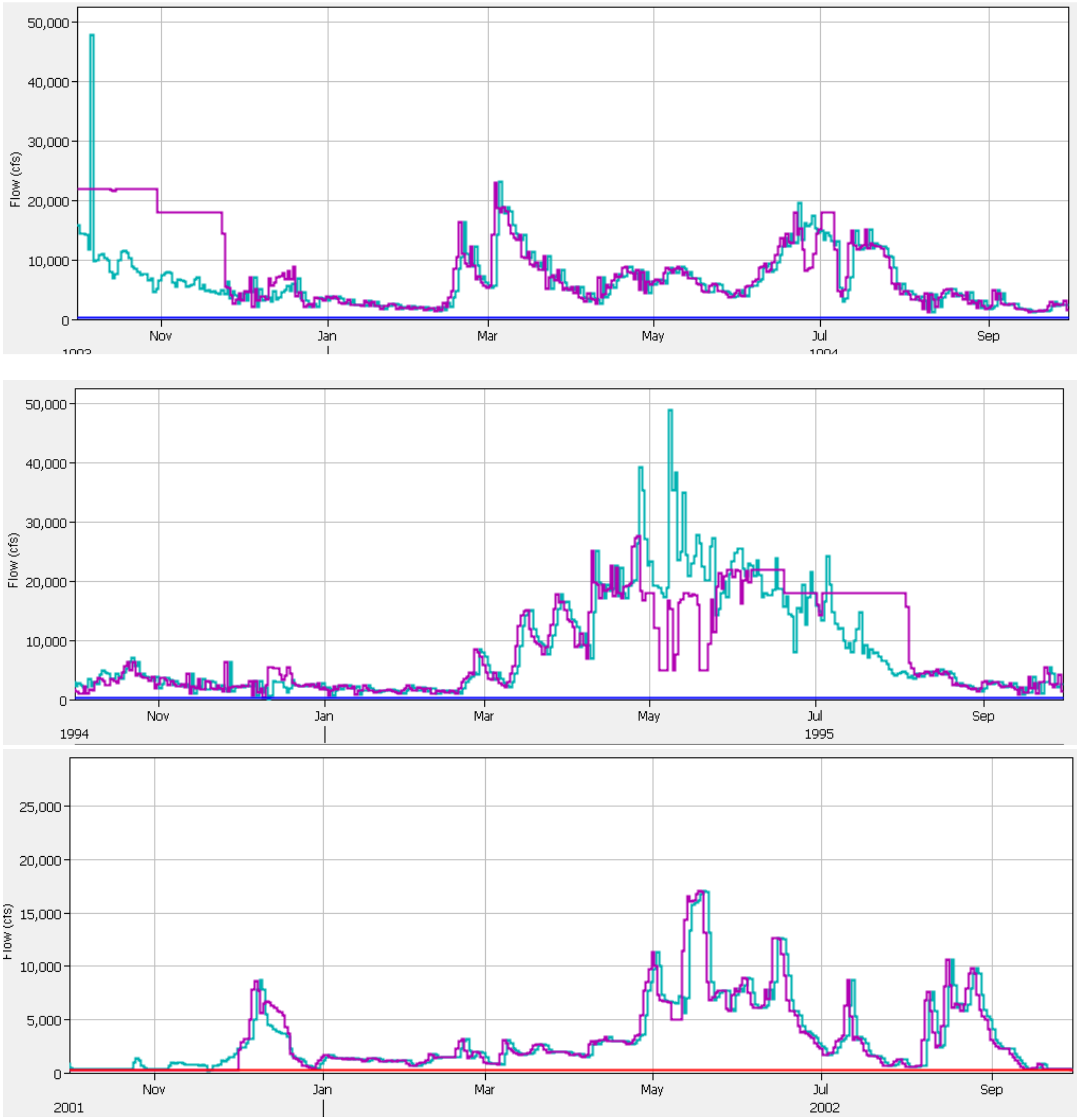



**Figure 7.** RPT time series for example water years for the reach below Red Rock, comparing regulated (purple) to unregulated (turquoise) flows, using "average" (1994, 1995) and "dry" (2002) year examples. Although 1994 was an "average" year, a high flow pulse in October 1993 was captured and stored, leading to higher releases for much of October and November than without the dam. In 1995, Lake Red Rock captured and stored several peak flow events in the spring, prolonging the 18,000 cfs flow release well into August. In many of the dry year scenarios such as 2001, the main impact of dam operations is to reduce the low flows in October and November down to the 300 cfs minimum flow, in order to accomplish the fall pool rise.

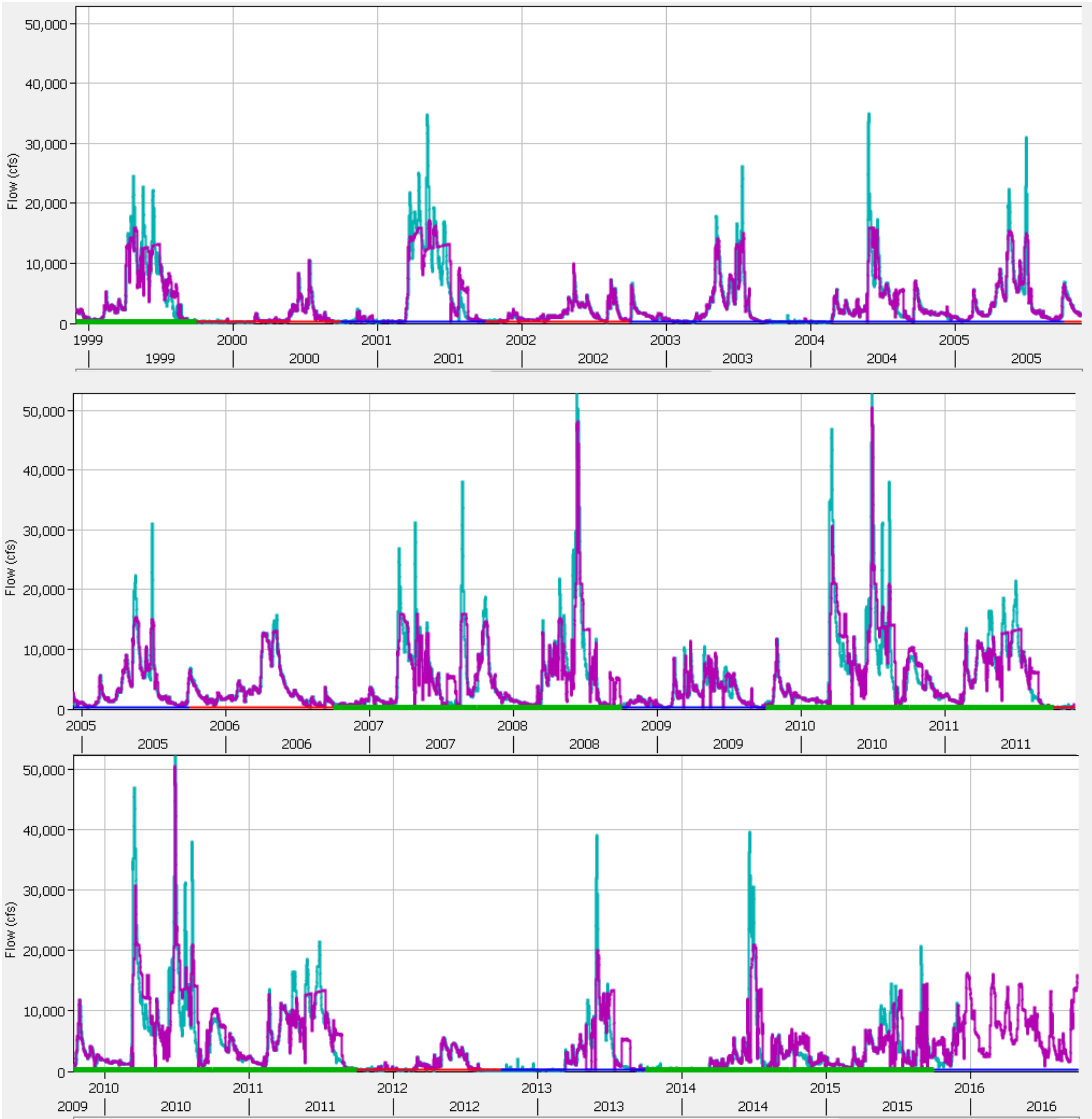



**Figure 8.** RPT time series for multiple years for the reach below Saylorville, comparing regulated (purple) to unregulated (turquoise) flows. "Wet" years are indicated along the horizontal axis in green, "average" in blue, and "dry" years in red. Regulated and unregulated flows are similar in general except during high flows. High flows of 15-40,000 cfs are captured and stored by the project, with prolonged releases of 12-15,000. Flows exceeding 45-50,000 cfs (such as occurred in 2008 and 2010) are not fully captured and stored, and result in flood releases.

**Table 4.** Preliminary flow hypotheses for environmental flow needs by reach, from the literature review.

| Saylorville & upstream | Saylorville to Red Rock | Below Red Rock |
|---|---|---|
| Explore whether pool elevations can better mimic natural seasonal inflows to improve fish, herp, & bird habitat | Coordinate Saylorville releases with recreational use, boating & fishing initiatives in DMMA | Bolster low flow releases during heat waves to moderate instream temperatures and reduce downstream fish and mussel mortality |
| Explore implications of manipulating reservoir time for denitrification | Explore implications of manipulating reservoir time for denitrification | More gradual rise and fall rates; reduce rapid fall storage drawdown and winter releases |
| Implications of sedimentation for waterfowl/shorebird habitat | Explore whether pool elevations can better mimic natural seasonal inflows to improve fish, herp, & bird habitat | Short-term low flow releases to benefit downstream recreation (as long as rise rate is not too rapid) |
| | Implications of excess sedimentation for habitat | Restore more natural seasonal pattern of low flows (higher & more variable) |
| | | Explore costs & benefits of restoring natural flood frequency & duration for floodplain inundation / channel maintenance / off-channel habitat |

## Detailed Breakout Group Discussions and Environmental Flow Definitions

### 1. Fish and Mussels

The fish group and mussels began by discussing factors contributing to fish and mussel mortality on the Des Moines River (2 of 8 issues and concerns identified by series of stakeholder input meetings that initiated the Des Moines SRP partnership), and whether flow changes could be made to reduce the incidence of these mortality events.

For fish, the literature survey revealed two major contributors to significant mortality events as well as—less well documented—potentially chronic drivers of fish mortality:

(1) Gas bubble trauma associated with supersaturated conditions downstream of Red Rock dam, and
(2) Thermal conditions in the Des Moines downstream of Red Rock and Ottumwa that periodically exceed lethal tolerance limits for fish and other aquatic taxa. Mortality concerns relate primarily to shovelnose sturgeon.

Based on the literature review and participant first-hand knowledge, gas bubble trauma induced fish kills are linked to periods when there is a rapid stepdown in flow through the dam at Red Rock. Operators at Red Rock have already begun working with fisheries managers to try to reduce the rate of change during step down to reduce the incidence of gas bubble trauma; however, more understanding is needed. Gas bubble disease appears to be related to a combination of gas supersaturation combined with a lack of habitat of sufficient depth where fish can move to re-equalize pressure. Therefore, the problem is compounded during low flow periods, when fish have less access to deeper habitats. However, it can also occur at high flows, because gas supersaturation is typically higher when the Tainter gates are in operation.

The rate of change (rise rate and fall rate) was also a major focus of discussion. Although current operating rules restrict the rate of drawdown at Saylorville to a maximum of 3000 cfs per day, there are no such restrictions at Red Rock. Workshop participants discussed placing a restriction on the maximum rate of change, both increasing (rise rate) and decreasing (fall rate). Several values were proposed as hypotheses, ranging from 3000 to 5000 cfs maximum change per day. The group also discussed whether the restrictions on the rate of change should be flow dependent, i.e., smaller maximum rate of change allowed at low flow than during average or high flow conditions. Research needs and uncertainties were discussed, including the need to determine rate of acclimation needed for fish to prevent gas bubble trauma, and the need to understand how the future operation of hydropower turbines may impact the problem. The environmental assessment concluded the new hydropower facility would be unlikely to exacerbate the supersaturation problem, given the elevation of the turbines at the midpoint of the reservoir elevation. However, requirements are in place for monitoring water quality once the hydropower turbines begin operating.

With respect to thermal conditions, participants discussed the fact that several recent major fish kills involving significant numbers of shovelnose sturgeon (a state listed fish species in Iowa) have been attributed primarily to thermal stress due to summer water temperatures that exceeded many species' physiological tolerances. For example, a major fish kill occurred in July 2012, when water temperatures in parts of the Des Moines River reached 98 °F. The fish kill involved many different species, but by far the largest count and greatest concern was for sturgeon. A news account dated July 22, 2012[3] noted that people started noticing dead fish around July 7, at a time when flow releases from Red Rock were still well above the 300 cfs minimum release. The group discussion of flow-related hypotheses focused on whether (1) boosting flow at baseflow conditions might help to alleviate thermal stress downstream during critical periods and (2) thermal stratification in the reservoirs might provide some flexibility or help adjust downstream water temperature; for example, taking water off different sections of the pool depending on water temperatures in the reservoir.

The group recognized that it was unclear, and possibly unlikely, that cooler releases from the reservoir at Red Rock would be able to mitigate or moderate water temperatures in the river well below Ottumwa, where the fish kill occurred, given existing channel morphology and the time and distance water has to travel from the dam. They suggested that water quality models applied retroactively (e.g., for the July 2012 conditions) could be used to assess whether flow manipulations would have made any difference at all to water temperatures downstream during critical periods, and recommended a sensitivity analysis to resolve the question.

The group also discussed the relationship of temperature and channel morphology changes on the lower Des Moines. It was hypothesized that excessive water temperatures in some reaches of the lower Des Moines River may be exacerbated, especially at low flow, by channel widening and simplification that has occurred in response to the dams and other changes in the river's flow regime, i.e., a "fluvial geomorphology problem". There was significant uncertainty about whether anything could be done on the flow management side that would affect or restore channel morphology, given that land use, levees, and other changes may now constrain the function of channel-forming flood flows to significantly re-shape the river channel. Legacy channel changes were also discussed in terms of how "reference flows" might need to be adjusted to achieve the same ecological benefit, i.e. for any given magnitude of flow, the results/ amount of habitat created are likely to be different now than they were prior to the construction of the Corps projects. For example, the currently authorized 300 cfs minimum flow may not provide the benefits it once did in terms of instream wetted habitat. Understanding how the channel has changed, and what the implications are for habitat at different flow magnitudes, was identified as a significant knowledge gap. It was suggested that flow increases may provide benefits closer to the dam at Red Rock, but may not be maintained or extended very far downstream. There is just "not a lot of deep pool habitat between Ottumwa and Keosauqua." Ultimately, the group hypothesized that given recent historical climate conditions, the current minimum flow of 300 cfs may be overly conservative, and could potentially be increased without significantly impairing authorized

[3] http://www.thegazette.com/2012/07/22/des-moines-river-fish-kill-tops-10-million-in-value

purposes of the dam at Red Rock. It was suggested that increases in the minimum flow release could be coordinated with climate conditions as a buffer against excessive temperatures downstream. However, there was uncertainty about this recommendation, and recognition that modeling would be useful to explore what the implications would be both in terms of downstream benefits and impacts on the conservation pool.

The group also discussed whether it might be possible to make changes at Ottumwa that would be beneficial to fish. One suggestion was to explore the possibility of creating a fish passage bypass channel around Ottumwa that would facilitate upstream movement of fish even at low flow, and especially during times when temperatures downstream are creating thermal stress. Changes to the hydropower operation were also discussed, particularly preventing sub-daily peaking operations.

With respect to environmental flow components, the fish and mussel group began by thinking about connectivity to the floodplain during critical spawning and nursery periods for fish. Critical timing for fish passage for spawning fish is April-May-June; however, high flow pulses in late summer and early fall may also benefit fish by moderating temperatures and creating greater connectivity between patches of more suitable habitat. Although traditionally it has been believed that shovelnose sturgeon typically spawn in April or May, experts cited recent research from Missouri suggesting that they may in fact be protracted or opportunistic spawners that can spawn throughout the year whenever conditions are appropriate. Furthermore, some of the sturgeon killed in the Des Moines River in 2012 were observed to be carrying eggs; and recently hatched sturgeon have been found as late as October. Previous work has suggested that spawning is triggered by a combination of rising flows, daylight length, and water temperature, so it is possible that they can take advantage of combinations of environmental conditions whenever they occur.

Ecologically, the group recognized that flood pulses need to be predictable within the operational windows. Most fish species in the Des Moines spawn during spring and early summer high flows. Experts observed, based on reviewing the historical flow records in RPT, that there appears to be potentially a role for a bimodal flood pulse, with one peak that primarily benefits early season spawners (March-April) and a second one later that supports May-July spawning fish, as well as providing juveniles and backwater species access to shallow, productive nursery habitats in early summer. There was also discussion of the need for a fall rise to allow juvenile fish to access habitats on the margins for forage. The natural flow regime tends to be associated with a fall “rise” as the growing season ends, evapotranspiration by terrestrial vegetation shuts down, and stored water in the system becomes more available. Although the group recognized that dam operations, ongoing and legacy climate, land use, and drainage changes do represent constraints in terms of the feasibility of returning the system to a “natural” hydrograph, attempting to “mimic” the natural hydrograph is a guiding paradigm for identifying environmental flows. The goal is to design releases that yield the greatest ecological benefit. There was some question from a water management standpoint of how certain defined environmental flows would impact the reservoir water storage.. The group felt that in general, matching outflows to inflows represented the best way to "mimic" the natural flow regime; however, some planning would be needed to avoid excessive rate of change in either flows or pool levels when transitioning from wet to dry condition operating rules and vice versa, as well as in conducting pool raises and drawdowns.

On Day 2, the fish and mussel group continued discussion about flow needs throughout the year for fish during wet, dry, and average conditions, and attempted to define specific environmental flow needs. They also discussed whether the environmental flow recommendations they had put forward for fish were appropriate, necessary and sufficient for mussels as well. Much discussion centered on the implications of timing and rate of change of "unnatural" flow releases for mussel mortality and other potential negative impacts to aquatic and aquatic-dependent biota, particularly during winter. There was group consensus to modify the current approach transitioning from fall to winter pool levels by dumping massive amounts of water in December, once the fall pool raise period is completed. The group finding was to restore the winter pool elevation much more gradually and limit the daily rate of change to a maximum of 5000 cfs per day, if not less.

Overall, there appeared to be consensus that modifications need to zero in on restoring a more natural ***rate of change***, as opposed to identifying specific flow or pool elevation targets. Analysis of pre- and post-project flow regimes suggest that the hydrologic indicators that have been the most altered are the rise rate and the fall rate. For example, both the literature review summary and the RPT hydrograph analysis identified differences between the regulated and unregulated flows in late December, specifically an apparent spike in daily $10^{th}$ percentile low flows under the regulated flow regime. Historically, once the period ends for the fall pool rise (~Dec 15-20), operations at Red Rock have moved to restore normal pool elevation by immediately releasing large amounts of water through the dam. This has resulted in a pattern of rapidly increased flows in late December that is highly unseasonal (or unnatural), which could well be highly disruptive to aquatic and aquatic-dependent wildlife, especially mussels and herps. Ecologically, radical changes in flows and pool elevations were identified as very detrimental to mussel populations, particularly when entering cold periods, as well as likely detrimental to certain herps (especially turtles and frogs). There was a question of whether the fall pool raise should be maintained throughout the winter, given that mussels and other taxa are most vulnerable to exposure mid-December through February, and some expressed the view that rapid drawdowns in pool elevation and/or river levels during the winter should be avoided if at all possible. At the same time, slowly lowering the lake pool during the winter could result in a continuum of sheet ice along the shore, and raised the question of impacts to herps that are hibernating during the winter. Therefore, the group finding was to hold the pool at the fall rise elevation well into late winter/early spring. However, this could be in conflict with the authorized purposes of the dams in terms of ensuring adequate spring flood storage. The question was discussed of whether spring flood storage could still be achieved by restoring the winter pool elevation much more gradually, and when to begin restoring the normal conservation pool elevation. In terms of reservoir elevations, the expert finding was to extend/prolong the releases from both Red Rock and Saylorville to a drop of the pool no more than 3" a day in the winter, and no more than 6” a day in the fall. However, even 3-6” / day may have negative ecological impacts at certain times of year.

Next, the group used the RPT volume tracking feature to assess whether flows in average and dry water years would be sufficient to sustain environmental flows developed for wet year conditions. RPT volume tracking indicated there should be sufficient flow in most years to accommodate the environmental flow needs. For dry years, however, there might be insufficient flow to achieve the bimodal flood pulse, and it might be necessary to allow spring flood pulses only in conjunction with natural inflows. There was also significant discussion about whether management should exploit the capacity of the reservoir to store water in order to ensure predictable timing of spring flood pulses during the periods identified for early or late season spawning, or to allow timing to be determined naturally based on storms and to ensure natural variability in timing that may benefit different species in different years. A consensus formed around a preference for natural climate variability, i.e., coordinating the flood pulse releases with natural storm events and inflow magnitudes, especially during dry years. There was uncertainty about the ecological value and function of dry year flood pulses that do not exceed bankfull.

Recognizing that there might not be sufficient flow in some dry years to meet flood pulse environmental flows, the group then discussed whether flood pulses should include using some of the conservation pool storage to artificially create or enhance flood pulses during prolonged drought periods (e.g, 3+ years of dry conditions). For example, even during dry years, a spring pulse could be achieved if the fall pool raise was held through the winter, especially if the fall pool raise was increased (> 4 ft). Discussion acknowledged that this would likely create conflict with recreational uses or purposes, if it substantially reduced the elevation of the conservation pool. Any such use would also be subject to constraints related to authorized purposes of water supply, e.g. the water supply contract with the state of Iowa grants the state 18% of the conservation pool.

Between Saylorville and Red Rock Pool

The fish and mussel group observed that there are ecologically significant mussel populations upstream of metropolitan Des Moines, on the Raccoon, and other tributaries upstream of the dams. Notable fisheries in the river include smallmouth bass and catfish. Because of the extent of urban infrastructure, it was initially assumed that there would be limited opportunity to restore floodplain inundation dynamics in this reach. However, there are now significant public green space and conservation holdings within the DM metro area, and the opportunity to continue to build on the (currently unfunded) Greenbelt Plan that had restored significant areas along the river corridor for recreational, green space, and wildlife benefits. Some areas along the river just downstream of Saylorville, upstream of the confluence with the Raccoon, were described anecdotally as providing extensive flooded areas during recent flooding events. For example, there is an area of oxbows and floodplain habitat downstream of Saylorville that gets inundated at somewhere between 16-17,000 cfs (see map below, generated from the IFC floodplain inundation mapping tool), without creating an excessive amount of “inconvenience.” [sic] The connectivity and management of these areas could possibly be improved in the future.

In comparing the regulated and unregulated flow series for Saylorville, it appeared that for the most part Saylorville is passing natural inflows, with the regulated flows being very similar to the predicted unregulated flow series, except when flows exceed 16,000 cfs, or when the Raccoon is forecast to have flooding issues. Below the confluence with the Raccoon, flow in the river shows a very strong signature from the Raccoon River contributions. This is because outflows from Saylorville are typically cut back rapidly when very high flows are forecast for the Raccoon. The rate of change is currently limited to 3000 cfs per day, driven primarily by concerns about bank stability in-reservoir as well as downstream safety. However, even 3000 cfs per day is a significantly greater rate of change than under the natural flow regime (comparing the regulated versus unregulated rise and fall rate). Although it is unknown to what extent this rate of change results in detrimental effects in the reach between Saylorville and Raccoon, it is certainly plausible.

Summarizing uncertainties, the group identified a need to further evaluate whether 3000 cfs per day is a sufficiently protective restriction on the rate of change below Saylorville, as well as whether 200 cfs minimum flow is still adequate.

There was some discussion of the 2 low head dams on the mainstem Des Moines in this reach, both of which have both been identified and proposed for removal for safety, recreational, and ecological reasons (Hoogeveen 2010). Discussion centered on whether these dams currently influence reservoir operations at Saylorville, and if so, how; as well as implications of their removal for fish passage, habitat connectivity, and Corps operations. Removal of the dams would open up additional potential floodplain habitat below Saylorville Dam.

<u>Lake Red Rock.</u> Discussion on flow and water level management at Lake Red Rock began with how current management of conservation pool and elevation changes affects existing fisheries and mussel populations. Although the reservoirs themselves are manmade, it was hypothesized that the ecological communities they support would be best adapted to a water level regime that follows the natural pattern of water level dynamics in regional lakes, wetlands, and floodplains. As an example of a key fishery resource, water level needs were discussed for crappie and temperate bass. Crappie initially spawn starting at the end of May through the $2^{nd}$ – $3^{rd}$ week of June. Therefore, it would be best to avoid falling water surface elevations during that period.

A 0.5 ft (6 “) increase to the conservation pool elevation was proposed starting 01July (742.5 ft), that would be slowly lowered (1”/week) for 8-12 weeks. The purpose of this water level manipulation is to create exposed mudflat habitat for shorebirds (see additional discussion on mudflats in next section).

The discussion of uncertainties identified some questions about the rate of fish “loss” through the dam (downstream passage), whether this is affected by the elevation of the gates, and where the turbines are drawing from in relation to the water surface elevation. It was observed that larger releases can suck sediment laden waters into the lake more quickly and create turbid water conditions downstream (water quality issue). High inflows to the lake cause large inputs of sediment that largely settle out in the upper reaches of the reservoir. Releases from the dam are sediment deprived and promote less turbid waters but may contribute more to downstream bank erosion as those waters pick up sediment, especially at high outflows. There was significant uncertainty related to how the operation of the new hydropower facility (Missouri River Energy Services), once it is brought on line, could potentially influence all of the above issues.

For mussels, experts observed that species diversity in the reservoir itself is typically lower than in the riverine environment, as most Des Moines River species prefer moving waters. The 5-6 species known from Lake Red Rock typically prefer littoral areas. For this reason, and because mussels have limited mobility, rapid changes in lake elevation, e.g. when the lake is "dumping" water to achieve a pool elevation target, are detrimental to mussels. Slow drawdowns are therefore preferred from the point of view. The group proposed a preliminary initial limit of no more than 3-inches of change per day. It was unknown what level of flow release a 3" elevation change corresponds to at different pool elevations. The exception is at times of very high flow, usually during spring or summer, when areas have been rapidly inundated and there is a need to get water off inundated areas in the floodpool in order to manage them. At these times, rapid drawdown is unlikely to impact mussels because the rise was also rapid, and they will not have moved into those areas yet anyway.

Overall, the fish and mussel group agreed that the restriction on the daily rate of change proposed to benefit the river downstream of Red Rock would also benefit Lake Red Rock by restricting the rate of change in reservoir elevations. Recommendations also included monitoring designed explicitly to understand what if any impacts the hydropower facility operation is having, once it begins operating.

### 2. Water Quality and Reservoir Considerations

The water quality and reservoir group focused primarily on questions related to how flow and pool level management in the reservoirs affects residence time, denitrification, and waterfowl versus shorebird habitat (both vegetated and mudflats), and the interaction among these various dynamics.

There was much discussion about the appropriate timing of flow level manipulations to create the optimal mix of vegetated as well as exposed mudflat habitats at the "right" time for waterfowl and shorebirds. Discussion highlighted significant uncertainty about how to maintain these dynamics over time, given gradual shifts in spatial habitat availability caused by sedimentation of the reservoir. Water levels will likely need adjusted over time to realize the same benefits. There was also discussion about the value of mudflats for denitrification (likely greater per unit area than the denitrification occurring in bottom sediments or in the water column). The group discussed the feasibility of managing variability in water levels explicitly to enhance denitrification, and recognized that there might be benefits as well as costs associated with trying to optimize any one variable. For example, optimizing denitrification by manipulating residence time may negatively affect in-lake water quality, flood storage benefits, and/or downstream ecological flow benefits.

To restore a more “natural” hydrologic regime, the group proposed greater variability in target pool elevations. For the purposes of waterfowl, a slow and relatively steady drawdown of water levels throughout the growing season is best for managing smartweed and other waterfowl forage. A drawdown by mid-July allows for vegetative establishment prior to the fall rise, or the period after October (ideally, mid-October) when these marginal areas are inundated to benefit fall migratory waterfowl. Exposed mudflats in late July, August and September benefit migratory shorebirds.

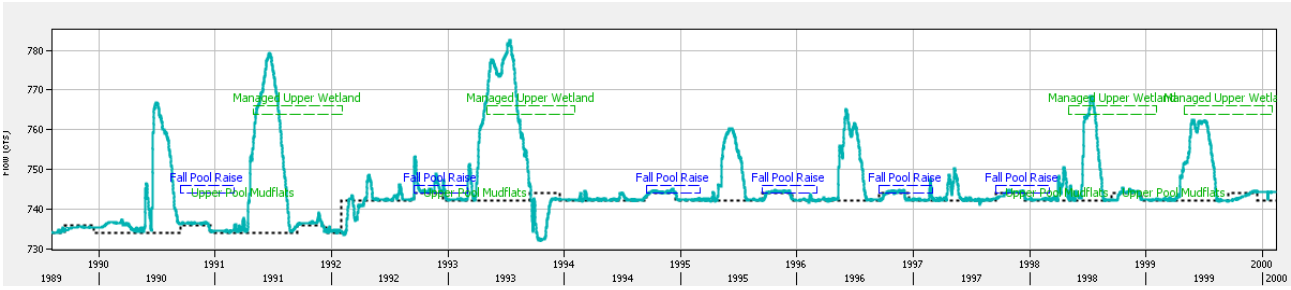
Framed in terms of current operational targets, the group consensus was to elevate the current “normal” pool target by ~6” during the spring and early summer (from 742 to 742.5” by July 1), and then allow for a gradual drawn down starting in mid-July (July 15). Gradual drawdown (1” or 2” / week) to slightly below normal pool of 741.5 NGVD by September 1 would gradually expose mudflats. This level would be held until the end of the September, allowing plants to become established that serve as forage for waterfowl when inundated by the fall rise. Current operations have created exposed mudflat areas that are gradually migrating longitudinally, as areas previously 1-2’ deep are raised by sedimentation. Again, pool level targets may need to be adjusted gradually over time in response to ongoing sedimentation.

A second theme of discussion in this group focused on concerns about bank sloughing in the immediate area of the reservoir, primarily in response to rapid changes in reservoir elevations, and the implications for sedimentation, turbidity, and water quality. Participants were initially uncertain regarding the ideal rate of change to reduce bank sloughing, but recommended that the Corps explore the implications of further restrictions on the rate of change in downstream releases. Discussion also moved to upstream sediment contributions (i.e., tributary channels immediately upstream of Saylorville and Red Rock), and the degree to which the USACE has the authority to work on tributaries on private land, e.g. working with private landowners to conduct instream grade and/or bank stabilization work on channelized tributaries upstream. The group also proposed investigating the potential for water quality credit trading as a mechanism to reduce sediment inputs. It was also noted that promoting riparian, emergent and submerged aquatic vegetation for the purposes of wildlife, waterfowl and fish habitat could also benefit lake water quality by holding sediment and increasing water clarity/reducing turbidity.

Overall, the water quality / reservoir group identified the need for greater flexibility and variability in pool level management and elevation targets than under the current operating rules, which tend to focus on static pool elevation targets. To ensure that changes in water level targets do not interfere with authorized purposes of flood control or recreation, improved forecasting is needed to allow for more proactive and real-time adaptive management. Restrictions on the maximum daily change in outflow were proposed for both Saylorville (a reduction from the current limit of < 3000 cfs/day) and Red Rock (which does not currently have an operating restriction related to the rate of change).

RPT was adapted for the purposes of defining alternative pool management for the environment. The tool is able to display pool elevations rather than flows (Figure 9).

Water Quality / reservoir group




Fish group

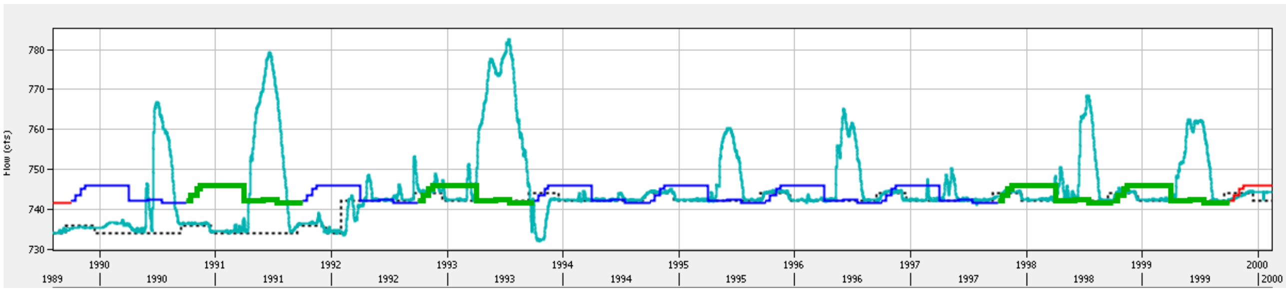



**Figure 9 a-b.** Examples of RPT output for discussion of pool elevation environmental definitions in the (a) water quality/reservoir group and (b) fish and mussel group.

**Uncertainties and research needs**

The water quality/reservoir group identified numerous research questions relating to management manipulations that might impact water quality in the reservoir. Research and expert findings from this project should guide reevaluation and development of USACE future water monitoring plan, to ensure monitoring is addressing the key information needs identified in the workshop.

A major focus of discussion was uncertainty about denitrification. Where and how is the majority of denitrification occurring? Is there a tradeoff between floodplain and riparian denitrification in saturated riparian areas, both downstream of and around the margins of the reservoirs, versus retention time in the reservoirs? How is the rate of denitrification impacted by water level manipulations (proposed during the workshop) designed to meet environmental flow needs? Other manipulations discussed as potentially worthy of further feasibility analysis included aeration, circulation and mixing, as well as the feasibility of manipulating the elevation of water intakes to the turbines as a means to influence water quality. With respect to phosphorus, the group expressed a lack of knowledge about how phosphorus levels in the reservoirs compare to ambient lakes in the ecoregion or to P criteria.

The question of turbidity was also discussed in relation to nutrients, as well as the interrelationships between turbidity, nutrients and algae blooms, light penetration, fluctuating water levels, and implications for emergent and submergent aquatic vegetation.

Another area of uncertainty identified is the increasingly frequent problem of cyanobacteria blooms (toxic algae). More research is needed on what conditions trigger the blooms, what factors influence toxicity, and how these can be controlled or mitigated. Increasing residence time to enhance denitrification would potentially conflict with the goal of managing or reducing the frequency of these blooms, which seem to be associated with retention. The group debated whether there was potential for "skimming" water off the top using the Tainter gates during times of high water temperature or algal blooms– this would reduce the temp of the water surface, and reduce algae blooms, and skim off cyanobacteria. Although the concern was that this would simply export the negative impacts of temperature and algae to the river reach downstream, the idea was that the river would create a more turbid state and there would be less likelihood of large mats of blue-green algae forming.

The reservoir group also identified a number of research needs related to shorebird habitat and population response, in particular the need to evaluate shorebird response if proposed changes to water level management are made. Beach bacteria were also identified as a major concern, particularly as they impact recreational uses. Waterfowl and shorebirds are likely a major source. Is there a tradeoff between managing for high waterfowl and shorebird use and nutrient inputs to the lake? Could "artificial" solutions be designed to mitigate for high animal source inputs (e.g. "pooper scooper", aeration, etc.)?

Additional understanding is needed of water quality issues basinwide, in terms of loads and solutions. Finally, climate change was identified as a major unknown that needs to be explored in terms of implications for water quantity (including inflows and pool level targets) and water quality.

### 3. Floodplains

The floodplain group focused on the importance of overbank flooding to ensure maintenance and connection of oxbows, as well as the seasonally appropriate "charging" of floodplain ecosystems during timeframes important for multiple wildlife species. The floodplain group focused primarily on the sections of the river immediately downstream of the Saylorville and Red Rock Reservoirs, as the ability to truly control the flows in those areas is the greatest. Above Saylorville Dam, the hydrograph analysis showed that the current, managed flow regime does not differ significantly from the unregulated flow series. The only change from that original flow regime in this reach is that water can be retained over longer periods of time, which in general serves to benefit water quality by enhancing denitrification in the river.

Wildlife taxa of primary concern for developing environmental flow definitions were insects, amphibians, reptiles, and turtles. However, the group discussed wildlife needs across a broad range of taxa, including waterfowl, songbirds, and shorebirds. The timing of mud flat use by shorebirds differs from the period of the rise designed to benefit migratory waterfowl. However, most felt that management geared towards restoring a more natural flow regime would benefit almost all species and taxa of interest. Plant species were discussed to include timeframes that would be the least damaging to desired species and a chart through the software program provided was managed for "pulse" flooding to best meet the goals of the group. High flows are needed to create oxbows and ephemeral wetlands in backwaters to support wildlife ranging from wood ducks to Topeka shiners. However, these wetlands need to be spatially diverse, as well as have a range of hydroperiods; at least some of them need to be fishless in order to minimize predation on eggs and juveniles (invertebrates, amphibians, reptiles, etc) after hatching. High flows are also needed to scour channels and create new depositional habitats such as sandbar habitat for turtles and other herps. Habitat requirements for floodplain birds (e.g., wood ducks, migrating songbirds) and mammals (e.g. beaver, mink, muskrat, river otter, etc) were also discussed, but considered subsumed within the natural hydrograph.

The floodplain group spent significant time discussing the implications of the fact that the “natural” floodplain has been permanently altered (Table 5). Legacy implications of past alterations of river dynamics, and the challenge of restoring floodplain geomorphology and dynamics was discussed extensively. Soil types and deposits are factors influencing plant species growth and habitat suitability for wildlife at key stages of life history. For example, herps and shorebirds both require certain sediment deposition dynamics to create or maintain nesting, foraging, basking, and overwintering habitats. To attempt to “mimic” or manually restore these habitat mosaics by specifying where and how sediments are deposited is a daunting task, but one which is likely to have a high impact on what can survive where.

**Table 5. Changes below Red Rock since construction of the Red Rock Dam**

| Pre-dam | vs | Post-dam |
|---|---|---|
| Closed canopy | | deforested |
| Narrow channels | | widened channel |
| Sediment load | | sediment starved |
| Tree buffers | | lost riparian buffer |
| Open connected | | disconnected |

Natural communities and species composition has already been permanently altered in ways which will influence feasible restoration trajectories. The Des Moines River, like many other highly developed rivers and streams, is incised, or entrenched, from increased scour from basin-wide hydrologic alteration as well as potentially due to the dams. Land clearing, ditching and draining, subsurface tiling, and climate change in the 20$^{th}$ century (increased rainfall) have all contribute to increased erosive flow from watersheds. Bank full conditions from controlled reservoir release maintains stream power that scours river beds and banks leading to greater entrenchment and can ultimately result in significant disconnection of the river or riparian area from the floodplain and alluvial groundwater. Storage reservoirs can also distribute and prolong erosive flows by storing and releasing large floods over longer periods.

In conjunction with flood protection, urbanization, levees, and other changes, groundwater tables have been altered. In many places, the floodplain has been disconnected from the river both physically and hydraulically. The combined effect of flood control and entrenchment results in less frequent out-of-bank events. In response, oak trees (Swamp white, bur, and pin) and other less flood tolerant tree species have been drawn in closer to the river. Although semi-tolerant of flooding (e.g., 1 in 10 years), these species are susceptible to prolonged saturation of their roots, especially later in the season. Oak mortality is being observed in recent years, possibly in response to frequent flooding and longevity of flooding events in recent decades.

Based on these past changes, the floodplain group spent considerable time discussing to what extent flood pulses based on past flow frequency analysis will result in sufficient reconnection of the floodplain. The group referenced the preliminary analysis from the DM SRP Literature Review, showing that although the unregulated flow corresponding to the bankfull frequency flow would be predicted to have occurred ~20 times post-project (i.e., every 1-2 years), regulated flows exceeding this level have resulted in overbank flooding only three times based on the flood protection measures in place.

Active management approaches discussed by the floodplain breakout group (i.e., going beyond environmental flow definitions) included but were not limited to:

- Excavating pools in the floodplain to create connections to groundwater in winter
- Fire management to control invasives and favor native vegetation
- Mechanical removal and herbicide control of invasives

Overall, the floodplain group hypothesized that with improved management (including both flow controls and active management of vegetation, including restoration of fire) geared toward species of greatest concern, the river system could be managed to restore portions of the floodplain to something approximating pre-project floodplain ecological systems and communities. Restoring the magnitude and frequency of out-of-bank flood events should benefit downstream floodplain ecology in many ways. Habitat forming processes supporting wetlands and floodplain forest are highly visible responses. Animal migrations respond to seasonal habitat availability, with fish moving onto floodplains during floods. Sediment, nutrient, and microbial responses that sequester nutrients on floodplains are less visible but are critical supporting services in an ecosystem services context.

Even without full restoration of hydrology, this would benefit many species by increasing habitat availability and connectivity within the river corridor. It would also enhance denitrification and carbon sequestration in the floodplain. However, the group recognized that the river system has been altered to a state that it will not be able to fully return to what it was in “native” species diversity. Going forward, “what we get” will depend very much on what we explicitly manage for in terms of desired future conditions, whether that is biodiversity, aesthetics, ...or neglect.

The final environmental flow definitions proposed by the floodplain group for the high flow components are summarized below, integrated with the fish and mussel group defined environmental flows (Table 6). These include regular flood pulses of 10K cfs or more and occasional flood flows resulting in overbank flows inundating all or a portion of the remaining floodplain (> 40K cfs, lasting 3-7 days). For oxbow formation, the flood duration needs to be of sufficient duration for fines to settle. Additional work is needed to refine environmental flow recommendations so as to ensure maintenance and restoration of the floodplain trees and understory plant communities across the full spectrum of the natural flood disturbance regime and hydroperiods.

For low flow definitions, the floodplain group observed that current median low flows under the Corps' current operational flows are actually lower than they were historically, even though overall there is more water moving through the system now in terms of annual water yield. Currently, the 90$^{th}$ percentile low is much higher than 300 cfs. There were some occasional extreme low flow periods in the pre-project time series, when flows actually went below 300 cfs. During these critical low flow periods, reservoirs are re-filling, but the system as a whole is producing more water than 300 cfs which could be passed. At the same time, changes in river channel morphology mean that 300 cfs today results in a very different habitat mosaic than many years ago. Overall, there is probably an opportunity to modify low flows to better mimic the natural low flow hydrology by simply passing inflows during these low flow periods.

Red Rock and Saylorville pool elevation targets. The floodplain group found that pool level targets for both Red Rock and Saylorville should be primarily driven by waterfowl, shorebird, fish and wildlife habitat needs, as opposed to water quality considerations. They hypothesized that restoring natural floodplain inundation and frequency downstream of the dams, as well as restoring seasonable variability pattern to pool elevation management (initially the discussion focused on 4 feet, but this was raised to 6 feet in seasonal variation in elevation), would provide the best opportunity to enhance denitrification in marginal wetlands and saturated habitats. (Significant denitrification is likely to occur both upstream of the dam along the margins of the pool and mudflats, as well as downstream when elevated flows are in contact with the floodplain.) In years of late flooding, this would allow water to extend into vegetation at higher elevations, which would improve water quality and waterfowl food. The group felt that attempting to manage pool elevations or artificially increase residence time in the reservoirs for the purposes of optimizing denitrification might be in conflict with other management goals, in part because the timing of ecologically based opportunities to store water does not necessarily coincide with the timing of peak nitrogen delivery to the reservoirs. No conflict was seen between water quality and creation of mudflats and managing for vegetation on behalf of waterfowl. Environmental river flow and pool level definitions as articulated are likely to result in some conflicts, and will need to be refined once these conflicts and implications have been identified and explored in linked models.

The floodplain group also discussed implications of flow and pool level manipulations for control of invasive species. It was hypothesized that because the flood control reservoirs at Red Rock are designed to reduce the frequency of overbank flows, current drivers of invasive species are driven to a greater extent by terrestrial succession dynamics and not as influenced by flood disturbance. However, in recent years there have been several record floods and downstream releases have on several occasions exceeded the flood flows the reservoir was intended to contain and/or minimize. Within the reservoirs, elevated pool levels can help to kill off invasive plants, but often kill off or cause disturbance to native species as well, and provide extensive areas of disturbed habitat that provide opportunity for invasives to re-establish. For this reason, active management is often required to facilitate restoration of native species. There was some discussion of the role of fire in the natural disturbance regime, and the prospects of restoration with and without fire, particularly in reference to restoring native vegetation.

**Uncertainties and research needs**

Key uncertainties identified and discussed by the floodplain group in relation to environmental flow definitions focused on interactions between climate and hydrology. Significant discussion focused on the question of how past alteration and legacy channel changes may affect prospects for restoring “natural” hydrology particularly with respect to groundwater/surface water dynamics in the active river area. Drainage management both in the floodplain and in the tributaries upstream has led to changes and disconnections in hydrology. There was discussion about how this would affect floodplain dynamics, including wetland hydrology, cottonwood (and other floodplain/wetland vegetation) regeneration and establishment, denitrification, as well as how altered hydrology would ramify ecologically throughout the food web (from vegetation to invertebrates to fish and wildlife). They recommended monitoring of groundwater and surface water in the floodplain at two locations: (1) downstream of Red Rock and (2) at the upper end of the Red Rock.

## Integration of Expert Defined Environmental Flows

### Below Red Rock.

For the second half of Day 2, participants re-convened in plenary session to integrate flow recommendations developed by each breakout group. For example, spring flood pulses for early season spawning fish were merged with the flood pulse definitions made by the floodplain group for sandbar habitat formation (for turtle nesting). This process triggered additional discussion of appropriate magnitude, frequency and duration for each of the environmental flow components (high and low), given the need for a diversity of hydroperiods and inundation frequencies in the floodplain to ensure access to some habitats for fish, as well as fishless habitats for herps and other species dependent on temporary wetlands.

Flood pulse magnitudes proposed for fish were also explored in terms of implications for floodplain vegetation and forest regeneration and maintenance. Some species can tolerate significant inundation (i.e. 1-2 feet); however, timing, duration and frequency are all important considerations. The pulse magnitude required to trigger willow and cottonwood regeneration is fairly large and infrequent--perhaps 1 in 50 years. The magnitude of the late spring/early summer rise flow component developed by the fish group, however, raised concerns for the floodplain group in terms of implications for oaks, which, although flood tolerant, are subject to limits on duration and frequency of inundation, particularly later in the season. In years where flooding occurs before May, or lasts only 6-8 days, oak mortality would be less of a concern. The fish group pointed out that the spring flood flow magnitude was a wet year flow recommendation, and therefore would occur in theory only 1 in 3 years. Ultimately, it was agreed to alter the environmental flow definition by thinning the pulse (i.e., shorter duration), and allowing for multiple, shorter duration spikes. The final proposed environmental flow component involved flood pulses sustained for 4-7 days, receding back to near bankfull (between 20,000–30,000 cfs) for the remaining portion of the seasonal flood window. Given that there would be significant spatial variability in depth and extent of inundation at any given flow level, the implications of any prescribed r flow could be evaluated spatially with stage-discharge models to determine the exact spatial distribution of habitats of different flow durations and frequencies. Additional research/literature review is needed to determine the duration that would result in excessive oak mortality risk.

The plenary group also elaborated on low flow environmental recommendations developed by the breakout groups, proposing that low flows should mimic the natural flows through the system to the extent that inflows and pool levels allow (while maintaining as much as possible a minimum flow of 300 cfs or more). The benefits and feasibility of bolstering low flows below Red Rock during critical heat periods should be further explored, especially given the potential flexibility provided by long-term increased water yield as well as the potential to mitigate impacts of downstream channel alteration.

Several non-flow related recommendations were left on the table, for example the possibility of exploring creating a side or bypass channel for fish passage at Ottumwa, to allow fish to access coolwater refugia.

**Table 6.** RPT Combined Discussion and Expert Defined Environmental Flows

| Environmental Flow Component | Combined Findings& Remaining Questions |
|---|---|
| Pulse flow component | Spring: Recruitment, maintenance and staging for the summer spawn/mussel drop<br>Maintenance-Growth Flows between the early and summer rise – something that models the best guesstimate of the natural flow – smooth transition between the 2 peaks. Uncertainty about the magnitude of flow to maintain in between the 2 peaks: how low can you go to sustain the newly spawned fish, and assist with the preparation of summer spawners? 10-20k?<br>From a mussel perspective – need enough water for them to survive. They seem to prefer side channel habitat. Mussels drop at different times for different species. Need to look at mussel assemblage and what is actually living there – target specific groups |
| Fall forage 9/1-9/15<br>15,000-25,000<br># peaks 1 | Should engage oxbows, create connectivity to the river old channel scars that are on the landscape, connected under high flow conditions (historically 3-5 year event ) Need to refine: how much floodplain will you engage if only go to 30,000 cfs?Are there particular areas that are good for spawning or are problem areas? (e.g. Are agricultural fields good for fish spawning?) What flows does it take to engage those kinds of areas?<br>Attempt to time early season releases with storm events to engage as much of the ecosystem as possible. If inflows occur prior to Early Season Spawning, might hold the water until can be released during early season spawning. Early season spawning peak could be moved around based on storms and to accommodate different spawning species if you are going to only get one of the pulses for the year. In general, best to leave it to the storm events to assist in when we're going to trigger that pulse.<br>Dry years: based on historical inflows, dry years usually only have one or two pulses. Therefore, coordinate releases with storms. May need to draw into available conservation pool to get these pulses. Need to verify these dry year pulses – what benefit are we getting from this? Are we getting fisheries recruitment? Clarifying: these pulses are not getting out of bank for floodplain inundation every year; these pulses are for in-channel spawning conditions (walleye) |
| Wet year pulse flows | Flood Tolerant Oak Flow Prescription. Swamp white oaks, southern pin oaks, burr oaks. preferred 1 in 10 years.<br>Habitat forming flood to create sandbars for nesting and basking. Infrequent extreme floods create habitat high on the floodplain. Common floods create habitat on the rest of the floodplain. |
| Average years | Create ephemeral pools for amphibians and insects to feed bats. Minnows and bullfrogs will overwinter. Amphibians, turtles and many other species require access to the floodplain to reproduce in stagnant water, or isolated pools. Ideally would occur every third year. Also for wood ducks, hooded mergansers, red shouldered hawks, night herons, prothonotary warblers, wading birds. Unusual rare plants and associated insects and bats. Emphasize ponding after pulse. |
| Dry years, Low flows | Includes a minimum of 300 cfs. This low flow needs to be evaluated as to whether it is sufficient, given that it appears a larger low flow could be sustained based on recent climate trends. Evaluate whether enhancing low flows during heat waves could potentially moderate river temperatures and reduce thermal stress. |

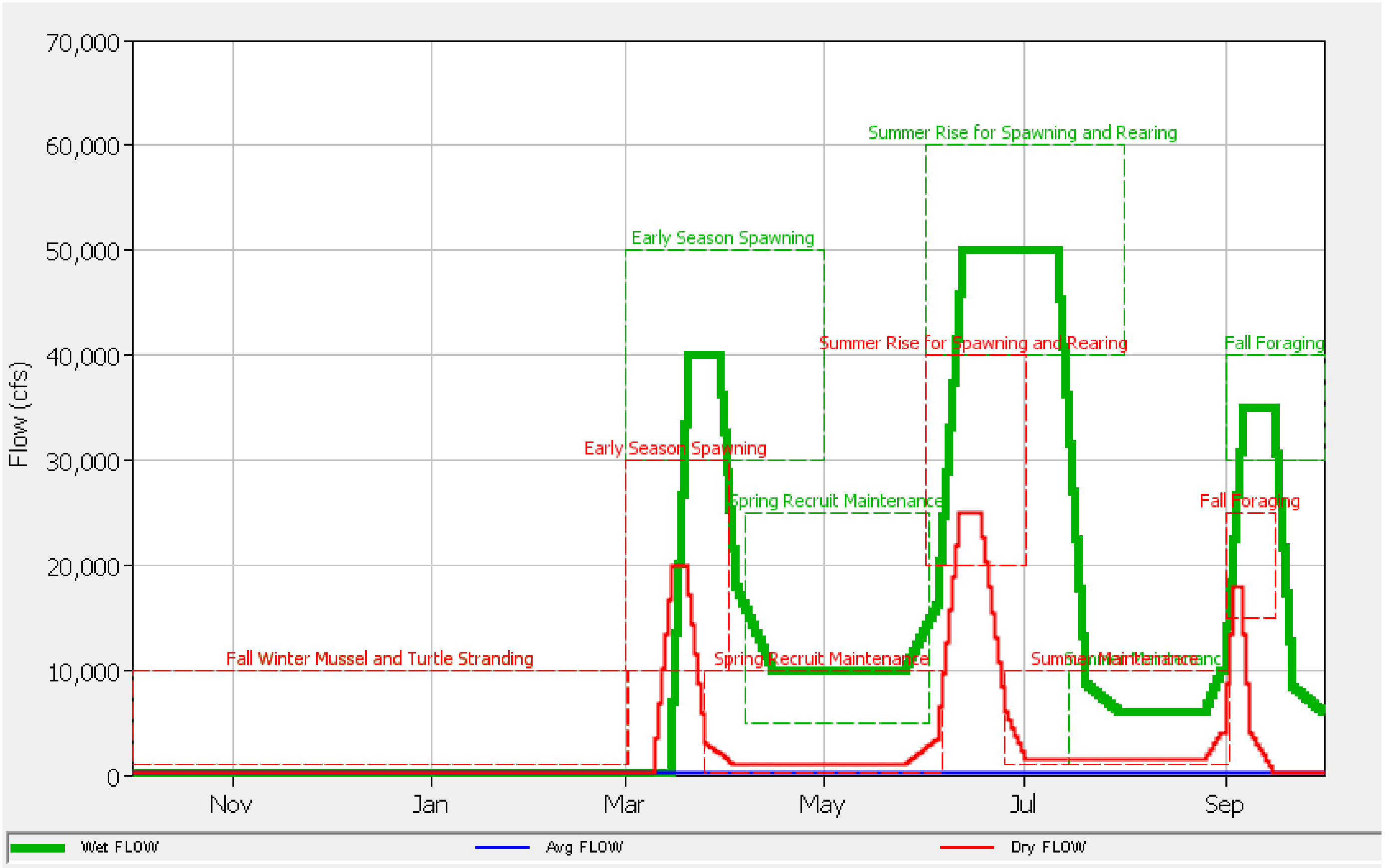



**Figure 10. Final integrated environmental flow recommendations for the reach below Red Rock.**

### Below Saylorville.

Both in breakout group sessions and in plenary, workshop participants felt that the regulated hydrograph below Saylorville appears to be very similar to the unregulated, “natural” flow hydrograph. The exceptions to this were when Saylorville outflows are rapidly cut off in response to flooding on the Raccoon. Overall, the group was uncertain of whether there is substantial opportunity or benefit to be gained from significantly altering current operations beyond those that would result from implementing proposed pool elevation changes (see below). They also recognized that any proposed alterations to current operating rules would require monitoring and/or modeling to assess how changes might affect target pool elevations, water quality, metro area flood protection, and other authorized purposes. For this reason, we do not include a final RPT environmental flow graph for this reach.

The final environmental flow finding for the reach below Saylorville was to continue the current practice of allowing releases to correspond closely to inflows, as modified by the pool level changes for Saylorville and Red Rock, with one significant caveat: the need to explore whether the current 3000 cfs per day restriction on daily rate of change is adequate to protect mussels, herps, and other riverine or riparian flora and fauna from washout or stranding. For example, the IHA analysis for the reach below Red Rock, comparing pre-project unregulated flows to post-project regulated flows, shows that the highest hydrologic alteration (HA) indicators are for rise and fall rate (i.e., the daily rate of change). Specifically, the median and maximum rise rate prior to 1969 was 190 and 817 cfs, versus 451 and 1494 cfs post-project. Even more dramatic, the median and maximum fall rates prior to 1969 were 160 and 568 cfs/day, compared to 426 and **3198 cfs** after 1969. Based on the workshop discussion, the change in rise rate is perhaps less ecologically significant. However, the IHA analysis suggests that the 3000 cfs restriction on the fall rate is perhaps insufficiently protective, given that it is almost 500% of the pre-project maximum daily fall rate as measured below Red Rock. It was noted, however, that depending on the timing of rate restrictions, a slower drop in pool levels could substantially impact the management of DNR managed area above the dams. For example, for late summer flooding past July 1 has different implications than earlier flooding where levels could be back to normal by end of June makes a huge difference.

Numerous non-flow related recommendations were also made for this reach, including building on the Water Trails and Greenways Master Plan (adopted by the MPO policy committee in November 2016[4]), and extending the Greenbelt planning process to all the counties adjacent to the Des Moines River from Des Moines to Red Rock, and ideally all the way to the confluence with the Mississippi River at Keosauqua. Workshop participants recognized that creating green space along the river corridor, for recreation as well as wildlife, would also provide more flexibility in environmental flow management, to allow restoration of both physical and hydrologic connectivity of the river to its floodplain throughout this reach and the entire river corridor. Participants also expressed support for exploring and implementing, via the Master Plan, proposals to remove obsolete, low-head dams on the mainstem river--including the 15-ft high Center Street Dam--for reasons ranging from improved safety and recreational opportunities to fish passage.[5]

### Red Rock and Saylorville Pool Levels.

Final integrated pool elevation findings for both Red Rock and Saylorville reflected a similar pattern (see Figures 11 and 12):

- greater flexibility in pool target elevations designed to mimic natural variability
- reducing the allowable daily rate of change when or raising or lowering pool levels to achieve target elevations or downstream flows
- a small spring rise-- in addition to the fall rise—followed by a slow and gradual drawdown through the summer months, designed to promote establishment of vegetation and mudflats

[4] https://dmampo.org/water-trails/

[5] http://www.desmoinesregister.com/story/news/local/des-moines/2016/04/23/imagine-dam-free-downtown-des-moines/83387710/

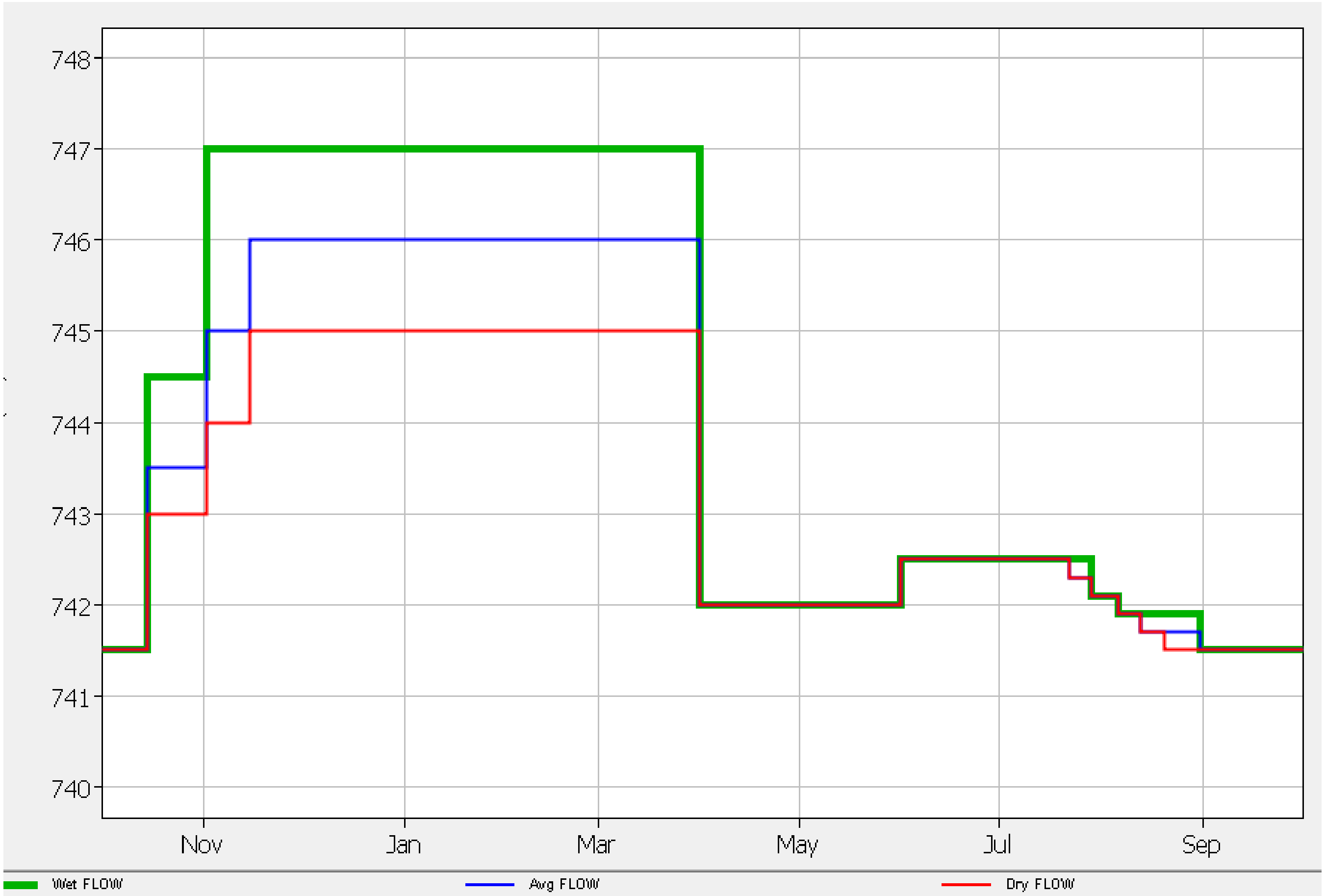



**Figure 11.** Integrated pool level findings for Lake Red Rock**.**

| Date | Dry | Avg | Wet | Description |
|---|---|---|---|---|
| 01Oct | 741.5 | 741.5 | 741.5 | Fall pool raise for waterfowl per DNR request. In late flood years, DNR would likely request this elevation change starting at 1-2 feet higher (ending up at a max of 6 feet above normal pool). Elevations will be variable based on vegetative conditions. |
| 15Oct | 743 | 743.5 | 744 | |
| 01Nov | 743.5 | 744 | 745 | |
| 15Nov | 744 | 745 | 746 | Flexibility in wet years up to 748 (DNR objectives) |
| 15Mar | 744 | 745 | 746 | Hold fall rise through winter |
| 01Apr | 742 | 742 | 742 | Restore conservation pool for spring flows |
| | | | | Maintain spring pool levels for late fish spawners. |
| 01Jun | 742.5 | 742.5 | 742.5 | For the summer pool raise and drop, increasing quickly is fine, but the levels should drop more slowly/incrementally. In wet years, hold the drop in flood pool levels to a maximum of 3” per day. |
| 15Jul | 742.5 | 742.5 | 742.5 | Drop 2" per week to 741.5 by end of August (6 weeks). Elevations will be variable based on vegetative conditions. |
| 31Aug | 741.5 | 741.5 | 741.5 | Hold it at this level until end of September, until lake pool rise begins for waterfowl management. |


**Figure 12.** Integrated pool level findings for Saylorville Lake. All years (based on baseline conservation pool elevation of 836' NGVD): Allow for ½ foot rise for spring pool levels for late fish spawners (01 JUN to 15 JUL). Hold 836.5' until July 15. Drop 2" per week to 835.5' by end of August (6 weeks). Fall pool rise after 01 Oct--per DNR request—according to stepped pattern.

During integration of environmental flow recommendations, the plenary group also discussed whether reservoir management findings, specifically slowing the rate of rises and drawdowns of pool elevations, are compatible with the environmental flow needs. It was recognized that this would have to be explored subsequent to the workshop using linked models. For example, the fish and mussel group recommendation for a fall foraging flow pulse downstream of Red Rock may have implications for whether the fall pool rise can be accomplished, particularly in dry years. Models linking flows to pool level elevations are needed to explore the probability and frequency of conflicts between potentially competing environmental flow and environmental pool management benefits.

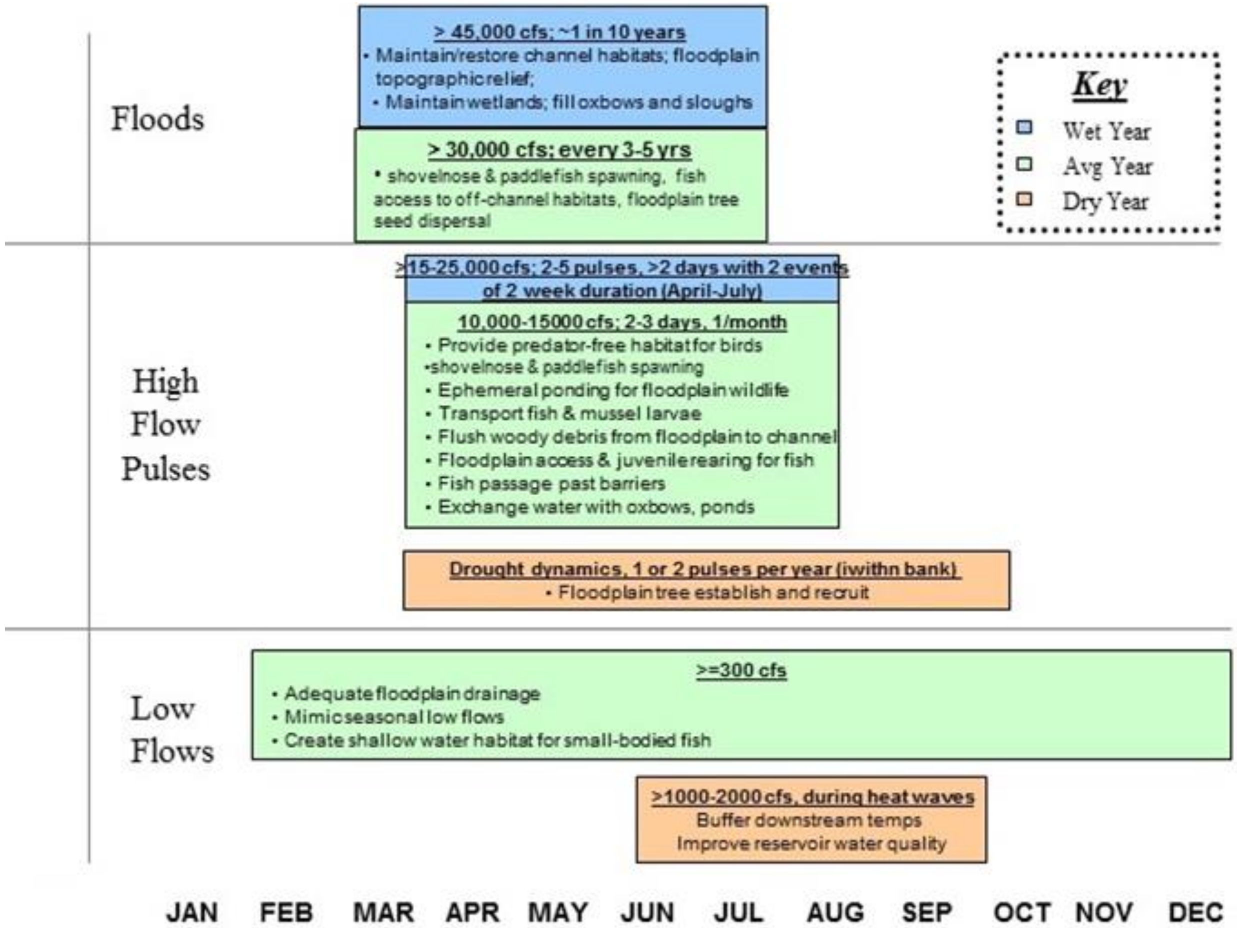



**Figure 13**. Integrated Final Environmental Flow Needs Proposed for Red Rock. Workshop participants found that flows for Saylorville were not substantially different than current operations, because outflows under current operations resemble natural inflows, except when flows are ratcheted back during Raccoon River flooding. Implications of hypothesized pool level modifications on river flowswill need to be further explored in reservoir simulation models.

## Research and modeling needs by reach

Each of the breakout groups identified significant uncertainties and knowledge gaps while formulating their flow requirements, many of which were common to multiple breakout groups. The following list is a synthesis of key knowledge gaps for each reach.

**Table 7. Summary of uncertainties, knowledge gaps, and research needs**

| Saylorville & Red Rock pools | Saylorville to Red Rock | Below Red Rock |
|---|---|---|
| Can retention time be manipulated to appreciably enhance denitrification without interfering with other authorized purposes? | How do different constraints on rate of outflow and/or pool level change (e.g., no more than 5000 cfs per day, no more than 3" per day) affect outflow operations? | Monitor/model whether low flow releases during heat waves can moderate instream temperatures and reduce downstream fish and mussel mortality |
| Sediment budget and identify sources; bank sloughing in relation to the rate of pool level changes | Is the 3000 cfs limit on Saylorville rate of change sufficient to protect fish and mussels below Saylorville? | Cost/ benefit of restoring out-of-bank flood flows (public and private; alternative strategies; e.g. habitat/wildlife/wq benefits vs cost of floodplain acquisition, easements, damages |
| Relationship of water level management, vegetation dynamics, nutrient and sediment loading and in-reservoir turbidity | Can restoration of flood pulse flows and floodplain inundation also enhance denitrification? | Feasibility of flow and water level changes to restore and/or improve habitat by restoring sediment dynamics, given past changes |
| Mudflat and vegetation management role in denitrification | Can restoration of flood pulse flows and floodplain inundation aid in control of invasives/ restoration of floodplain plant communities? | Implications of channel change and legacy effects for restoration prospects; e.g. can flood pulses that remain within the channel positively affect fish and mussels while not causing flood damages? |
| Cyanobacteria and toxins: Source, what causes blooms, and does increasing residence time for denitrification cause an increase in harmful algal blooms? | Is the minimum 200 cfs from Saylorville adequate for environmental concerns? | Magnitude and duration of flows required to mimic the role of corresponding "natural" ecological flow components, especially for "prescribed" floods. How much of each type of habitat is created at each level of flow, e.g. at what flow are sandbars and/or backwater areas inundated? |
| Beach bacteria sources and management options | At what outflow does the area identified below Saylorville benefit floodplain inundation? | Are there (non-flow related) options to restore fish passage at Ottumwa? (i.e. bypass fish passageway) |

| | |
|---|---|
| Implications of reservoir sedimentation rates for when and how official target elevation for conservation pool(s) will be raised | What is the maximum rate of change in daily flows that can be sustained at different flow levels without triggering gas bubble disease? |
| Evaluate implications of recommended pool level changes for shorebird habitat and population response<br><br>Feasibility of maintaining fall pool raise through the winter months. | Can restoration of flood pulse flows and floodplain inundation also enhance denitrification?<br><br>Is the minimum 300cfs outflows from Red Rock adequate for environmental concerns? |
| Can pool level manipulations designed to mimic natural seasonal hydrology aid in control of invasives?<br><br>Investigate the recommendation to monitor ground water and surface water in the floodplain downstream of Red Rock and at the upper end of Red Rock. | Can restoration of flood pulse flows and floodplain inundation aid in control of invasives / restoration of floodplain plant communities?<br><br>How do different constraints on rate of outflow and/or pool level change (e.g., no more than 5000 cfs per day, no more than 3” per day) affect outflow operations? |

## Appendix A. Workshop Participants

| | Name | Affiliation | Email |
|---|---|---|---|
| 1 | Hugh Howe | USACE, Lake Red Rock | |
| 2 | Dave DeGeus | TNC | |
| 3 | Andrew Warner | USACE – IWR Affiliate | |
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| 5 | Kristen Blann | TNC | |
| 6 | Brett Call | USACE, Lake Red Rock | |
| 7 | Perry Thostenson | USACE, Lake Red Rock | |
| 8 | Joe Jordan | USACE, RID | |
| 9 | Bradley Palmer | USACE, RID | |
| 10 | Bruce Ehresman | IDNR | |
| 11 | Cheryl Groom | USFWS | |
| 12 | Chris Jones | IIHR | |
| 13 | Chris Trefry | USACE, RID | |
| 14 | Chuck Theiling | USACE, RID | |
| 15 | Clay Pierce | ISU | |
| 16 | Dan Kendall | IDNR | |
| 17 | Doug Helmers | FWS | |
| 18 | Doug Latka | USACE, Omaha District | |
| 19 | Glenn Harman | IDNR | |
| 20 | Jake Hansen | IDALS | |
| 21 | Jeff Rose | USACE, Saylorville | |
| 22 | Jennifer Kurth | IDNR | |
| 23 | Jess Jackson | NRCS | |
| 24 | John Olson | IDNR | |
| 25 | John Wenck | IDNR | |
| 26 | Jonathan Wuebker | USACE - Saylorville | |
| 27 | Joshua Gansen | IDNR | |
| 28 | Karen Kinkead | IDNR | |
| 29 | Katy Reed | IDNR | |
| 30 | Kelly Poole | IDNR | |
| 31 | Mark Flammang | IDNR | |
| 32 | Martin Konrad | IDNR | |
| 33 | Marty Adkins | NRCS | |
| 35 | Mary Skopec | IDNR | |
| 36 | Michael Schueller | University of Iowa | |
| 37 | Mindy Grupe | USACE, RID | |

| | Name | Affiliation | Email |
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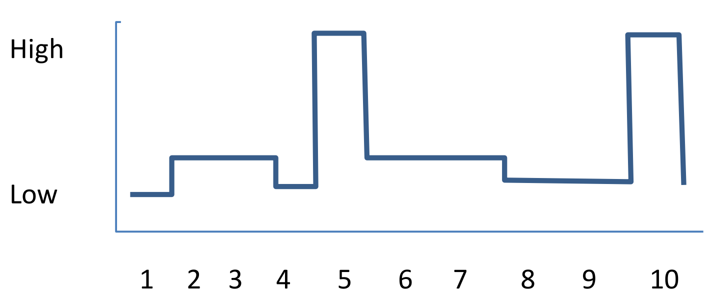
| 39 | Nathan Seibert | USACE, Lake Red Rock | |
| 40 | Nathan Young | Univ. of Iowa Flood Center | |
| 41 | Nicole Manasco | USACE, RID | |
| 42 | Peter Levi | Drake University | |
| 43 | Rich Leopold | Polk County Conservation | |
| 44 | Roger Bruner | IDNR | |
| 45 | Scott Gilje | USFWS | |
| 46 | Scott Peterson | IDNR | |
| 47 | Stephen Dinsmore | ISU | |
| 48 | Ted Corrigan | Des Moines Water Works | |
| 49 | Timothy Parks | Wisconsin DNR | |
| 51 | Todd Gosselink | IDNR | |
| 52 | Tom Wilton | IDNR | |
| 53 | Thomas Heinold | USACE, RID | |
| 54 | Pete Eyheralde | William Penn University | |
| 55 | Junifer Kruse | USACE, Lake Red Rock | |
| 56 | Loren Lown | Polk County Conservation | |
| 57 | Justin Edwards | USACE, Saylorville Lake | |

## Appendix B. "Considerations" identified by Workshop Participants at the Start of the Breakout Sessions

- Adjust pool stage to decrease thermal stability to decrease potential for cyanobacterial blooms.
- Increase water residency time to decrease nitrates below Saylorville. A mass balance should be done to look at actual reduction in nitrates.
- More stability to benefit establishment of a permanent vegetation cover.
- 6" inundation of permanent floodplains for 14-36 days during May-June segments 2&3.
- Nitrate Concentration, Nitrate Load, Ammonia Concentration, Cyanobacteria/toxins
- Loss of storage volume at low flow.
- Partnering on upland treatment to reduce sedimentation.
- Streambank stabilization- proper technical review (i.e. fluvial geomorphologists)
- Downstream impacts of construction activity- placement of dredged sediment?
- Timing of pulses and impacts on adjacent agricultural lands.
- Pool manipulation to de-nitrify through residence time.
- Use of mud flats as a denitrifying wetland area.
- More sub-impoundments within the lake pool (e.g. 750-770) to improve water quality and maintain more stable water level regime for wildlife use.
- Re-connect old river/ stream channels and oxbows to spread water flow out in the reservoir basin
- Create smaller catchment "pond" wetlands in the heavily eroded gullies onto corps property off adjacent private property.
- Data on changes in residence time, nutrient processing rates, sedimentation deposition rates, gas efflux, and other ecological parameters.
- Strong models to demonstrate how changes in reservoir height affect the ecological processes and parameters (e.g. how much longer is the residence time per foot of reservoir height)
- Goal: high spring flow followed by a drop to conservation pool by 15 July, which is then maintained through 1 October with periodic raises (1-2') to curtail vegetation. This would benefit many migratory birds including shorebirds and waterfowl.
- Sedimentation should be considered with respect to mudflat habitats.
- Willow encroachment is a serious problem that is getting worse.
- Late summer pulses are needed to reduce blue-green algae blooms.
- Rate of Changes. Slower changes to mimic natural fluctuation changes, winter flows, fish passage.
- Get appropriation to continue Des Moines River greenbelt.
- Extend greenbelt to mouth and allow for flood easements on flood plains.
- Install natural non-structural landscape projects in watershed.
- High Pulse Duration and Duration of flood---increase this duration time for increased flood pulse during spring-summer. Major implications for Round body Sucker Growth and Production. Decrease annual rate of change throughout the year---helps with pulse duration and frequency.
- High water permits should be predictable in time. Low water periods should be predictable in time.
- Rate of change seems too dramatic, needs to be spread out over more days. Bi-modal spring/summer flood pulse needs mimic.

- Peak discharge happening later in summer when mussels are dropping fish hosts-Adjust for more natural regime.
- Do geomorphic impacts to alter the naturalized flow paradigm? Geomorphic recovery.
- Rejuvenate oxbows.
- Winter flows should be maintained for overwintering fish and mussels.
- Maintain spring pool levels for late fish spawners.
- Transitioning flow releases to minimize impact to aquatic life. That is effort to: 1.minimize nitrogen super saturation in Red Rock tailwater: 2. to prevent stranding mussels on river bed during draw downs.
- How does the December release impact things?(spike in flows)
- Do we need to explore management for more native riparian/floodplain vegetation (instead of Japanese millet).
- Mitigation for drawdown-separate issue.
- Rapid rise and fall rate has negative implications for herps too?
- Increased vegetation growth for food production for waterfowl habitats.
- Restricted recreation use during nesting season.
- Management to promote long term plant sustainability through flooding cycles.
- Intentional flooding of oxbows 2-3 year cycle to re-charge for herps. Flood/Raise annually (fall)
- General floodplain forest health-connectivity on a historical basin –flooding to appropriate levels on timeframes historically occurring.
- Restorations of oxbows/sloughs.
- Hold high water levels over winter for hibernating herps and mussels.
- In general, mimic historic phenology of natural flows.
- Consider inundation days as marker for perennial vegetation establishment.
- Manage actively for late-season minimum outflows (especially Red Rock) including mini-pulses in late season.
- Spring flood pulse mimicked to greatest practical degree. More reliably emulate 1-2 year recurrence.
- Promote flow regime that maintains water in oxbows, sub impoundments, etc. for an amphibian reproduction (mid-march through June). This will also benefit state threatened Red-Shouldered Hawk.
- Ideal flow regime: out of bank ~1.5 yrs., large floods each decade, low flow each decade. See image below.



## Appendix C.  Stakeholder Issues

In stakeholder workshops conducted in 2015 and 2016 to identify the major concerns held by expert stakeholders and river users, 8 issues were identified as primary issues of concern for flow regime management. In addition to articulating flow hypotheses, workshop participants were encouraged to identify opportunities for flow management with respect to these 8 issues:

1. Nitrate levels
2. Mussel Mortality
3. Sturgeon Mortality
4. Gas Bubble Trauma
5. Migrating Waterfowl and Shorebirds
6. Herptiles
7. Streambank Erosion and Sedimentation
8. River Recreation

1. **Reduce Nitrate Levels**
    - What water level management practices can maximize nitrate reductions within Saylorville and Red Rock reservoirs?
    - What flow management practices at Saylorville and Red Rock can maximize nitrate reductions for downstream customers and aquatic life?  Quantify benefits on a graduated scale.
    - Correlate nitrate reduction to economic benefit in water treatment for users on the Des Moines River.
2. **Reduce Mussel Mortality**
    - In general, identify presence and status of mussel species from upper limits of Saylorville to the Mississippi. What are the seasonal habitat preferences of mussels and what is their ability to move with changing flows and water levels?  What are the lifecycle and reproductive needs of mussels and or impacts related to water flow, water depth, temperature, oxygen, host species, stability of substrate, nutrients, and sediment?  Which mussels are reproducing fast enough in the lower Des Moines to sustain healthy populations?  Which mussels are in decline or not longer present?
    - Are mussel host species able to pass upstream of the Ottumwa hydroelectric plant?  During what flows and/or gate settings? Are there flow management strategies that could benefit mussels relative to current operations?
3. **Reduce Sturgeon Mortality**
    - How do sturgeon populations below the Red Rock Dam respond to temperature stimuli and low flows during hot periods and what measures (in-stream and riparian structural or flow management) can be utilized to help mitigate those adverse periods?   How can flows be altered to reduce temperature induced mortality?
    - What are the reproductive requirements and habits of sturgeon and how important is the lower Des Moines River to the overall population of sturgeon in the Mississippi River for spawning?
    - Identify time of the year sturgeon are in the Lower Des Moines River and identify geographically their major areas of use.
    - Identify flow management strategies that would potentially benefit sturgeon.
4. **Reduce Gas Bubble Trauma**
    - What flow conditions from both Saylorville and Red Rock dams cause gas bubble trauma and what specific measures can be taken to reduce or eliminate these effects?

5. **Improve Conditions for Migrating Waterfowl and Shorebirds**
   - Lake Red Rock and Saylorville Lake is deemed a Globally Important Bird Area by the American Bird Conservancy. The Iowa Audubon Society has designated Lake Red Rock an Important Bird Area, citing its values of rare or unique habitats, and significant species concentrations. What are the specific needs and optimal reservoir conditions for migrating birds at Saylorville Lake and Lake Red Rock? What reservoir water management practices would encourage germination of wild plants for waterfowl to benefit migrating birds?
   - Saylorville Lake and Lake Red Rock Regulation Manuals currently allow the Iowa Department of Natural Resources to request a fall lake raise for the purpose of aiding waterfowl. Lake Red Rock can raise the lake from September to December 15th of each year and Saylorville Lake can hold the fall lake raise through March 1st of the following year. IDNR Wildlife Bureau managers do not believe the allowable raise is adequate due to accumulated sediment and impact on hunting access via water. What are the ideal fall lake raise parameters for waterfowl hunting at Saylorville Lake and Lake Red Rock?
   - Recommend flow management strategies that are most beneficial to migrating waterfowl and shorebirds.
6. **Improve Conditions for Herps**
   - What are the seasonal habitat preferences of herps and what is their ability to move with changing flows and water levels in the Des Moines River from the upper limits of Saylorville to the Mississippi? Are there riparian or riverine habitat restorations that could benefit reptiles and amphibians when subjected to changing flow regimes?
   - Which herps are reproducing fast enough in the Des Moines River to sustain healthy populations? Which herps are in decline or no longer present? In general, geographically identify presence of herps species from upper limits of Saylorville to the Mississippi.
   - What flow management practices at Saylorville and Red Rock Dam could aid herp life cycles?
7. **Reduce Stream Bank Erosion**
   - Are there opportunities to reduce stream bank erosion with specific flow regime practices at Saylorville and Red Rock Dams?
   - Identify geographically the areas of most active bank erosion along the Des Moines River from upper limits of Saylorville to the Mississippi.
8. **Improve Conditions for River Recreation**
   - Identify events in the past five years (canoe/kayak/triathlon) that have been affected by stream flows in the Des Moines River and determine what, if any, could have been improved with short term flow deviations from Saylorville and Red Rock Dams.
   - What are the ideal flows for specific stretches of the Des Moines River for canoe/ kayak/boating?
   - Recommend flow management strategies that would be most beneficial to Des Moines River non-motorized boating.