Environmental Flows Recommendations Workshop Summary

Kansas River Sustainable Rivers Program
December 2021

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Kansas City District

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Acknowledgments

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The shared purpose of the project was to convene key personnel and partners to provide strong scientific and stakeholder support for the Sustainable River Program's commitment to improving ecological flows and reservoir health in the Kansas River system. Stakeholders and partners provided the input, expertise, and hypotheses on current and historical conditions as well as issues and needs.

A core team, represented by the project partners led the science and technical integration effort. This group spent extensive time developing a plan for coordination and communication of science-based planning across stakeholder groups and identifying and targeting technical assistance as needed. The Nature Conservancy, Kansas and the U.S. Army Corps of Engineers, Kansas City District, initiated the project as well as provided input, guidance, and feedback throughout this initial phase (literature review and summary).

The information developed for the Environmental Flow Requirements for the Kansas River: Background Literature Review and Summary by Debra Baker, Assistant Director and Informatics Specialist, Central Plains Center for BioAssessment. Kansas Biological Survey & Center for Ecological Research, Donald Huggins, Senior Scientist, Director, Central Plains Center for BioAssessment, Kansas Biological Survey & Center for Ecological Research, Steve Cringan, Kansas Department of Health and Environment, Robert Angelo, U.S. Environmental Protection Agency, The Nature Conservancy, and the U.S. Army Corps of Engineers, Kansas City District (Baker et al. 2021) was integral to discussions during the environmental flows workshop and development of environmental flow proposals presented.

We are grateful to everyone who has participated for their interest and contribution to improving the health of the Kansas River. The extensive contributions and collaboration efforts from the various agencies and individuals are integral to the effort now and for future coordination and implementation efforts.

Disclaimer: The development of environmental flow plans is based on best available science and will be carefully balanced with the needs and requirements of stakeholders, to benefit the Kansas River ecosystem while improving or not adversely affecting the system. Environmental flow plans are developed within the constraints of authorized purposes of the reservoirs, water rights, and other human use requirements, and in collaboration with stakeholders.

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1.0 Sustainable Rivers Program

The Nature Conservancy (TNC) and U.S. Army Corps of Engineers (USACE) have partnered to form the Sustainable Rivers Program (SRP) to examine opportunities to optimize reservoir releases and river flows to benefit river ecology while maintaining the federal mandates of the reservoir system in the United States. The mission of the SRP is to improve the health and life of rivers by changing water infrastructure operations to restore and protect ecosystems, while maintaining or enhancing other project benefits. The founding objective of SRP is implementation of environmental flows (e-flows), which are defined as the quantity, timing, and quality of water flows required to sustain ecosystems. Here, e-flows are considered management decisions that manipulate water and land-water interactions to achieve ecological environmental goals. SRP efforts complement other reservoir-centric water resource projects by demonstrating that a strategic and science-based approach can be used at USACE projects to maintain or enhance benefits provided to the nation. As of 2019, SRP involved work on 66 USACE reservoirs in 16 river systems and 5,083 river miles. SRP is now the largest scale and most comprehensive program for implementing e-flows at USACE reservoirs.

In 2017, the USACE Kansas City District and TNC Kansas added the Kansas River to the SRP. An initial workshop, with Kansas River stakeholders (reservoirs, businesses, drinking water, recreation, etc.) and regional biology and hydrology experts, was held to help guide the process of identifying e-flows. Subsequently, a literature review and data mining exercises were undertaken to identify flow-dependent fish, mussels, and other species in the Kansas River, examine changes in these species over time, and propose the likely causes of these changes (Baker et al. 2021). USACE used this information to better understand reservoir operation impacts and examine possibilities for reservoir management modifications within the range of authorized reservoir releases that would create flows beneficial to the Kansas River ecosystem. The draft literature review was completed in July of 2020 providing the groundwork for informed development of flow-related hypotheses for the e-flows workshop involving expert stakeholders. It summarized the 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 the other. Background data in the literature review included ecology and biology flow needs, as well as hydrologic conditions before and after construction of dams and impoundment.

Using input from stakeholders and data obtained related to hydrology and information from the ecological assessment an e-flows workshop was held in September 2020. The goal of the workshop was to develop Kansas River e-flow recommendations that could result in benefits to fish, wildlife, and the ecosystem while avoiding conflicts with current human uses. Participants included multi-disciplinary experts and representatives from federal government, state government, academics, non-governmental organizations (NGOs), private industry, and utilities. During this meeting experts crafted e-flow prescriptions for one reach of the mainstem Kansas River below USACE dams. This document summarizes the results of that meeting.

2.0 Summary Ecology/Flow Recommendations

During the Kansas River Basin SRP e-flows workshop, experts worked through a series of tasks and questions to draft e-flow prescriptions for specific reaches of the Kansas River mainstem downstream of one or more dams. A list of the focus reaches considered is included below and shown in Figure 1.

<u>Focus Reaches</u>

- Reach 1 – Kansas River – Below Milford Reservoir to Big Blue River Confluence
- Reach 2 – Kansas River - Big Blue River Confluence to Willard (below Milford and Tuttle reservoirs)

- Reach 3 – Kansas River – Delaware River Confluence to Lawrence (below Perry Reservoir)
- Reach 4 – Kansas River – Wakarusa River Confluence to Bonner Springs (below Clinton Reservoir)

Workshop experts were also provided a list of reaches referred to as Reach 0 that includes reservoirs and tributary reaches directly below each of the reservoirs.

- Reach 0 – Milford Reservoir
- Reach 0 – Republican River - Below Milford Reservoir to Kansas River Confluence
- Reach 0 – Tuttle Creek Reservoir
- Reach 0 – Blue River – Below Tuttle Creek Reservoir to Kansas River Confluence
- Reach 0 – Perry Reservoir
- Reach 0 – Delaware River – Below Perry Reservoir to Kansas River Confluence
- Reach 0 – Clinton Reservoir
- Reach 0 – Wakarusa River – Below Clinton Reservoir to Kansas River Confluence

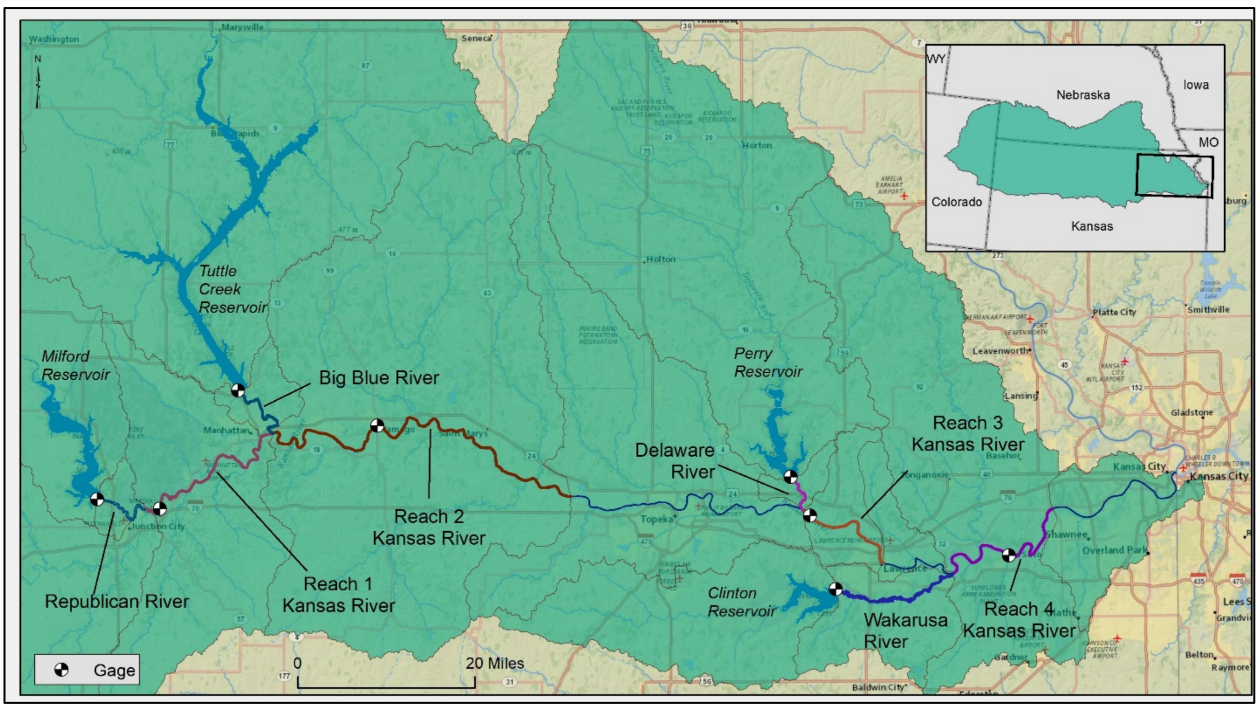

Figure 1. Kansas River SRP Focus Reaches

Reach 2 was selected to start the discussions during the breakout group sessions because of the proximity downstream of both Milford and Tuttle Creek Reservoirs and because it is believed to be the least impacted reach of the Kansas River. Reach 2 would have a greater likelihood of potential benefits from releases from the two reservoirs. Other reaches would only be influenced by releases from a single reservoir (e.g., Reach 1 below Milford Reservoir; Reach 3 below Perry Reservoir) or are too far downstream to realize any meaningful effects due to attenuation the further downstream (e.g., Reach 4 below Clinton). Reaches below Bowersock Dam were not considered as flows from USACE reservoirs would likely be attenuated below the dam and dredging occurs in Reaches 3 and 4.

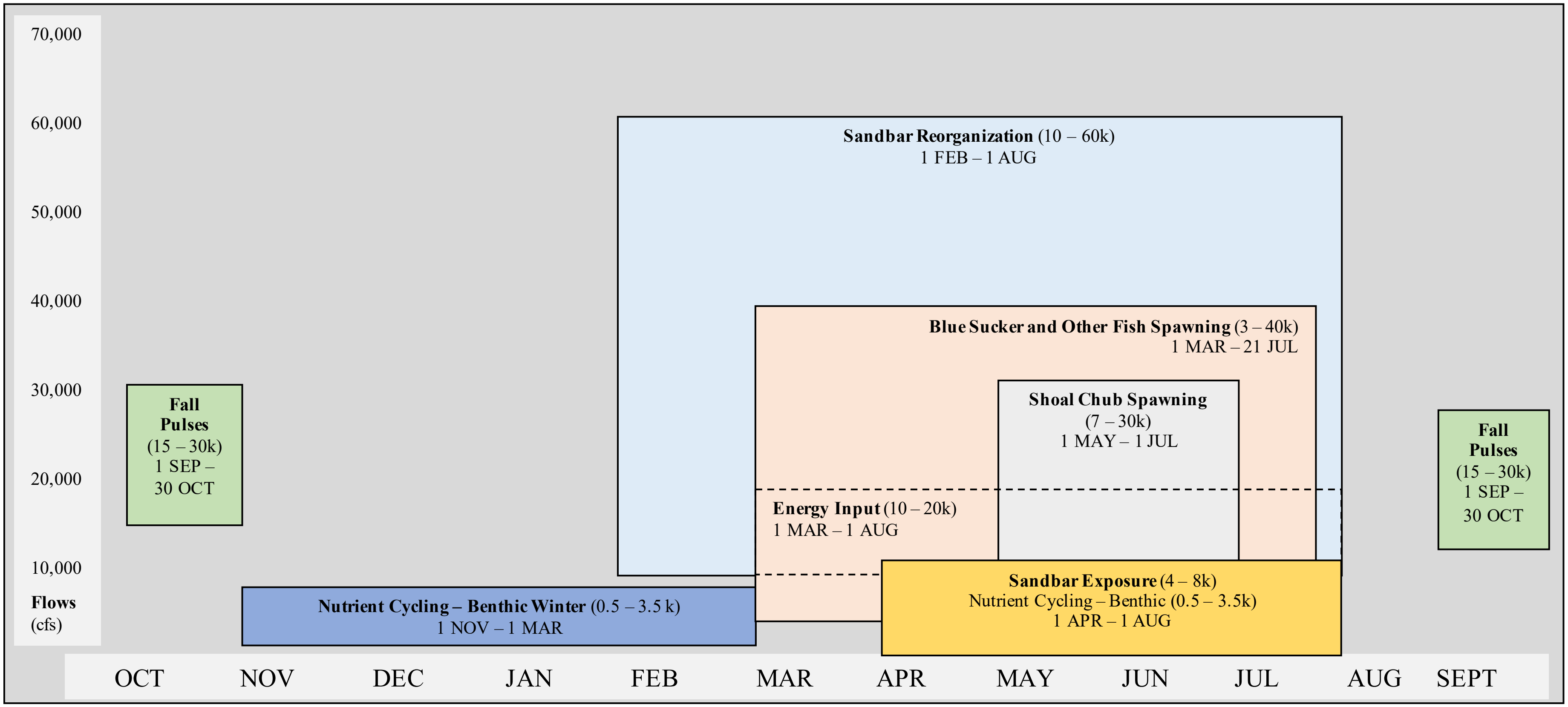

Figure 2. Kansas River SRP Unified Flow Prescriptions with Ecological Explanations for Reach 2 Wet/Average/Dry Combined

Figure 2 is an example summary of ecological considerations and environmental flow targets for Reach 2 (Kansas River – Big Blue River Confluence to Willard) that emerged from the September 1-2, 2020 expert e-flow workshop. This flow prescription is specific to the Kansas River mainstem influenced by Milford and Tuttle Creek Reservoir operation. Figure 2 is a culmination of ideas for fish, mussels, riparian and floodplain systems, and sandbar nesting birds. The rest of this report will summarize the process to general flow recommendations, specific flow prescriptions from individual groups, as well as the unified flow recommendations for multiple stretches of the river.

3.0 Workshop Goals and Agenda

The goal of the workshop was to develop e-flow recommendations in the Kansas River that could result in benefits to the Kansas River ecosystem while avoiding conflicts with current human uses by exploring operational changes at one or more of the dams in the Kansas River Basin. The full workshop agenda and list of participants are included in Appendix A and Appendix B, respectively.

The two-day workshop began with a welcome and formal participant introduction, review of the SRP process, and discussion of desired workshop outcomes. Next was an overview of USACE projects in the basin followed by a presentation on existing operating rules at USACE reservoirs and hydrologic analysis and flow/ecology relationships as background for developing e-flow recommendations. The group then received instruction for working groups and an overview of the Regime Prescription Tool (RPT) software, for use in visualizing e-flow prescriptions.

Experts were broken into two different groups: 1) fish and other aquatic species, and 2) birds/riparian and floodplain systems. Each of the two groups were given the same reach to formulate (Reach 2) at least one e-flow prescription to serve as a base model with which to move forward during the unification of all reaches. Experts drafted desired hydrographs for fish and other aquatic species and birds/riparian and floodplain systems at a specific reach of the river. These recommendations included desired hydrographs in wet, dry, and normal years. Experts were asked to define hypotheses regarding flow-related issues and potential flow change enhancements to maximize or enhance benefits via water management (i.e. flow manipulations) related to the selected habitats, target species (i.e. fish and other aquatic species and birds/riparian and floodplain systems), or riverine processes. Experts were provided information on the location, timing, magnitude, duration, and rate of change of flow for low flows, flood pulses, small floods, and large floods. During the breakout sessions, experts were instructed to focus on their ecological target without consideration of current operational constraints, such as feasibility of making releases to enhance downstream overbank flooding. Although USACE water management staff were part of each working group, current operations manuals were not considered a constraint to the hydrograph recommendations at this time. Future coordination would include these discussions prior to implementation. Participants were asked to provide their opinion on the significance of environmental flow components in relation to the following:

- Hydrogeomorphic processes – including channel formation, sediment dynamics and substrate 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, dissolved oxygen 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.

Flow recommendations for aquatic species considered spawning cues, conditions for shaping appropriate spawning substrates, access to floodplains, migration needs, flow impacts to critical life stages (i.e. nursery habitats, stranding of invertebrates) and velocities that support good water quality. The birds/riparian and floodplain systems group was tasked with identifying flow conditions that result in healthy, functioning riparian and floodplain systems and support breeding and nesting of rare sandbar nesting birds. Flow recommendations considered the length of time that sandbars need to be inundated, the timing of inundation, the vegetation hydrology requirements, and other related matters. Specific questions that the breakout groups considered include:

- What questions, hypotheses, and recommendations would you make to ecosystem health on the river?
- How have dam operations changed river hydrology, morphology, and habitat?
- What are the factors contributing to declines in species/groups?
- Can flow changes be made to reduce the effects to declining species/groups?
- Are there specific species, groups, habitats, locations, or processes that we should focus on for this workshop?
- What recommendations would you make for low flows? High flows? Flood events?
- What opportunities exist in the Kansas River to develop structure or off-channel habitat for aquatic and bird life (e.g. reconnection of old oxbows)?
- When considering birds, herps, mussels and fish species of greatest conservation need, are there flow management strategies that would benefit all?

Specifically, working groups were tasked with identifying e-flow hydrographs for Reach 2 (Kansas River – Big Blue River Confluence to Willard) designed to improve ecological conditions associated with each group's focus area. Reach 2 was selected because of the proximity downstream of both Milford and Tuttle Creek Reservoirs and because it is believed to be the least impacted reach of the Kansas River. Reach 2 would have a greater likelihood of potential benefits from releases from the two reservoirs. Other reaches would only be influenced by releases from a single reservoir (e.g., Reach 1 below Milford Reservoir; Reach 3 below Perry Reservoir) or are too far downstream to realize any meaningful effects due to attenuation the further downstream (e.g., Reach 4 below Clinton). Reaches below Bowersock Dam were not considered as flows from USACE reservoirs would likely be attenuated below the dam and dredging occurs in Reaches 3 and 4 minimizing any effects form e-flow proposals.

Working groups continued for the rest of the first day and first half of the second day to define flow needs in Reach 2 (Kansas River – Big Blue River Confluence to Willard) and took notes on any related but non-focus issues such as further research needs or other unknowns. These issues were logged in what was referred to as the "Parking Lot" but were not addressed at this workshop. Parking lot ideas included, 1) obtaining information on reservoir level management and management of reservoir fisheries in other regions, and 2) looking at releases that are typically made prior to icing at reservoir and potentially holding more water over the winter to release later. "Parking lot" discussions were tabled during the workshop, but it was agreed that it could be beneficial in consideration of proposals for the Kansas River.

Throughout this time, USACE technical specialists were available to answer any questions the working groups had. On the afternoon of the second day working groups presented flow recommendations for their target species/habitats and worked to integrate flow recommendations from each working group into a unified set of flow recommendations. The workshop ended with conclusion and parting discussion, which included remaining uncertainties, next steps, research needs, and concluding thoughts.

4.0 Basin Characteristics and USACE Operations

4.1 Basin Characteristics

USACE photo

The Kansas River begins at the confluence of the Republican and Smoky Hill Rivers near Junction City, Kansas and flows 173 miles to the confluence with the Missouri River (Kansas City, Missouri). The Kansas River Basin drains most of northern Kansas, as well as parts of Nebraska and Colorado (60,500 square miles in all) (Figure 3) and is the longest prairie-based river in the world. The basin is approximately 490 miles long west to east, with a maximum width of approximately 200 miles north to south from Polk County, Nebraska, to McPherson County, Kansas. The Kansas River Basin includes 18 federal reservoirs (7 USACE and 11 USBR), 12 within Kansas, five in Nebraska, and one in Colorado (Table 1). USACE dams manage water flowing from most of the Kansas River Basin with a total of approximately 45,800 square miles upstream of USACE dams. Approximately 9,730 square miles of unregulated areas remain below major dams and the mouth of the Kansas River. Table 1 lists federal dam projects in the Kansas River Basin. Figure 3 shows the major impoundments in the Kansas River Basin. The Bowersock Dam also stores water within the Kansas River for release through its hydropower turbines.

Table 1. Water Management Projects

Water Management Project	Basin or Stream	Date of Closure	Operating Agency
Republican River Basin			
Bonny Dam	South Fork Republican River	1950	Bureau of Reclamation
Trenton Dam (Swanson Lake)	Republican River	1953	Bureau of Reclamation
Enders Dam	Frenchman Creek	1950	Bureau of Reclamation
Red Willow Dam (Hugh Butler Lake)	Red Willow Creek	1961	Bureau of Reclamation
Medicine Creek Dam (Harry Strunk Lake)	Medicine Creek	1949	Bureau of Reclamation
Norton Dam (Keith Sebelius Lake)	Prairie Dog Creek	1964	Bureau of Reclamation

Water Management Project	Basin or Stream	Date of Closure	Operating Agency
Harlan County Dam	Republican River	1951	USACE, Kansas City District
Lovewell Dam	White Rock Creek	1957	Bureau of Reclamation
Milford Dam	Republican River	1964	USACE, Kansas City District
Smoky Hill River Basin			
Kanopolis Dam	Smoky Hill River	1946	USACE, Kansas City District
Glen Elder Dam (Waconda Lake)	Solomon River	1967	Bureau of Reclamation
Wilson Dam	Saline River	1963	USACE, Kansas City District
Cedar Bluff Dam	Smoky Hill River	1950	Bureau of Reclamation
Webster Dam	South Fork Solomon River	1956	Bureau of Reclamation
Kirwin Dam	North Fork Solomon River	1955	Bureau of Reclamation
Lower Kansas River Basin			
Clinton Dam	Wakarusa River	1975	USACE, Kansas City District
Perry Dam	Delaware River	1966	USACE, Kansas City District
Tuttle Creek Dam	Big Blue River	1959	USACE, Kansas City District

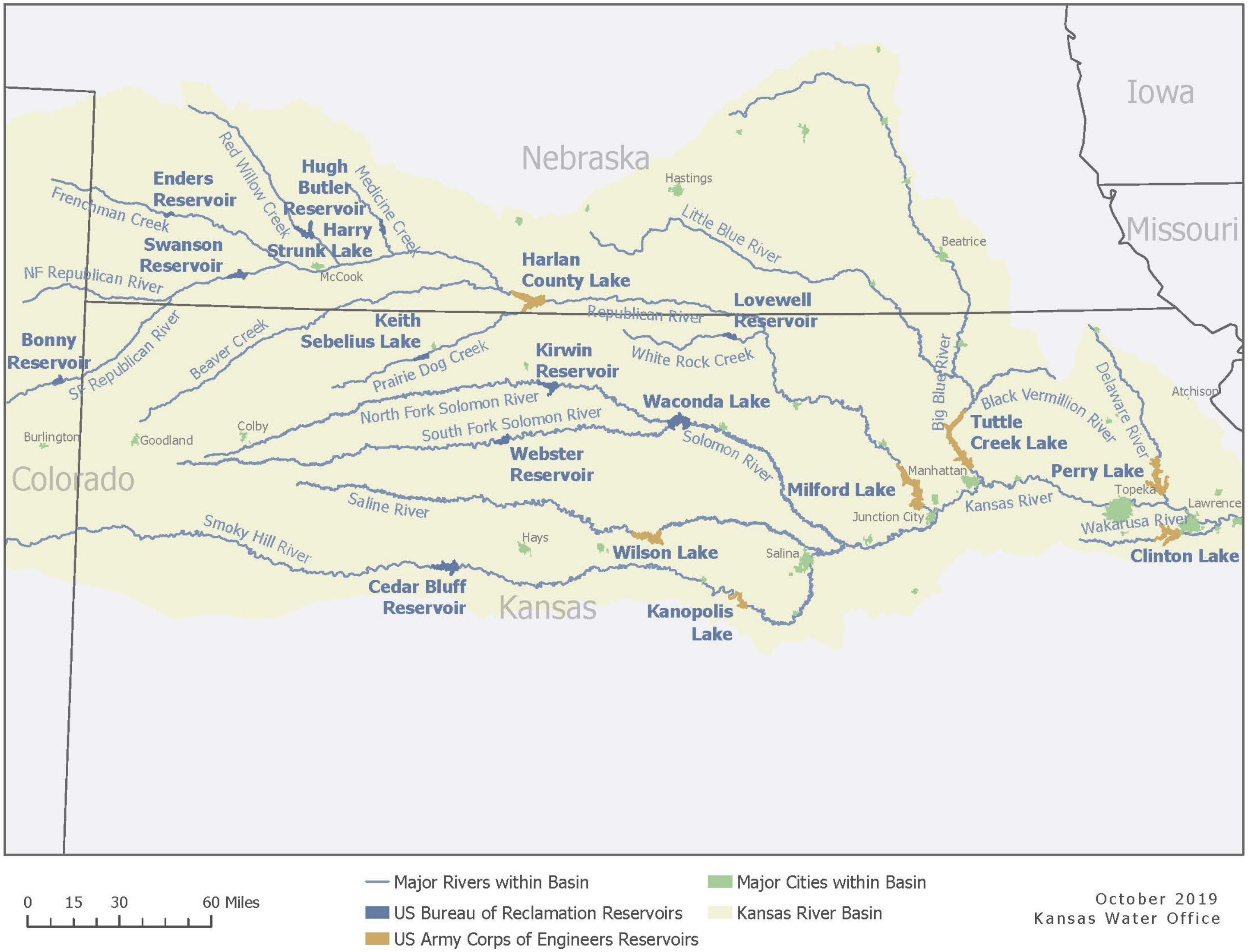

Figure 3. Kansas River Basin

There are approximately 640 freshwater stream miles below all major dams, and approximately 100,000 acres of federally owned freshwater impoundments, including U.S. Army Corps of Engineers and U.S. Bureau of Reclamation (USBR) reservoirs, in the Kansas River Basin.

There are many tributaries contributing to the Kansas River. Table 2 summarizes the origin, length, and basin area of the various tributaries.

Table 2. Kansas River Tributaries

Tributary	Origin	Length	Basin Area
Kansas River	KS	148 mi (238 km)	60,114 mi2 (155,695 km2)
Republican River	NE	453 mi (729 km)	24,900 mi2 (64,491 km2)
White Rock Creek	KS	22 mi (35 km)	358 mi2 (930 km2)
Smoky Hill River	CO	575 mi (925 km)	19,260 mi2 (49,883 km2)
Big Blue River	NE	575 mi (925 km)	2,330 mi2 (6,000 km2)
Delaware River	KS	359 mi (578 km)	9,600 mi2 (25,000 km²)
Wakarusa River	KS	94 mi (151 km)	1,117 mi2 (2,890 km2)
Solomon River	KS	80.5 mi (130 km)	367 mi2 (950 km2)
North Fork Solomon	KS	184 mi (296 km)	6,835 mi2 (17,703 km2)
South Fork Solomon	KS	287 mi (462 km)	1,367 mi2 (3,540 km2)
Saline River	KS	292 mi (470 km)	1,150 mi2 (3,000 km2)
Prairie Dog Creek	KS	397 mi (639 km)	3,419 mi2 (8,855 km2)

The Kansas River Basin exhibits significant variation in natural stream flows. Annual and daily discharges for any given location vary through a wide range, and similar weather conditions can produce considerably different discharges at different locations. Severe drought periods frequently follow a flood. The entire Kansas River Basin is subject to severe flooding at infrequent intervals, erratically interspersed by less severe floods of varying magnitudes.


Photo by The Nature Conservancy

Channel capacities vary from 4,000 cubic feet per second (cfs) immediately below Wilson Lake Dam to 16,700 cfs at Enterprise, Kansas on the Smoky Hill River. Channel capacities become progressively larger from Junction City, Kansas to the mouth, varying from 40,000 cfs to 119,000 cfs. Relatively large areas exist in the western portion of the basin that contribute little to no surface runoff to the Kansas River flows, while most of the runoff in the eastern portion of the basin contribute surface runoff to the Kansas River flows (USACE 1966).

4.1.1 Floodplain and Channel Modifications: Geomorphology

The Kansas River floodplain and the floodplains of its tributaries are important resources that convey large stormwater events and provide high-quality wildlife habitat. The floodplain of the Kansas River is defined as a riverine floodplain, which is comprised of the floodway and the flood fringe. The floodway encompasses the channel and a portion of the adjacent floodplain area necessary to convey floodwaters. The flood fringe is land located outside the floodway that is at or below the base flood elevation and stores but does not effectively convey floodwaters.

Most of the floodplain (74%) is covered by agricultural lands, while grassland and water covers 6% of the floodplain. Woodlands comprise 7% of the Kansas River floodplain. Some of the larger woodland tracts are in the east half of the floodplain in the bluffs bordering the Kansas River and along some of the river's small tributaries. Woodlands generally have less coverage west of Topeka and are confined to many small drainages and creek valleys branching off the Kansas River and its larger tributaries. In the Fort Riley area northeast of Junction City and north of the Kansas River, the larger tributary valleys are filled with woodlands; however, on privately owned land south of the river, tributary valleys are mostly cropland. Although few large woodland tracts can be found, a discontinuous riparian forest grows along the entire length of the Kansas River.

The Kansas River floodplain is generally a flat topographic feature where conditions are favorable for development of woody plants during prolonged drought periods. The reaches of the Republican, Saline, and Big Blue Rivers below the reservoirs and the lower Smoky Hill River are much like the Kansas River. The Solomon and Delaware Rivers have comparatively narrow, deep, and well-defined channels in the lower reaches where willow growth is less likely to develop but where degradation is likely. The Smoky Hill River just below Kanopolis Reservoir is much like these latter mentioned streams. Here, degradation has amounted to about four feet for about a mile and then progressively less until, at ten miles downstream, no trend is discernable (USACE 1966).

Wetlands remaining along the Kansas River occur both in the floodplain and the river. Floodplain wetlands include farmed wetlands, scrub-shrub wetlands, palustrine emergent wetlands, and forested wetlands. Floodplain wetlands are supported by overland runoff, overbank flooding and occasionally by high water tables. In-stream wetlands primarily occur on islands within the Kansas River.

Several natural and man-made modifications (e.g. weirs, dams, river training structures, bank protection structures) to the river continue to change the river channel and flow characteristics. These man-made features affect aggradation/degradation and lateral erosion along the channel. Many of these structures are not operated by the USACE and are referenced only for context. Changes to these structures would not be considered in development of e-flows.

The Kansas River upstream of Bowersock Dam has a relatively stable morphology, except for the Topeka area. A 2011 survey indicates that one to two feet of riverbed degradation has occurred within the Topeka area since 1992. The river channel in the Topeka area has been hardened and narrowed with flood-control works. Based on long-term gaging station data and survey data collected in 1992, the river channel downstream of Bowersock Dam appears to be less stable than the areas monitored upstream of the dam.

4.1.2 Streambank Erosion and Sedimentation

Soils of the Kansas River floodplain are sandy, readily eroded unless protected, and in many places underlain by sand. Generally, where the outside of bends are not protected by vegetation or bank stabilization structures, erosion occurs during moderate to high stages. At many places, bank stabilization works have been constructed by local interests and are working satisfactorily to slow erosion, except in places where they do not extend far enough upstream or downstream.

The Kansas River and all principal tributaries are sediment bearing streams and usually meander through a relatively wide floodplain. Streambeds of the Kansas and Republican Rivers are generally composed of sand. Long sections of the Big Blue, Solomon, and Saline Rivers appear to have silt or a mixture of silt and sand beds (USACE 1966).

Sediment loads of the Kansas River are affected by existing reservoirs. Reservoirs trap the bedload material and between 95 to 100% of the suspended sediment load (USACE 1966).

During the past several decades, various reaches of the Kansas River have experienced riverbed degradation. The most pronounced adverse effects have occurred in the lower river. Over the years these effects have been attributed to several causes, including commercial sand and gravel dredging, the federal reservoir system, lowering of the Missouri River's water surface elevations, and other man-made influences such as Bowersock Dam and a water supply weir in Johnson County. Riverbed degradation can create an unstable river channel which results in secondary impacts such as bank erosion, channel widening, lowering of water surface elevations in the river channel, lowering of water table elevations adjacent to the river, and alteration of aquatic and terrestrial habitat (KGS 1998).

Bank erosion and channel widening have a high potential to impact the biological community. Bank erosion impacts aquatic organisms by increasing suspended solids concentrations in the river which reduce light transmission and increase siltation and embeddedness of the channel bottom material. Erosion adversely impacts wildlife populations by destroying riparian habitat. Some reaches of the Kansas River have only a narrow band of uncleared land along their banks and, when erosion destroys these fringe areas, many birds, mammals, and other terrestrial animals lose habitat. Channel widening increases the river's cross-sectional area and therefore, may reduce flow velocities and increase siltation.

4.2 Operations and Authorized Purposes for the Kansas River

4.2.1 Operations Overview

The USACE Kansas City District includes the Missouri River watershed from Rulo, Nebraska, (river mile 498.1 above the mouth) to the junction of the Missouri and Mississippi Rivers near St. Louis, Missouri. The Kansas City District fully operates 18 storage projects and manages flood control releases from 11 Section 7 USBR reservoirs. In the Kansas River Basin, there are 7 USACE reservoirs and 11 USBR lakes. The location of each lake and reservoir in the Kansas City District is shown on Figure 1.

Kansas River flows serve as a critical drinking water supply for more than 600,000 people in addition to being used for irrigation, municipal wastewater and industrial discharges, power generation, and as a source of commercial sand and gravel. Additionally, recreation use in the Kansas River Basin (boating, kayaking, camping, picnicking, fishing, swimming, hunting, wildlife viewing, etc.) provides substantial benefits to the local, regional, and national economy.

Each USACE reservoir operates for specific congressionally authorized purposes and has a Water Control Manual which details the rules and regulations specific to each reservoir. The following sections summarize the main rules used to regulate releases in both flood control and multipurpose pools. Within the Kansas River Basin, the congressionally authorized purposes include flood control, water supply, water quality, fish and wildlife, recreation, navigation support, and irrigation. Table 3 summarizes the authorized purposes for each.

Table 3. Kansas River Basin Reservoirs Authorized Purposes

Reservoir	Flood Control	Water Supply	Water Quality	Fish and Wildlife	Recreation	Navigation	Hydropower	Irrigation
Kanopolis	X	X	X	X	X	*	*	*
Wilson	X		X	X	X	*		*
Harlan County	X			X	X			X
Milford	X	X	X	X	X	X		
Tuttle Creek	X	X	X	X	X	X		
Perry	X	X	X	X	X	X		
Clinton	X	X	X	X	X			

* Authorized purpose, not operating purpose

Based on PR-19 Authorized and Operating Purposes of Corps of Engineers Reservoirs July 1992, revised 1994

Operations can be broken into three major categories, flood control, multipurpose, and surcharge, each being governed by separate rules. Releases made from USACE reservoirs serve to fulfill one or more of the authorized purposes. Flood control and the various multipurpose operations are explained in the following sections.

4.2.2 Kansas River Basin Reservoir Operations

Typically, the flood control pools are designed to store runoff from major floods based on a standard project storm. Stored flood flows are then evacuated as rapidly as the downstream channel capacities allow.

When flooding is not occurring, USACE works to seasonally fluctuate reservoir elevations near the multipurpose pool level in order to principally benefit on-reservoir fish and wildlife purposes. Minor releases at some projects are managed to benefit downstream fish and wildlife and special requests from river users. Minimum releases are maintained at all projects for the purpose of sustaining water quality control in the first reach downstream. Large portions of the multipurpose pools at Milford, Tuttle Creek, Perry, and Clinton have been purchased or reserved by the State of Kansas for downstream water supply (both municipal and industrial) in cooperation with the Kansas River Water Assurance District No. 1. Releases from this contracted storage are tracked and accounted for by the Kansas Water Office consistent with USACE monthly reservoir accounting for each project. Storage in the multipurpose pools at USACE projects that support irrigation have been contracted to irrigation districts. Generally, a portion of each multipurpose pool is reserved for sediment storage. On an interim basis, a portion of the multipurpose pools at Milford, Tuttle Creek, and Perry are available for supplementation of navigation flows on the Missouri River.

Minimum releases from each of the USACE reservoirs in the Kansas River Basin were established during the original design and authorization process using U.S. Public Health Service guidelines for downstream water quality needs along the tributary before it reaches the Kansas River. Minimum releases range from 7 cfs to 100 cfs (Figure 4 and Figure 5; Table 4). Clinton is also authorized to provide supplemental low flow releases for downstream fisheries during April through September. Authorizations were also included at Milford, Tuttle Creek, and Perry reservoirs for low flow supplementation for water quality on the lower Kansas River and the Missouri River at Kansas City. The seepage through the USBR dams is considered enough for water quality purposes in the upper Kansas River Basin.

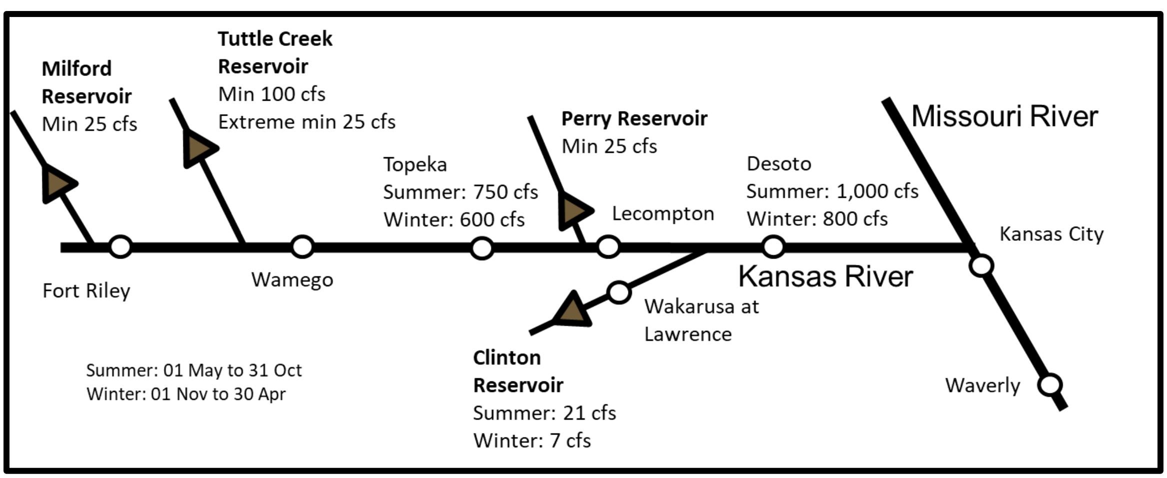

Figure 4. Kansas River Basin Low Flow Releases and Flow Targets

Table 4. Kansas River Flow Objectives

Tuttle Creek Elevation	Topeka	Desoto
1,075 – 1,070	750 cfs	1,000 cfs
1,070 – 1,065	Summer: 750 cfs Winter: 600cfs	Summer: 1,000cfs Winter: 800cfs
1,065 – 1,048	600 cfs	Summer: 750cfs Winter: 700cfs

Summer: 1 May to 31 Oct; Winter: 1 Nov to 30 Apr

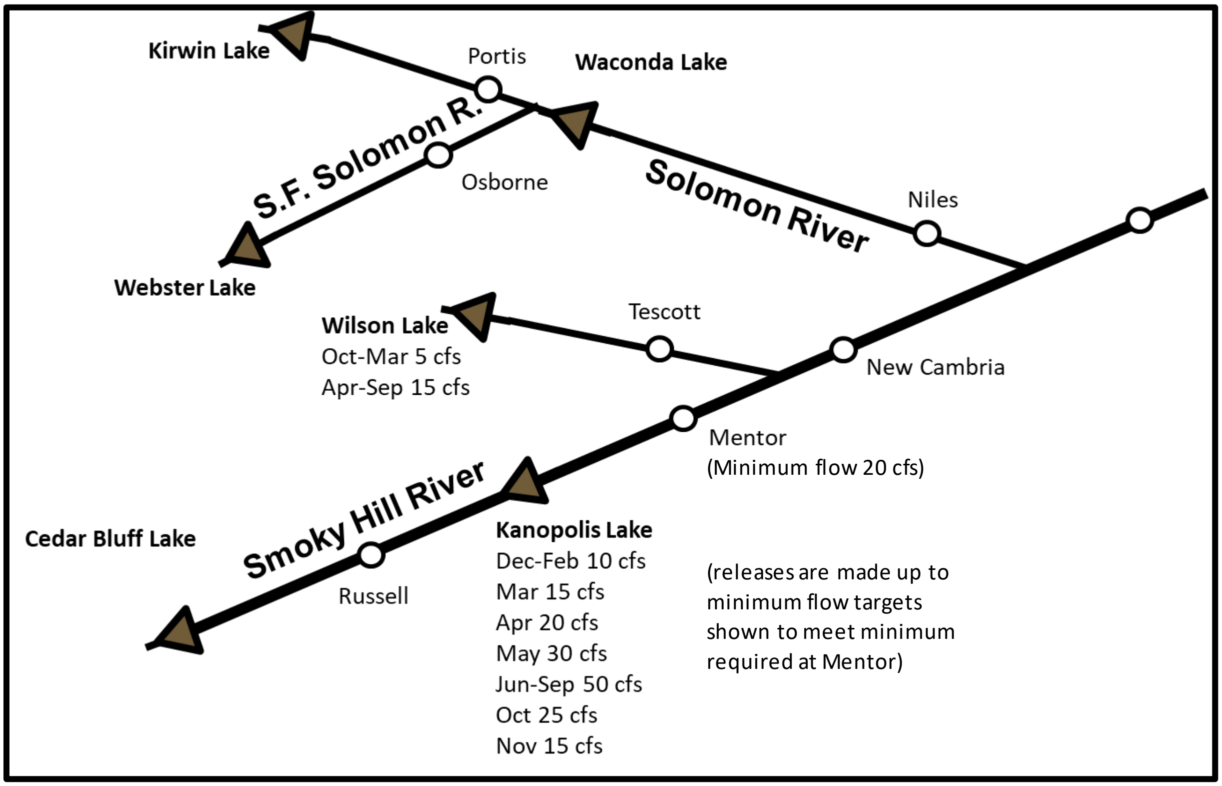

Figure 5. Upper Kansas River Basin Low Flow Reservoir Releases

Close cooperation between the USACE Kansas City District office, project operating personnel, and Kansas Department of Wildlife and Parks (KDWP) has resulted in operation plans recognizing reservoir fish and wildlife management objectives. One significant feature of this cooperation is the annual development of water level management plans for each reservoir. These plans modify the effective multipurpose pool elevation for water release guidance to principally benefit fish and wildlife on the reservoir. Those plans are reviewed and modified annually in cooperation with the state with the restriction not to exceed the lowest 5% of the respective flood control storage.

Photo by Kansas Water Office

The typical water level management plan for Kansas River reservoirs calls for a low winter level for ice control and to provide additional buffer storage for large winter and spring flows. In the spring, a slow pool rise is preferred to enhance fish spawning. For the same reason, large releases are minimized to prevent fish entrainment through dams and improve nesting/rearing conditions for bank spawning species. Later in the spring and in the summer, the pool is usually maintained close to the multipurpose level to enhance recreation and maximize flood control benefits during the wet season. In the late summer or early fall, the pool may be lowered to enhance shoreline vegetation growth. Then later in the fall the pool is allowed to rise when water is available to inundate the vegetation growth and maximize waterfowl habitat and hunting access. In late December the pool is lowered to its winter level.

5.0 Key Findings from the Literature Review

5.1 Fish

Native fish are adapted to the natural heterogeneity of the Kansas River and need not only the habitat that is shaped by variance in flows, but also physical dynamics of the water for egg and juvenile development. The review looked at historic and modern flows and fish data for the Kansas River main stem. Maintaining e-flows, or flows that benefit native species and ecological systems, would increase flow heterogeneity providing year-round river water levels suitable for the behavioral, reproductive, and habitat needs of river and floodplain flora and fauna. The flow regime of the river also impacts nutrient cycling, sediment transport, and bank erosion. (Baker et al. 2021)

Compared to natural conditions, reservoir regulation has resulted in a widely differing flow regime. The two principal differences (comparing pre- to post-impoundment conditions) include flow duration and sediment load changes. Flow duration for floods have changed from a natural hydrograph with a high peak and a few days duration, to a modified hydrograph with a lower peak and a longer duration (Figure 6) (from unpublished Huggins and Liechti work using USGS 2019).

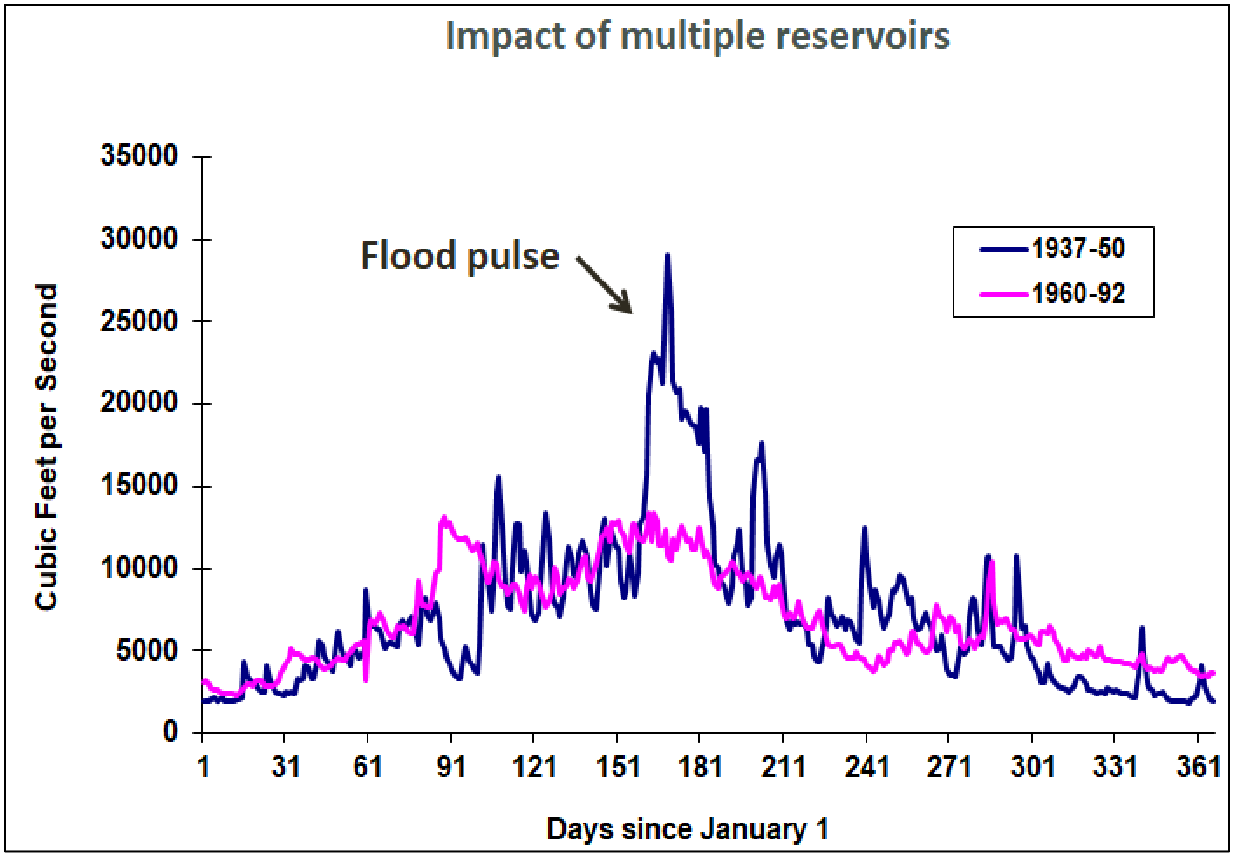

Figure 6. Kansas River Hydrographs at Lecompton, Kansas Pre- and Post-Impoundment

Source: Huggins and Liechti unpublished using USGS 2019

O'Neil (2010) examined how the hydrology of the Kansas River affects habitat complexity and concluded that impoundments on the river have eliminated much of the complexity. This, in turn, has reduced the diversity of aquatic species found in the Kansas River as there is less refugia from abrupt flow changes due to reservoir operations as well as less variation in the hydrograph which is needed for reproduction and feeding. (Baker et al. 2021)

The database of fish collected from the Kansas River (1886-2018) was examined for life history needs of fish species and provides information to estimate critical flow needs for Kansas River fish. To reintroduce heterogeneity in flows and subsequently to habitat in the Kansas River, modification of dam releases in consideration of these flow needs must incorporate (Baker et al. 2021):

- Frequency – How often flows increase and decrease (variability of flows). Frequency in flows increases water and terrestrial connectivity and shifts instream habitat availability.
- Duration – The temporal range of flow events. While large flood peaks must be attenuated, both high and low flow periods should follow normal patterns.
- Extent – The magnitude of flow increases and decreases. Again, while flood peaks need to be attenuated, both extreme high and low flow periods should not be extended beyond normal time periods.
- Temporal shifts – Current flow regimes remain closely correlated with natural flow regimes. The historic changes in river flows were linked to climate and precipitation patterns within the basin and shifts in seasonal flow patterns should be minimized.

Other measures that would benefits fish in the Kansas River Basin include:

- Allowing variability (low flows, average flows, seasonal) and some high-water events in the summer will shape habitats (e.g., bed materials, sandbars, mid-channel bars, gravel bars, pools, riffles, oxbows), while reducing flows in the fall enhance habitat (e.g., refugia for fry) and flow conditions for fish. Intermediate flows could benefit young-of-year fish species in certain groups (i.e. Cyprinidae family). These conditions could benefit many of the native species on the Kansas River. However, other species may have different life history requirements.
- Lower late summer/fall discharges (following the critical spawning window) would provide lower water velocities which should benefit young-of-year fishes during early life history.

5.2 Freshwater Mussels

An assessment of freshwater mussels in the Kansas River was conducted by Cringan et al (2020). The assessment provided information on the occurrence and distribution of freshwater mussels in the Kansas River and examined major changes in the mussel community over the past 150 years. The assessment discussed opportunities and challenges relating to protection and restoration of mussels in the Kansas River and its watershed. Photo (left) by S. Cringan, R.T. Angelo, and D.S Baker.

Today the watershed supports 18 mussel species, showing a 44% decline in taxa richness with some found only in a few isolated, widely scattered habitats. Since the turn of the 20th century, dominant mussel species in the Kansas River have changed from three long-lived, slowly maturing species (hickorynut [*Obovaria olivaria],* fatmucket [*Lampsilis siliquodea*], yellow sandshell [*L. teres*]) to two short-lived, rapidly maturing species (fragile papershell [*Leptodea fragilis*], pink papershell [*Potamilus ohiensis*]). Rapid attenuation of releases from reservoirs can strand mussels on exposed sand and gravel bars resulting in lethal heat stress and heavy predation jeopardizing entire mussel communities (Cringan et al. 2020). The assessment recommended that reservoir releases are slowly attenuated over at least a one to two-week period, particularly during the summer and early fall. Freshwater mussels rely on fish to act as hosts for their larvae, with some mussel species requiring specific fish species. Improving native fish populations may yield additional benefits for freshwater mussels as well.

5.3 Sandbar Nesting Birds

Photo by Cal Vornberger

Many species of shore and wading birds use the Kansas River; however, it is the sand-bar nesting species that have limited and tenuous habitat on the river. The two sandbar-nesting species in the Kansas River are piping plover (*Charadrius melodus*) and least tern (*Sternula antillarum*). Both prefer sandy beaches, open lake shores, and sparsely vegetated sandbars.

Piping plovers and least terns have been sighted in the Kansas River area indicating that they are present during the breeding and nesting season. Anthropogenic changes in flows, such as diminished variance and duration, has decreased nesting habitat as well as food (invertebrate and fish) availability. While high episodic flows create the emerged sandbars that these birds need for nesting, high flows during the nesting period will destroy nests. Above 8,000 cfs sandbars are reduced in some locations on the Kansas River (http://kansasriver.org/). However low flows allow encroachment of vegetation which provides cover for predators (Boyd and Olsen 2006). Modifying river flows to allow for sandbar creation and adequate exposure during nesting season will improve habitat for these threatened and endangered birds. (Baker et al. 2021)

6.0 Flow-Ecology Relationships for the Workshop

A natural flow regime or hydrologic regime refers to the characteristic pattern of a river's flows in terms of quantity, timing, and natural variability. The natural flow regime influences many of the key characteristics of, and processes in, river systems such as physical habitat (channel structure and characteristics such as substrate), water quality (issues such as chemical and temperature regimes), energy supply in terms of nutrient input and availability, and species interactions. Flow regime ecosystem influences vary greatly depending on if the flow is low, high, or flooding, but all can benefit the ecological integrity of a river system.

A dam-altered flow pattern can result in significant changes to a river's hydrologic regime with impacts to timing, duration, magnitude, frequency, and rate of change. The aim of the Kansas River SRP is to identify preferred flow regimes for fish and other aquatic species (e.g., mussels) populations, ecosystem function, and river and riparian floodplain habitat health that could later be explored to determine whether it is possible to modify Corps' dam operations to accommodate these flow regimes. The task was to consider e-flows in the Kansas River, especially below Milford and Tuttle Creek dams. The goal was to identify opportunities congruency between hydrology and species/habitat flow needs. The desired outcome was e-flow prescriptions that create adequate conditions for all native species/habitats enough of the time.

6.1 Fish and Other Aquatic Species

Experts were tasked with considering the life history needs of fish and other aquatic species.

Fish

Fish needs considered:

- Turbidity
- Habitat heterogeneity (e.g., smooth sand or gravel bottoms versus fine gravel or coarse sand bottoms; islands; braided channels; deep water versus shallow water habitats; strong currents versus slow water areas)
- Spawning triggers, flows, and habitat (e.g., velocity, discharge, timing, and duration of flows)
- Rearing habitat / food sources (lower river discharge during the fall season following the critical spawning window would benefit fish species)
- Adult habitat
- Temperature needs
- Floodplain inundation

Mussels

Mussel needs considered:

- Gradual attenuation of high reservoir release rates over at least a one to two-week period (rapid attenuation can strand mussels on exposed sand and gravel bars)
- Minimum 5,000 cfs in summer and early fall

- Riparian areas and riverine wetlands
- Host fish for the glochidia stage of their reproductive cycle

6.2 Birds / Riparian and Floodplain Systems

Experts were asked to consider the hydrology requirements that are linked to rare sandbar nesting bird species (piping plover and least tern) that utilize the river during the nesting season and those linked to healthy riparian and floodplain systems.

Sandbar Nesting Birds

Bird Needs Considered:

- Nesting habitat creating flows (i.e., sandbars)
- Flows during nesting season (high flows will destroy nests)(above 8,000 cfs there are no sandbars)(mid-late April through July)
- Sandy beaches
- Open lake shores
- Sparsely vegetated sandbars
- Food availability

Riparian and Floodplain Systems

Riparian and Floodplain Systems Needs Considered:

- Nesting habitat creating flows (i.e., sandbars)

6.3 Assessment Tools

An important ecological consideration for each group was the occurrence of river overbank flows and flows high enough to develop favorable habitat conditions. During the workshop, the main method used for estimating overbank flow was use of gage data and aerial photography at different locations to examine areas where historic or current oxbows occur and backwater areas. HEC-RAS was used to estimate flows that would allow scouring of cobble substrate needed for fish spawning habitat and inundation of sandbars. Generally, the benchmark for sandbar inundation is approximately 8,000 cfs. This may vary depending on the reach of the river.

7.0 Summary of Regime Prescription Tool (RPT)

The USACE and TNC used RPT to help technical experts craft their e-flow prescriptions. RPT was developed by the USACE Institute for Water Resources Hydrologic Engineering Center and TNC to facilitate entry, viewing, and documentation of flow recommendations in real-time, public settings. The RPT seeks to improve 1) communications in group settings by allowing real-time recording and plotting of the recommendations as they are developed, and 2) the recommendations produced by making hydrologic information more immediately accessible to scientists, engineers, and water managers during the formulation process. RPT is a visualization tool and not intended to perform the quantitative analyses already performed by other software packages. Instead, RPT seeks to complement those packages by making it easier to create flow time series that other software can import and use in analyses.

The USACE and TNC displayed hydrographs of wet, dry, and average years in the RPT. A description of how water years were determined is in Appendix C. The software was then used to draw hydrographs on top of the data. RPT is primarily a visualization tool and is not intended to perform the detailed quantitative analyses (e.g., statistical analyses or reservoir and river routing) already performed by other software packages. Instead RPT seeks to complement other software by making it easier to create flow time series that other software packages can import and use in their analyses (USACE 2012).

8.0 Unification

8.1 Process

As previously stated, breakout groups created their flow prescriptions for fish and other aquatic species (Appendix D) and birds/riparian and floodplain systems (Appendix E) separately. The intent of the workshop was to develop a flow prescription that benefits the Kansas River ecosystem. During the second day of the workshop, the group reconvened to combine flow prescriptions.

Both groups completed Reach 2 flow prescriptions, so this was the starting reach for the unification process. During the workshop, the group was able to unify flow prescriptions for fish and other aquatic species and birds/riparian and floodplain systems developed during breakout groups for Reach 2 in a water year average during the workshop. There were some follow ups and research needs identified but the group came to consensus on the prescriptions for this reach. The group then agreed that prescriptions for the other Focus Reaches (Reach 1, 3, and 4) would largely mirror those of Reach 2.

When unifying Reach 2 the group came to the following agreements:

- Variability in the system is desired. Opportunistically varying the flow regime (wet, average, dry years) would more closely resemble the natural annual variation that occurred from annual differences in runoff amounts. The intent of operational adjustments, while designed for a particular group or species, are to benefit the entire ecosystem rather that a specific species group or species.
- The birds/riparian and floodplain group agreed that flow recommendations would be done every other year as the need for variability of when these occur is desired.
- Fish that are short lived with narrow spawning windows have the highest conflicts with other flow recommendations. The timing for these species is important.
- For mussels it is important to elongate a flow recession. 1-2-week attenuation of pulses is desired.
- The group agreed that there is some compatibility between flows in the spring for blue sucker spawning and flows that move sediments. The flows developed for the blue sucker and sediment movement could be combined.
- The higher peaks developed in the birds/riparian and floodplain group could be modified to include a slower recession.
- Focus on the first pulse in May for fish spawning.
- Monitoring plans should account for lag time for ecological and hydrogeomorphic responses and be long-term to identify trends.

The life stages and habitat needs of fish and other aquatic species and birds/riparian and floodplain systems were considered in crafting ecological operational windows during the unification process. The species selected are those that would allow measurement of a response to flow prescriptions (species that have low population numbers may not be a good candidate to measure response). The characteristics (i.e. season, events per season, magnitude, duration, duration of peak) of each flow component by water year are detailed in Appendix F.

While the number of pulses or magnitude of the pulses might differ between a wet year, average year, dry year, or reach of the river, the break-out teams stayed consistent on necessary hydrologic needs during certain parts of the year for fish and other aquatic species and birds/riparian and floodplain systems. These include:

Shoal Chub Spawning: Shoal chub represent a guild of pelagic spawning fish that have a short spawning period (May 20-July 15) and are a species of interest in the Great Plains. The range of discharge during spawning needed for the species under natural conditions is 7,607 – 23,139 cubic feet per second (cfs). Duration of flows at an appropriate peak would be a limiting factor for shoal chub spawning. The species is a good candidate to measure response to a flow prescription. Creating improved spawning conditions for the shoal chub would benefit other fish species with longer spawning periods that would spawn during a specific prescription window.

A unified flow prescription was developed in wet, average, and dry years to cue spawning for the shoal chub and other species with similar habitat needs. During an average year compared to a wet year the velocity of the flow prescription would be reduced (30,000 to 25,000 cfs) but maintained for a similar duration (7 days). During a dry year the magnitude and duration of the peak would be reduced compared to an average year (25,000 to 20,000 cfs; 7 to 5 days).

Blue Sucker and Other Fish Spawning: Blue sucker spawns on substrate and needs clean cobble for fertilized eggs to adhere. Higher flows would condition habitat prior to the spawning cue. Temperature rather than flow triggers the spawning cue for the blue sucker, but juveniles need the appropriate rearing conditions that come from higher flows that condition the habitat. Newly hatched fry also have flow requirements that influence refugia and food sources. Flows following the peak for conditioning the habitats that are attenuated for longer periods (1-2 months) maintain habitat for fish recruitment following the spawn and promote habitat/channel complexity to support multiple life stages. Blue sucker would be considered an umbrella species, therefore, creating suitable habitat conditions for the species would benefit other fish species with similar habitat needs and those with a longer spawning window (March 31 – July 20).

Fish spawning and larval growth is affected by many dimensions of stream flow, not just velocity and discharge, but also duration and timing of flows. The variety of spawning and habitat needs of the native fish of the Kansas River and its tributaries point to a need for a heterogeneous flow regime. Critical periods are those that contain the most overlap among species, plus ranges that contain state listed species. May 1 – June 30 has the highest overlap of spawning ranges. Most fish species found on the Kansas River spawn between May through June and two critical time periods occur in late May and during June for state-listed species. The flows from May 1 – June 30, when the majority of fish species spawn, ranges from a minimum to maximum discharge of 7,163 – 29,009 cfs for natural flows and from 7,680 – 13,450 cfs for modified flows. The breakout groups discussed that more variation in flows may enhance spawning success.

A unified flow prescription was developed in wet, average, and dry years to cue spawning for the blue sucker and other species with similar spawning habitat needs. The blue sucker spawning window is relatively long and would capture the spawning windows of other fish species.

A series of higher flows (5 events ranging from 12,000-19,000 cfs during the peaks) was developed during a wet year within the spawning window for the majority of fish species (May 1 – June 30) to provide more variation in flows to enhance spawning success. A series of peaks were not defined for an average or dry year, but peaks could occur opportunistically that would occur during important spawning windows and benefit the majority of fish species.

Habitat Creation: Spawning and larval growth is not just affected by stream flows but also how flow shapes the channel and alters substrate. Spawning substrate is important and can vary within species depending on other habitat conditions. Higher flows in some years prior to the spawning cue for the majority of species (May 1 – June 30) (see Figure D-1) would condition habitat by scouring and providing sediment transport and redeposition creating suitable areas for spawning, rearing, and foraging. These flows should be sustained for approximately 30 days.

A unified flow prescription was developed in wet years that includes habitat forming flows (20,000 – 40,000 cfs) to create suitable habitat for fish spawning and rearing. This flow prescription would also benefit mussel species by creating suitable habitat (e.g., shorelines and sand and gravel bars).

Energy Input: The Kansas River has generally experienced a decrease in the frequency and magnitude of flow pulses. Incorporating a series of scouring pulses would discourage recruitment of perennial vegetation on sandbars and improve habitat. Flow pulses help to pull allochthonous materials (organic debris, plants, animal waste, etc.) into the river system to provide carbon and nutrients for the system. Periodic pulses could increase the interface between the aquatic and terrestrial environments (side channels, oxbows, floodplains), and provide more variability in habitats. The moisture will also encourage cottonwood recruitment in riparian areas. However, high flow pulses (above 8000-13,000 cfs where sandbars are inundated) could be detrimental to sandbar-nesting birds and turtles during the nesting period. It is advantageous to these species to reduce these peaks and durations as much as possible during nesting season. Flows above 8,000 cfs during March and April in dry years generally would not be possible. During average and wet years, at least one large (>13,000 cfs) pulse would be advantageous to habitat and as a cue to fish spawning but should be done prior to the arrival of male birds around April 1. Female birds arrive a week or so later and nest for 60 days. If a pulse does need to occur during this window, it would be preferable in early April rather than mid-June.

A unified prescription for wet, average, and dry years includes a series of pulses to help pull in allochthonous material into the river system to serve as energy for the system. Timing and duration of these peaks should be considered to avoid negative effects to sandbar nesting birds or turtles during this period. The timing of the initial pulse should be early enough to cue spawning for fish species but prior to arrival of sandbar nesting male bird species. A late season pulse (July) may provide opportunity for short-term rearing habitat for young-of-year fish.

Fall Pulses: Fall pulses with troughs in between would increase waterfowl habitat and other species by facilitating connectivity of oxbows. These pulses can be of short duration and flashy, and timing is flexible. Timing could be opportunistic and in response to an inflow event into a reservoir ("run of the river" operation). At least one fall pulse would be could benefit rearing habitat for young-of-year fish, but there may be opportunity for more pulses in wet years. The trough periods between flashy pulses area emphasized, so flows should quickly return to base level. 20,000 cfs would likely inundate the oxbows. Smaller oxbows and side channels in the reach could be inundated with lower flows. Pulses should be variable to encourage variable effects to the system. Use prevailing hydrographs as a guide to determine magnitudes in regard to differing peak flows.

A unified prescription for wet, average, and dry years includes fall pulses that are flashy in nature quickly returning to troughs in between to increase habitat of waterfowl and other species and facilitate connectivity of oxbows. The duration of flows may be short (e.g., five days) and having at least one pulse could benefit young-of-year fish. The timing would be more opportunistic and occur only if water was available. Approximately 20,000 cfs would likely inundate the oxbows. Smaller oxbows in the reach could be inundated with slightly less flow. Pulses should be variable (e.g., 15,000-30,000 cfs) to encourage variable effects to the system. Existing hydrographs should be used as a guide to determine magnitudes of differing peak flows. The group recognized that potential dislodging of mussels could be a concern, particularly when temperatures are high. Flows that provide mussel transition flows, especially for early season, higher temperature pulses should also be considered under a separate prescription.

Mussel Flow Needs: Rapid attenuation of flows in late summer can leave mussels stranded, cause heat stress, and increase predation of mussels. High flows should be followed by a slow tapering decline. A flow prescription may not be needed but instead consideration of rules or guidelines to bring flows down more slowly to prevent adverse effects. The preferred considerations should include a decline of one foot in reservoir elevation over a 5-day period with flows kept above 5,000 cfs in late summer.

It was decided during the unification that the flows in the fall during average years were suitable related to the need for a slower decline to prevent stranding of mussels. The unified flow prescription for mussels in average years allows for a slow decline of high flows that are proposed for sandbar reorganization in the spring. During an average year the flow prescription would include a gradual decline of flows with no more than a one-foot decline in reservoir elevation over a 5-day period. Mussel flow needs were not included in wet and dry years.

Sandbar Exposure: While early spring scouring flows are advantageous to clear sandbar habitat, summer exposure of sandbars is useful for turtle and bird nesting. Ideally, sandbars would be exposed for up to 60 days through May and June to allow for arrival, nesting, and hatching. In the case of pulses for sandbar exposure, it is desired to return to low flows as soon as possible. The most important aspect of these recommendations is to restore more variability in timing and magnitude of pulse flows. In the instance of a manageable pulse inflow, it could be beneficial to hold back these flows for the purpose of keeping a ~60-day period needed for birds nesting, hatching, etc., or attenuate the flow enough to remain within the sandbar exposure range. However, there was some concern about being overly prescriptive (for example, in an uncontrolled natural system, there will occasionally be summer events that wash away nests). Therefore, it may be most advantageous to allow flows through the dams that mimic the inputs ("run of the river" operation) when possible.

The unified prescription for wet, average, and dry years includes flows held low enough (4,000-8,000 cfs) to avoid inundation of sandbars and provide habitat for sandbar nesting birds species (i.e., piping plover) and nesting turtles.

Sandbar Reorganization: As stated above, there is generally a need for more frequent pulses of varying duration to alternately inundate and expose sandbars. More variable pulses throughout the year will destabilize and reorganize sandbars. Another purpose is the removal of woody vegetation, which discourages use of the sandbar by certain species of birds. The season is flexible and could be done in the winter period. One week of inundation would be sufficient to remove vegetation and bring allochthonous energy sources into the system. In dry years, an instance of sandbar reorganization isn't necessarily expected but if the opportunity is there it could be beneficial.

The unified flow prescription includes flows high enough during wet, average, and dry years to reorganize and scour sandbars and remove woody vegetation to provide habitat for sandbar nesting bird species (i.e., piping plover) and nesting turtles. These flows could occur approximately every 5 years or timed during a wet year and include a series of higher flows. Wet years include a series of flow peaks from February through July with higher magnitudes (i.e. up to 60,000 cfs) compared to an average year (i.e. 20,000 cfs). An average year only prescribes one peak done opportunistically from March to August. During a dry year reorganization of sandbars isn't necessarily expected but if opportunity arises it could be beneficial.

Nutrient Cycling: Along the theme of reintroducing variability into the system, it was recommended that a series of approximately monthly small pulses (within the range of 1000-5000 cfs) would mimic natural rises for the purpose of nutrient cycling and benthic organisms. Timing would be flexible, so these could mimic inflows into the dam ("run of the river" operation). In the summer season or times of extreme low-flow, these small pulses would help flush the system and improve dissolved oxygen concentrations.

During dry years a set of nutrient cycling prescriptions was developed that includes a series of monthly small pulses used to mimic natural rises for the purpose of nutrient cycling and benthic production. One would occur spring through summer (i.e. April to July) and one would occur during the winter months (i.e. November, January, February). The timing of these peaks is not strict but could follow reservoir inflows and what would be a natural pulse if water was to pass through a dam. The prescription includes four events per season ranging from 500 to 3,500 cfs for a duration of 3 days with a peak for one day during the event.

Table 5 lists the prescriptions developed for all water year types in Reach 2 with the dates and cfs columns listing the full range of the water prescriptions. Appendix F includes more exact date ranges and cfs for particular water year types for this reach.

Table 5. Unified Reach 2 Flow Prescriptions

Flow Prescriptions	Dates	CFS	Details, Purpose, and Benefits
Shoal Chub Spawning	1 MAY – 1 JUL	7 – 30 K	• Cue spawning for shoal chub • Benefits to other species • Surrogate candidate to measure response
Blue Sucker and Other Fish Spawning	20 MAR – 21 JUL	3 – 40 K	• Umbrella species • Creation of spawning habitat (clean cobbles) • Spawning cue • Attenuate flows needed to maintain recruitment habitat • Promotes habitat/channel complexity • Heterogeneous flow regime • Enhancement of spawning success
Habitat Creation	1 MAR – 1 APR	20 – 40 K	• Higher flows to create scouring • Fish spawning and rearing habitat • Mussel habitat
Energy Input	20 MAR – 1 AUG	10 – 20 K	• Series of pulses to discourage recruitment of perennial vegetation on bird nesting habitat • Pulls in allochthonous material and nutrients • Late season pulse (July) also provides short-term rearing habitat for young-of-year fish
Fall Pulses	1 SEP – 30 OCT	15 – 30 K	• Increase production of waterfowl habitat • Inundate oxbows and backwaters
Mussel Flow Needs	5 MAR – 23 APR	4 – 11 K	• High flows followed by a slow tapering decline • Reduces stranding and mortality
Sandbar Exposure	1 APR – 1 AUG	4 – 8 K	• Habitat for turtle and bird nesting • Reduces chance of bird nest failure

Flow Prescriptions	Dates	CFS	Details, Purpose, and Benefits
Sandbar Reorganization	1 FEB – 1 AUG	10 – 60 K	• Reorganization of materials to create and maintain habitat • Removal of woody vegetation
Nutrient Cycling - Benthic	1 APR – 01 AUG	0.5 – 3.5 K	• Mimics natural rises for the purpose of nutrient cycling and benthic success
Nutrient Cycling – Benthic Winter	1 NOV – 1 MAR	0.5 – 3.5 K	• Mimics natural rises for the purpose of nutrient cycling and benthic success

9.0 Next Steps in the SRP Process

The Kansas River SRP team successfully hosted a technical stakeholder e-flows workshop in September of 2020 and produced flow prescriptions for the river. Further work is dependent on funding and the Kansas River is currently under consideration for SRP funds for 2021. Depending on funding and workload availability of partners, the team plans to pursue the following next steps:

- Initiate discussions to implement prescribed flow pulses for ecological benefits to native aquatics and birds that fall within USACE current operational flexibility.
- Coordinate with water managers and stakeholder to develop an Implementation / Monitoring Plan.
- TNC and the USACE will update stakeholders as implementation and monitoring plans are finalized.

10.0 Literature Cited

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Appendix A: Agenda

Kansas River SRP
Environmental Flows Workshop

September 1 - 2, 2020

Webex Meeting

https://usace.webex.com/meet/laura.totten

888-363-4735

Meeting Number: 146 277 3189

Access Code: 840 491 1

Meeting Password: 1234

AGENDA

September 1, 2020

10:00 Welcome and Introductions – U.S. Army Corps of Engineers and The Nature Conservancy

10:15 Review of SRP Process, Kansas River SRP, and Discussion of Meeting Outcomes – Laura Totten, U.S. Army Corps of Engineers; Heidi Mehl, The Nature Conservancy

10:30 Overview, Questions and Answers, and Discussion of Kansas River System

- Existing Operating Rules at USACE Reservoirs – Paul Simon
    - Design considerations underlying existing operating prescriptions and current operating constraints
    - Water level management plans

11:00 Ecological Report Summary

- Hydrologic Analysis and Flow/Ecology Relationships – Background for Developing Environmental Flow Recommendations – Deb Baker, KBS
- Group Discussion – Clarification of science resources and workshop process

11:45 Breakout Groups Charge – Laura Totten, U.S. Army Corps of Engineers

12:00 Regime Prescription Tool – John Hickey, U.S. Army Corps of Engineers

Focus Reaches

Reach 1 – Milford Reservoir to Fort Riley Gage

Reach 2 – Fort Riley Gage to Wamego Gage

Reach 3 – Perry Reservoir to Lecompton Gage

Reach 4 – Clinton Reservoir to Desoto Gage

12:15 Lunch Break

1:00 Breakout Groups (2 breakout groups running concurrently, each looking at a different focus topic)

Breakout Group 1 – Fish and Other Aquatic Species

Facilitator: Laura Totten
RPT Staff: Paul Simon
Notetaker: Julie MacLachlan

Webex Meeting
https://usace.webex.com/meet/laura.totten
888-363-4735
Meeting Number: 146 277 3189
Access Code: 840 491 1
Meeting Password: 1234

Breakout Group 2 – Birds/Riparian and Floodplain Systems

Facilitator: Heidi Mehl
RPT Staff: Connor Szarwinski
Notetaker: Matt Rea

Webex Meeting
https://usace.webex.com/meet/john.hickey
877-336-1274
Access Code: 1423089
Meeting Password: 1111

- Breakout groups will:
  - Clarify hypotheses regarding flow-related issues and potential flow changes enhancements that could be made, or where the greatest opportunity is to enhance benefits via pool-level or flow manipulations related to the selected habitats, target species, or riverine processes.
  - Develop environmental flow hypotheses based on specific Environmental Flow Components (low flows, flood pulses, small floods, and large floods), understanding the existing flow prescriptions, and how existing flows could be modified.
  - Groups should think about the location, timing, magnitude, duration, and rate of change of flow for the Environmental Flow Components.
  - The discussion will consider a range of species, communities, and ecological processes.
- Groups will also identify significant knowledge and information gaps and potential monitoring elements.

4:00 Adjourn

September 2, 2020

9:00 Breakout Groups continued

Breakout Group 1 – Fish and Other Aquatic Species

Facilitator: Laura Totten
RPT Staff: Paul Simon
Notetaker: Julie MacLachlan

Webex Meeting
https://usace.webex.com/meet/laura.totten
888-363-4735
Meeting Number: 146 277 3189
Access Code: 840 491 1
Meeting Password: 1234

Breakout Group 2 – Birds/Riparian and Floodplain Systems

Facilitator: Heidi Mehl
RPT Staff: Connor Szarwinski
Notetaker: Matt Rea

Webex Meeting
https://usace.webex.com/meet/john.hickey
877-336-1274
Access Code: 1423089
Meeting Password: 1111

12:00 Lunch Break

1:00 Presentations by Breakout Groups

- Discussion of flow recommendations for each breakout group (20 minutes each)

1:40 Integration of flow recommendations from Breakout Groups into a single unified set of flow recommendations

3:20 Summary of Results and Discussion of Next Steps

4:00 Adjourn

Appendix B: Participant List

Name	Affiliation	Break Out Group
Jared Schmalstieg	U.S. Environmental Protection Agency, Region 7	Fish and Other Aquatic Species
Gretchen Benjamin	The Nature Conservancy	Fish and Other Aquatic Species
Martha Mather	Kansas State University	Fish and Other Aquatic Species
Keith Gido	Kansas State University	Fish and Other Aquatic Species
Jordan Hofmeier	Kansas Department of Wildlife, Parks and Tourism	Fish and Other Aquatic Species
Tom Stiles	Kansas Department of Health and Environment	Fish and Other Aquatic Species
Craig Thompson	U.S. Environmental Protection Agency, Region 7	Fish and Other Aquatic Species
Don George	Kansas Department of Wildlife, Parks and Tourism	Fish and Other Aquatic Species
Olivia Rode	Graduate Student	Fish and Other Aquatic Species
Steve Adams	Kansas Department of Wildlife, Parks and Tourism	Fish and Other Aquatic Species
Elizabeth Smith	Kansas Department of Health and Environment	Fish and Other Aquatic Species
Jessica Mounts	Kansas Alliance for Wetlands and Streams	Fish and Other Aquatic Species
Mark VanScoyoc	Kansas Department of Wildlife, Parks and Tourism	Fish and Other Aquatic Species
Caitlyn Aymami	Kansas State University	Fish and Other Aquatic Species
Kirk Tjelmeland	Kansas Water Office	Fish and Other Aquatic Species
Nate Westrup	Kansas Water Office	Fish and Other Aquatic Species
Lucas Kowalewski	Kansas Department of Wildlife, Parks and Tourism	Fish and Other Aquatic Species
Wes Fleming	Evergy	Fish and Other Aquatic Species
Tony Stahl	Kansas Department of Wildlife, Parks and Tourism	Fish and Other Aquatic Species

Name	Affiliation	Break Out Group
Marvin Boyer	U.S. Army Corps of Engineers	Fish and Other Aquatic Species
John Shelley	U.S. Army Corps of Engineers	Fish and Other Aquatic Species
Richard Rockel	Kansas Water Office	Fish and Other Aquatic Species
Justina Gonzales		Fish and Other Aquatic Species
Dawn Buehler	Friends of the Kaw	Birds/Riparian and Floodplain Systems
Michelle Probasco	Kansas Department of Health and Environment	Birds/Riparian and Floodplain Systems
Steve Schaff	U.S. Environmental Protection Agency, Region 7	Birds/Riparian and Floodplain Systems
Jason Daniels	U.S. Environmental Protection Agency, Region 7	Birds/Riparian and Floodplain Systems
Bob Atchison	Kansas Forest Service	Birds/Riparian and Floodplain Systems
Erin Seybold	Kansas Geological Survey/Kansas University	Birds/Riparian and Floodplain Systems
Sam Zipper	Kansas Geological Survey	Birds/Riparian and Floodplain Systems
Aaron Deters	Kansas Department of Wildlife, Parks and Tourism	Birds/Riparian and Floodplain Systems
Josh Olson	Kansas Water Office	Birds/Riparian and Floodplain Systems
Deb Baker	Kansas Biological Survey	Birds/Riparian and Floodplain Systems
Brian Kelly	U.S. Geological Survey	Birds/Riparian and Floodplain Systems
Chelsea Paxson	Kansas Department of Health and Environment	Birds/Riparian and Floodplain Systems
Gary Koons	Kansas Water Office	Birds/Riparian and Floodplain Systems

Name	**Affiliation**	**Break Out Group**
Amy Shields	U.S. Environmental Protection Agency, Region 7	Birds/Riparian and Floodplain Systems
Don Huggins	Kansas Biological Survey	Birds/Riparian and Floodplain Systems
John Hickey	U.S. Army Corps of Engineers	Birds/Riparian and Floodplain Systems
Matt Rea	U.S. Army Corps of Engineers	Birds/Riparian and Floodplain Systems
Rob Penner	The Nature Conservancy	Birds/Riparian and Floodplain Systems
Jeff Conley	Kansas Department of Wildlife, Parks and Tourism	Birds/Riparian and Floodplain Systems
Todd Gemeinhardt	U.S. Army Corps of Engineers	Birds/Riparian and Floodplain Systems

Appendix C: Water Year Type Determination Explanation and Low Flows

Water Year Determination and Explanation

The workshop objective was to develop flow recommendations by evaluating how reservoir management affects flows under a variety of conditions. To aid in visualizations with RPT software for group discussions, water years were defined by name and year as Wet, Average, and Dry years, over the period of record within the Kansas River watershed.

The period of record used was 1984 – 2020. Each year in the period of record is assigned to a state. For each temporal period year types were assigned as follows:

- Wettest 25% for year based on period of record average -->'Wet' (W)
- Driest 25% for year based on period of record average --> 'Dry' (D)
- All other years (middle 50% for year based on period of record average) --> 'Average' (A)

For the 37 years of data considered, 12 years (1984-1987, 1993-1996, 1998-1999, 2008, 2019) were assigned as 'Wet', 11 years (1989, 1991, 2002-2006, 2012-2014, 2018) were assigned as 'Dry', and 14 years (1988, 1990, 1992, 1997, 2000-2001, 2007, 2009-2011, 2015-2017, 2020) were assigned as 'Average'. Flow recommendations are plotted within the period of record assigned to each state.

Low Flows

Fish and Other Aquatic Species

Low flows (or essentially baseflows) are assigned to each day of the water year for each state (i.e., wet, dry, average) in each system (e.g., shoal chub spawning, energy inputs). Low flows assigned for each state were assigned as follows:

Wet Years: 01 Oct – 3,000 cfs, 01 Mar – 3,000 cfs, 01 Apr – 4,000 cfs, 01 May – 8,000 cfs, 15 May – 8,000 cfs, 01 Jun – 8,000 cfs, 01 Jul – 5,000, 01 Aug – 4,000 cfs, 30 Sep – 3,000 cfs

Dry Years: 01 Oct – 2,000 cfs, 01 Mar – 2,000 cfs, 01 Apr – 2,500 cfs, 01 May – 3,000 cfs, 15 May – 3,500 cfs, 01 Jun – 4,000 cfs, 01 Jul – 2,500 cfs, 01 Aug – 2,000 cfs, 30 Sep – 2,000 cfs

Average Years: 01 Oct – 3,000 cfs, 15 Dec – 2,000 cfs, 01 Mar – 3,000 cfs, 01 Apr – 4,000, 01 May – 8,000 cfs, 15 May – 8,000 cfs, 01 Jun – 6,000 cfs, 01 Jul – 5,000 cfs, 01 Aug – 3,000 cfs, 15 Aug – 4,000 cfs, 15 Sep – 4,000 cfs, 30 Sep – 3,000 cfs

Birds / Riparian and Floodplain Systems

Low flows (or essentially baseflows) are assigned to each day of the water year for each state (i.e., wet, dry, average) in each system (e.g., shoal chub spawning, energy inputs). Low flows assigned for each state were assigned as follows:

Wet Years: 01 Apr – 6,000 cfs, 01 Dec – 3,500 cfs, 01 Mar – 6,000 cfs

Dry Years: 01 Apr – 750 cfs, 01 Nov – 600 cfs, 01 Mar – 750 cfs

Average Years: 01 Apr – 3,500 cfs, 01 Nov – 1,500 cfs, 01 Mar – 3,500 cfs

Appendix D: Fish and Other Aquatic Species Break-out Group Findings

Fish and Other Aquatic Species Break-out Group Findings

Details for the Fish and Other Aquatic Species break-out group findings include:

- Process
- General prescription goals for each year
- Flow prescriptions for fish and other aquatic species for Reach 2
- Research and modeling needs from the fish and other aquatic species group

The fish and other aquatic species group was tasked to create flow recommendations for the suite of fish and other aquatic species that are known to occur on the Kansas River. Flow recommendations included spawning cues, migration needs, access to back floodplains, flow needs for shaping appropriate spawning substrates, temperature needs, attenuation of the hydrograph, and the flow levels that support good water quality. The group convened and decided that flow prescriptions would consider fish species with a more restricted (e.g., shorter) spawning period, fish that would represent the needs required for a number of fish species (i.e., umbrella species), and broadly consider mussels and the recommendations related to flows included in the ecological report. It was acknowledged that additional consultation should occur with fish and mussel expert's post-workshop.

Process

The group was tasked with starting their flow prescription for Reach 2 on the Kansas River, from the Big Blue River confluence to Willard, Kansas. Collectively, the group decided to start with an average year.

At the end of the group break-out time, the fish and other aquatic species team collectively finished Reach 2 average and began wet and dry years. The prescriptions for Reach 2 should be sufficient for Reach 1 (Kansas River below Milford Reservoir to Big Blue River confluence), Reach 3 (Kansas River from the Delaware River confluence to Lawrence, Kansas), and Reach 4 (Kansas River from the Wakarusa River confluence to Bonner Springs, Kansas).

General Prescription Goals for Each Year

The life stages and habitat needs of fish and mussels were considered in crafting ecological operational windows. The species selected are those that would allow measurement of a response to flow prescriptions (species that have low population numbers may not be a good candidate to measure response). While the number of pulses or magnitude of the pulses might differ between a wet year, average year, dry year, or reach of the river, the break-out team stayed consistent on necessary hydrologic needs during certain parts of the year for fish or mussel needs. These include:

Shoal Chub Spawning: Shoal chub represent a guild of pelagic spawning fish that have a short spawning period (May 20-July 15) and are highly endangered in the Great Plains (Baker et al. 2021). The range of discharge during spawning needed for the species under natural conditions is 7,607 – 23,139 cubic feet per second (cfs) (Baker et al. 2021). Duration of flows at an appropriate peak would be a limiting factor for shoal chub spawning. Although the Shoal Chub is state-listed as threatened, recent survey efforts in the Kansas River have documented greater populations numbers than anticipated. The species is a good candidate to measure response to a flow prescription. Creating improved spawning conditions for the shoal chub would benefit other fish species with longer spawning periods that would spawn during a specific prescription window.

Mussel Flow Needs: Rapid attenuation of flows in late summer can leave mussels stranded, cause heat stress, and increase predation of mussels. High flows should be followed by a slow tapering decline (Cringan et al. 2020). A flow prescription may not be needed but instead consideration of rules or guidelines to bring flows down more slowly to prevent adverse effects. The preferred considerations should include a decline of one foot in reservoir elevation over a 5-day period with flows kept above 5,000 cfs in late summer.

Blue Sucker Habitat: Blue sucker spawns on substrate and needs clean cobble for fertilized eggs to adhere. Higher flows would condition habitat prior to the spawning cue. Temperature rather than flow triggers the spawning cue for the blue sucker, but juveniles need the appropriate rearing conditions that come from higher flows that condition the habitat. Newly hatched fry also have flow requirements that influence refugia and food sources. Flows following the peak for conditioning the habitats that are attenuated for longer periods (1-2 months) maintain habitat for fish recruitment following the spawn and promote habitat/channel complexity to support multiple life stages. Blue sucker would be considered an umbrella species, therefore, creating suitable habitat conditions for the species would benefit other fish species with similar habitat needs and those with a longer spawning window (March 31 – July 20) (Baker et al. 2021).

Habitat Creation: Spawning and larval growth is not just affected by stream flows but also how flow shapes the channel and alters substrate. Spawning substrate is important and can vary within species depending on other habitat conditions. Higher flows in some years prior to the spawning cue for the majority of species (May 1 – June 30) (see Figure D-1) (Baker et al. 2021) would condition habitat by scouring and providing sediment transport and redeposition creating suitable areas for spawning, rearing, and foraging. These flows should be sustained for approximately 30 days.

Fish Spawning: Spawning and larval growth is affected by many dimensions of stream flow, not just velocity and discharge, but also duration and timing of flows. The variety of spawning and habitat needs of the native fish of the Kansas River and its tributaries point to a need for a heterogeneous flow regime. However, changes in fish assemblages and increase in non-native species point to a homogenization of habitat and flow, corresponding with modification of the river by reservoirs. This can be seen on hydrographs comparing pre- and post-impoundment flows. Critical periods are those that contain the most overlap among species, plus ranges that contain state listed species. May 1 – June 30 has the highest overlap of spawning ranges, with 33 - 35 of 46 species of fish spawning during this time (see Figure D-1). Within that window, are 3 peaks including 34 or more species. Most fish species found on the Kansas River spawn between May through June and two critical time periods occur in late May and during June for state-listed species. The flows from May 1 – June 30, when the majority of fish species spawn, ranges from a minimum to maximum discharge of 7,163 – 29,009 cfs for natural flows and from 7,680 – 13,450 cfs for modified flows. (Baker et al. 2021) The breakout group discussed that more variation in flows may enhance spawning success.

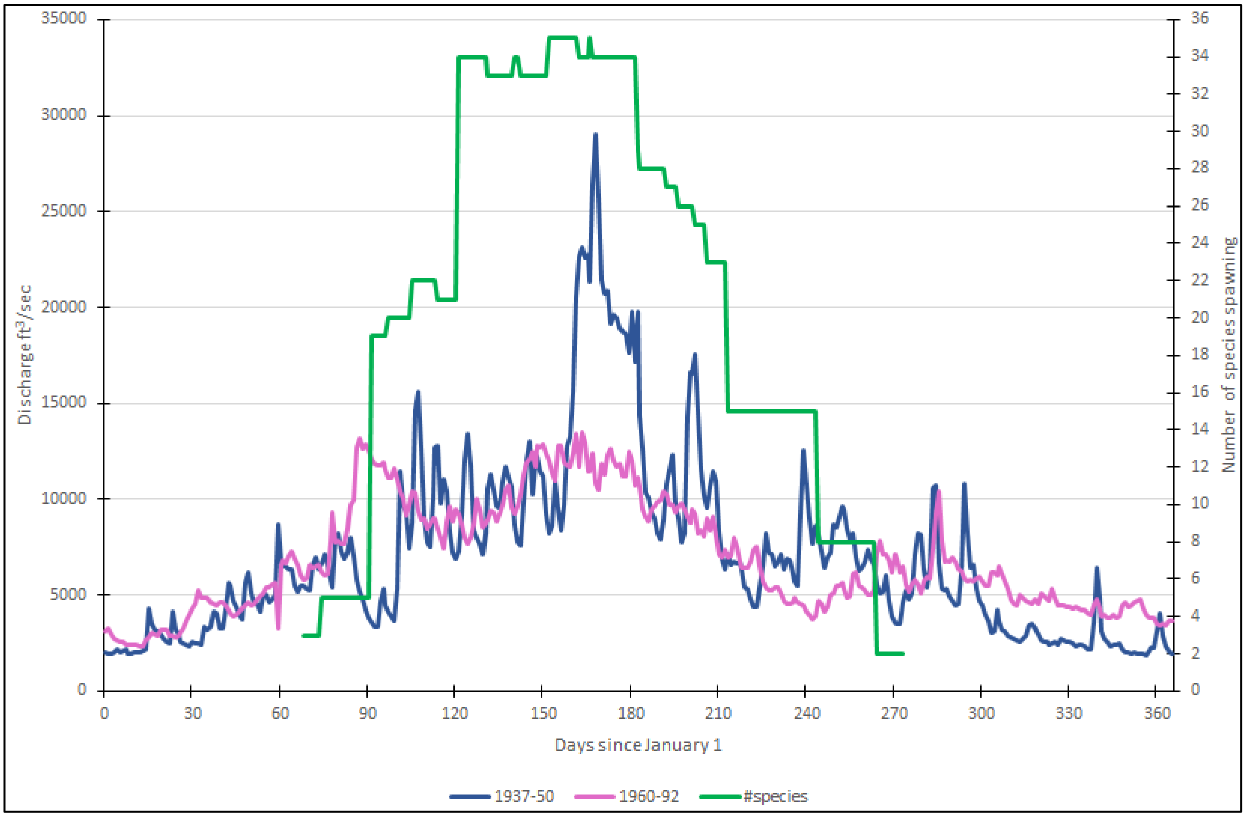


Figure D - 1. Number of Fish Species Spawning on the Kansas River

Source: Huggins and Liechti unpublished using USGS 2019

Flow Prescriptions for Fish and Other Aquatic Species

Fish and Other Aquatic Species, Reach 2, Wet

The fish and other aquatic species team started Reach 2 Wet during the workshop. Experts were consulted after the workshop to refine details of the prescription. The Reach 2 average year was the starting point for the Reach 2, wet year prescription and magnitudes and durations were changed as needed. Environmental flow recommendations for Fish and Other Aquatic Species Reach 2 Wet are shown in Figure D-2. Characteristics of each flow component are detailed below.

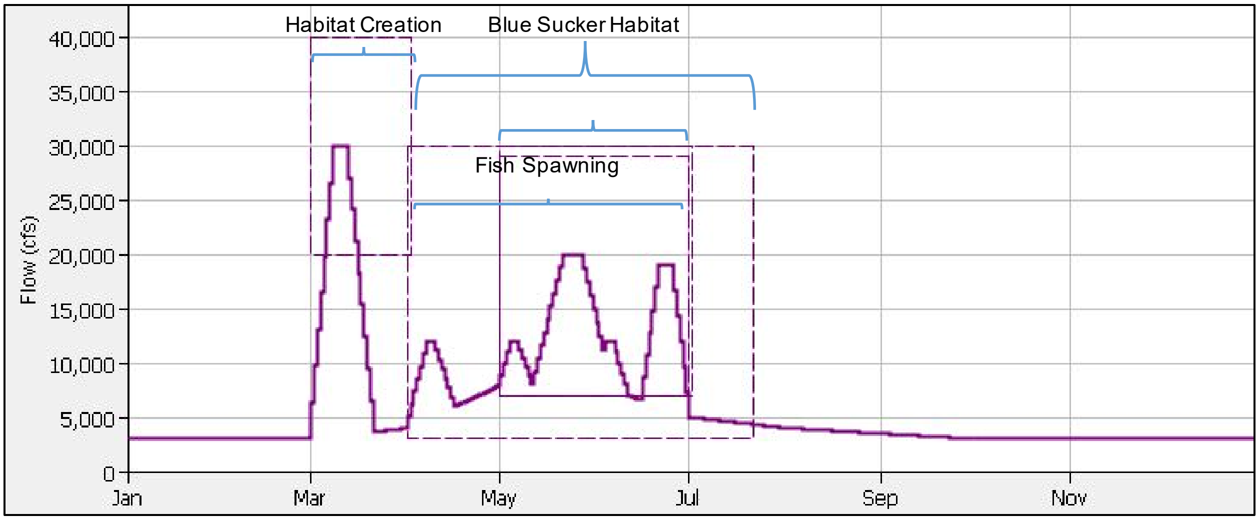


Figure D - 2. Flow Prescription for Fish and Other Aquatic Species, Reach 2, Wet

Shoal Chub Spawning (Fish and Other Aquatic Species, Reach 2, Wet, Table D-1)

Season: 01 May to 01 July
Events per season: 1
Magnitude: 7,000 – 30,000 cfs, most peaks in the 20,000 cfs range
Duration: 25 days with a slow fall
Duration of peak: 7 days

Table D - 1. Shoal Chub Spawning Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
May 12	25	20,000	7

Purpose: Flows to help cue spawning.

Description: A flow prescription was developed in wet years to cue spawning for the shoal chub and other species with similar habitat needs. During a wet year the flow prescription would start at 7,000 cfs on May 1 with an increase starting May 12, for a duration of 25 days, and held at a peak of 20,000 cfs for 7 days. Following the 7-day peak of 20,000 cfs flows would begin to decrease back to 7,000 cfs by early June. The pulse would be brought down slowly to support larval growth. The shoal chub was selected as a surrogate candidate to measure response to a flow prescription. Creating improved spawning conditions for the shoal chub would benefit other fish species with longer spawning periods that would occur during a specific prescription window. The group recognized that there is uncertainty around duration and magnitude needed to create successful spawning conditions for the shoal chub. An adaptive management and monitoring approach should be used to test and address the species needs to meet objectives.

Habitat Creation (Fish and Other Aquatic Species, Reach 2, Wet, Table D-2)

Season: 01 March to 01 April
Events per season: 1
Magnitude: 20,000 – 40,000 cfs; most peaks in the 30,000 cfs range
Duration: 20 days
Duration of peak: 5

Table D - 2. Habitat Creation Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
March 1	20	30,000	5

Purpose: During wet years higher flows would create scouring that creates suitable habitat for fish spawning and rearing and could also create habitat for mussels.

Description: A flow prescription was developed in wet years to create suitable habitat for fish spawning and rearing (e.g., clean cobbles, channel sandbars, shallow water areas). Habitat forming flows would be high enough (20,000-40,000 cfs) to destabilize and reorganize bed materials or scour fines. This flow prescription would also benefit mussel species by creating suitable habitat. The higher flow (20,000 – 40,000 cfs) would be released prior to the start of the main spawning window (May 1) for the majority of species (see Figure D-1) and held for a duration of 30 days.

Blue Sucker Habitat (Fish and Other Aquatic Species, Reach 2, Wet, Table D-3)

Season: 01 April to 21 July
Events per season: 1
Magnitude: 3,000 – 30,000 cfs, most peaks in the 12,000 cfs range
Duration: 15 days
Duration of peak: 3 days

Table D - 3. Blue Sucker Habitat Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
April 1	15	12,000	3

Purpose: Flows to help create spawning habitat and cue spawning.

Description: Higher flows prior to the spawning cue were developed to condition habitat. During a wet year the flow prescription would start April 1 at 3,000 cfs with an increase in flows starting immediately for a duration of 15 days and held at a peak of 12,000 cfs for 3 days. Following the 3-day peak of 12,000 cfs flows would begin to decrease and be attenuated for a longer period to maintain habitat for fish recruitment until approximately July 21.

Fish Spawning (Fish and Other Aquatic Species, Reach 2, Wet, Table D-4)

Season: 1 April – 30 June
Events per season: 1
Magnitude: 7,000 – 29,000 cfs; most peaks in the 12,000 cfs range
Duration: 10 days with a quick rise and fall
Duration of peak: 3

Table D - 4. Fish Spawning Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
May 1	10	12,000	3

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
May 20	10	12,000	3
June 1	10	12,000	3
June 16	15	19,000	3

Purpose: Flows to cue spawning for a broad suite of species.

Description: A series of higher flows were developed within the spawning window for the majority of fish species (May 1 – June 30) (see Figure D-1) to provide more variation in flows to enhance spawning success. This prescription would only occur during a wet year. During a wet year the flow prescription would start May 1 at 7,000 cfs with increased in flows for 10-15 days and peaks of 12,000 cfs occurring for a duration of 3 days. These would occur periodically from May 1 to June 30.

Fish and Other Aquatic Species, Reach 2, Average

The Fish and Other Aquatic Species team finished Reach 2 Average during the workshop. Experts were consulted after the workshop to refine details of the prescription. Environmental flow recommendations for Fish and Other Aquatic Species Reach 2 Average are shown in Figure D-3. Characteristics of each flow component are detailed below.

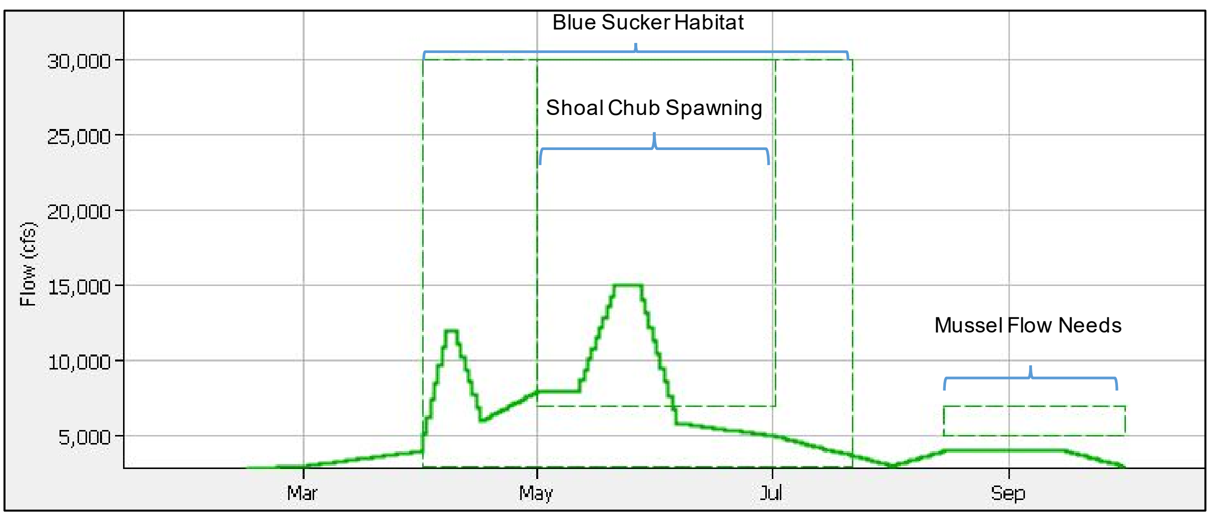


Figure D - 3. Flow Prescription for Fish, Reach 2, Average

Shoal Chub Spawning (Fish and Other Aquatic Species, Reach 2, Average, Table D-5)

Season: 01 May to 01 July
Events per season: 1
Magnitude: 7,000 – 30,000 cfs, most peaks in the 15,000 cfs range
Duration: 25 days with a slow fall
Duration of peak: 7 days

Table D - 5. Shoal Chub Spawning Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
May 12	25	15,000	7

Purpose: Flows to help cue spawning.

Description: A flow prescription was developed in average years to cue spawning for the shoal chub and other species with similar habitat needs. During an average year compared to a wet year the velocity of the flow prescription would be reduced but maintained for a similar duration. During an average year the flow prescription would start at 7,000 cfs May 1 with an increase starting May 12 for a duration of 25 days and held at a peak of 15,000 cfs for 7 days. Following the 7-day peak of 15,000 cfs flows would begin to decrease back to 7,000 cfs by early June.

Mussel Flow Needs (Fish and Other Aquatic Species, Reach 2, Average, Table D-6)

Season: Mid-August to late-September
Events per season: 1
Magnitude: 10,000 – 5,000 cfs; Gradual decline (5 days per foot in reservoir) kept above 5,000 cfs until late September
Duration: N/A
Duration of peak: N/A

Table D - 6. Mussel Flow Needs Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
August 15	45	N/A	N/A

Purpose: Gradual decline in flows late summer to prevent harm to mussel community.

Description: A flow prescription was developed in average years to allow for a slow decline of high flows mid-August to late-September. During an average year the flow prescription would include a gradual decline of flows with no more than a one-foot decline in reservoir elevation over a 5-day period. Flows would also be kept above 5,000 cfs for a 24-day period during this slow decline to avoid adverse effects to mussels.

Blue Sucker Habitat (Fish and Other Aquatic Species, Reach 2, Average, Table D-7)

Season: 01 April to 21 July
Events per season: 1
Magnitude: 3,000 – 30,000 cfs, most peaks in the 12,000 cfs range
Duration: 15 days
Duration of peak: 3 days

Table D - 7. Blue Sucker Habitat Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
April 1	15	12,000	3

Purpose: Flows to help condition spawning habitat and cue spawning.

Description: Higher flows prior to the spawning cue were developed to condition habitat (e.g., cobbles). During an average year the flow prescription would start April 1 at 3,000 cfs with an increase in flows starting immediately for a duration of 15 days and held at a peak of 12,000 cfs for 3 days similar to a wet year. Following the 3-day peak of 12,000 cfs flows would begin to decrease and be attenuated for a longer period to maintain habitat for fish recruitment until approximately July 21.

Fish and Other Aquatic Species, Reach 2, Dry

The Reach 2 average year was the starting point for the Reach 2, dry year prescription. In general, the group was more conservative with water use assuming it was a dry year. Environmental flow recommendations for Fish and Other Aquatic Species Reach 2 Dry are shown in Figure D-4. Characteristics of each flow component are detailed below.

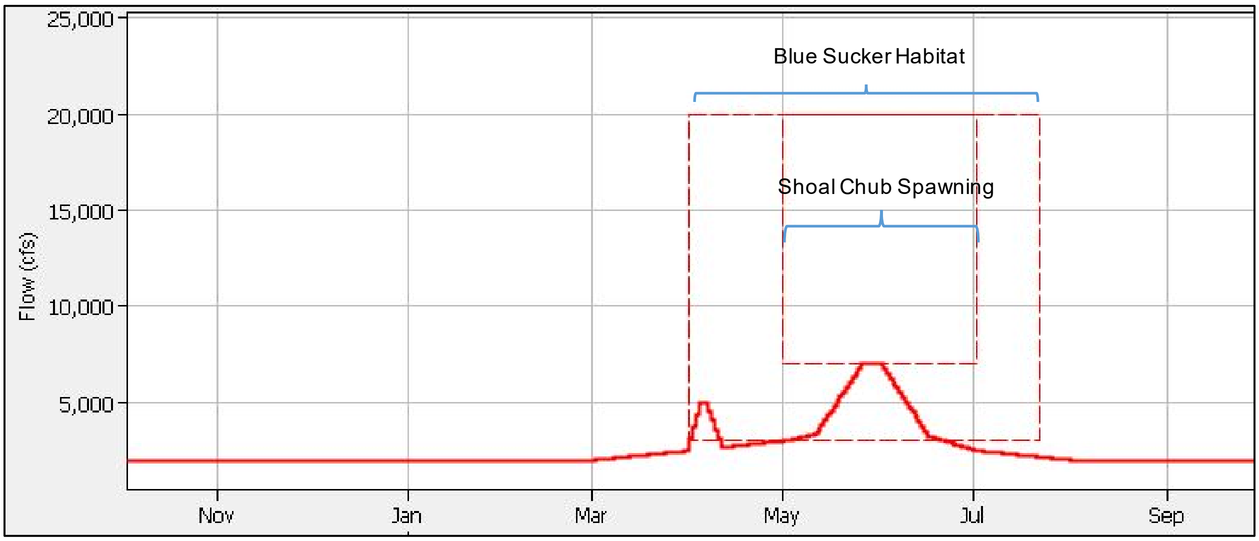


Figure D - 4. Flow Prescription for Fish, Reach 2, Dry

Shoal Chub Spawning (Fish and Other Aquatic Species, Reach 2, Dry, Table D-8)

Season: 01 May to 01 July
Events per season: 1
Magnitude: 7,000 – 20,000 cfs, most peaks in the 7,000 cfs range
Duration: 35 days with a slow fall
Duration of peak: 7 days

Table D - 8. Shoal Chub Spawning Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
May 12	35	7,000	7

Purpose: Flows to help cue spawning.

Description: A flow prescription was developed in dry years to cue spawning for the shoal chub and other species with similar habitat needs. During a dry year compared to an average year the velocity of the flow prescription would be reduced but maintained for a slightly longer duration. During a dry year the flow prescription would start at 7,000 cfs May 1 with an increase starting May 12 for a duration of 35 days and held at a peak of 7,000 cfs for 7 days.

Blue Sucker Habitat (Fish and Other Aquatic Species, Reach 2, Dry, Table D-9)

Season: 01 April to 21 July
Events per season: 1
Magnitude: 3,000 – 20,000 cfs, most peaks in the 5,000 cfs range
Duration: 10 days
Duration of peak: 3 days

Table D - 9. Blue Sucker Habitat Hypothetical Sample Schedule
(cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
April 1	10	5,000	3

Purpose: Flows to help condition spawning habitat and cue spawning.

Description: Higher flows prior to the spawning cue were developed to condition habitat (e.g., cobbles). In a dry year the duration and velocity of the pulse would be reduced. During a dry year the flow prescription would start April 1 at 3,000 cfs with an increase in flows starting immediately for a duration of 10 days and held at a peak of 5,000 cfs for 3 days. Following the 3-day peak of 5,000 cfs flows would begin to decrease and be attenuated for a longer period to maintain habitat for fish recruitment until approximately July 21.

Research and modeling needs from the fish and other aquatic species team:

- How have other regions used reservoir level management to benefit downstream habitat?
- Baseline data would be needed prior to implementation of a flow proposal to compare post-test results.
- Need a more robust data set on river conditions from a year where species performed well for the species used in flow proposals.
- Would there be ecological benefits in performing the winter drawdown later (i.e. February) that normal.

Appendix E: Birds/Riparian and Floodplain Systems Break-out Group Findings

Birds/Riparian and Floodplain Systems Break-out Group Findings

Details for the Birds/Riparian and Floodplain Systems break-out group findings include:

- Process
- General prescription goals for each year
- Flow prescriptions for birds/riparian and floodplain systems by reach
- Research and modeling needs from the birds/riparian and floodplain systems group

The Bird/Riparian and Floodplain Systems group was tasked with determining the needs of sandbar-nesting and migratory birds, and the riparian and floodplain systems. Flow recommendations included flows needed to shape habitat (e.g., flows that build or expose sandbars, scouring flows that limited perennial vegetation growth on sandbars), flows that provide energy inputs to the river (e.g., inundate floodplains and backwaters, nutrient cycling), and flows that connect off-channel areas (e.g., oxbows, floodplains). The group decided to focus on goals and objectives that could bring the desired states for Kansas River listed bird species (Piping Plover and Least Tern) and riparian and floodplain systems including side channel habitat.

Birds

Many species of shore and wading birds use the Kansas River; however, it is the sand-bar nesting species that have limited and tenuous habitat on the river. The two listed sandbar-nesting species in the Kansas River are Piping Plover (*Charadrius melodus*) and Least Tern (*Sternula antillarum*). Snowy plover and Killdeer also utilize sandbar habitat on the river. These species prefer sandy beaches, open lake shores, and sparsely vegetated sandbars. Populations of both have declined in the central United States due to loss of habitat. Piping Plover is federally, and state threatened, while Least Tern is state endangered. The Least Tern was previously federally endangered and recently delisted (February 12, 2021) due to its population having met recovery goals. The entire length of the Kansas River is designated as critical habitat (KDWPT 2019).

Anthropogenic changes in flows, such as diminished variance and duration, has decreased nesting habitat as well as food (invertebrate and fish) availability. While high episodic flows create the emerged sandbars that these birds need for nesting, high flows during the nesting period will destroy nests. Above 8,000 cfs most sandbars on the Kansas River will be submerged (http://kansasriver.org/). However, low flows allow encroachment of vegetation which provides cover for predators (Boyd and Olsen 2006).

Modifying river flows to allow for sandbar creation and adequate exposure during nesting season will improve habitat for these threatened and endangered birds.

Conditions to Promote with the Use of a Flow Prescription

- Protection of nesting/fledging birds
- Habitat building and maintenance
- Exposure of sandbars
- Sandbar reorganization

Riparian and Floodplain Systems

Riparian zones and floodplain systems are particularly important as breeding and wintering sites for bird communities and as stopover sites used during migration. In a study of fish assemblages and food web structure along the Kansas River, Eitzman and Paukert (2008) found that heterogenous in-stream reaches with more riparian forests supported more complex food webs and intolerant fluvial specialist fish species compared to more macrohabitat generalist fish species in urbanized and channelized homogenous reaches with less riparian habitat.

Most of the floodplain (74%) of the Kansas River is covered by agricultural lands and grassland. Woodlands comprise 7% of the Kansas River floodplain. Some of the larger woodland tracts are in the east half of the floodplain in the bluffs bordering the Kansas River and along some of the river's small tributaries. Woodlands generally have less coverage west of Topeka and are confined to many small drainages and creek valleys branching off the Kansas River and its larger tributaries. In the Fort Riley area northeast of Junction City and north of the Kansas River, the larger tributary valleys are filled with woodlands; however, on privately owned land south of the river, tributary valleys are mostly cropland. Although few large woodland tracts can be found, a discontinuous riparian forest grows along the entire length of the Kansas River.

Areas adjacent to the Kansas River and its floodplain are in need of riparian and floodplain vegetation establishment or management. In a remote assessment of riparian buffers in 57 HUC-12 watersheds in 10 Kansas basins, predominantly above federal reservoirs, the Kansas Forest Service and the Kansas Alliance for Wetlands and Streams (2017) identified 51.5% of the riparian areas as in need of riparian forest establishment (currently in cropland, pasture and grassland) and 30.2% in need of riparian forest management, out of total of 160,627 acres assessed for two active channel widths along the streams and rivers. Only 2.3% of the riparian area was assessed as in need of conservation (higher quality forest with adequate cover), with the remainder of the riparian area in development. The predominance of the riparian areas in the ten basins needed attention to ensure adequate functioning condition, health, and biodiversity, which could include a suite of best management practices ranging from tree and shrub establishment, timber stand improvement, natural channel design to address head-cut migration upstream and bank instability and floodplain connectivity.

Establishment and management of riparian and floodplain systems typically requires consideration of several measures including but not limited to flow recommendations, plantings, and invasive species control. The majority of the floodplain and bottomland areas adjacent to river systems in the basin are currently in agriculture. For the purposes of the workshop the Birds/Riparian and Floodplain Systems group focused on flow recommendations to support the establishment and management of riparian and floodplain systems. Establishment of riparian and floodplain systems in many areas would likely require conversion of agricultural lands. Coordination with private landowners would occur prior to any implementation. Flow recommendations that would support establishment and management of riparian and floodplain systems include flows that not only provide adequate hydrology for growth and recruitment of vegetation but also flows that shape habitat that is suitable for establishment and maintenance. These recommendations should have seasonal components and include flows that are high enough to move and deposit sediment. Flows that would inundate floodplains would pull energy (e.g., debris, plants, organic materials) into the river system to provide cycling of nutrients. Flows that inundate off-channel areas (i.e., backwaters, oxbows, floodplains) would encourage habitat for species that utilize these areas (e.g., waterfowl, turtles) as well as promote production of benthic organisms that are an important food source for many riparian, floodplain, and riverine species.

Indicator Species

- Riparian Vegetation
  - Hackberry (*Celtis occidentalis*)
  - Black Walnut (*Juglans nigra*)

- American Elm (*Ulmus americana*)
- Honeylocust (*Gleditsia triacanthos*)
- Oak *(Quercus spp.)*

- Floodplain Vegetation
  - Cottonwood (*Populus deltoides*)
  - Willow (*Salix* spp.)
- Benthic Organisms (macroinvertebrates – e.g., Ephemeroptera, Plecoptera, Trichoptera)
- Turtles
- Waterfowl

Conditions to Promote with the Use of a Flow Prescription

- Energy input
- Nutrient cycling
- Sediment movement and deposition
- Habitat building and maintenance
- Connections to oxbows/wetlands/backwaters
- Floodplain inundation

Process

The group was tasked with starting their flow prescription for Reach 2 on the Kansas River, from the Big Blue River confluence to Willard, Kansas. Collectively, the group decided to start with a wet year.

At the end of the group break-out time, the birds/riparian and floodplain systems team collectively finished Reach 2 wet and began average and dry years. The prescriptions for Reach 2 should be sufficient for Reach 1 (Kansas River below Milford Reservoir to Big Blue River confluence), Reach 3 (Kansas River from the Delaware River confluence to Lawrence, Kansas), and Reach 4 (Kansas River from the Wakarusa River confluence to Bonner Springs, Kansas).

General Prescription Goals for Each Year

The life stages of birds and riparian and floodplain systems were considered in crafting ecological operational windows. While the number of pulses or magnitude of the pulses might differ between a wet year, average year, dry year, or reach of the river, the break-out team stayed consistent on necessary hydrologic needs during certain parts of the year for bird and riparian and floodplain systems needs. These include:

Energy Input: The Kansas River has generally experienced a decrease in the frequency and magnitude of flow pulses. Incorporating a series of scouring pulses would discourage recruitment of perennial vegetation on emergent sandbar habitat supporting nesting periods for birds and improve habitat. Flow pulses help to pull allochthonous materials (organic debris, plants, animal waste, etc.) into the river system to provide carbon and nutrients for the system. Periodic pulses could increase the interface between the aquatic and terrestrial environments (side channels, oxbows, floodplains), and provide more variability in habitats. The moisture will also encourage cottonwood recruitment in riparian areas.

However, high flow pulses (above 8000-13,000 cfs where sandbars are inundated) could be detrimental to sandbar-nesting birds and turtles during the nesting period. It is advantageous to these species to reduce these peaks and durations as much as possible during nesting season. Flows above 8,000 cfs during March and April in dry years generally would not be possible. During average and wet years, at least one large (>13,000 cfs) pulse would be advantageous to habitat and as a cue to fish spawning but should be done prior to the arrival of male birds around April 1. Female birds arrive a week or so later and nest for 60 days. If a pulse does need to occur during this window, it would be preferable in early April rather than mid-June.

Fall Pulses: Fall pulses with troughs in between would encourage waterfowl habitat and other species by facilitating connectivity of oxbows. These pulses can be of short duration and flashy, and timing is flexible. Timing could be opportunistic and in response to an inflow event into a reservoir ("run of the river" operation). At least one fall pulse could benefit young-of-year fish and species that use shallow water habitats (backwaters, oxbows), but there may be opportunity for more pulses in wet years. The trough periods between flashy pulses area emphasized, so flows should quickly return to base level. 20,000 cfs would likely inundate the oxbows. Smaller oxbows and side channels in the reach could be inundated with lower flows. Pulses should be variable to encourage variable effects to the system. Use prevailing hydrographs as a guide to determine magnitudes in regard to differing peak flows.

Sandbar Exposure: While early spring scouring flows are advantageous to clear sandbar habitat, summer exposure of sandbars is useful for turtle and bird nesting. Male birds arrive around April 1. Female birds arrive a week or so later. Ideally, sandbars would be exposed for up to 60 days through May and June to allow for arrival, nesting, and hatching. In the case of pulses for sandbar exposure, it is desired to return to low flows as soon as possible. The most important aspect of these recommendations is to restore more variability in timing and magnitude of pulse flows. In the instance of a manageable pulse inflow, it could be beneficial to hold back these flows for the purpose of keeping a ~60-day period needed for birds nesting, hatching, etc. (see June 1997 unimpaired flow), or attenuate the flow enough to remain within the sandbar exposure range. However, there was some concern about being overly prescriptive (for example, in an uncontrolled natural system, there will occasionally be summer events that wash away nests). Therefore, it may be most advantageous to allow flows through the dams that mimic the inputs ("run of the river" operation) when possible.

Sandbar Reorganization: As stated above, there is generally a need for more frequent pulses of varying duration to alternately inundate and expose sandbars. More variable pulses throughout the year will destabilize and reorganize sandbars. Another purpose is the removal of woody vegetation, which discourages use of the sandbar by certain species of birds. The season is flexible and could be done in the winter period. One week of inundation would be sufficient to remove vegetation and bring allochthonous energy sources into the system. In dry years, an instance of sandbar reorganization isn't necessarily expected but if the opportunity is there it could be beneficial

Nutrient Cycling: Along the theme of reintroducing variability into the system, it was recommended that a series of approximately monthly small pulses (within the range of 1000-5000 cfs) would mimic natural rises for the purpose of nutrient cycling and benthic organisms. Timing would be flexible, so these could mimic inflows into the dam ("run of the river" operation). In the summer season or times of extreme low-flow, these small pulses would help flush the system and improve dissolved oxygen concentrations.

Flow Prescriptions for Birds/Riparian and Floodplain Systems

Birds/Riparian and Floodplain Systems, Reach 2, Wet

The Birds/Riparian and Floodplain Systems team started Reach 2 Wet during the workshop. Experts were consulted after the workshop to refine details of the prescription. The Reach 2 Average year was the starting point for the Reach 2. Wet year prescription and magnitudes and durations were changed as needed. Environmental flow recommendations for Birds/Riparian and Floodplain Systems Reach 2 Wet are shown in Figure E-1. Characteristics of each flow component are detailed below.

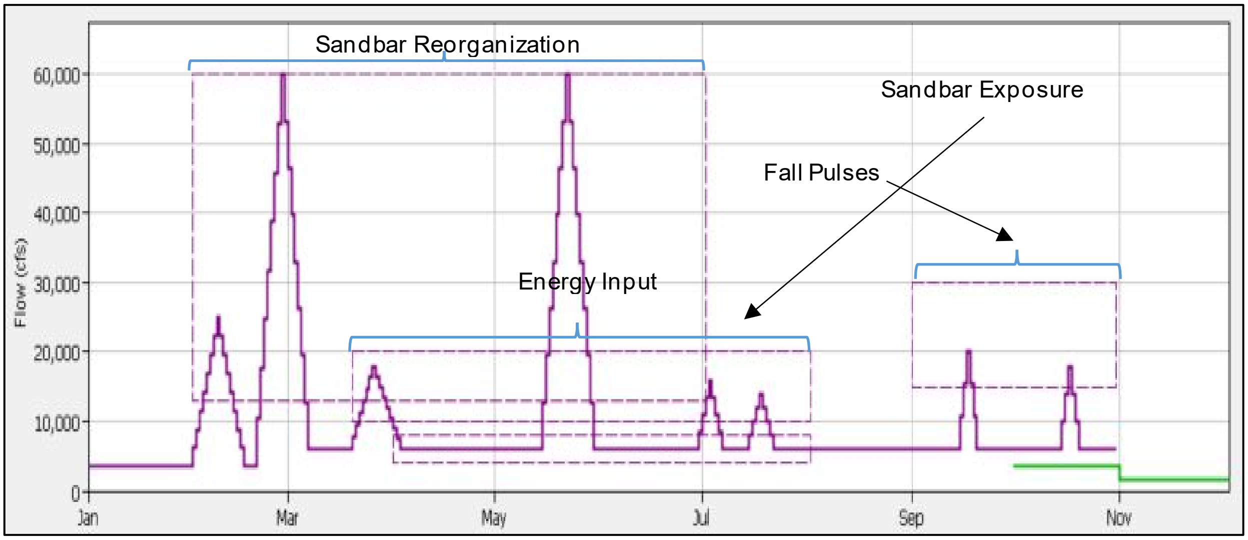


Figure E - 1. Flow Prescription for Birds/Riparian and Floodplain Systems, Reach 2, Wet

Energy Input (Birds/Riparian and Floodplain Systems, Reach 2, Wet, Table E-1)

Season: 20 March – 01 August
Events per season: 3
Magnitude: 10,000 – 20,000 cfs
Duration: 7 – 14 days
Duration of peak: 1 day

Table E - 1. Energy Inputs Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
March 20	14	18,000	1
June 30	7	16,000	1
July 15	7	14,000	1

Purpose: The prescription for a wet year includes a series of pulses to help pull in allochthonous material into the river system to serve as energy for the system. A late season pulse (July) may provide opportunity for short-term rearing habitat for young-of-year fish.

Description: During a wet year the flow prescriptions would range from 10,000 – 20,000 cfs with increased flows for 7-14 days. Peaks would occur periodically from March 20 to August 1. During a wet year the flow prescription would start on March 20 for a duration of 14 days with a peak held at 18,000 cfs for a duration of 1 day. This would be followed by 2 additional flows starting June 30 and July 15 for a duration of 7 days with a peak held at 16,000 and 14,000 cfs respectively for a duration of 1 day. Timing and duration of these peaks should be considered to avoid negative effects to sandbar nesting birds or turtles during this period, as described above. During average and wet years, at least one large (>13,000 cfs) pulse would be advantageous to habitat and as a cue to fish spawning but should be done prior to the arrival of sandbar nesting male bird species around April 1. Female birds arrive a week or so later and nest for 60 days. If a pulse does need to occur during this window, it would be preferable in early April rather than mid-June.

Fall Pulses (Birds/Riparian and Floodplain Systems, Reach 2, Wet, Table E-2)

Season: 01 September – 30 October
Events per season: 2
Magnitude: 15,000 – 30,000 cfs
Duration: 5 days
Duration of peak:1 day

Table E - 2. Fall Pulses Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
September 15	5	20,000	1
October 15	5	18,000	1

Purpose: The prescription for a wet year includes fall pulses that are flashy in nature, quickly returning to troughs in between to increase waterfowl habitat and other species and facilitate connectivity of oxbows. The duration of flows may be short and having at least one pulse could benefit young-of year fish and species that use shallow water habitats.

Description: During a wet year the flow prescription would start September 1 at 15,000 cfs with increased flows for 5 days and peaks of 18,000-20,000 cfs occurring for a duration of 1 day. The timing would be more opportunistic and occur only if water was available. Approximately 20,000 cfs would likely inundate the oxbows. The velocity needed would be specific to site conditions and further analysis would be needed to refine flow needs during implementation. Additionally, specific locations of oxbows were not identified during the workshop, but review of aerial imagery indicates that old oxbows exist along the Kansas River mainstem. If proposed oxbows are on lands under private ownership coordination would be done with the landowner prior to any further planning. Smaller oxbows in the reach could be inundated with slightly less flow. Pulses should be variable to encourage variable effects to the system. Existing hydrographs should be used as a guide to determine magnitudes of differing peak flows. The group recognized that potential dislodging of mussels could be a concern, particularly when temperatures are high. Flows that provide mussel transition flows, especially for early season, should also be considered under a separate prescription.

Sandbar Exposure (Birds/Riparian and Floodplain Systems, Reach 2, Wet, Table E-3)

Season: 01 April – 01 August
Events per season: 1
Magnitude: 4,000 – 8,000 cfs
Duration: 60 days
Duration of peak: N/A

Table E - 3. Sandbar Exposure Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
April 1	60	N/A	N/A

Purpose: The prescription for a wet year includes flows held low enough to avoid inundation of sandbars and provide habitat for sandbar nesting birds species (i.e., piping plover) and nesting turtles.

Description: Flows (4,000 – 8,000 cfs) would be held for a duration of 60 days to allow time for arrival, nesting, and brooding.

Sandbar Reorganization (Birds/Riparian and Floodplain Systems, Reach 2, Wet, Table E-4)

Season: 01 February – 01 July
Events per season: 3
Magnitude: 13,000 – 60,000 cfs
Duration: 15 days
Duration of peak: 1 day

Table E - 4. Sandbar Reorganization Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
February 1	15	25,000	1
February 20	15	60,000	1
May 15	15	60,000	1

Purpose: Flows high enough during a wet year to reorganize and scour sandbars and remove woody vegetation to provide habitat for sandbar nesting bird species (i.e., piping plover) and nesting turtles.

Description: A series of higher flows was developed. During a wet year the flow prescriptions would range from 13,000 – 60,000 cfs with increased flows for 15 days. Peaks would occur periodically from February 1 to July 1. During a wet year the flow prescription would start on February 1 for a duration of 15 days with a peak held at 25,000 cfs for a duration of 1 day. This would be followed by 2 additional flows starting February 20 and May 15 for a duration of 15 days with a peak held at 60,000 cfs for a duration of 1 day. Flows in between peaks would taper off to 13,000 cfs. These flows could occur approximately every 5 years or timed during a wet year.

Birds/Riparian and Floodplain Systems, Reach 2, Average

The Birds/Riparian and Floodplain Systems team finished Reach 2 Average during the workshop. Generally the magnitudes and durations for the Reach 2 Average year prescriptions were reduced compared to the Reach 2 Wet year prescriptions. Experts were consulted after the workshop to refine details of the prescription. Environmental flow recommendations for Birds/Riparian and Floodplain Systems Reach 2 Average are shown in Figure E-2. Characteristics of each flow component are detailed below.

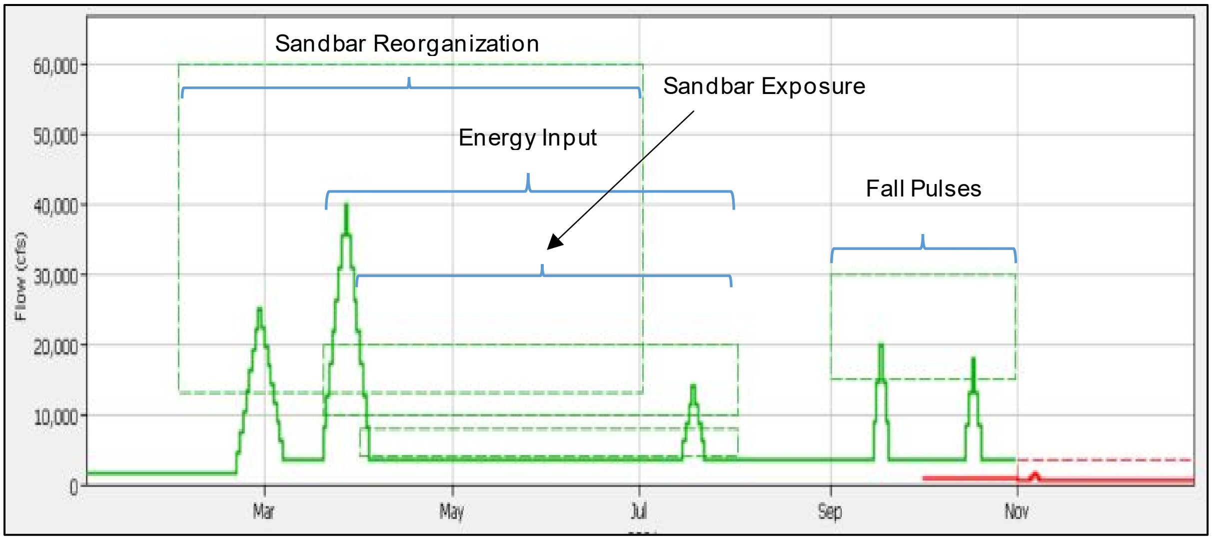


Figure E - 2. Flow Prescription for Birds/Riparian and Floodplain Systems, Reach 2, Average

Energy Input (Birds/Riparian and Floodplain Systems, Reach 2, Average, Table E-5)

Season: 20 March – 01 August
Events per season: 1
Magnitude: 10,000 – 20,000 cfs
Duration: 7 days
Duration of peak: 1 day

Table E - 5. Energy Inputs Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
July 15	7	14,000	1

Purpose: The prescription for an average year includes a series of pulses to discourage recruitment of perennial vegetation on emergent sandbar habitat supporting nesting periods for birds. Pulses help to pull in allochthonous energy (debris, plant material) into the river system to serve as nutrients for the system. A late season pulse (July) may provide opportunity for short-term rearing habitat for young-of-year fish.

Description: During an average year the flow prescription would start at 10,000 cfs March 20 with an increase starting July 15 for a duration of 7 days and held at a peak of 14,000 cfs for 1 day. Following the peak, flows would begin to decrease until early August. These pulses could be detrimental to nesting of birds or turtles during this period. It is advantageous for these species to reduce these peaks and durations as much as possible. During average and wet years, at least one large (>13,000 cfs) pulse would be advantageous to habitat and as a cue to fish spawning but should be done prior to the arrival of male birds around April 1. Female birds arrive a week or so later and nest for 60 days. If a pulse does need to occur during this window, it would be preferable in early April rather than mid-June.

Fall Pulses (Birds/Riparian and Floodplain Systems, Reach 2, Average, Table E-6)

Season: 01 September – 30 October
Events per season: 2
Magnitude: 15,000 – 30,000 cfs
Duration: 5 days
Duration of peak: 1 day

Table E - 6. Fall Pulses Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
September 15	5	20,000	1
October 15	5	10,000	1

Purpose: The prescription for an average year is the same as a wet year and includes fall pulses that are flashy in nature quickly returning to troughs in between to encourage habitat of waterfowl and other species and to facilitate connectivity of oxbows. The durations may be short and having at least one pulse could benefit young-of-year fish and species that use shallow water habitats.

Description: During an average year the flow prescription would start September 1 at 15,000 cfs with increased flows for 5 days and peaks of 10,000-20,000 cfs occurring for a duration of 1 day. The timing would be more opportunistic and occur only if water was available. Approximately 20,000 cfs would likely inundate the oxbows. The velocity needed would be specific to site conditions and further analysis would be needed to refine flow needs during implementation. Additionally, specific locations of oxbows were not identified during the workshop, but review of aerial imagery indicates that old oxbows exist along the Kansas River mainstem. If proposed oxbows are on lands under private ownership coordination would be done with the landowner prior to any further planning. Smaller oxbows in the reach could be inundated with slightly less flow. Pulses should be variable to encourage variable effects to the system. Existing hydrographs should be used as a guide to determine magnitudes of differing peak flows. The group recognized that potential dislodging of mussels could be a concern, particularly when temperatures are high. Flows that provide mussel transition flows, especially for early season, should also be considered under a separate prescription.

Sandbar Exposure (Birds/Riparian and Floodplain Systems, Reach 2, Average, Table E-7)

Season: 01 April – 01 August
Events per season: 1
Magnitude: 4,000 – 8,000 cfs
Duration: 60 days
Duration of peak: N/A

Table E - 7. Sandbar Exposure Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
April 1	60	N/A	N/A

Purpose: The prescription for an average year includes flows held low enough to avoid inundation of sandbars and provide habitat for sandbar nesting birds species (i.e., piping plover) and nesting turtles.

Description: Flows (4,000 – 8,000 cfs) would be held for a duration of 60 days to allow time for arrival, nesting, and brooding.

Sandbar Reorganization (Birds/Riparian and Floodplain Systems, Reach 2, Average, Table E-8)

Season: 01 February – 01 July
Events per season: 2
Magnitude: 13,000 – 60,000 cfs
Duration: 15 days
Duration of peak: 1 day

Table E - 8. Sandbar Reorganizations Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
February 20	15	25,000	1
March 20	15	40,000	1

Purpose: Flows high enough during an average year to reorganize and scour sandbars and remove woody vegetation to provide habitat for sandbar nesting bird species (i.e., piping plover) and nesting turtles.

Description: During an average year this flow is only proposed once compared to a wet year when a series of flows are proposed to avoid negative effects to fish spawning. During an average year the flow prescription would range from 13,000 – 60,000 cfs with increased flows for 15 days with a peak held at 25,000 – 40,000 cfs for a duration of 1 day.

Birds/Riparian and Floodplain Systems, Reach 2, Dry

The Reach 2 Average year was the starting point for the Reach 2, Dry year prescription. In general, the group was more conservative with water use assuming it was a dry year. Environmental flow recommendations for Birds/Riparian and Floodplain Systems Reach 2 Dry are shown in Figure E-3. Characteristics of each flow component are detailed below.

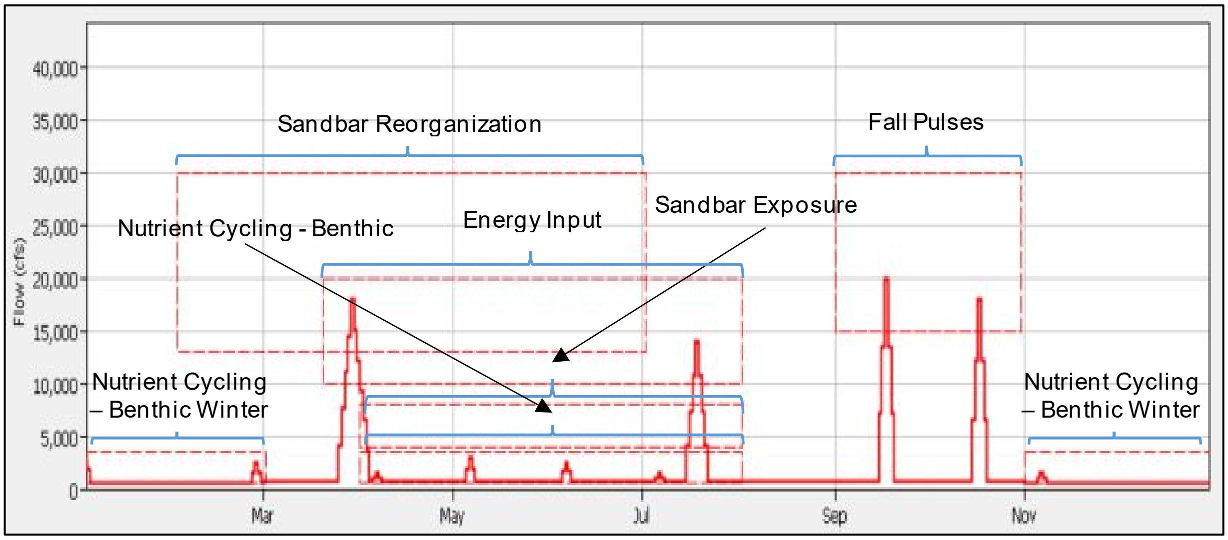


Figure E - 3. Flow Prescription for Birds/Riparian and Floodplain Systems, Dry

Energy Inputs (Birds/Riparian and Floodplain Systems, Reach 2, Dry, Table E-9)

Season: 20 March – 01 August
Events per season: 2
Magnitude: 10,000 – 20,000 cfs
Duration: 7 – 10 days
Duration of peak: 1 day

Table E - 9. Energy Inputs Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
March 25	10	18,000	1
July 15	7	14,000	1

Purpose: The prescription for a dry year includes two pulses to discourage recruitment of perennial vegetation on emergent sandbar habitat supporting nesting periods for birds. Pulses help to pull in allochthonous energy (debris, plant material) into the river system to serve as nutrients for the system. A late season pulse (July) may provide opportunity for short-term rearing habitat for young-of-year fish.

Description: During a dry year the flow prescription would start at 10,000 cfs March 20 with an increase starting March 25 for a duration of 10 days and held at a peak of 18,000 cfs for a duration of 1 day. A second increase would start July 15 for a duration of 7 days and held at a peak of 14,000 cfs for 1 day. Following the peak, flows would begin to decrease until early August. These pulses could be detrimental to nesting of birds or turtles during this period. It is advantageous to these species to limit these peaks in frequency and duration. Large spring/summer pulses are advantageous to habitat and as a cue to fish spawning but should be done prior to the arrival of male birds around April 1. Female birds arrive a week or so later and nest for 60 days. If a pulse does need to occur during this window, it would be preferable in early April rather than mid-June.

Fall Pulses (Birds/Riparian and Floodplain Systems, Reach 2, Dry, Table E-10)

Season: 01 September – 30 October
Events per season: 2
Magnitude: 15,000 – 30,000 cfs
Duration: 5 days
Duration of peak: 1 day

Table E - 10. Fall Pulses Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
September 15	5	20,000	1
October 15	5	18,000	1

Purpose: The prescription for a dry year includes fall pulses that are flashy in nature quickly returning to troughs in between to encourage habitat of waterfowl and other species and facilitate connectivity of oxbows. The duration of flows may be short and having at least one pulse could benefit young-of-year fish and species that use shallow water habitats.

Description: During a dry year the flow prescription would start September 1 at 15,000 cfs with increased flows for 5 days and peaks of 18,000-20,000 cfs occurring for a duration of 1 day. The timing would be more opportunistic and occur only if water was available. Approximately 20,000 cfs would likely inundate the oxbows. The velocity needed would be specific to site conditions and further analysis would be needed to refine flow needs during implementation. Additionally, specific locations of oxbows were not identified during the workshop, but review of aerial imagery indicates that old oxbows exist along the Kansas River mainstem. If proposed oxbows are on lands under private ownership coordination would be done with the landowner prior to any further planning. Smaller oxbows in the reach could be inundated with slightly less flow. Pulses should be variable to encourage variable effects to the system. Existing hydrographs should be used as a guide to determine magnitudes of differing peak flows. The group recognized that potential dislodging of mussels could be a concern, particularly when temperatures are high. Flows that provide mussel transition flows, especially for early season, higher should also be considered under a separate prescription.

Nutrient Cycling – Benthic (Birds/Riparian and Floodplain Systems, Reach 2, Dry, Table E-11)

Season: 01 April – 01 August
Events per season: 4
Magnitude: 500 – 3,500 cfs
Duration: 3 days
Duration of peak: 1 day

Table E - 11. Nutrient Cycling - Benthic Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
April 5	3	1,500	1
May 5	3	3,000	1
June 5	3	2,500	1
July 5	3	1,500	1

Purpose: The prescription for a dry year includes a series of monthly small pulses used to mimic natural rises for the purpose of nutrient cycling and benthic production.

Description: This prescription would only occur during a dry year. The timing of these peaks is not strict but could follow reservoir inflows and what would be a natural pulse if water was to pass through a dam. The flow prescription would start at 500 cfs April 1 with an increase starting April 5 for a duration of 3 days and held at a peak of 1,500 cfs for a duration of 1 day. A second increase would start May 5 for a duration of 3 days and held at a peak of 3,000 cfs for a duration of 1 day. A third and fourth increase would start June 5 and July 5 held at 2,500 cfs and 1,500 cfs respectively for a duration of 1 day.

Nutrient Cycling – Benthic Winter (Birds/Riparian and Floodplain Systems, Reach 2, Dry, Table E-12)

Season: 01 November – 01 March
Events per season: 3
Magnitude: 500 – 3,500 cfs
Duration: 3 days
Duration of peak: 1 day

Table E - 12. Nutrient Cycling - Benthic Winter Hypothetical Sample Schedule (cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
November 5	3	1,500	1
January 1	3	3,000	1
February 25	3	2,500	1

Purpose: The prescription for a dry year includes a series of monthly small pulses in the winter used to mimic natural rises for the purpose of nutrient cycling and benthic production.

Description: This prescription would only occur during a dry year. The timing of these peaks is not strict but could follow reservoir inflows and what would be a natural pulse if water was to pass through a dam. The flow prescription would start at 500 cfs November 1 with an increase starting November 5 for a duration of 3 days and held at a peak of 1,500 cfs for a duration of 1 day. A second increase would start January 1 for a duration of 3 days and held at a peak of 3,000 cfs for a duration of 1 day. A third increase would start February 25 held at 2,500 cfs for a duration of 1 day.

Sandbar Exposure (Birds/Riparian and Floodplain Systems, Reach 2, Dry, Table E-13)

Season: 01 April – 01 August

Events per season: 1
Magnitude: 4,000 – 8,000 cfs
Duration: 60 days
Duration of peak: N/A

Table E - 13. Sandbar Exposure Hypothetical Sample Schedule
(cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
April 1	60	N/A	N/A

Purpose: The prescription for a dry year includes flows held low enough to avoid inundation of sandbars and provide habitat for sandbar nesting birds species (i.e., piping plover) and nesting turtles.

Description: Flows (4,000 – 8,000 cfs) would be held for a duration of 60 days to allow time for arrival, nesting, and brooding.

Sandbar Reorganization (Birds/Riparian and Floodplain Systems, Reach 2, Dry, Table E-14)

Season: February 1 – July 1
Events per season: 1
Magnitude: 13,000 -30,000 cfs
Duration: up to 60 days
Duration of peak: N/A

Table E - 14. Sandbar Reorganization Hypothetical Sample Schedule
(cfs targets are only estimates)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
April 1	60	N/A	N/A

Purpose: The prescription for a dry year includes flows high enough during a dry year to reorganize and scour sandbars and remove woody vegetation to provide habitat for sandbar nesting bird species (i.e., piping plover) and nesting turtles.

Description: During a dry year the flow prescription would range from 13,000 – 30,000 cfs without any proposed flow increases or peaks. During a dry year reorganization of sandbars isn't necessarily expected but if the opportunity arises it could be beneficial during a dry year.

Research and modeling needs from the birds/riparian and floodplain systems team:

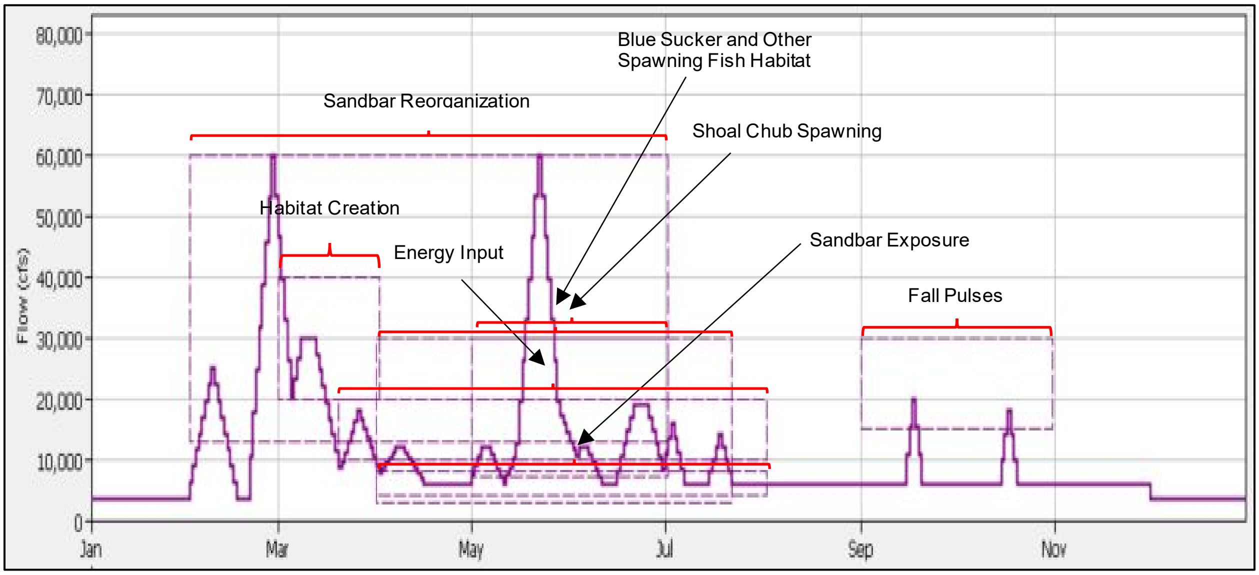
- How have other regions used reservoir level management to benefit downstream habitat?
- Baseline data would be needed prior to implementation of a flow proposal to compare post-test results.
- Would there be ecological benefits in performing the winter drawdown later (i.e. February) that normal.
- How will these flow prescriptions affect nutrient cycling and water quality?

Appendix F: Unified Flow Prescriptions

Unified Flow Prescriptions

Unified, Reach 2, Wet

Environmental flow recommendations for Unified Reach 2 Wet are shown in Figure F-1. Characteristics of each flow component are detailed below.



F- 1. Flow Prescription for Unified, Reach 2 Wet

Shoal Chub Spawning (Unified, Reach 2, Wet, Table F-1)

Season: 01 May – 01 July
Events per season: 1
Magnitude: 7,000 – 30,000 cfs
Duration: 25 days
Duration of peak: 7 days

Table F-1. Shoal Chub Spawning Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
May 12	25	20,000	7

Additional Details and Caveats: A unified flow prescription was developed in wet years to cue spawning for the shoal chub and other species with similar spawning needs. During a wet year the flow prescription would start at 7,000 cfs on May 1 with an increase starting May 12, for a duration of 25 days, and held at a peak of 20,000 cfs for 7 days. Following the 7-day peak of 20,000 cfs flows would begin to decrease back to 7,000 cfs by early June. The pulse would be brought down slowly to support larval growth. The shoal chub was selected as a surrogate candidate to measure response to a flow prescription. Creating improved spawning conditions for the shoal chub would benefit other fish species with longer spawning periods that would occur during a specific prescription window. The group recognized there is uncertainty around duration and magnitude needed to create successful spawning conditions for the shoal chub. An adaptive management and monitoring approach should be used to test and address the species needs to meet objectives.

Blue Sucker and Other Spawning Fish Habitat (Unified, Reach 2, Wet, Table F-2)

Season: 01 April – 21 July
Events per season: 5
Magnitude: 3,000 -30,000 cfs
Duration: 10 – 15 days
Duration of peak: 3 – 5 days

Table F-2. Blue Sucker and Other Spawning Fish Habitat Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
April 1	15	12,000	3
May 1	10	12,000	3
May 20	10	12,000	3
June 1	10	12,000	3
June 16	15	19,000	5

Additional Details and Caveats: It was decided during the unification to merge the Blue Sucker Habitat and the Fish Spawning flow prescriptions as the blue sucker spawning window is relatively long and would capture the spawning windows of other fish species. Higher flows prior to the spawning cue were developed to condition habitat. During a wet year the flow prescription would start April 1 at 3,000 cfs with an increase in flows starting immediately for a duration of 15 days and held at a peak of 12,000 cfs for 3 days. Following the 3-day peak of 12,000 cfs flows would begin to decrease and be attenuated for a longer period to maintain habitat for fish recruitment until approximately July 21.

A series of higher flows was also developed within the spawning window for the majority of fish species (May 1 – June 30) (see Figure D-1) to provide more variation in flows to enhance spawning success. This prescription would only occur during a wet year. During a wet year the additional flow prescriptions would start May 1 at 7,000 cfs with increased in flows for 10-15 days and peaks of 12,000 cfs occurring for a duration of 3 days. These would occur periodically from May 1 to June 30.

Habitat Creation (Unified, Reach 2, Wet, Table F-3)

Season: 01 March – 01 April
Events per season: 1
Magnitude: 20,000 – 40,000 cfs
Duration: 20 days
Duration of peak: 5 days

Table F-3. Habitat Creation Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
March 1	20	30,000	5

Additional Details and Caveats: A unified flow prescription was developed in wet years to create suitable habitat for fish spawning and rearing (e.g., clean cobbles, channel sandbars, shallow water areas). Habitat forming flows would be high enough (20,000-40,000 cfs) to destabilize and reorganize bed materials or scour fines. This flow prescription would also benefit mussel species by creating suitable habitat. The higher flow (20,000 – 40,000 cfs) would be released prior to the start of the main spawning window (May 1) for the majority of species (see Figure D-1) and held for a duration of 20 days with a peak at 30,000 cfs held for 5 days.

Energy Input (Unified, Reach 2, Wet, Table F-4)

Season: 20 March – 01 August
Events per season: 3
Magnitude: 10,000 – 20,000 cfs
Duration: 7 – 14 days
Duration of peak: 1 day

Table F-4. Energy Input Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
March 20	14	18,000	1
June 30	7	16,000	1
July 15	7	14,000	1

Additional Details and Caveats: The unified prescription for a wet year includes a series of pulses to help pull in allochthonous material into the river system to serve as energy for the system. Timing and duration of these peaks was considered to avoid negative effects to sandbar nesting birds or turtles during this period. The timing of the initial pulse would be early enough to cue spawning for fish species but prior to arrival of sandbar nesting male bird species (March and April) and would be below 8,000 cfs. A late season pulse (July) may provide opportunity for short-term rearing habitat for young-of-year fish. During a wet year the flow prescriptions would range from 10,000 – 20,000 cfs with increased flows for 7-14 days. Peaks would occur periodically from March 20 to August 1. During a wet year the flow prescription would start on March 20 for a duration of 14 days with a peak held at 18,000 cfs for a duration of 1 day. This would be followed by 2 additional flows starting June 30 and July 15 for a duration of 7 days with a peak held at 16,000 and 14,000 cfs respectively for a duration of 1 day.

Fall Pulses (Unified, Reach 2, Wet, Table F-5)

Season: 01 September – 30 October
Events per season: 2
Magnitude: 15,000 – 30,000 cfs
Duration: 5 days
Duration of peak: 1 day

Table F-5. Fall Pulses Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
September 15	5	20,000	1

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
October 15	5	18,000	1

Additional Details and Caveats: The unified prescription for a wet year includes fall pulses that are flashy in nature quickly returning to troughs in between to increase habitat of waterfowl and other species and facilitate connectivity of oxbows. The duration of flows may be short and having at least one pulse could benefit young-of-year fish. During a wet year the flow prescription would start September 1 at 15,000 cfs with increased flows for 5 days and peaks of 18,000-20,000 cfs occurring for a duration of 1 day. The timing would be more opportunistic and occur only if water was available. Approximately 20,000 cfs would likely inundate the oxbows. The velocity needed would be specific to site conditions and further analysis would be needed to refine flow needs during implementation. Additionally, specific locations of oxbows were not identified during the workshop, but review of aerial imagery indicates that old oxbows exist along the Kansas River mainstem. If proposed oxbows are on lands under private ownership coordination would be done with the landowner prior to any further planning. Smaller oxbows in the reach could be inundated with slightly less flow. Pulses should be variable to encourage variable effects to the system. Existing hydrographs should be used as a guide to determine magnitudes of differing peak flows. The group recognized that potential dislodging of mussels could be a concern, particularly when temperatures are high. Flows that provide mussel transition flows, especially for early season, should also be considered under a separate prescription.

Sandbar Exposure (Unified, Reach 2, Wet, Table F-6)

Season: 01 April – 01 August
Events per season: N/A
Magnitude: 4,000 – 8,000
Duration: N/A
Duration of peak: N/A

Table F-6. Sandbar Exposure Hypothetical Sample Schedule
(cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
April 1	60	N/A	N/A

Additional Details and Caveats: The unified prescription for a wet year includes flows held low enough to avoid inundation of sandbars and provide habitat for sandbar nesting birds species (i.e., piping plover) and nesting turtles. Flows (4,000 – 8,000 cfs) would be held for a duration of 60 days to allow time for arrival, nesting, and brooding.

Sandbar Reorganization (Unified, Reach 2, Wet, Table F-7)

Season: 01 February – 01 July
Events per season: 3
Magnitude: 13,000 – 60,000 cfs
Duration: 15 days
Duration of peak: 1 day

Table F-7. Sandbar Reorganization Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
February 1	15	25,000	1
February 20	15	60,000	1
May 15	15	60,000	1

Additional Details and Caveats: Flows high enough during a wet year to reorganize and scour sandbars and remove woody vegetation to provide habitat for sandbar nesting bird species (i.e., piping plover) and nesting turtles. These flows could occur approximately every 5 years or timed during a wet year. A series of higher flows was developed. During a wet year the flow prescriptions would range from 13,000 – 60,000 cfs with increased flows for 15 days. Peaks would occur periodically from February 1 to July 1. During a wet year the flow prescription would start on February 1 for a duration of 15 days with a peak held at 25,000 cfs for a duration of 1 day. This would be followed by 2 additional flows starting February 20 and May 15 for a duration of 15 days with a peak held at 60,000 cfs for a duration of 1 day. Flows in between peaks would taper off to 13,000 cfs.

Unified, Reach 2, Average

Environmental flow recommendations for Unified Reach 2 Average are shown in Figure F-2. Characteristics of each flow component are detailed below.

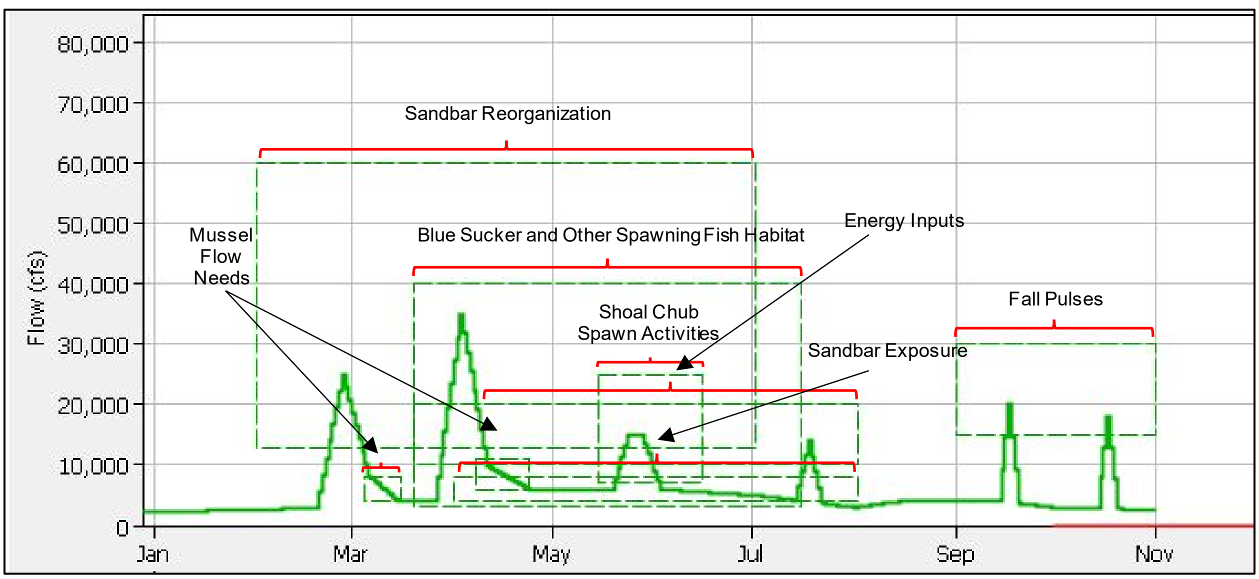


Figure F-2. Flow Prescription for Unified Reach 2 Average

Shoal Chub Spawning (Unified, Reach 2, Average, Table F-8)

Season: 15 May – 15 June
Events per season: 1
Magnitude: 7,000 – 25,000 cfs, most peaks in the 15,000 cfs range
Duration: 14 days
Duration of peak: 5 days

Table F-8. Shoal Chub Spawning Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
May 20	14	15,000	5

Additional Details and Caveats: A flow prescription was developed in average years to cue spawning for the shoal chub and other species with similar spawning needs. During an average year compared to a wet year the velocity of the flow prescription would be reduced but maintained for a similar duration. During an average year the flow prescription would start at 7,000 cfs May 15 with an increase starting May 20 for a duration of 14 days and held at a peak of 15,000 cfs for 5 days. Following the 5-day peak of 15,000 cfs flows would begin to decrease back to 7,000 cfs by early June. Flows should decrease slowly to support larval growth. The shoal chub was selected as a surrogate candidate to measure response to a flow prescription. Creating improved spawning conditions for the shoal chub would benefit other fish species with longer spawning periods that would spawn during a specific prescription window. The group recognized there is uncertainty around duration and magnitude needed to create successful spawning conditions for the shoal chub. An adaptive management and monitoring approach should be used to test and address the species needs to meet objectives. The prescription could be used with the sandbar exposure prescription to support sandbar nesting birds and turtles.

Blue Sucker and Other Spawning Fish Habitat (Unified, Reach 2, Average, Table F-9)

Season: 20 March – 15 July
Events per season: N/A
Magnitude: 3,300 – 40,000 cfs
Duration: N/A
Duration of peak: N/A

Table F-9. Blue Sucker and Other Spawning Fish Habitat Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
March 20	120	N/A	N/A

Additional Details and Caveats: The unified flow prescription for an average year include higher flows prior to the spawning cue to condition habitat. During an average year the flow prescription would start March 20 at 3,300 cfs and could increase up to 40,000 cfs over a 120-day period. A series of peaks were not defined for an average year, but peaks could occur opportunistically that would occur during important spawning windows and benefit the majority of fish species.

Mussel Flow Needs (Unified, Reach 2, Average, Table F-10)

Season: 5 March – 23 April
Events per season: 2
Magnitude: 4,000 – 11,000 cfs
Duration: N/A
Duration of peak: N/A

Table F-10. Mussel Flow Needs Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
March 5	10	N/A	N/A
April 8	15	N/A	N/A

Additional Details and Caveats: It was decided during the unification that the flows in the fall were suitable related to the need for a slower decline to prevent stranding of mussels and that the mussel flows developed by the fish group could be removed. However, a similar flow was developed under the unified flow prescription for mussels in average years to allow for a slow decline of high flows that are proposed for sandbar reorganization in the spring. During an average year the flow prescription would include a gradual decline of flows with no more than a one-foot decline in reservoir elevation over a 5-day period. Flows would slowly decline from 8,000 cfs to 4,000 cfs and be kept above 4,000 cfs to avoid adverse effects to mussels.

Energy Input (Unified, Reach 2, Average, Table F-11)

Season: 20 March – 01 August
Events per season: 1
Magnitude: 10,000 – 20,000 cfs
Duration: 7 days
Duration of peak: 1 day

Table F-11. Energy Inputs Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
July 15	7	14,000	1

Additional Details and Caveats: The unified prescription for an average year includes pulses to help to pull in allochthonous material into the river system to serve as energy for the system. These pulses could be detrimental to nesting of birds or turtles during this period. It is advantageous for these species to reduce these peaks and durations as much as possible. The timing of the initial pulse would be early enough to cue spawning for fish species but prior to arrival of sandbar nesting male bird species (March and April) and would be below 8,000 cfs. A late season pulse (July) may provide opportunity for short-term rearing habitat for young-of-year fish. During an average year the flow prescription would start at 10,000 cfs March 20 with an increase starting July 15 for a duration of 7 days and held at a peak of 14,000 cfs for 1 day. Following the peak, flows would begin to decrease until early August.

Fall Pulses (Unified, Reach 2, Average, Table F-12)

Season: 01 September – 31 October
Events per season: 2
Magnitude: 15,000 – 30,000 cfs
Duration: 5 days
Duration of peak: 1 day

Table F-12. Fall Pulses Hypothetical Sample Schedule
(cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
September 15	5	20,000	1
October 15	5	18,000	1

Additional Details and Caveats: The unified prescription for an average year is the same as a wet year and includes fall pulses that are flashy in nature quickly returning to troughs in between to increase habitat of waterfowl and other species and to facilitate connectivity of oxbows. The durations may be short and having at least one pulse could benefit young-of-year fish. During an average year the flow prescription would start September 1 at 15,000 cfs with increased flows for 5 days and peaks of 18,000-20,000 cfs occurring for a duration of 1 day. The timing would be more opportunistic and occur only if water was available. Approximately 20,000 cfs would likely inundate the oxbows. The velocity needed would be specific to site conditions and further analysis would be needed to refine flow needs during implementation. Additionally, specific locations of oxbows were not identified during the workshop, but review of aerial imagery indicates that old oxbows exist along the Kansas River mainstem. If proposed oxbows are on lands under private ownership coordination would be done with the landowner prior to any further planning. Smaller oxbows in the reach could be inundated with slightly less flow. Pulses should be variable to encourage variable effects to the system. Existing hydrographs should be used as a guide to determine magnitudes of differing peak flows. The group recognized that potential dislodging of mussels could be a concern, particularly when temperatures are high. Flows that provide mussel transition flows, especially for early season, should also be considered under a separate prescription.

Sandbar Exposure (Unified, Reach 2, Average, Table F-13)

Season: 01 April – 01 August
Events per season: N/A
Magnitude: 4,000 – 8,000 cfs
Duration: N/A
Duration of peak: N/A

Table F-13. Sandbar Exposure Hypothetical Sample Schedule
(cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
April 1	60	N/A	N/A

Additional Details and Caveats: The unified prescription for an average year includes flows held low enough to avoid inundation of sandbars and provide habitat for sandbar nesting birds species (i.e., piping plover) and nesting turtles. Flows (4,000 – 8,000 cfs) would be held for a duration of 60 days to allow time for arrival, nesting, and brooding.

Sandbar Reorganization (Unified, Reach 2, Average, Table F-14)

Season: 20 March – 01 August
Events per season: 1
Magnitude: 10,000 – 20,000 cfs
Duration: 7 days
Duration of peak: 1 day

Table F-14. Sandbar Reorganization Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
July 15	7	14,000	1

Additional Details and Caveats: Flows high enough during an average year to reorganize and scour sandbars and remove woody vegetation to provide habitat for sandbar nesting bird species (i.e., piping plover) and nesting turtles. During an average year this flow is only proposed once compared to a wet year when a series of flows are proposed to avoid negative effects to fish spawning. During an average year the flow prescription is lower and would range from 10,000 – 20,000 cfs with increased flows for 7 days with a peak held at 14,000 cfs for a duration of 1 day.

Unified, Reach 2, Dry

Environmental flow recommendations for Unified Reach 2 Dry are shown in Figure F-3. Characteristics of each flow component are detailed below.

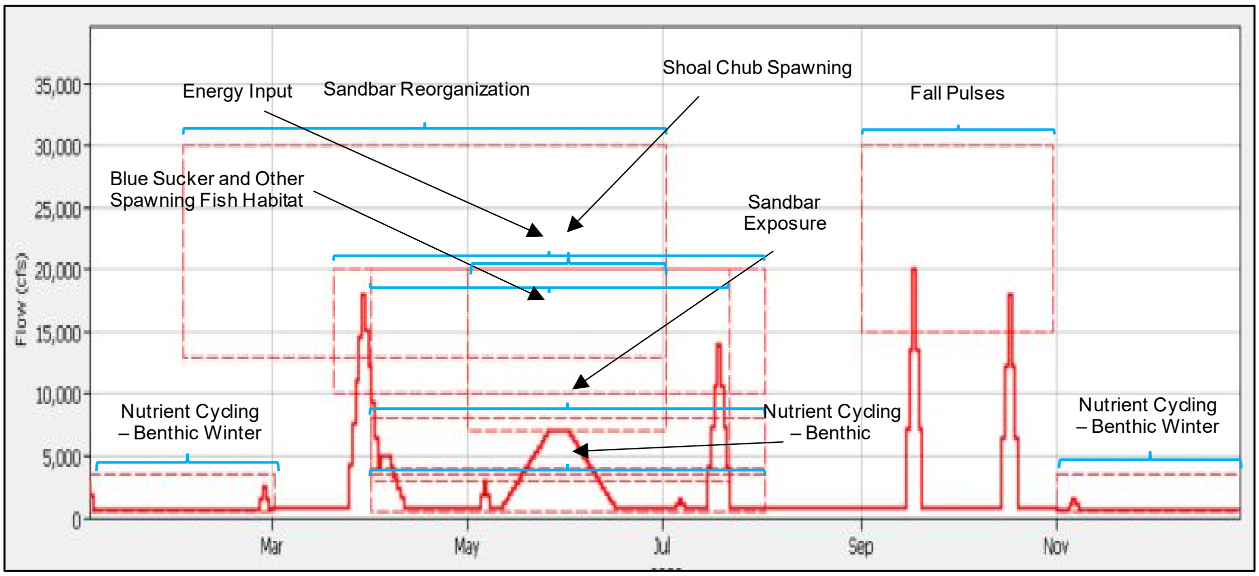


Figure F-3. Flow Prescription Unified for Reach 2 Dry

Shoal Chub Spawning (Unified, Reach 2, Dry, Table F-15)

Season: 01 May – 01 Jul
Events per season: 1
Magnitude: 7,000 – 20,000 cfs
Duration: 35 days
Duration of peak: 7 days

Table F-15. Shoal Chub Spawning Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
May 12	35	7,000	7

Additional Details and Caveats: A unified flow prescription was developed in dry years to cue spawning for the shoal chub and other species with similar spawning needs. During a dry year the flow prescription would start at 7,000 cfs on May 1 for a duration of 35 days and held at a peak of 7,000 cfs for 7 days. The pulse would be brought down slowly to support larval growth. The shoal chub was selected as a surrogate candidate to measure response to a flow prescription. Creating improved spawning conditions for the shoal chub would benefit other fish species with longer spawning periods that would spawn during a specific prescription window. The group recognized there is uncertainty around duration and magnitude needed to create successful spawning conditions for the shoal chub. An adaptive management and monitoring approach should be used to test and address the species needs to meet objectives.

Blue Sucker and Other Spawning Fish Habitat (Unified, Reach 2, Dry, Table F-16)

Season: 01 April – 21 July
Events per season: 1
Magnitude: 3,000 – 20,000 cfs
Duration: 10 days
Duration of peak: 3 days

Table F-16. Blue Sucker and Other Spawning Fish Habitat Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
April 1	10	5,000	3

Additional Details and Caveats: The unified flow prescription for a dry year include higher flows prior to the spawning cue to condition habitat. During a dry year the flow prescription would start April 1 at 3,000 cfs and could increase up to 20,000 cfs over a 111-day period. A series of peaks were not defined for a dry year, but one peak was defined at 5,000 cfs for a during of 3 days. Other peaks could occur opportunistically that would occur during important spawning windows and benefit the majority of fish species.

Energy Input (Unified, Reach 2, Dry, Table F-17)

Season: 20 March – 01 August
Events per season: 2
Magnitude: 10,000 – 20,000 cfs
Duration: 7 – 10 days
Duration of peak: 1 day

Table F-17. Energy Inputs Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
March 25	10	18,000	1

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
July 15	7	14,000	1

Additional Details and Caveats: The unified prescription for a dry year includes pulses to help to pull in allochthonous material into the river system to serve as energy for the system. These pulses could be detrimental to nesting birds or turtles during this period. It is advantageous to these species to reduce these peaks in frequency and duration. The timing of the initial pulse would be early enough to cue spawning for fish species but prior to arrival of sandbar nesting male bird species (March and April) and would be below 8,000 cfs. A late season pulse (July) may provide opportunity for short-term rearing habitat for young-of-year fish. During a dry year the flow prescription would start at 10,000 cfs March 20 with an increase starting March 25 for a duration of 10 days and held at a peak of 18,000 cfs for a duration of 1 day. A second increase would start July 15 for a duration of 7 days and held at a peak of 14,000 cfs for 1 day. Following the peak, flows would begin to decrease until early August.

Fall Pulses (Unified, Reach 2, Dry, Table F-18)

Season: 01 September – 30 October
Events per season: 2
Magnitude: 15,000 – 30,000 cfs
Duration: 5 days
Duration of peak: 1 day

Table F-18. Fall Pulses Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
September 15	5	20,000	1
October 15	5	18,000	1

Additional Details and Caveats: The unified prescription for a dry year includes fall pulses that are flashy in nature quickly returning to troughs in between to increase habitat of waterfowl and other species and facilitate connectivity of oxbows. The duration of flows may be short and having at least one pulse could benefit young-of-year fish. During a dry year the flow prescription would start September 1 at 15,000 cfs with increased flows for 5 days and peaks of 18,000-20,000 cfs occurring for a duration of 1 day. The timing would be more opportunistic and occur only if water was available. Approximately 20,000 cfs would likely inundate the oxbows. The velocity needed would be specific to site conditions and further analysis would be needed to refine flow needs during implementation. Additionally, specific locations of oxbows were not identified during the workshop, but review of aerial imagery indicates that old oxbows exist along the Kansas River mainstem. If proposed oxbows are on lands under private ownership coordination would be done with the landowner prior to any further planning. Smaller oxbows in the reach could be inundated with slightly less flow. Pulses should be variable to encourage variable effects to the system. Existing hydrographs should be used as a guide to determine magnitudes of differing peak flows. The group recognized that potential dislodging of mussels could be a concern, particularly when temperatures are high. Flows that provide mussel transition flows, especially for early season, should also be considered under a separate prescription.

Sandbar Exposure (Unified, Reach 2, Dry, Table F-19)

Season: 01 April – 01 August
Events per season: N/A

Magnitude: 4,000 – 8,000 cfs
Duration: N/A
Duration of peak: N/A

Table F-19. Sandbar Exposure Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
April 1	60	N/A	N/A

Additional Details and Caveats: The unified prescription for a dry year includes flows held low enough to avoid inundation of sandbars and provide habitat for sandbar nesting birds species (i.e., piping plover) and nesting turtles. Flows (4,000 – 8,000 cfs) would be held for a duration of 60 days to allow time for arrival, nesting, and brooding.

Sandbar Reorganization (Unified, Reach 2, Dry, Table F-20)

Season: 01 February – 01 July
Events per season: N/A
Magnitude: 13,000 – 30,000 cfs
Duration: N/A
Duration of peak: N/A

Table F-20. Sandbar Reorganization Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
February 1	150	N/A	N/A

Additional Details and Caveats: The unified prescription for a dry year includes flows high enough during a dry year to reorganize and scour sandbars and remove woody vegetation to provide habitat for sandbar nesting bird species (i.e., piping plover) and nesting turtles. During a dry year the flow prescription would range from 13,000 – 30,000 cfs without any proposed flow increases or peaks. During a dry year reorganization of sandbars isn't necessarily expected but if the opportunity arises it could be beneficial during a dry year.

Nutrient Cycling - Benthic (Unified, Reach 2, Dry, Table F-21)

Season: 01 April – 01 August
Events per season: 4
Magnitude: 500 – 3,500 cfs
Duration: 3 days
Duration of peak: 1 day

Table F-21. Nutrient Cycling - Benthic Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
April 5	3	1,500	1
May 5	3	3,000	1

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
June 5	3	2,500	1
July 5	3	1,500	1

Additional Details and Caveats: This prescription would only occur during a dry year. The unified prescription for a dry year includes a series of monthly small pulses used to mimic natural rises for the purpose of nutrient cycling and benthic production. The timing of these peaks is not strict but could follow reservoir inflows and what would be a natural pulse if water was to pass through a dam. The flow prescription would start at 500 cfs April 1 with an increase starting April 5 for a duration of 3 days and held at a peak of 1,500 cfs for a duration of 1 day. A second increase would start May 5 for a duration of 3 days and held at a peak of 3,000 cfs for a duration of 1 day. A third and fourth increase would start June 5 and July 5 held at 2,500 cfs and 1,500 cfs respectively for a duration of 1 day.

Nutrient Cycling – Benthic Winter (Unified, Reach 2, Dry, Table F-22)

Season: 01 November – 01 March
Events per season: 3
Magnitude: 500 – 3,500 cfs
Duration: 3 days
Duration of peak: 1 day

Table F-22. Nutrient Cycling - Benthic Winter Hypothetical Sample Schedule (cfs targets are estimates only)

Date	Duration (Days)	Peak (cfs)	D.O.P. (days)
November 5	3	1,500	1
January 1	3	3,000	1
February 25	3	2,500	1

Additional Details and Caveats: This prescription would only occur during a dry year. The unified prescription for a dry year includes a series of monthly small pulses in the winter used to mimic natural rises for the purpose of nutrient cycling and benthic production. The timing of these peaks is not strict but could follow reservoir inflows and what would be a natural pulse if water was to pass through a dam. The flow prescription would start at 500 cfs November 1 with an increase starting November 5 for a duration of 3 days and held at a peak of 1,500 cfs for a duration of 1 day. A second increase would start January 1 for a duration of 3 days and held at a peak of 3,000 cfs for a duration of 1 day. A third increase would start February 25 held at 2,500 cfs for a duration of 1 day.