Photograph of the Cossatot River, taken by Dustin Lynch (Arkansas Natural Heritage Commission).

COSSATOT RIVER AND GILLHAM LAKE, ARKANSAS, FLOW RECOMMENDATIONS AND WORKSHOP SUMMARY

Sustainable Rivers Program 2023

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Executive Summary

A flow recommendations workshop was held in June of 2022 and included subject matter experts from several State and Federal agencies. Each workshop group attendee was asked to identify flow needs for their Species of Greatest Conservation Need (SGCN) or the floodplain for three sections of the Cossatot, if applicable, which include the reach above Gillham Lake (Reach 0), the reach below the dam to the "Fall Line" (Reach 1), and the reach from the Fall Line to the Confluence of the Little River (Reach 2).

Overall flow recommendations include increased variability (flow pulses) during the periods of low flow, particularly during the summer months, for thermal refugia and to take out the flatness in the hydrograph. Low flows do not need to be built in artificially during normal precipitation years; the natural decrease in streamflows during the summer months is sufficient for ecological needs. In other words, low flows for fish benefit the interspecies interactions and competition and broadcast spawners. However, pulses need to occur even during the dry years. These pulses should occur 1 to 2 times per year, be 100 to 300 cfs, maybe up to 400 cfs, over 2 to 3 days to benefit the fisheries. Ouachita Mountain Shiner spawn season is during the summer months and those summer pulses are needed to sustain pools for species success. These summer pulses also benefit water willow enhancement and cut grass removal. Finally, if at all possible, flows need to remain above 20 cfs for temperature concerns. There will never be a need to reduce flow to a pre-dam natural flow of 0 cfs because the fish species within the Cossatot are unnaturally vulnerable. Furthermore, having a constant flow during any month, for example, a constant 1,500 to 3,000 cfs release during May, is unhealthy for the ecosystem.

One recommendation of utmost importance is high flows due to rain runoff need to recede quickly and not be drawn out. Lake elevations above 540 feet are potentially catastrophic for Leopard Darters, and, therefore, keeping lake levels below this critical elevation is necessary for Leopard Darter survival. Another beneficial recommendation is that during the months of July through September the flows should be kept at the minimum of the Water Control Manual (39 to 53 cfs). This would allow for volume build up (producing a volume neutral situation) in Gillham pool in order to provide the flow pulses later into the fall, dry season. The pulses could then be made during the low flows of September when the air temperatures are lower, and the Water Control Manual states flows can be released from Gillham at 39 cfs. Additionally, this pool build-up could provide the ability to bump the flow out of the dam if the DeQueen gage is reading 8,000 to 10,000 cfs.

Oxbow and floodplain connectivity flows should occur during the winter and early spring months (01 January to 28 February) when the flushing flows are needed for the stream clearing and channel maintenance. This would allow for all beneficial flood flows to occur at the same time. However, the only requirement during this time period would be to make sure there are enough peaks of 1 to 2 pulses of 8,000 to 15,000 cfs. These high-flow pulses could also occur during the tropical season, i.e., during the fall wet year when tropical season occurs during the months of August to November. However, and if at all possible, it is very important that no big flushing flows occur during the Leopard Darter spawning season of 01 March to 30 April. Maintenance flows should occur in the wet and average precipitation years and during the dry years, the 15,000 cfs flow could be lowered to 8,000 cfs. Even though these high flows might be infeasible, there is important ecosystem value in documenting them within a report such as this.

The following diagram (Figure 1) and table (Table 1) summarize the flow recommendations developed during the workshop. Table 1 provides the developed recommendations by reach, gives a brief description of the flow component associated with the recommendations, and the Gillham Dam operations that pertain to the outlined recommendations.

Figure 1. Diagram summarizing flow recommendations developed for the Cossatot River below Gillham Dam. Color coding matches the color coding for each flow component in Table 1.

Season	Summer	Fall	Winter	Spring
Floods	*Cossatot River, below Gillham Dam*	<u>Fall Seed Dispersal</u> ➢3,000 to 8,000 cfs ➢1:Multiple pulses within same season and from year to year ➢2-4 days •Disperse mast producing seeds onto the floodplain	<u>Channel Restructuring</u> ➢10,000 to 25,000 cfs ➢1:5 years ➢7 days with recession limb longer than rising limb •Sediment movement, berm renewal, and large woody debris recruitment •Create floodplain habitat through overbank erosion and deposition •High rain runoff may naturally serve as a pulse or supplement a pulse out of the dam •Magnitude based on whether it is a dry (10,000 cfs), average (~17,000 cfs), or wet year (25,000 cfs) <u>Channel Maintenance and Oxbow Connectivity</u> ➢8,000 to 15,000 cfs ➢1-4:1-4 years ➢7-10 days •To "clean-up" spawning beds, i.e., remove fines from interstitial spaces •Sediment movement, berm renewal, and large woody debris recruitment •"Water up" oxbows created by legacy channels to benefits fishes and other fauna that utilize oxbow habitat •High rain runoff may naturally serve as a pulse or supplement a pulse out of the dam •Magnitude based on whether it is a dry (8,000 cfs), average (~11,000 cfs), or wet year (15,000 cfs)	<u>Spring Seed Dispersal</u> ➢1,000 to 8,000 cfs ➢1:Multiple pulses within same season and from year to year ➢2-4 days •Disperse herbaceous seeds, such as ironwoods, elms, and cottonwoods onto the floodplain
Pulses	<u>Flushing Flows</u> ➢300 to 400 cfs ➢2-4:Annually ➢Recession rate of 50 cfs/day •Remove algae and regulate stream temperature •Promote Water Willow growth and Cut Grass removal •Sediment transport for bar development and new pools and riffles			
Low Flows	<u>Rabbitsfoot Fertilization and Infestation</u> ➢May 15-Jun 15: 150-250 cfs ➢30 days:Annually ▪ Mitigating prolonged high water and rapid releases <u>Rabbitsfoot Excystment</u> ➢Jun 1-Jul 1: 50-150 cfs ➢30 days:Annually ▪ Keep water levels from rising too high during this period while also preventing large releases from the reservoir	<u>Winged Mapleleaf and Long-term Brooders Fertilization</u> ➢Sep 21-Oct 31: 50 to 150 cfs ➢2-3 days:Annually ▪ Creating current for optimal fertilization for a duration of 2-3 days <u>Winged Mapleleaf Host Infestation</u> ➢Oct 20-Nov 10: 50 to 150 cfs ➢21 days:Annually ▪ Creating current for optimal fertilization for a duration of 2-3 days		<u>Long-term Brooders Host Infestation</u> ➢Apr 1-May 15: 100 to 500 cfs ➢7 days:Annually ▪ The duration of lower flows is more important than a high peak of a short duration with a short recession <u>Long-term Brooders Excystment</u> ➢May 1-Jun 1: 100 to 350 cfs ➢30 days:Annually ▪ Mitigating long duration, high flows is important <u>Winged Mapleleaf Excystment</u> ➢Apr 1-May 15: 100 to 350 cfs ➢30 days:Annually
	Jun Jul Aug	Sep Oct Nov	Dec Jan Feb	Mar Apr May

Table 1. Flow recommendations given for each flow component identified during the Cossatot River Workshop.

Reach	Season	E-Flow Component	Number of Events	Flow (cubic feet per second)	Duration	Frequency	Purpose
Reach 0	01 Mar to 30 Apr	Leopard Darter spawn season	365.5 - Gillham Lake elevation to stay below 540 feet	--	Every day	Annually	High flows due to rain runoff need to recede quickly and not be drawn out
Reach 1 and Reach 2	10 Jun to 31 Oct	Summer flushing flows	2-4 pulses with a recession rate of 50 cfs/day; high rain runoff may serve naturally as a pulse	300 to 400	2-3 days	Annually	Remove algae and regulate stream temperature; promote Water Willow growth and Cut Grass removal
Reach 1 and Reach 2	01 Jan to 28 Feb	Winter channel maintenance flows	1-2 pulses with a 7-day recession; high rain runoff may naturally serve as a pulse; magnitude based on whether it is a dry, average, or wet year	8,000 to 15,000	7-10 days	Every 2-3 years	To "clean-up" spawning bed, i.e., remove fines from interstitial spaces
Reach 2	21 Sep to 31 Oct	Long-term brooders fertilization	1-2 low-flow pulses	50 to 150	2-3 days	Annually	Help in reproduction /fertilization
Reach 2	01 Apr to 15 May	Long-term brooders host infestation	The duration of lower flows is more important than a high peak of a short duration with a short recession	100 to 500	7 days	Annually	Help in host infestation
Reach 2	01 May to 01 Jun	Long-term brooders excystment	Mitigating long duration, high flows is important	100 to 350	30 days	Annually	Allow enough time for the byssal thread to develop
Reach 2	15 May to 15 Jun	Rabbitsfoot fertilization and infestation	Mitigating prolonged high water and rapid releases	150 to 250	30 days	Annually	Help in reproduction/fertilization and host infestation

Reach 2	01 Jun to 01 Jul	Rabbitsfoot excystment	Need to keep water levels from rising too high during this period while also preventing large releases from the reservoir	50 to 150	30 days	Annually	Provide optimal habitat for juveniles to succeed
Reach 2	21 Sep to 31 Oct	Winged Mapleleaf fertilization	2-3 small pulses around 100 cfs (plus or minus 50 cfs) that last for 2 to 3 days	50 to 150	2-3 days	Annually	Creating current for optimal fertilization
Reach 2	20 Oct to 10 Nov	Winged Mapleleaf host infestation	--	50 to 150	21 days	Annually	Help in host infestation
Reach 2	01 Apr to 15 May	Winged Mapleleaf excystment	--	100 to 350	30 days	Annually	Support for juveniles to succeed
Reach 1 and Reach 2	01 Dec to 28 Feb	Channel restructuring	1 event during the frequency specified	10,000 to 25,000	7 days with recession limb longer than rising limb	Every 5 years	Sediment movement, berm renewal, and large woody debris recruitment
Reach 1 and Reach 2	01 Nov to 31 Dec	Fall seed dispersal	1 event during the frequency specified	3,000 to 8,000	2-4 days	Multiple pulses within same season and from year to year	Disperse mast producing seeds onto the floodplain
Reach 1 and Reach 2	01 Mar to 31 May	Spring seed dispersal	1 event during the frequency specified	1,000 to 8,000	2-4 days	Multiple pulses within same season and from year to year	Disperse herbaceous seeds, such as ironwoods, elms, and cottonwoods onto the floodplain
Reach 2	01 Dec to 28 Feb	Oxbow connectivity	3 to 5 events	5,000 to 20,000	7 days	Annually	"Water up" oxbows created by legacy channels to benefits fishes and other fauna that utilize oxbow habitat

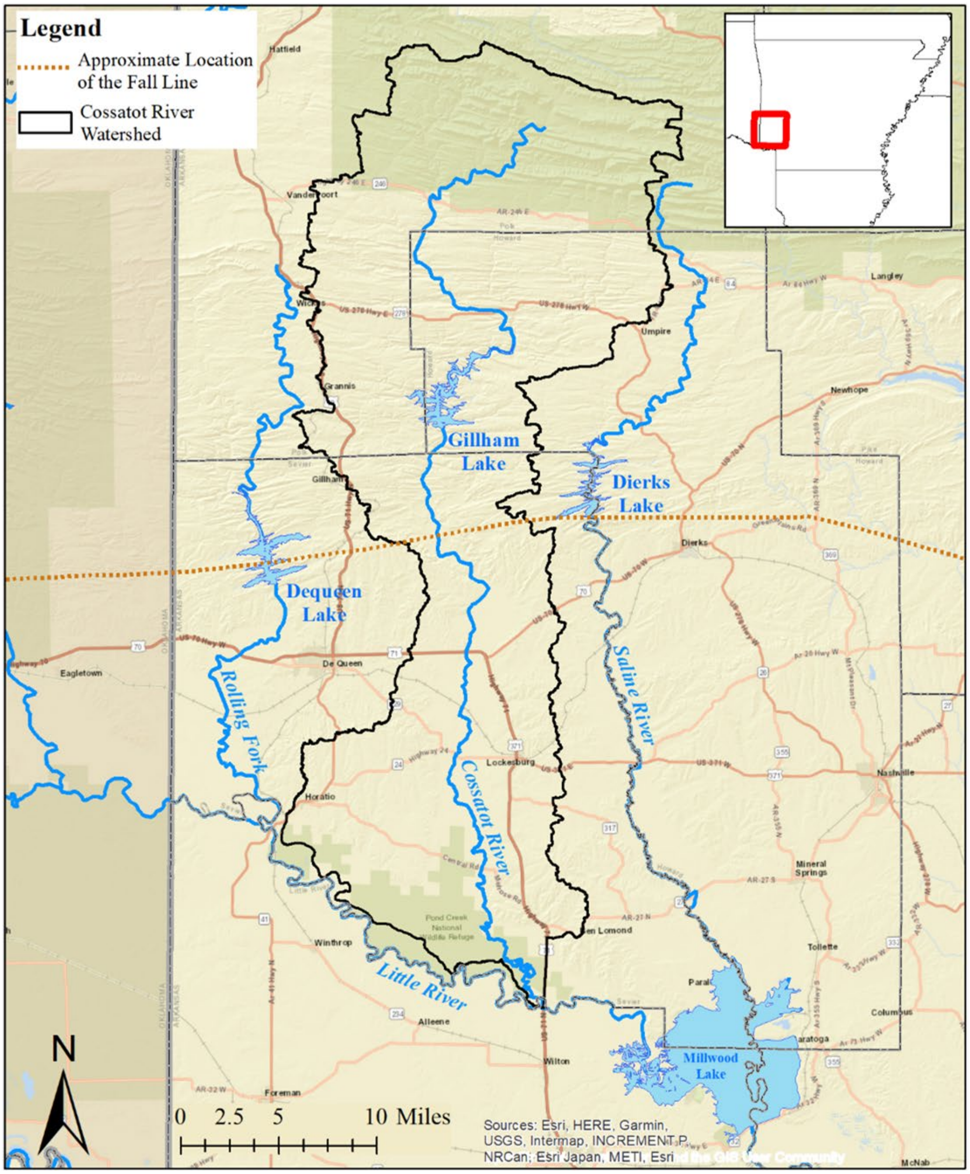
Introduction

Background

The Cossatot River is home to many unique, threatened and endangered species. For this reason, the Cossatot River was added to the Sustainable Rivers Program (SRP) in 2020, a cooperative program between the U.S. Army Corps of Engineers (USACE) and The Nature Conservancy (TNC), to recommend a dam reoperation plan for Gillham Dam, an impoundment of the Cossatot River. The goal of the SRP is to provide more ecologically based flows by identifying opportunities for dam reoperations while also supporting other congressionally authorized purposes, such as flood control. As part of the SRP process, a State of the Science and Literature report was completed in 2022 (Hart et al., 2022). After completion of the State of the Science report, a flow prescriptions workshop was held in early June of 2022 to develop environmental flow recommendations for the Cossatot River. This report details the recommendations from that workshop.

Cossatot River

The Cossatot River upstream of Gillham Lake is part of the National Wild and Scenic Rivers system and, along with its tributary Caney Creek, is designated as an Extraordinary Resource Water. Additionally, the Cossatot River upstream of Gillham Lake and its tributary Brushy Creek are designated as a Natural and Scenic Waterway (ANRC, 2018). The Cossatot River (herein referred to as simply "the Cossatot") is impounded by Gillham Dam to form Gillham Lake. Gillham Dam is located in Howard County, Arkansas, at mile 49 of the 89-mile-long Cossatot, approximately 6 miles northeast of Gillham, Arkansas (Figure 2). The reservoir has a storage capacity of 23,000 acre-feet (at a conservation pool elevation of 502 feet), provides 36 miles of shoreline, and drains approximately 273 square miles.



US Army Corps of Engineers

Figure 2. Map of the Cossatot River, its watershed, and Gillham Lake.

Environmental Flow Workshop

A flow recommendations workshop was held at Arkansas Game and Fish Commission (AGFC) Headquarters in Little Rock, Arkansas. There were approximately 25 attendees from TNC, AGFC, U.S. Fish and Wildlife Service (USFWS), Arkansas Department of Environmental Quality (ADEQ), Arkansas Natural Heritage Commission (ANHC), Arkansas Department of Agriculture - Natural Resources Division (ANRD), and the USACE. After brief introductions and technical presentations given by the USACE, the group was divided into three groups based on areas of expertise: Fish, Mussels, and Floodplain. Each group was asked to identify flow needs for their Species of Greatest Conservation Need

(SGCN) or the floodplain for three sections of the Cossatot, if applicable, which include the reach above Gillham Lake, the reach below the dam to the “Fall Line”, and the reach from the Fall Line to the Confluence of the Little River.

For each breakout group, a facilitator and an individual who ran the Regime Prescription Tool (HEC-RPT) were provided. The RPT software (http://www.hec.usace.army.mil/software/hec-rpt/) allows for the group to view hydrologic information and create flow recommendations on the fly. Hydrologic information was provided as daily streamflow for the regulated and unregulated time period. The regulated time period represented the actual, observed streamflows for the Cossatot below Gillham dam and the unregulated streamflows were developed through regression analysis using Random Forest (see Hart et.al, 2022, for a more detailed explanation) and represent the “natural”, predicted streamflows (Figure 3). Also provided in RPT were reservoir elevations; these were important for developing flow recommendations for the reach above Gillham Lake.

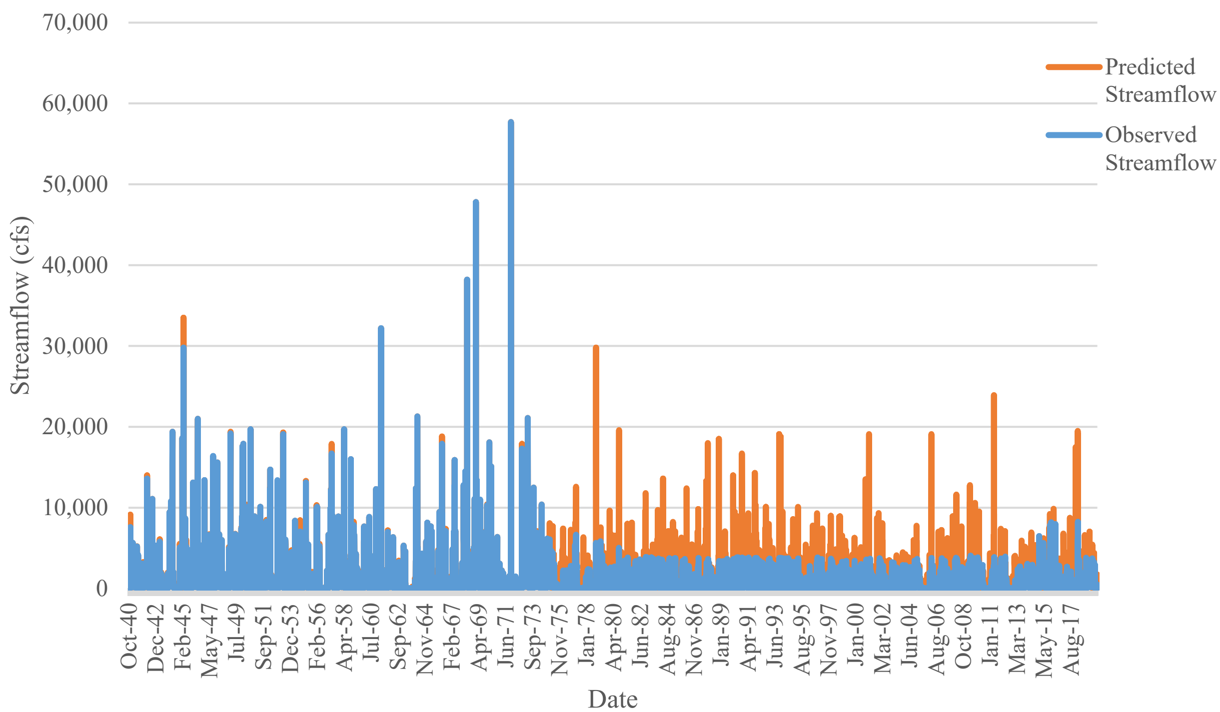


Figure 3. Observed and predicted streamflow representing the regulated and unregulated time period, respectively, for use in the Regime Prescription Tool to guide in the development of environmental flow recommendations for the Cossatot River.

Workshop Results

Fish

There are six fish SGCN that reside within the Cossatot River. They are the threatened Leopard Darter (Percina pantherina), Ouachita Mountain Shiner (Lythrurus snelsoni), Blackspot Shiner (Notropis atrocaudalis), Kiamichi Shiner (Notropis ortenburgeri), Rocky Shiner (Notropis suttkusi), and Western Starhead Topminnow (Fundulus blairae). These fish are microhabitat specialists and very prey selective. Therefore, the Fish Breakout Group focused on these rare and important fish and their environmental flow needs. In particular, the Leopard Darter, which is endemic to the Little River watershed and is, by far, the most imperiled fish species in the Cossatot. This species is now found in the watershed primarily above Gillham Lake and was listed by the USFWS as threatened under the Endangered Species Act because the species' habitat has been eliminated due to impoundment of reservoirs, such as Gillham Lake in Arkansas and others in Oklahoma (USFWS 1978). The most important management action for the conservation of Leopard Darter is to minimize days of reservoir flooding during the spawning season above Gillham Lake. Carlisle et al. (2010) found that biologically impaired fish sites had maximum streamflows less than 0.4 of the expected value. Impairment was also likely for sites with minimum streamflows less than 0.4 or greater than 1.8 of the expected value (pre-dam).

Downstream of Gillham Dam, to sustain the Leopard Darter, other darters, and shiners, i.e., the Ouachita Mountain Shiner, pulse flows are needed during the summer and channel maintenance flows are needed during the winter. The typical low flows during the summer need pulses to take out the "flatness" in the hydrograph. It is recommended that there be 2 to 4 summer pulses with a magnitude of 300 to 400 cubic feet per second (cfs) with a 7-day recession; high-rain runoff may naturally serve as a summer pulse flow (Figure 1; Table 1). However, it has been determined that a high May mean flow (e.g., greater than 1,500 cfs) is negatively associated with Leopard Darter spawning success. Therefore, the summer pulses must occur after the Leopard Darter spawning season (i.e., after 30 April) and after the May critical period for egg and larval development. These rare Cossatot River fish species heavily favor beds of Water Willow (Justicia americana), which has been replaced by Rice Cut Grass (Leersia oryzoides) in parts of the watershed. Flushing flows during the late spring and summer are very important for removing sediment that favors the grass, while also removing siltation and clearing out the interstitial spaces used by Leopard Darters in spawning. Furthermore, these pulses provide thermal refuge, physically remove filamentous algae, and benefit redhorses (Moxostoma sp.) as well, which are important fish for mussel survival (discussed further in the Mussels section).

In addition to the annual summer pulses, winter channel maintenance flow for fish communities needs to occur every 2 to 3 years to clean sediments from spawning beds. Again, a high-rain runoff may naturally serve as a winter channel maintenance flow. These flows need to be large enough to cause boulder moving conditions (i.e., flows large enough to cause D85 movement) and to also move debris and detritus, breakup woody debris, and prepare the beds for spawning. The magnitude of this flow would be determined based on whether it is a dry, average, or wet precipitation year. For example, if it is a dry year, the lower end of the suggested magnitude would be used for the channel maintenance flow, i.e., 8,000 cfs and if it is a wet year, the higher end of the magnitude would be used, i.e., 15,000 cfs. However, it has been determined that a negative correlation exists between species abundance and a hydrograph recession rate of 1,500 cfs, or greater, per day. Therefore, it is recommended there be a recession of 500 cfs per day from any pulse peak. So, in summary, two peaks of 8,000 to 15,000 cfs, every 2 to 3 years, would be ideal to provide channel maintenance conditions with several, 2 to 4, more frequent peaks of 300 to 400 cfs, occurring annually, during the summer flushing period (Figure 1; Table 1).

Leopard Darter Spawn Season

Generally, 80 percent of the population turns over every year. Therefore, it is imperative that conditions are maintained to increase the survival rate every year, since the lifespan of the Leopard Darter is only 2 years. As previously mentioned, high May mean flow is negatively associated with Leopard Darter spawning success, and it is critically important to have good spawning zones the years following a big flood. Therefore, a winter channel maintenance flow needs to occur every couple of years and small summer pulses (2 to 4) are needed to clean sediments from spawning beds.

Gillham Lake

Higher lake elevations in the spring spawning season (15 March to 30 April) are detrimental to the Leopard Darter because the lake floods spawning riffles. The most important management action for conservation of Leopard Darters is to minimize days of reservoir flooding during the spawning season above Gillham Lake. At elevations greater than 540 feet, spawning riffle habitat rapidly disappears above Gillham Lake, and stages above 540 feet during the spawning season risk extirpating the species from the river. Spawning habitat starts being degraded at elevations above 515 feet. Stages above 520 feet in Gillham Lake inundates Harris Creek (tributary to the Cossatot) and eliminates spawning habitat for one of two known locations for the Leopard Darter. It is important for Gillham Lake pool to remain below 510 feet elevation during the summer growth period. If at all possible, there must be zero days where Gillham Lake elevation exceeds 540 feet during the spawning period (Figure 1; Table 1), and it would be ideal if Gillham Lake elevation could maintain 510 feet elevation and below during the summer. For Leopard Darter conservation efforts to be successful, the number of days that Gillham Lake exceeds 540 feet needs to be minimized during the spawning season.

Reach 1

Since the Leopard Darter are near extirpation or possibly extirpated from the Cossatot River below Gillham Dam, the following recommendations are given on the chance the species can successfully be reintroduced. Small tributaries (e.g., Carter's Creek) of the Cossatot above the fall line often contribute substantially to the largest flood peaks in this reach. High flows due to large precipitation runoff need to recede quickly and not be drawn out. Furthermore, having a constant flow during any month, for example, a constant 1,500 to 3,000 cfs release during May, is unhealthy for the ecosystem. Maintaining Water Willow is good for the species, so flow recommendations (see the Floodplain section) for Water Willow will be given, as well. Uncertainty remains about what exactly is the ideal spawning flow condition for the Leopard Darter; however, the natural, pre-dam conditions show a flashy hydrograph during the spawn period.

Reach 2

Again, since Leopard Darters may be extirpated or near extirpation from the Cossatot below Gillham Dam, the following recommendations are given on the chance the species can successfully be reintroduced. High flows due to large precipitation runoff need to recede quickly and not be drawn out. As with Reach 1, maintaining Water Willow is good for the species.

Ouachita Mountain Shiner Spawn Season

The Ouachita Mountain Shiner spawn season is during the summer months of May to late July and prefers deep and narrow pools. However, there is less known about this species than other species within the Cossatot, and, therefore, flow recommendations will be given to support this type of habitat, such as, 2 to 4 summer pulses to sustain the pools. This species is also dependent on Water Willow enhancement for success and cut grass removal, which can be achieved through winter channel maintenance flows and the summer flushing flows (Figure 1; Table 1).

Reach 1

As with the Leopard Darter, the Ouachita Mountains Shiner needs any flood event to recede quickly. The species does not do well with constant, drawn-out high flows from 1,500 to 3,000 cfs. Natural, pre-dam conditions indicate flows below 14 cfs during spawning. However, in order to not affect the other species of concern within the Cossatot, i.e., the mussels, it is recommended that flows stay at or above the minimum flow given in the Water Control Manual. For dry years, a tradeoff is recommended for high flows in the spring to maintain pulses throughout the year.

Reach 2

As with Reach 1, any flood event needs to recede quickly. The Ouachita Mountain Shiner does not do well with drawn out high flows. Natural, pre-dam conditions indicate flows below 14 cfs during spawning. However, in order to not affect the other species of concern within the Cossatot, i.e., the mussels, it is recommended that flows stay at or above the minimum flow given in the Water Control Manual. For dry years, a tradeoff is recommended for high flows in the spring to maintain pulses throughout the year.

Mussels

Life cycles and life history traits of freshwater mussels are extremely complex. The three critical periods for mussel survival include excystment, fertilization, and host infestation, in decreasing order of importance. The spawning strategy for freshwater mussels is unique in that males release sperm into the water column collected by females during normal siphoning. Upon fertilization, embryos develop into glochidia; this period of gravidity is also called brooding. Generally, mussels are categorized into short-term and long-term brooders. Typically, short-term brooders spawn, brood, and release glochidia over a 2 to 6-week time period in late spring or summer, while long-term brooders spawn in late summer or early fall, brood eggs over winter and release glochidia the following spring to summer. Therefore, when implementing flow recommendations, these periods of mussel development need to be considered.

Long-term brooders within the Cossatot include the Ouachita Rock Pocketbook, Pink Mucket, and Scaleshell mussels; the short-term brooders include the Rabbitsfoot and the Winged Mapleleaf mussels, all of which, are federally listed mussels of conservation concern in the Cossatot. For the purpose of assigning environmental flow prescriptions for the Cossatot, the long-term brooders were grouped under one broad category and environmental flow recommendations were given based on their life cycles of fertilization, host infestation, and excystment. The short-term brooders were broken out by specific species and their life cycles of excystment and fertilization with environmental flow recommendations given for each species and life cycle. Because the mussels of concern within the Cossatot exist only below the Fall Line, flow recommendations are only given for Reach 2.

For mussels in the Little River system natural mortality events are rare, only around 1 percent. Examples of mortality events include major predation and dewatering of the mussel beds. Water temperatures must be extreme for them to have an effect on mortality; minimum temperatures do not have much of an effect except changing cues for reproduction. Overall mussel recruitment is low and, therefore, the ideal water conditions need to be achieved most of the time during average precipitation years to benefit the species. So, in the case of reservoir management, during dry precipitation years, and if available, more water needs to be added to the system below the dam to sustain the population. Furthermore, in general, short-term brooders are less affected by dam operations and long-term brooders are more affected by dams and operations. Also, to note, the only time turbidity might be an issue is if the host fish cannot see the mantle (aka, the “lure”) and would not be drawn into close proximity to a mussel where the glochidia could attach to the host.

Long-term brooders fertilization

The long-term brooders fertilization period occurs during late September through the end of October. It has been observed that a flow around 105 cfs is a good flow for the Ouachita Rock Pocketbook, which is one of the long-term brooders found in the Cossatot. So, maintaining flows at or above 105 cfs is ideal for this species, and other long-term brooders, success. As with the fish SGCN, 2 to 4 low-flow pulses of at least an increase of 50 cfs, but not more than an increase of a 150 cfs, are ideal for the long low-flow periods, which coincides with the long-term brooder fertilization period. These low-flow pulses need to last for 2 to 3 days in order to help these long-term brooders in successful reproduction (Figure 1; Table 1).

Long-term brooders host infestation

Long-term brooder host infestation occurs when water temperatures reach approximately 61 degrees Fahrenheit (F) (16 degrees Celsius (C)) and during the time period of 01 April to 15 May. Furthermore, if water temperatures are below 59 degrees F (15 degrees C), the mussels are not actively trying to attract fish, and infestation really picks up around 64 degrees F (18 degrees C). During this period, the duration of lower flows is more important than a high peak of a short duration with a short recession (Figure 1; Table 1).

Long-term brooders excystment

Long-term brooders excystment occurs from the beginning of May to the beginning of June, when water temperatures reach 68 degrees F (20 degrees C), and, typically, 20 days after infestation. The excystment period is the most critical period for mussel survival. The mussels need to be in the right habitat without having a large flow event that flushes them out of their critical habitat. After a month, the juvenile should be developed enough to have a byssal thread in order to stay attached to the substrate. Therefore, during the period before the byssal thread develops, mitigating for long duration, high flows is important during this critical stage of their life cycle.

Rabbitsfoot fertilization and infestation

Rabbitsfoot fertilization is triggered by water temperature and varies by population, but generally occurs from mid-May to mid-June. Furthermore, the correct water pressure and velocity triggers sperm release. Once these variables are met, a lower flow is needed. Rabbitsfoot fertilization can be strained by prolonged high water and a rapid release. Therefore, a flow of 150 to 250 cfs is recommended during this critical period of their life cycle (Figure 1; Table 1). Furthermore, there is no explicitly defined infestation period for these short-term brooders; it is such a short-term time frame from fertilization, infestation, and excystment, that infestation was lumped with fertilization for flow recommendations. The primary host for the Rabbitsfoot is a shiner, which are edge dwellers. It can take up 10 to 15 days for glochidia to mature for attachment to the host fish and some flow is needed for the conglutinate process to occur for these short-term brooders.

Rabbitsfoot excystment

Rabbitsfoot excystment is the period when the juveniles fall off the host fish and is the most critical part of the mussel's life cycle. This period occurs from the first of June through the first of July and host interaction is key. Once a host is infested it takes 10 to 15 days for the juveniles to fall off the host fish. Streamflows need to be low when the juveniles fall off, so they are not swept downstream. As mentioned previously, the host fish is a shiner, which is an edge dweller, and, therefore, when the juveniles are released, it will be along the margins of the river. This is important to note. If the water level is too high during this period, the edges of the stream will go dry after the river recedes, killing the juveniles. Conversely, if the habitat happens to be optimal and there is a large precipitation event, a large release from the reservoir might flush the juveniles out of the optimal habitat into a non-optimal location for survival. Currently, the Water Control Manual has a minimum flow of 52 cfs in June which should suffice for all the short-term brooders excystment.

Winged Mapleleaf fertilization

Winged Mapleleaf fertilization is extremely sensitive to water temperature and occurs in late September through late October. However, it has been documented that the earliest gravid day occurred on 12

October at 66 degrees F (19 degrees C) and the latest was 08 November. This indicates that water temperatures need to be greater than 66 degrees F (19 degrees C) for Winged Mapleleaf fertilization to occur. In general, fertilization occurs around 68 degrees F (20 degrees C) with a low threshold of 62 to 63 degrees F (16.7 to 17.2 degrees C), where they are no longer found gravid. It would be ideal to have 2 to 3 small pulses around 100 cfs (plus or minus 50 cfs) that last for 2 to 3 days for these and the other long-term brooders (Figure 1; Table 1); this action is more about creating current for optimal fertilization than creating water depth.

Winged Mapleleaf host infestation

Winged Mapleleaf host infestation occurs in late October through mid-November. Streamflows should be between 50 and 150 cfs during this period of the mussels' life cycle. Host infestation occurs in the tail end of the pool, in the glide area where current velocities begin to increase due to the transition from a pool to a riffle.

Winged Mapleleaf excystment

Winged Mapleleaf excystment is thought to occur during the spring from the beginning of April through mid-May (Figure 1; Table 1). However, not much is known about this period of the Winged Mapleleafs' life cycle, and, therefore, the temperature transformation rate is unknown. However, it is known that the Winged Mapleleafs' host fish are catfish, which are not as sensitive to changes in flows since they are bottom dwellers.

Floodplain

Small, regular floods help to restore floodplain connectivity and have many ecological benefits. There are other key ecological dynamics related to flooding in addition to providing connectivity to the floodplain. These include channel restructuring, reestablishing connectivity to oxbows, flushing of sediment, nutrient introduction, seed dispersal, and recruiting large woody debris. These dynamics should be occurring at or above a 1.5 to 2-year recurrence flood interval. Additionally, intra- and inter-year sequences and contingencies are important for these floodplain dynamics. Another major opportunity to manage river flows for the Cossatot is to encourage establishment of grasses and pioneer tree species like willows and cottonwoods. Therefore, a major goal would be to create a more vegetated bank, which would, in turn, provide more habitat and cover for other species, including fish.

Floodplain flow recommendations for the Cossatot are focusing on habitat and ecological benefits, including floodplain connectivity in the spring and fall for dispersal of seeds onto the floodplain; connection of oxbows with larger flow pulses to allow for nutrient enrichment and to keep the rice cut grass under control during the winter; and the scouring and movement of sediment and channel restructuring with larger flow pulses also during the winter. If adequate flow exists, floodplain ecological needs should be attained, if possible, without sacrificing the needs or requirements of the fish and mussel SGCN. For all flow recommendation, a main goal would be to get the water up quick with a sharp rising limb of the hydrograph and then step the falling limb down. During wet precipitation years, this process might take 2 weeks to step the falling limb down. Also for consideration is the opportunity to achieve higher river flows by following a natural flow paradigm. When seasonally appropriate, if there is operational room to combine maximum releases from Gillham Dam with tributary contributions, higher flows could be achieved without causing problematic inundation. However, for this to be accurately accomplished, additional hydraulic and hydrologic expertise, modeling, and/or more real-time data from tributaries must be obtained. This opportunity would most likely be pronounced during winter to early spring high flows season.

Water quality is always a concern when considering flow recommendations. Known water quality concerns for the Cossatot include anoxic hypolimnetic releases from Gillham Lake and iron precipitate which has been detected approximately 3 miles below Gillham Dam at Mize Crossing.

Fall Seed Dispersal

Mast producing seeds predominantly occur in the fall. Therefore, for fall seed dispersal, one pulse is likely enough to accomplish this seed dispersal dynamic during average precipitation years. However, additional pulses are not anticipated to have negative effects for this component. The streamflow duration should be relatively brief, i.e., no more than 7 days, however, a shorter duration would be more beneficial, i.e., 2 to 4 days. It is important to note that there is more tolerance to inundation for the fall seed dispersal species as the season goes later into fall. Variability is highly important with multiple pulses occurring within the same season and also from year to year. Furthermore, changing the number of pulses from year to year is also good for seed dispersal. Again, this adds variability.

There are separate, unique streamflow and ecological dynamics for reach 1, below the Dam to the 'fall line', and for reach 2, from the 'fall line' to the confluence. For reach 1, the ecological dynamics are accomplished, predominantly within the narrow stream channel and floodplain because of the geomorphology of the system. For reach 2, the ecological dynamic is accomplished as the river overtops its banks and engages the wider floodplain. However, actual flow rates where this occurs varies spatially and is uncertain and needs further investigation.

The recommended flows for seed dispersal should be between 3,000 to 8,000 cfs (Figure 1; Table 1), which is the expected initial inner berm. Finally, for wet precipitation years, the number of events, magnitude, and duration of events should be more than average years, but all the environmental-flow components are still pertinent.

Spring Seed Dispersal

Herbaceous seeds occur mostly in the spring and some plant fragments are also still viable. This environmental dynamic is also beneficial for some wind dispersed spring seed producing trees such as ironwoods, elms, and cottonwood. Therefore, for spring seed dispersal, one pulse is likely enough to accomplish this seed dispersal dynamic during average precipitation years. However, additional pulses are not anticipated to have a negative effect for this component. The streamflow duration should be relatively brief, i.e., no more than 7 days, however, a shorter duration would be more beneficial, i.e., 2 to 4 days. Variability is highly important with multiple pulses occurring within the same season and also from year to year. Furthermore, changing the number of pulses from year to year is also good for seed dispersal. Again, this adds variability. However, a shorter duration may be more critical in spring than fall because plant communities are in active growing season. for average years, number of events, magnitude, and duration of events should be less than wet, but the e-flow components are still pertinent.

The recommended flows for seed dispersal should be between 1,000 to 8,000 cfs (Figure 1; Table 1). Streamflow around 1,000 cfs starts to engage lower parts of inner berm and streamflow around 3,000 cfs engage the expected initial inner berm. These ranges in streamflows are important for seed dispersal dynamics as these flows would be depositing seeds onto different parts of the floodplain. However, there is uncertainty in how these streamflows translate into inundation. Finally, for wet precipitation years, the number of events, magnitude, and duration of events should be more than average years, but all the environmental-flow components are still pertinent.

Channel Restructuring

The ecological purpose for channel restructuring is for sediment movement, berm renewal, and large woody debris recruitment. The streamflow ranges for this important ecological dynamic are based on a 5-year recurrence interval which is approximately 25,000 cfs (Figure 1; Table 1). The streamflow events needed could be isolated and independent or clustered with multiple spikes, and it would be okay to have multiple high flow events. One thing to note is that the recession limb of the hydrograph should be longer than the rising limb and should probably occur during the winter months to coincide with other ecological benefits.

Scour Event

The ecological purpose of a scour event is to discourage herbaceous encroachment in the stream channel, specifically in regard to maidencane. Maidencane is a perennial grass that occurs from New Jersey to Texas, forms dense stands in channel areas, and is displacing other plant species within the channel. Therefore, the main goal of a scour event is to remove or discourage establishment of maidencane. There is not a high streamflow ceiling for this component, therefore, the recommendation would be to create more favorable conditions for water willow and other aquatic plants. Maidencane is water dependent, however, it needs to be determined whether the plant is promoted during dry conditions. In other words, it needs to be determined whether low flows encourage establishment or whether seed dispersal events in dry or even average precipitation years promote maidencane through distribution of viable plant materials, rhizomes, seeds, etc. Additionally, during dry precipitation periods, a scour event is important to cut down on the rice cut grass.

Oxbow Connectivity

Oxbow connectivity within the Cossatot occurs primarily in reach 2, from the 'fall line' to the confluence. The primary ecological goal is to "water up" oxbows created by legacy channels to benefit fishes and other fauna that utilize oxbow habitat. Streamflow pulses should be brief to allow floodplain soils to drain sufficiently and to avoid stress to the floodplain vegetation communities. Streamflow duration is more important to fish assemblages and proximity from oxbow to the stream channel. Other fauna benefit more from just watering up the oxbows. In terms of frequency of the events, 3 to 5 separate flows that engage oxbows would be sufficient or even fewer flow events with extended connectivity, though this could be problematic for floodplain soils. Additionally, there would be additional ecological benefits for one or more of the pulses to have a longer duration and perhaps higher magnitude to maximize oxbow connectivity. Connection of oxbows with larger pulses would allow for nutrient enrichment during the late summer. Therefore, it is recommended that there be 3 to 5 pulses of 5,000 to 20,000 cfs (Figure 1; Table 1).

Overall Flow Recommendations

Overall flow recommendations include increased variability (flow pulses) during the periods of low flow, particularly during the summer months, for thermal refugia and to take out the flatness in the hydrograph. Low flows do not need to be built in artificially during normal precipitation years; the natural decrease in streamflows during the summer months is sufficient for ecological needs. In other words, low flows for fish benefit the interspecies interactions and competition and broadcast spawners. However, pulses need to occur even during the dry years. These pulses should occur 1 to 2 times per year, be 100 to 300 cfs, maybe up to 400 cfs, over 2 to 3 days to benefit the fisheries. Ouachita Mountain Shiner spawn season is during the summer months and those summer pulses are needed to sustain pools for species success. These summer pulses also benefit water willow enhancement and cut grass removal. Finally, if at all possible, flows need to remain above 20 cfs for temperature concerns. There will never be a need to reduce flow to a pre-dam natural flow of 0 cfs because the fish species within the Cossatot are unnaturally vulnerable. Furthermore, having a constant flow during any month, for example, a constant 1,500 to 3,000 cfs release during May, is unhealthy for the ecosystem.

One recommendation of utmost importance is high flows due to rain runoff need to recede quickly and not be drawn out. Lake elevations above 540 feet are potentially catastrophic for Leopard Darters, and, therefore, keeping lake levels below this critical elevation is necessary for Leopard Darter survival. Another beneficial recommendation is that during the months of July through September the flows should be kept at the minimum of the Water Control Manual (39 to 53 cfs). This would allow for volume build up (producing a volume neutral situation) in Gillham pool in order to provide the flow pulses later into the fall, dry season. The pulses could then be made during the low flows of September when the air temperatures are lower, and the Water Control Manual states flows can be released from Gillham at 39 cfs. Additionally, this pool build-up could provide the ability to bump the flow out of the dam if the DeQueen gage is reading 8,000 to 10,000 cfs.

Oxbow and floodplain connectivity flows should occur during the winter and early spring months (01 January to 28 February) when the flushing flows are needed for the stream clearing and channel maintenance. This would allow for all beneficial flood flows to occur at the same time. However, the only requirement during this time period would be to make sure there are enough peaks of 1 to 2 pulses of 8,000 to 15,000 cfs. These high-flow pulses could also occur during the tropical season, i.e., during the fall wet year when tropical season occurs during the months of August to November. However, and if at all possible, it is very important that no big flushing flows occur during the Leopard Darter spawning season of 01 March to 30 April. Maintenance flows should occur in the wet and average precipitation years and during the dry years, the 15,000 cfs flow could be lowered to 8,000 cfs. Even though these high flows might be infeasible, there is important ecosystem value in documenting them within a report such as this.

Recommendations for Future Studies

As this was the first attempt at defining flow recommendation for the Cossatot, there are several recommendations for future studies that were presented during the workshop. Flow recommendations were not made for any terrestrial animals, and, therefore, it would be beneficial to have the input from bird, amphibian, and reptile experts to better define flows needed for those species' success. Modeling work from an entity such as the Corps' Hydrology and Hydraulics Section would be beneficial for better defining flow magnitudes for all flow components. For example, the floodplain group identified that the fall seed dispersal dynamic is accomplished as the river overtops its banks and engages the floodplain. However, the actual flow rates where this dynamic occurs varies spatially and is uncertain.

Harperella is a SGCN within the State. It is unknown of the location of this plant species in or near the Cossatot. Therefore, flow recommendations were not made for this particular species of concern. Identifying the location and defining flow recommendation for Harperella are recommended. Furthermore, a better understanding of all vegetation distribution below the Dam would help in defining future flow recommendations for the floodplain.

The larvae drift of Leopard Darter is unknown and knowing this part of the fish's life cycle could help in defining better flow recommendations. Additional fish data would include a better understanding of the life history of the Ouachita and Kiamichi Shiner and the Black-Spotted Shiner. Also, knowing the Rocky Shiner presence, distribution, and life history would be beneficial to the other SGCN within the Cossatot.

In order for any success to be measured, there is a need for pre-implementation surveys to determine whether the recommended changes in management are working. Therefore, a detailed monitoring program, including adaptive management strategies, needs to be defined and implemented to measure success. Additionally, to determine whether the defined flow recommendations are successful, it is recommended that instream incremental flows of mussel beds, fish habitat, species abundance and detection, etc. be monitored. It is also recommended that monitoring includes additional Dissolved Oxygen and temperature.

Conclusions

It is suspected that it should take 1 to 3 years to implement flow recommendations for the Cossatot. To further the implementation process, an implementation checklist was created specifying the criteria and enabling conditions needed for the recommended flow conditions to occur, as well as a means to capture whether the recommended flow was implemented (Appendix A). After implementing the developed flow recommendations, it is suggested that the recommendations be incorporated into the Gillham Lake Water Control Manual as an addendum or something similar. Additionally, annual follow-ups should occur to share whether the changes in management are working and who should be involved in future follow-ups. The hopes are that this workshop summary and flow recommendations report will be used as a stepping point for the continued involvement of other organizations and stakeholders.

References

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Appendix A: Implementation Checklist

Environmental flow recommendations formulated in the June 2022 workshop were reviewed by Little Rock District staff to identify implementation opportunities and feasibilities. Each environmental flow component (Figure 4) was considered in terms of the "criteria" (water volumes needed) and the "enabling conditions" that would be conducive to making environmental flow releases (Table 2). Several of the components that required higher flow were less feasible due to the physical outlet works of Gillham Dam (see dark gray shading, Figure 4 and Table 2). Most components were deemed feasible given the right combination of water availability and enabling conditions (see light gray shading, Figure 4 and Table 2). This appendix relates workshop recommendations to water management decision making. It is intended as a bridge between environmental flows formulation and implementation.

Season	Summer	Fall	Winter	Spring
Floods	*Cossatot River, below Gillham Dam*	Fall Seed Dispersal ➢3,000 to 8,000 cfs ➢1:Multiple pulses within same season and from year to year ➢2-4 days •Disperse mast producing seeds onto the floodplain	Channel Restructuring ➢10,000 to 25,000 cfs ➢1:5 years ➢7 days with recession limb longer than rising limb •Sediment movement, berm renewal, and large woody debris recruitment •Create floodplain habitat through overbank erosion and deposition •High rain runoff may naturally serve as a pulse or supplement a pulse out of the dam •Magnitude based on whether it is a dry (10,000 cfs), average (~17,000 cfs), or wet year (25,000 cfs) Channel Maintenance and Oxbow Connectivity ➢8,000 to 15,000 cfs ➢1-4:1-4 years ➢7-10 days •To "clean-up" spawning beds, i.e., remove fines from interstitial spaces •Sediment movement, berm renewal, and large woody debris recruitment •"Water up" oxbows created by legacy channels to benefits fishes and other fauna that utilize oxbow habitat •High rain runoff may naturally serve as a pulse or supplement a pulse out of the dam •Magnitude based on whether it is a dry (8,000 cfs), average (~11,000 cfs), or wet year (15,000 cfs)	Spring Seed Dispersal ➢1,000 to 8,000 cfs ➢1:Multiple pulses within same season and from year to year ➢2-4 days •Disperse herbaceous seeds, such as ironwoods, elms, and cottonwoods onto the floodplain
Pulses	Flushing Flows ➢300 to 400 cfs ➢2-4:Annually ➢Recession rate of 50 cfs/day •Remove algae and regulate stream temperature •Promote Water Willow growth and Cut Grass removal •Sediment transport for bar development and new pools and riffles			
Low Flows	Rabbitsfoot Fertilization and Infestation ➢May 15-Jun 15: 150-250 cfs ➢30 days:Annually ▪ Mitigating prolonged high water and rapid releases Rabbitsfoot Excystment ➢Jun 1-Jul 1: 50-150 cfs ➢30 days:Annually ▪ Keep water levels from rising too high during this period while also preventing large releases from the reservoir	Winged Mapleleaf and Long-term Brooders Fertilization ➢Sep 21-Oct 31: 50 to 150 cfs ➢2-3 days:Annually ▪ Creating current for optimal fertilization for a duration of 2-3 days Winged Mapleleaf Host Infestation ➢Oct 20-Nov 10: 50 to 150 cfs ➢21 days:Annually ▪ Creating current for optimal fertilization for a duration of 2-3 days		Long-term Brooders Host Infestation ➢Apr 1-May 15: 100 to 500 cfs ➢7 days:Annually ▪ The duration of lower flows is more important than a high peak of a short duration with a short recession Long-term Brooders Excystment ➢May 1-Jun 1: 100 to 350 cfs ➢30 days:Annually ▪ Mitigating long duration, high flows is important Winged Mapleleaf Excystment ➢Apr 1-May 15: 100 to 350 cfs ➢30 days:Annually
	Jun Jul Aug	Sep Oct Nov	Dec Jan Feb	Mar Apr May

Figure 4. Diagram summarizing flow recommendations developed for the Cossatot River below Gillham Dam. Color coding matches the color coding for each flow component in Table 2.

Table 2. Flow recommendations given for each flow component identified during the Cossatot River Workshop. Also given, the criteria and enabling conditions that would be conducive to making environmental flow releases.

Flow Recommendations							Implementation		
Reach	Season	E-Flow Component	Number of Events	Flow (cfs)	Duration	Frequency	Criteria	Enabling Conditions	Did it happen? Yes or No? When?
Reach 1 and Reach 2	10 Jun to 31 Oct	Summer flushing -- Remove algae and regulate stream temperature	2-4 pulses with a recession rate of 50 cfs/day; high rain runoff may serve naturally as a pulse	300-400	2-3 days	Annually	880 to 2,630 acre-feet needed per pulse; 0.5-1% of flood storage 2,630 acre-feet to ensure 3 minimum pulses; 1.4% of flood storage	HW Elevation 502.74 – 504.18 feet No deviation if using rainfall event HW Elevation 504.19 feet Deviation required to capture once for season	
Reach 2	21 Sep to 31 Oct	Long-term brooders fertilization	1-2 low-flow pulses	50-150	2-3 days	Annually	44 to 480 acre-feet needed per pulse; 0.02-0.4% of flood storage	HW Elevation 502.04 – 502.66 feet No Deviation	

Reach 2	01 Apr to 15 May	Long-term brooders host infestation	Lower flow duration is more important than a high peak of a short duration with a short recession	100- 500	7 days	Annually	1,390 to 6,940 acre-feet; 1-4% of flood storage	HW Elevation 503.17 – 507.27 feet Deviation maybe required; refer to temp requirements Note possible overlap with next prescription	
Reach 2	01 May to 01 Jun	Long-term brooders excystment -- Allow enough time for the byssal thread to develop	Mitigating long duration, high flows is important	100- 350	30 days	Annually	5,950 - 20,825 acre-feet; 3-11% of flood storage	HW Elevation 506.6 – 515.60 feet Deviation required	
Reach 2	15 May to 15 Jun	Rabbitsfoot fertilization and infestation	Mitigating prolonged high water and rapid releases	150-250	30 days	Annually	8,920 - 14,875 acre-feet; 5-8% of flood storage	HW Elevation 508.57 -512.23 feet Deviation required	

Reach 2	01 Jun to 01 Jul	Rabbitsfoot excystment -- Provide optimal habitat for juveniles to succeed	Need to keep water levels from rising too high during this period while also preventing large releases from the reservoir	50-150	30 days	Annually	2,975 - 8,924 acre-feet; 2-5% of flood storage	HW Elevation 504.46 - 508.57 feet Deviation required	
Reach 2	21 Sep to 31 Oct	Winged Mapleleaf fertilization -- Creating current for optimal fertilization	2-3 small pulses around 100 cfs (plus or minus 50 cfs)	50-150	2-3 days	Annually	2,975 - 8,924 acre-feet; 2-5% of flood storage	HW Elevation 504.46 - 508.57 feet No deviation if using rainfall event	
Reach 2	20 Oct to 10 Nov	Winged Mapleleaf host infestation	--	50-150	21 days	Annually	2,975 - 8,925 acre-feet; 2-5% of flood storage	HW Elevation 504.46 - 508.57 feet Deviation required	
Reach 2	01 Apr to 15 May	Winged Mapleleaf excystment -- Support for juvenile success	--	100-350	30 days	Annually	5,950 – 20,820 acre-feet; 3-11% of flood storage	HW Elevation 506.60-515.60 feet Deviation required	

Reach 0	01 Mar to 30 Apr	Leopard Darter spawn season -- High flows need to recede quickly	365.5 days Gillham Lake elevation to stay below 540 feet	--	Every day	Annually	Reservoir elevation below 540 feet = 60% of flood storage; 25% chance of exceeding 540 feet in any given year	The WCM already maximizes what can be done. Water above 540 feet is evacuated as fast as possible with regard to downstream conditions. Requires change in WCM and study to release more and pull it down faster.	
Reach 1 and Reach 2	01 Mar to 31 May	Spring seed dispersal -- Disperse herbaceous seeds onto the floodplain	1 event during the frequency specified	1,000-8,000	2-4 days	Multiple pulses within same season and from year to year	3,970-23,800 acre-feet; 6-13% of flood storage[1]	HW Elevation 505.21-517.20 feet No deviation required when driven by rain event Deviation required if downstream flow target >3,000 cfs	

[1] These data are limited to a 3,000 cfs maximum release because of limitations of outlet; 8,000 cfs 4-day pulse would be 17% of the flood storage, which is 32,000 acre-feet, which might be possible with deviation when lake is several feet above the spillway crest at elevation 527 feet.

Reach 1 and Reach 2	01 Jan to 28 Feb	Winter channel maintenance -- To "clean-up" spawning bed; remove fines from interstitial spaces	1-2 pulses with a 7-day recession; high rain runoff may naturally serve as a pulse	8,000-15,000	7-10 days	Every 2-3 years	Below calculation uses maximum release of 12,000 cfs which is the NWS action stage at DeQueen. 110,880 to 237,600 acre-feet; 59-126%[2] of flood storage	HW Elevation forecast of >550 feet Deviation required	
Reach 1 and Reach 2	01 Dec to 28 Feb	Channel restructuring -- Sediment movement, berm renewal, and large woody debris recruitment	1 event during the frequency specified	10,000-25,000	7 days with recession limb longer than rising limb	Every 5 years	Below calculation uses maximum release of 12,000 cfs which is NWS action stage at DeQueen. 69,400-83,300 acre-feet; 37-44% of flood storage	HW Elevation 536.92 – 541.76 feet. Peak release can only be maintained when pool higher than 533 feet Deviation required	
Reach 2	01 Dec to 28 Feb	Oxbow connectivity -- "Water up" oxbows created by legacy channels	3-5 events	5,000-20,000	7 days	Annually	Below calculation uses maximum release of 12,000 cfs which is NWS action stage at DeQueen. 69,410-116,570ac-feet; 37-88% of flood storage.	HW Elevation >536.92 feet. Peak releases greater than 13,600 requires greater than flood storage. Deviation required	

[2] The pulses greater than 9,500 cfs would have to be ramped down very quickly to be possible, not enough storage in flood pool otherwise.

Reach 1 and Reach 2	01 Nov to 31 Dec	Fall seed dispersal -- Disperse mast producing seeds onto the floodplain	1 event during the frequency specified	3,000-8,000	2-4 days	Multiple pulses within same season and from year to year	11,900-23,800 acre-feet; 6-13% of flood storage.	HW Elevation 536.92-569.97 feet Deviation required	

Appendix B: Workshop Agenda

Cossatot River, Sustainable Rivers
Program Environmental Flows Workshop

June 7-8, 2022

Arkansas Game and Fish Commission Headquarters
2 Natural Resources Dr, Little Rock, AR 72205
Main Conference Room

AGENDA

June 7, 2022

Location: Director's Conference Room

9:00 Welcome and introductions – *Rheannon Hart (USACE, Little Rock District)*

9:30 Review of SRP process and discussion of meeting outcomes – *John Hickey (USACE, Hydrologic Engineering Center)*

10:00 Overview of Gillham Lake Authorizations and Little River System Operations – *David Bostwick (USACE, Little Rock District)*

10:45 Hydrologic analysis and flow/ecology relationships as background for developing environmental flow recommendations – *Rheannon Hart (USACE, Little Rock District), Jeff Quinn (AGFC)*

11:45 Lunch (in house)

1:00 Overview of Regime Prescription Tool software that will be used in Working Groups – *John Hickey (USACE, Hydrologic Engineering Center)*

1:20 Instructions for Working Groups – *Rheannon Hart (USACE, Little Rock District)*

1:30 Breakout groups: Working Groups have been organized by leveraging individuals having specific expertise. The aim of these Working Groups is to identify hydrographs for each reach designed to improve ecological conditions associated with each Group’s focus area.

- 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 purpose, timing, magnitude, duration, frequencies, and rates of change for the e-flow components. Please also note any contingencies and uncertainties.

- The discussion will consider a range of species, communities, and ecological processes.

Working Groups break out:

Group #1 – Fish, with a focus on rare fish (reach order 1, 0, 2) -- Director's Conference Room
Facilitator: Jeff Quinn (*AGFC*)
RPT: Dave Bostwick (*USACE*)

Group #2 – Mussels (reach order 1, 2) -- Lower East Conference Room
Facilitator: Bill Posey (*AGFC*)
RPT: Rheannon Hart (*USACE*)

Group #3 – Floodplain health and function, vegetative reestablishment, and water quality (reach order 1, 2) -- HR Conference Room
Facilitator: Jaysson Funkhouser (*USACE*)
RPT: Cherrie-Lee Phillip (*USACE*)

Focus Reaches:

Reach #0 – Gillham Lake

Reach #1 – Gillham Lake to Fall Line

Reach #2 – Fall Line to Little River Confluence

3:15 Break (15 min)

3:30 Resume working groups

4:30 Group reconvenes to address "parking lot issues" and review tasks for June 8

5:00 Adjourn

<u>June 8, 2022</u>

Location: Main Conference Room

9:00 Working groups continue to define flow needs per reaches

10:30 Break (15 min)

10:45 Working groups continue to define flow needs per reaches

11:45 Lunch (in house)

1:00 Each group presents its findings (~20 minutes each)

2:00 Unification of flow recommendations (~30 minutes per reach)

3:30 Break (15 min)

3:45 Conclusion and parting discussion – Discussing uncertainties, parking lot issues, next steps, modeling needs, concluding thoughts

4:30 Adjourn

Appendix C: List of Workshop Attendees

John Hickey – US Army Corps of Engineers
Jim Howe – The Nature Conservancy
Jon Barry – US Army Corps of Engineers
Nathaniel Keen – US Army Corps of Engineers
Rheannon Hart – US Army Corps of Engineers
David Bostwick – US Army Corps of Engineers
Jaysson Funkhouser – US Army Corps of Engineers
Jeff Quinn – Arkansas Game and Fish Commission
Dustin Lynch – Arkansas Natural Heritage Commission
Justin Stroman – Arkansas Game and Fish Commission
Kenneth Jones – Arkansas Game and Fish Commission
Eric Brinkman – Arkansas Game and Fish Commission
Emiley Purvis – Arkansas Game and Fish Commission
Chris Davidson – US Fish and Wildlife Service
Trey Shelton – US Army Corps of Engineers
Dylan Hann – Arkansas Game and Fish Commission
Jeff Fore – The Nature Conservancy
Jim Wise – Arkansas Department of Environmental Quality
Tate Wentz – Arkansas Department of Agriculture - Natural Resource Division
Bill Posey – Arkansas Game and Fish Commission
Kendall Moles – Arkansas Game and Fish Commission

USACE photo