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Cumberland River Basin

Environmental Opportunities Workshop

June 2024

Report Date: September 2024

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Report Finalized: 13 September 2024

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1.0 Project Purpose

The Sustainable Rivers Program (SRP) is a collaboration between The Nature Conservancy (TNC) and the U.S. Army Corps of Engineers (USACE) that aims at improving the health and life of rivers by changing infrastructure operations to restore and protect ecosystems while maintaining or enhancing other project benefits. The purpose of the Cumberland River Basin SRP Workshop was to gather engineers and scientists with knowledge and expertise of the basin to identify existing conditions in the basin, examine the potential for dam operations to improve environmental conditions, and discuss potential opportunities for implementation in the basin. The overall goal of the workshop was to identify actionable opportunities across the basin for potential operational changes at USACE facilities to provide ecosystem benefits.

LRN submitted a proposal for a Cumberland River Basin stakeholder workshop to the SRP for consideration in November 2023 and received approval and support shortly after.

2.0 Background

The Cumberland River Basin is an 18,000 square mile area that covers portions of Tennessee and Kentucky counties and contains over 22,000 miles of streams and rivers. The upper region of the basin is defined by four watersheds in eastern Kentucky and Tennessee. These watersheds include the Upper Cumberland, Rockcastle, Big South Fork, and Lake Cumberland (Figure 1). In Harlan, Kentucky a headwater stream originates and flows where it then converges with other streams forming the Clover Fork, Martin's Fork, and Poor Fork creeks. The confluence of these forks is where the Cumberland River begins. It flows naturally for 135 miles before expanding into Lake Cumberland, the largest man-made reservoir by volume east of the Mississippi and a result of the Wolf Creek Dam (Cumberland River Compact, n.d.). The river flows for 310 miles from its headwaters in Harlan to Celina, Tennessee. The upper middle region of the basin is defined by four watersheds: Obey River, Cordell Hull, Caney Fork, and Collins Fork. The river flows 72 miles between Celina and Carthage, Tennessee. This region includes the basin's longest tributary, the Caney Fork, as well as major reservoirs, including Dale Hollow, Cordell Hull, and Center Hill. The lower middle region of the basin is defined by four watersheds in middle Tennessee: Old Hickory, Stones River, Middle Cumberland, and Harpeth River. The river runs 155 miles between Carthage and Ashland City, Tennessee. This region contains J. Percy Priest, Old Hickory, and Cheatham reservoirs. Finally, the lower region is defined by two major watersheds: Red River and Lower Cumberland. The river runs 150 miles from Ashland City to Smithland, Kentucky. At the basin's outlet, water from 18,000 square miles of basin land and 22,000 miles of basin streams and rivers empty into the Ohio River. This region is the least developed but is also the most agricultural region and contains more cropland than all other regions combined (Cumberland River Compact, n.d.).

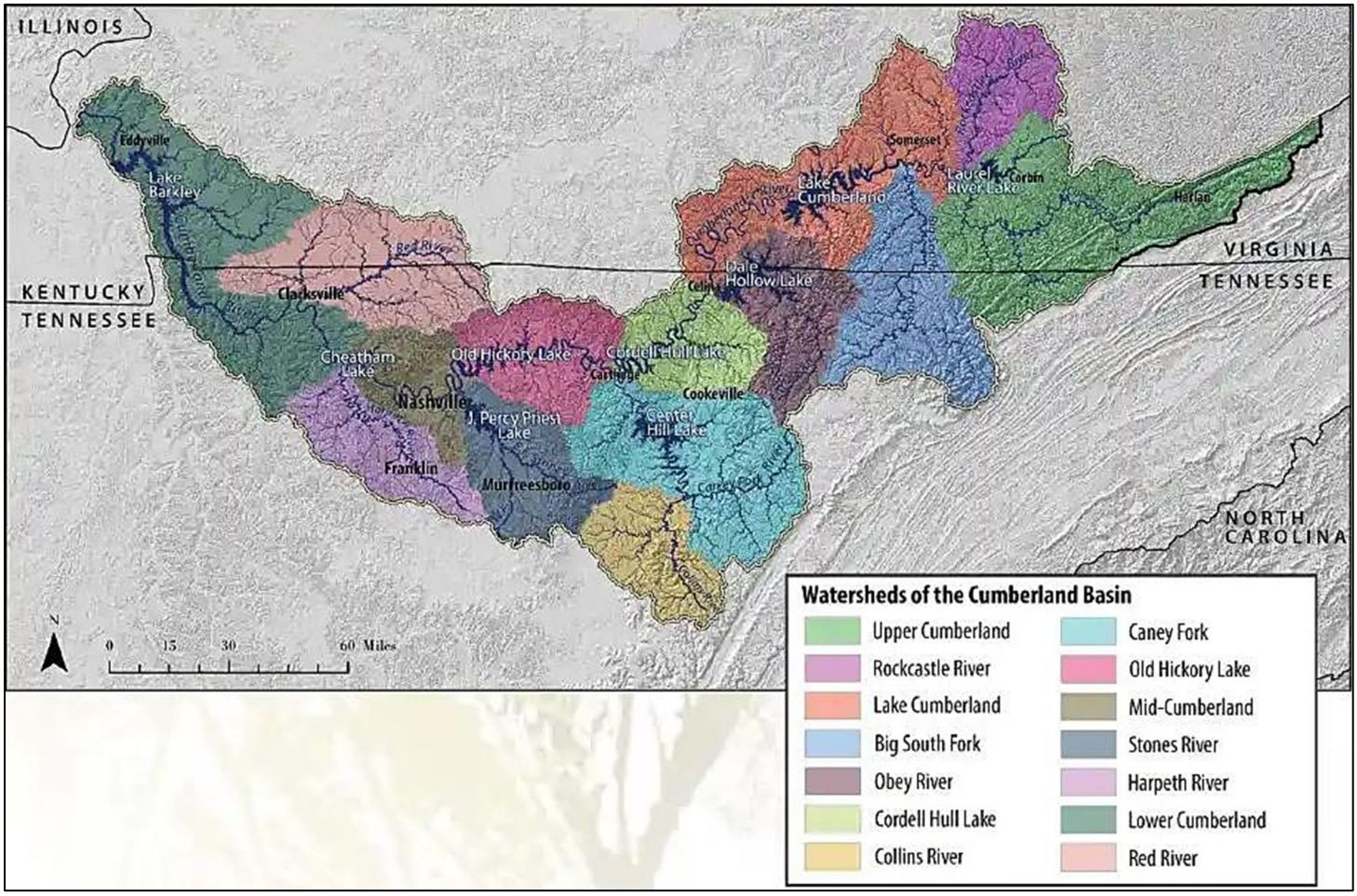

Figure 1: Cumberland River Basin - Watersheds *(Cumberland River Compact, n.d.)*

Throughout the history of the basin, the Cumberland River and its tributaries were major transportation corridors for exporting goods such as tobacco, cotton, and timber. Waterfalls across the region were also used to run historic mills. Today, the Cumberland River has many more major uses, including water supply, energy production, agricultural practices, flood protection, and recreation. Much of the Cumberland River and its tributaries are used as a source of public water supply. In terms of energy production, since the mid-20th century, USACE has worked with the Tennessee Valley Authority (TVA) and the Southeastern Power Administration (SEPA) to generate hydropower at Wolf Creek, Center Hill, Dale Hollow, Cordell Hull, Old Hickory, J. Percy Priest, Cheatham, and Barkley dams to meet the needs of the surrounding communities. While maintained by USACE, East Kentucky Power is responsible for hydropower production at Laurel Dam, which began producing energy in the late-20th century. The use of each reservoir is guided by project-specific water control manuals (WCMs) to ensure project compliance with congressionally approved operating purposes.

The Cumberland River Basin is one of the most biologically diverse river systems in North America with abundant fish and freshwater mussel populations. It is home to multiple species that are critically endangered, such as the Pink Mucket Pearly mussel (*Lampsilis abrupta*) and Bluemask Darter (*Etheostoma akatulo*), a small fish which occurs nowhere else in the world (USFWS, n.d.). It is also home

to iconic species such as the Hellbender Salamander (*Cryptobranchus alleganiensis*) and robust recovery efforts for Lake Sturgeon (*Acipenser fulvescens*), whose habitat has been significantly altered by the impoundment of waterways.

The objective of this workshop was to highlight the unique diversity of the Cumberland River Basin and discuss potential environmental opportunities throughout the basin.

3.0 Scope

The workshop scope included a description of the work to be completed for the project, as well as an estimated schedule for deliverables. This work included the identification of key Nashville District representatives and basin stakeholders, the planning and execution of a workshop to identify ecosystem problems and opportunities, and the preparation of a summary report. The workshop attendees include engineers and scientists from USACE Engineering, Operations, and Planning divisions, as well as water managers, reservoir project staff, natural resource agencies, scientific experts, academia, and other relevant stakeholders in the Cumberland River Basin. This report serves as the workshop summary report detailing the potential projects, resources, and information that can be used to improve the health and sustainability of the Cumberland River Basin aquatic ecosystems in future efforts.

4.0 Planning Process

4.1 Collaboration Efforts

Workshop planning involved collaboration between USACE and TNC representatives. The Nashville District team met with representatives from the Louisville District early in the planning process for feedback and recommendations they learned from the Green River Basin (GRB) Workshop. The workshop format was largely modeled based on the GRB efforts.

4.1.1 Project Delivery Team (PDT)

For the planning of the workshop, there was an internal USACE Nashville District team, as well as a PDT involving the internal team and TNC representatives to help answer questions and provide feedback on the planning of the workshop. The PDT can be seen in Table 1 below.

Table 1: Members, Roles, and Affiliations of the Project Delivery Team

PDT Member	Roles & Responsibilities	Organization
Abi Harvey	Hydraulic Engineer / H&H Lead	USACE - LRN
Daniel Clark	Biologist/Operations Lead	USACE - LRN
Faye Valerio	Hydraulic Engineer / H&H Lead	USACE - LRN
Michael Rawetzki	Hydraulic Engineer	USACE - LRN
Patrick Garner	Biologist/Environmental	USACE - LRN
Ryan Wigner	Hydraulic Engineer	USACE - LRN
Trey Church	Chief of Operations Section	USACE - LRN
Tyler Matthews	Biologist/Operations	USACE - LRN
Becca Winterringer	SRP Project Advisor	TNC - NA
Jim Howe	Senior Policy Advisor	TNC - NA
Rob Bullard	Director of Freshwater Programs	TNC - TN Chapter
Lane Richter	SRP Support/Wildlife Biologist	USACE - MVP
John Hickey	SRP Support/Hydraulic Engineer	USACE - IWR
Michelle Mattson	SRP Support/Ecologist	USACE - IWR

4.2 Outreach Efforts

To identify key stakeholders and experts that collect data and have the knowledge needed for the workshop, various strategies were used. Initial discussions occurred between the PDT to identify agencies for participant consideration. From there, points of contact were acquired and reached out to regarding the initial information about the workshop and its purpose. During initial correspondence, agency points of contact were asked to identify representatives or other agencies that would be best suited to attend and participate in the workshop.

After an initial list of invitees were identified, three external stakeholder meetings were scheduled and held to help provide background information to stakeholders, as well as to allow them time to prepare for the content of the workshop. In these meetings, agencies were asked to send the contact information for any other representatives or agencies that would be suitable for the workshop. We also provided them with a brief background of SRP, the goal of the workshop, the agenda, and a description of the breakout sessions to help attendees get acquainted with the expectations of the workshop.

5.0 Workshop Summary

The Cumberland River Basin SRP Workshop was a two-day event that included presentations from representatives with different stakeholder agencies, as well as three breakout sessions that allowed for communication and collaboration of existing conditions in the basin and potential for environmental opportunities. The workshop was held at the Wilson County Board of Education in Lebanon, Tennessee on June 25th and 26th, 2024.

5.1 Workshop Attendance

Invitations for the workshop were sent to numerous agencies and stakeholders with knowledge and expertise on the basin. A total of 48 individuals attended the workshop, with 46 attending on the 25th and 41 attending on the 26th (Figure 2). The following agencies and affiliations were represented at the workshop:

- Cumberland River Compact
- Kentucky Department of Fish and Wildlife Resources (KDFWR)
- Tennessee Department of Environment and Conservation (TDEC)
- Tennessee Technological University
- The Nature Conservancy (TNC)
- Tennessee Valley Authority (TVA)
- Tennessee Wildlife Resources Agency (TWRA)
- USACE Nashville District (LRN)
- USACE St. Louis District (MVS)
- U.S. Fish and Wildlife Service (USFWS)
- U.S. Geological Survey (USGS), Tennessee Cooperative Fishery Research Unit

A complete list of workshop attendees is included in Appendix A – Workshop Attendees.

Figure 2: Workshop Attendees on June 26th, 2024

5.2 Workshop Agenda

The workshop agenda can be found in Appendix B – Workshop Agenda. The first day of the workshop included multiple presentations and the first breakout session. The goal of the presentations was to provide background information on the Cumberland River Basin to participants before they were tasked with the first breakout session, identifying existing conditions.

The morning began with an introduction and welcome from USACE Operations Division Deputy Chief Tim Dunn, followed by an overview of SRP given by TNC representatives Jim Howe and Rob Bullard. The goal of the workshop from the Nashville District's perspective was presented by USACE representative Ryan Wigner. The morning continued with an overview of the Cumberland River Basin, given by Nashville District water manager Robert Dillingham,

highlighting authorized purposes and the water management program. The following three presentations were given by outside stakeholders to provide more background information on the different species found in the basin. A presentation on fish was given by TWRA representative Travis Scott who highlighted current fish management and monitoring practices, as well as research projects and conservation concerns they are seeing in the basin. The wildlife presentation was also given by TWRA representative Mallory Cogburn, with a focus on best management practices for bats found in Tennessee. A presentation on mussels was given by Tennessee Tech Professor Amanda Rosenberger. This presentation highlighted the importance of mussels, historic and current conditions of mussels in the Cumberland River Basin, including tributaries, and the current research needs. The second half of the day involved the first breakout session, Existing Conditions (Figures 3 and 4). Further information regarding this breakout session can be found in section 5.3.1.

The day ended with a presentation given by USACE representative Lane Richter and TNC team member Becca Winterringer on environmental flows (e-flows) and SRP success stories, including a case study on the Cape Fear River's ongoing SRP project in the Wilmington District, to help aid in the remaining breakout sessions.

Figure 3: Hellbender Group during Breakout Session (Photo: USACE)

The second day of the workshop started with a presentation by the Nashville District water quality program lead, Mark Campbell, on water quality conditions in the basin. This was followed by breakout sessions 2 and 3 which carried over ideas from the existing conditions identified in breakout session 1 and focused on identifying SRP opportunities in the basin. These breakout sessions are discussed in detail in sections 5.3.2 and 5.3.3. The list of presenters and their affiliation can be found in Table 2.

Table 2: Workshop Presenters

Presentation	Name	Agency
Introductions/Welcome	Tim Dunn	USACE - LRN
Presentation 1: Sustainable Rivers Program Overview and Workshop Goal	Jim Howe	TNC
	Ryan Wigner	USACE - LRN
	Rob Bullard	TNC
Presentation 2: Overview of Cumberland River System	Robert Dillingham	USACE - LRN
Presentation 3: Fish	Travis Scott	TWRA
Presentation 4: Wildlife	Mallory Cogburn	TWRA
Presentation 5: Mussels	Amanda Rosenberger	USGS, TN Tech
Presentation 6: E-Flows/SRP Success Stories	Lane Richter	USACE - MVP
	Becca Winterringer	TNC
Presentation 7: Water Quality	Mark Campbell	USACE - LRN
Presentation 8: Closing/Path Forward	Patrick Garner	USACE - LRN

5.3 Breakout Sessions

A total of three breakout sessions were held during the two-day workshop to facilitate discussion and collaboration between various agencies and expertise. The workshop participants were divided into six groups. The groups were chosen based on agency, experience, and focus of group members. Each group also contained an internal USACE employee to act as a moderator and facilitator of discussion. The breakout session groups are listed below. Group members and their focus can be found in Appendix C – Breakout Group Members.

- Group 1 – Hellbender
- Group 2 – Bigmouth Buffalo
- Group 3 – Cracking Pearly mussel
- Group 4 – Striped Mullet
- Group 5 – Common Pawpaw
- Group 6 – Brown Thrasher

Figure 4: Common Pawpaw Group during Breakout Session (Photo: USACE)

Before the workshop, moderators were given instructions on their tasks, as well as a guide that included the goal of each breakout session and questions to consider to help guide conversation. These instructions can be found in Appendix D – Breakout Session Facilitator Guide. The moderator in each group was responsible for capturing their groups ideas by using the provided worksheets for each breakout session. Notes for the larger group discussion were taken by a Nashville District team member. These notes capture prioritized thoughts and ideas discussed at the conclusion of each breakout session. The notes for the larger group discussion can be found in Appendix E – Larger Group Breakout Session Notes. Worksheets provided for each breakout session can be found in Appendix F – Breakout Session Worksheets.

5.3.1 Breakout Session 1: Existing Conditions

The first breakout session focused on familiarizing each group with existing conditions by identifying strengths and weaknesses within the Cumberland River Basin. Various materials were provided to each group for their reference, these included: a basin map, reservoir elevation guide curves for each project, and temperature and dissolved oxygen profiles. Along with reference materials, each group was provided with a worksheet where they would compile their ideas to share with the larger group. All materials provided in breakout session 1 can be found in Appendix G – Breakout Session Material.

During group discussion, a major weakness identified by most groups was the lack of data surrounding mussel populations, as well as the overall population of mussels in the basin. Another notable weakness considered was sedimentation throughout the basin caused by low water levels. During periods of low flow, the sediment can settle and cover eggs and/or suitable spawning habitat, affecting reproduction. There was also conversation on poor water quality related to low dissolved oxygen and thermal diversity. Different species require specific temperatures, and this variability can be an

issue. There are conflicts between native species that require warm water and game species that prefer cool water. Inconsistency with releases and flows was also noted as a weakness. This can affect mussel production and fish spawning by shocking the system through drastic releases instead of gradual releases. Further discussion highlighted that overall data collection in the basin is a strength; however, this data is not openly shared and communicated with outside agencies.

5.3.2 Breakout Session 2: Environmental Opportunities

The goal of the second breakout session was to identify specific opportunities, targeting specific species needs, from the strengths and weaknesses identified in breakout session 1. The materials provided in breakout session 1 were also provided in this breakout session, along with a worksheet to take notes. Also provided was a list of potential SRP environmental opportunities, based on previous submittals to the program. This was supplied as a reference to give groups additional context for the types of projects SRP can support. This list of Environmental Opportunities can be found in Appendix H – Environmental Opportunity Types.

Several environmental opportunities were identified through the strengths and weaknesses discussed in breakout session 1. One opportunity that was highlighted included monitoring and maintaining minimum generation at projects to keep sediment suspended during spawning for native fish species. This may involve continuous flow from 1 generator. Additional ideas for environmental opportunities included collecting more mussel population data through habitat assessments, surveys, and eDNA samples. Mussel populations may also benefit from more consistent flows and warmer water temperatures; this might involve blended releases or selective withdrawals. Pool level management was also discussed as a potential opportunity to improve sturgeon populations and promote the growth of shoreline vegetation. Small reductions in pool levels, as well as gradual drawdowns during spring spawning could improve conditions for both terrestrial and aquatic species. Other ideas highlighted included another stakeholder workshop with hydropower for collaboration, and a basin wide model to provide predictive modeling for environmental purposes.

5.3.3 Breakout Session 3: SRP Opportunities

The goal of the final breakout session was to further discuss and develop priority ideas from breakout session 2 that had potential to be actionable SRP proposals, highlighting the operational changes needed to achieve them. Groups were encouraged to consider all ideas for further discussion in this breakout session. These discussions included what the concern was, what project this occurs at, any data or studies needed for implementation, what the implementation process might look like, any risks to implementation, and the benefits that would occur from implementation. All prior materials were still available for reference, as well as a worksheet to take notes on.

Ideas from breakout session 2 were taken and further refined for this breakout session, and a list of potential project ideas that would be beneficial to the basin and stakeholders was generated.

An idea incorporating e-flows included maintaining stable flows, to keep sediment suspended, during spawning for native fish species. Data needed for this would include historic generation data, species genetic information, fish community and habitat surveys, and spawning data. Historic generation and genetic data could be compared to determine the relationship between historic reservoir operations and fish spawning and growth. The implementation process would include modeling experimental flows to determine what operational change would provide the best benefits to species of interest. Some risks might include off-peak hydropower generation as well as negative impacts to other species. On the other hand, the benefits might be more productive spawning for native fish species.

Another opportunity identified to benefit fish and vegetation was the management of pool levels during spawning. Fluctuating pool levels during spawning can negatively impact species and holding pool levels stable during the spring spawning season can benefit the reproduction of species, create a positive vegetative response, and restore river length and function. Risks to this might include hydropower, water supply, and flood control, as this would be weather dependent.

Another opportunity discussed among various groups is the data needed surrounding mussel populations and habitats throughout the basin. Data needed includes side scan sonar, historic data, eDNA samples, inventory surveys, substrate data, and habitat assessments. Implementation for this opportunity might include collaboration between universities or other agencies, selective withdrawals, and blended releases. A risk associated with this opportunity would include the compatibility with other opportunities and species because different species require different flow regimes and temperatures, as highlighted above.

6.0 Workshop Outcomes

The overall goals for the workshop were to determine opportunities for environmental improvement in the Cumberland River Basin, as well as build and strengthen connections between different agencies and organizations.

6.1 Potential Opportunities

Having various perspectives from experts with unique experiences with the basin and species therein provided lots of discussion and ideas for environmental improvement. Ideas discussed were summarized in the breakout session notes as well as in the above sections. Several ideas are listed below.

- Improving natural recruitment of Lake Sturgeon
- Stabilizing flows during spawning season to limit sediment deposition
- Stair-stepping guide curves in the fall for shorebird habitat improvement
- Holding pool levels as long as possible for an improved vegetative response, mussel population, and shorebird habitat
- Establishing mussel population and habitat databases through surveys and assessments
- Improving water quality conditions

Ideas are not limited to this list and are not in priority order. The ideas were generated in the allotted workshop time and further refinement was completed by the internal USACE team. All opportunities were discussed between hydraulics and hydrology, environmental, and operations staff, and those influenced directly by operational changes were selected as priority opportunities. While not all ideas discussed during the workshop are feasible for SRP, there are other means for pursual and implementation.

6.2 Potential Resources

Along with environmental opportunities, there were many data gaps and areas for improvement identified in the workshop. Studies and data identified from stakeholders are listed below.

- Habitat assessments
- eDNA samples
- Mussel surveys
- Fish community surveys
- Substrate data
- Conservation assessment plan
- Freshwater mussel database
- Basin wide hydraulic model with environmental component
- Workshop with hydropower and environmental stakeholders
- WMA management partnership workshop between USACE and TWRA

7.0 Lessons Learned

The June 2024 SRP Cumberland River Basin Workshop was the Nashville District's first step and introduction into the SRP. There were many takeaways and lessons learned from the workshop to aid in the planning and coordination of future workshops. The lessons learned include:

- Allowing more time for stakeholder engagement. Agencies of interest were identified by the USACE, and initial stakeholders were identified and corresponded with three months prior to the workshop. There was limited knowledge from USACE on the best representatives from each agency to support the workshop. Therefore, outreach heavily relied on recommendations from stakeholders. Allowing at least an additional month for stakeholder outreach, as well as being more persistent in efforts, would have been beneficial.

- Providing an example of what was expected from each breakout session. Giving an example of a strength or weakness in the basin for breakout session 1, then using that idea for breakout session 2 and relating it to specific species' needs, and finally translating that idea for breakout session 3 and providing specific details for what an implementation process might be. This could have provided a better explanation of what the expectations for the breakout sessions were. The goal was to have details pertaining to operational changes instead of broad ideas.

8.0 References

Compact, C. R. (n.d.). *Cumberland River Basin Profiles*. Retrieved from https://cumberlandrivercompact.org/explore/the-basin/

Cumberland River Compact. (n.d.). *Cumberland River Basin Profiles*. Retrieved from https://cumberlandrivercompact.org/explore/the-basin/

USACE Louisville District. (2023). *Green River Basin SRP Workshop.* Louisville.

USFWS. (n.d.). *U.S. Fish and Wildlife Service*. Retrieved from https://www.fws.gov/

Appendix A – Workshop Attendees

SRP - Cumberland River Basin Workshop Participants			
Name	**Agency**	**Focus/Title**	**Group**
Gray Perry	Cumberland River Compact	Watershed Science and Restoration Program Manager - Watershed Modeling, Geomorphology	Bigmouth Buffalo
Jed Grubbs	Cumberland River Compact	Watershed Planning and Restoration Program Manager	Bigmouth Buffalo
Emily Lawson	Kentucky Department of Fish and Wildlife Resources	Environmental Branch Coordinator	Brown Thrasher
Nick Zemlachenko	Tennessee Department of Environment and Conservation	Environmental Scientist- ARAP permitting	Hellbender
Richard Cochran	Tennessee Department of Environment and Conservation	Environmental Manager (water quality assessment, monitoring, modeling, TMDL)	Striped Mullet
Robby Baker	Tennessee Department of Environment and Conservation	Permitting, stream ecology	Brown Thrasher
Becca Winterringer	The Nature Conservancy	SRP Project Advisor; Expertise: SRP work and Mussels, Eflows	Hellbender
Jim Howe	The Nature Conservancy	Senior Policy Advisor, SRP guidelines and practices	Bigmouth Buffalo
Mark Thurman	The Nature Conservancy	Director of Conservation	Common Pawpaw
Rob Bullard	The Nature Conservancy	Director of Freshwater Programs - TN	Striped Mullet
James Everett	Tennessee Valley Authority	General Manager, River Management	Bigmouth Buffalo
Connor Ballard	Tennessee Wildlife Resources Agency	Stream and Rivers Fisheries Biologist	Bigmouth Buffalo
Jason E Miller	Tennessee Wildlife Resources Agency	Rare species, Project Environmental Review	Striped Mullet
Justin Spaulding	Tennessee Wildlife Resources Agency	Fish Biologist	Cracking Pearlymussel/Hellbender
Mallory Tate	Tennessee Wildlife Resources Agency	Wildlife Survey Manager/Biodiversity	-
Michael Clark	Tennessee Wildlife Resources Agency	Fisheries Biologist	Bigmouth Buffalo
Mike Jolley	Tennessee Wildlife Resources Agency	TWRA Region 3 Reservoir Fisheries Manager	Common Pawpaw
Ted Alfermann	Tennessee Wildlife Resources Agency	Manager 3-fisheries biology	Brown Thrasher
Todd St. John	Tennessee Wildlife Resources Agency	Region 2 Fisheries Program Manager, reservoir fisheries	Hellbender
Travis Scott	Tennessee Wildlife Resources Agency	Assistant Chief Fisheries Division	Striped Mullet
Will Collier	Tennessee Wildlife Resources Agency	Fisheries Manager	Cracking Pearlymussel
Abigail Harvey	USACE - Nashville District	Hydraulic Engineer, Water Resources Section	-
Andrew Brimm	USACE - Nashville District	Power plant operations and river control	Brown Thrasher
Anna Lee Warren	USACE - Nashville District	Hydraulic Engineer, Water Resources Section	Common Pawpaw
Ashley Fuentes	USACE - Nashville District	Chief, Environmental and Cultural Resources Section	Common Pawpaw
Ashley Urbat	USACE - Nashville District	Student Intern, Water Management	Brown Thrasher
Austin Auld	USACE - Nashville District	Hydraulic Engineer, Water Management Section	Striped Mullet
Claire Beal	USACE - Nashville District	Student Intern, Water Resources	-
Clint Neel	USACE - Nashville District	Acting Section Chief, Water Management Section	Hellbender
Faye Valerio	USACE - Nashville District	Hydraulic Engineer, Water Management Section	-
Grace Vollmers	USACE - Nashville District	Biologist, Environmental and Cultural Section	Hellbender
Kelley Peck	USACE - Nashville District	Chief, Water Resources Section	Brown Thrasher
Mark Campbell	USACE - Nashville District	Hydrologist, Water Quality	-
Michael Rawetzki	USACE - Nashville District	Hydraulic Engineer, Water Resources Section	Bigmouth Buffalo
Mike Sorrels	USACE - Nashville District	Hydraulics and Hydrology Branch Chief	Cracking Pearlymussel/Common Pawpaw
Patrick Garner	USACE - Nashville District	Biologist/NEPA Planner, Environmental and Cultural Section	Hellbender
Robert Dillingham	USACE - Nashville District	Hydraulic Engineer, Water Management Section	Cracking Pearlymussel
Ryan Wigner	USACE - Nashville District	Hydraulic Engineer, Water Management Section	-
Sidney Riddle	USACE - Nashville District	Biologist - Aquatic Wildlife and Fisheries	Striped Mullet
Timothy Dunn	USACE - Nashville District	Deputy Chief Operations Division	-
Trey Church	USACE - Nashville District	Chief, Operations Section (NRM)	Striped Mullet
Tyler Matthews	USACE - Nashville District	Biologist - lease, licensing and outgrant of federal lands	Cracking Pearlmussel/Brown Thrasher
Daniel Clark	USACE - Nashville District	Biologist - Land & Water Conservation	Common Pawpaw
Lane Richter	USACE - St. Louis District	Wildlife Biologist / Environmental Pool Management	Cracking Pearlymussel/Bigmouth Buffalo
Anthony Ford	U.S. Fish and Wildlife Services	Listing and Recovery Biologist (Freshwater Mussel)	Bigmouth Buffalo
David Pelren	U.S. Fish and Wildlife Services	Fish & Wildlife Biologist - threatened and endangered species, aquatic and karst ecosystems	Common Pawpaw
Robbie Sykes	U.S. Fish and Wildlife Services	Fish & Wildlife Biologist - Permits coordinator	Brown Thrasher
Amanda Rosenberger	USGS, Tennessee Cooperative Fishery Research Unit/Tennessee Tech	Associate Professor, Assistant Unit Leader; Ecology and conservation of aquatic biota	Cracking Pearlymussel/Common Pawpaw

Appendix B – Workshop Agenda

Sustainable Rivers Program

Cumberland River Basin Workshop Schedule

Tuesday, June 25, 2024

Time	Topic	Duration
8:00	Welcome and Intros	30 min
8:30	**Presentation 1:** Review of SRP and goal of workshop	45 min
9:15	**Presentation 2:** Overview of Cumberland River System	30 min
9:45	Break	15 min
10:00	**Presentation 3:** Fish	30 min
10:30	**Presentation 4:** Wildlife	30 min
11:00	Break	15 min
11:15	**Presentation 5:** Mussels	45 min
12:00	Lunch	1 hr 15 min
13:15	Instructions for Working Groups	15 min
13:30	**Breakout Session 1:** Existing Conditions	1 hr
14:30	Break	15 min
14:45	Findings/Open discussion	1 hr
15:45	**Presentation 6:** E-Flows and SRP Success Stories	1 hr 15 min
17:00	Dismiss	EOD

Wednesday, June 26, 2024

Time	Topic	Duration
8:00	Review	30 min
8:30	**Presentation 7:** Water Quality	30 min
9:00	Instructions for Breakout Session 2	15 min
9:15	**Breakout Session 2:** Environmental Opportunities	1 hr 30 min
10:45	Break	15 min
11:00	Findings/Open discussion	1 hr
12:00	Lunch	1 hr 15 min
13:15	Instructions for Breakout Session 3	15 min
13:30	**Breakout Session 3:** Deep Dive into Opportunities	1 hr
14:30	Break	15 min
14:45	Findings/Open discussion	1 hr
15:45	Closing/Path Forward	45 min
16:30	Dismiss	EOD

"Examining environmental opportunities across the Cumberland River Basin through potential operation changes at priority USACE facilities."

US Army Corps of Engineers

The Nature Conservancy

Appendix C – Breakout Group Members

Hellbender		
Name	**Agency**	**Focus**
Becca Winterringer	TNC	SRP Project Advisor; Expertise: SRP work and Mussels, Eflows
Clint Neel	USACE - CELRN	Acting Section Chief, Hydraulic Engineer
Todd St. John	TWRA	Region 2 Fisheries Program Manager, reservoir fisheries
Jamie Feddersen	TWRA	Migratory Gamebird Coordinator - migratory gamebirds
Nick Zemlachenko	TDEC	Environmental Scientist- ARAP permitting
Grace Vollmers	USACE - CELRN	Biologist, Environmental and Cultural Resources Section
Patrick Garner	USACE - CELRN	Biologist/NEPA Planner
Bigmouth Buffalo		
Name	**Agency**	**Focus**
Jim Howe	TNC	Senior Policy Advisor, SRP guidelines and practices
James Everett	TVA	General Manager, River Management
Michael Clark	TWRA	Fisheries Biologist - West TN
Andy Ford	USFWS	Listing and Recovery Biologist (Freshwater Mussel)
Gray Perry	Cumberland River Compact	Watershed Science and Restoration Program Manager - Watershed Modeling, Geomorphology
Jed Grubbs	Cumberland River Compact	Watershed Planning and Restoration Program Manager
Connor Ballard	TWRA	Stream and Rivers Fisheries Biologist
Michael Rawetzki	USACE - CELRN	Hydraulic Engineer, hydrology & hydraulics
Cracking Pearlymussel		
Name	**Agency**	**Focus**
Lane Richter	USACE - CEMVP	Wildlife Biologist / Environmental Pool Management
Robert Dillingham	USACE - CELRN	Hydraulic Engineer, Water Management/Reservoir Regulation
Justin Spaulding	TWRA	Fish Biologist
Amanda Rosenberger	USGS, Tennessee Tech	Associate Professor, Assistant Unit Leader; Ecology and conservation of aquatic biota
Will Collier	TWRA	Fisheries Manager
Mike Sorrels	USACE - CELRN	Hydraulics and Hydrology Branch Chief
Tyler Matthews	USACE - CELRN	Biologist - lease, licensing and outgrant of federal lands
Striped Mullet		
Name	**Agency**	**Focus**
Rob Bullard	TNC	Director of Freshwater Programs - TN
Trey Church	USACE - CELRN	chief, operations section (NRM)
Travis Scott	TWRA	Assistant Chief Fisheries Division
Jason Miller	TWRA	Rare species, Project Environmental Review
Richard Cochran	TDEC	Environmental Manager (water quality assessment, monitoring, modeling, TMDL)
Austin Auld	USACE - CELRN	Hydraulic Engineer, Water Management Section
Sidney Riddle	USACE - CELRN	Biologist - Aquatic Wildlife and Fisheries
Common Pawpaw		
Name	**Agency**	**Focus**
Mark Thurman	TNC	Director of Conservation
Wesley Butler	USACE - CELRN	Maintenance Supervisor for Cordell Hull Power Plant. Oversee operators and maintenance staff.
Mike Jolley	TWRA	TWRA Region 3 Reservoir Fisheries Manager
David Pelren	USFWS	Fish & Wildlife Biologist - threatened and endangered species, aquatic and karst ecosystems
Ashley Fuentes	USACE - CELRN	Environmental supervisor
Anna Lee Warren	USACE- CELRN	Hydraulic Engineer, Water Resources Section
Daniel Clark	USACE - CELRP	Biologist - Land & Water Conservation
Brown Thrasher		
Name	**Agency**	**Focus**
Andy Brimm	USACE - CELRN	Power plant operations and river control
Kelley Peck	USACE - CELRN	Chief, Water Resources Section
Ted Alfermann	TWRA	Manager 3-fisheries biology
Robby Baker	TDEC	permitting, stream ecology
Emily Lawson	KDFWR	Environmental Branch Coordinator
Robbie Sykes	U.S. Fish and Wildlife Services	Fish & Wildlife Biologist - Permits coordinator
Ashley Urbat	USACE - CELRN	WM Student Intern

Appendix D – Breakout Session Facilitator Guide

Existing Conditions

Objective: To familiarize themselves and identify strengths and weaknesses within the Cumberland River Basin.

Instructions:

1.) Group introductions
2.) Explain that you will be the facilitator for the group, taking notes, and reporting out to the rest of the groups at the end of the session.
3.) Re-iterate goal of the session: Identify strengths & weaknesses of the Cumberland in its current condition. What's going well, what's not going well & why? These problems can be anywhere in the basin.
4.) Initiate group discussion, and
    a. Fill out worksheet for group.
    b. Keep discussion notes on the notecard.
    c. If needed, use prompts in the section below to keep conversations moving/on track.
5.) Towards the end of discussion time, have the group condense the conditions/problems identified into top three items which will be shared with the rest of the group.
6.) Share group's items, while trying to not repeat other groups' items.
7.) Place group's materials into group folder (maps, notecard, species sheets). Folders will be collected after the breakout session, then redistributed for next breakout session.
8.) Each facilitator hangs worksheet for entire group to see

Existing Conditions
Questions to Consider:
1. What areas might need improvement in the basin?
2. What areas are hotspots for biodiversity in the basin?
3. Where are species/populations declining, and why?
4. What species are thriving?
5. Are there general water quality/habitat/flow regime problems in the basin?
6. Are there data gaps that might need to be addressed before we can answer these questions for the whole basin?

Environmental Opportunities

Objective: To identify specific opportunities from strengths/weaknesses identified in breakout session 1 with specific species needs.

Instructions:

1.) Using the notecard, give a recap of the problems that were identified in the previous breakout session.
2.) Ask the group if there are any other problems they want to add to the list. If yes, take note of these additions.
3.) Re-iterate goal of the session: Brainstorm potential opportunities for improving conditions (i.e., ways we can solve the problems identified in Breakout Session 1). Remember – these don't have to be USACE specific exclusively, but USACE opportunities should be discussed.
4.) Initiate group discussion, and
   a. Fill out worksheet for the group.
   b. Keep discussion notes on the notecard.
   c. If needed, use prompts in the section below to keep conversations moving/on track.
5.) Towards the end of discussion time, have the group condense the opportunities they identified into top three items which will be shared with the rest of the group.
6.) Share your group's items, while trying to not repeat other groups' items.
7.) Place group's materials into group folder (maps, notecards, species sheets, opportunities list, tower drawings). Folders will be collected after the breakout session, then redistributed for next breakout session.
8.) Each facilitator hangs worksheet for entire group to see

Environmental Opportunities
Questions to Consider:
1. What questions, hypotheses, and recommendations would you make to ecosystem health on the river?
2. How have dam operations changed river hydrology, morphology, and habitat?
3. What are the factors contributing to declines in species/groups?
4. Can flow changes be made to reduce the effects to declining species/groups?
5. Are there specific species, groups, habitats, locations, or processes that we should focus on for this workshop?
6. What recommendations would you make for low flows? High flows? Flood events?
7. When considering birds, herps, mussels and fish species of greatest conservation need, are there flow management strategies that would benefit all?

Deep Dive into Opportunities

Objective: To identify actionable SRP proposal opportunities for identified concerns

Instructions:

1.) Using the notecards from breakout sessions 1 & 2, give a recap of the problems and opportunities that were identified in the previous breakout sessions.
2.) Ask the group if there are any other opportunities that they want to add to the list. If yes, take note of these additions.
3.) Re-iterate goal of the session: Focus on priority opportunities and discuss details like how to achieve it, benefits, risks, pros/cons, data/studies needed before/during/after implementation, etc. If time allows, rank opportunities based on priority.
4.) Ask the group to select 3-5 opportunities they want to focus on for this session.
5.) Initiate group discussion, and
    a. keep discussion notes on the notecard.
    b. If needed, use prompts in the section below to keep conversations moving/on track.
    c. If needed, remind group of the tower drawings, opportunities list, and species information sheets, all of which may aid in brainstorming details about opportunities.
6.) Towards the end of discussion time, have the group condense the conditions/problems identified into top three items which will be shared with the rest of the group. Share your group's items, while trying to not repeat other groups' items.
7.) Place group's materials into group folder (maps, notecard, species sheets). Folders will be collected after the breakout session, then redistributed for next breakout session.

Deep Dive Into SRP Opportunities
Questions to Consider
1. What problem(s) will this opportunity solve?
2. Where would we implement this opportunity?
3. What does implementation process look like?
4. Data and studies needed before, during, and after implementation
5. Risks/downsides to implementation?
6. Perceived economic benefits
7. What is the top priority for the group and why?

Appendix E – Larger Group Breakout Session Notes

June 25, 2024

Breakout Session 1: Existing Conditions

- **Hellbender:**
    1. Striped bass fishery below Cordell Hull – current strength if water warms it could affect fishery
    2. Flows during fish spawning season (mid-March – April); below Cordell Hull
        - Silt suffocates eggs when flow is too low
    3. Nature based features in bank stabilization due to riprap creating habitat disruption; rip rap can be good for mussels
    4. High angling effort due to quality habitat in Middle TN
        - Old Hickory and JPP (reservoir)
    5. Below Lake Barkley – good habitat for mussels, temperatures are good for native species
- **Bigmouth Buffalo:**
    1. Temperature and flow for mussels – prohibiting mussel production downstream of dams, geriatric population; tributaries have these populations
    2. Low DO that affects fish populations
    3. Lack of habitat downstream of dams
    4. Lack of riparian buffer on Cumberland; floodplain connectivity
    5. Data gaps – habitat for lake sturgeon, mussel species, benthics
- **Cracking Pearlymussel:**
    1. Tailwaters
        - Weakness – sediment routing downstream, thermal diversity – spatial variability - substrate vs. temperature
    2. Tailwaters/reservoirs
        - Weakness – Habitat diversity
    3. Strong fisheries
    4. Weakness - Communication between natural resource professionals and the Corps
    5. Invasive species approach is more reactive than proactive
    6. Overall mussel richness is weak; need more data
- **Striped Mullet:**
    1. Dale Hollow, Center Hill
        - Weakness - Summer pool is often released immediately after reaching its max
    2. JPP/Cordell Hull
        - Weakness – eutrophication
            - JPP – chlorophyll
            - COR - pH

3. Strength - Data collection; Weakness - not shared openly with stakeholders
4. Lack of predictive models to evaluate success of WCM updates

- **Common Pawpaw:**
    1. Upper Old Hickory Lake area:
        - Strength - remanent mussel population
        - Weakness – losing mussel genetics; surveys could be beneficial (Hartsville/Carthage)
    2. At all tributary projects –
        - biodiversity is strong in free-flowing tributary headwaters.
        - weakness – isolated
    3. At all reservoirs – poor tailwater water quality
- **Brown Thrasher:**
    1. Whole system/Upper Cumberland
        - Weakness - Temperature of water is too low; mussels die off/can't reproduce
    2. Cordell Hull Tailwater/JPP/Old Hickory
        - Strength – cold water temp/good fisheries/striper trout thrive in cold water
    3. Lack of mussel survey data throughout upper Cumberland
    4. Cheatham/All
        - Weakness - Sedimentation/erosion throughout entire basin allows water to get too shallow and covers fisheries

Group Discussion:

Opportunity for bank stabilization – data gaps

June 26, 2024

Breakout Session 2: Environmental Opportunities

- **Hellbender:**
    1. Walleye, Sauger, Sturgeon
        - Below Cordell Hull – suspended sediment will settle on eggs and hurt spawning
        - Maintain minimum generation to keep sediment suspended March-April
        - continuous flow from 1 generator
    2. Aquatic vegetation
        - In pool management – controlling small amounts of reduction in pool elevation to promote growth of vegetation
        - Downstream from reservoirs – making sure generation schedules are not creating too much turbidity and sedimentation
    3. Bass/crappie
        - tributary projects/Cordell Hull
        - maintain stable pool levels during spring spawning season
    4. Tributaries
        - Study opportunity to examine how operations affect shad abundance
    5. Stakeholder workshop including current stakeholders and hydropower stakeholders
- **Bigmouth Buffalo:**
    1. Invasive carp
        - US/DS – BAR, CHE, COR
        - inconsistency of flow out of reservoirs can prevent carp from establishing long term habitat; reducing lockages through Cordell Hull to prevent carp habitat
    2. Mussels – more data is required to make any operational suggestions; flow – scour is a problem; lower more consistent flows would be better; habitat – downstream are deprived of sediment and need more gravel – dredging upstream of reservoir and distributing is downstream; low level outlets; increasing temperature through blending releases or selective withdrawals
    3. Pool management
        - Barkley – water level drops as warm water species are spawning; benefit from holding pool higher through the end of May
        - Migratory birds – stair stepping guide curve to support bird habitat (Sept – Nov); at Barkley
        - Cordell Hull – unnecessarily high pool due to little navigation interest – reduce pool level to a lower value in order to increase length of free-flowing Cumberland River upstream

- **Common Pawpaw:**
    1. Mussels
        - Upstream of Dale Hollow
        - Reservoir fluctuation has negative impact on – hold pool lower/timing
        - Conflict between cold and warm water species; manage different reaches of stream for water temps
    2. Fisheries
        - Tailwater/whole system
        - spawning influenced by flow queues– focus on flows/pool level/timing
    3. Mussels – missing data on species and existing conditions
        - Habitat assessments, visual surveys, conservation management, EDNA sample
        - At targeted tributary projects
- **Striped Mullet:**
    1. Basin wide – modeling technique – adding environmental layer to existing hydraulic model; used for future water control manual updates; predictive model, living model
    2. Lake Sturgeon – downstream Center Hill and basin wide
        - lack of spawning opportunity
        - stepped, gradual drawdown during spring spawning period – gradual is less of a shock to the system
    3. Native sport fish, bats, waterfowl
        - upstream JPP – water quality could negatively impact fishing and habitat suitability
        - modify how operations and real estate at the corps handle agricultural lease practices– increase buffer width
        - west fork of Stones River
    4. Mussels
        - Upstream of reservoir tributaries
        - spawning period water conditions of concern
        - time drawdowns with spawning period
    5. Mud flat grass/waterfowl
        - Upstream Cheatham and Barkley - Environmental pool management
        - Increased grass growth for waterfowl; lack of suitable habitat for waterfowl – short duration spring drawdown
- **Brown Thrasher:**
    1. Centrarchids (fish)
        - JPP
        - Dropping elevation too soon after flood storage capacity
        - reach summer pool sooner (March – April 1) for spawning;

2. Sauger, paddlefish, walleye
    - Downstream of Cordell or Old Hickory
    - keeping constant flow of 1 unit March-April for the spawning
3. Lake Sturgeon
    - Center Hill – monitoring low flow for lake sturgeon for spawning
4. Mussels
    - Cordell Hull – more mussel surveys downstream
    - Concern: how trout are affected by mussel conditions

June 26, 2024

Breakout Session 3: Deep Dive into Opportunities

- **Hellbender:**
    1. Shoreline stability and habitat diversity – Barkley and mid Cumberland: highlands losing shoreline
        - Data needed: geospatial info, where most erosion is happening, veg surveys
        - Implementation: EWN, rip rap, cypress
        - Risks: difficult to assess benefits, long implementation timeframe
        - Benefits: fish, birds, bugs
        - Pairs with environmental pool management – pool levels affect the way cypress grows
    2. Buy in from hydropower stakeholders
        - Hold workshop involving environmental and hydropower stakeholders to create collaborative solutions
        - Data: Cost benefit info related to operations/historic generation info
        - Risk of implementation: Financial compensation for ecological flows (risk of)
    3. Sediment deposition suffocating eggs during spawning and disturbing habitat
        - Cordell hull
        - Implement stable flows during spawning to keep sediment suspended
        - Data: Need hydropower data, experimental flow, compare historic generation data to species data
        - Risk: with continuous generation, risking off-peak hydropower generation, long evaluation period
        - Benefit: ensure natural reproduction of game fish, walleye, sauger, sturgeon
    4. Fluctuating pool levels during spawning and guide curves
        - High head tributary projects
        - Data: TWRA sampling data paired with historic ops information

        - Implementation: holding pool levels stable during March-April spawning season
        - Risk: weather determines ability to manage pool
        - Benefit: stable spawning conditions for crappie, bass, shad
    5. Lack of mussel survey data below Carthage and Barkley, Cheatham reservoir
        - Data: mussel survey/substrate data
        - Implementation: Mussel habitat surveys and report
    6. Fluctuation in tailwater (minimum flow) – tributary projects
        - Data: ability to model flows, habitat surveys and modeling, fish community surveys
        - Risk: impacts to hydropower production
        - Benefits: every species in tailwater
- **Bigmouth Buffalo:**
    1. Lack of data on mussel habitats – mussel survey, database, and habitat assessments, survey of historic and current pops
        - Data: side scan, historic data, EDNA
        - Implementation: funding with schools, agencies, researcher
        - risks: funding, typical funding stream for SRP, staff
        - benefits: groundwork completed by USFWS, would provide state of science
    2. Loss of mussel biodiversity – water quality, temp, and flow improvements
        - Data needs: mussel habitat survey, historic data
        - Implementation: selective withdraw and blended release
        - Risks: uncertain of implementation (compatibility with other goals), cost
    3. Drawdowns on pools, reproduction cycles of game species (bass and crappie), waterfowl, plants
        - Barkley pool management
        - Data needs: pop surveys, initial conditions, TWRA funds
        - Implementation: draw down pool later in spring
        - Risks: flood control pool
        - Benefits: TWRA collects data already, more consistent reproductive success of species
    4. Reducing spread of Invasive species, Cordell Hull
        - Data: purpose of Cordell lockages
        - Implementation: electrifying lock chamber for each lockage, reduce lockages to 0.
        - Risk: impacts to recreation, need to perform work on dam, operate
        - Benefits: preventing spread of carp
        - Removing lockages, during weekly lockages electrifying lock features
- **Striped Mullet:**

1. Lack of basin wide water quality model
    - Building water quality model for different tributaries and mainstem
    - Data: USACE has expertise but missing data
    - Implementation: cost-sharing with partners, stakeholder coordination
    - Risk: long term maintenance
    - Benefit: defensible, shows how operations affect water quality; current data process may be too infrequent
    - Data may be too infrequent
2. Lake sturgeon spawning data gaps
    - Tributary projects
    - Data: habitat suitability, better understanding of drawdown duration, 2D hydro models
    - Implementation: Habitat needs for species/parameters from other systems
    - Risks: transferability of habitat parameters, drawdown could affect hydropower
    - Benefits: changes could bring back spawning
3. WMA management partnership between USACE and TWRA– lack of coordination between USACE and TWRA
    - Data: Vegetation and wildlife needs in shoreline habitat
    - Implementation: Stakeholder coordination
    - Benefit: reduce cost and time of TWRA pumping water

- **Common Pawpaw:**
    1. Lack of spatial analysis of current conditions along mainstem and tributaries
        - Data: conservation assessment plan
        - Implementation: identifying priority areas, partner agencies
        - Risk: funding, public perception
        - Benefits: data gathered can be leveraged to identify possibility of restoration of pre-impoundment functions
    2. Reservoirs influence area on river flows impacting upper reaches– reservoirs, Dale Hollow/Wolf River
        - Data: where does the influence begin
        - Implementation: Holding pool as low as possible through winter going into spring/summer for as long as possible
        - Risk: impacts to hydropower, water supply, negative perception
        - Benefits: vegetative response, mussels, shore birds
        - Desire to restore as much of river length and function as possible
    3. Unknown if conditions exist to benefit lake sturgeon
        - Caney Fork/Center Hill
        - Data: review and find existing data

        - Implementation: make necessary adjustments to flow regime based on data
        - Risk: impacts to other species
        - Benefits: self-sustaining lake sturgeon populations
- **Brown Thrasher:**
    1. Perceived lack of mussels along mainstem
        - Data: habitat assessments of systems and surveys
        - implementation process: bathymetric data, large donor
        - benefits: to discover unknown populations
    2. Dropping water levels after spawning centrarchids - JPP and storage projects; Reaching summer pool earlier for
        - Data: historical spawning data and water surface elevation, prior WCM restraints, SRP state of science
        - Implementation: updating WCM
        - risk: flood storage capacity
        - benefit: increase recruitment
    3. Lack of natural recruitment of paddlefish, sauger, walleye - Old Hickory, Barkley, Cheatham; constant flow 1 unit March and April
        - Data: historical spawning data and water surface elevation, prior WCM restraints, SRP state of science
        - Implementation: updating WCM
        - risk: power generation
    4. Lack of natural recruitment of lake sturgeon – Center Hill/JPP
        - Data: historical spawning data and water surface elevation, prior WCM restraints, SRP state of science
        - Implementation: updating WCM
        - risk: power generation

Group Discussion:

- Lake sturgeon highlighted by most groups
- Mussel database – lacking in specific areas
    - Gathering data from partners and reliable data sources
    - Interagency support
    - Cost
- Summer pool manipulation
    - More gradual drawdown summer pool, less you can shock system
- Lack of vegetation
- Water quality modeling
    - USGS should have data
    - What data the model would need?

- Hydropower buy-in meeting
    - What are priorities of hydropower
    - Sharing perspectives of fisheries, mussels, etc.
    - Existing conditions
    - Communicating value of power generation vs. value of agencies (cost-benefit between the two)
    - Current SRP projects with hydropower

Appendix F – Breakout Session Worksheets

Breakout Session 1 Worksheet

Existing Conditions			
Strengths	**Weaknesses**	**Project**	**Other/Notes**

Breakout Session 2 Worksheet

Environmental Opportunities						
Species	**Type**	**Upstream/Downstream**	**Project**	**Concerns**	**Operations or Opportunities**	**Notes**

Breakout Session 3 Worksheet

SRP Opportunities						
Concern/Problem	**Project**	**Data/Studies Needed for Implementation**	**Implementation Process**	**Risks to Implementation**	**Benefits**	**Notes**

Appendix G – Breakout Session Material

(Basin map and reservoir information provided in Figures 5 to 21)

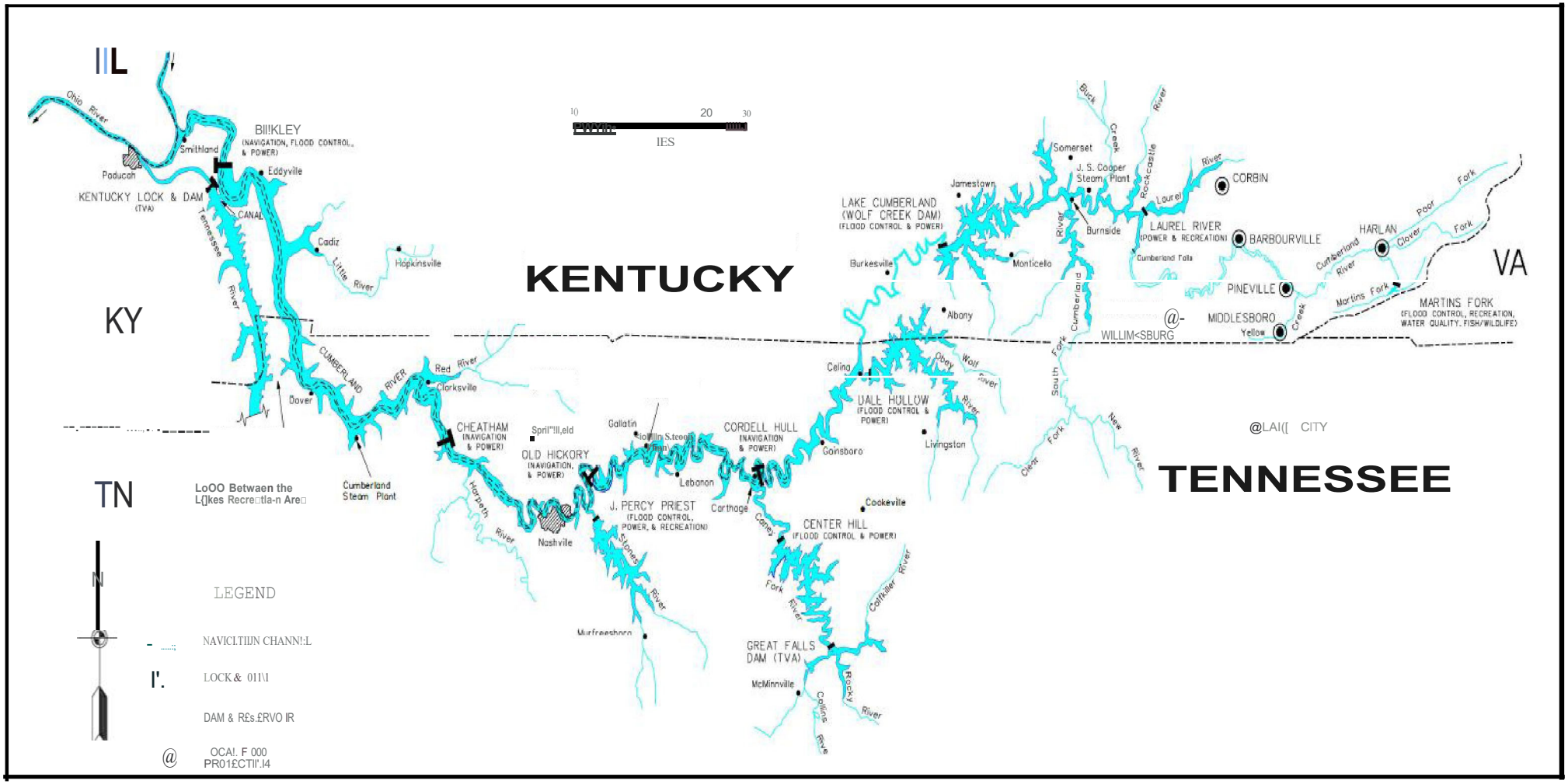

Figure 5: Cumberland River Basin Map

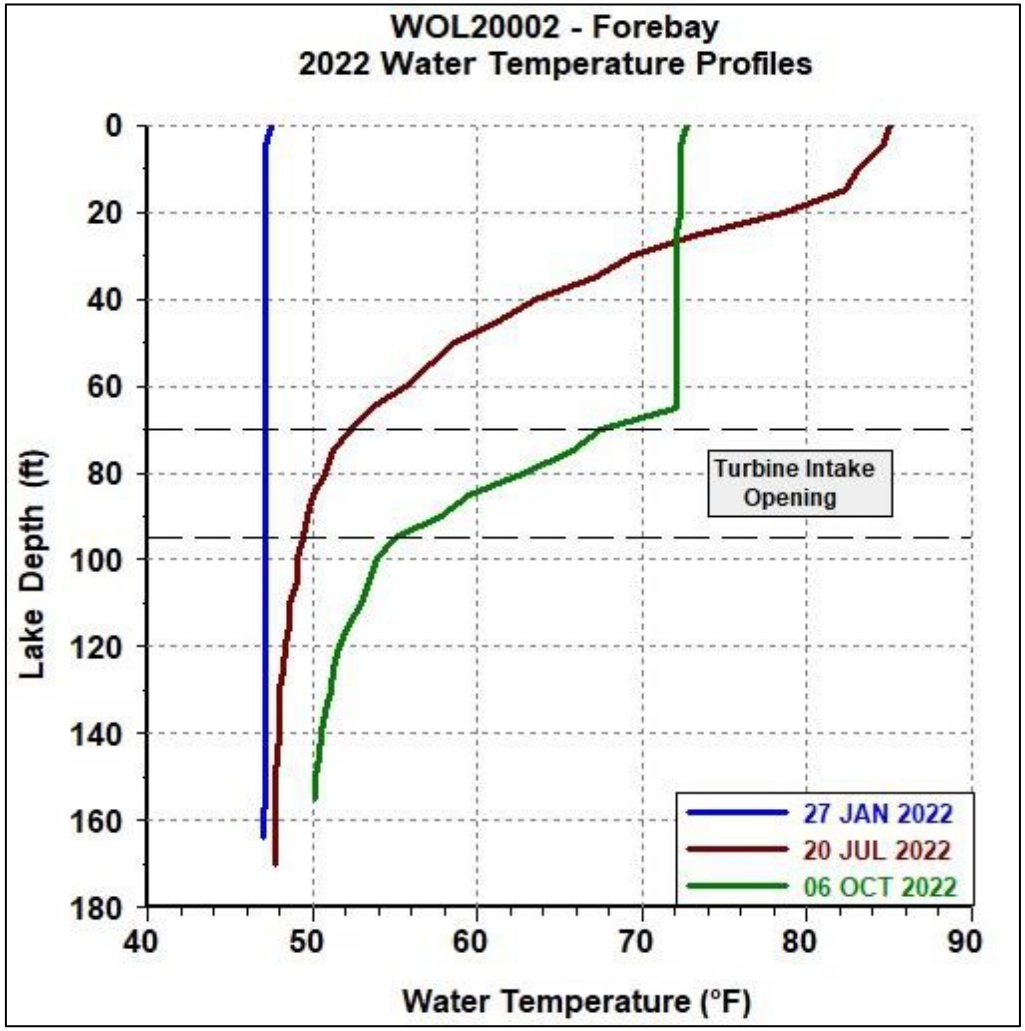

Figure 6: Wolf Creek Temperature Profiles

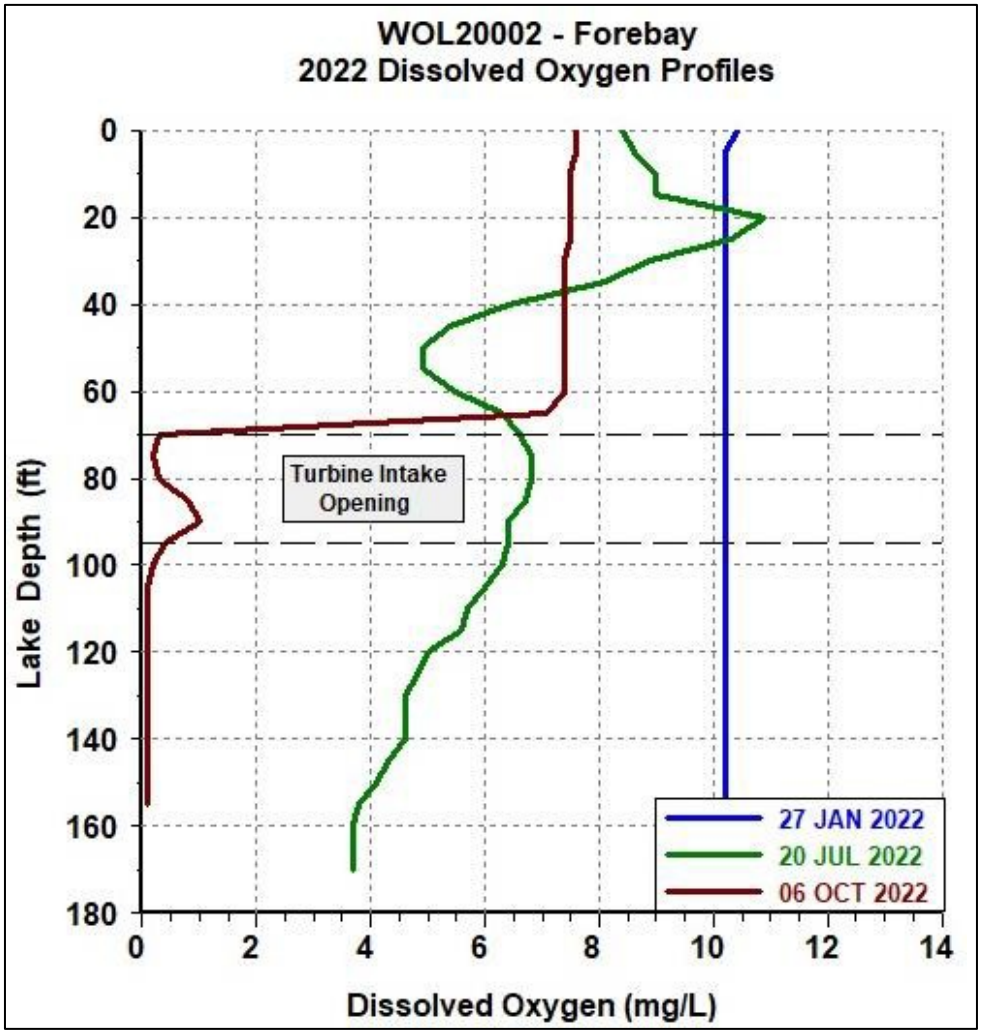

Figure 7: Wolf Creek Dissolved Oxygen Profiles

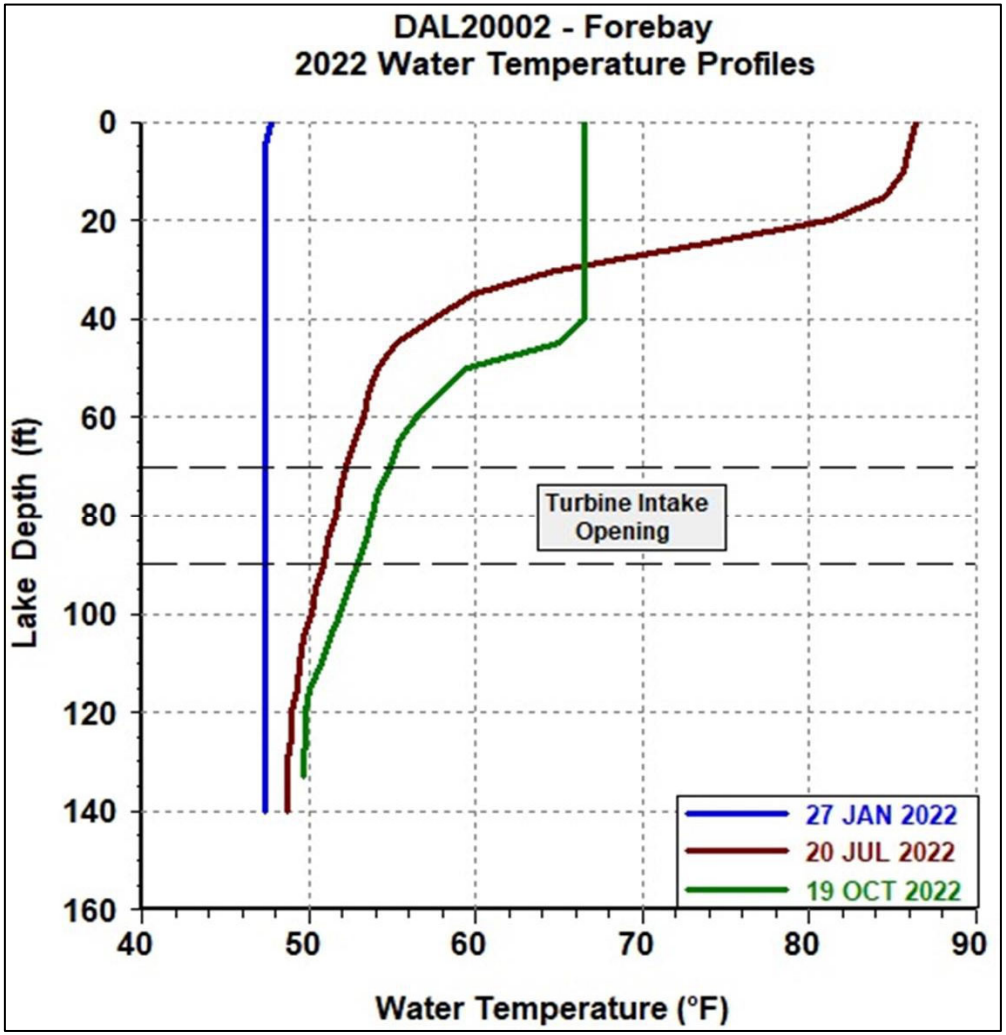

Figure 8: Dale Hollow Temperature Profiles

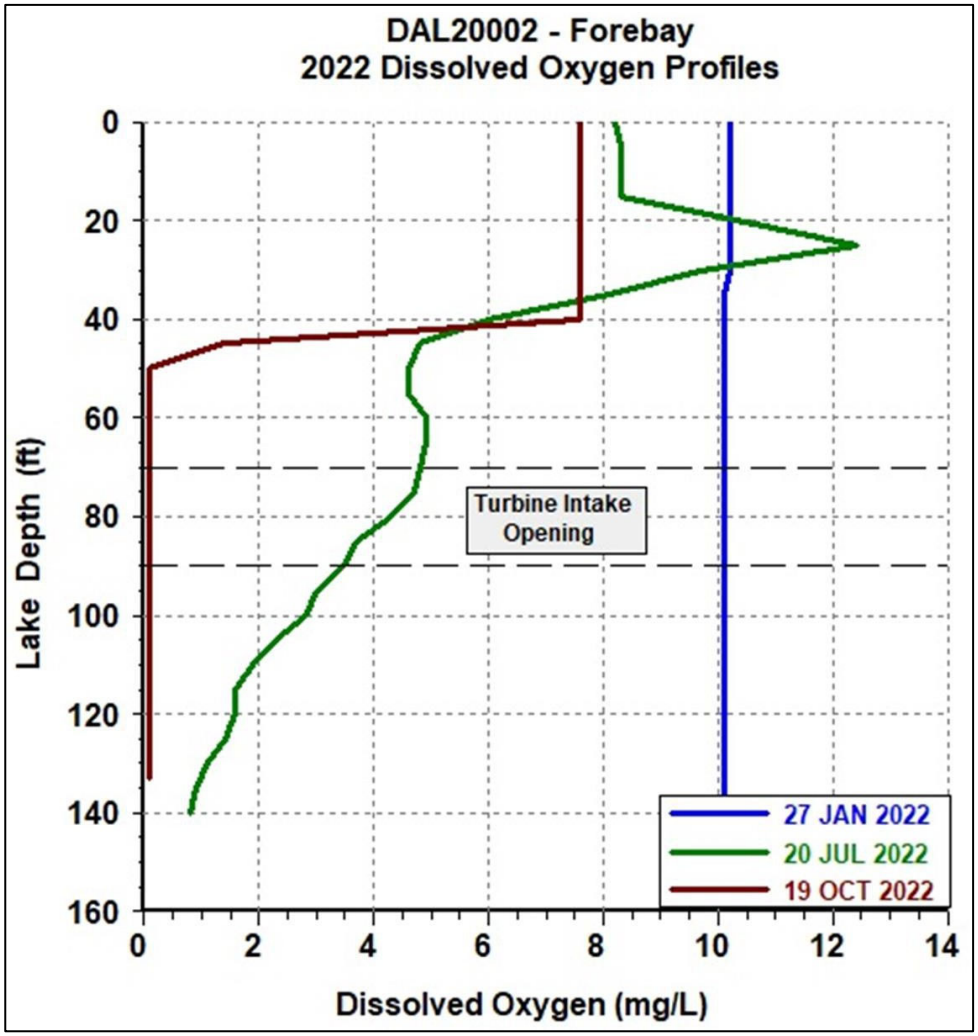

Figure 9: Dale Hollow Dissolved Oxygen Profiles

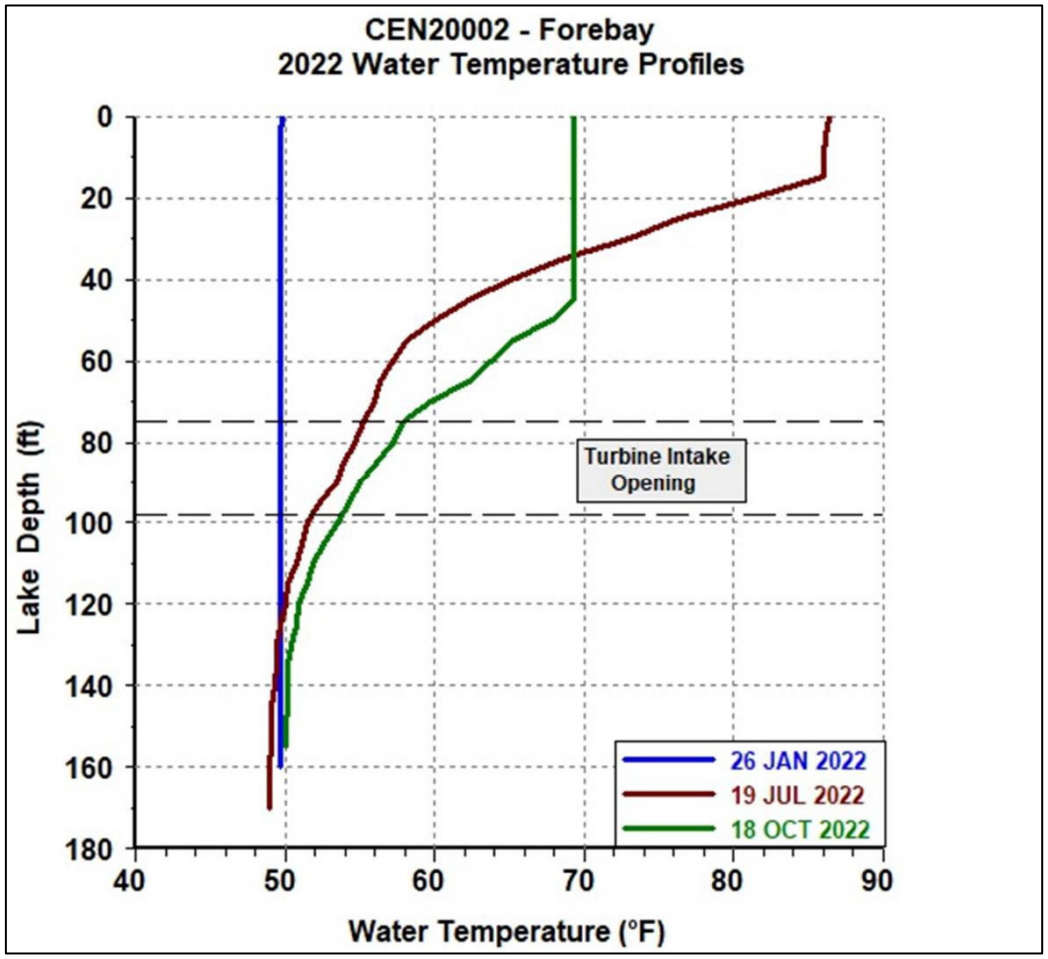

Figure 10: Center Hill Temperature Profiles

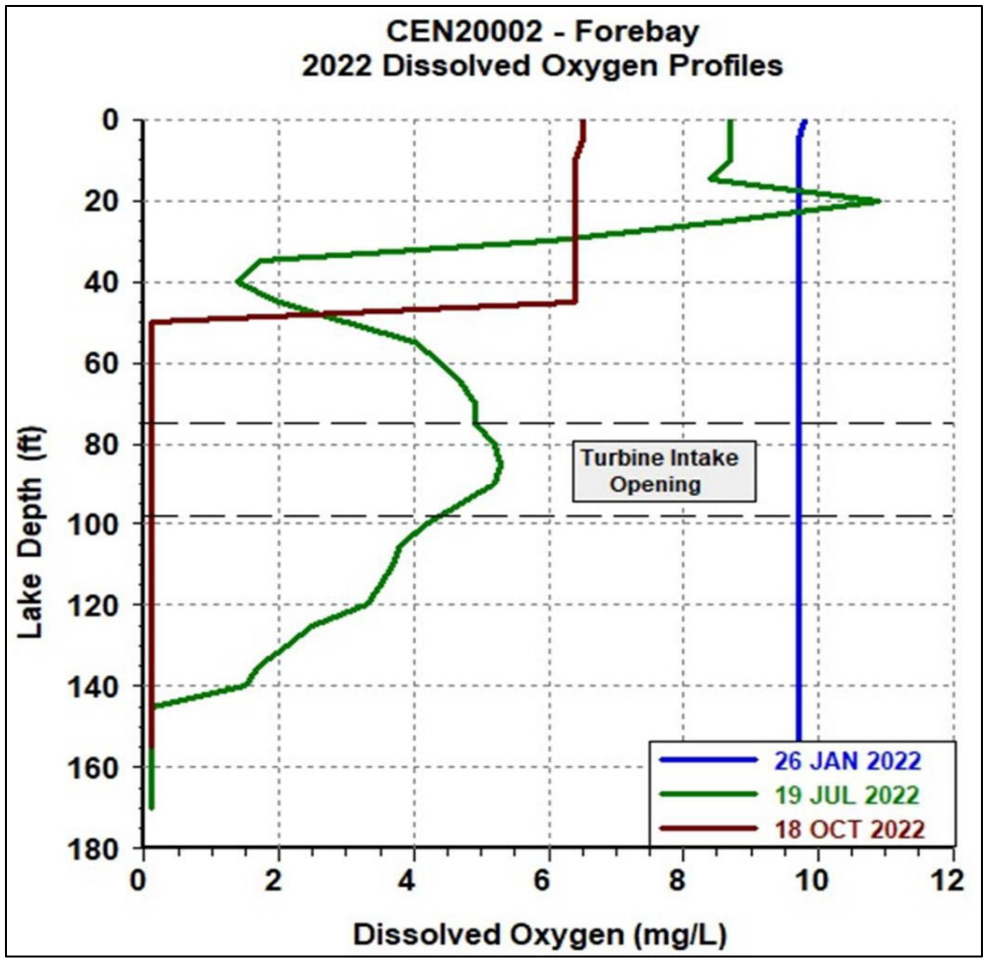

Figure 11: Center Hill Dissolved Oxygen Profiles

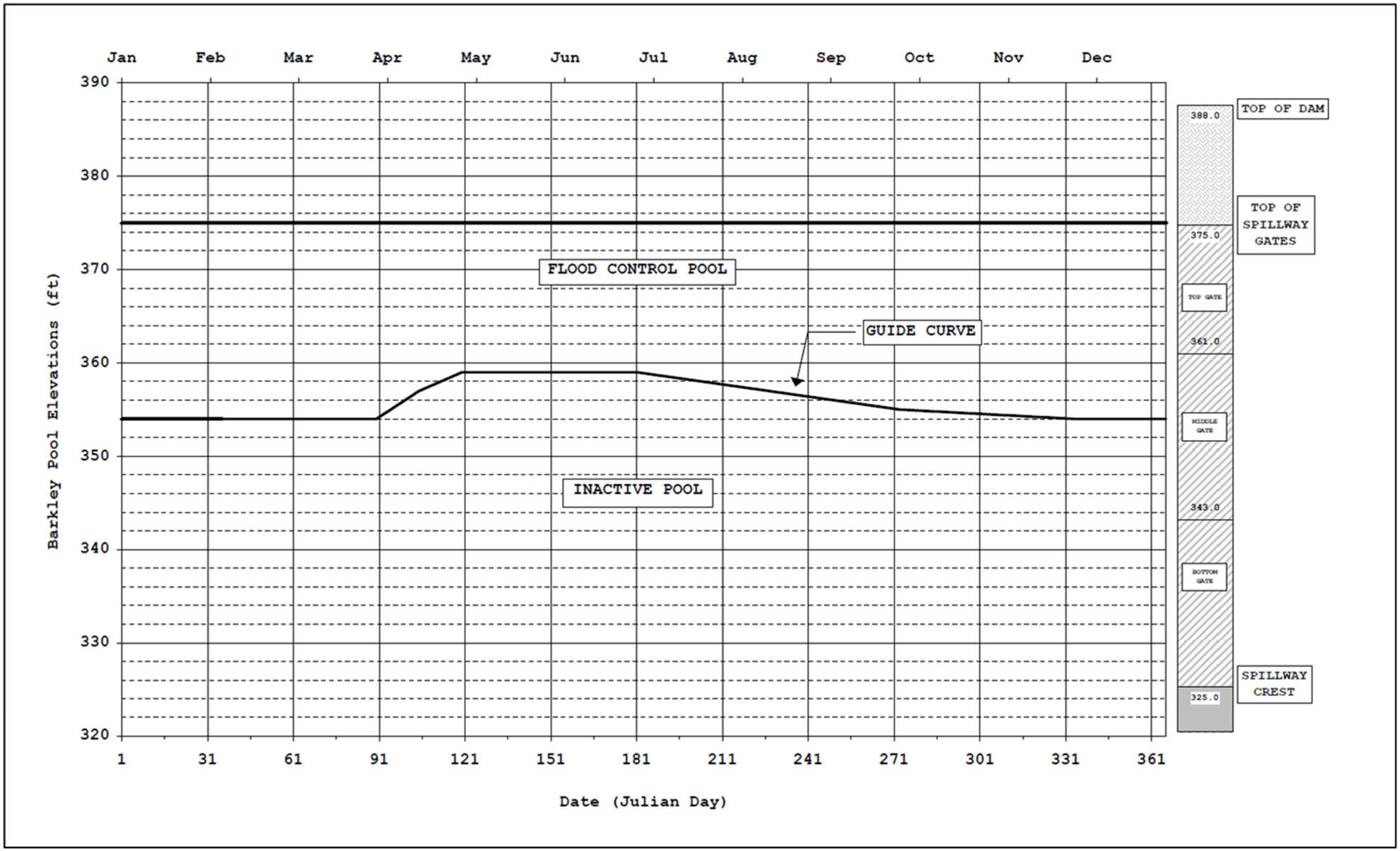

Figure 12: Barkley Guide Curve

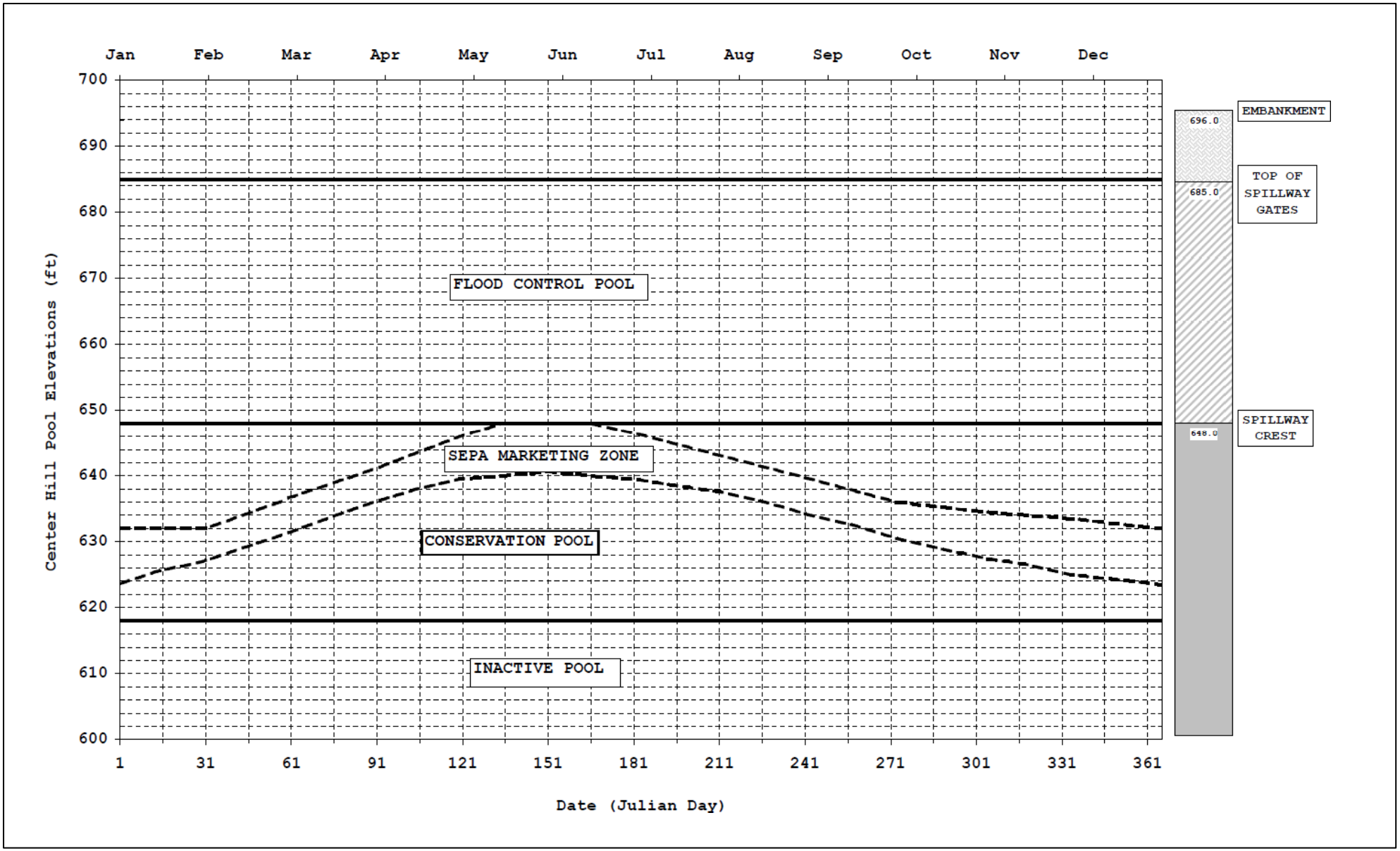

Figure 13: Center Hill Guide Curve

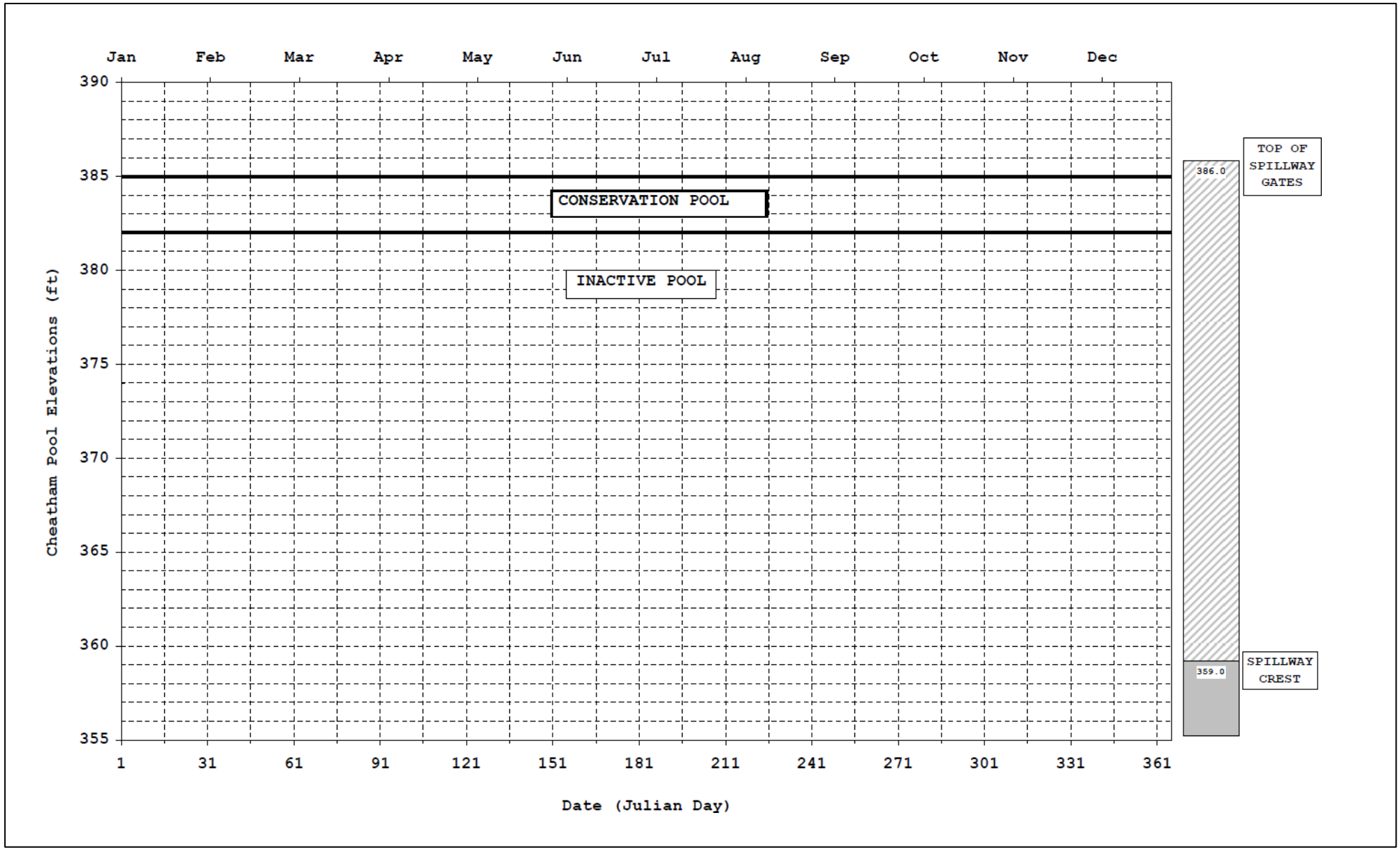

Figure 14: Cheatham Guide Curve

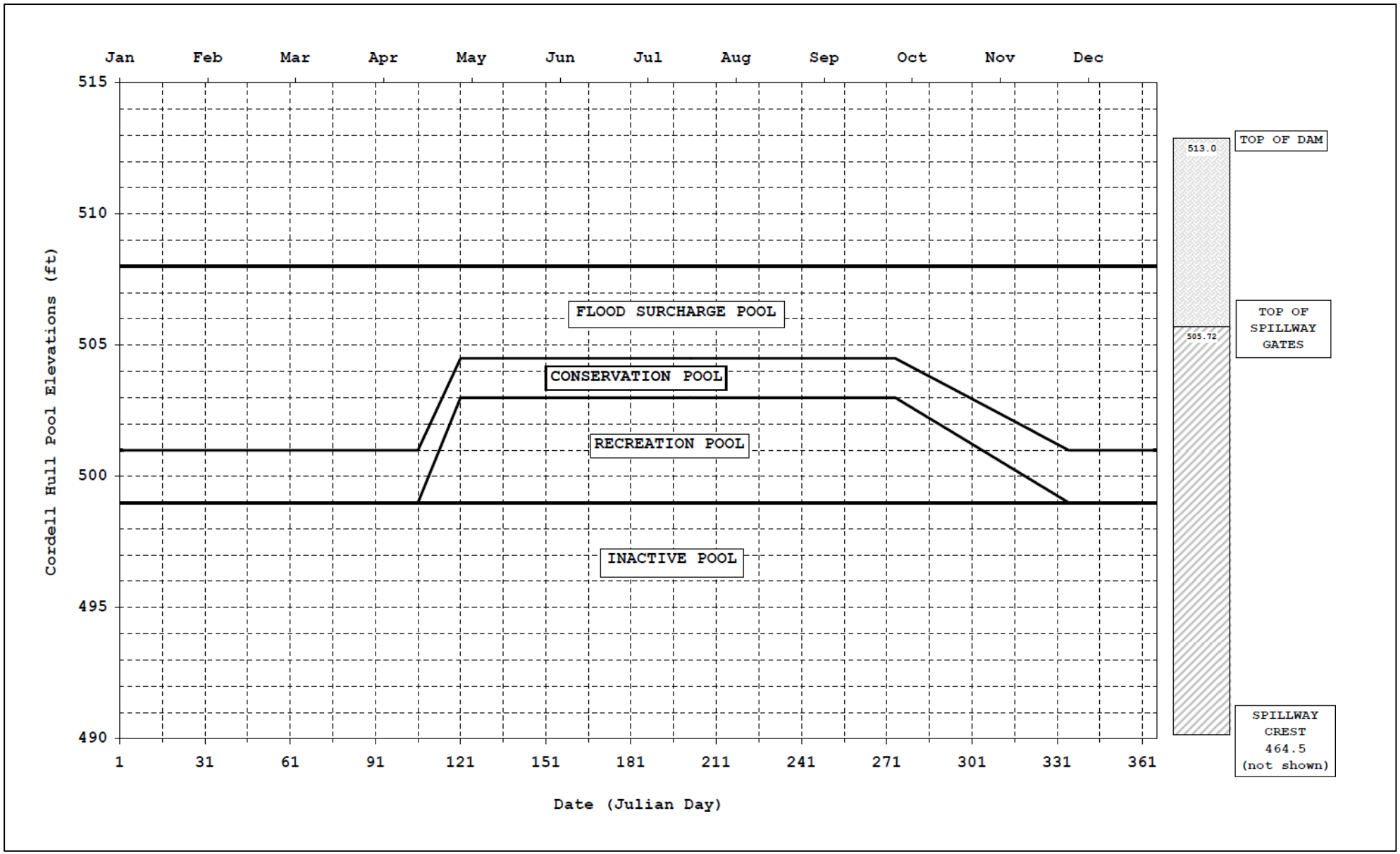

Figure 15: Cordell Hull Guide Curve

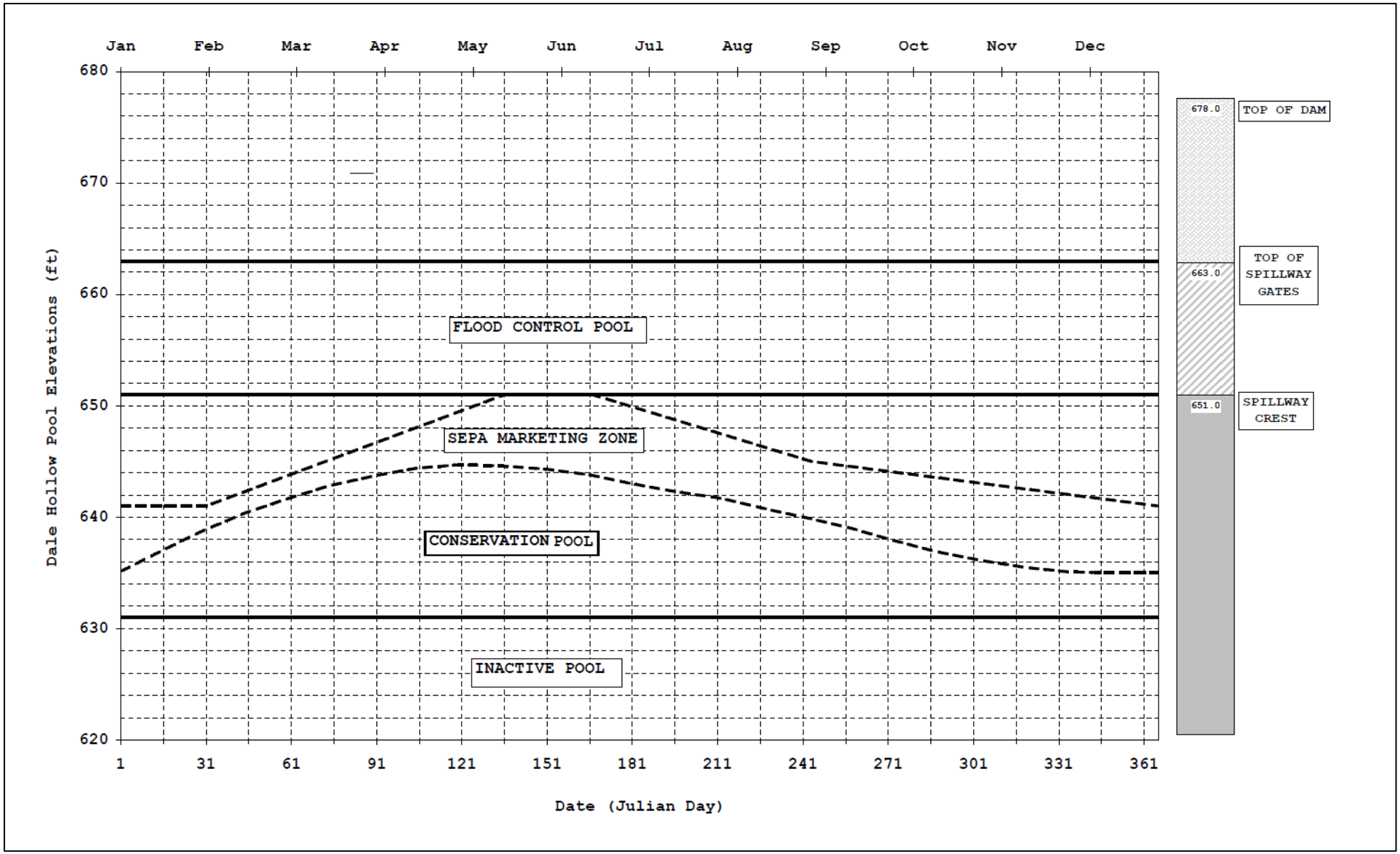

Figure 16: Dale Hollow Guide Curve

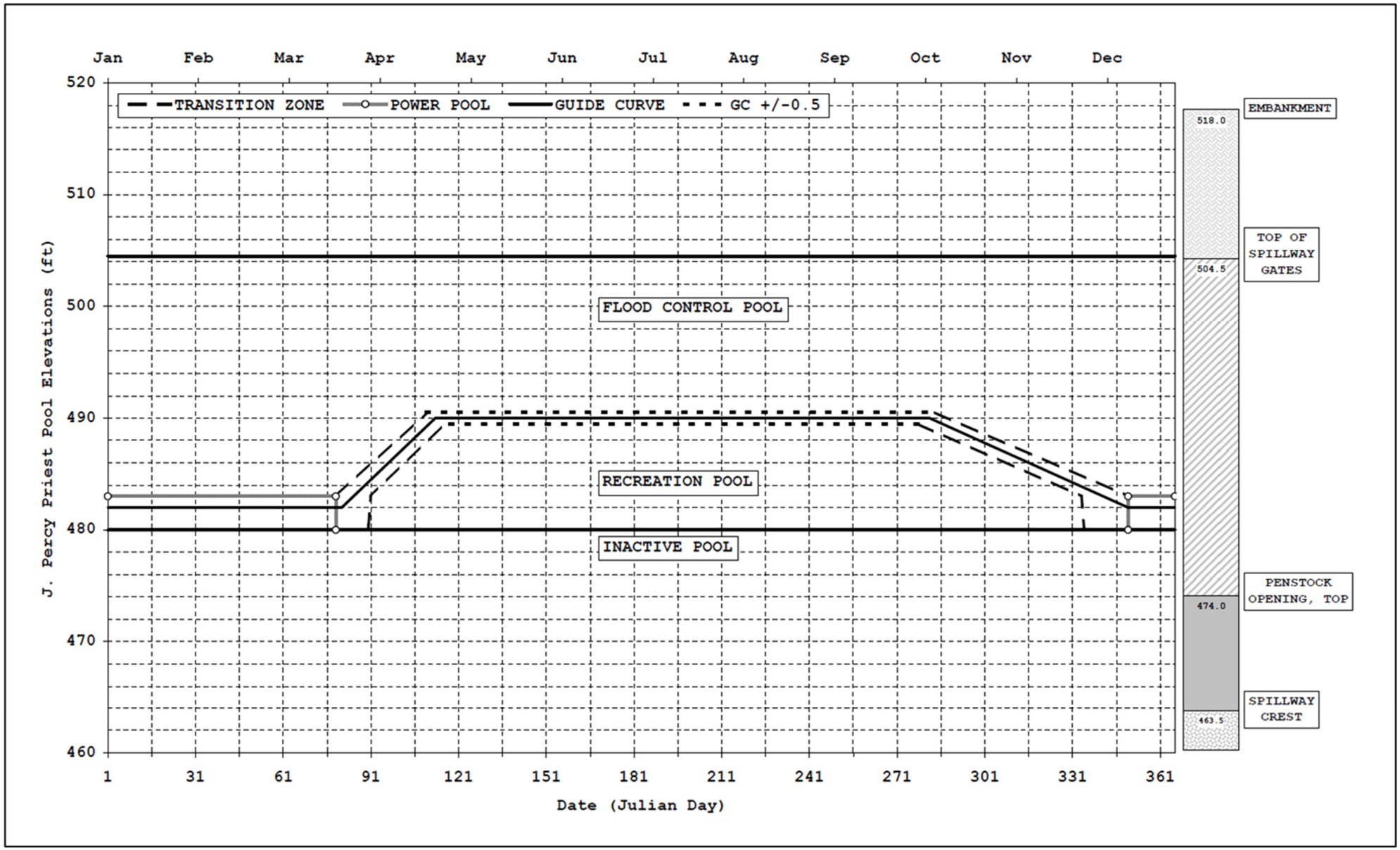

Figure 17: J. Percy Priest Guide Curve

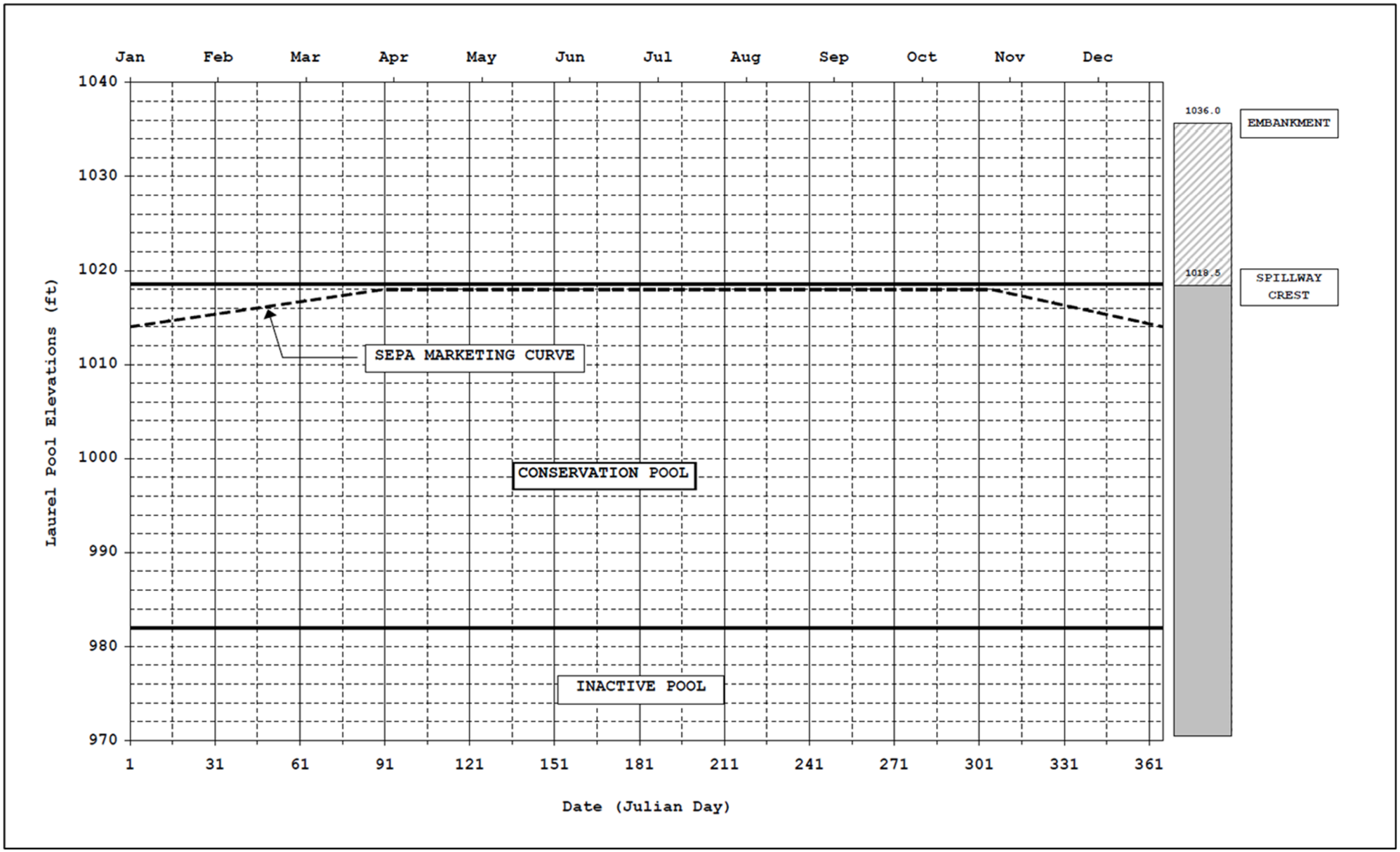

Figure 18: Laurel Guide Curve

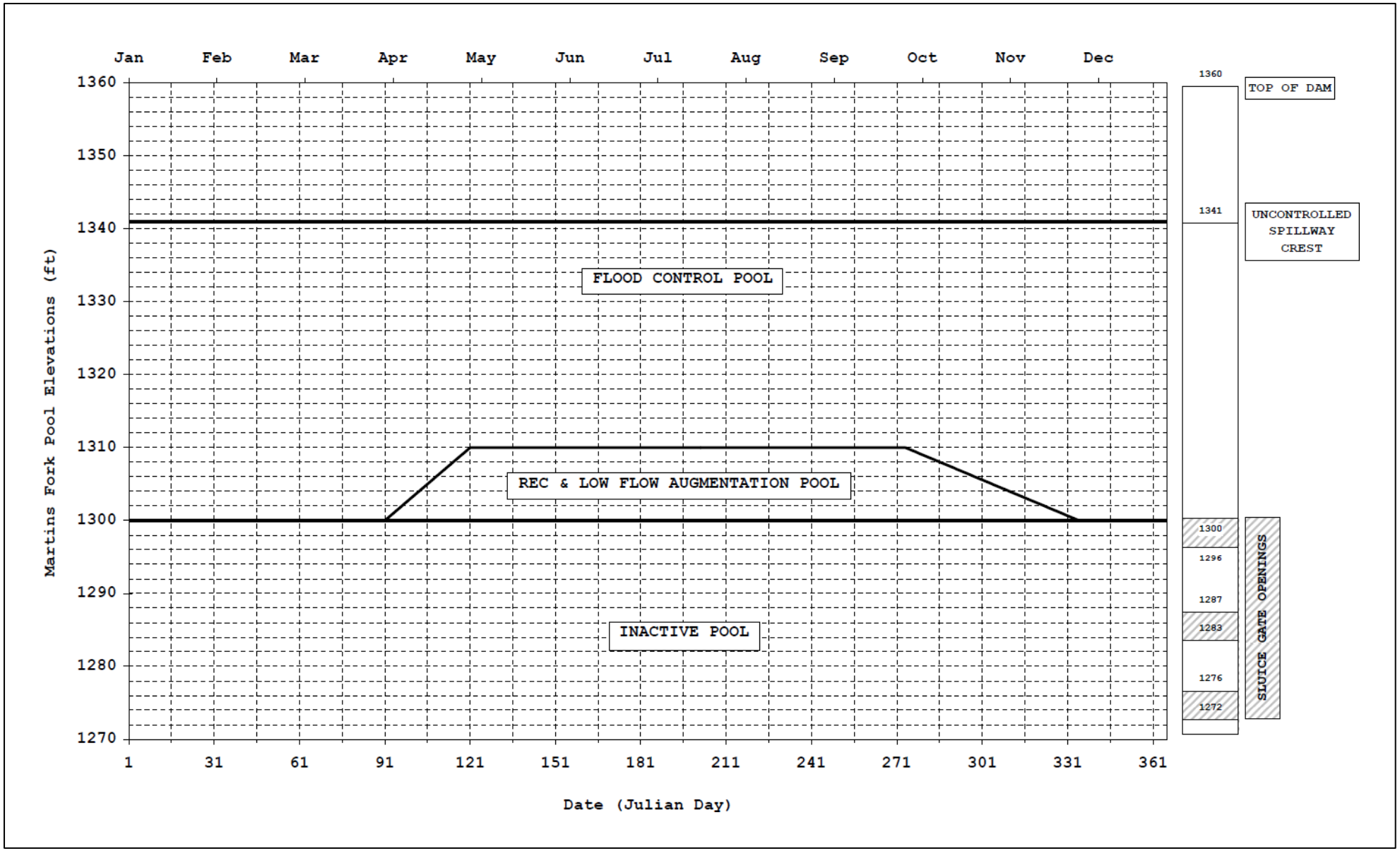

Figure 19: Martins Fork Guide Curve

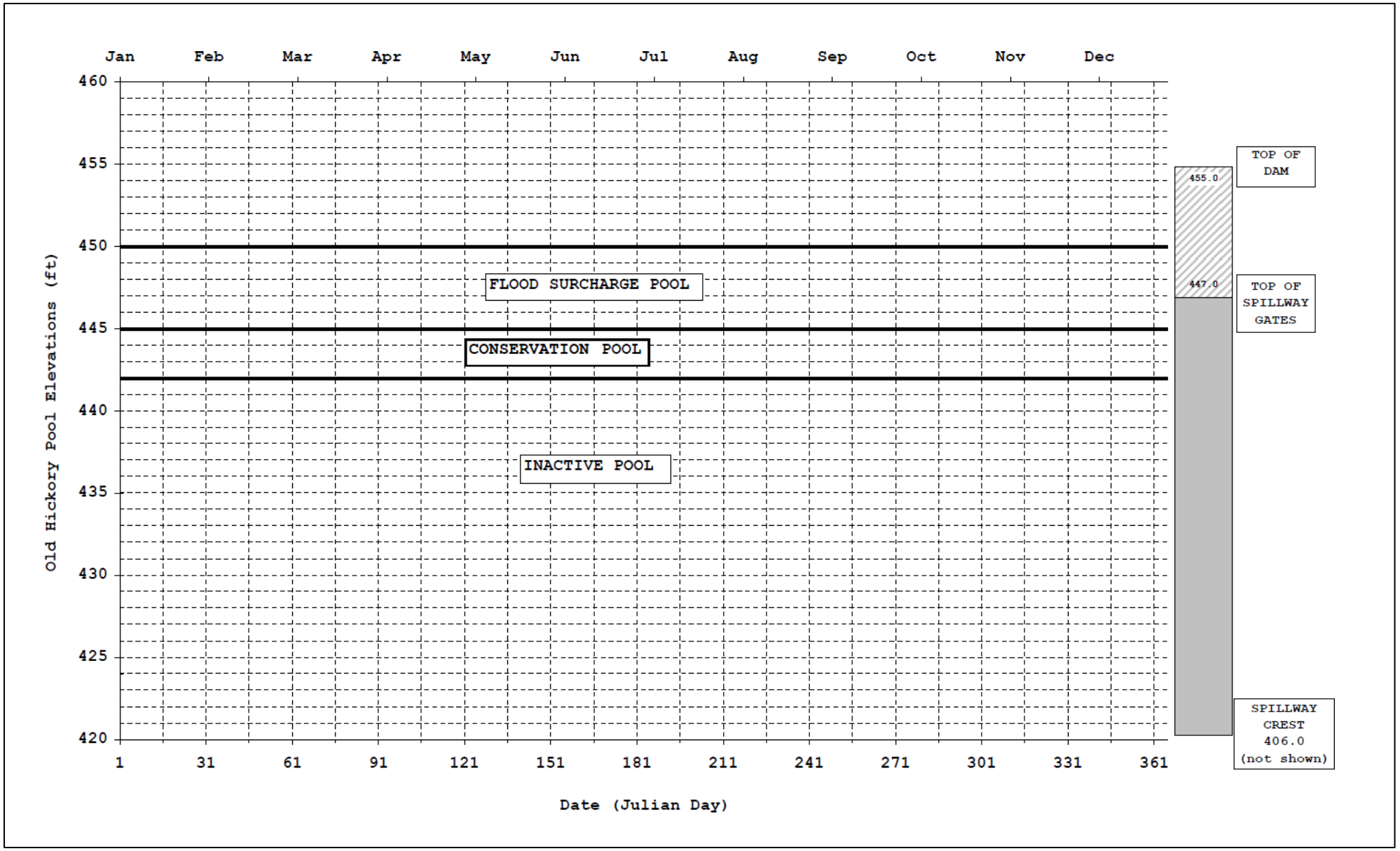

Figure 20: Old Hickory Guide Curve

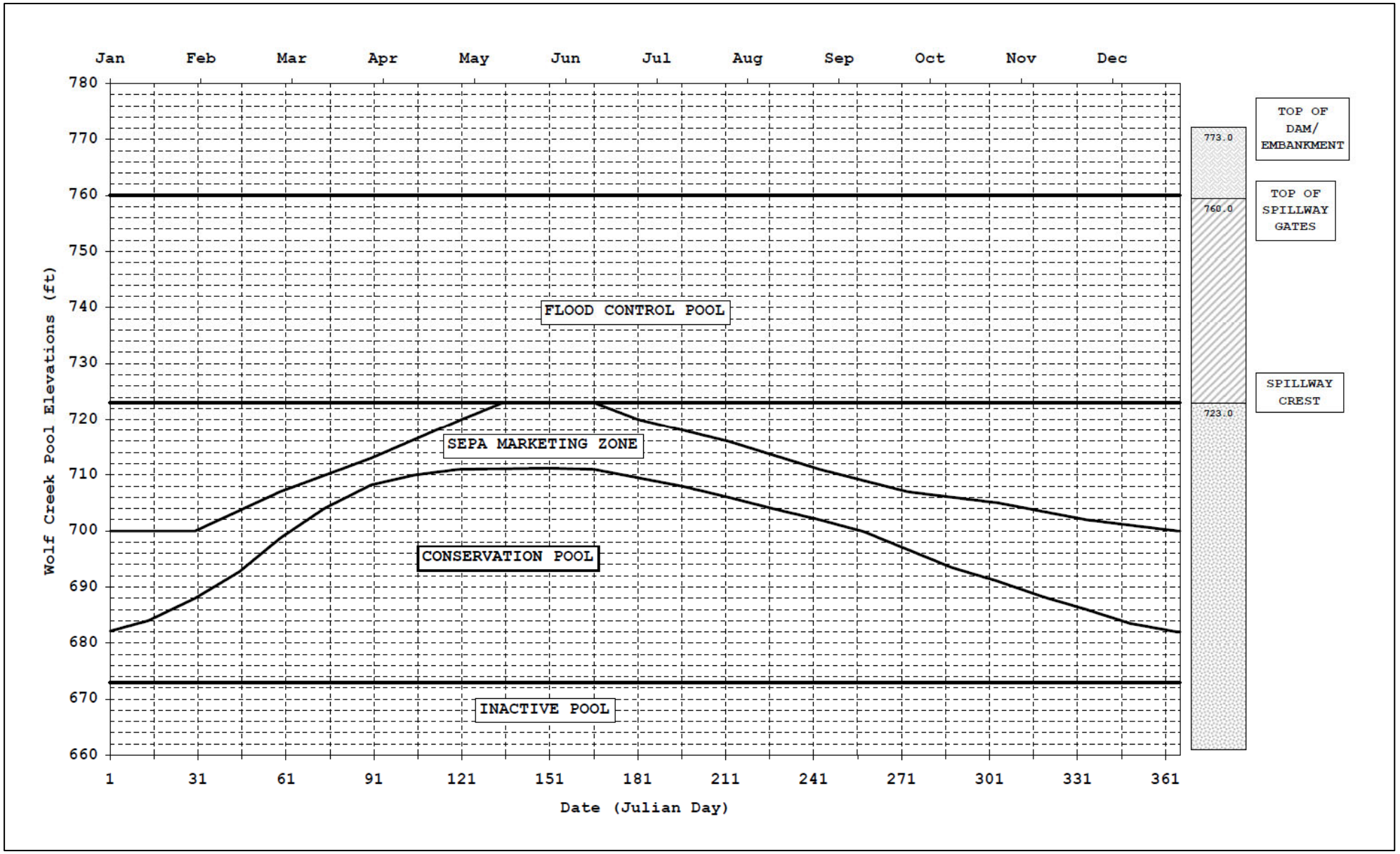

Figure 21: Wolf Creek Guide Curve

Appendix H – Environmental Opportunity Types

Environmental Opportunity Types

Environmental Actions	Action - Purpose
Environmental Pool Management	Fish Passage
	Fisheries (Life History Support)
	Mussels (Life History Support)
	Benthics (Life History Support)
	Herptiles (Life History Support)
	Overwinter Biota (Life History Support)
	Shorebirds, Gulls, Other Water Birds (Life History Support)
	Waterfowl (Life History Support)
	Invasive Species (Suppress/Restrict)
	Floodplain Connectivity
	Vegetation - Riparian
	Vegetation - Wetlands
	Debris Management
	Harmful/Nuisance Algal Blooms (Disrupt/Disperse)
	Water Temperature Management
	Water Quality (Nutrients, Dissolved Gases, Turbidity)
	Physical Habitat Enhancement (use of dredged material, oxbows/floodplain restoration)
	Pool Rate of Change - Shoreline Integrity (Water Quality)
	Sediment Passage

E-Flows	Fish Passage
	Fisheries (Life History Support)
	Mussels (Life History Support)
	Benthics (Life History Support)
	Herptiles (Life History Support)
	Overwinter Biota (Life History Support)
	Shorebirds, Gulls, Other Water Birds (Life History Support)
	Waterfowl (Life History Support)
	Floodplain Connectivity
	Vegetation - Riparian
	Vegetation - Wetlands
	Geomorphic Process
	Invasive Species (Suppress/Restrict)
	Debris Management
	Physical Habitat Creation (use of dredged material, oxbows)
	Harmful/Nuisance Algal Blooms (Disrupt/Disperse)
	Water Temperature Management
	Water Quality (Nutrients, Dissolved Gases, Turbidity)
	Other