US Army Corps
of Engineers®
Pittsburgh District

Planning and Environmental Branch
William S. Moorhead Federal Building
1000 Liberty Avenue
Pittsburgh, Pennsylvania 15222

Public Notice Date: April 19, 2022
Expiration Date: May 19, 2022

NOTICE OF AVAILABILITY

Draft Engineering Report and Environmental Assessment

Mahoning River Basin Water Control Manual Updates
Berlin Lake
Michael J. Kirwan Dam and Reservoir
Mosquito Creek Lake

U.S. Army Corps of Engineers Pittsburgh District (USACE) is evaluating updates to the Water Control Manuals for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake within the Mahoning River Basin located in the State of Ohio.

USACE invites submission of comments on the draft Engineering Report, draft Environmental Assessment, and draft Finding of No Significant Impact for the revised Water Control Manuals. USACE will consider all submissions received before the expiration date of the public comment period. The nature or scope of the proposal may be changed upon consideration of the comments received.

The draft Engineering Report, draft Environmental Assessment, and draft Finding of No Significant Impact are available electronically at:

https://www.lrp.usace.army.mil/Missions/Planning-Programs-Project-Management/

Comments can be submitted to the address posted at the top of this notice or to lrp.plan.enviro@usace.army.mil. Comments must be received by May 19, 2022 to ensure consideration.

A public meeting is scheduled for:

Tuesday, May 3, 2022 | 7 – 8:30 p.m.
Stambaugh Auditorium | 1000 5th Avenue, Youngstown, OH 44504.

The purpose of this meeting is to inform the public of the updates to the Water Control Manuals and answer questions about the project.

Berlin Lake,
Michael J. Kirwan Dam and Reservoir,
and Mosquito Creek Lake

Engineering Report
for
Revisions to the Water Control Manuals

APRIL 2022

Pittsburgh District, USACE

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1.0 PURPOSE/INTRODUCTION

The Mahoning River Watershed includes Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake (Projects). These three flood risk management Projects are operated as a system to maintain downstream flow requirements on the Mahoning River. This Engineering Report (ER) details an analysis of current and potential reservoir operations and provides recommendations for proposed reservoir operations. In this document, reservoir operations refers to how the United States Army Corps of Engineers (USACE) Pittsburgh District (District) maintains reservoir levels and outflow release rates, based on the effective water control plans.

Flood risk management activities cannot be considered in isolation. Effective water resources management must often balance competing needs. An integrated approach to water resource planning considers flood risk management as one of many objectives needed in a watershed. Other objectives might include ecosystem restoration, recreation, water supply, hydropower, or navigation depending on the needs in the basin. A collaborative approach to water resource planning and management engages multiple competing stakeholders in the development of watershed management plans to fulfill these needs.

This ER documents the technical engineering and stepwise approach throughout the analytical process by the District. Based on the results of the analysis and process, this report makes recommendations for changes to the Water Control Manuals (WCMs) for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake. The revised WCMs for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake, written together as a part of this process, accomplish the same as a single Master Water Control Plan, as discussed in Engineer Regulation 1110-2-240.

2.0 GUIDING REGULATIONS and MANUALS

The following regulations, manuals and guiding documents were considered in the development of this Engineering Report:

- ER 1110-2-240, “Water Control Management”, 30 May 2016
  This regulation prescribes policies governing water control management activities as required by Federal Law and directives, including the establishment of water control plans as appropriate, by the USACE at all USACE-owned and USACE-operated reservoirs, locks, dams, and other water control projects in which storage is operated and managed for authorized purposes such as flood control, navigation, and other uses. This engineering regulation also applies to USACE actions in developing water control plans and manuals or in operating non-USACE reservoirs, locks, dams, and other water control projects in which storage is operated and managed for flood control and navigation and subject to USACE direction pursuant to Section 7 of the Flood Control Act of 1944 or other law.

- EM 1110-2-3600, "Management of Water Control Systems", 10 October 2017
  This Engineer Manual (EM) provides guidance to field offices for water management at all USACE owned and operated reservoirs, locks, dams, and other water control projects in which water storage is managed and operated for multiple authorized purposes such as flood risk management, navigation, and other uses. It also applies to USACE actions in developing water control plans and manuals or in operating non-USACE reservoirs, locks, dams, and other water control projects in which water storage is managed and operated for flood risk management or navigation, and which are subject to USACE direction pursuant to Section 7 of the Flood Control Act of 1944 or other law.

- ER 1110-2-8154, "Water Quality Management", 31 May 2018
  This regulation provides direction for the water quality management of USACE civil works projects. USACE operates a water quality management program to ensure that all applicable state and federal water quality standards are met, water quality degradation of USACE resources is avoided or minimized and project responsibilities are attained.

- ER 1110-2-8156, "Preparation of Water Control Manuals", 11 December 2018
  This regulation standardizes the format, content, and procedures to be followed in the preparation of water control manuals prepared by USACE.

- ER 1110-2-1941, "Drought Contingency Plans", 2 February 2018
  This regulation provides policy and guidance for the preparation of drought contingency plans as part of the USACE overall water management activities.

3.0 BACKGROUND

The District operates three Projects located within the Mahoning River Watershed: Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake **(**Figure 3-1). Lake Milton is owned and operated by the Ohio Department of Natural Resources (ODNR). In accordance with the Plan of Coordination of Operation of Berlin Lake and Lake Milton, discussed below, the District furnishes information regarding proposed operation of Berlin Lake to the ODNR and provides ODNR with recommended operations for Lake Milton.

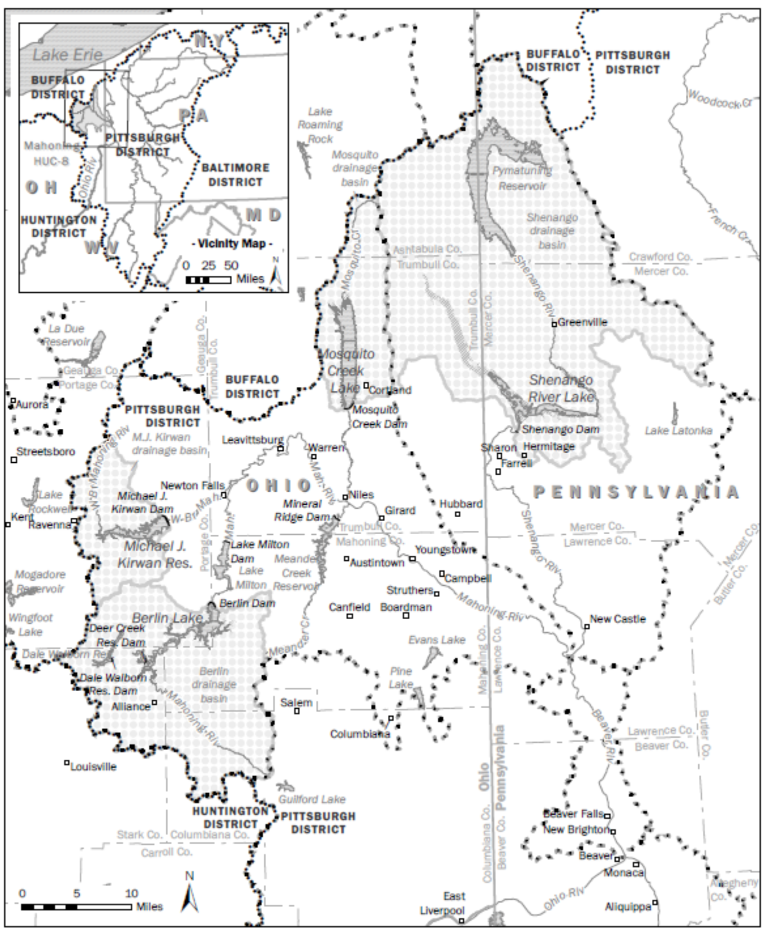
The Mahoning River begins in Columbiana County, Ohio, about 12 miles southeast of Alliance, Ohio. It flows generally northward to a point near Warren, Ohio, and then flows southeast through Niles and Youngstown, Ohio, into Pennsylvania. After traversing approximately 109 miles, it joins the Shenango River at New Castle to form the Beaver River. The Beaver River drains 3,153 square miles of the upper Ohio River basin in northeastern Ohio and northwestern Pennsylvania. The river flows in a southerly direction for approximately 22 miles to Beaver, Pennsylvania where it enters the Ohio River.

The Mahoning River watershed drains a total of 1,085 square miles in Ohio and Pennsylvania and flows through Ashtabula, Geauga, Trumbull, Portage, Mahoning, Stark and Columbiana counties. Major municipalities partially or fully in the watershed include Youngstown, Warren, Alliance, and Lordstown. The eastern portion of the watershed is predominantly comprised of urban development with some forest and agricultural lands. The western portion of the watershed is a mixture of forest, hay and pasture lands, cultivated crops, and urban development.

Berlin Lake, which began operation in 1943, is located along the Mahoning River in Mahoning and Portage Counties, Ohio, approximately 7.8 miles upstream of Lake Milton and about 25 miles upstream of Leavittsburg, Ohio. Reservoir operations of Berlin Lake are integrated with those of Lake Milton. Lake Milton began operation in 1917. A Plan of Coordination of Operation of Berlin Lake and Lake Milton was signed in 1954, wherein the District agreed to furnish information regarding proposed operations of Berlin Lake and recommended operations for Lake Milton.

Michael J. Kirwan Dam and Reservoir, which began operation in 1966, is located within Portage County, Ohio, on the West Branch Mahoning River, 10.6 miles above the confluence of the West Branch Mahoning River and the Mahoning River, at Newton Falls, Ohio. The confluence of these two rivers is located approximately 15.5 miles upstream of Leavittsburg, Ohio.

Mosquito Creek Lake, which began operation in 1944, is located within Trumbull County, Ohio, on Mosquito Creek, 13.3 miles upstream of the confluence of Mosquito Creek and Mahoning River at Niles, Ohio. The confluence of these two rivers is approximately 8 miles upstream of Youngstown, Ohio.



Note: The Mahoning River Watershed is part of the larger Beaver River Watershed

Figure 3-1: Beaver River Watershed

4.0 AUTHORIZATIONS

The authorized purposes for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake include flood control, water quality control, fish and wildlife, recreation, and water supply. A summary of Reservoir Operating and Authorized Purposes is provided in Table 4-1.

Table 4-1: Reservoir Operating and Authorized Purposes

Project	Storage Allocated	Operating Purposes	Authorized Purposes	Authorizing Laws
Michael J. Kirwan Dam and Reservoir	Flood Control	Flood Control	Flood Control	PL 85-500 (A)
	Water Quality Control	Water Quality Control	Water Quality Control	PL 85-500 (A), PL 86-645 (A), PL 92-500 (G)
		Fish/Wildlife	Fish/Wildlife	PL 85-624 (G)
		Recreation	Recreation	PL 78-534 (G)
		Water Supply	Water Supply	PL 85-500 (A), PL 86-645 (A)
Berlin Lake	Flood Control	Flood Control	Flood Control	PL 75-761 (A)
	Water Quality Control	Water Quality Control	Water Quality Control	PL 75-761 (A), PL 92-500 (G)
		Fish/Wildlife	Fish/Wildlife	PL 85-624 (G)
		Recreation	Recreation	PL 78-534 (G)
	Water Supply	Water Supply	Water Supply	PL 75-761 (A)
Mosquito Creek Lake	Flood Control	Flood Control	Flood Control	PL 75-761 (A)
	Water Quality Control	Water Quality Control	Water Quality Control	PL 75-761 (A), PL 92-500 (G)
		Fish/Wildlife	Fish/Wildlife	PL 85-624 (G)
		Recreation	Recreation	PL 78-534 (G)
	Water Supply	Water Supply	Water Supply	PL 75-761 (A)

NOTES:

Operating Purpose – A reservoir purpose for which water control management decisions are made. Either the volume of water retained in storage, the water surface elevation, or the rate of discharge is regulated to serve the stated purpose.

Authorized Purpose – A purpose that a reservoir is to serve as given in laws may be grouped into the following categories:

(A) Laws initially authorizing construction of the project
(S) Laws specific to the project passed subsequent to construction
(G) Laws that apply generally to all Corps reservoirs

Berlin Lake was authorized by the Flood Control Act of 28 June 1938 (Public Law 75-761). Berlin Lake was constructed to provide flood control and low flow augmentation along the Mahoning, Beaver, and upper Ohio Rivers. Authorized purposed of Berlin Lake include flood control (Flood Control Act of 1938), water quality control (Flood Control Act of 1938 and Federal Water Pollution Control Act Amendments of 1972), water supply (Flood Control Act of 1938), fish and wildlife enhancement (Fish and Wildlife Coordination Act of 1958), and recreation (Flood Control Act of 1944).

Michael J. Kirwan Dam and Reservoir was authorized by the Flood Control Act of 3 July 1958 (Public Law 85-800) as modified by the Flood Control Act of 14 July 1960 (Public Law No. 86-645). Michael J. Kirwan Dam and Reservoir was constructed to provide flood control and low flow augmentation along the Mahoning, Beaver, and upper Ohio Rivers. Authorized purposes of Michael J. Kirwan Dam and Reservoir include water quality control (Flood Control Act of 1958, River and Harbor Act of 1960, and Federal Water Pollution Control Act Amendments of 1972), fish and wildlife enhancement (Fish and Wildlife Coordination Act of 1958), recreation (Flood Control Act of 1944), and water supply (Flood Control Act of 1958 and River and Harbor Act of 1960).

Mosquito Creek Lake was authorized by the Flood Control Act of 28 June 1938 (Public Law 75-761). Authorized purposes of Mosquito Creek Lake include water quality control (Flood Control

Acts of 1938 and Federal Water Pollution Control Act Amendments of 1972), fish and wildlife enhancement (Fish and Wildlife Coordination Act of 1958), recreation (Flood Control Act of 1944), and water supply (Flood Control Acts of 1938).

5.0 WATER CONTROL MANUAL

Water management activities of USACE reservoirs are governed by a project's authorized purposes as defined by the project's authorizing laws and must also be consistent with other legal requirements related to real estate, environmental principles, public use, and public safety.

A WCM is the guiding document that specifies how the USACE operates one of its reservoirs. Each reservoir has congressionally mandated purposes, and these manuals are what USACE uses to balance those purposes. The WCMs also provide details on the reservoir's history, authorizations, watershed characteristics, data collection networks, forecasting methods, and stakeholder coordination. The most critical section of the manual is the Water Control Plan (WCP), which outlines the operational plan (when and how to release or hold water) to meet the reservoir's congressionally mandated purposes. Water control plans (e.g., regulation schedules or guide curves) are developed using historical hydrometeorological data such as water levels, streamflow, and rainfall. Guide curves for individual reservoirs define various amounts of storage as conservation storage, or flood storage. The flood storage zone elevations vary based on the time of year to accommodate the associated risk of flooding along with the ability to forecast reservoir inflows (e.g., snowmelt runoff vs. thunderstorm rainfall runoff), and to store water for use during the dry seasons.

6.0 CHANGES IN THE WATERSHED

The Mahoning River Watershed has changed significantly over the past 40 years. The watershed was the site of intensive steel making activity throughout much of the 20th century. Point source loadings from the major industrial facilities in the lower Mahoning River watershed were documented in the early 1950s. Pollution control in the Mahoning Valley during this time period was essentially nonexistent, with the steel industry directly discharging untreated coke plant wastes, rudimentary solids removal for blast furnace gas wash water, scale pits with and without oil skimming for hot forming wastes, untreated emulsified cold rolling oils, spent pickling acids and untreated coating wastes (Amendola et al. 1977). Since then, significant loading reductions of wastewater volume, total suspended solids, oil and grease, total iron and phenolics have occurred. These reductions became possible with pollution control improvements at several steel mills, but mostly because of the partial to total shutdown of many of the major steel producing facilities in the late 1970's and early 1980's, dramatically reducing thermal pollution and the loadings of industrial pollutants to the Mahoning River (OEPA, 1996).

Current land use within the eastern portion of the watershed is predominantly comprised of urban development with some forest and agricultural lands. The western portion of the watershed is a mixture of forest, hay and pasture lands, cultivated crops and urban development.

Over the past few decades, residential and commercial development has moved outward from the urban Mahoning River corridor to previously rural areas of Mahoning and Trumbull Counties. This movement accelerated after the decline of the steel industry and was much more pronounced in Youngstown than in Warren. The population of Youngstown declined dramatically from 168,330 in 1950 to 82,026 in 2000. However, the populations of Mahoning and Trumbull Counties as a whole have only declined slightly from their peaks in 1960. This reflects the movement of residential and commercial development into suburban communities such as Boardman, Poland, and Canfield to the south of Youngstown, Austintown to the west of Youngstown and south of Warren, and Liberty and Howland north of Youngstown and east of Warren (YSU, 2004).

In the Lower Mahoning River Corridor watershed, the major change in land use over the past 30 years has been the increase in unused or underused urban land. Thousands of acres of “brownfields” (abandoned industrial land) lie along the Mahoning River between Warren and the state line(YSU, 2004).

In the Mosquito Creek watershed, some former industrial sites along the Mahoning River have been abandoned. In addition, over the past 40 years, much of the commercial activity has moved from the City of Warren to the area near SR 422 in the City of Niles. This, combined with increased residential development in Howland, Liberty, and Cortland, has resulted in a modest decrease in agricultural land, and to a lesser extent, forest land in these areas (YSU, 2004).

7.0 OBJECTIVE OF ANALYSIS

Berlin Lake, Lake Milton, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake are operated as a system to meet minimum downstream flow requirements, as those requirements are set out by the current water control manuals for all three Projects. With the reduction of thermal and industrial pollutants within the watershed, as evidenced by the District’s water quality data and a study by the Ohio EPA (2018), potential revisions to the operation of Berlin Lake, Lake Milton, Michael J. Kirwan Dam and Reservoir and Mosquito Creek Lake were evaluated. The goals were to:

1. Determine if there was a reservoir operating scenario or combination of reservoir operating scenarios, that would better balance the current and future needs of the watershed, allowing the system of reservoirs to optimize the benefits of the projects while still meeting their congressionally authorized purposes (further defined in Section 10.4.1).

2. Increase flexibility in operational decisions to balance the releases from Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake based on the availability of water and each reservoir’s current water level.

Since the construction of these reservoirs was staggered, a systems approach to management of the Mahoning River basin was not considered when the original WCMs for Berlin Lake, Lake Milton, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake were developed.

This Engineering Report (ER) describes the analyses conducted in support of a systems approach which seeks to accomplish the projects' purposes that benefits them to the greatest extent possible while seeking to minimize the risk to public safety.

7.1 BEYOND SCOPE OF EFFORT

7.1.1 Reauthorization / Reallocation

The District Project Delivery Team (PDT) did not consider reauthorization or reallocation of water storage as viable options for the study. Reauthorization, the act of changing the authorized purposes of a reservoir, requires an act of Congress. A Reallocation Study, the process of evaluating and recommending action based on the potential changing of the relative reservoir storage allowed for each authorized purpose, requires a viable partner for a cost sharing project. Each of these options were outside the scope of the effort and not considered.

7.1.2 Comprehensive Watershed Study

The District PDT did not consider a comprehensive watershed study, including removal of the established temperature schedule and flow schedule downstream of the projects at Leavittsburg, OH and Youngstown, OH.

7.1.3 Flowage Easements

The PDT did not consider land acquisition or changes to the flowage easements for Berlin Lake, Michael J. Kirwan Dam and Reservoir and Mosquito Creek Lake. Flowage easement land is non-federally owned land over which the United States Government has acquired certain perpetual rights, such as the right to overflow, flood and submerge the land, the right to prohibit structures for human habitation, and the right to approve all other structures proposed for construction within the flowage easement.

For context of the flowage easement, the taking line for Berlin Lake is at EL 1034 ft, two feet above the crest of the uncontrolled spillway. The government obtained real estate in fee or easement on all properties upstream of the dam which contained areas lower than EL 1034 ft.

There were two criteria applied regarding land acquisition for Michael J. Kirwan Dam and Reservoir. The first was land contained within the boundary formed by a line 300 feet out from the full pool contour acquired in fee by the government. The other was flowage easements obtained over land lying outside of this boundary but below EL 998 ft, five feet below full pool. There are some exceptions to this criteria above EL 998 ft acquired for recreational use.

EL 906 ft represents the taking line at Mosquito Creek Lake. All land below this elevation was obtained by the government by fee or easement.

7.2 SCOPE OF EFFORT

Computer programs, including Hydrologic Engineering Center (HEC) Hydrologic Modeling System (HEC-HMS), HEC Reservoir Simulation (HEC-ResSim), Risk Management Center Reservoir Frequency Analysis (RMC-RFA), CE-QUAL-W2, and Microsoft Excel were used to model the watershed and reservoirs. Using these computer programs for modeling and statistical methods, the report quantifies hydrologic, hydraulic, and water quality impacts on the congressional authorizations for each project.

Two public workshops were conducted in 2020 to engage stakeholders and the public. As a result of the workshops and discussion with the District's Project Delivery Team (PDT), proposed operational changes to Berlin Lake, Lake Milton, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake were considered. These changes were applied in mixed and matched configurations, yielding a set of system operating scenarios. Through a partnership with the USACE Institute for Water Resources (IWR), a Decision Support Tool (DST) was used to evaluate each scenario, using metrics for each specific authorization (discussed in Section 10.3.1, Section 10.3.2, Section 10.3.3, Section 10.3.4, and Section 10.3.5).

The PDT evaluated each scenario's predicted effects as generated from the DST to determine predicted impacts to project authorizations. Scenarios that best maintained and enhanced the missions of the reservoirs, were carried forward in a CE-QUAL-W2 water quality (WQ) model developed to evaluate within reservoir and downstream water quality constituent changes. All other scenarios were not examined any further. In conjunction with this engineering report an Environmental Assessment (EA), considering the selected scenarios (defined as "Alternatives" in the EA), was also conducted. The EA assesses the impact of proposed Alternatives to ensure compliance with the National Environmental Policy Act (NEPA) and other environmental laws.

8.0 PUBLIC INVOLVEMENT

The District conducted public engagement events over the course of the study at locations throughout the watershed. These events included public outreach meetings, resource agency meetings, and workshops in which stakeholders were encouraged to attend and provide input that would be used to enhance the watershed study. The information gathered at these events was valuable in developing solutions to address the stakeholders' needs within the watershed. Federal, state, and local agencies were regularly invited and involved with these public meetings. Appendix B contains a list of points of contact for the federal, state, and local agencies invited to public meetings.

Notification of all public events were disseminated by the District's Pittsburgh's Public Affairs Office. Public meeting announcements are disseminated through a variety of communication channels. The standard is to send an initial subject matter expert (SME)-approved press release two weeks before the meeting directly to news outlets and published concurrently on social media, defense information-communication platforms and our public website. A follow-up, or reminder, press release is sent to the same news outlets and published on the same platforms two or three days before the meeting. Depending on the type of meeting, we may use additional communication channels, such as reverse-911 calls to the local community and other relevant stakeholders. Notifications were also posted on LRP's social media sites and the project specific webpage created for the study.

The list of public outreach events conducted by the District are summarized below.

July 2017 Public Meeting. The District held a public meeting in July 2017 to gather information from interested parties. The presentation and agenda are located on the USACE website (https://www.lrp.usace.army.mil/Missions/Recreation/Lakes/Berlin-Lake/Berlin-Lake-Visioning-Meeting).

January 29, 2019, Project Kickoff Meeting. A project kickoff meeting was held on January 29, 2019 from 7:00 – 8:30 PM at the Stambaugh Auditorium in Youngstown, Ohio. The purpose of the meeting was to inform the public of the Water Control Manual update process and answer questions about the process. The LRP District Commander, LRP senior leaders, LRP project staff, LRP project team members, local media outlets, and over 100 stakeholders were in attendance. The list of attendees is included as Table C-1, within Appendix C.

June 26, 2019, and July 24, 2019, Community Outreach Events. Three Community Outreach Meetings were held at locations near one of the three reservoirs being studied for the convenience of local stakeholder groups. Two were conducted on June 26, 2019, from 4:30 – 7:00 PM at the Trumbull County Extension Office in Cortland, Ohio [Mosquito Creek Lake] and at Michael J. Kirwan Dam and Reservoir Resource Manager's Office in Wayland, Ohio [Michael J. Kirwan Dam and Reservoir]. One was conducted on July 24, 2019, from 4:30 – 7:00 PM at the Western Reserve High School in Berlin Center, Ohio [Berlin Lake]. The purpose of these meetings was to provide an update on the scope and schedule for completion of the study. These meetings also provided a forum for stakeholders to provide information or recommendations for consideration in the study. LRP project staff, LRP project team members, local media outlets, and other stakeholders were in attendance. The list of attendees for all three events was conglomerated together and the conglomerated list of attendees is included as Table C-2, within Appendix C.

July 24, 2019, Resource Agency Meeting. A Resource Agency Meeting was held on July 24, 2019, from 10:00 AM – 2:30 PM at the Ohio Department of Natural Resources District Office in Akron, Ohio. The purpose of this meeting was to discuss the WCM effort and boundaries within which decisions would be made for the effort. The meeting was an opportunity to identify current and future basin resource needs, problems, and opportunities; and discuss ways to measure and model the impacts to resources. LRP project staff, LRP project team members, and representatives from federal and state regulatory agencies were in attendance. The list of both the invitees and attendees of this meeting are included in Table C-3, within Appendix C.

May 27, 2020, Public Workshop. A modeling scenario building workshop was held virtually, using WebEx, on May 27, 2020 from 9:30 AM – 4:00 PM due to COVID-19 restrictions that prohibited large gatherings. The objectives of the workshop were: to establish familiarity between recreation, environmental conditions/water quality, flood risk reduction, water supply representatives, and their interests in the basin; create a shared understanding of how the reservoir system is managed and how the system would be modeled for the study; identify reservoir management scenarios and conditions that would meet current and future regional water requirements and interests; and brainstorm a list of criteria for measuring scenario success. LRP project staff, LRP project team members, and over 30 stakeholders were in attendance. The list of both the invitees and attendees of this meeting are included in Table C-4, within Appendix C.

December 16, 2020, Public Workshop. A modeling scenario evaluation workshop was held virtually, using WebEx, on December 16, 2020 from 9:00 AM – 4:00 PM due to COVID-19 restrictions that prohibited large gatherings. The objectives of the workshop were: to share the scenarios that had been evaluated to determine and prioritize whether any additional modifications to scenarios should be made or evaluated; explore how the management scenarios helped to meet regional water requirements and goals; and discuss the evaluation findings and the tradeoffs between scenarios. LRP project staff, LRP project team members, and over 30 stakeholders were in attendance. The list of both the invitees and attendees of this meeting are included in Table C-5, within Appendix C.

Multiple Local Stakeholder Meetings. The District has been invited on multiple occasions to present at the quarterly meetings of the Berlin Lake Association. These meetings were not conducted by USACE, but USACE was invited and attended as a guest. USACE did not prepare any formal presentation for these meetings. However, USACE answered questions when the Association has asked for project updates to be provided at these meetings. It was also an opportunity for the stakeholders to ask questions about the study. The LRP District Commander, LRP senior leadership, LRP project staff, and LRP project team have attended these meetings. As these meetings were not hosted by the USACE, records of attendance were not kept.

Post-Completion Community Outreach Event. A Community Outreach Event is planned after completion of the study. The date, time, and location of the event will be determined at a later date. The purpose of this event will be to provide the results of the study to project stakeholders and provide information on the updated WCMs. It is anticipated that the LRP District Commander, LRP senior leadership, LRP project staff, and LRP PDT will be in attendance. It is also anticipated that local media outlets and many stakeholders will be in attendance as well.

9.0 ENVIRONMENTAL OPERATING PRINCIPALS

ER 1110-2-240 requires that district water control management documentation and activities are guided by the USACE Environmental Operating Principles in accordance with authorized or approved purposes. The Environmental Operating Principles and considerations for this engineering report are outlined below:

1. Foster sustainability as a way of life throughout the organization.
    - This engineering report considered the protection of natural systems and the environment by maintaining authorized purposes and metrics for water quality.

2. Proactively consider environmental consequences of all USACE activities and act accordingly.
    - This engineering report and supporting EA document how effects of a candidate actions have been considered. Recommendations that minimize negative environmental effects or enhance positive ones were ultimately supported.

3. Create mutually supporting economic and environmentally sustainable solutions.

- This engineering report considered actions that minimize environmental conflicts and would enhance multipurpose projects with ancillary benefits.

4. Continue to meet our corporate responsibility and accountability under the law for activities undertaken by the USACE which may impact human and natural environments.
    - An assessment of compliance with environmental requirements was conducted as early in our planning processes as practicable. The PDT also engaged with external entities (Section 8.0) to better anticipate problems and promote collaboration. Coordination with partners and stakeholders occurred as early as feasible.

5. Consider the environment in employing a risk management and systems approach throughout life cycles of projects and programs.
    - This engineering report supports a systems approach to management of Berlin Lake, Michael J. Kirwan Dam and Reservoir and Mosquito Creek Lake through goals listed in Section 7.2. Risks are analyzed qualitatively and quantitatively openly in this document and supporting EA.

6. Leverage scientific, economic, and social knowledge to understand the environmental context and effects of USACE actions in a collaborative manner.
    - Environmental concerns were considered in early conceptual stages of the work. The PDT engaged and subject matter experts and multiple disciplines within the USACE for reviews including engineering, environmental, policy and legal. Detailed computer modeling for water quality constituents was undertaken to understand the effects possible candidate actions.

7. Employ an open, transparent process that respects views of individuals, groups, and businesses interested in and affected by USACE activities.
    - USACE, to the extent practicable, made maximum effective use of transparency in scoping and planning actions to gain insights from individuals and diverse stakeholder groups (Section 8.0). This helped to ensure that all USACE decisions on resource management provided appropriate consideration of interested individuals, groups, and businesses. This engineering report will also be made available for public comment.

10.0 TECHNICAL ANALYSIS

The following analyses were performed to determine the impacts associated with revising reservoir levels and outflow release rates contained in the WCPs for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake, while maintaining the congressional authorizations associated with each of the Projects. In summary, the engineering stepwise approach taken was as follows:

1) Step 1 - Evaluate the existing Corps Water Management System (CWMS) model as a baseline model which represents the existing WCPs. If needed, incorporate changes to the existing CWMS model (Section 10.1).

2) Step 2 - Conduct public involvement and stakeholder engagement to develop Proposed WCP Changes and develop a set of system test scenarios. Perform modeling using HEC-HMS software and HEC-ResSim software, to test the proposed system scenarios (Section 10.2). HEC-HMS is designed to simulate the complete hydrologic processes of dendritic watershed systems. The software includes many traditional hydrologic analysis procedures such as event infiltration, runoff, and hydrologic routing. HEC-ResSim is a reservoir simulation tool developed for use in modeling reservoir operations given a variety of operational goals and constraints. HEC-ResSim inputs include inflow data, reservoir stage-storage relationships, rating curves for reservoir outlets, and a set of rules to determine reservoir operations for one or more reservoirs.

3) Step 3 - Evaluate the scenarios using the DST with inclusion from the public and stakeholders and support from the IWR (Section 10.3).

4) Step 4 - Select scenarios that fulfill project goals while balancing watershed needs and/or enhancing authorized uses for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake. Examine these scenarios further in the CE-QUAL-W2 model (Section 10.4). CE-QUAL-W2 is a water quality and hydrodynamic model in 2D (longitudinal-vertical) for rivers, estuaries, lakes, reservoirs, and river basin systems. The program models numerous constituents such as temperature, nutrients, chlorophyll a, dissolved oxygen, organic matter, and others.

5) Step 5 - Perform Reservoir Frequency Analysis (RFA) using the USACE Risk Management Center (RMC) RFA model to quantify the flood risk (Section 10.5) for the selected scenarios. RMC-RFA is a stochastic flood modeling software that employs advanced statistical and computing techniques, allowing a user to perform a stage-frequency analysis and examine uncertainty bounds.

After the technical analysis was completed, the following steps were taken to analyze the Mahoning River Watershed.

1) Using the selected scenarios (defined as Alternatives in the EA), conduct an EA to assess the impact and to ensure compliance with the National Environmental Policy Act (NEPA) and other environmental laws. (Section 11.0)

2) For the selected scenarios, evaluate impacts from climate change using the Climate Hydrology Assessment Tool (Section 13.0).

3) For the selected scenarios, evaluate impacts from previously identified risk driving failure modes for the reservoir or reservoirs with proposed operational changes (Section 14.0).

4) Provide a recommendation for changes to the WCMs for Berlin Lake, Michael J. Kirwan Dam and Reservoir and Mosquito Creek Lake (Section 15.0 and Section 16.0).

10.1 EVALUATE EXISTING CWMS MODEL

10.1.1 STEP 1 – PART A - BASELINE MODEL

The base CWMS model developed for the Beaver River watershed was used as a starting point for the analysis. Inputs from the HEC-HMS and HEC-ResSim models within CWMS were examined and, if required, revised so the baseline model matched the logic used within the existing WCPs more closely. This approach was carried out as follows:

1. Review the existing CWMS HEC-HMS hydrologic model and HEC-ResSim reservoir simulation model for understanding. Determine potential areas for improvement that will yield results more closely aligned with the WCPs.

2. Develop a set of inflow values using HEC-HMS and available observed data to input into the HEC-ResSim model and test model performance. Test the bounds of reservoir operations and evaluate model performance for four years: Water Year (WY) 2004, WY 1999, and Calendar Year (CY) 2013, and CY2014. The four years provide a variety of hydrologic conditions for testing including wetter than average and dryer than average years. Water Year 2004 was chosen as the wettest year on record that had available high quality gridded precipitation data. Water Year 1999 was chosen as the driest year on record that had available gridded precipitation data. CY 2013 and CY 2014 were chosen to test two consecutive years with intermediary flows.

   It was assumed that modeling four years was sufficient for determining the impact that revising the reservoir operations for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake would have on the watershed. This approach bookends the historical record from the perspective of wettest and driest years, however it is noted that this approach may not reflect the important differences in event timing (e.g., large runoff events occurring back-to-back or spanned apart) and the inter-year variability of watershed conditions (e.g., multi-year dry or wet periods) within the Mahoning River watershed. The RMC-RFA modeling (Section 10.5) does capture the flood risk for extreme events (e.g., back-to-back large runoff events) with simplified operational rules.

3. Revise the existing HEC-HMS and HEC-ResSim models to better represent existing and/or baseline conditions. Doing this ensures that the models more closely match the WCPs for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake.

4. Perform a visual inspection of the results to determine if the model provides results which are reasonable and exhibit behaviors matching the intent of the WCPs. The visual inspection included a review of reservoir elevations and outflows, as well as an observation of the flow rates at Leavittsburg, OH and Youngstown, OH. It is important to note that the reservoirs' ability to meet the WCP goal is dependent upon the runoff occurring both upstream and downstream of the reservoir and the amount and timing of the runoff (weather dependent conditions).

10.1.2 STEP 1 - PART B - RECALIBRATION/REVISION TO BASELINE

Reservoir operational decisions are made with some operational judgment, based on real-time and future forecast conditions, and not stand-alone sets of historical data. HEC-ResSim cannot account for the operational judgements made by the trained individual. Due to this, HEC-ResSim does not always compare in line with historical outflow and reservoir elevation data. In order to reconcile the model with daily operational decisions, a visual inspection of the model output was the preferred method. As a visual inspection of the results suggested that the HEC-ResSim baseline model followed the intent of the WCP, the model was considered satisfactory.

The following revisions were made to the HEC-HMS baseline model:

1. A maximum deficit of approximately 3.5 inches was present in most of the model subbasins, resulting in moderate sized precipitation events being transformed into zero runoff. To correct this issue, the maximum deficit was decreased by 1 inch across all subbasins (as opposed to changing other runoff loss metrics or loss parameterization methods). Decreasing the maximum deficit by 1 inch allowed the HEC-HMS model to provide reasonable outflows during low precipitation years, specifically during WY1999.

2. The baseflow recession method was leading to near zero flow over multiple dry days for many of the unregulated basins. To address the issue of near zero flows during dry periods, the baseflow method was changed from recession to a monthly average baseflow. A ratio between the baseflow and drainage area of the Phalanx Station subbasin was developed for each month. This ratio was then applied to the drainage area of each subbasin to estimate monthly baseflow for all other unregulated subbasins.

The following revisions were made to the HEC-ResSim baseline model:

1. The addition of the transition zone, which were part of the WCP but were not included in the existing CWMS model, for all four reservoirs.

2. Revisions to the coding (state variable) which specifies when Berlin Lake, Lake Milton, and Michael J. Kirwan Dam and Reservoir phase in and out of their respective flood control schedules. Mosquito Creek Lake did not require this coding revision.

3. Revisions to the rules governing the appropriate reservoir release percentages for augmentation flow at Leavittsburg, OH. It was determined that the original model was not correctly releasing the required augmentation flow. Historical District records indicate the current split in augmentation flow is based on computations determining the equitability of outflow to Leavittsburg using a 64% / 36% split. This correction ensures that 64% and 36% of the augmentation flow, as specified by the records, comes from Berlin Lake and Michael J. Kirwan Dam and Reservoir, respectively.

4. Removal of the explicit system storage, which was set up to meet low flow downstream, but was based on storage, not outflow percentages.

5. Revision to the minimum flow during the flood control schedule to match the flows in the WCPs.

6. Addition of channel capacity flow downstream of Mosquito Creek Lake. This channel capacity flow was included in the WCP, but was not included in the existing CWMS model.

7. Addition of a rule that closes all gates at Michael J. Kirwan Dam and Reservoir once reservoir elevations exceed the spillway.

8. Revisions to the stage-storage relationships, stage-outflow relationships, and operational zones based on updated survey data.

10.1.3 STEP 1 - PART C – CHECK OF UPDATED BASELINE

To determine whether the updated existing model results were consistent with Berlin Lake, Lake Milton, Mosquito Creek Lake and Michael J. Kirwan Dam and Reservoir WCPs, visual inspections of the reservoir elevations, reservoir outflow, as well as the flow rates in the Mahoning River at the two downstream control points at Leavittsburg and Youngstown, OH were performed. Observed discrepancies are a result of changes to normal operations due to maintenance, flood operations, and actual operational changes (human intervention element). It was determined that the updated HEC-ResSim model provides reasonable results with expected model outcomes that follow the specified WCPs. A comparison of the existing CWMS model (i.e., CWMS model prior to updates) and the revised baseline model (i.e., updated CWMS model), as described in Section 10.1.2, for WY2004 are show in Figure 10-1 for Berlin Lake.

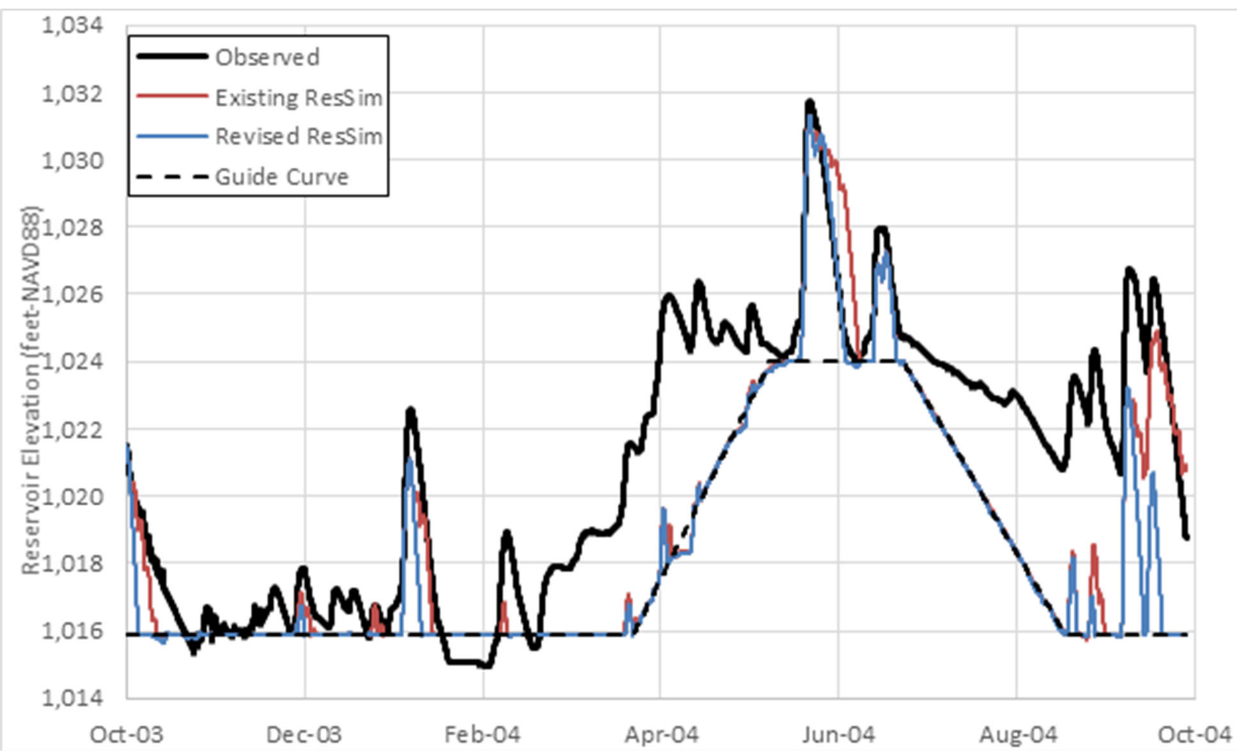


Figure 10-1: WY 2004 Berlin Lake Elevation Comparison of Observed and HEC-ResSim Results

10.2 PROPOSED CHANGES TO WCP AND SET OF SYSTEM SCENARIOS

10.2.1 STEP 2 – PART A - PUBLIC INVOLVEMENT

In 2020, there were two public workshops including members of the PDT and public stakeholders. During the public workshop, public stakeholders were provided an opportunity to offer suggestions on the Proposed WCP Changes to reservoir operations which would be studied. These public workshops became the basis for Proposed WCP Changes 1, 2, and 3, listed below.

10.2.2 STEP 2 - PART B – ADDITIONAL PROPOSED WCP CHANGES

Further discussion within the PDT led to further Proposed WCP Changes 4, 5, 6 and 7. These Proposed WCP Changes were studied to answer questions from public stakeholders, to provide a wide range of options to evaluate the system of reservoirs and to perform analyses on the sensitivity of the watershed to the Proposed WCP Changes. Along with the seven Proposed WCP Changes, a base case where reservoir operations were not changed, was also modeled. The seven Proposed WCP Changes to reservoir operations were:

1. Begin drawdown from summer pool for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and/or Mosquito Creek Lake on September 7, instead of late June for Berlin Lake, mid-September for Michael J. Kirwan Dam and Reservoir, and mid-August for Mosquito Creek Lake. For Berlin Lake, the anticipated benefit of this proposed change is a longer summer pool and additional recreational opportunities during the peak recreational season. To a lesser extent, this anticipated benefit applies to Mosquito Creek Lake as well, though Mosquito Creek Lake begins drawdown mid-August. For Michael J. Kirwan Dam and Reservoir, there is no anticipated intrinsic benefit in reducing summer pool earlier, however scenarios where drawdown of Berlin Lake and Michael J. Kirwan began drawdown at the same time were considered.

2. Revise Berlin Lake's WCP during the fall drawdown to reflect utilizing 25% flood storage of the original guide curve. This change will begin the drawdown later than the current WCP and slows the rate of drawdown. The anticipated benefit of this proposed change is that it would allow for a longer summer pool at Berlin Lake.

3. Augment flow deficiencies in the Mahoning River at Leavittsburg 50% by Berlin Lake-Lake Milton and 50% by Michael J. Kirwan Dam and Reservoir, instead of 64% by Berlin Lake-Lake Milton and 36% by Michael J. Kirwan Dam and Reservoir. The anticipated benefit of this proposed change is that it would create an equal requirement for Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir to maintain downstream flow targets.

4. Begin drawdown of Michael J. Kirwan Dam and Reservoir on June 26, when Berlin Lake's WCP requires drawdown to begin. The anticipated benefit of this proposed change is that it would bring Michael J. Kirwan Dam and Reservoir in line with the drawdown of Berlin Lake, reducing the burden of Berlin Lake to maintain downstream flow targets.

5. Augment flow deficiencies in the Mahoning River at Leavittsburg by Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir, with no specified percentage, instead of 64% by Berlin Lake-Lake Milton and 36% by Michael J. Kirwan Dam and Reservoir. The anticipated benefit of this proposed change is that it would provide greater flexibility in which Berlin Lake and Michael J. Kirwan Dam and Reservoir should release water, rather than forcing a constrained ratio. The District's Water Management team will balance the releases from Berlin Lake and Michael J. Kirwan Dam and Reservoir based on the availability of water and each reservoir's current water level.

6. Begin filling Berlin Lake, Michael J. Kirwan Dam and Reservoir and Mosquito Creek Lake on February 15, instead of mid-March for Berlin Lake and late February for Mosquito Creek Lake. The anticipated benefit of this proposed change is that it may provide a more stable pool during the spring spawning period for fish by reaching summer pool sooner to potentially enhance fish spawning success.

7. Provide no augmentation flow in the Mahoning River for the Leavittsburg, OH or Youngstown, OH control points. The anticipated benefit of this proposed change is that it would remove the requirement to maintain a flow schedule downstream.

The individual Proposed WCP Changes are described in more detail in the subsequent sections.

Using these seven Proposed WCP Changes, a combination of twenty-five operating scenarios were developed and applied in different configurations for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake. The resulting twenty-five scenarios are defined in Table 10-1.

Table 10-1: Scenarios

Scenario Number	Scenario Description[1]
01	Existing Conditions (Existing WCP)
02	Begin Drawdown for Berlin Lake on September 7, Michael J. Kirwan Dam and Reservoir, Lake Milton, and Mosquito Creek Lake follow Existing WCPs
03	Utilize 25% Original Reservoir Storage for Berlin Lake during Drawdown
04	Flow deficiencies at Leavittsburg are augmented 50% by Berlin Lake-Lake Milton and 50% by Michael J. Kirwan Dam and Reservoir
05	Begin Drawdown for Berlin Lake on September 7, and Flow deficiencies at Leavittsburg are augmented 50% by Berlin Lake-Lake Milton and 50% by Michael J. Kirwan Dam and Reservoir
06	Utilize 25% Original Reservoir Storage for Berlin Lake during Drawdown and Flow deficiencies at Leavittsburg are augmented 50% by Berlin Lake-Lake Milton and 50% by Michael J. Kirwan Dam and Reservoir
07	Begin Drawdown for Mosquito Creek Lake on September 7, Michael J Kirwan Dam and Reservoir, Lake Milton, and Berlin Lake follow Existing WCP
08	Begin Drawdown for Berlin Lake and Mosquito Creek Lake on September 7, Michael J Kirwan Dam and Reservoir and Lake Milton, and follow Existing WCP
09	Utilize 25% Original Reservoir Storage for Berlin Lake during Drawdown and Begin Drawdown for Mosquito Creek Lake on September 7
10	Begin Drawdown for Mosquito Creek Lake on September 7, and Flow deficiencies at Leavittsburg are augmented 50% by Berlin Lake-Lake Milton and 50% by Michael J. Kirwan Dam and Reservoir
11	Begin Drawdown for Berlin Lake and Mosquito Creek Lake on September 7, and Flow deficiencies at Leavittsburg are augmented 50% by Berlin Lake-Lake Milton and 50% by Michael J. Kirwan Dam and Reservoir
12	Utilize 25% Original Reservoir Storage for Berlin Lake during Drawdown, Begin Drawdown for Mosquito Creek Lake on September 7, and Flow deficiencies at Leavittsburg are augmented 50% by Berlin Lake-Lake Milton and 50% by Michael J. Kirwan Dam and Reservoir
13	Extend Berlin Lake Curve to September 7, and Early drawdown of Michael J. Kirwan Dam and Reservoir
14	Utilize 25% Original Reservoir Storage for Berlin Lake during Drawdown and Early drawdown Michael J. Kirwan Dam and Reservoir
15	Extend Berlin Lake guide curve, Early drawdown of Michael J. Kirwan Dam and Reservoir and Flow deficiencies at Leavittsburg are augmented 50% by Berlin Lake-Lake Milton and 50% by Michael J. Kirwan Dam and Reservoir
16	Utilize 25% Original Reservoir Storage, Early drawdown of Michael J. Kirwan Dam and Reservoir and Flow deficiencies at Leavittsburg are augmented 50% by Berlin Lake-Lake Milton and 50% by Michael J. Kirwan Dam and Reservoir
17	Extend Berlin Lake and Mosquito Creek Lake guide curves, Early drawdown of Michael J. Kirwan Dam and Reservoir and Flow deficiencies at Leavittsburg are augmented 50% by Berlin Lake-Lake Milton and 50% by Michael J. Kirwan Dam and Reservoir
18	Utilize 25% Original Reservoir Storage, Extend Mosquito Creek Lake guide curve, Early drawdown of Michael J. Kirwan Dam and Reservoir Drawdown and Flow deficiencies at Leavittsburg are augmented 50% by Berlin Lake-Lake Milton and 50% by Michael J. Kirwan Dam and Reservoir
19	Flow deficiencies at Leavittsburg are augmented by Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir, with no specified percentage
20	Berlin Lake and Michael J. Kirwan Dam and Reservoir Begin Drawdown on September 7
21	Berlin Lake, Michael J. Kirwan Dam and Reservoir and Mosquito Creek Lake Begin Filling Early
22	Berlin Lake and Michael J. Kirwan Dam and Reservoir Begin Drawdown on September 7, and Flow deficiencies at Leavittsburg are augmented by Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir, with no specified percentage
23	Berlin Lake Begins Drawdown on September 7, and Flow deficiencies at Leavittsburg are augmented by Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir, with no specified percentage **(EA Alternative 1)**
24	Utilize 25% Original Reservoir Storage during Drawdown and Flow deficiencies at Leavittsburg are augmented by Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir, with no specified percentage **(EA Alternative 2)**
25	No Augmentation Flow to Leavittsburg or Youngstown

[1] Scenarios 23 and 24 were carried forwarded as "Alternatives" examined within the Environmental Assessment. Highlighted scenarios were examined in the CE-QUAL-W2 model (i.e., Scenarios 3, 23, 24, and 25).

Each of these scenarios were modeled in HEC-ResSim with the updated basin model using 4 years of historical precipitation and inflow data. High resolution gridded precipitation data was available from 1997 through 2019 for Mahoning River Watershed. This was chosen as the best available data to determine inflows into the modeled system. Based on this data year range, WY 2004, beginning October 1, of the previous year and ending September 30, of the specified year, was chosen as the wettest year on record, and WY 1999 was chosen as the driest year on record. CY 2013 was also modeled to provide data which could be entered into the CE-QUAL-W2 model (refer to Section 10.4). A fourth year, CY 2014, was also modeled to increase the variability of inflow hydrographs to the models. CY 2013 and CY 2014 were modeled as a continuous period, which also helps identify any negative interannual impacts.

10.2.3 STEP 2 – PART C – PERFORM MODELING USING HEC-HMS and HEC-ResSim TO TEST PROPOSED SCENARIOS

10.2.3.1 Base Conditions

Maintain current reservoir operations
Figure 10-2 through Figure 10-6 show the existing WCPs for Berlin Lake, Lake Milton, Combined Storage for Berlin Lake and Lake Milton, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake, respectively. Several of the twenty-five proposed operating scenarios include one or more reservoirs maintaining current operations.

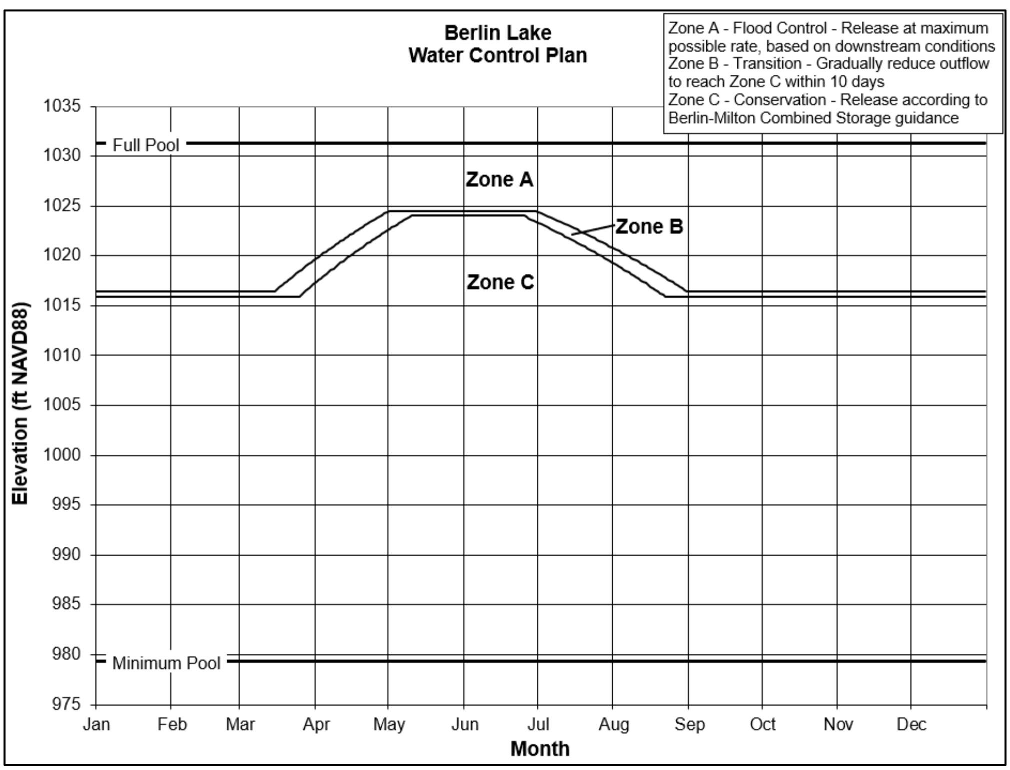


Figure 10-2: Existing Berlin Lake WCP

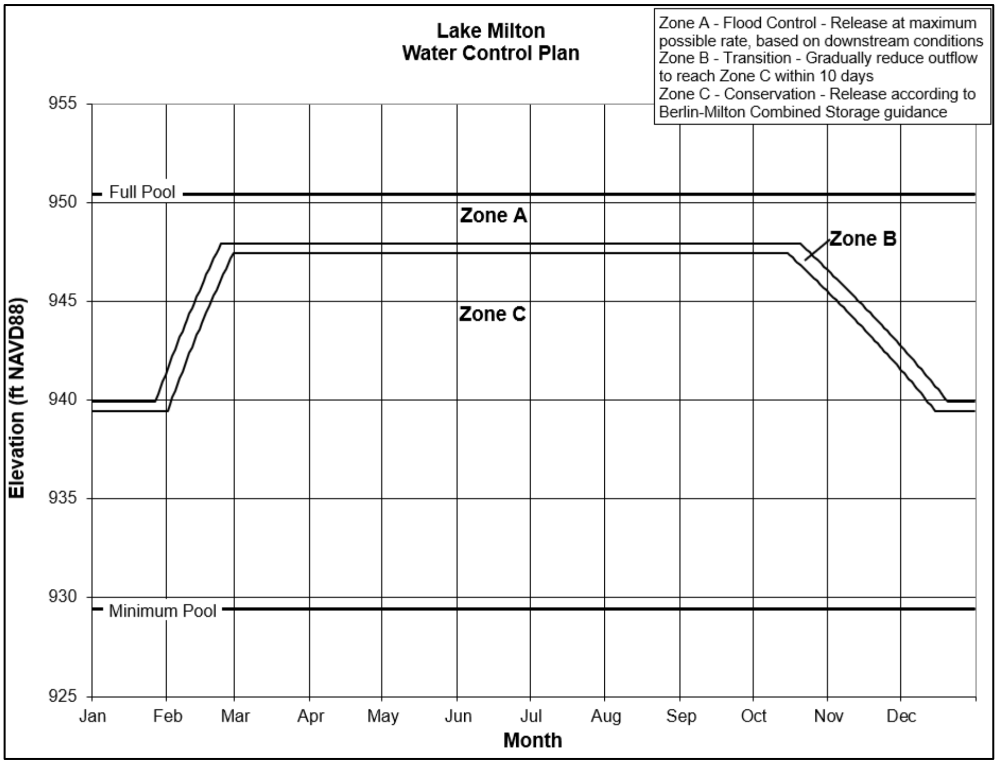


Figure 10-3: Existing Lake Milton WCP

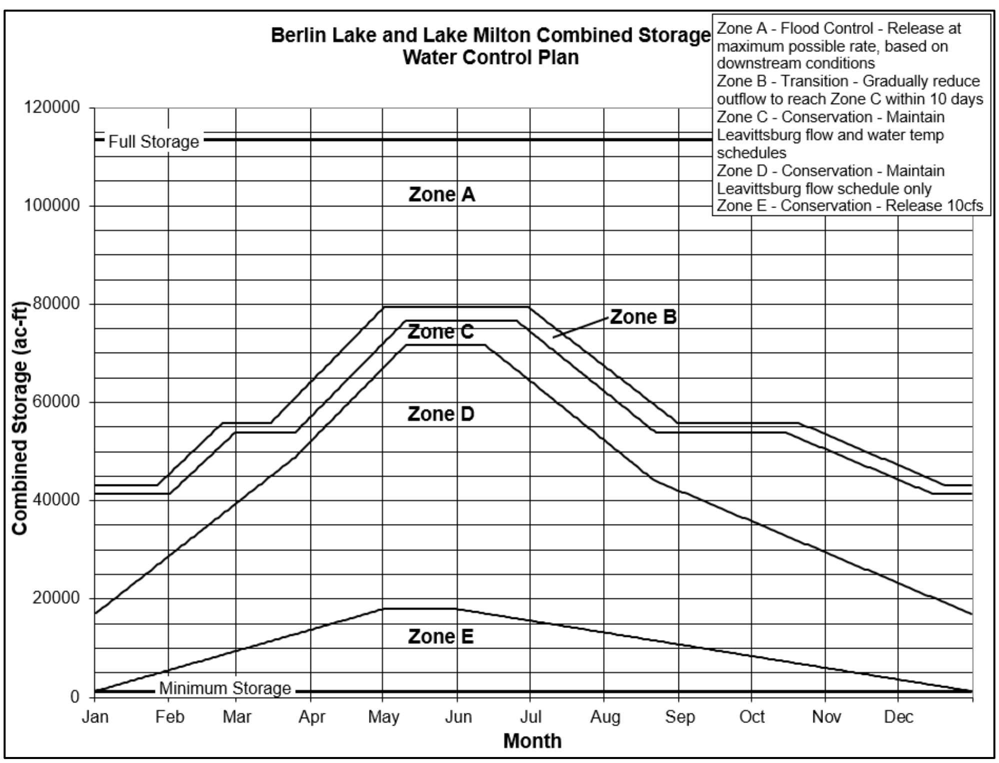


Figure 10-4: Existing Berlin Lake and Lake Milton Storage Combined WCP

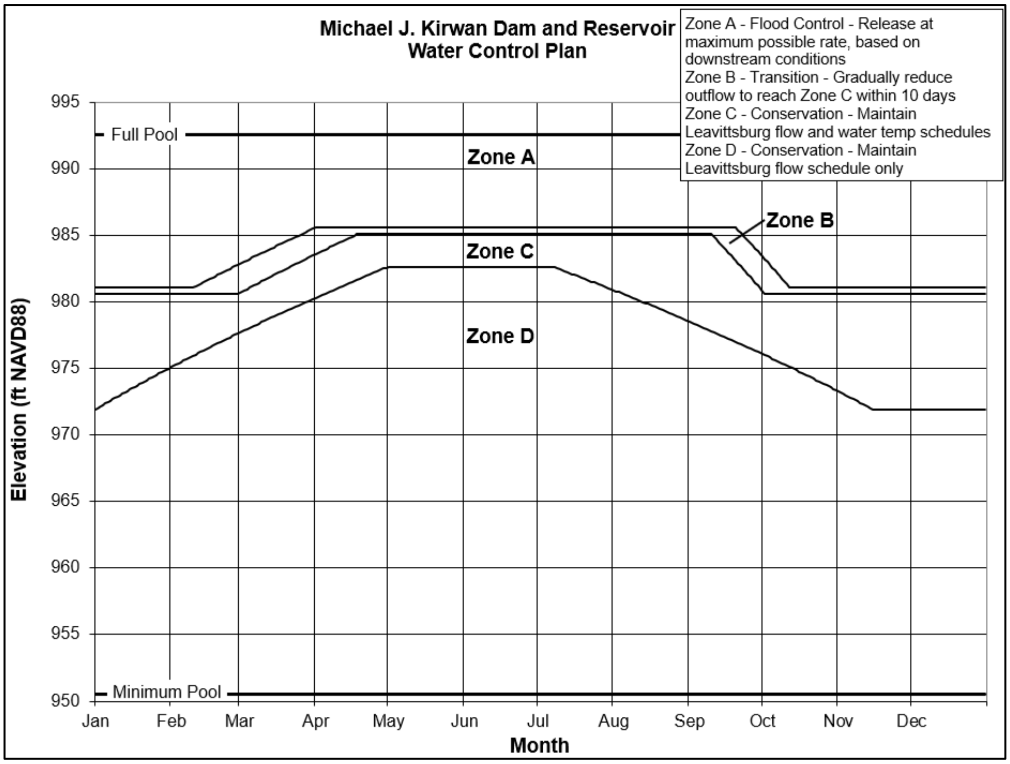


Figure 10-5: Existing Michael J. Kirwan Dam and Reservoir WCP

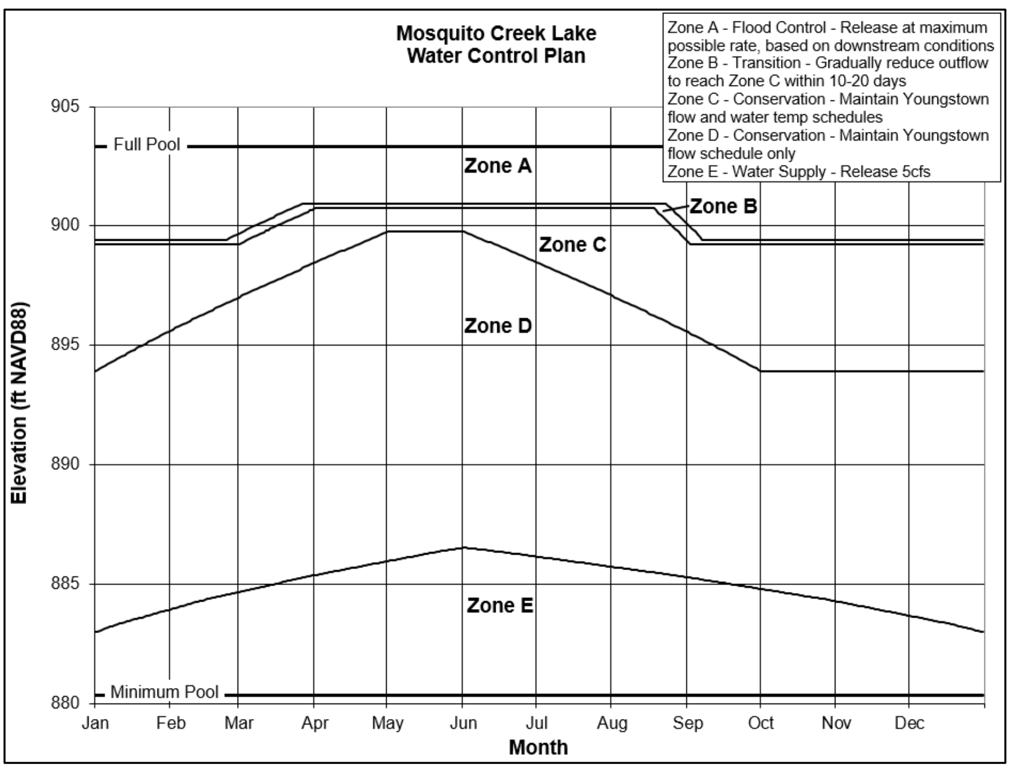


Figure 10-6: Existing Mosquito Creek Lake WCP

10.2.3.2 Proposed WCP Change 1

Begin drawdown for Berlin Lake, Michael J. Kirwan Dam and Reservoir and/or Mosquito Creek Lake on September 7

The proposed guide curves associated with Proposed WCP Change 1 are represented in Figure 10-7, Figure 10-8, and Figure 10-9. The proposed combined storage of Berlin Lake with Lake Milton is represented in Figure 10-10. This proposed reservoir operation was considered as extending the summer pool for Berlin Lake into September would enhance the potential for recreational use of Berlin Lake. Berlin Lake is currently scheduled to begin drawing down from summer pool to winter pool at the end of June and is scheduled to be at winter pool by the middle of August. While recreation is an authorized purpose for Berlin Lake, each year there are fewer in reservoir recreational opportunities at Berlin Lake than either Michael J. Kirwan Dam and Reservoir or Mosquito Creek Lake due to the short summer pool duration.

Of the 25 proposed scenarios, ten (10) scenarios include extending the Berlin Lake summer pool so that Berlin Lake begins drawdown on September 7 (See Figure 10-7), eight (8) scenarios include extending the Mosquito Creek Lake summer pool so that Mosquito Creek Lake begins drawdown on September 7 (See Figure 10-9), and one (1) scenario considers both Berlin Lake and Michael J. Kirwan Dam and Reservoir beginning drawdown on September 7 (See Figure 10-8), simultaneously. For all of these scenarios, drawdown began on September 7, allowing the summer pool to be maintained through Labor Day, despite Labor Day occurring on an inconsistent date throughout the first week of September. Colored lines on the subsequent figure indicate the proposed scenarios. Under this scenario, the District will need to balance the releases of the reservoirs as part of daily operational release decisions. This will help to ensure the operations do not cause downstream flooding because of the reservoirs drawing down at the same time.

The current WCMs force a drawdown at Berlin Lake which puts additional water within the Mahoning River and has allowed Mosquito Creek Lake to maintain a low outflow throughout the summer. If Berlin Lake does not drawdown and provide those additional flows in the summer, then Mosquito Creek Lake may have to release more water than it had to release in the past to meet the Youngstown schedule. This situation will be weather and runoff dependent.

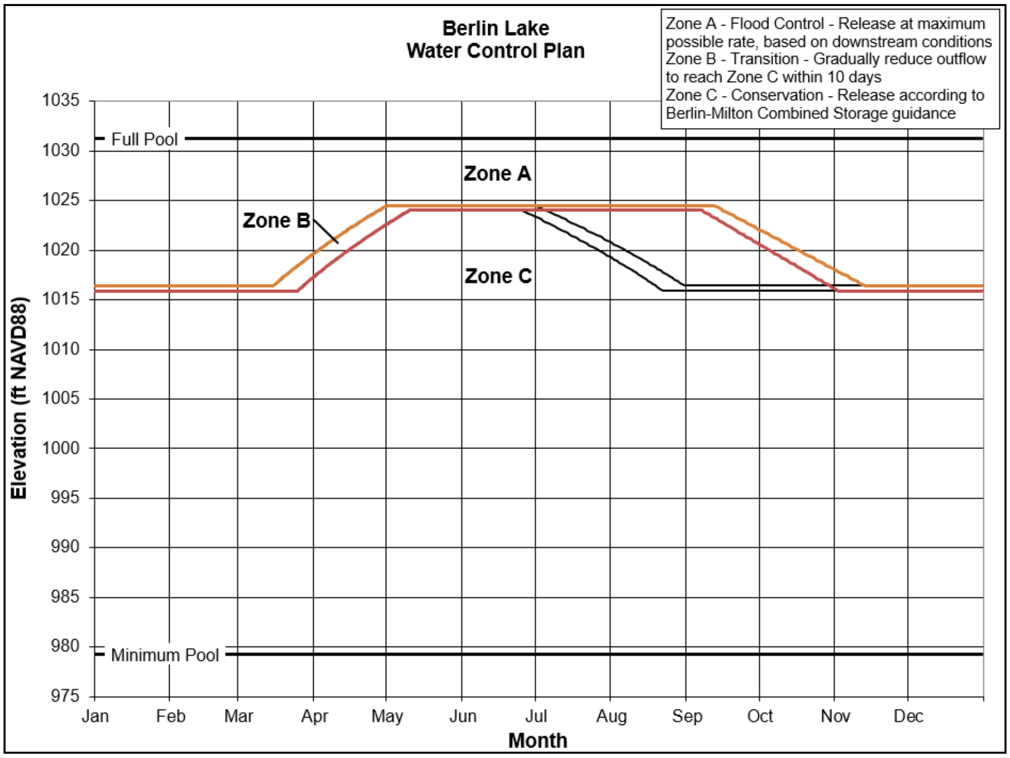


Figure 10-7: Proposed WCP Change 1 for Berlin Lake – Extend Summer Pool to September 7

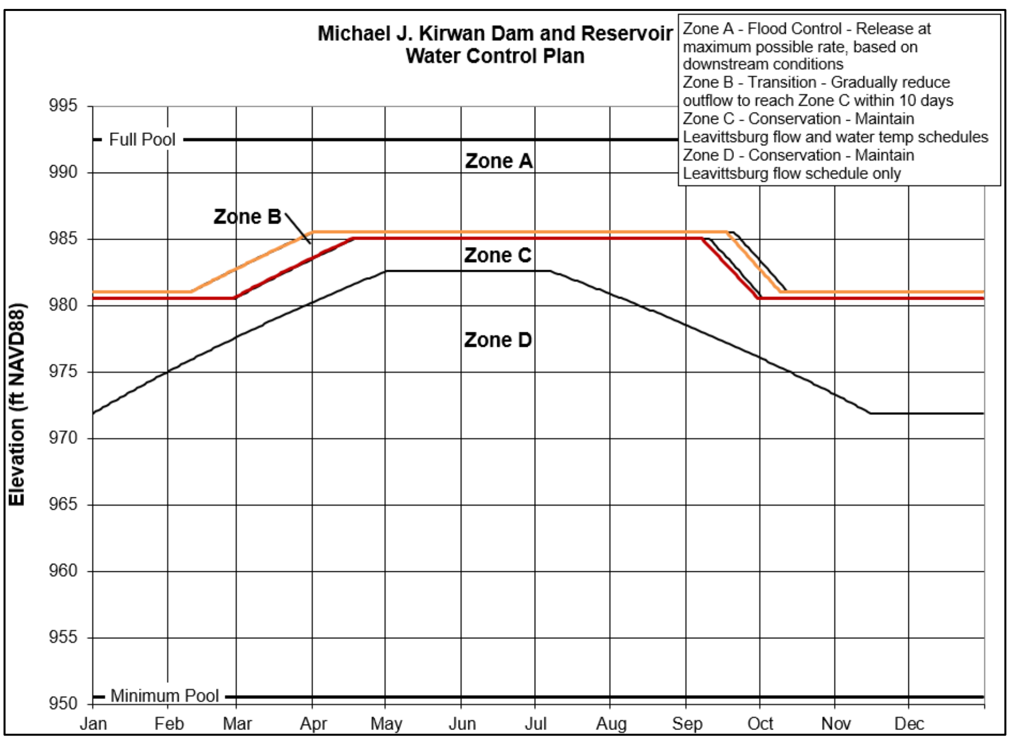


Figure 10-8: Proposed WCP Change 1 for Michael J. Kirwan Dam and Reservoir – Drawdown Begins September 7

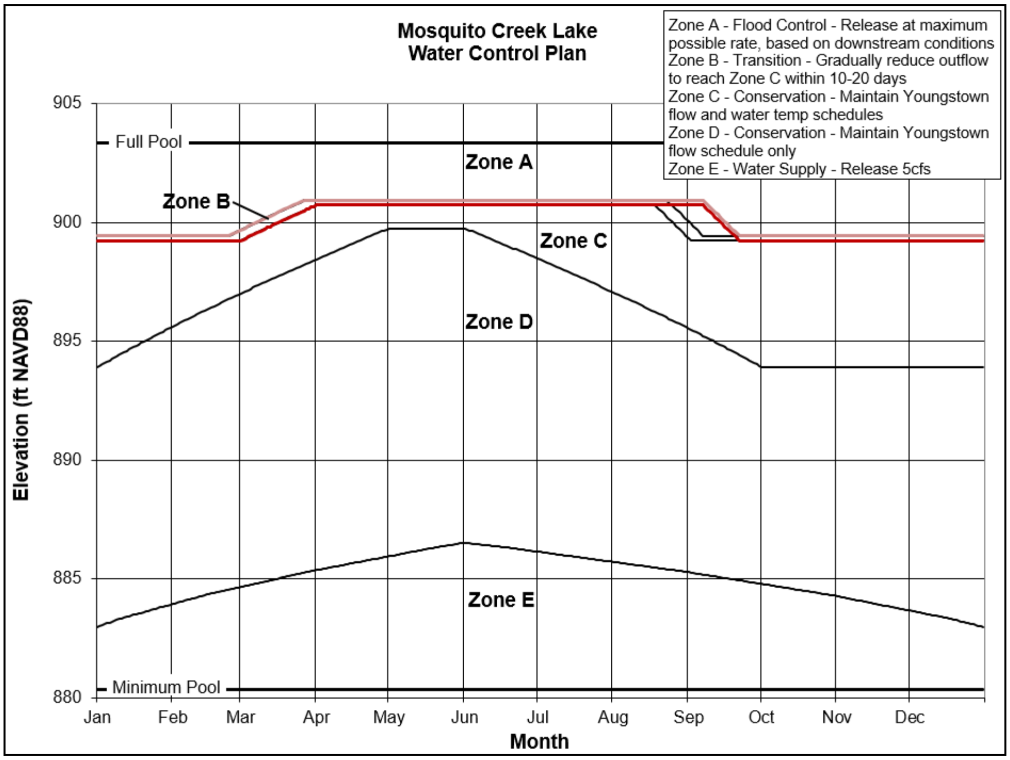


Figure 10-9: Proposed WCP Change 1 for Mosquito Creek Lake – Extend Summer Pool to September 7

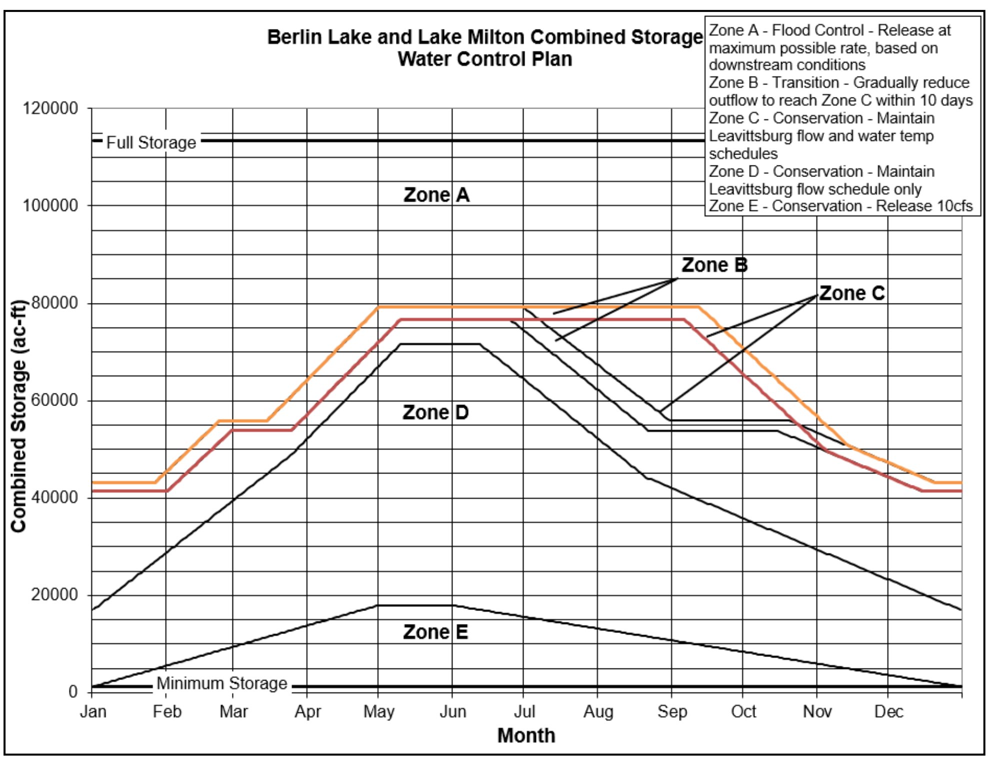


Figure 10-10: Proposed WCP Change 1 for Berlin Lake – Extend Summer Pool to September 7 - Berlin Lake and Lake Milton Storage Combined WCP

10.2.3.3 Proposed WCP Change 2

Berlin Lake Reservoir's WCP would be revised during the drawdown to reflect utilizing 25% of the existing reservoir flood storage

During many of the last fifteen years, Berlin Lake has been operated such that the summer pool has been held longer than called for by the existing WCP, by slowing the rate of drawdown. Stakeholders are favorable to historical reservoir operations that provide economic and recreational benefits to the local region by slowing the required drawdown of Berlin Lake to allow for recreation through Labor Day as much as practicable. As Berlin Lake has been historically operated by utilizing the existing reservoir storage (See Figure 10-11), this Proposed WCP Change is modeled. This Proposed WCP Change is considered for eight (8) of the twenty-five (25) proposed scenarios.

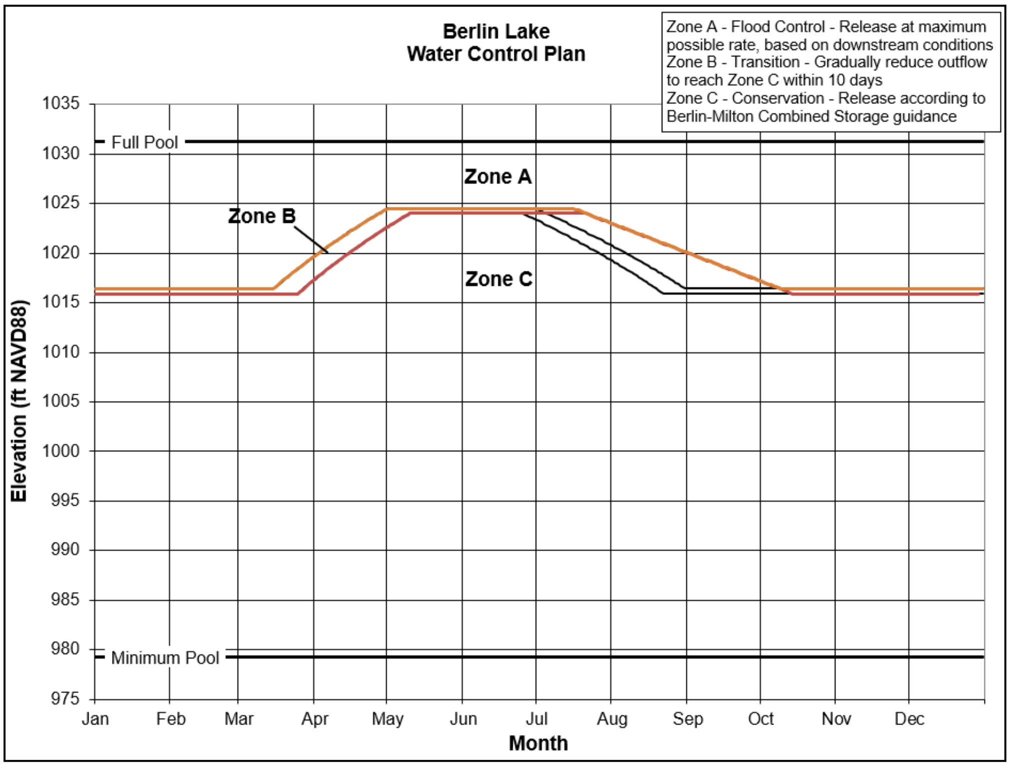


Figure 10-11: Proposed WCP Change 2 for Berlin Lake – Utilize 25% of Original Reservoir Flood Storage During Drawdown

10.2.3.4 Proposed WCP Change 3

Flow deficiencies in the Mahoning River at Leavittsburg are augmented 50% by Berlin Lake-Lake Milton and 50% by Michael J. Kirwan Dam and Reservoir, instead of 64% by Berlin Lake-Lake Milton and 36% by Michael J. Kirwan Dam and Reservoir

One of the largest contributing factors of outflow from Berlin Lake and Michael J. Kirwan Dam and Reservoir is the downstream flow augmentation schedule for the Mahoning River at Leavittsburg, OH. The flow augmentation schedule developed for Youngstown, OH, was originally developed to ensure enough water for cooling purposes along the lower Mahoning River and Beaver River to support iron and steel production and was revised several times from the 1940's through the 1970's. Ten (10) scenarios include revising the proposed augmentation percentage from a 64% Berlin Lake-Lake Milton and 36% Michael J. Kirwan Dam and Reservoir to a more equal share of 50% Berlin Lake-Lake Milton and 50% Michael J. Kirwan Dam and Reservoir.

10.2.3.5 Proposed WCP Change 4

Michael J. Kirwan Dam and Reservoir begin drawdown on June 26

Michael J. Kirwan Dam and Reservoir starting the drawdown on June 26, was modeled for comparison only. This operation was modeled to determine how sensitive outflows and reservoir elevations within Michael J. Kirwan Dam and Reservoir were to the current WCP (Figure 10-12).

It is important to note that June 26, is when Berlin Lake currently begins its drawdown, while either extending Berlin Lake's guide curve to begin drawdown on September 7, or extending the summer pool for Berlin Lake by utilizing 25% of original reservoir flood storage during drawdown from summer pool to winter pool. This Proposed WCP Change was considered to determine the impact Michael J. Kirwan Dam and Reservoir's outflow on Berlin Lake's outflow. This Proposed WCP Change is considered for six (6) of the twenty-five (25) proposed scenarios.

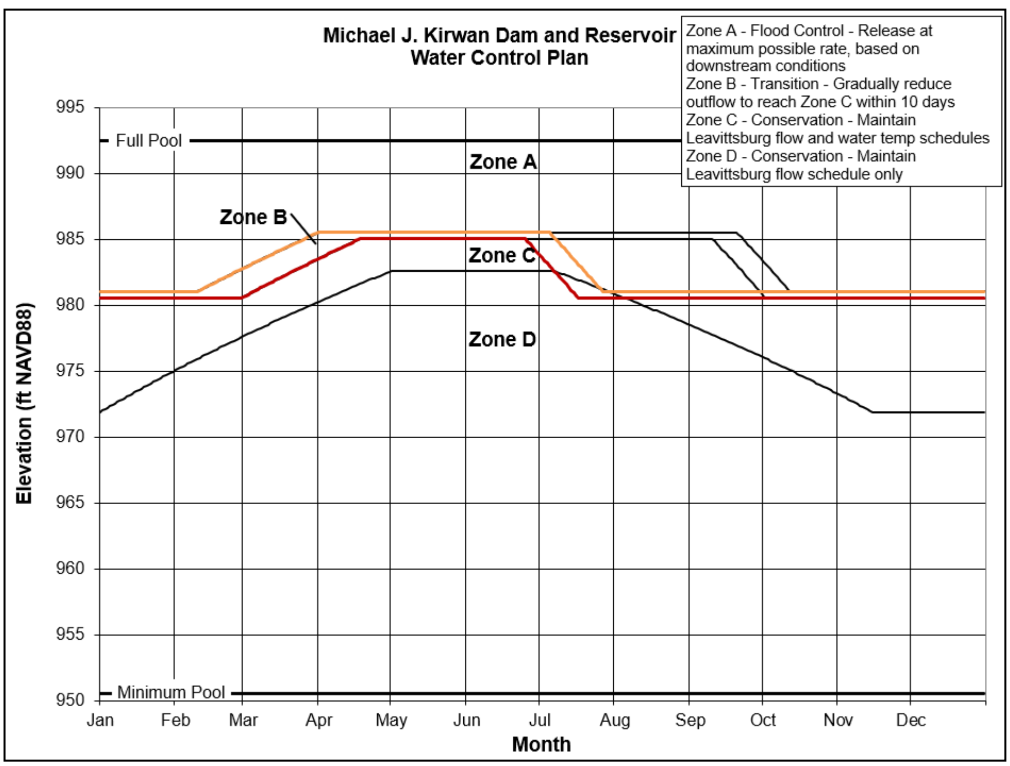


Figure 10-12: Proposed WCP Change 4 for Michael J. Kirwan Dam and Reservoir – Begin Drawdown on June 26

10.2.3.6 Proposed WCP Change 5

Flow deficiencies in the Mahoning River at Leavittsburg, OH are augmented by Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir, with no specified percentage, instead of 64% by Berlin Lake-Lake Milton and 36% by Michael J. Kirwan Dam and Reservoir

Instead of revising the percentage of augmentation flow from Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir from one set value to another set value, another possibility is to use the District reservoir operator's judgment each day to determine releases from Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir to meet the flow requirements downstream in the Mahoning River at Leavittsburg, OH and Youngstown, OH. This Proposed WCP Change is considered for four (4) of the twenty-five (25) proposed scenarios.

Releases from Michael J. Kirwan Dam and Reservoir and Berlin Lake will be balanced with respect to their water control plans. If Michael J. Kirwan Dam and Reservoir is using flood storage and Berlin Lake is using conservation storage, additional releases will be made from Michael J. Kirwan Dam and Reservoir to reduce the impact at Berlin Lake.

If Berlin Lake is using flood storage and Michael J. Kirwan Dam and Reservoir is using conservation storage, additional releases will be made from Berlin Lake to reduce the impact at Michael J. Kirwan Dam and Reservoir.

When both reservoirs have fallen below 100% conservation storage, while still meeting the downstream schedule, Michael J. Kirwan Dam and Reservoir and Berlin Lake will manage releases such that the rate of fall at each reservoir mimics the fall drawdown rate.

10.2.3.7 Proposed WCP Change 6

Begin filling Berlin Lake, Michael J. Kirwan Dam and Reservoir and Mosquito Creek Lake on February 15

Proposed WCP Change 6 included beginning filling all three reservoirs on February 15 (See Figure 10-13, Figure 10-14, and Figure 10-15), leading to a more stable pool during the fish spawning season. Stable reservoir elevations are better for fish during the spawning season than reservoirs with significant elevation fluctuations. This Proposed WCP Change is considered for one (1) of the twenty-five (25) proposed scenarios.

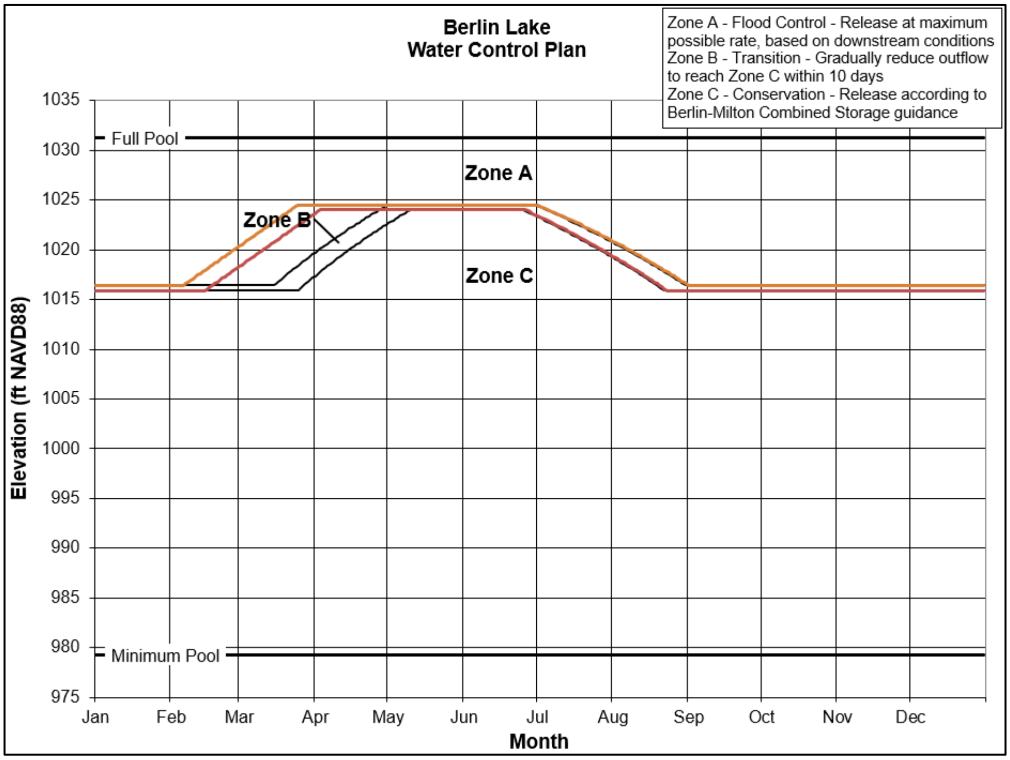


Figure 10-13: Proposed WCP Change 6 for Berlin Lake – Begin Filling on February 15

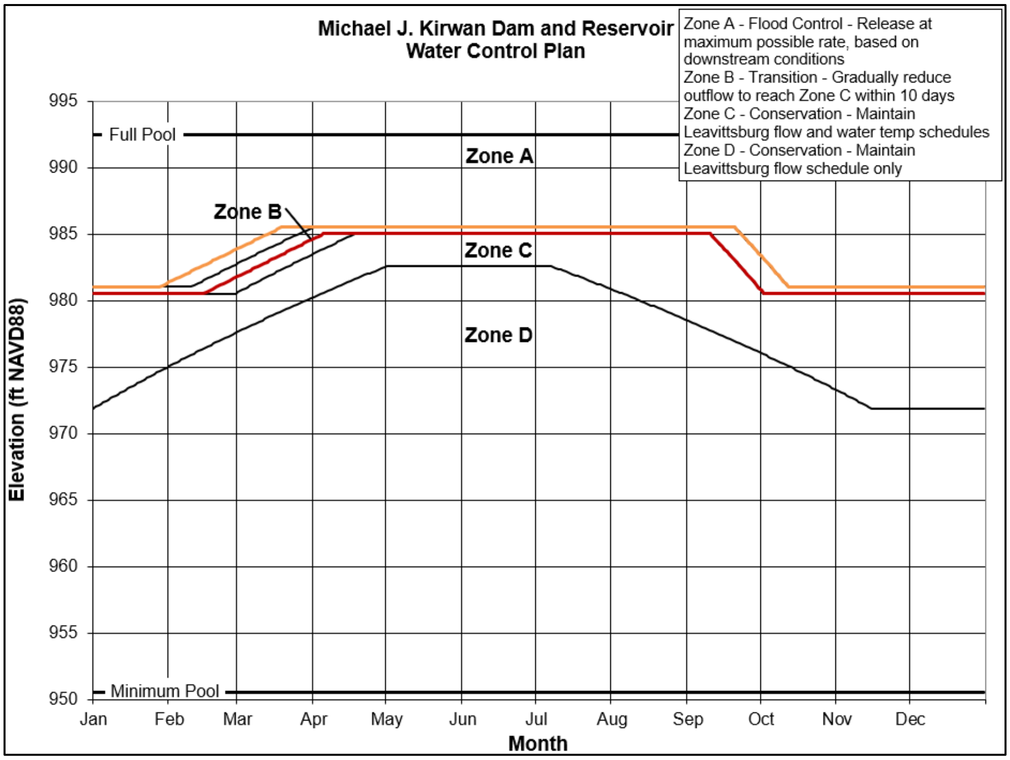


Figure 10-14: Proposed WCP Change 6 for Michael J. Kirwan Dam and Reservoir – Begin Filling on February 15

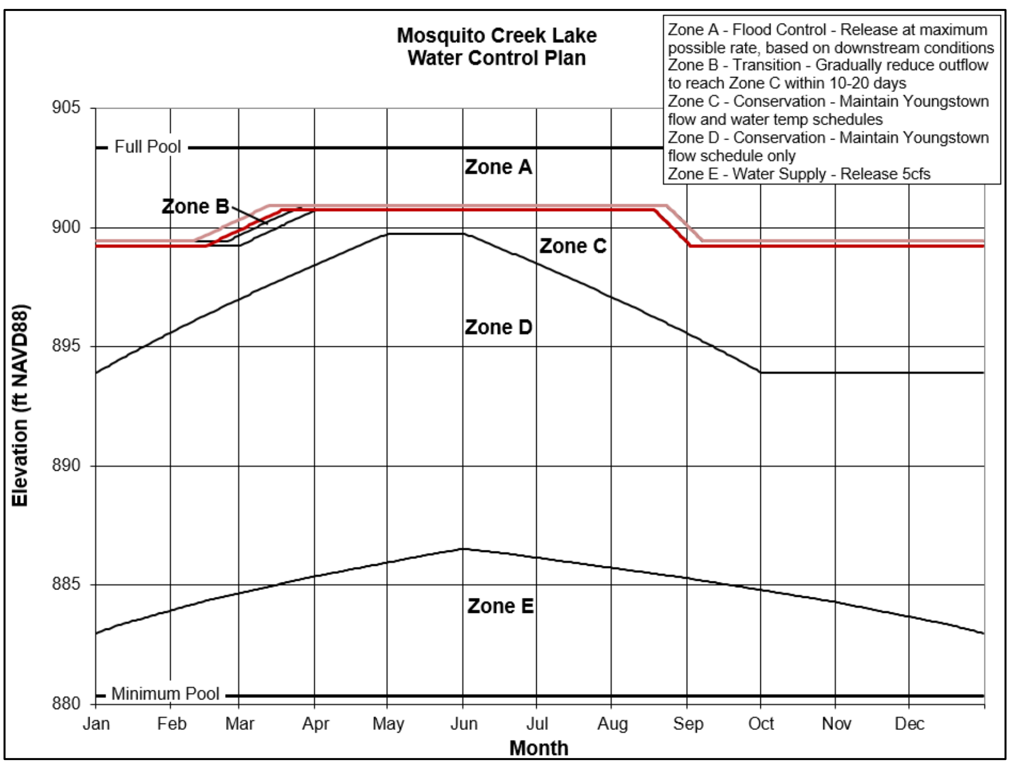


Figure 10-15: Proposed WCP Change 6 for Mosquito Creek Lake – Begin Filling on February 15

10.2.3.8 Proposed WCP Change 7

No Augmentation Flow in the Mahoning River for the Leavittsburg, OH or Youngstown, OH Control Points

Proposed WCP Change 7 would remove the established flow schedule for water quality downstream at Leavittsburg, OH and Youngstown, OH. For purposes of this analysis, the WCPs were not revised, however the rules within the model requiring that Lake Milton and Michael J. Kirwan Dam and Reservoir release flow to meet augmentation flow requirements at Leavittsburg were removed.

This proposed operation is not considered as a feasible operation as it would not allow the reservoirs to meet their authorized purposes of water quality control, but modeling this scenario allows for a comparison metric when examining project benefits. This Proposed WCP Change is considered as one (1) of the twenty-five (25) proposed scenarios.

10.2.3.9 Modeling Proposed Scenarios using HEC-ResSim

The inflow series for WY 1999, WY 2004, CY 2013, and CY2014 was developed using HEC-HMS and available observed data, as described in Section 10.1.1. All twenty-five (25) proposed scenarios are modeled within HEC-ResSim for WY 1999, WY 2004, CY 2013 and CY 2014. The Proposed WCP Changes discussed in Section 10.2.3.2 through Section 10.2.3.8 are incorporated into HEC-ResSim and the models run. The HEC-ResSim model generated proposed reservoir operations and outflows for each of the twenty-five scenarios for each of the modeled year.

10.3 STEP 3 – EVALUATE SCENARIOS in the DECISION SUPPORT TOOL

The interactive Decision Support Tool (DST), which uses Microsoft Excel, is a tool developed by the IWR to measure how well each scenario met each of the reservoirs authorized purposes. Performance measures were developed with help from both the project stakeholders and the PDT to measure how well each reservoir managed flood risks, recreation, water supply, water quality, and fish and wildlife needs. The DST is designed to provide information a decision-maker would need when deciding which scenario best balances each reservoir's authorized purposes. The DST provides techniques for analyzing or displaying tradeoffs, but it is not meant to rationalize decisions based on a comparison between purposes (e.g., is a slight improvement in water quality at the expense of recreation worthwhile in comparison to the existing conditions). The DST results are provided to illustrate the tradeoffs between the proposed reservoir scenarios and are used to make informed decisions.

The proposed 25 scenarios, listed in Table 10-1, were modeled within HEC-ResSim. The hourly reservoir elevations, reservoir storage, reservoir outflows, and flow rates at Leavittsburg and Youngstown were read from the model output and then entered into the DST, which determined the performance thresholds for each of the performance measures. Refer to Table 10-2 for a summary of the performance measures.

Table 10-2: Performance Measures Captured within the Decision Support Tool

Authorized Purpose	Season	Measure Location	Performance Measure	Threshold*
Flood Risk Management	Wet	Leavittsburg	Number of Days above Threshold Flow (days), roughly 2/3 of flood stage flow	4,000 cfs
	Wet	Youngstown	Number of Days above Threshold Flow (days), roughly 2/3 of flood stage flow	8,000 cfs
	Wet	Leavittsburg	Max flow (cfs)	N/A
	Wet	Youngstown	Max flow (cfs)	N/A
	Wet	Leavittsburg	Total Annual Volume of water above flood flows (cubic feet/year)	4,000 cfs
	Wet	Youngstown	Total Annual Volume of water above flood flows (cubic feet/year)	8,000 cfs
	Wet	Berlin Lake	Number of Days near channel capacity (days)	2,600 cfs
	Wet	Michael J. Kirwan Dam and Reservoir	Number of Days near channel capacity (days)	1,125 cfs
	Wet	Mosquito Creek Lake	Number of Days near channel capacity (days)	900 cfs
	Wet	Berlin Lake	Number of Days Berlin Lake levels ≥ 1030.75 ft (days)	1030.75 ft
	Wet	Michael J. Kirwan Dam and Reservoir	Number of Days Michael J. Kirwan Dam and Reservoir levels ≥ 986.5 ft (days)	986.5 ft
	Wet	Mosquito Creek Lake	Number of Days Mosquito Creek Lake levels ≥ 901 ft (days)	901 ft
Recreation	Wet	Berlin Lake	Number of Days boat ramps flooded (days)	1027.5 ft
	Wet	Michael J. Kirwan Dam and Reservoir	Number of Days boat ramps flooded (days)	987 ft
	Wet	Mosquito Creek Lake	Number of Days boat ramps flooded (days)	900.8 ft
	Both	Leavittsburg	Number of Days meeting downstream recreation ideal flow at the Leavittsburg gage (days)	299 to 1168 cfs
	Dry	Berlin Lake, Michael J. Kirwan Dam and Reservoir	Berlin Lake-Lake Milton / Michael J. Kirwan Dam and Reservoir relative % contribution to downstream Water Quality flows (e.g., Baseline = 64/36) (percentage split)	N/A
	Dry	Berlin Lake	Number of Days between Memorial Day and September 7. the pool is below the lowest preferred level (days)	1020 ft
	Dry	Michael J. Kirwan Dam and Reservoir	Number of Days between Memorial Day and September 7. the pool is below the lowest preferred level (days)	981 ft
	Dry	Mosquito Creek Lake	Number of Days between Memorial Day and September 7. the pool is below the lowest preferred level (days)	899 ft
Water Supply	Dry	Berlin Lake	Number of Days reservoir does not meet intake level (days)	980 ft
	Dry	Mosquito Creek Lake	Number of Days reservoir does not meet intake level (days)	892.5 ft
Water Quality	Dry	Berlin Lake	Residence Time (days)	N/A
	Dry	Michael J. Kirwan Dam and Reservoir	Residence Time (days)	N/A
	Dry	Mosquito Creek Lake	Residence Time (days)	N/A
	Dry	Leavittsburg	Number of days we met the required flow downstream @ Leavittsburg (days)	Minimum Flow as per WCP
	Dry	Youngstown	Number of days we met the required flow downstream @ Youngstown (days)	Minimum Flow as per WCP
Fish and Wildlife	Both	Berlin Lake	Rate of change/water stability in Spring (Mar - Jun) (ft/week)	N/A
	Both	Michael J. Kirwan Dam and Reservoir	Rate of change/water stability in Spring (Mar - Jun) (ft/week)	N/A
	Both	Mosquito Creek Lake	Rate of change/water stability in Spring (Mar - Jun) (ft/week)	N/A
	Both	Berlin Lake	Rate of change/water stability in Autumn drawdown (Jun - Sep) (ft/week)	N/A
	Both	Michael J. Kirwan Dam and Reservoir	Rate of change/water stability in Autumn drawdown (Jun - Sep) (ft/week)	N/A
	Both	Mosquito Creek Lake	Rate of change/water stability in Autumn drawdown (Jun - Sep) (ft/week)	N/A

* Elevations correspond to ft-NAVD 88

10.3.1 Flood Risk Management

Performance Measure 1

The first performance measure considered was the maximum flow at Leavittsburg and Youngstown, OH. The reservoirs are operated to reduce floods below the National Weather Service (NWS) established flood stage of 12.5 feet, or an approximate flow of 5,800 cfs at Leavittsburg, and 14 feet, or an approximate flow of 11,800 cfs at Youngstown. The maximum flow from the HEC-ResSim model output is compared against the known flood stage flow by means of a rating curve to ensure that the maximum flow remains below the downstream flood stages. The higher the maximum flow at Leavittsburg and Youngstown, the higher the potential flood risk for the watershed, given a sufficiently larger storm. The flows at Leavittsburg and Youngstown, OH are a combination of outflows from the Projects plus uncontrolled flow, runoff, from drainage areas downstream of the Projects.

Performance Measure 2

The Mahoning River watershed typically sees two types of significant inflow events: an early spring snowmelt event, which tends to have a lower peak flow rate, but a higher overall runoff volume, and summer thunderstorm events, which tends to a have a higher peak flow rate, but a lower overall runoff volume. Performance measure 2, which considers annual volume of flow over a threshold, is geared towards consideration of early-spring snowmelt events.

The annual volume of flow that exceeded the threshold value of 4,000 cfs at Leavittsburg, and the annual volume of flow that exceeded the threshold value of 8,000 cfs at Youngstown were considered as performance measures for each scenario.

Since the model avoids exceeding the actual downstream flood thresholds, the performance measure threshold values were chosen as approximately two-thirds of the flows associated with established flood stage thresholds, 5,800 cfs at Leavittsburg and 11,800 cfs at Youngstown. Thus, the reservoir model operates to avoid exceeding the downstream flood threshold values, and this performance measure scores how much flow volume exceeded thresholds that were high, but not as high as the flood threshold. The higher the volume of flow at Leavittsburg and Youngstown over the threshold flows, the higher the potential flood risk for the watershed, given a sufficiently larger storm.

The District's Water Management team reduces outflows from the reservoirs when the Mahoning River at Leavittsburg or Youngstown is forecast to exceed flood stage; however, there is not unlimited flood storage within the reservoirs. In some situations, it may be necessary to release higher flows from the reservoirs despite the risk of downstream flooding. The HEC-ResSim model is incapable of accounting for meteorologically derived forecast flows downstream. The modeled reservoir operation is based only on historic data and specific operating goals that avoid exceeding the established downstream thresholds. HEC-ResSim does account for the lag time and attenuation of reservoirs releases to avoid violating the downstream thresholds.

Another throttle to downstream flow at Leavittsburg and Youngstown is the channel capacity downstream of each reservoir. All reservoirs are operated to keep the outflow less than or equal to the channel capacity to mitigate downstream flooding. Each reservoir's directly downstream channel capacity is summarized in Table 10-3 and Table 10-4.

Table 10-3: Reservoirs Downstream Channel Capacity

Projects	State	Channel Capacity
Michael J. Kirwan Dam and Reservoir	OH	1,000 cfs
Berlin Lake	OH	3,400 cfs
Mosquito Creek Lake	OH	1,000 cfs

Table 10-4: Non-Corps Reservoirs Downstream Channel Capacity

Projects	State	Channel Capacity
Lake Milton	OH	2,600 cfs

Performance Measure 3

The number of days that outflow from Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake exceed threshold values of 2,600 cfs, 1,125 cfs, and 900 cfs, respectively, is used as a performance measure. High outflow is indicative for potentially higher flood risk. These threshold flows do not represent a flooding condition but are the highest outflow that could be used to allow the DST to calculate non-zero values for these performance metrics. These thresholds are meant to determine which reservoirs are releasing relatively high outflows for longer periods, and whether they release relatively high outflows more often than the baseline WCP.

Performance Measure 4

The number of days that the pool elevations at Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake are above 1026.0 ft-NAVD88, 987.0 ft-NAVD88, and 901.0 ft-NAVD88, respectively, are considered the final set of flood risk management performance measures. These threshold elevations are below the spillway for each reservoir, so they do not represent flooding conditions, but were chosen as the highest reservoir elevation that could be used to allow the DST to calculate non-zero values for these performance metrics. The greater the number of days the reservoirs are higher, the greater the potential flood risk for the watershed, given a sufficiently wet year. The thresholds are meant to determine whether a scenario leads to higher reservoir elevations. Summer pool elevations for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake are 1024.01 ft-NAVD88, 985.06 ft-NAVD88, and 900.73 ft-NAVD88, respectively.

10.3.2 Recreation

Recreational performance measures were established based on feedback given during the May 27, 2020, Public Workshop where public stakeholders provided a list of criteria for measuring scenario success. During this meeting, recreation was mainly discussed in terms of larger vessel boating in the reservoirs and canoeing downstream of the reservoirs.

Performance Measure 1

The first recreational performance measure considered is the number of days that Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake pool elevations are higher than the boat ramps within that reservoir, making them unusable. The boat ramps within Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake, as provided by local stakeholders, are at elevation 1027.5 ft-NAVD88, 987 ft-NAVD88, and 900.8 ft-NAVD88, respectively. These high elevations are sufficiently high to make low-elevation boat docks and boat ramps unusable.

Performance Measure 2

The second recreational performance measure considered was the number of days that the Mahoning River at the Leavittsburg gage will be at ideal recreational flow, defined as a gage height of 3 to 5 feet (based on public stakeholder feedback), which corresponds to a flowrate of 299-1168 cfs, according to the Rating Curve for US Geological Survey (USGS) Gage 03094000. The greater the number of days that Mahoning River at Leavittsburg is within the ideal flow range, the better for recreation. Note that downstream recreation is not part of the authorization for recreation. However, downstream recreation is a possible ancillary benefit.

Performance Measure 3

The final set of recreational performance measures was the number of days that Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake pool elevations are below optimum reservoir elevations for on-the-water recreation, as provided by local stakeholders. The lowest preferred recreation water surface elevation for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake, as provided to the USACE by local stakeholders, are 1020 ft-NAVD88, 981 ft-NAVD88, and 899 ft-NAVD88, respectively. Only days during the typical recreation season, between Memorial Day and Labor Day, were counted. The greater the number of days below preferred water levels for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake, the worse for in reservoir recreation.

10.3.3 Water Supply

Performance Measure 1

For water supply, the only set of performance measures used were the number of days when reservoir elevation within Berlin Lake and Mosquito Creek Lake were below the water supply intakes. The water supply intake for Berlin Lake is at 980 ft-NAVD88, and the lowest water supply intake for Mosquito Creek Lake is at 892.5 ft-NAVD88. Any number above zero means that there are scenarios when water supply needs are not met.

10.3.4 Water Quality

Performance Measure 1

To account for water quality within the DST, results from the HEC-ResSim model were used to determine the reservoir residence time for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake. The residence time is effectively the average length of time that an entity will remain in a reservoir. By definition, the residence time is the volume of water in the reservoir, divided by either the inflow or the outflow (they are equal when the reservoir is at equilibrium). The residence time is especially important where pollutants are concerned.

Performance Measure 2
Additionally, HEC-ResSim can perform an analysis on how well each scenario meets minimum flow downstream, at Leavittsburg and Youngstown, as specified in the current WCPs. The higher these performance measures, the more days the minimum flow at Leavittsburg and Youngstown is met.

The minimum flow at Leavittsburg is 145 cfs from Nov 29 to March 6. From there it gradually increases until reaching a constant minimum flow of 310 cfs from June 24 to Aug 10, then slowly decreasing back to 145 cfs by Nov 29. The minimum flow at Youngstown is 225 cfs from Oct 31 to April 1. From there it gradually increases until reaching a constant minimum flow of 480 cfs from July 22 – 31, then slowly decreasing back to 225 cfs by Oct 31.

10.3.5 Fish and Wildlife

Performance Measure 1
This performance metric quantifies the reservoir's ability to support areas that increase the benefits for fish and wildlife. Reservoir pool stability, which is the relative change in pool elevation of the reservoir, was determined to be the best overall proxy to determine benefits to fish and wildlife given the metrics ability to preserve fish eggs during spawning and facilitate the buildup of mudflats by slowing down sediment filled waters from inflows, which are then eventually exposed for migratory birds in the upper end of the reservoir (Taylor et al 1993). The reservoirs are natural spawning areas for freshwater fish and other wildlife. The more stable the reservoir pool elevations are, the better the reservoirs are for fish reproduction. The greatest instability within the reservoirs is due to runoff storage and filling to summer pool; all of which raise pool elevations rapidly. Similarly, the same instability can occur during the drawdown of a reservoir, but the projects are able to control the drawdown better as opposed to the weather-related runoff during filling.

Stability (rate of change of water level) for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake is considered for fish spawning season, typically considered to occur from March 1 through June 15.

Performance Measure 2
Stability (rate of change of water level) for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake were considered from June 27, through September 30, when the young of year fish are likely foraging.

10.3.6 Results of the Decision Support Tool

Each of the 25 scenarios were evaluated using the DST. The results of the DST indicated that Scenario 1 through Scenario 24 were all feasible scenarios. Scenario 25, which modeled no augmentation flow at Leavittsburg and Youngstown, was modeled for comparison purposes only.

Balancing purposes was complex and reservoir operations required tradeoffs. However, the DST provided a useful tool to visualize the complicated nature of the reservoir system and how revising operations for one reservoir impacted the authorized uses for all three Mahoning River reservoirs. Based on the results of the DST, four scenarios were selected for further study.

10.4 SELECT SCENARIOS and EXAMINE in CE-QUAL-W2

10.4.1 STEP 4 – PART A - SELECTION OF SCENARIOS THAT FULFULL PROJECT GOALS

To select the scenarios for further study, the PDT focused on the DST results that would:

- Ensure adequate flood risk reduction benefits currently provided to the Mahoning River Basin watershed from Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake;
- Ensure the provision of water supply, per contractual agreements, for withdrawals within and downstream of the reservoirs at Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake (Mahoning Reservoirs);
- Ensure recreation opportunities within and downstream of the Mahoning Reservoirs, provided that project authorizations for flood risk reduction, water supply, and water quality are minimally impacted;
- Ensure flow requirements at Leavittsburg and Youngstown, OH;

10.4.2 STEP 4 – PART B – SCENARIOS NOT RECOMMENDED

Of the 25 scenarios modeled, a first pass of the results yielded the conclusion that Proposed WCP Change 3, 4, 6, and 7 (Scenarios 4, 5, 6, 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 25) were not recommended for the following reasons listed below. The first pass elimination was based on engineering judgement for the most logical ways to operate the reservoirs.

Proposed WCP Change 3, which models augmenting flow deficiencies in the Mahoning River at Leavittsburg with 50% of the augmentation flow from Berlin Lake-Lake Milton and 50% from Michael J. Kirwan Dam and Reservoir, is not recommended. Both Berlin Lake and Lake Milton have significantly more storage and upstream drainage area than Michael J. Kirwan Dam and Reservoir. Forcing Michael J. Kirwan Dam and Reservoir to release as much flow as Berlin Lake and Lake Milton may challenge Michael J. Kirwan Dam and Reservoir to maintain sufficient water for in-reservoir recreation and/or other authorized uses.

Proposed WCP Change 4, which would force Michael J. Kirwan Dam and Reservoir to begin drawing down on June 26, is not recommended as it will likely negatively impact the reservoirs in reservoir recreational use during the summer.

Proposed WCP Change 6, which models beginning to fill Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake on February 15, is not recommended as the watershed typically sees high flow events during February and March. This Proposed WCP Change could negatively impact the reservoirs' ability to store early spring floods and lead to increased flood risk.

Proposed WCP Change 7, representing no augmentation flow at Leavittsburg or Youngstown is not a feasible operation as it would not allow Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake to meet their currently authorized purposes of water quality control. The removal of downstream flow requirements would need significant coordination with numerous federal, state, and local agencies as this would impact environmental resources and permits. However, while this change was not recommended, modeling scenario 25 provides valuable insight to the current benefits provided by Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake and was carried forward for further comparison purposes.

Removal of these Proposed WCP Changes reduced the number of scenarios from twenty-five (25) to eleven (11).

10.4.3 STEP 4 – PART C – EXAMANIATION/EVALUATION OF THE REMAINING SCENARIOS

Flood Risk Management
As noted in Section 10.3.1, many of the Flood Risk Management performance metrics had to be set below flooding thresholds so that the DST was able to provide non-zero values. Based on the results in Table 10-5 and Table 10-6 which summarized the DST results for Flood Risk Management, most of the scenarios exceed the established metric threshold, but none of the proposed scenarios yielded results indicating downstream flooding (above channel capacity) or exceeded the spillway elevation.

The District would continue to cooperate with the Ohio Department of Natural Resources by furnishing ODNR with information regarding proposed operation of Berlin Lake and providing ODNR with recommended operations for Lake Milton. During the time when reservoirs are at (or near) summer pool, the District will continue to incorporate operational precipitation forecast issued by the NWS as well as monitor the potential of tropical storm and/or hurricane remnants passing through the Mahoning River Basin. The District will continue to operate the reservoirs to reduce the risk of flooding downstream as it has successfully been doing since the construction of the projects.

Based on the analysis performed based on four years of data, there are no scenarios where Flood Risk Management exceeds the flood risk thresholds that the District's Water Management team operates to, such as flood stage downstream at Leavittsburg and Youngstown, or maximum pool for Berlin Lake, Lake Milton, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake. Based on the DST, the reservoirs could be operated under the remaining scenarios to reduce the risk of flooding within the reservoir and downstream, for each of the eleven scenarios.

Table 10-5: Summary of Flood Risk Management Performance Measures

Authorized Purpose	Flood Risk Management					
Season	Wet	Wet	Wet	Wet	Wet	Wet
Measure Location	Berlin	MJ Kirwan	Mosquito	Berlin	MJ Kirwan	Mosquito
Performance Measure	Number of Days Outflow >= 2600 cfs	Number of Days Outflow >= 1125 cfs	Number of Days Outflow >= 900 cfs	Number of Days Berlin levels ≥ 1030 ft (days)	Number of Days MJK levels ≥ 988.5 ft (days)	Number of Days Mosquito levels ≥ 901.3 ft (days)
Scenario 01	8.63	9.79	9.71	1.54	1.71	1.88
Scenario 02	9.25	8.75	9.67	1.54	1.71	1.88
Scenario 03	8.08	9.38	9.75	1.54	1.71	1.88
Scenario 07	8.00	9.88	8.42	1.63	1.58	4.00
Scenario 08	8.88	8.88	7.54	1.63	1.58	3.29
Scenario 09	9.50	9.67	7.17	1.63	1.58	3.29
Scenario 19	8.38	10.25	9.58	4.08	2.63	1.88
Scenario 20	9.38	9.50	9.67	1.54	1.71	1.88
Scenario 22	8.92	10.13	9.33	4.08	1.71	1.88
Scenario 23	8.83	9.38	9.33	4.08	1.71	1.88
Scenario 24	8.83	10.38	9.71	4.08	2.50	1.88

Table 10-6: Summary of Flood Risk Management Performance Measures Downstream of the Reservoirs

Authorized Purpose	Flood Risk Management			
Season	Wet	Wet	Wet	Wet
Measure Location	Leavittsburg	Youngstown	Leavittsburg	Youngstown
Performance Measure	Max flow (cfs)	Max flow (cfs)	Total Annual Volume of water above 4,000 cfs (cubic feet/year)	Total Annual Volume of water above 8,000 cfs (cubic feet/year)
Scenario 01	5,427.18	10,953.07	3,006.66	2,807.54
Scenario 02	5,494.31	11,291.09	3,001.45	2,974.97
Scenario 03	5,463.47	11,151.98	3,210.05	2,910.86
Scenario 07	5,412.10	10,911.93	2,995.59	2,563.43
Scenario 08	5,462.27	11,329.83	2,984.44	2,715.30
Scenario 09	5,463.80	11,138.91	3,342.21	2,672.44
Scenario 19	5,391.42	10,864.20	3,551.85	2,797.85
Scenario 20	5,458.16	11,309.61	2,999.43	2,972.66
Scenario 22	5,458.21	11,310.35	3,431.31	2,971.88
Scenario 23	5,494.31	11,291.25	3,433.28	2,974.02
Scenario 24	5,466.37	11,138.59	4,213.38	2,909.16

Water Supply
Table 10-7 summarizes the DST results for Water Supply, none of the scenarios posed a threat to water supply. For all scenarios, the pool elevation stayed above the elevation of the water intakes. No increased risk to meet water supply was observed for any of the eleven scenarios.

Table 10-7: Summary of Water Supply Performance Measures

Authorized Purpose	Water Supply	
Season	Dry	Dry
Measure Location	Berlin	Mosquito
Performance Measure	Number of Days reservoir does NOT meet intake level (days)	Number of Days reservoir does NOT meet intake level (days)
Scenario 01	0.00	0.00
Scenario 02	0.00	0.00
Scenario 03	0.00	0.00
Scenario 07	0.00	0.00
Scenario 08	0.00	0.00
Scenario 09	0.00	0.00
Scenario 19	0.00	0.00
Scenario 20	0.00	0.00
Scenario 22	0.00	0.00
Scenario 23	0.00	0.00
Scenario 24	0.00	0.00

Recreation
Table 10-8 and Table 10-9 summarizes the DST results for Recreation. Scenarios 19, 22, 23 and 24 have the biggest impact on the recreation performance measures.

Scenarios 02 through 09 and Scenario 20 do not provide significantly more recreational benefit than Scenario 01, representing the existing WCMs. For each scenario, the biggest impact is a couple days more of reservoir elevations above boat ramp elevation, or a couple days more of ideal flow downstream at Leavittsburg.

Scenario 19, 22, 23 and 24 all include flow deficiencies at Leavittsburg augmented by Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir, with no specified percentage. These Proposed WCP Changes lead to significantly more (between 55 and 70) days where flow downstream at Leavittsburg meets the ideal flow during dry weather, and significantly more days where Berlin Lake is not below the lowest preferred level for recreation, though at a cost of impacting reservoir elevations within Michael J. Kirwan Dam and Reservoir that would need to be balanced amongst the Projects.

Of all the scenarios, the three scenarios that lead to the most significant increase in recreation are Scenarios 22 through 24. Scenarios 22 and 23 provide the highest benefit at Berlin Lake for in-reservoir recreation, providing approximately 15.3 days more where reservoir elevations within Berlin Lake are not below the lowest preferred level. Pending runoff within the basin, during a dry year Michael J. Kirwan Dam and Reservoir and Mosquito Creek Lake may experience a reduction in the number of days below the lowest preferred level.

Table 10-8: Summary of Recreation Performance Measures

Authorized Purpose	Recreation					
Season	Wet	Wet	Wet	Dry	Dry	Dry
Measure Location	Berlin	MJ Kirwan	Mosquito	Berlin	MJ Kirwan	Mosquito
Performance Measure	Number of Days boat ramps flooded (Elevation > 1027.5 ft) (days)	Number of Days boat ramps flooded (Elevation > 987 ft) (days)	Number of Days boat ramps flooded (Elevation > 900.8 ft) (days)	Number of Days between Memorial Day and Labor Day the pool is below the lowest preferred level (days)	Number of Days between Memorial Day and Labor Day the pool is below the lowest preferred level (days)	Number of Days between Memorial Day and Labor Day the pool is below the lowest preferred level (days)
Scenario 01	10.42	0.46	12.13	93.42	76.17	57.88
Scenario 02	13.21	0.46	12.13	93.42	76.17	57.88
Scenario 03	10.42	0.46	14.83	93.88	76.21	57.83
Scenario 07	8.58	0.29	16.88	93.42	76.17	57.88
Scenario 08	11.46	0.29	13.83	93.42	76.17	57.88
Scenario 09	8.58	0.29	19.96	93.88	76.21	57.83
Scenario 19	12.50	0.46	12.88	78.13	92.54	64.29
Scenario 20	13.21	0.46	12.13	93.42	76.17	57.88
Scenario 22	15.29	0.46	12.88	78.13	92.54	64.83
Scenario 23	15.29	0.46	12.88	78.13	92.54	64.83
Scenario 24	12.50	0.46	15.38	78.29	92.58	64.83

Table 10-9: Summary of Recreation Performance Measures Downstream of the Reservoirs

Authorized Purpose	Recreation	
Season	Wet	Dry
Measure Location	Leavittsburg	Leavittsburg
Performance Measure	Number of Days meeting downstream recreation ideal flow preferences (days)[1]	Number of Days meeting downstream recreation ideal flow preferences (days)[1]
Scenario 01	236.63	167.13
Scenario 02	237.79	159.79
Scenario 03	236.33	157.58
Scenario 07	236.92	170.67
Scenario 08	237.75	159.79
Scenario 09	237.92	157.58
Scenario 19	239.25	222.29
Scenario 20	238.13	162.21
Scenario 22	235.58	236.83
Scenario 23	235.25	237.54
Scenario 24	238.04	235.00

[1] Ideal flow preference is three to five feet of gage elevation

Water Quality

Table 10-10 and Table 10-11 summarizes the DST results for Water Quality.

For Berlin Lake, residence time ranges from approximately 106 days for Scenarios 01 and 07 to approximately 144 days for Scenarios 22 and 23. For Michael J. Kirwan Dam and Reservoir, residence time ranges from approximately 181 days for Scenario 22 to approximately 286 days for Scenario 01. For Mosquito Creek Lake, residence time ranges from approximately 191 days for Scenario 22 to approximately 286 days for Scenario 01. For Mosquito Creek Lake, residence times ranges from approximately 191 days for Scenarios 02 and 08, to approximately 215 days for Scenario 20.

When considering overall residence time at Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake, Scenarios 22 and 23 provide the lowest overall reservoir residence times. Conversely, the DST indicates an increase in residence time associated with Berlin Lake for Scenarios 22 and 23. Increased residence times can result in prolonged physical, chemical and biological processes such as increased water temperatures, nutrient availability, bacterial decomposition, and primary productivity.

For Scenarios 2, 3, 8, 9, and 20, the number of days when Leavittsburg and Youngstown meet the needed flow rates downstream, decreases compared to the current WCP. For Scenario 7, 19, 22, 23, and 24, the number of days when Leavittsburg and Youngstown meet the needed flow rates downstream increases, with the largest increases occurring for Scenario 22, Scenario 23, and Scenario 24.

For Water Quality, based on the DST, Scenario 22, Scenario 23 and Scenario 24 provide the best results for meeting or enhancing water quality benefits downstream at both Leavittsburg and Youngstown, Ohio. However, there could be impacts to in-reservoir water quality conditions at Berlin Lake as a result of increased retention times in Scenarios 22 and 23.

Table 10-10: Summary of Water Quality Performance Measures

Authorized Purpose	Water Quality		
Season	Dry	Dry	Dry
Measure Location	Berlin	MJ Kirwan	Mosquito
Performance Measure	Residence Time (days)	Residence Time (days)	Residence Time (days)
Scenario 01	106.42	285.72	203.93
Scenario 02	131.69	278.94	190.83
Scenario 03	118.51	271.55	207.97
Scenario 07	105.50	279.68	208.07
Scenario 08	131.33	280.21	190.80
Scenario 09	118.51	259.86	214.12
Scenario 19	110.98	226.68	208.15
Scenario 20	140.95	214.49	214.83
Scenario 22	143.84	181.37	214.02
Scenario 23	143.44	182.55	206.87
Scenario 24	124.83	212.29	208.12

Table 10-11: Summary of Water Quality Performance Measures Downstream of the Reservoirs

Authorized Purpose	Recreation	
Season	Wet	Dry
Measure Location	Leavittsburg	Leavittsburg
Performance Measure	Number of days the flow schedule was met (days)	Number of days the flow schedule was met (days)
Scenario 01	236.63	167.13
Scenario 02	237.79	159.79
Scenario 03	236.33	157.58
Scenario 07	236.92	170.67
Scenario 08	237.75	159.79
Scenario 09	237.92	157.58
Scenario 19	239.25	222.29
Scenario 20	238.13	162.21
Scenario 22	235.58	236.83
Scenario 23	235.25	237.54
Scenario 24	238.04	235.00

Fish and Wildlife
Table 10-12 summarizes DST results for Fish and Wildlife.

Michael J. Kirwan Dam and Reservoir releases more augmentation flow during the summer, especially for those scenarios where the flow deficiencies in the Mahoning River at Leavittsburg, OH are augmented by Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir, with the revised or no specified percentage. Rate of change of reservoir elevation for Berlin Lake between March 1, and June 15, ranges from 2.4 feet per week to 2.7 feet per week during a wet year, and is 1.2 feet per week during dry season, for all eleven scenarios. Rate of change of reservoir elevation for Michael J. Kirwan Dam and Reservoir between March 1, and June 15, ranges from 0.9 feet per week to 1.0 feet per week during a wet year and arranges between 0.6 feet per week and 0.7 feet per week during a dry year.

Rate of change of reservoir elevation for Mosquito Creek Lake is 0.4 feet per day, both during a dry year and wet year for all eleven scenarios. The fisheries at all three reservoirs require more stable pool elevations during the spawning seasons. While there is not a specified range of pool elevation that is optimal, it has been determined that a low rate of pool elevation change over time benefits the spawn by providing optimum habitat for a longer period of time. The District's Water Management team works to minimize fluctuations in pool elevation during the spring fill and fall drawdown, regardless of which scenario is considered.

Table 10-12: Summary of Fish and Wildlife Performance Measures

Authorized Purpose	Fish and Wildlife											
Season	Wet	Wet	Wet	Dry	Dry	Dry	Wet	Wet	Wet	Dry	Dry	Dry
Measure Location	Berlin	MJ Kirwan	Mosquito	Berlin	MJ Kirwan	Mosquito	Berlin	MJ Kirwan	Mosquito	Berlin	MJ Kirwan	Mosquito
Performance Measure	Rate of change/water 3/1-6/15 (ft/week)	Rate of change/water 3/1-6/15 (ft/week)	Rate of change/water 3/1-6/15 (ft/week)	Rate of change/water 3/1-6/15 (ft/week)	Rate of change/water 3/1-6/15 (ft/week)	Rate of change/water 3/1-6/15 (ft/week)	Rate of change/water 6/28 - 9/30 (ft/week)	Rate of change/water 6/28 - 9/30 (ft/week)	Rate of change/water 6/28 - 9/30 (ft/week)	Rate of change/water 6/28 - 9/30 (ft/week)	Rate of change/water 6/28 - 9/30 (ft/week)	Rate of change/water 6/28 - 9/30 (ft/week)
Scenario 01	2.40	0.89	0.26	1.15	0.64	0.25	1.59	0.83	0.37	0.90	0.63	0.37
Scenario 02	2.40	0.89	0.26	1.15	0.64	0.25	1.48	0.92	0.27	0.94	0.64	0.37
Scenario 03	2.49	0.86	0.26	1.16	0.64	0.25	2.09	0.89	0.28	0.92	0.64	0.38
Scenario 07	2.61	0.86	0.27	1.15	0.64	0.25	1.65	0.81	0.37	0.92	0.63	0.37
Scenario 08	2.61	0.86	0.27	1.15	0.64	0.25	1.47	0.83	0.22	0.94	0.64	0.37
Scenario 09	2.70	0.85	0.27	1.16	0.64	0.25	1.33	0.89	0.32	0.92	0.64	0.38
Scenario 19	2.62	0.95	0.26	1.15	0.69	0.27	1.65	0.91	0.42	1.05	1.20	0.35
Scenario 20	2.40	0.89	0.26	1.15	0.64	0.25	1.48	0.90	0.27	0.94	0.64	0.37
Scenario 22	2.62	0.95	0.26	1.15	0.69	0.25	1.48	0.98	0.27	0.87	1.02	0.34
Scenario 23	2.62	0.95	0.26	1.15	0.69	0.25	1.48	0.91	0.27	0.91	1.06	0.40
Scenario 24	2.73	0.88	0.26	1.16	0.69	0.26	2.09	0.99	0.30	0.90	1.17	0.37

10.4.4 STEP 4 – PART D – SCENARIOS SELECTED THAT ENHANCE PROJECT BENEFITS

The following scenarios were selected to maximize the flexibility in operating the reservoirs and to enhance benefits of the Projects where practicable, while still ensuring the capability of meeting their authorized purposes.

The four selected scenarios were:

- Scenario 03 - Represents most closely how the reservoirs have been operated over the past fifteen years, and best represent current operating conditions within the watershed. This scenario was carried forward and examined in the CE-QUAL-W2 water quality model. Note, the EA did not consider Scenario 03, but rather the no action alternative of continuing to operate using the existing WCPs. The No Action alternative, for the purposes of analysis under the National Environmental Policy Act (NEPA), is described as no change to the existing water control manuals and water control plans.

- Scenario 23 and Scenario 24 - Represent two operational scenarios that will balance reservoir authorized purposes (flood control, water quality control, fish and wildlife, recreation, and water supply) to optimize project benefits of Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake. These scenarios were carried forward as Alternative 1 and Alternative 2 in the EA and examined in the CE-QUAL-W2 water quality model. Scenarios 23 and 24 remove the constraints that force a drawdown at Berlin Lake even if downstream flow requirements would be met without increased flow augmentation from the Projects. Similarly, these scenarios provide greater flexibility in which Projects should release water, rather than forcing a constrained ratio of flow augmentation per reservoir. Under Scenarios 23 and 24, the District's Water Management team will balance the releases from the Projects based on the availability of water and each reservoir's current water level. These scenarios also bring the guide curve of Berlin Lake more in line with Michael J. Kirwan Dam and Reservoir and Mosquito Creek Lake.

- Scenario 25 - Represents no flow augmentation for the Mahoning River downstream from any of the reservoirs, where the outflows are not constrained by minimum flow requirements at Leavittsburg, OH or Youngstown, OH. While this change was not recommended, Scenario 25 provides valuable insight to the current benefits provided by Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake and was carried forward for further comparison purposes in the Water Quality model. This scenario was not examined in the EA. The removal of downstream flow requirements would also need significant coordination with numerous federal, state, and local agencies as this would impact environmental resources and permits

10.4.5 STEP 4 – PART E – EXAMINE SCENARIOS in CE-QUAL-W2

The USGS, in cooperation with the District, developed a CE-QUAL-W2 water quality models for Berlin Lake, Lake Milton, Michael J. Kirwan Dam and Reservoir, Mosquito Creek Lake and the Mahoning River downstream of the reservoirs. CE-QUAL-W2 is a two-dimensional, laterally averaged, hydrodynamic and water-quality model that has broad global application. The CE-QUAL-W2 models were run to determine the impacts that four proposed scenarios, including an existing operations scenario, have on water quality parameters. Water Quality constituents modeled included flow, velocity, ice cover, water temperature, total dissolved solids, sulfate, chloride, inorganic suspended sediment, nitrate, ammonia, total Kjeldahl nitrogen, orthophosphate, total phosphorus, dissolved and particulate organic matter, algae, and dissolved oxygen. Iron was included for the CE-QUAL-W2 reservoir model for Berlin Lake, Lake Milton, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake, but not the CE-QUAL-W2 model for the Mahoning River downstream of the reservoirs.

The CE-QUAL-W2 models for the Mahoning River downstream of the reservoirs were developed by first constructing model grids to represent reservoir and river bathymetry. Then, needed boundary data were collected and formatted to provide meteorological, hydrological, and water temperature and water-quality model inputs. In situ water quality data was utilized to calibrate and check model performance. All CE-QUAL-W2 models were developed for two calendar years so that calibration could encompass different flow and climate conditions. The modeled years were different for each reservoir and river, due to the different availability of water quality data through the basin.

A synthetic, whole-basin CE-QUAL-W2 model was then constructed for calendar year 2013 and used for the model scenarios. It used measured or estimated flows for year 2013 for model construction and calibration. No HEC-ResSim flows were used in the base case whole-basin model, but HEC-ResSim flows were used in other scenarios that examined possible changes from that base case condition. The whole-basin CE-QUAL-W2 model also necessitated construction of a Mosquito Creek CE-QUAL-W2 model between Mosquito Creek Lake and the Mahoning River.

The CE-QUAL-W2 model was run for the following four scenarios. The scenarios also examined in the Environmental Assessment are in parentheses:

1. Scenario 03 (Not Considered in the EA) – Berlin Lake Reservoir's WCP would be revised during the drawdown to reflect utilizing 25% flood storage of the original guide curve. This mostly accurately reflects how Berlin Lake has been operated over the past 15 plus years (refer to Attachment A). Note, in the EA the no action alternative considers the effects of continuing to operate and manage the reservoirs utilizing the existing water control manuals and water control plans.

2. Scenario 23 (EA Alternative 1) – Berlin Lake begins drawdown September 7. and flow deficiencies at Leavittsburg are augmented by Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir, with no specified percentage.

3. Scenario 24 (EA Alternative 2) – Berlin Lake Reservoir's WCP would be revised during the drawdown to reflect utilizing 25% flood storage of the original guide curve, and flow deficiencies at Leavittsburg are augmented by Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir, with no specified percentage.

4. Scenario 25 (Not Considered In EA) – No Augmentation Flow to Leavittsburg or Youngstown, for WQ modeling comparison purposes only.

CE-QUAL-W2 models were run to examine the effect of altered reservoir water surface elevations and reservoir outflows on water quality in the reservoirs, in the reservoir outflows, and in the Mahoning River downstream. Scenario 3 was selected as the EA baseline no-action alternative as, historically, reservoir operations have reflected, on average, an approximately 25% increase in storage during drawdown since the early 2000's. This alternative was used as a comparison for flow and water quality in the operational Scenario 23 (EA Alternative 1), Scenario 24 (EA Alternative 2), and Scenario 25.

Scenario 23 (EA Alternative 1) kept Berlin Lake's water surface elevations higher in summer, delaying drawdown until September 7. Scenario 24 (EA Alternative 2) utilized 25% of the original reservoir storage during the drawdown to extend the guide curve. Scenario 23 and Scenario 24 both removed the percentage of augmentation flow from Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir. In Scenario 25, reservoir water surface elevations were not constrained by minimum flow requirements at Leavittsburg and Youngstown.

Implementing these water surface elevations in the model required changes to the amounts and timing of the reservoir outflows. For example, Scenario 25 maintained higher water surface elevations in the reservoirs compared to the others; this mostly decreased flows to the Mahoning River during certain periods from April through mid-September. Then, from mid-September through November for Scenario 25, outflows from the reservoirs increased relative to Scenario 3, as more drawdown was required to reach winter guide curve elevations.

10.4.6 STEP 4 – PART F – IMPACTS SHOWN IN CE-QUAL-W2 MODELING TO AUTHORIZED PURPOSES

The results of these analyses were compared to water quality thresholds for each of the specified water quality parameters. The water quality constituents, acronyms and thresholds are presented in Table 10-13 below. Table 10-14, Table 10-15, Table 10-16, and Table 10-17 summarize the preliminary results for number of days when the outflows for Berlin Lake, Lake Milton, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake, respectively, exceed, or reduce, out of compliance water quality thresholds, compared to the baseline Scenario 3.

Table 10-13: Water Quality Thresholds

Water Quality Constituents and Thresholds

Dissolved Oxygen DO	Total Dissolved Solids TDS	Sulfate SO4	Chloride Clr	Chlorophyll a Chl	Total Phosphorous TP	Nitrate + Nitrite NO3	Iron Fe	Temperature T
> 5 mg/L	< 340 mg/L	< 100 mg/L	< 90 mg/L	< 20 ug/L	< 50 ug/L	< 10 mg/L	< 1,500 ug/L	< 89 Deg F

For example, a positive number result, such as 25, means that scenario had 25 days where there was an exceedance of the threshold as compared to the baseline. Conversely, a negative number result, such as -17, means that scenario had 17 fewer days where there was an exceedance of the threshold when compared to the baseline. This segment describes the preliminary results of these model runs in relation to water quality threshold exceedances for the outflows of the aforementioned reservoirs.

Table 10-14: Number of Days when Berlin Lake Exceeds, or Reduces, Out of Compliance Water Quality Thresholds

Berlin Lake											
EA Alternative (Scenario #)	DO_day change	TDS_day change	SO4_day change	Clr_day change	Chl_day change	TP_day change	NO3_day change	Fe_day change	T_Jan1-Feb_28 day change	T_Mar1-Mar15 day change	T_Mar16-31 day change
	days	days	days	days	days	days	days	days	days	days	days
1 (Scenario 23)	0	-17	0	0	-1	0	0	-5	0	0	0
2 (Scenario 24)	0	3	0	0	-1	0	0	-8	0	0	0
N/A (Scenario 25)	0	-54	0	0	-2	0	0	-3	0	0	0
EA Alternative (Scenario #)	T_Apr1-15 day change	T_Apr16-30 day change	T_May1-15 day change	T_May16-31 day change	T_Jun1-15 day change	T_Jun16-Sep15 day change	T_Sep16-30 day change	T_Oct1-15 day change	T_Oct16-31 day change	T_Nov1-30 day change	T_Dec1-30 day change
	days	days	days	days	days	days	days	days	days	days	days
1 (Scenario 23)	0	0	0	0	0	0	0	0	0	0	0
2 (Scenario 24)	0	0	0	0	0	0	0	0	0	0	0
N/A (Scenario 25)	0	0	0	0	0	0	0	0	0	0	0

Table 10-15: Number of Days when Lake Milton Exceeds, or Reduces, Out of Compliance Water Quality Thresholds

Lake Milton											
EA Alternative (Scenario #)	DO_day change	TDS_day change	SO4_day change	Clr_day change	Chl_day change	TP_day change	NO3_day change	Fe_day change	T_Jan1-Feb_28 day change	T_Mar1-Mar15 day change	T_Mar16-31 day change
	days	days	days	days	days	days	days	days	days	days	days
1 (Scenario 23)	0	0	0	0	-34	0	0	25	0	0	0
2 (Scenario 24)	0	0	0	0	-35	0	0	25	0	0	0
N/A (Scenario 25)	0	0	0	0	-41	0	0	19	0	0	0
EA Alternative (Scenario #)	T_Apr1-15 day change	T_Apr16-30 day change	T_May1-15 day change	T_May16-31 day change	T_Jun1-15 day change	T_Jun16-Sep15 day change	T_Sep16-30 day change	T_Oct1-15 day change	T_Oct16-31 day change	T_Nov1-30 day change	T_Dec1-30 day change
	days	days	days	days	days	days	days	days	days	days	days
1 (Scenario 23)	0	0	0	0	0	0	0	0	0	0	0
2 (Scenario 24)	0	0	0	0	0	0	0	0	0	0	0
N/A (Scenario 25)	0	0	0	0	0	0	0	0	0	0	0

Table 10-16: Number of Days when Michael J. Kirwan Dam and Reservoir Exceeds, or Reduces, Out of Compliance Water Quality Thresholds

Michael J. Kirwan Dam and Reservoir											
EA Alternative (Scenario #)	DO_day change	TDS_day change	SO4_day change	Clr_day change	Chl_day change	TP_day change	NO3_day change	Fe_day change	T_Jan1-Feb_28 day change	T_Mar1-Mar15 day change	T_Mar16-31 day change
	days	days	days	days	days	days	days	days	days	days	days
1 (Scenario 23)	0	0	0	0	0	0	0	8	0	0	0
2 (Scenario 24)	0	0	0	0	0	0	0	-1	0	0	0
N/A (Scenario 25)	0	0	0	0	0	0	0	-9	0	0	0
EA Alternative (Scenario #)	T_Apr1-15 day change	T_Apr16-30 day change	T_May1-15 day change	T_May16-31 day change	T_Jun1-15 day change	T_Jun16-Sep15 day change	T_Sep16-30 day change	T_Oct1-15 day change	T_Oct16-31 day change	T_Nov1-30 day change	T_Dec1-30 day change
	days	days	days	days	days	days	days	days	days	days	days
1 (Scenario 23)	0	0	0	0	0	0	0	0	0	0	0
2 (Scenario 24)	0	0	0	0	0	0	0	0	0	0	0
N/A (Scenario 25)	0	0	0	0	0	0	0	0	0	0	0

Table 10-17: Number of Days when Mosquito Creek Lake Exceeds, or Reduces, Out of Compliance Water Quality Thresholds

Mosquito Creek Lake											
EA Alternative (Scenario #)	DO_day change	TDS_day change	SO4_day change	Clr_day change	Chl_day change	TP_day change	NO3_day change	Fe_day change	T_Jan1-Feb_28 day change	T_Mar1-Mar15 day change	T_Mar16-31 day change
	days	days	days	days	days	days	days	days	days	days	days
1 (Scenario 23)	0	0	0	0	-2	0	0	0	0	0	0
2 (Scenario 24)	0	0	0	0	-2	0	0	0	0	0	0
N/A (Scenario 25)	0	0	0	0	4	0	0	0	0	0	0
EA Alternative (Scenario #)	T_Apr1-15 day change	T_Apr16-30 day change	T_May1-15 day change	T_May16-31 day change	T_Jun1-15 day change	T_Jun16-Sep15 day change	T_Sep16-30 day change	T_Oct1-15 day change	T_Oct16-31 day change	T_Nov1-30 day change	T_Dec1-30 day change
	days	days	days	days	days	days	days	days	days	days	days
1 (Scenario 23)	0	0	0	0	0	0	0	0	0	0	0
2 (Scenario 24)	0	0	0	0	0	0	0	0	0	0	0
N/A (Scenario 25)	0	0	0	0	0	0	0	0	0	0	0

At Berlin Lake, Total Dissolved Solids (TDS), Chlorophyll a (Chl) and Iron (Fe) were all influenced by a change in operations. TDS exceedance days decreased in Scenario 23 (-17) and Scenario 25 (-54) and increased in Scenario 24 (3). Chl exceedance days decreased for all scenarios. Fe exceedance days decreased for all scenarios as well.

At Lake Milton, Chlorophyll a (Chl) and Iron (Fe) were all influenced by a change in operations. Chl exceedance days decreased for all scenarios and Fe exceedance days increased for all scenarios.

At Michael J. Kirwan Dam and Reservoir, only Fe was influenced by a change in operations with an increase of eight exceedance days in Scenario 23, a decrease of one exceedance day in Scenario 24, and a decrease of nine exceedance days in Scenario 25.

At Mosquito Creek Lake, only Chl was influenced by a change in operations with a decrease of two exceedance days in Scenario 23, a decrease of two exceedance days in Scenario 24, and an increase of four exceedance days in Scenario 25.

In the reservoirs and the reservoir outflows, Scenarios 23, 24 and 25 differed from Scenario 03, representing the existing WCMs at certain times and locations for water temperature, dissolved oxygen, iron, and nutrient concentrations. The modeled effect of these differences on the water quality of the Mahoning River at Leavittsburg was relatively small for all scenarios. The largest changes in Mahoning River water quality were observed between Leavittsburg and Lowellville for Scenario 25. The periods of lower reservoir outflows between April and mid-September led to correspondingly higher concentrations of total dissolved solids and nutrients for those same periods in that portion of the river. Conversely, the overall greater reservoir outflows from mid-September through November in Scenario 25 led to periods of lower concentration of total dissolved solids and nutrients in that portion of the river, at that time of year, compared to the baseline.

These model results for all scenarios suggest that there may be no, or very little, detrimental impacts to in-reservoir or downstream water quality because of a change in reservoir operations, unless there aren't any operations for downstream flow schedules. The exception to this was Lake Milton, in which model results indicated differences between each of the scenarios in relation to anoxic conditions and the build-up of ammonia and dissolved iron in the hypolimnion in summer months due to low flows and Lake Milton's highly regulated inflow and outflow. Scenario 25 illustrates the benefits provided by existing reservoir release schedules that result in improved water quality conditions during low-flow conditions along the Mahoning River. Although modeled values occasionally deviated significantly from observed data in some instances, this can be explained by the different spatial scale of measured data and model output, gaps in data used to create model input files, and water quality processes not included in the model. The contrast between modeled and observed values highlights the fact that any model attempting to represent an incredibly complex natural system is dependent on the quality of the observations.

DOWNSTREAM OF RESERVOIRS

The water quality within Berlin Lake, Lake Milton, Michael J. Kirwan Dam and Reservoir. Mosquito Creek Lake and the Mahoning River downstream of each of the reservoirs was simulated using the CE-QUAL-W2 model. The results of that analysis are compared to water quality standards for each of the specified water quality parameters. Table 10-18, Table 10-19, Table 10-20 and Table 10-21 summarize how much more often the water quality parameters at

Leavittsburg, Warren, Youngstown and Lowellville, respectively, exceed the water quality standards, compared to the baseline Scenario 3. These locations represent the locations along the Mahoning River downstream of the reservoirs which have flow or water quality gages. The most substantial impacts in water quality conditions for the Mahoning River are for total phosphorous at Leavittsburg and Warren, OH and TDS for Youngstown and Lowellville, OH under Scenario 25; illustrating the benefits provided by existing reservoir release schedules that result in improved water quality conditions during low-flow conditions along the Mahoning River.

Table 10-18: Number of Days when Leavittsburg, Ohio is Outside of Water Quality Thresholds

Leavittsburg											
EA Alternative (Scenario #)	DO_day change	TDS_day change	SO4_day change	Clr_day change	Chl_day change	TP_day change	NO3_day change	T_Jan1-Feb_28 day change	T_Mar1-Mar15 day change	T_Mar16-31 day change	T_Apr1-15 day change
	days	days	days	days	days	days	days	days	days	days	days
1 (Scenario 23)	0	0	0	0	-1	-10	0	0	0	0	0
2 (Scenario 24)	0	0	0	0	-1	2	0	0	0	0	0
N/A (Scenario 25)	0	0	0	0	-1	23	0	0	0	0	0

EA Alternative (Scenario #)	T_Apr16-30 day change	T_May1-15 day change	T_May16-31 day change	T_Jun1-15 day change	T_Jun16-Sep15 day change	T_Sep16-30 day change	T_Oct1-15 day change	T_Oct16-31 day change	T_Nov1-30 day change	T_Dec1-30 day change
	days	days	days	days	days	days	days	days	days	days
1 (Scenario 23)	0	0	0	0	0	0	0	0	0	0
2 (Scenario 24)	0	0	0	0	0	0	0	0	0	0
N/A (Scenario 25)	0	0	0	0	0	0	0	0	0	0

Table 10-19: Number of Days when Warren, Ohio is Outside of Water Quality Thresholds

Warren											
EA Alternative (Scenario #)	DO_day change	TDS_day change	SO4_day change	Clr_day change	Chl_day change	TP_day change	NO3_day change	T_Jan1-Feb_28 day change	T_Mar1-Mar15 day change	T_Mar16-31 day change	T_Apr1-15 day change
	days	days	days	days	days	days	days	days	days	days	days
1 (Scenario 23)	0	0	0	0	-1	3	0	0	0	0	0
2 (Scenario 24)	0	0	0	0	-1	-4	0	0	0	0	0
N/A (Scenario 25)	0	0	0	0	-1	25	0	0	0	0	0

EA Alternative (Scenario #)	T_Apr16-30 day change	T_May1-15 day change	T_May16-31 day change	T_Jun1-15 day change	T_Jun16-Sep15 day change	T_Sep16-30 day change	T_Oct1-15 day change	T_Oct16-31 day change	T_Nov1-30 day change	T_Dec1-30 day change
	days	days	days	days	days	days	days	days	days	days
1 (Scenario 23)	0	0	0	0	0	0	0	0	0	0
2 (Scenario 24)	0	0	0	0	0	0	0	0	0	0
N/A (Scenario 25)	0	0	0	0	0	0	0	0	0	0

Table 10-20: Number of Days when Youngstown, Ohio is Outside of Water Quality Thresholds

Youngstown											
EA Alternative (Scenario #)	DO_day change	TDS_day change	SO4_day change	Clr_day change	Chl_day change	TP_day* change	NO3_day change	T_Jan1-Feb_28 day change	T_Mar1-Mar15 day change	T_Mar16-31 day change	T_Apr1-15 day change
	days	days	days	days	days	days	days	days	days	days	days
1 (Scenario 23)	0	16	0	0	-1	0	0	0	0	0	0
2 (Scenario 24)	0	8	0	0	-1	0	0	0	0	0	0
N/A (Scenario 25)	0	55	0	2	-1	0	0	0	0	0	0
EA Alternative (Scenario #)	T_Apr16-30 day change	T_May1-15 day change	T_May16-31 day change	T_Jun1-15 day change	T_Jun16-Sep15 day change	T_Sep16-30 day change	T_Oct1-15 day change	T_Oct16-31 day change	T_Nov1-30 day change	T_Dec1-30 day change	
	days	days	days	days	days	days	days	days	days	days	
1 (Scenario 23)	0	0	0	0	0	0	0	0	0	0	
2 (Scenario 24)	0	0	0	0	0	0	0	0	0	0	
N/A (Scenario 25)	0	0	0	0	0	0	0	0	0	0	

* For Youngstown and Lowellville, all scenarios showed exceedance of the TP criterion on all days. There is no difference in days between scenarios

Table 10-21: Number of Days when Lowellville, Ohio is Outside of Water Quality Thresholds

Lowellville											
EA Alternative (Scenario #)	DO_day change	TDS_day change	SO4_day change	Clr_day change	Chl_day change	TP_day* change	NO3_day change	T_Jan1-Feb_28 day change	T_Mar1-Mar15 day change	T_Mar16-31 day change	T_Apr1-15 day change
	days	days	days	days	days	days	days	days	days	days	days
1 (Scenario 23)	0	0	0	0	0	0	0	0	0	0	0
2 (Scenario 24)	0	-4	0	0	0	0	0	0	0	0	0
N/A (Scenario 25)	0	30	0	1	0	0	0	0	0	0	0
EA Alternative (Scenario #)	T_Apr16-30 day change	T_May1-15 day change	T_May16-31 day change	T_Jun1-15 day change	T_Jun16-Sep15 day change	T_Sep16-30 day change	T_Oct1-15 day change	T_Oct16-31 day change	T_Nov1-30 day change	T_Dec1-30 day change	
	days	days	days	days	days	days	days	days	days	days	
1 (Scenario 23)	0	0	0	0	0	0	0	0	0	0	
2 (Scenario 24)	0	0	0	0	0	0	0	0	0	0	
N/A (Scenario 25)	0	0	0	0	0	0	0	0	0	0	

10.5 STEP 5 – RMC-RFA MODEL

The RMC developed the RMC-RFA software to facilitate hydrologic hazard assessments within the USACE Dam Safety Program. RMC-RFA uses a deterministic flood routing model while stochastically sampling inflow volume, inflow hydrograph shape, month of the flood event, and antecedent reservoir elevation to produce a reservoir stage-frequency curve with uncertainty bounds. RMC-RFA does not directly account for reservoir operations or downstream conditions. Within RMC-RFA, reservoir outflow is directly dependent on the reservoir elevation rather than the many competing operational goals that influence operational decisions. This simplification between outflow and elevation is reasonable considering that during a high flow event, the reservoir is typically operated for flood storage. Another way reservoir operations indirectly impact the RMC-RFA results is that the historical reservoir operations have an influence on the antecedent reservoir elevations that are sampled. RMC-RFA outputs a reservoir stage-frequency curve with uncertainty bounds, which provides the annual risk of a full range of peak reservoir elevations.

Selected scenarios (3, 23 and 24) all propose changes to Berlin Lake's WCP. Therefore, RMC-RFA modeling was limited to Berlin Lake only since Berlin Lake is the only reservoir (in scenarios 3, 23 and 24) with a Proposed WCP Change to the guide curve. Scenario 25 cannot be modeled using RMC-RFA as it is based on changing downstream conditions, a metric that RMC-RFA cannot evaluate.

As a point of comparison, although not considered in the EA or water quality modeling efforts, Scenario 21 (early fill of the reservoir) was also examined in the RMC-RFA model. The purpose of Scenario 21 was to examine the full seasonality effects of varying pool levels throughout the year (early fill, existing WCP, and later drawdown).

The RMC-RFA program was utilized to estimate the increased risk or probability of reservoir elevations within Berlin Lake reaching the crest of the uncontrolled spillway, at elevation 1031.73 ft-NAVD88, for the proposed new operating scenarios. If reservoir elevations reach the crest of the uncontrolled spillway, the reservoir would begin to release uncontrolled flow over the spillway downstream towards Lake Milton. This represents a challenge for reservoir operations as Lake Milton would need to be operated such that it does not release uncontrolled flow downstream towards Leavittsburg or Youngstown.

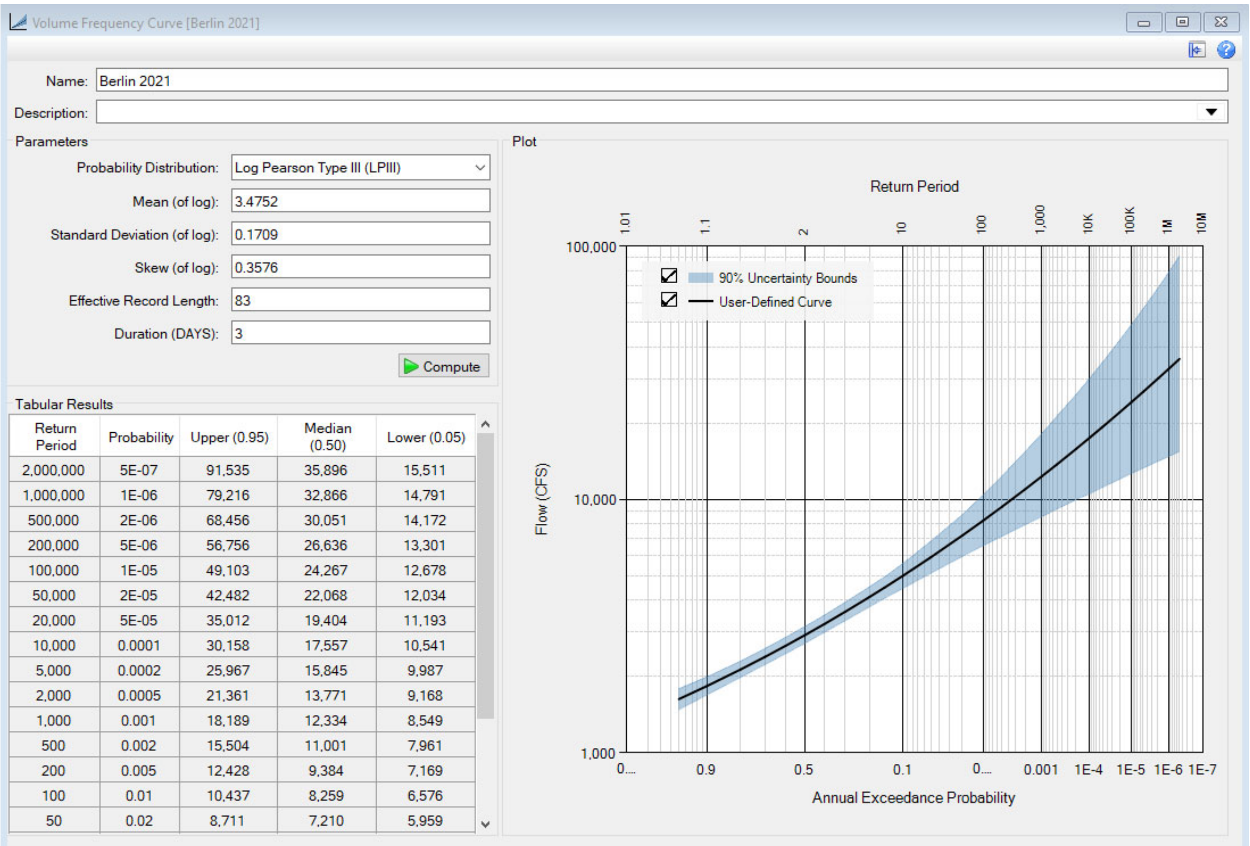
An increase of annual exceedance probability (AEP), the probability that Berlin Lake will reach or exceed the crest of the uncontrolled spillway in any one year, of 1 percent or less was considered to be a minimal increased risk. In such a situation, the probability of Berlin Lake activating the spillway and releasing uncontrolled flow downstream to Lake Milton is not significantly more than it is under present conditions.

10.5.1 Inflow Volume Frequency Curve

RMC-RFA requires a volume frequency analysis, which is computed in (the Hydrologic Engineering Center Statistical Software Package (HEC-SSP). Daily inflow records maintained by the District had a continuous record from 1943 to 2017. This dataset was merged with daily average inflows obtained from the CWMS Database to create a continuous record from 1943-

2021. A volume frequency analysis was completed within HEC-SSP using this dataset to generate an annual maximum series of volumes for the 1, 2, 3, 4, 5, and 7-day durations based on the continual inflow record from 1943 through 2021.

The results from HEC-SSP were input into a spreadsheet developed by the RMC titled, "Effective Record Length Estimation for a Bulletin 17C Flow Frequency Analysis". This spreadsheet uses information from the HEC-SSP to estimate the effective record length. This effective record length in addition to the probability distribution (log pearson Type III distribution), mean of log, standard deviation of log, skew of log, and duration are input into RMC-RFA to define the volume frequency curve, as shown in Figure 10-16.



Return Period	Probability	Upper (0.95)	Median (0.50)	Lower (0.05)
2,000,000	5E-07	91,535	35,896	15,511
1,000,000	1E-06	79,216	32,866	14,791
500,000	2E-06	68,456	30,051	14,172
200,000	5E-06	56,756	26,636	13,301
100,000	1E-05	49,103	24,267	12,678
50,000	2E-05	42,482	22,068	12,034
20,000	5E-05	35,012	19,404	11,193
10,000	0.0001	30,158	17,557	10,541
5,000	0.0002	25,967	15,845	9,987
2,000	0.0005	21,361	13,771	9,168
1,000	0.001	18,189	12,334	8,549
500	0.002	15,504	11,001	7,961
200	0.005	12,428	9,384	7,169
100	0.01	10,437	8,259	6,576
50	0.02	8,711	7,210	5,959

Figure 10-16: Volume Frequency Curve Input to RMC-RFA

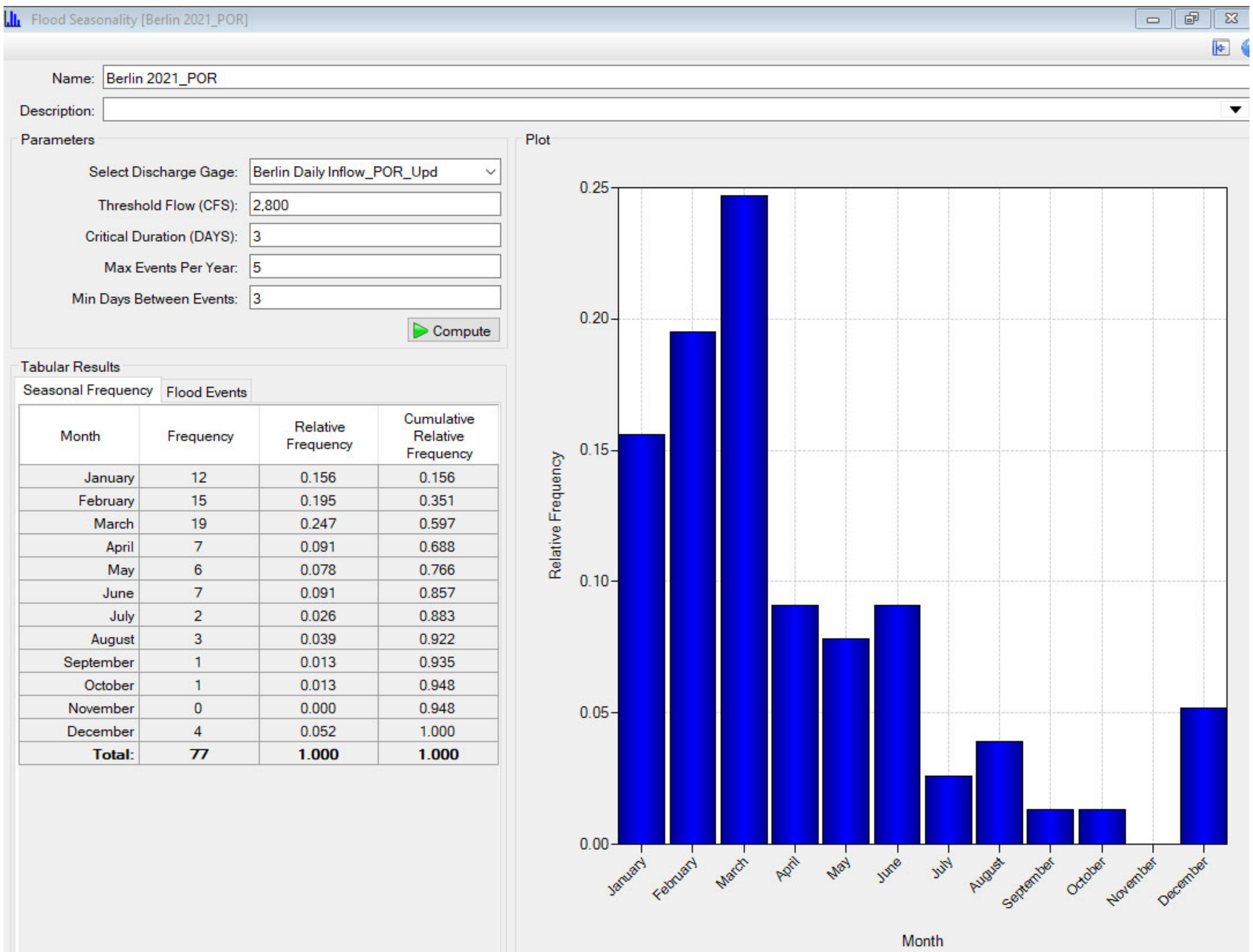
10.5.2 Inflow Hydrograph

The spillway design flood, equal to the probable maximum flood when the reservoir was designed and determined based on Hydrometeorological Report 33, was input into RMC-RFA as an input hydrograph shape.

10.5.3 Flood Seasonality

The flood seasonality is an analysis computed within RMC-RFA that is used to perform an RMC-RFA simulation. To perform the flood seasonality analysis, a continuous, daily inflow dataset is required. The previously discussed inflow record was used but limited to 01 January 1944 to 31 December 2020. Limiting to this timeframe would ensure that partial years did not bias the analysis. The other inputs to the flood seasonality analysis include, threshold flow, critical duration, maximum events per year, and minimum days between events.

The threshold flow is adjusted until the number of events identified is equal to the number of years in the period of record. The critical duration of three days was continued into this analysis. The maximum events per year was set at five to ensure multiple high inflows in a single year were not excluded. The minimum days between events was set at three days to ensure the same event was not counted twice. This analysis, shown as Figure 10-17, shows that the occurrence of flood events is predominantly in the winter through early summer.



Month	Frequency	Relative Frequency	Cumulative Relative Frequency
January	12	0.156	0.156
February	15	0.195	0.351
March	19	0.247	0.597
April	7	0.091	0.688
May	6	0.078	0.766
June	7	0.091	0.857
July	2	0.026	0.883
August	3	0.039	0.922
September	1	0.013	0.935
October	1	0.013	0.948
November	0	0.000	0.948
December	4	0.052	1.000
Total:	**77**	**1.000**	**1.000**

Figure 10-17: RMC-RFA Flood Seasonality Analysis

10.5.4 Reservoir Starting Stage Duration

The reservoir starting stage duration is another analysis within RMC-RFA and was the primary variable used to assess guide curve changes. Starting stage duration curves represent the percent of time during which specified reservoir stages are exceeded at a given location. In RMC-RFA, reservoir starting stage duration curves are used to derive reservoir stage-frequency curves by combining the annual exceedance probability of the inflow flood event with the probability of the stage prior to the flood event. This analysis uses a continuous, daily reservoir elevation dataset as input. This analysis is based on historical reservoir elevation data, between 1943 and 1995. During this time period, Berlin Lake was operated so that reservoir elevations typically went below 1,010 ft-NAVD88. After 1996, Berlin Lake was operated so that reservoir elevations typically stayed at or above 1,010 ft-NAVD88. To ensure that the RMC-RFA modeled current reservoir operations, only the period between 01 January 1996 thru 31 December 2020 was used for this analysis.

This analysis also requires a pool change threshold and typical high pool duration. The pool change threshold was set to one foot, and the typical high pool duration was set to four days. These settings seemed to best exclude stages when the pool was quickly rising. These pools would be unlikely to serve as antecedent pools. The four-day high pool duration does not overly exclude data after an event has passed. This four-day duration is measured from when the pool change threshold is triggered, which typically happens as the pool is rising. Consequently, the peak stage caused by an event is typically included in the starting stage duration analysis as it typically requires several days to pass the volume from a large inflow event.

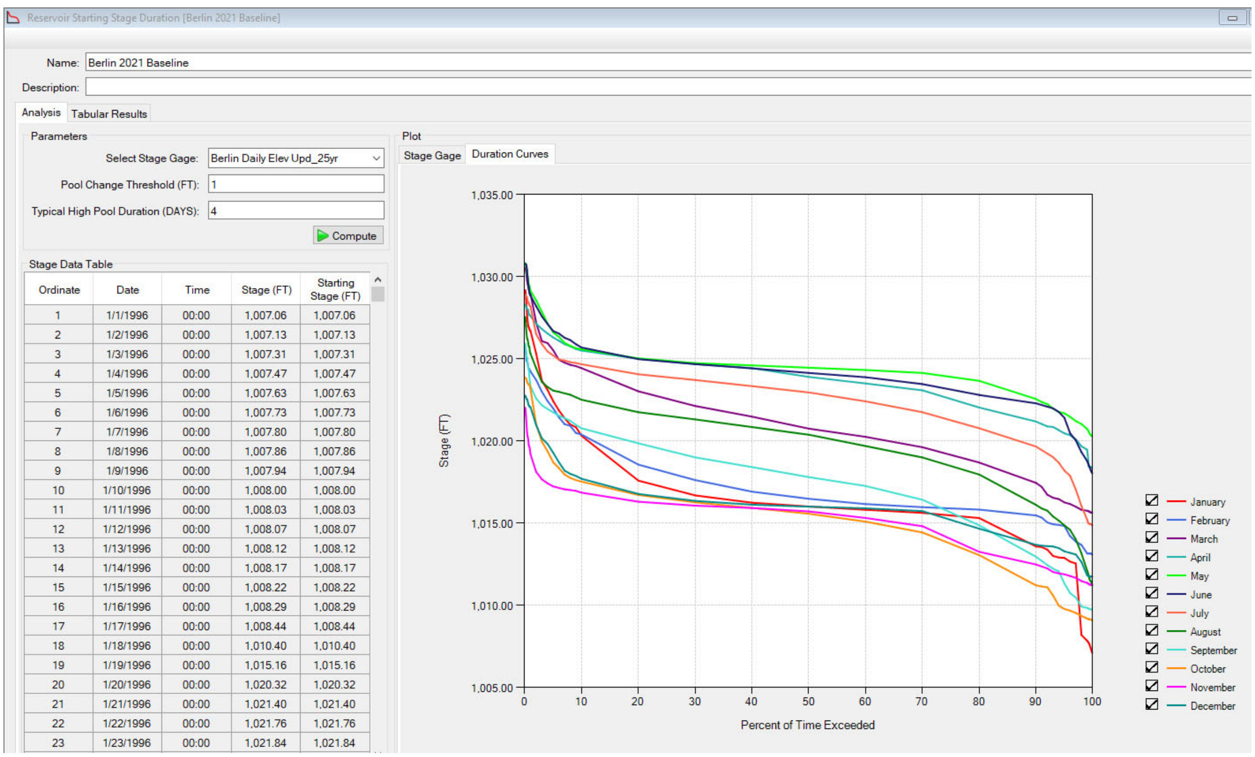


Figure 10-18: RMC-RFA Reservoir Starting Stage Duration Analysis

To estimate the impact of filling Berlin Lake on February 15, rather than March 25 (Scenario 21), the historical stage duration curve for May was used for April and May. April was used for March, and March was used for February. The later spring months have higher stages than early spring due to the filling of the reservoirs. If filling earlier, higher stages are expected earlier into the spring or late winter.

To estimate the impact of delaying the forced drawdown until September 7. rather than June 25, the starting stage duration curve for May was copied to June, July, and August. July was copied to September to represent the drawdown month.

Copying May's starting stage duration curve into June, July and August, and copying July's starting stage duration curve into September artificially inflates the likelihood of a higher inflow event being modeled for this scenario.

10.5.5 Reservoir Model

The Reservoir Model within RMC-RFA is the relationship between stage, storage, and outflow. The stage-storage relationship is based on the 1999 sedimentation survey for Berlin Lake. For the stage-storage-outflow relationship, simplifying assumptions need to be made to determine a single stage-outflow relationship based on historical stage and outflow data.

One assumption made is that during the synthetic event that RMC-RFA simulates, the crest gates are held closed such that Berlin Lake stores the event. This is conservative, but in line with current district practices. Ten cubic feet per second (cfs), the minimum outflow allowed through Berlin Lake, is used for elevations below 1009.31 ft-NAVD88. Above the uncontrolled spillway, the fixed crest spillway rating curve was used to inform the outflow. Between 1009.31 and the uncontrolled spillway (elevation 1031.73 ft-NAVD88) is the operating range of reservoir elevations within Berlin Lake.

To better represent operations prior to elevation 1031.73 ft-NAVD88, historical hourly elevations, inflow, and outflow data from the CWMS Database (28 July 2013 to 23 March 2021) was assessed. Time steps when outflow was greater than inflow were discarded as these time steps should represent releases after the reservoir elevation has peaked and reservoir storage is being released. The rising limb is more pivotal to capture the peak stage within RMC-RFA. This process should be more conservative as some high discharge events are discarded. The remaining time steps are then used to develop a relationship between the reservoir elevation and outflow. A linear trendline was fit to this data (Figure 10-19). Ultimately, it was decided to use 10 cfs until elevation 1029.31 ft-NAVD88 and then transition to this linear fit at 1030.31 ft-NAVD88. This decision was made after initial simulations in RMC-RFA showed model results below the historic peak elevation distribution. This practice of calibrating the reservoir model to the historic peak elevation distribution is common for Periodic Assessments and Semi-Quantitative Risk Assessments (SQRAs). It is discussed in RMC-TR-2018-03 titled, "Hydrologic Hazard Methodology for Semi-Quantitative Risk Assessments: An Inflow Volume-Based Approach to Estimating Stage-Frequency Curves for Dams" (USACE, 2018).

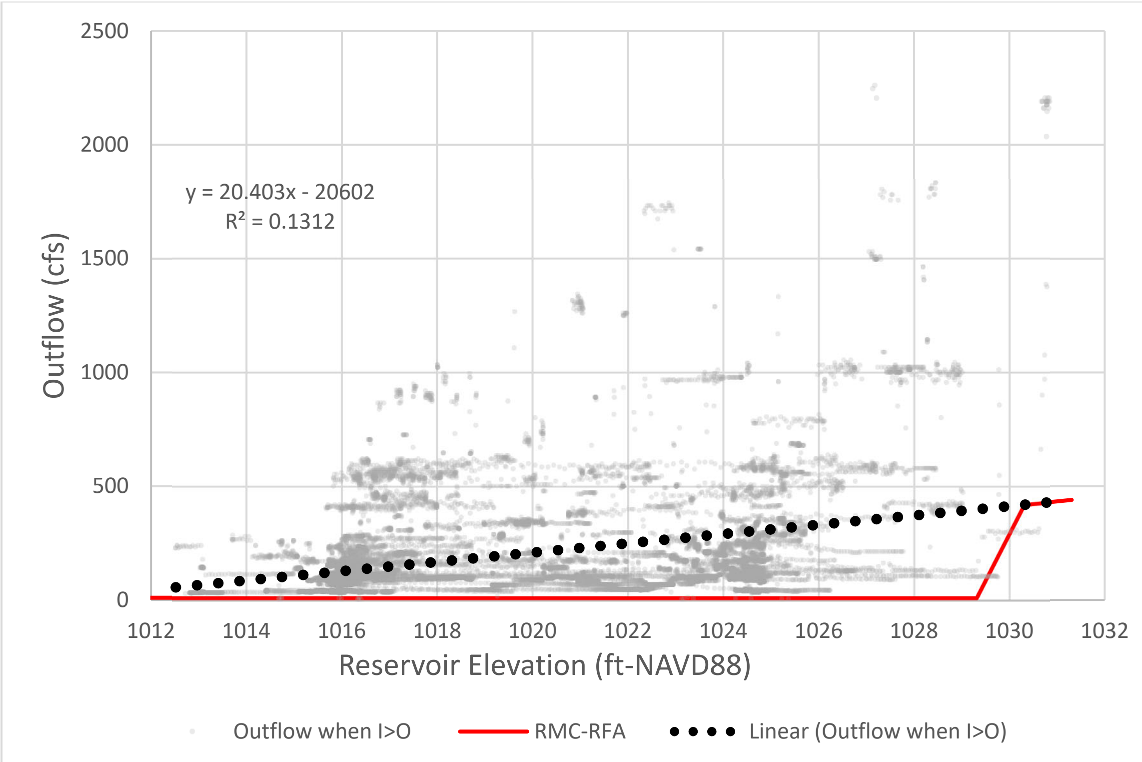


Figure 10-19: Outflow versus Reservoir Elevation at Berlin Lake

IMPACTS TO AUTHORIZED PURPOSES

The AEP results of the RMC-RFA model for Berlin Lake are presented in Figure 10-20. These include AEP results for the current operating conditions (i.e., using the historical data), the proposed plans that include extending the Berlin Lake summer pool to September 7, and as a point of comparison, filling Berlin Lake early on February 15 (Scenario 21). Most years from 2005-2021 have had slower drawdown rates similar to the scenarios that include utilizing 25% of the original reservoir storage during drawdown, those scenarios are expected to be represented in the results for the current operating (existing) conditions.

The existing conditions model results match the annual peak elevation distribution near the crest of the spillway (elevation 1031.73 ft-NAVD88), which provides confidence in the RMC-RFA model. Figure 10-20 the results of the current operating conditions RMC-RFA model. The shape of the graphical stage-frequency curve is impacted by physical processes that explain the slope increase until reservoir elevation 1031.73 ft-NAVD88. The only noticeable change in slope is above the full pool/top of gates elevation. Below 1031.73 ft-NAVD88, the project is limited to outflows of 3,400 cfs for Berlin Lake. Above 1031.73 ft-NAVD88, there is some reduction of pool elevation due to gated spillway discharge. Table 10-22 summarizes the upper limit, lower limit, and best estimate of the probability of the uncontrolled spillway being activated given the proposed revised operations of Berlin Lake.

The increased AEP of exceeding the uncontrolled spillway between the existing and two proposed scenarios is minimal, increasing from 0.037 (1 in 27 years) for the current operating conditions run, to 0.042 (1 in 24 years) for the scenarios that include extending Berlin Lake’s summer pool to on September 7, refer to Table 10-23. This small effect is confirmed by past observations as historically, Berlin Lake tends to get more storms during late winter and early spring than it does in late summer, refer to Figure 10-17.

The District currently operates the reservoirs to minimize downstream flooding and is able to fully control reservoir releases up to the uncontrolled spillway elevation. When a runoff event occurs and downstream control points exceed their respective thresholds, outflows from Berlin Lake, Michael J. Kirwan Dam and Reservoir and Mosquito Creek Lake will be set to their respective flood settings and remain there until the downstream control points recede and allow for the safe evacuation of excess storage. Water will be released in accordance with the conditions of the respective WCPs until the target pool is again achieved. This same process will be followed for the modeled scenarios.

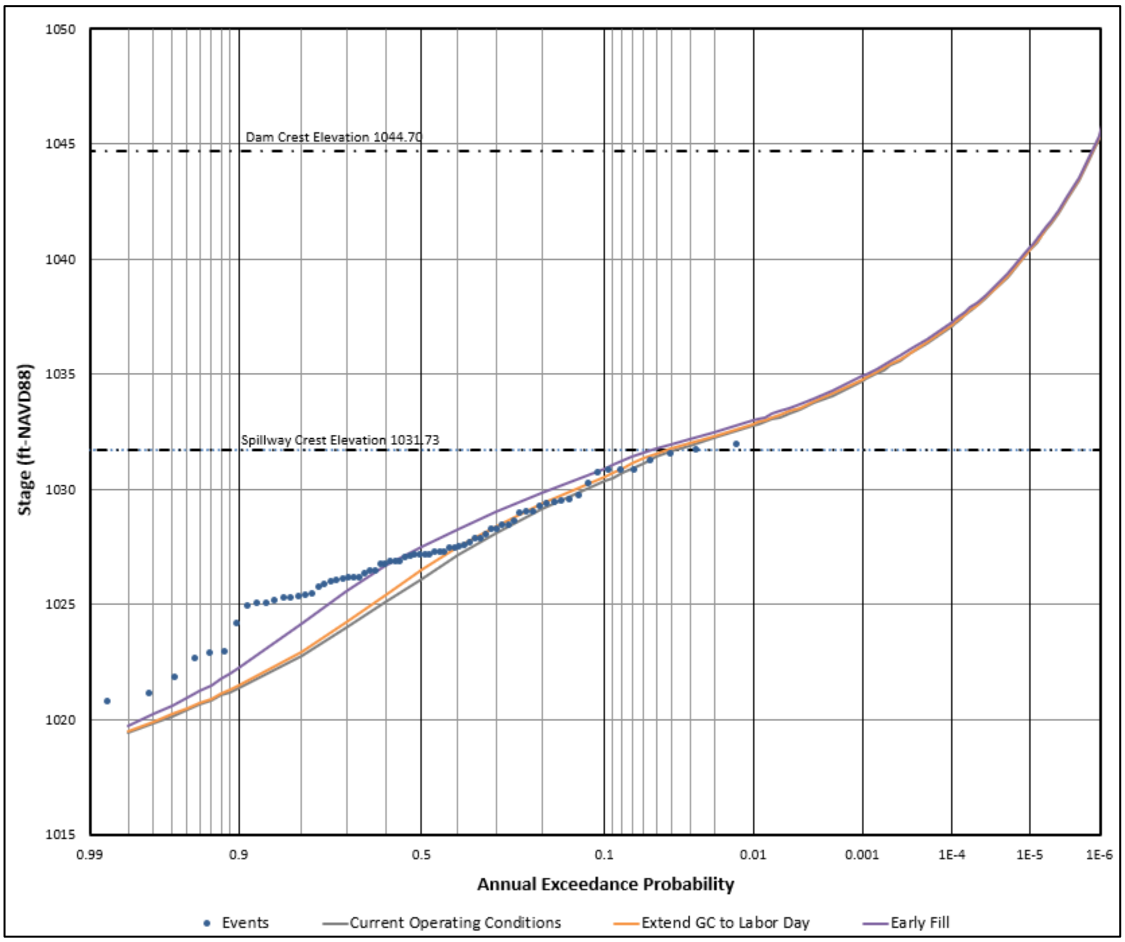


Figure 10-20: Results of the RMC-RFA Model

Table 10-22: Pool Elevation-Frequency Relationship for Berlin Lake Current Operating Conditions determined within RMC-RFA

Percent Chance Exceedance	Expected Elevation	Confidence Limits	
		10%	90%
%	(ft-NAVD88)	(ft-NAVD88)	(ft-NAVD88)
0.1	1,034.70	1,036.21	1,033.18
0.2	1,034.07	1,035.39	1,032.90
0.5	1,033.31	1,034.31	1,032.48
1	1,032.74	1,033.54	1,032.13
2	1,032.24	1,032.80	1,031.71
5	1,031.41	1,031.90	1,030.76
10	1,030.34	1,030.87	1,029.89
20	1,029.11	1,029.55	1,028.67
50	1,026.12	1,026.54	1,025.71
80	1,022.78	1,023.22	1,022.37
90	1,021.38	1,021.78	1,021.01

Table 10-23: Annual Exceedance Probability of Each RMC-RFA Scenario of Activating the Spillway

Scenario	Annual Exceedance Probability (AEP) of Activating Berlin Lake's Uncontrolled Spillway		
	Upper 90% Bound	Best Estimate	Lower 90% Bound
Current Operating Conditions	1/17	1/27	1/52
Drawdown on September 7	1/16	1/24	1/45
Early Fill	1/13	1/19	1/36

10.5.6 Berlin Lake Historical Pools & Outflows

Due to the increased probability of activating the uncontrolled spillway at Berlin Lake under Scenario 23, the downstream flooding risks were further evaluated with the historical pools and larger storm runoff events at Berlin Lake.

Historical pools of record were examined first, to determine if Berlin Lake ever reached full pool and activated the uncontrolled spillway. The uncontrolled spillway, at elevation 1013.73 ft-NAVD88, has been activated three times in the last 30 years. Table 10-24 lists the three storms within the last 30 years that activated the uncontrolled spillway and the maximum reservoir elevation for those events. For each of the three events, the reservoir elevation, outflow and reservoir operations were examined to determine the downstream impacts if the events occurred during summer pool.

Table 10-24: Berlin Lake Record Pools

Rank	High Pool (ft-NAVD88)	Date
1	1032.00	12-May-1996
2	1031.74	23-May-2004
3	1031.61	12-Mar-2011

12 May 1996 High Pool Event

The 12 May 1996 event caused the pool of record at Berlin Lake, reaching an elevation of 1032.0 ft NAVD88, which is slightly higher than the uncontrolled spillway elevation of 1031.73 ft NAVD88. The May 1996 event was one of a series of storms in April and May 1996. Prior to 12 May, Berlin Lake was already experiencing an elevated pool of approximately 1027 ft and was above summer pool of 1024.0 ft NAVD88. On 12 May 1996 releases from Berlin Lake did not exceed channel capacity. If this same event were to occur between mid-July and Labor Day (change proposed in Scenario 23), assuming the reservoir was at summer pool prior to the event, the expected impacts downstream would not change since the starting pool for the 12 May 1996 event is higher than Berlin Lake's summer pool. Refer to Figure A-3 in Appendix A for the plot of the pool elevation. Historical gate operations for Berlin Lake during the May 1996 event are presented in Table 10-25.

Table 10-25: Berlin Lake Reservoir Operations 1996 Event

Date	Elevation* (ft-NAVD88)	Outflow* (cfs)	Reservoir Operations
5/8/1996	1,027.55	1,218	3:00 PM - Close Gates 1, 4 Completely Reason: Heavy rain forecast
5/9/1996	1,027.26	824	No Change to Operations
5/10/1996	1,027.35	834	No Change to Operations
5/11/1996	1,029.06	843	No Change to Operations
5/12/1996	1,031.56	1,230	10:30 AM - Close Gate Valves 2, 3 Completely, Open Gates 1, 2, 3, and 4 to 0.5 ft each. 11:30 AM - Open Gates 1, 2, 3 and 4 to 0.75 ft each Reason: Release excess storage
5/13/1996	1,031.84	3,007	No Change to Operations
5/14/1996	1,031.30	2,495	9:00 AM - Close Gates 1 and 4 to 0.5 ft each. Reason: Reduce flow to draw Lake Milton below its spillway crest

*Elevation and Outflow at 7:00 AM

23 May 2004 High Pool Event

The 23 May 2004 event caused the second highest pool of record at Berlin Lake, reaching an elevation of 1031.74 ft NAVD88. Prior to the 23 May event, Berlin Lake was already at a summer pool of 1024.0 ft. On 23 May 2004 releases from Berlin Lake did not exceed channel capacity. If this same event were to occur between mid-July and September 7 (change proposed in Scenario 23) the expected impacts downstream would not change since the starting pool for the 23 May

2004 event is the same. Refer to Figure A-5 in Appendix A for the plot of the pool elevation. Historical gate operations for Berlin Lake during the May 2003 event are presented in Table 10-26.

Table 10-26: Berlin Lake Reservoir Operations 2004 Event

Date	Elevation* (ft-NAVD88)	Outflow* (cfs)	Reservoir Operations
5/18/2004	1,024.66	181	10:30 AM - Open Gates 1 and 2 to 0.4 ft each Reason: Slow rate of rise of pool
5/19/2004	1,024.97	326	No Change to Operations
5/20/2004	1,025.20	326	9:00 AM - Open Gates 1 and 2 to 1.0 ft each Reason: Hold pool
5/21/2004	1025.48	700	No Change to Operations
5/22/2004	1028.49	700	No Change to Operations
5/23/2004	1031.73	700	9:00 AM - Open Gate Valve 2 to 90 in. 12:00 PM - Open Gate Valve 3 to 90 In. Reason: Release excess storage / Spillway flow
5/24/2004	1031.71	1,500	8:30 AM - Open Gate 1 to 1.5 ft Reason: Release excess storage
5/25/2004	1031.38	1,870	No Change to Operations
5/26/2004	1031.00	1,850	No Change to Operations
5/27/2004	1030.57	1,830	No Change to Operations
5/28/2004	1030.06	1,800	12:00 PM - Open Gate 2 to 1.25 ft Reason: Release excess storage.
5/29/2004	1029.46	1,950	No Change to Operations

*Elevation and Outflow at 7:00 AM

12 March 2011 High Pool Event

The 12 March 2011 event caused the third highest pool of record at Berlin Lake, reaching an elevation of 1031.61 ft NAVD88. The event started on 28 February 2011, as a rain with snowmelt event. Berlin Lake was at a winter pool of 1015.9 ft NAVD88 at the start of the event. Total snowmelt runoff was between 2 and 3 inches of water (. Over the next ten days several additional runoff events followed the initial event causing the pool to crest on 12 March, with the most substantial pool rise with the initial event between 28 February and 2 March. This same type of event is not likely between mid-July and September 7 due to an unavailable snowpack during the summer months. Refer to Figure A-3 in Appendix A for the plot of the pool elevation. Historical gate operations for Berlin Lake during the March 2011 event are presented in Table 10-27.

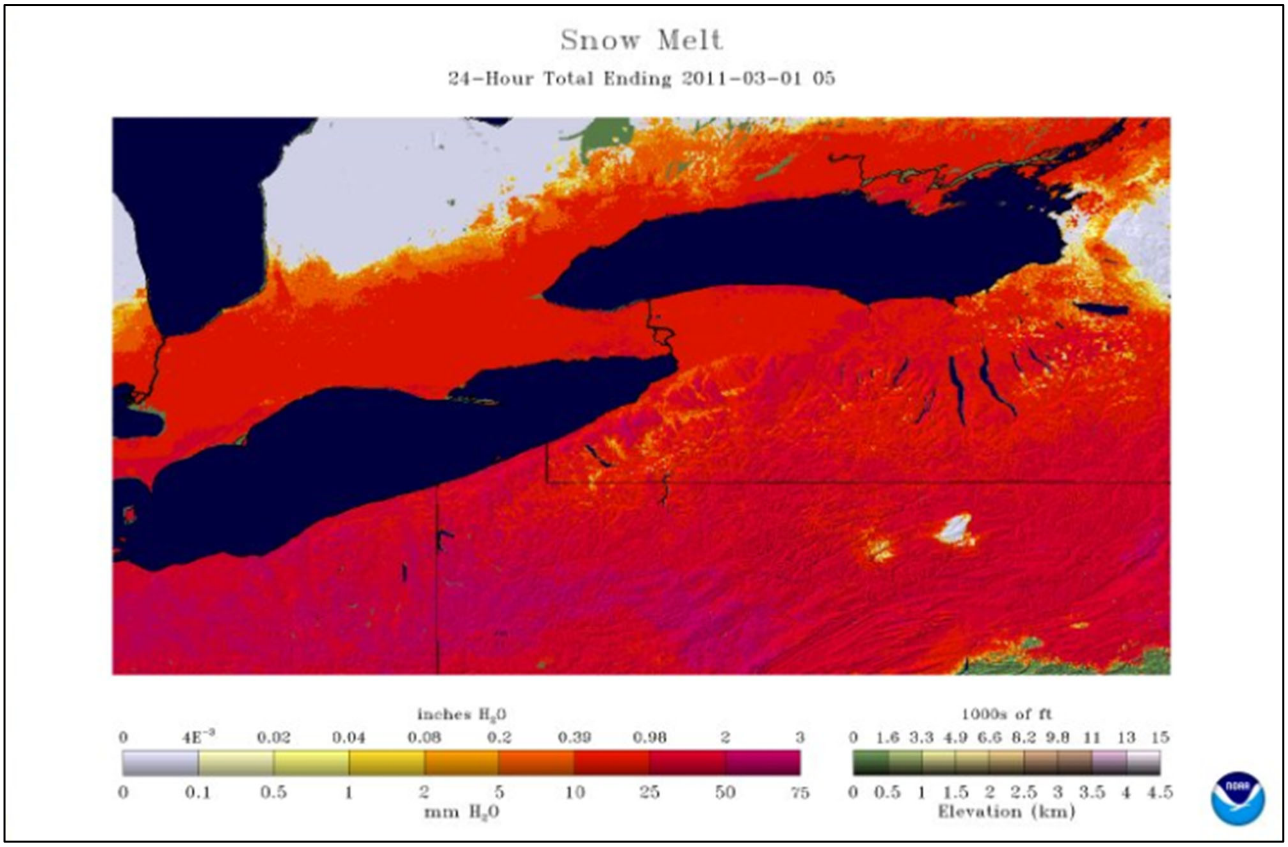


Figure 10-21: 12 March 2011 Snowmelt

Table 10-27: Berlin Lake Reservoir Operations 2011 Event

Date	Elevation* (ft-NAVD88)	Outflow* (cfs)	Reservoir Operations
3/4/2011	1,025.75	1,070	3:00 PM - Close Ball Valve 2 Completely Reason: Reduce flow due to heavy rain forecast
3/5/2011	1,026.28	640	9:00 AM - Close Ring Jet 1 and 2 to 40% Each 12:00 PM - Close Ring Jet 1 and 2 to 10% each. Reason: Go to flood setting
3/6/2011	1,027.93	114	No Change to Operations
3/7/2011	1,029.22	111	9:00 AM - Open Ring Jet 1 and 2 to 45% each 12:00 PM - Open Ring Jet 1 and 2 to 100% each Reason: Slow rate of rise of pool
3/8/2011	1,029.48	663	9:00 AM - Open Ball Valve 2 Full 12:00 PM - Close Ball Valve 2 Completely and Open Ball Valves 1 and 3 to full. Reason: Release excess storage
3/9/2011	1029.23	1,500	9:00 AM - Close Ball Valves 1 and 3 Completely and Open Ball Valve 2 to full. Reason: Reduce flow due to heavy rain forecast
3/10/2011	1,030.10	1,120	7:00 AM - Close Ball Valve 2 completely open, Valves 1 and 3 to full, 9:00 AM - Open Ball Valve 2 to Full Reason: Slow rate of rise of pool
3/11/2011	1,031.29	2,005	No Change to Operations
3/12/2011	1,031.58	2,005	No Change to Operations
3/13/2011	1,031.55	2,005	No Change to Operations
3/14/2011	1,031.28	1,990	No Change to Operations

*Elevation and Outflow at 7:00 AM

Secondly, historical runoff events occurring between July 1, and October 31, were examined to determine the potential impacts downstream if the events had occurred when the reservoir is at summer pool. This analysis replicates the "what if" as part of Scenario 23, where the pool at Berlin Lake is held at summer pool until September 7 (refer to Figure 10-7). This is currently the time during the year when the reservoir experiences a drawdown from summer to winter pool or is at winter pool. The process was conducted as follows:

- Select large observed pool increases from 1943 to 2021, the lifetime of Berlin Lake, from July 1 to October 31.
- Convert the starting pool elevation at the time of the event to a known volume of reservoir storage using the elevation storage curve in Figure 10-22. Note this is the current elevation storage curve, the elevation storage curve at the time of the events may have been slightly different, but reasonably close for the purpose of this analysis.
- Convert the maximum pool elevation resulting from the event to a known volume of reservoir storage using the elevation storage curve in Figure 10-22.

- Compute the volume of water stored during the event by subtracting the final storage from the starting storage.
- Consider the effects of the event if it had occurred when the reservoir was at summer pool (1024.01 ft) by comparing the volume between summer pool and full pool (uncontrolled spillway elevation), the available flood storage, to the volume of water stored during the event.
- If the volume of water stored during the event is less than the available flood storage, controlled reservoir releases would reduce downstream impacts.

Results are presented in Table 10-28, and show that none of the storms that historically occurred between July 1, and October 31, would have activated the uncontrolled spillway if they had occurred while Berlin Lake was still at summer pool at the start of the event. Therefore, the District would have been able to maintain control of the releases from the Project to reduce the risk of flooding downstream and not increase the downstream flood risk. The District would wait until after the downstream control points crest and begin to fall before outflows are increased from the Projects.

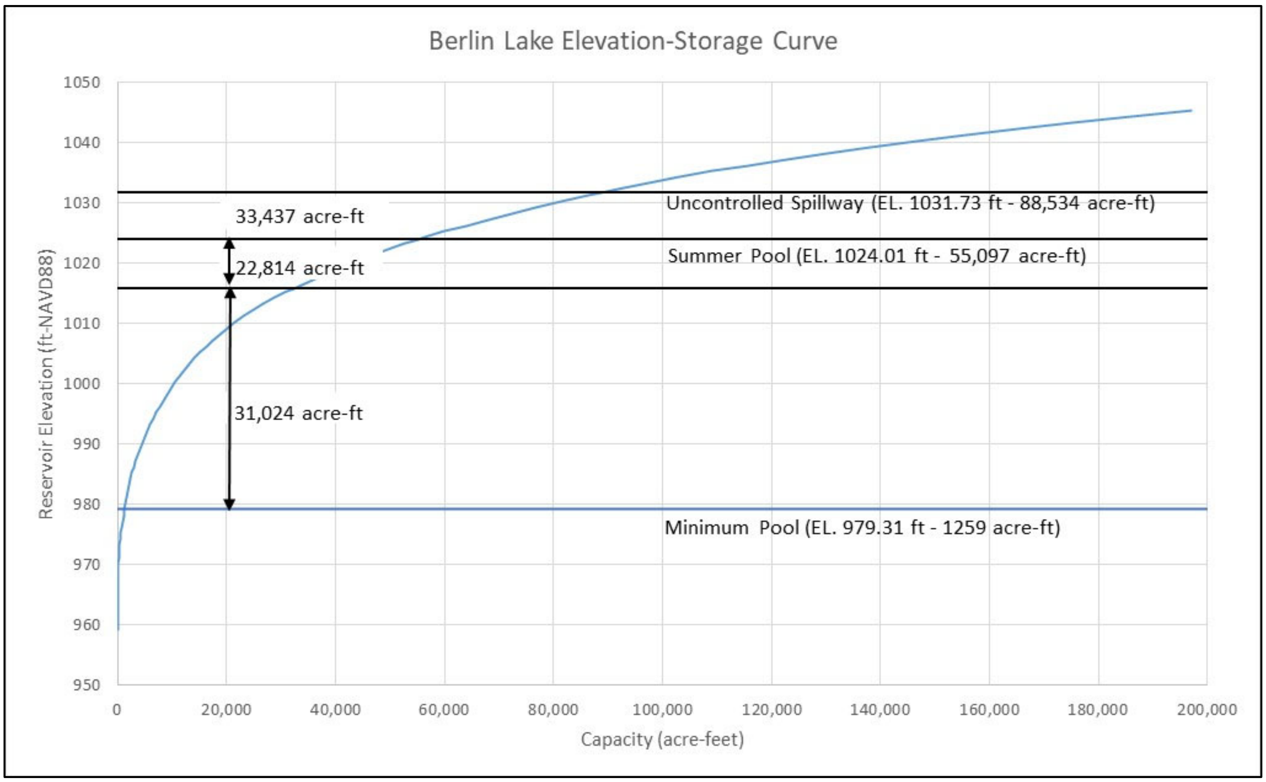


Figure 10-22: Berlin Lake Elevation Storage Curve

Table 10-28: Berlin Lake Estimated Peak Pool Elevation

Events	Historical Pool Elevation and Storage at Start of Event		Historical Pool Elevation Peak and Storage Peak		Estimated Peak Starting at Summer Pool	
	Elevation (ft-NAVD88)	Total Storage Used (ac-ft)	Elevation (ft-NAVD88)	Total Storage Used (ac-ft)	Elevation (ft-NAVD88)	Total Storage Used (ac-ft)
Oct-54	1008.24	21,779	1018.66	41,980	1029.03	75,298
Aug-58	1021.42	49,714	1029.05	79,475	1031.02	84,858
Oct-75	998.26	11,282	1005.41	18,121	1025.82	61,936
Jul-92	1014.72	32,915	1025.87	65,386	1031.55	87,568
Aug-98	1020.50	44,116	1022.29	49,449	1025.44	60,430
Jul-03	1025.00	58,703	1029.47	77,251	1028.65	73,645
Sep-04	1020.64	44,610	1026.75	65,577	1029.20	76,064
Oct-06	1019.13	40,389	1023.98	54,891	1027.70	69,599
Aug-07	1019.02	39,992	1026.52	64,760	1030.01	79,865

11.0 CONDUCT AN ENVIRONMENTAL ASSESSMENT

An Environmental Assessment (EA) was written for the Mahoning River Basin Water Control Manual Updates at Berlin Lake, Michael J. Kirwan Dam & Reservoir and Mosquito Creek Lake. The EA evaluated the impacts of revising the reservoir operations for Berlin Lake, Lake Milton and Michael J. Kirwan Dam and Reservoir.

12.0 DROUGHT CONTINGENCY PLANNING

Drought Contingency Plans (DCPs) provide a framework for water management decisions to be made during drought conditions. The intent of the DCP is to quickly identify and, if possible, avoid any major problems and resolve conflicts which may arise between authorized uses of the reservoir. A separate DCP was developed for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake in 1992, all three DCPs follow similar methodology:

- The drought watch curve was developed by plotting the lower 25th percentile of observed pool elevations.
- The drought emergency curve was developed by examining the historically lowest pool elevations, for both the pool of record and the historical drought simulations developed for the 1930s.
- The drought warning curve was placed approximately half-way between the other two curves.

The actions of the District during a drought are related to a specified threshold of drought severity. The three thresholds or stages of drought severity are: drought watch, drought warning, and drought emergency. The drought watch is designed as an alert phase in which the water managers carefully monitor the onset of a potentially mild drought situation. Drought watch requires normal operational procedures and coordination with other District personnel for monitor of storage and low flow augmentation. The drought warning expands the actions of the drought watch by initiating the activation of a Corps Drought Management Committee (CDMC), which will coordinate all actions related to water management. Drought warning allows for normal operational procedures, unless it becomes apparent that the project will enter into a drought emergency. The drought emergency requires activation of an Inter-agency Drought Management Committee (IDMC) which will decide what actions are necessary to maintain critical water needs at this level.

Proposed scenarios/alternatives identified in Section 10.4.4 do not impact the minimum conservation water pools that would trigger any drought thresholds. Additionally, methodology used to develop the DCPs are correlated to historical pool levels. Pool levels since 1992 have varied from the guide curves due to runoff events and operation decisions and would artificially inflate the DCP curves above the current guide curves. Therefore, the DCPs were not updated for Berlin Lake, Michael J. Kirwan Dam and Reservoir and Mosquito Creek Lake.

13.0 EVALUATION for IMPACTS FROM CLIMATE CHANGE

USACE projects, programs, missions, and operations have generally proven to be robust enough to accommodate the range of natural climate variability over their operating life spans. However. climate change within the Mahoning River watershed was evaluated to ensure that Berlin Lake, Michael J. Kirwan Dam and Reservoir and Mosquito Creek Lake are resilient to future changes in hydrology. The expectation is that the procedures in the manual should be updated to represent the present climate, and that manual updates will occur frequently enough that climate changes will be reflected in the periodic updates.

Historical records show that there has been a slight increase at the inflows over the last twenty years. However, the increase at the inflows have not exceeded the capacity of the reservoirs to maintain summer and winter pools, as well as manage the associated flood risk. In the future, peak flows are likely to increase throughout the Mahoning River watershed (Figure 13-1 and Figure 13-2); however, the magnitude of the increase is uncertain. To better understand the relationship between climate change and streamflow within the Mahoning River watershed, two USACE products are used to examine the expected impact of climate change on runoff within the watershed.

Both the Climate Hydrology Assessment Tool (USACE, 2020) and the downscaled climate models presented in the paper "Ohio River Basin – Formulating Climate Change Mitigation / Adaptation Strategies through Regional Collaboration with the ORB Alliance" (IWR, 2017) were utilized to evaluate the effects climate change will have on the proposed project. The Climate Assessment Tool detects trends in observed annual peak instantaneous streamflow and provides the equation for the trend line, providing a reasonable estimate of the expected increase or decrease in flowrate for a watershed, based on historical data. This trendline can be seen for the entire Hydrologic Unit Code (HUC)-4 for the Upper Ohio, which includes the Beaver River and the Ohio River below the confluence of the Allegheny and Monongahela River Basins to the confluence with the Kanawha River Basin, excluding the Muskingum River Basin. Additionally, the Climate Assessment Tool can be run for a specific USGS Gage. For this analysis, the USGS Gage at Eagle Creek at Phalanx Station is chosen, as Eagle Creek is an unregulated stream (no dams or other impounding features) that flows into the Mahoning River upstream of Leavittsburg. Many other gages in the area have been influenced by upstream regulation, which biases long term analyses. Due to the long record and unregulated status of the Eagle Creek gage, it makes an ideal dataset to analyze the long-term trends within the Mahoning River watershed.

The downscaled climate model presented in the 2017 IWR report forecasts future precipitation, temperature change, and future stream flow throughout the Upper Ohio Watershed, including the Beaver River watershed. These forecasts provide another best estimate of the impact that climate change will have on stream flow entering the Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake. Both sources were reviewed for the expected impact of climate change on the watershed.

13.1 Climate Hydrology Assessment Tool

The Corps' Climate Hydrology Assessment Tool provides estimates for the rate of streamflow change through time, summarized based on the four digit Hydrologic Unit Code (HUC) watershed, or for the watershed upstream of USGS gages. Figure 13-1 shows the trend line for HUC 0503, Upper Ohio-Wheeling, which includes the entire Beaver River. Note that Figure 13-1 shows that annual maximum flows are expected to increase approximately 0.05% per year based on the combination of 93 climate-change hydrology models. Note that the p-value is approximately 0.004, which is associated with an 0.4% chance of a false positive (i.e., the chance of no statistically significant increase in flows). This analysis assumes that the climate-changed hydrology models are representative of future conditions.

Figure 13-2 shows the trend line for the USGS Gage at Eagle Creek at Phalanx Station, OH. Figure 13-2 shows that annual maximum flows are expected to increase approximately 0.3% per year based on the historic record at the gage. Note that the p-value is approximately 0.08, which is associated with an 8% chance of a false positive (i.e., the chance of no statistically significant increase in flows).

The HUC 0503 and USGS Gage at Eagle Creek at Phalanx Station, OH both show annual maximum flows increasing over time, but the yearly percent change is relatively small at 0.05% and 0.3% per year, respectively. The RMC-RFA modeling for Berlin Lake (Section 10.5) captures historical flows from 1943 to 2021, which includes the period captured by the Eagle Creek gage. Also, it is important to note that the increase found with the Climate Hydrology Assessment Tool is relatively small. Given the magnitude of the change, USACE projects within Mahoning River watershed are not expected to be meaningfully impacted in the next several decades, but the impact and associated risk will be reassessed during future, periodic updates to the WCMs.

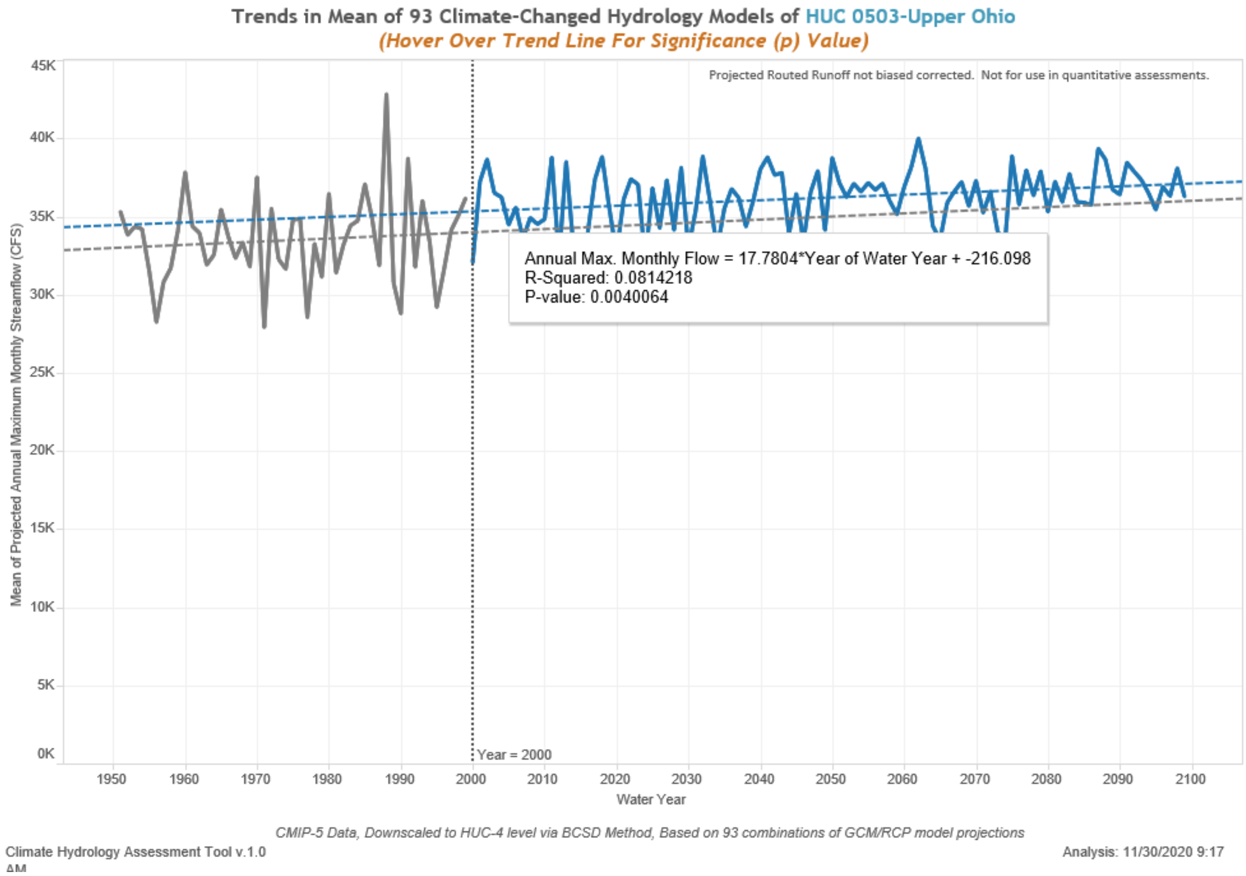


Figure 13-1: Climate Hydrology Assessment Tool Trend for HUC 0503-Upper Ohio

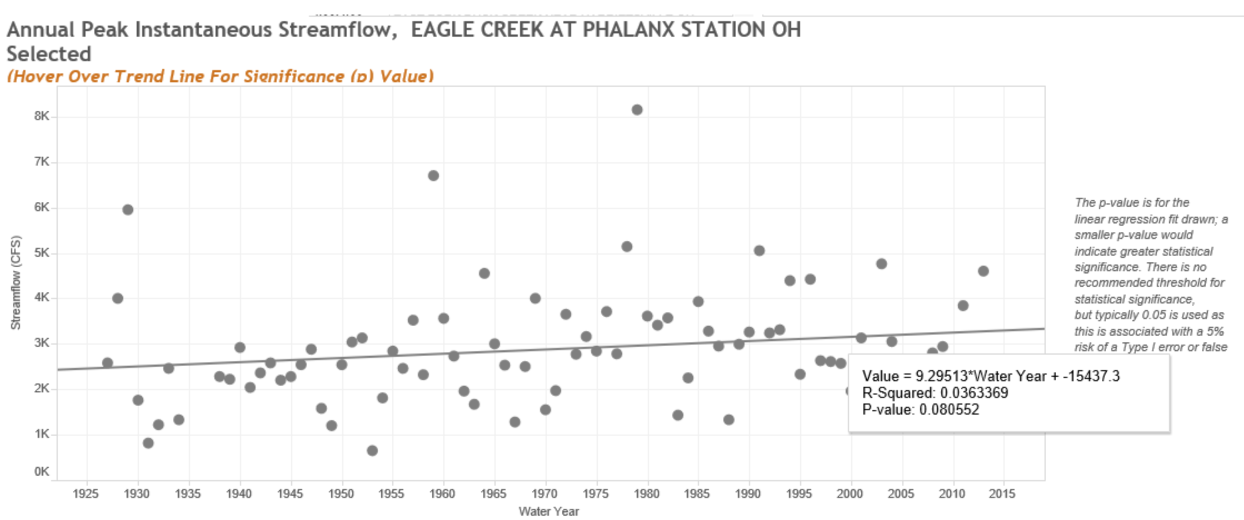


Figure 13-2: Climate Hydrology Assessment Tool Trend for USGS Gage 0309300 - Eagle Creek at Phalanx Station OH

13.2 Ohio River Basin – Formulating Climate Change Mitigation / Adaptation Strategies through Regional Collaboration with the ORB Alliance

The 2017 IWR report predicts an increase in overall streamflow and a decrease of October streamflow. These predictions are summarized in Appendix B of the IWR report, Section B.5.2. The report notes that projected mean, maximum, and minimum streamflows are expected to be in their historical range through 2040, except during autumn, and subsequently may increase by 20-40% across the entire Upper Ohio River watershed. Additionally, the report noted that minimum flows may decrease, particularly from 2040 and beyond. The estimated increases in expected flow for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake are specified in Tables B-21 of the IWR report, shown as Table 13-1. The estimated decrease in expected minimum flow is specified in Table B-22 of the IWR report, shown as Table 13-2. The IWR report had incomplete data at the Projects, and the tables are copied over as shown in the report.

The District will continue to incorporate the operational precipitation forecasts issued by the NWS as well as monitor the potential of tropical storm and/or hurricane remnants passing through the District in the Mahoning River Basin. This includes evaluating NWS river forecasts at NWS established forecast locations (Leavittsburg, Warren, Youngstown, and Lowellville). By operating to reduce the flooding at NWS established forecast locations, it also provides flood protection benefits to other communities along the Mahoning River downstream of the Projects.

Table 13-1: Potential Increases in Annual and March Flow Rates for Mahoning River Dams

Potential Flow Discharge Impacts to Ohio River Basin Dams w/ Flood Control and Stormwater Purposes			
Project Name	2041-2070	2071-2099	
	Annual Max	Annual Max	March Mean
Berlin Lake	+15 to +25	+25 to +35	+15 to +25
Michael J. Kirwan Dam and Reservoir	+15 to +25	+25 to +35	+15 to +25
Mosquito Creek Lake	+15 to +25	+25 to +35	+15 to +25

Reference: IWR, 2017, Table B-21

Table 13-2: Potential Decreases in Annual and October Flow Rates for Mahoning River Dams

Potential Flow Discharge Impacts to Ohio River Basin Dams w/ Hydropower and Water Supply Purposes		
Project Name	2041-2070	2071-2099
	October Min	October Min
Berlin Lake	-5 to -15	-5 to -15
Michael J. Kirwan Dam and Reservoir	-5 to -15	-5 to -15
Mosquito Creek Lake	-5 to -15	-5 to -15

Reference: IWR, 2017, Table B-22

14.0 EVALUATE IMPACT FROM PREVIOUS RISK DRIVING DAM FAILURE MODES

14.1 Periodic Assessment Risk Drivers - Scenarios

In 2017, District completed a Periodic Assessment (PA) for Berlin Lake in accordance with Engineering Report (ER) 1110-2-1156. The PA consisted of a facilitated Potential Failure Mode Analysis (PFMA), a Periodic Inspection (PI), and a risk assessment of potential failure modes judged to be risk-drivers. Risk-driving failure modes are those potential failure modes deemed likeliest to occur based on the current understanding of the state of the site. The actual risk of the potential failure mode (PFM) is based in part on the probability of the reservoir getting up to the elevation necessary for the PFM to begin and in part on the probability that, should the reservoir reach the prerequisite elevation, that failure occurs. Risk driving PFMs were only examined for scenarios/alternatives identified in Section 10.4.4, which include:

1. Scenario 3 (Not examined in EA) – Berlin Lake Reservoir's WCP would be revised during the drawdown to reflect utilizing 25% flood storage of the original guide curve;
2. Scenario 23 (EA Alternative 1) – Berlin Lake begins drawdown on September 7 and flow deficiencies at Leavittsburg are augmented by Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir, with no specified percentage;
3. Scenario 24 (EA Alternative 2) – Berlin Lake Reservoir's WCP would be revised during the drawdown to reflect utilizing 25% flood storage of the original guide curve, and the flow deficiencies at Leavittsburg are augmented by Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir, with no specified percentage; and
4. Scenario 25 (Not examined in EA) – No Augmentation Flow to Leavittsburg or Youngstown

14.2 Berlin Lake

The PA determined that there were four risk-driver PFMs. Those four risk-driver PFMs are:

1. Overwash of embankment
2. Concentrated leak erosion (CLE) along right abutment spillway contact.
3. Crest gate failure due to trunnion pin friction
4. Monolith instability due to hydraulic loading

PFM 1, the overwash of the embankment, occurs at the elevation of the probable maximum flood, 1043.71 ft-NAVD88. Based on the RMC-RFA model developed as shown in Section 10.5.5, the probability of reaching the PMF elevation of 1043.7 ft-NAVD88 does not increase between the current operating condition and the scenarios where Berlin Lake's summer pool is extended to on September 7. The estimated AEP of the dam overtopping is 1/800,000 or less, so the small increase in loading frequency at spillway crest will have negligible impact to the probability of the dam overtopping and therefore no increase to the annual probability of failure (APF), which was determined to be between 1E-07 and 1E-06 during the 2017 PA (Figure 14-1).

PFM 2, the CLE along the right abutment spillway contact, occurs at an elevation above the pool of record, 1032 ft-NAVD88. Based on the RMC-RFA model, the probability of reaching the elevation 1032 ft-NAVD88 increases slightly from 0.026 (1/37.9) for current operating condition to 0.03 (1/33.3) for the scenarios where Berlin Lake's summer pool is extended to on September 7. However, the estimated APF remains the same, between 1E-07 and 1E-06 (Figure 14-1).

PFM 3, the failure of the crest gate due to trunnion pin friction, and PFM 4, monolith instability due to hydraulic loading, both occur at the top of active storage, 1031.3 ft-NAVD88. The top of the active storage is the top of the uncontrolled spillway. Based on the RMC-RFA model the probability of reaching the elevation 1032 ft-NAVD88 increases slightly (Figure 10-20) for the scenarios where Berlin Lake's where summer pool is extended to on September 7. However, the annual probability of failure remains the same, at between 1E-06 and 1E-05 for PFM 3 and between 3E-7 and 3E-6 for PFM 4 (Figure 14-1). The crest gates are operated annually with no signs of structural distress, noise, or other issues that indicate the potential for failure.

To understand Figure 14-1, note the lines in red. The horizontal line, the individual tolerable risk line, at 1E-04 represents the historical failure rate for all dams, worldwide. The diagonal line is the societal tolerable risk line. Society is willing to live with the risk associated with the dam or levee to secure the benefits provided by the dam or living and working downstream or in the leveed area. Risks would typically be unacceptable if risks exceed either individual or societal tolerable thresholds and there are no exceptional circumstances.

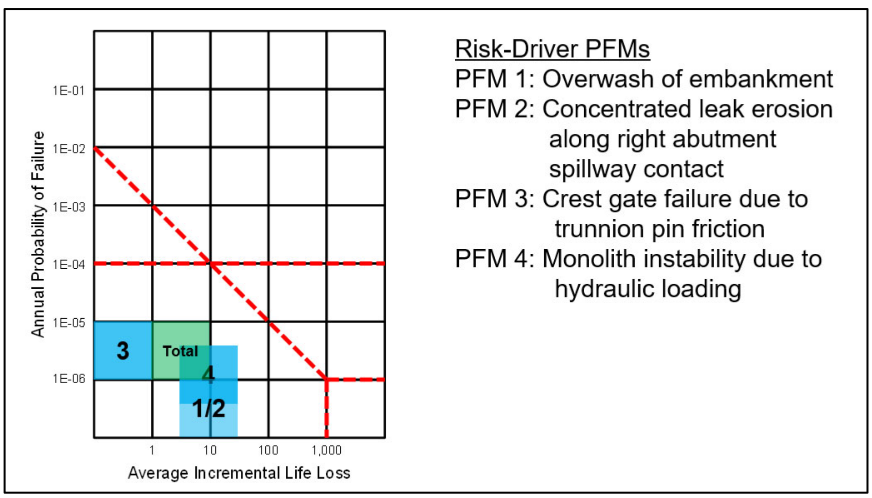


Figure 14-1: Incremental Life Safety Risk Matrix for Berlin Lake (USACE, 2017)

14.3 Michael J. Kirwan Dam and Reservoir

The only revision proposed to Michael J. Kirwan Dam and Reservoir's WCP is removing the specified percentage of augmentation flow from the reservoir. Revising the percentage of augmentation flow impacts how much flow Michael J. Kirwan Dam and Reservoir releases during lower flow to ensure that Leavittsburg and Youngstown meets their water quality criteria. Risk-driver PFMs occur when the reservoir is at a high elevation. As the probability of Michael J. Kirwan Dam and Reservoir reaching the prerequisite elevations for its PFMs to occur will not change as a direct result of extending Berlin Lake's summer pool, the risk associated with any of the risk-driver PFMs is not expected to change.

14.4 Mosquito Creek Lake

No revisions to the guide curve of Mosquito Creek Lake are proposed. As such, there will be no impacts to the risk-driving potential failure modes.

15.0 CONCLUSIONS

This analysis examined potential changes to the operation of Berlin Lake, Lake Milton, Michael J. Kirwan Dam and Reservoir and Mosquito Creek Lake and documented the technical engineering and stepwise approach used to determine the impacts of those potential changes to the authorized purposes with the goal of selecting proposed reservoir operations which best balance the competing operational goals. The District held public meetings and accepted comments and feedback on which performance measures could be used to determine how well the reservoir operations met their authorized purposes. Table 15-1 summarizes a comparison between Scenario 1, the existing Water Control Plan, and Scenario 23.

Based on the results, the following are concluded:

1. Extending summer pool at Berlin Lake would bring the WCP guide curve more in line with Michael J Kirwan Dam and Reservoir and Mosquito Creek Lake and provides more in-reservoir recreational benefits to Berlin Lake.

2. Reservoir elevations for Berlin Lake, Michael J Kirwan Dam and Reservoir and Mosquito Creek Lake, associated with winter pool and summer pool are not revised as a part of this analysis.

3. Augmenting flow deficiencies in the Mahoning River at Leavittsburg by Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir, with no specified percentage, instead of 64% by Berlin Lake-Lake Milton and 36% by Michael J. Kirwan Dam and Reservoir would allow operational decisions to balance the releases from Berlin Lake and Michael J. Kirwan Dam and Reservoir based on the availability of water and each reservoir's current water level.

   Releases from Michael J. Kirwan Dam and Reservoir and Berlin Lake will be balanced with respect to their water control plans. If Michael J. Kirwan Dam and Reservoir is using flood storage and Berlin Lake is using conservation storage, additional releases will be made from Michael J. Kirwan Dam and Reservoir to reduce the impact at Berlin Lake.

   If Berlin Lake is using flood storage and Michael J. Kirwan Dam and Reservoir is using conservation storage, additional releases will be made from Berlin Lake to reduce the impact at Michael J. Kirwan Dam and Reservoir.

   When both reservoirs have fallen below 100% conservation storage, while still meeting the downstream schedule, Michael J. Kirwan Dam and Reservoir and Berlin Lake will manage releases such that the rate of fall at each reservoir mimics the fall drawdown rate.

4. Augmenting flow deficiencies in the Mahoning River at Leavittsburg 50% by Berlin Lake-Lake Milton and 50% by Michael J. Kirwan Dam and Reservoir, instead of 64% by Berlin Lake-Lake Milton and 36% by Michael J. Kirwan Dam and Reservoir would not be favorable. Berlin Lake and Lake Milton have both significantly more storage and upstream drainage area than Michael J. Kirwan Dam and Reservoir. Forcing Michael J. Kirwan Dam and Reservoir to release as much flow as Berlin Lake and Lake Milton would negatively impact reservoir elevations within Michael J. Kirwan Dam and Reservoir.

5. Filling Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake on February 15, would negatively impact the reservoirs' ability to store early spring floods and lead to increased flood risk as the watershed typically sees high flow events during February and March.

6. Providing no augmentation flow in the Mahoning River for the Leavittsburg, OH or Youngstown, OH control points would not allow the reservoirs to meet their currently authorized purposes of water quality control.

7. Based on the DST, none of the scenarios posed a threat to water supply.

8. USACE projects, programs, missions, and operations have generally proven to be robust enough to accommodate the range of natural climate variability over their operating life spans. Increases in expected inflow for Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake found with the Climate Hydrology Assessment Tool were relatively small. Given the magnitude of the potential effects of climate change, USACE projects within Mahoning River watershed are not expected to be meaningfully impacted in the next several decades, but the impact and associated risk will be reassessed during future, periodic updates to the WCMs.

9. The District will continue to cooperate with the Ohio Department of Natural Resources by furnishing ODNR with information regarding proposed operation of Berlin Lake and providing ODNR with recommended operations for Lake Milton. During the time when all district-operated reservoirs are at (or near) summer pool, the District will continue to incorporate the operational precipitation forecast issued by the NWS as well as monitor the potential of tropical storm and/or hurricane remnants to pass through the District in the Mahoning River Basin. This includes evaluating NWS river forecasts at NWS established forecast locations (Leavittsburg, Warren, Youngstown, and Lowellville). Operating to reduce the flooding at NWS established forecast locations also provides flood protection benefits to other communities along the Mahoning River downstream of the Projects.

Scenarios 3, 23, and 24 combine the various benefits from changes listed above.

Scenario 3 utilizes 25% of original reservoir flood storage during Berlin Lake's drawdown, but still forces a drawdown at Berlin Lake even if downstream flow requirements would be met without increased flow augmentation from the Projects. Similarly, this scenario forces Berlin Lake and Michael J. Kirwan Dam and Reservoir to release water under a constrained ratio as prescribed by the current WCP. The probability of reaching Berlin Lake's uncontrolled spillway would be approximately 1/27 years based on historical reservoir pool levels. Project benefits from all projects would remain similar to those over the past 15 years.

Scenario 24 (EA Alternative 2) utilizes 25% of original reservoir storage during Berlin Lake drawdown, but still forces a drawdown at Berlin Lake even if downstream flow requirements would be met without increased flow augmentation from the Projects. However, this scenario provides greater flexibility in which Berlin Lake and Michael J. Kirwan Dam and Reservoir should release water, rather than forcing a constrained ratio. Under Scenarios 24, the District's Water Management team will balance the releases from Berlin Lake and Michael J. Kirwan Dam and Reservoir based on the availability of water and each reservoir's current water level. The probability of reaching Berlin Lake's uncontrolled spillway would be approximately 1/27 years based on historical reservoir pool levels.

Scenario 23 (EA Alternative 1) extends the summer pool at Berlin Lake and modify the augmentation flow percentages for Michael J. Kirwan Dam and Reservoir and Berlin Lake. Scenario 23 removes the constraints that forces a drawdown at Berlin Lake even if downstream flow requirements would be met without increased flow augmentation from the Projects. Similarly, this scenario provides greater flexibility in which Berlin Lake and Michael J. Kirwan Dam and Reservoir should release water, rather than forcing a constrained ratio. Under Scenario 23, the District's Water Management team will balance the releases from Berlin Lake and Michael J. Kirwan Dam and Reservoir based on the availability of water and each reservoir's current water level. This scenario also extends the summer pool and brings the guide curve of Berlin Lake more in line with Michael J. Kirwan Dam and Reservoir and Mosquito Creek Lake, which allows for additional in-reservoir recreational benefits for Berlin Lake.

Table 15-1 summarizes a comparison between the way we currently operate the reservoir and how we would operate the reservoirs under Scenario 23, as well as a summary of the expected impacts on the reservoirs authorized purposes. Table 15-2, Table 15-3, and Table 15-4 summarize the impact that operating the reservoirs using Scenario 23 would have on the performance metrics included within the DST, water quality, as modeled using CE-QUAL-W2, and the probability of reaching Berlin Lake's uncontrolled spillway, respectively.

Table 15-1: Comparison of Scenario 1 and Scenario 23

	Scenario 1	Scenario 23
End of Summer Pool for Berlin Lake	June 25	September 7
Percent of Augmentation Flow Deficiency from Berlin Lake-Lake Milton and Michael J. Kirwan Dam and Reservoir	64% from Berlin Lake-Lake Milton and 36% from Michael J. Kirwan Dam and Reservoir.	No specific percent. Reservoir operators to balance the releases from Berlin Lake and Michael J. Kirwan reservoir, based on reservoir storage and reservoir elevation.
Impact on Flood Risk Management	Represents Base Case, This case would have maximum flood storage available in	Holding higher reservoir elevations in June, August and early September would

	Scenario 1	Scenario 23
	Berlin Lake from August 22 to March 25.	mean less available flood storage. This case would have maximum flood storage available in Berlin Lake from November 2 to March 25. RMC-RFA shows that the risk of overtopping the uncontrolled spillway increases by less than 1%, which was considered a negligible increase in risk.
Impact on In-Lake Recreation	Represents Base Case. Historically, has made in-lake recreational opportunities on Berlin Lake from June through September more challenging.	Holding higher reservoir elevations would improve in-lake recreational opportunities for Berlin Lake, however, pending runoff, may lower in-lake recreational opportunities on Michael J. Kirwan Dam and Reservoir.
Impact on Water Supply	Water Supply Intakes in Berlin Lake and Mosquito Creek Lake can receive sufficient water.	Water Supply Intakes in Berlin Lake and Mosquito Creek Lake can receive sufficient water.
Impact on Water Quality	Base Case. Downstream Water Quality metrics are met.	Based on results of the CE-QUAL-W2 model, Scenario 23 suggests that there may be no, or very little, detrimental impacts to in-reservoir or downstream water quality because of a change in reservoir operations
Impact on Fish and Wildlife	Base Case. Mahoning River support both fish and wildlife.	Not expected to significantly impact fish and wildlife.

Table 15-2: Comparison of Performance Measures for Existing Conditions and Scenario 23

Performance Measure	Existing Conditions (Scenario 01)	Recommended Plan (Scenario 23)	Impact of Scenario 23 on Performance Measure
Max flow - Leavittsburg (cfs)	5,427.18	5,494.31	The USGS established a flood flow of approximately 5,800 cfs at Leavittsburg. Additional peak flow increases by approximately 1.2% but remains below the flood flow at Leavittsburg; therefore, no anticipated material impact to life or property.
Max flow - Youngstown (cfs)	10,953.07	11,291.25	The USGS established a flood flow of approximately 11,800 cfs at Youngstown. Additional peak flow increases by approximately 3.1% but remains below the flood flow at Youngstown; therefore, no anticipated material impact to life or property.
Total Annual Volume of water above 4,000 cfs - Leavittsburg (cubic feet/year)	3,006.66	3,433.28	Additional volume of flow over the chosen threshold increases by approximately 14.2%, but the peak flows remain below the 5,800 cfs flood flow at Leavittsburg; therefore, no anticipated material impact to life or property.
Total Annual Volume of water above 8,000 cfs - Youngstown (cubic feet/year)	2,807.54	2,974.02	Additional volume of flow over the chosen threshold increases by approximately 5.92%, but the peak flows remain below the 11,800 cfs flood flow at Youngstown; therefore, no anticipated material impact to life or property.
Number of Days Outflow - Berlin Lake >= 2600 cfs	8.63	8.83	Additional number of days flow is over the chosen threshold increases by 2.3%, but peak outflow never exceeds the 3,400 cfs channel capacity flow downstream of Berlin; therefore, no anticipated material impact to life or property.
Number of Days Outflow - Michael J Kirwan Dam and Reservoir >= 1125 cfs	9.79	9.38	Number of days flow is over the chosen threshold decreases.
Number of Days Outflow - Mosquito Creek Lake >= 900 cfs	9.71	9.33	Number of days flow is over the chosen threshold decreases.
Number of Days Berlin Lake ≥ 1030.75 ft (days)	1.54	4.08	Additional number of days reservoir elevation is above the threshold elevation is approximately 2.5 days, however the peak reservoir elevation never exceeds the crest of the uncontrolled spillway; therefore, no anticipated material impact to life or property.
Number of Days Michael J Kirwan Dam and Reservoir ≥ 986.5 ft (days)	1.71	1.71	Additional number of days reservoir elevation is above the threshold elevation does not change.

Performance Measure	Existing Conditions (Scenario 01)	Recommended Plan (Scenario 23)	Impact of Scenario 23 on Performance Measure
Number of Days Mosquito Creek Lake ≥ 901 ft (days)	1.88	1.88	Additional number of days reservoir elevation is above the threshold elevation does not change.
Number of Days boat ramps flooded (Elevation > 1027.5 ft) - Berlin Lake (days)	10.42	15.29	Threshold elevation provided by public stakeholders. Additional number of days lowest boat ramp becomes unusable increases by approximately five (5) days.
Number of Days boat ramps flooded - Michael J Kirwan Dam and Reservoir (Elevation > 987 ft) (days)	0.46	0.46	Threshold elevation provided by public stakeholders. Number of days lowest boat ramp becomes unusable does not change.
Number of Days boat ramps flooded - Mosquito Creek Lake (Elevation > 900.8 ft) (days)	12.13	12.88	Threshold elevation provided by public stakeholders. Additional number of days lowest boat ramp becomes unusable increases by less than one (1) day.
Number of Days meeting downstream recreation ideal flow preferences during a wet year - Leavittsburg gage elev. =3-5ft) (days)	236.63	235.25	Ideal flow preference range provided by public stakeholders. Number of days Leavittsburg is within ideal flow preference range during a wet year decreases by less than one (1) day.
Number of Days meeting downstream recreation ideal flow preferences during a dry year – Leavittsburg gage elev =3-5ft) (days)	167.13	237.54	Number of days Leavittsburg is within ideal flow preference range during a wet year increases by over 70 days.
Number of Days between Memorial Day and Labor Day the pool is below the lowest preferred level - Berlin Lake (days)	93.42	78.13	Preferred pool levels provided by public stakeholders. Number of days Berlin Lake is below the lowest preferred pool level decreases by over 15 days.
Number of Days between Memorial Day and Labor Day the pool is below the lowest preferred level - Michael J Kirwan Dam and Reservoir (days)	76.17	92.54	Preferred pool levels provided by public stakeholders. Number of days Michael J. Kirwan Dam and Reservoir is below the lowest preferred pool level increased by approximately 16.4 days.
Number of Days between Memorial Day and Labor Day the pool is below the lowest preferred level - Mosquito Creek Lake (days)	57.88	64.83	Preferred pool levels provided by public stakeholders. Number of days Mosquito Creek Lake is below the lowest preferred pool level increased by approximately 7 days.
Residence Time - Berlin Lake (days)	106.42	143.44	There is no exceedance value for residence time, however residence is an especially important variable for water quality. The residence time increases by approximately 37 days.

Performance Measure	Existing Conditions (Scenario 01)	Recommended Plan (Scenario 23)	Impact of Scenario 23 on Performance Measure
Residence Time - Michael J Kirwan Dam and Reservoir (days)	285.72	182.55	There is no exceedance value for residence time, however residence is an especially important variable for water quality. The residence time decreases by approximately 103 days.
Residence Time - Mosquito Creek Lake (days)	203.93	206.87	There is no exceedance value for residence time, however residence is an especially important variable for water quality. The residence time increases by approximately 3 days.
Number of days downstream flow met at Leavittsburg (days)	266.83	300.42	The minimum flow required at Leavittsburg varies seasonally. This number of days when Leavittsburg meets those minimum flows increases.
Number of days downstream flow met at Youngstown (days)	201.42	267.54	The minimum flow required at Youngstown varies seasonally. This number of days when Youngstown meets those minimum flows increases.
Rate of change/water 3/1-6/15 during a wet year - Berlin Lake (ft/week)	2.4	2.62	There is no exceedance value for the weekly rate of change of reservoir elevation for Berlin Lake. The weekly rate of change of reservoir elevation for Berlin Lake during a wet year increases by approximately .22 ft/week
Rate of change/water 3/1-6/15 during a wet year - Michael J Kirwan Dam and Reservoir (ft/week)	0.89	0.95	There is no exceedance value for the weekly rate of change of reservoir elevation for Michael J Kirwan Dam and Reservoir. The weekly rate of change of reservoir elevation for Michael J Kirwan Dam and Reservoir during a wet year increases by approximately 0.06 ft/week
Rate of change/water 3/1-6/15 during a wet year - Mosquito Creek Lake (ft/week)	0.26	0.26	There is no exceedance value for the weekly rate of change of reservoir elevation for Mosquito Creek Lake. The weekly rate of change of reservoir elevations for Mosquito Creek Lake during a wet year does not change.
Rate of change/water 3/1-6/15 during a dry year - Berlin Lake (ft/week)	1.15	1.15	There is no exceedance value for the weekly rate of change of reservoir elevation for Berlin Lake. The weekly rate of change of reservoir elevations for Berlin Lake during a dry year does not change.
Rate of change/water 3/1-6/15 during a dry year - Michael J Kirwan Dam and Reservoir (ft/week)	0.64	0.69	There is no exceedance value for the weekly rate of change of reservoir elevation for Michael J Kirwan Dam and Reservoir. The weekly rate of change of reservoir elevations for Michael J

Performance Measure	Existing Conditions (Scenario 01)	Recommended Plan (Scenario 23)	Impact of Scenario 23 on Performance Measure
			Kirwan Dam and Reservoir during a dry year increases by approximately 0.05 ft/week
Rate of change/water 3/1-6/15 during a dry year - Mosquito Creek Lake (ft/week)	0.25	0.25	There is no exceedance value for the weekly rate of change of reservoir elevation for Mosquito Creek Lake. The weekly rate of change of reservoir elevations for Mosquito Creek Lake during a dry year does not change.
Rate of change/water 6/28 - 9/30 during a wet year - Berlin Lake (ft/week)	1.59	1.48	There is no exceedance value for the weekly rate of change of reservoir elevation for Berlin Lake. The weekly rate of change of reservoir elevation for Berlin Lake during a wet year decreases by 0.11 ft/week.
Rate of change/water 6/28 - 9/30 during a wet year - Michael J Kirwan Dam and Reservoir (ft/week)	0.83	0.91	There is no exceedance value for the weekly rate of change of reservoir elevation for Michael J Kirwan Dam and Reservoir. The weekly rate of change of reservoir elevation for Michael J Kirwan Dam and Reservoir during a wet year increases by approximately 0.08 ft/week.
Rate of change/water 6/28 - 9/30 during a wet year - Mosquito Creek Lake (ft/week)	0.37	0.27	There is no exceedance value for the weekly rate of change of reservoir elevation for Mosquito Creek Lake. The weekly rate of change of reservoir elevation for Mosquito Creek Lake during a wet year decreases by 0.1 ft/week.
Rate of change/water 6/28 - 9/30 during a dry year - Berlin Lake (ft/week)	0.9	0.91	There is no exceedance value for the weekly rate of change of reservoir elevation for Berlin Lake. The weekly rate of change of reservoir elevation for Berlin Lake during a dry year increases by approximately by 0.01 ft/week.
Rate of change/water 6/28 - 9/30 during a dry year - Michael J Kirwan Dam and Reservoir (ft/week)	0.63	1.06	There is no exceedance value for the weekly rate of change of reservoir elevation for Michael J Kirwan Dam and Reservoir. The weekly rate of change of reservoir elevation for Michael J Kirwan Dam and Reservoir during a dry year increases by approximately 0.43 ft/week.
Rate of change/water 6/28 - 9/30 during a dry year - Mosquito Creek Lake (ft/week)	0.37	0.4	There is no exceedance value for the weekly rate of change of reservoir elevation for Mosquito Creek Lake. The weekly rate of change of reservoir elevation for Mosquito Creek Lake during a dry year increases by 0.03 ft/week

Table 15-3: Number of Days More that Scenario 23 Exceeds, or Reduces, Out of Compliance Water Quality Thresholds, Compared to Scenario 1

Water Quality Constituents and Thresholds	Berlin Lake	Lake Milton	Michael J Kirwan Dam and Reservoir	Mosquito Creek Lake	Leavittsburg	Warren	Youngstown	Lowellville
Number of days more than existing conditions that Dissolved Oxygen (DO) > 5 mg/L	0	0	0	0	0	0	0	0
Number of days more than existing conditions that Total Dissolved Solids (TDS) < 340 mg/L	-17	0	0	0	0	0	16	0
Number of days more than existing conditions that Sulfate (SO4) <100 mg/L	0	0	0	0	0	0	0	0
Number of days more than existing conditions that Chloride (Clr) < 90 mg/L	0	0	0	0	0	0	0	0
Number of days more than existing conditions that Chlorophyll A (Chl) < 20 mg/L	-1	-34	0	-2	-1	-1	-1	0
Number of days more than existing conditions that Total Phosphorous (TP) < 50 mg/L	0	0	0	0	-10	3	0	0
Number of days more than existing conditions that Nitrate and Nitrite (NO3) < 10 mg/L	0	0	0	0	0	0	0	0
Number of days more than existing conditions that Iron (Fe) < 1,500 ug/L	-5	25	8	0	0	0	0	0
Number of days more than existing conditions that Temperature is < 89 deg F - 01Jan-28Feb	0	0	0	0	0	0	0	0
Number of days more than existing conditions that Temperature is < 89 deg F - 01Mar-15Mar	0	0	0	0	0	0	0	0
Number of days more than existing conditions that Temperature is < 89 deg F - 16Mar-31Mar	0	0	0	0	0	0	0	0
Number of days more than existing conditions that Temperature is < 89 deg F - 01Apr-15Apr	0	0	0	0	0	0	0	0
Number of days more than existing conditions that Temperature is < 89 deg F - 16Apr-30Apr	0	0	0	0	0	0	0	0
Number of days more than existing conditions that Temperature is < 89 deg F - 01May-15May	0	0	0	0	0	0	0	0
Number of days more than existing conditions that Temperature is < 89 deg F - 16May-31May	0	0	0	0	0	0	0	0

Water Quality Constituents and Thresholds	Berlin Lake	Lake Milton	Michael J Kirwan Dam and Reservoir	Mosquito Creek Lake	Leavittsburg	Warren	Youngstown	Lowellville
Number of days more than existing conditions that Temperature is < 89 deg F - 01Jun-15Jun	0	0	0	0	0	0	0	0
Number of days more than existing conditions that Temperature is < 89 deg F - 16Jun-15Sep	0	0	0	0	0	0	0	0
Number of days more than existing conditions that Temperature is < 89 deg F - 16Sep-30Sep	0	0	0	0	0	0	0	0
Number of days more than existing conditions that Temperature is < 89 deg F - 01Oct-15Oct	0	0	0	0	0	0	0	0
Number of days more than existing conditions that Temperature is < 89 deg F - 16Oct-31Oct	0	0	0	0	0	0	0	0
Number of days more than existing conditions that Temperature is < 89 deg F - 01Nov-30Nov	0	0	0	0	0	0	0	0
Number of days more than existing conditions that Temperature is < 89 deg F - 01Dec-31Dec	0	0	0	0	0	0	0	0

Note: The table represents additional days that water quality parameters are above their thresholds. Numbers greater than zero represent negative impact to water quality.

Table 15-4: Annual Exceedance Probability of Scenario 1 and Scenario 23 Activating the Spillway

Scenario	Annual Exceedance Probability (AEP) of Activating Berlin Lake's Uncontrolled Spillway		
	Upper 90% Bound	Best Estimate	Lower 90% Bound
Current Operating Conditions	1/17	1/27	1/52
Drawdown on September 7	1/16	1/24	1/45

16.0 RECOMMENDATIONS

Based on the information provided in this report, the recommended course of action is to implement Scenario 23 (EA Alternative 1), which would extend the summer pool for Berlin Lake so that drawdown for Berlin Lake begins September 7 at elevation 1024.01, and drawdown ends November 4 at elevation 1015.91 ft-NAVD88, as shown on Figure 16-1.

Releases from Michael J. Kirwan Dam and Reservoir and Berlin Lake will be balanced with respect to their water control plans. If Michael J. Kirwan Dam and Reservoir is using flood storage and Berlin Lake is using conservation storage, additional releases will be made from Michael J. Kirwan Dam and Reservoir to reduce the impact at Berlin Lake.

If Berlin Lake is using flood storage and Michael J. Kirwan Dam and Reservoir is using conservation storage, additional releases will be made from Berlin Lake to reduce the impact at Michael J. Kirwan Dam and Reservoir.

When both reservoirs have fallen below 100% conservation storage, while still meeting the downstream schedule, Michael J. Kirwan Dam and Reservoir and Berlin Lake will manage releases such that the rate of fall at each reservoir mimics the fall drawdown rate.

Upon approval, the Water Control Manuals and Water Controls Plans will be updated accordingly for implementation of the recommended change.

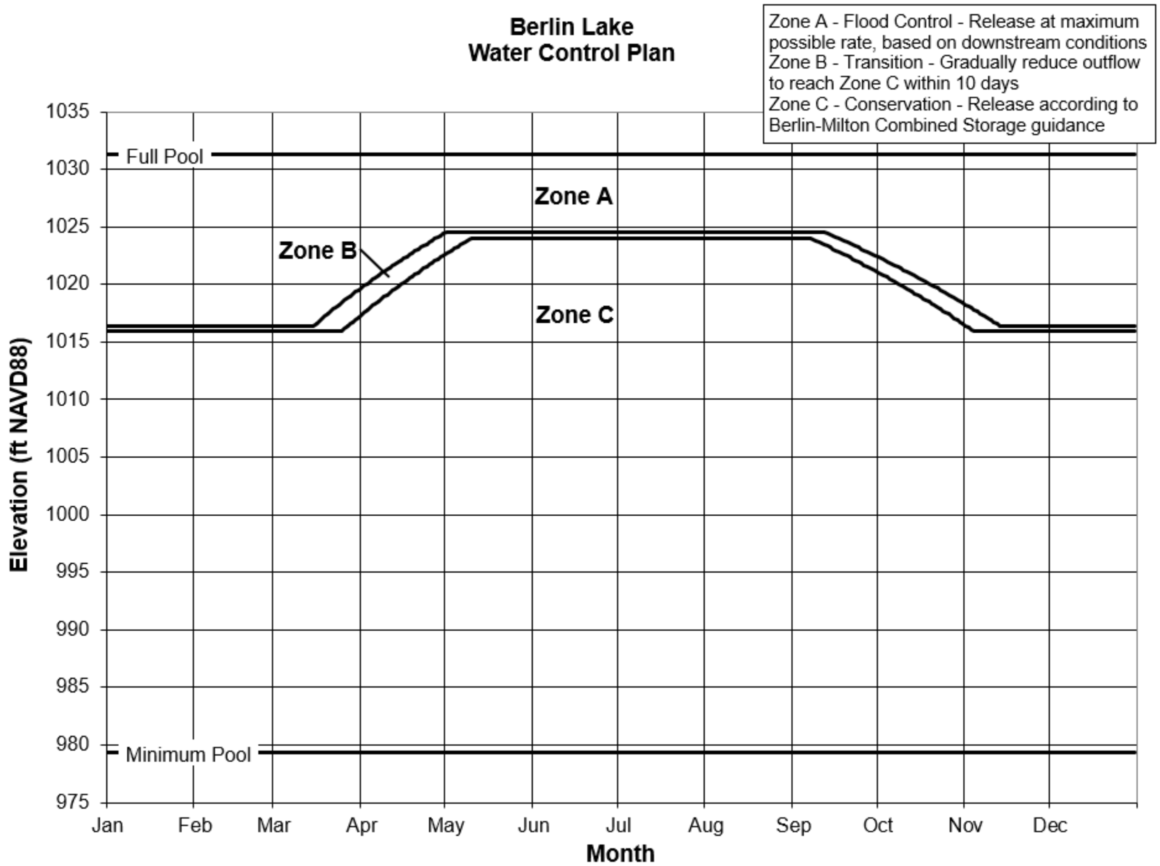


Figure 16-1: Proposed Berlin Lake Water Control Plan

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Attachment A – Berlin Lake Pool Elevations 2000 to 2021

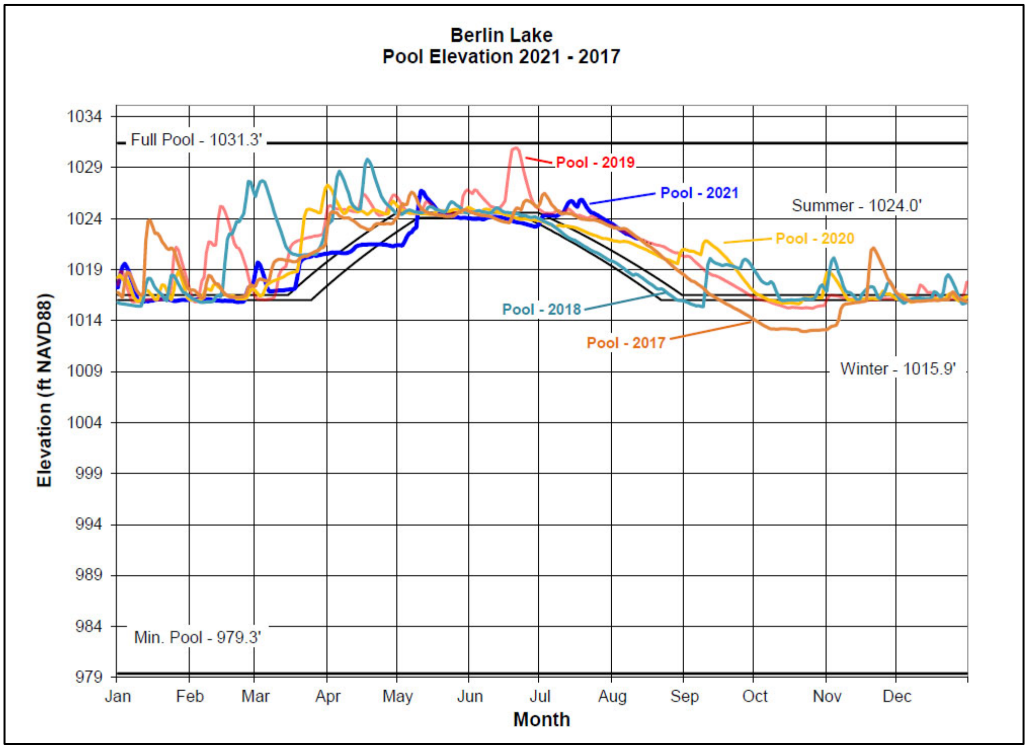

Figure A-1: Berlin Lake Pool Elevation 2017 to 2021

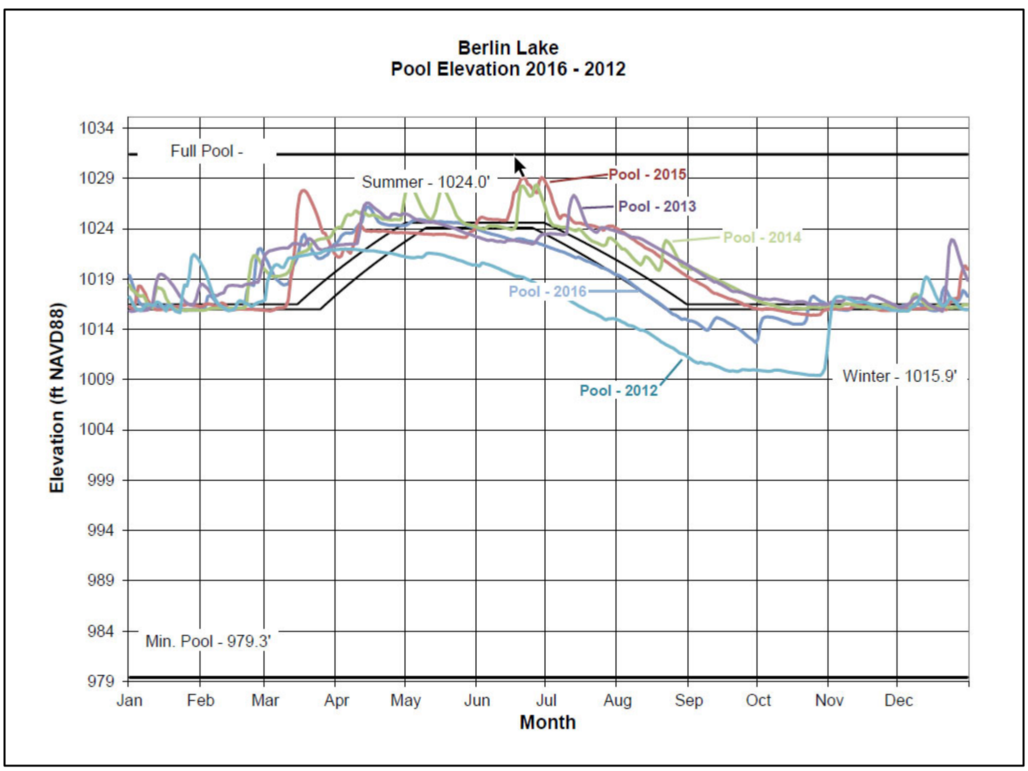

Figure A-2: Berlin Lake Pool Elevation 2012 to 2016

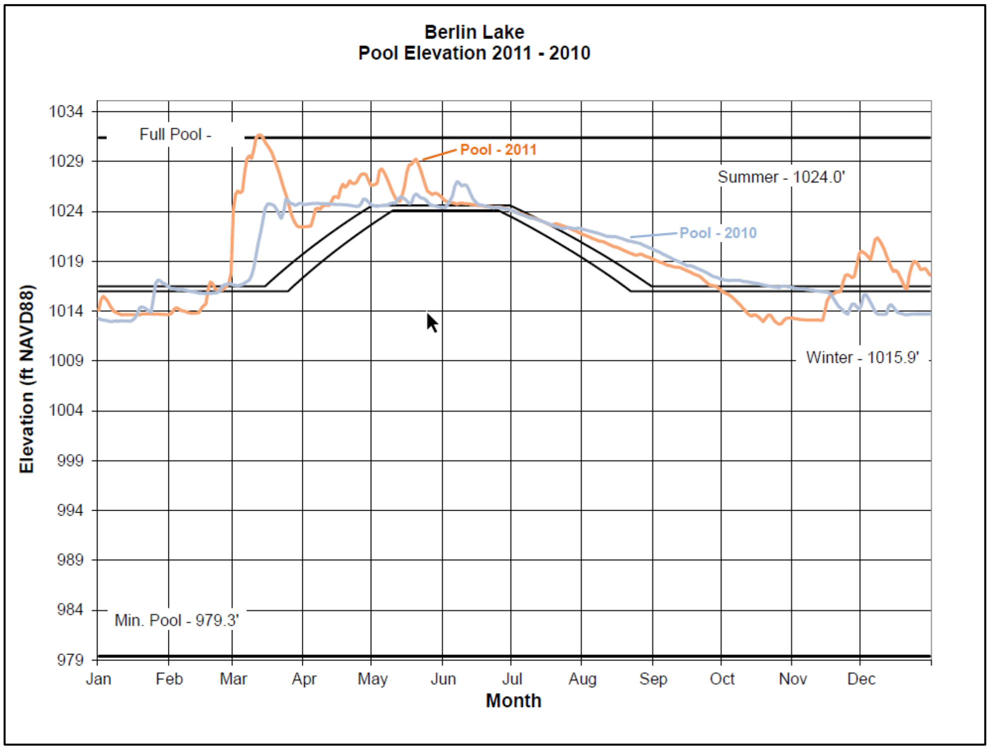

Figure A-3: Berlin Lake Pool Elevation 2010 to 2011

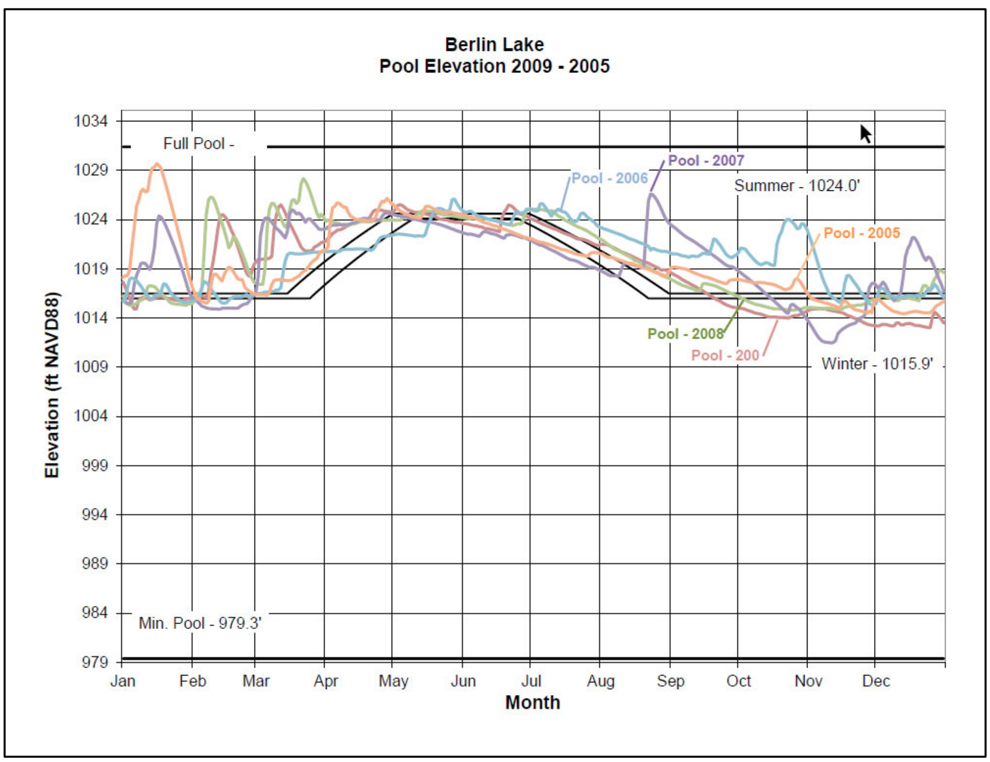

Figure A-4: Berlin Lake Pool Elevation 2005 to 2009

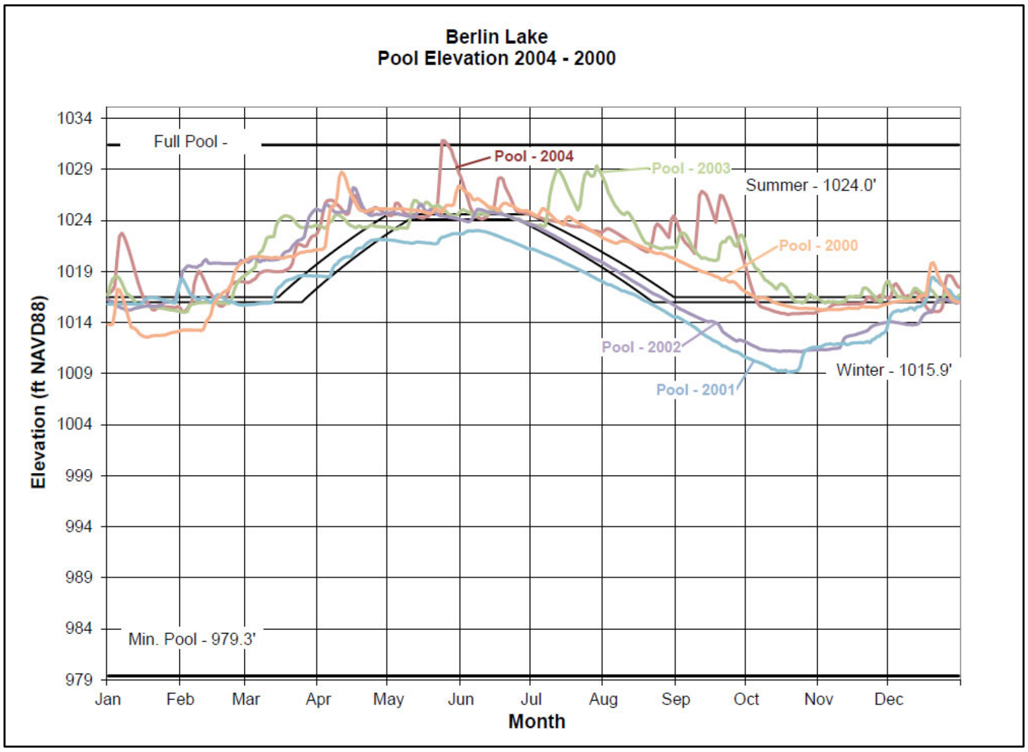

Figure A-5: Berlin Lake Pool Elevation 2000 to 2004

Attachment B – Federal, State and Local Agencies Invited to Public Meetings

Table B-1: Points of Contact for Federal, State and Local Agencies Invited to Public Meetings

Agency/ Organization	Point of Contact	Position	Phone	Email
Trumbull County Soil & Water Conservation District	Amy Reeher	District Administrator/Watershed Coordinator		reehera@embarqmail.com amy@trumbullohswcd.org
Stark Soil & Water Conservation District	John Weedon	District Administrator	330-451-7646	jsweedon@starkcountyohio.gov
Stark Soil & Water Conservation District	Rich Rohn	Urban Program Specialist	330-451-7644	rrrohn@starkcountyohio.gov
Portage County Soil & Water Conservation District	Lynn Vogel	Stormwater Educator	330-235-6815	lvogel@portageswcd.org
Portage County Soil & Water Conservation District	James Bierlair	District Coordinator		jbierlair@portageswcd.org
Mahoning Soil & Water Conservation District	Kathleen Vrable-Bryan	District Administrator	330-740-7995	kvrable-bryan@mahoningcountyoh.gov
Ohio Environmental Protection Agency	Kurt Princic	Chief, Northeast District Office		Kurt.Princic@epa.ohio.gov
Ohio Environmental Protection Agency	Gregory Orr	Environmental Scientist		Gregory.Orr@epa.ohio.gov
Ohio Environmental Protection Agency	Bill Zawiski	Environmental Supervisor		bill.zawiski@epa.ohio.gov
Ohio Department of Natural Resources - Division of Wildlife	Curt Wagner	Fisheries Management Supervisor	330.245.3018	Curtis.Wagner@dnr.state.oh.us
Ohio Department of Natural Resources - Division of Wildlife	Richard Zweifel	Supervisor, Inland Fisheries Research Unit		richard.zweifel@dnr.state.oh.us
Ohio Department of Natural Resources	John Navarro			John.navarro@dnr.state.oh.us

Ohio Department of Natural Resources	John Kessler			John.Kessler@dnr.state.oh.us
Ohio Department of Natural Resources - Parks and Watercraft	Douglas Lyons	Regional Manager		douglas.lyons@dnr.state.oh.us
Ohio Department of Natural Resources	John Trevelline	Park Manager, West Branch State Park		john.trevelline@dnr.state.oh.us
Ohio Department of Natural Resources	Josie McKenna	Park Manager, Mosquito Lake		Josie.McKenna@dnr.state.oh.us
US Fish and Wildlife Service	Jeromy Applegate	Fish and Wildlife Biologist		Jeromy_Applegate@fws.gov
US Environmental Protection Agency	Jennifer Tyler		312-886-6394	tyler.jennifer@epa.gov
US Environmental Protection Agency	Kenneth Westlake	Deputy Director, Office of Multimedia Programs	312-886-2910	westlake.kenneth@epa.gov
Pennsylvania Department of Environmental Protection Northwest District	Joseph Brancato	Water Pollution Biologist Supervisor	814-332-6942	jbrancato@pa.gov
National Weather Service – Cleveland, OH	Sarah Jamison	Senior Service Hydrologist		sarah.jamison@noaa.gov
US Geological Survey - Ohio-Kentucky-Indiana Water Science Center	Tom Harris	Data Chief / Supervisory Hydrologist	614-430-7727	tharris@usgs.gov

Attachment C – Invitee and Attendee Lists for Public Meetings

REDACTED