ERDC/EL TR-23-9

Environmental Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

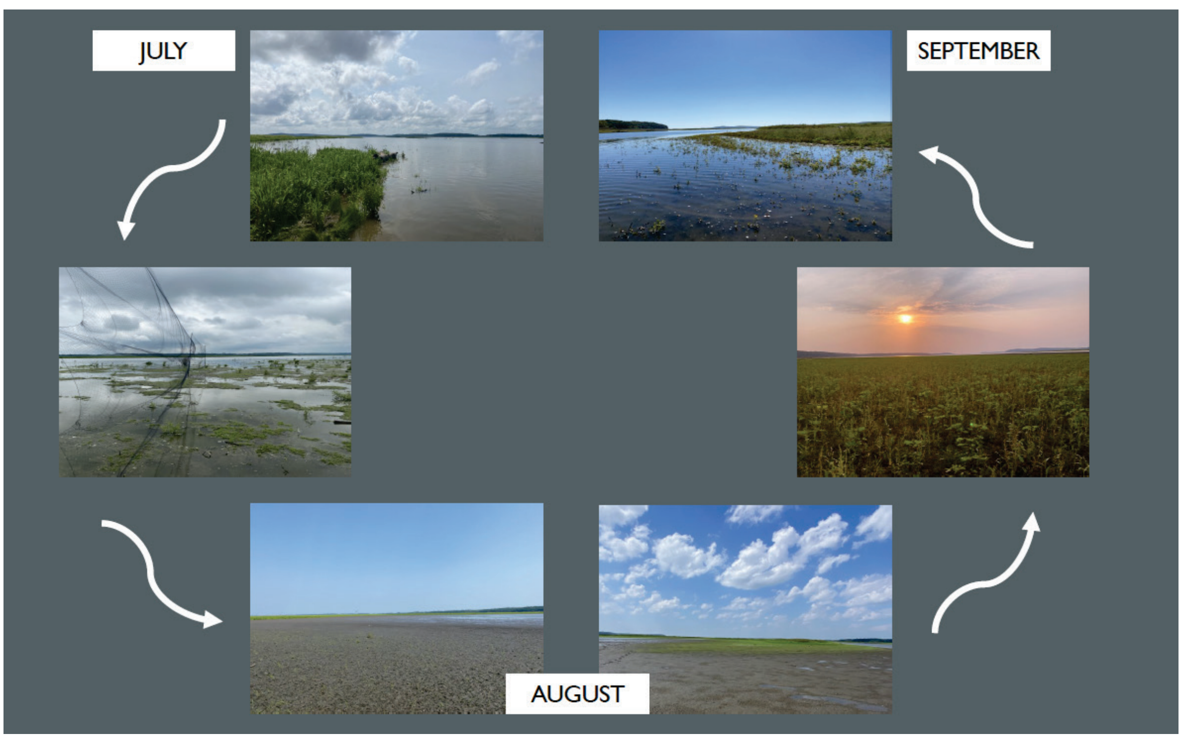
ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

Ecosystem Management and Restoration Research Program

Spatial Screening for Environmental Pool Management Opportunities

Elizabeth S. Neipert, Todd E. Steissberg, and Chuck Theiling

September 2023



Cover graphic: Nicole Bosco, Iowa State University

Ecosystem Management and Restoration Research Program

ERDC/EL TR-23-9
September 2023

Spatial Screening for Environmental Pool Management Opportunities

Elizabeth S. Neipert, Todd E. Steissberg, and Chuck Theiling

Environmental Laboratory
US Army Engineer Research and Development Center
3909 Halls Ferry Rd
Vicksburg, MS 39180-6199

Final report

Prepared for US Army Corps of Engineers
Washington, DC 20314-1000

Under Project SON 2019-1365/1409, “Evaluate Ecosystem Restoration (ER) Benefits of Reservoir Manipulations”

Abstract

US Army Corps of Engineers (USACE) reservoir projects significantly alter river ecosystem structure and function. Each project adheres to a defined set of operating rules to achieve primary objectives, which typically include flood risk management, hydropower, or navigation along with ancillary objectives for drinking water/irrigation, recreation, and natural resources management. Environmental flows (E-Flows) planning under the Sustainable Rivers Program has demonstrated new opportunities for environmental pool management (EPM; Theiling et al. 2021a, 2021b) that have no negative impact on other reservoir functions. In some locations, water level drivers can be managed to improve ecological outcomes, like wetlands, waterbirds, reptiles, and water quality, by altering the magnitude, timing, frequency, and duration of pool level changes that affect riparian and shoreline plant communities. Reservoirs with large delta areas may provide particularly important wetland or riparian habitat management along avian migratory pathways or in wildlife conservation regions (Johnson 2002). These large deltas can be identified and characterized using available satellite imagery, which along with water level habitat drivers available in hydrology databases, can be used to identify USACE reservoirs with good potential for EPM. A spatial analysis of USACE reservoirs capable to support EPM can be developed utilizing estimates of water occurrence, transition, and seasonality as well as surface elevation data derived from satellite imagery to assess geomorphology drivers. USACE water management records can be used to assess wetland drivers. Nationwide screening will be broken down into ecoregions to establish the anticipated geographic range of variation for wetland and riparian habitat drivers. Southwestern US reservoirs, for example, will have much different hydrology and fauna than Midwest and Eastern US reservoirs.

Contents

Figures and Tables

Figures

Tables

Preface

This study was conducted for the Ecosystem Management and Restoration Research Program (EMRRP) under Project SON 2019-1365/1409, "Evaluate Ecosystem Restoration (ER) Benefits of Reservoir Manipulations." The technical monitor was Dr. Brook Herman.

The work was performed by the Ecological Resources Branch (EE-E) of the Ecosystem Evaluation & Engineering Division (EEE), US Army Engineer Research and Development Center, Environmental Laboratory (ERDC-EL). At the time of publication, Mr. Joseph Minter was chief, CEERD-EE-E; Mr. Mark Farr was chief, CEERD-EE; and Dr. Jennifer Seiter-Moser, CEERD-EL was the technical director for EMRRP. The deputy director of ERDC-EL was Dr. Brandon Lafferty, and the director was Dr. Edmund Russo.

The Sustainable Rivers Program has supported Lake Red Rock E-flows investigations since 2015. The EMRRP funded this research beginning in Q4 FY20. Dr. Trudy Estes strengthened the work unit by recommending this regional spatial assessment. Drs. Billy Johnson and Jacob Jung provided technical review and helpful comments to improve this report.

COL Christian Patterson was the commander of ERDC, and Dr. David W. Pittman was the director.

This technical report should be cited as follows:

Neipert, E. S., T. E. Steissberg, and C. H. Theiling. 2023. *Spatial Screening for Environmental Pool Management Opportunities*. ERDC/EL TR-23-9. Vicksburg, MS: US Army Engineer Research and Development Center.

1 Introduction

1.1 Background

The US Army Corps of Engineers (USACE) operates approximately 700 dams across the US and Puerto Rico. Studies on the ecological impacts of dams have focused primarily on areas downstream, where dam operations have altered flow and temperature regimes and channel characteristics, resulting in considerable ecological impacts on aquatic and streamside communities (Graf 2006). Less attention has been directed to the upstream effects of dams, particularly in reservoir backwaters, where major ecological impacts have occurred that differ considerably from those downstream of dams (Johnson 2002).

In 2016, an Institute for Water Resources (IWR) assessment of 356 USACE reservoir projects identified five primary review topics for the National Portfolio effort: water supply storage and reallocation practices, water management trends, environmental considerations, reservoir sedimentation, and uncertainty in future conditions.* Although the report found that only 14 percent of USACE reservoirs incorporate environmental considerations into their water management plan, this percentage represents an increase from the 1980s. It was also noted that the main consideration for environmental flows was downstream releases, but there were also a few recommended in-pool management actions, such as Rock Island District reservoirs increasing water levels for fall waterfowl migrations. The US Fish and Wildlife Service (USFWS) has also developed environmental flows guidelines in some river basins of the southwestern United States to promote habitat for federally listed threatened and endangered species.

Ecological problems associated with flood control dam hydrologic alterations are well documented (Richter et al. 1996; Poff et al. 1997; Bunn and Arthington 2002; Arthington et al. 2006; Poff and Zimmerman 2010) and include upstream habitat transformations, downstream flow alterations, and reduced longitudinal connectivity and energy transport. Environmental flows management has been planned for water releases

* https://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/2016-RES-01.pdf

below many dams, but prior planning was limited and restricted in scope and capability until Lake Red Rock managers demonstrated they can achieve upstream, downstream, and year-round benefits with appropriate planning and the right hydrologic conditions at USACE lakes. Lake Red Rock water management strategies were recently updated to accommodate spring pulses to benefit fish spawning downstream and, in the lake, summer drawdowns for waterbird and wetland benefits that persist when reflooded for fall waterfowl migration and overwintering reptiles.

The Sustainable Rivers Program and multiple regional conservation programs support this approach to Integrated Water resource management. The 2018 Upper Mississippi River and Great Lakes Region Joint Venture Waterbird Conservation Plan (Soulliere et al. 2018), for example, defines "operational management" as "periodic or annual manipulation of areas under a persistent management regime to achieve desired outcomes for focal species or guilds. Management includes actions considered routine for the location to retain quality bird habitat for the breeding period (e.g., burning established grassland to reduce brush) or non-breeding period (e.g., impoundment drawdown for moist soil management or marsh successional setback)." Several Midwest reservoirs, for example, are managed to support fall waterfowl migration and hunting opportunities by raising water levels to flood emergent marsh habitat. Because lake managers have management authority on fee-title land and easements below maximum reservoir pool levels, there may be considerable opportunity for the USACE to manage for riparian vegetation on reservoir sediment deltas to meet conservation targets for riparian-dependent wildlife species. Compared with the highly heterogeneous land ownership patterns that occur downstream of many dams, this greatly simplifies the planning and implementation of resource management.

1.2 Objective

Considering environmental water management opportunities for the large number of USACE reservoirs for is quite challenging and thus has not been widely practiced. The potential benefits to be derived, however, can be great if suitable water management capabilities exist. Environmental pool management implementation and modeling both indicate enhanced benefits from the practice. There is potential that management practices can be shared by local managers and regional integrated management plans can be developed to support migratory birds for example.

Lott and Fischer developed a methodology to identify reservoirs and associated sediment deltas suitable for endangered bird management in the SW US.[*] Their methodology can be adapted to identify potential sediment deltas for USACE dams nationwide utilizing available satellite data. Available data include metrics for characterizing the occurrence, spatial extent, and seasonality of surface water to identify deltas. Water level variation during the growing season is the second key driver for wetland and riparian plant community establishment. All reservoirs maintain pool stage records which can serve as a proxy for water level variability in delta areas. These metrics will differ across ecoregions for which there would be an expected range of hydrologic conditions.

The objective of this research was to develop a rapid spatial screening method to identify reservoirs with suitable delta geomorphology and water management capability to support delta wetland management. The results can be used to inform lake managers that their projects may be able to provide increased ecosystem benefits for little cost.

1.3 Approach

This report describes methods to implement an automated USACE reservoir water level management screening methodology using available geospatial and hydrology data. No-cost Landsat-derived geospatial data can be used to analyze the inundation frequency and identify locations that provide the potential for delta/wetland formation (Weekley and Xi 2019).[1] Reservoir hydrology data and reservoir operating rules can be used to evaluate reservoir potential for EPM. An ecoregion approach can establish the expected range of variation among wetland geomorphic and hydrologic drivers. The individual ecoregion analyses can be combined to provide a national perspective and prioritization for the capacity to increase environmental benefits in the form of wetlands, fish, waterbirds, reptiles, and water quality in USACE-managed reservoirs.

---

[*] Lott, C. A., and R. A. Fischer. DRAFT. *Reservoir Sediment Deltas of the Southwestern United States: Challenges and Opportunities for Riparian Vegetation Management*. Vicksburg, MS: US Army Engineer Research and Development Center. www.doer.el.erdc.dren.mil.

2 Spatial Analysis

Water level management screening requires measuring two key wetland and riparian plant community drivers: delta geomorphology and water level variability. Reservoir sediment deltas can be identified using geospatial data sets derived from satellite imagery. Lott and Fischer developed a methodology to identify reservoirs and associated sediment deltas using the Global Surface Water Dataset (GSWD; Pekel et al. 2016).[*] The GSWD contains several metrics derived from 36 years of satellite imagery continuously acquired by the Landsat TM, ETM+, and OLI sensors. The GSWD is available via the Global Surface Water Explorer,[†] as well as via Google Earth Engine (GEE).[‡] GEE combines an immense (several petabytes) catalog of satellite imagery and geospatial datasets with extensive computational capabilities, including algorithms and Google's parallel computing resources, which currently consists of over 10,000 processors. The data and computational tools provided by GEE allow researchers to create computer scripts to post-process and analyze the data. Users can upload geographic shape files, images, and point data to combine with data provided by GEE to complement the analyses. The data and computational resources of GEE are available to the end users at no cost, and these resources are continually augmented by new data and computational capabilities.

The GSWD contains several useful metrics for characterizing the occurrence, spatial extent, and seasonality of surface water. Lott and Fischer employed the Water Occurrence data layer of the GSWD to identify permanent and seasonal areas of multiple watersheds.[1] Based on validation using aerial images, a water occurrence level of 82% occurrence level was selected to help identify permanent and seasonal water features. Areas in the GSWD water occurrence dataset that were inundated at a frequency of 82 – 100 percent (Figure 1) were used to derive river, reservoir, and lake polygons. These were filtered with appropriate parameters to identify reservoir systems associated with USACE dams in the southwestern United States. Proximity to USACE dams can be

---

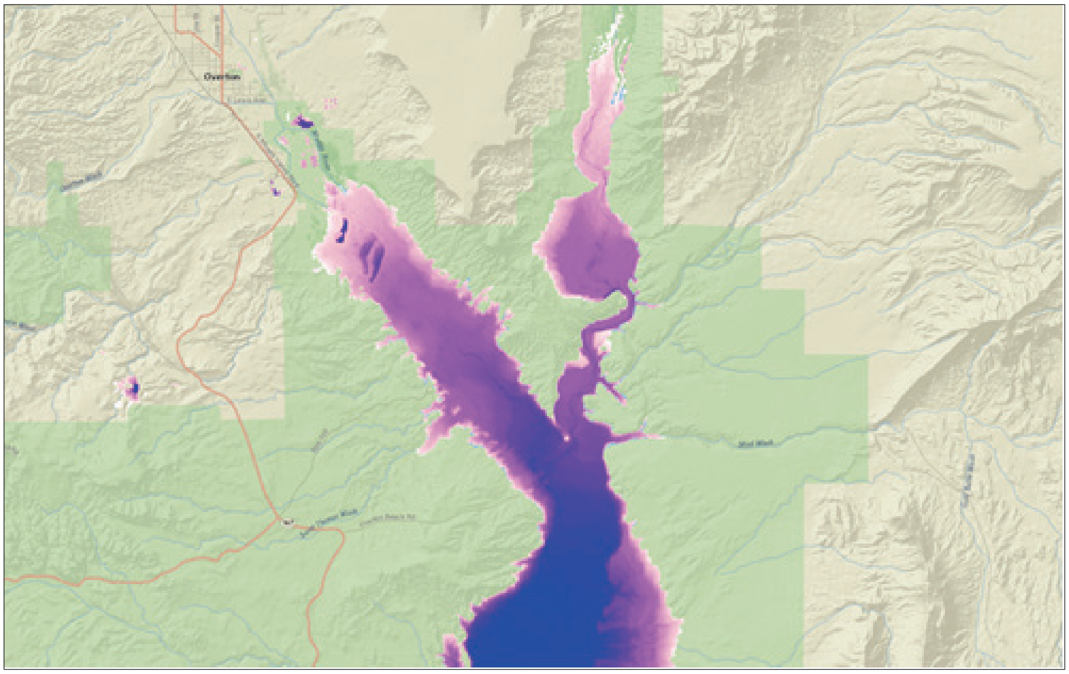
* Lott, C. A., and R. A. Fischer. DRAFT. *Reservoir Sediment Deltas of the Southwestern United States: Challenges and Opportunities for Riparian Vegetation Management*. Vicksburg, MS: US Army Engineer Research and Development Center. www.doer.el.erdc.dren.mil.

† https://global-surface-water.appspot.com/map

‡ https://code.earthengine.google.com

identified through a spatial buffer analysis that can capture one or more delta formations suitable for management.

Figure 1. Example of the “water occurrence” layer from the global surface water dataset in Lott and Fischer.[1] *Light purple* areas indicate periodically inundated surfaces and *blue* areas indicate relatively permanent water.



The methodology of Lott and Fischer[1] will be adapted to identify potential sediment deltas for USACE dams nationwide utilizing GEE. Data acquired by the Sentinel satellite sensors will be sampled across the US to verify and adjust the 82% threshold value used by Lott and Fischer.[*] If there is significant variability in the threshold values, a set of values will be derived by region (northwest, southwest, central, northeast, southeast), EPA ecoregion, or USACE District.

The GSWD provides metrics describing the inter-annual and intra-annual surface water variability, the Annual Water Recurrence, and Water Seasonality data layers, respectively. Inter- and intra-annual water variability are important factors in wetland ecosystem functioning. The intra-annual water availability provided by GSWD will be used to refine

[*] Lott, C. A., and R. A. Fischer. DRAFT. *Reservoir Sediment Deltas of the Southwestern United States: Challenges and Opportunities for Riparian Vegetation Management*. Vicksburg, MS: US Army Engineer Research and Development Center. www.doer.el.erdc.dren.mil.

the selection of viable sediment deltas where water levels vary seasonally due to USACE reservoir operations.

Spatial-temporal water level variability associated with sediment deltas is needed to identify adjustments to reservoir operations to support healthy wetland ecosystems. The Water Occurrence and other data layers provided by the GSWD can be used in conjunction with topography data to compute the statistics, particularly the mean and range, of water levels at each pixel associated with a sediment delta. For each level of water occurrence, water will spread to a certain extent defined by the topography. The mean difference in land surface elevation at the edge of a pool (zero depth) and the lowest elevation (maximum depth) in a given pool can be used to determine the maximum water depth. This can then be used to compute the depth of each pixel. Topographic data acquired by the Shuttle Radar Topography Mission (SRTM) is available at 30-m resolution as a data set on GEE (Farr et al. 2007). NASADEM, an updated Digital Elevation Model (DEM) and associated products, was developed by the Jet Propulsion Laboratory, National Aeronautics and Space Administration (NASA-JPL), using SRTM data (NASA JPL 2021).* The NASADEM data set is available on GEE as of 2021, which provides higher accuracy due to incorporation of auxiliary data from three geospatial data sets:

- ASTER GDEM: A Global Digital Elevation Map developed using satellite data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer
- ICESat GLAS: Geospatial data produced from the Geoscience Laser Altimeter System (GLAS) instrument that flew on NASA's Ice, Cloud, and land Elevation (ICESat) satellite
- PRISM: Parameter Elevation Regression on Independent Slopes Model. A set of monthly, yearly, and single-event gridded data products of mean temperature and precipitation, max/min temperatures, and dewpoints, primarily for the US. In-situ point measurements are ingested into the PRISM statistical mapping system

Most voids have been filled by including the other data sets, which is a significant improvement over the original SRTM data set. Higher resolution elevation data with resolutions up to 1 m are also available at many locations in the US and other countries. However, since Lidar data

* https://doi.org/10.5069/G93T9FD9

are not available for all watersheds, the methodology presented in this paper will focus on the 30 m NASADEM data set. This will provide consistent accuracy and resolution across all watersheds and sufficient spatial resolution. The results for individual watersheds may then be refined using local Lidar data.

The GSWD Water Occurrence data layer elevations will be validated for each watershed using gaged water surface elevations observed by the USGS and USACE. The GSWD elevations for each watershed will then be adjusted as needed to match the gage data. The elevations provided by the NASADEM data set will be subtracted from the adjusted elevations of the GSWD Water Occurrence data layer for each level of occurrence, from 0 to 100%. Spatial and temporal statistics will then be computed (Table 1). The results will be binned, and the resulting histograms will be used to identify the sediment deltas at USACE reservoirs that are ecologically viable, and experience water levels within a range that provides an opportunity to make minor adjustments to reservoir operations to meet the environmental objectives to support healthy seasonally inundated wetland ecosystems.

Table 1. Spatio-temporal statistics of pool area and stage to be computed.

Pool Area (acres)	Stage (ft^2)
Seasonal average area	Intra-annual variability (standard deviation)
Annual average area	Inter-annual variability (standard deviation)
Annual maximum area	-
Ratio of annual average to annual maximum area	-

3 Hydrologic Analysis

Water level variation during the growing season is the second key driver for wetland and riparian plant community establishment. Some reservoirs may be dynamic, with rapid and frequent short-term water level changes that impede plant community development. Some may have a wide range of variation, such that water levels rise and drop a great distance in a typical growing season where others may achieve a stable conservation pool level early in the growing season. All reservoirs maintain pool stage records which can serve as a proxy for water level variability in delta areas. Pool stage is an imprecise measurement of water levels in the delta because of the water level slope of the lake from incoming tributaries, through delta formations, and to the dam, but it represents the best available proxy for estimation.

Important growing season hydrologic metrics to be evaluated include the annual average minimum and maximum pool stage and range of pool stage variation, which are parameters used to assess the magnitude of water level fluctuations. The frequency of pool fluctuations (pool stage standard deviation) and number of reversals represent measures of water level variability that can limit emergent and riparian wetlands. These metrics will differ across ecoregions for which there would be an expected range of hydrologic conditions. When summary statistics are compiled, data visualization will determine how water management regimes might be classified; however, the range of geomorphic variation and plant community tolerance will also be considered. Average annual growing season pool stage range of variation classes will be classified by elevation range and standard deviation. Initially, annual change in pool elevations will be divided into four categories at five-foot increments (Table 2).

Table 2. Pool stage classes in five-foot increments.

Pool stage class	Pool elevation range (feet)
Very stable	<5
Stable	5–10
Variable	10–20
Highly variable	>20

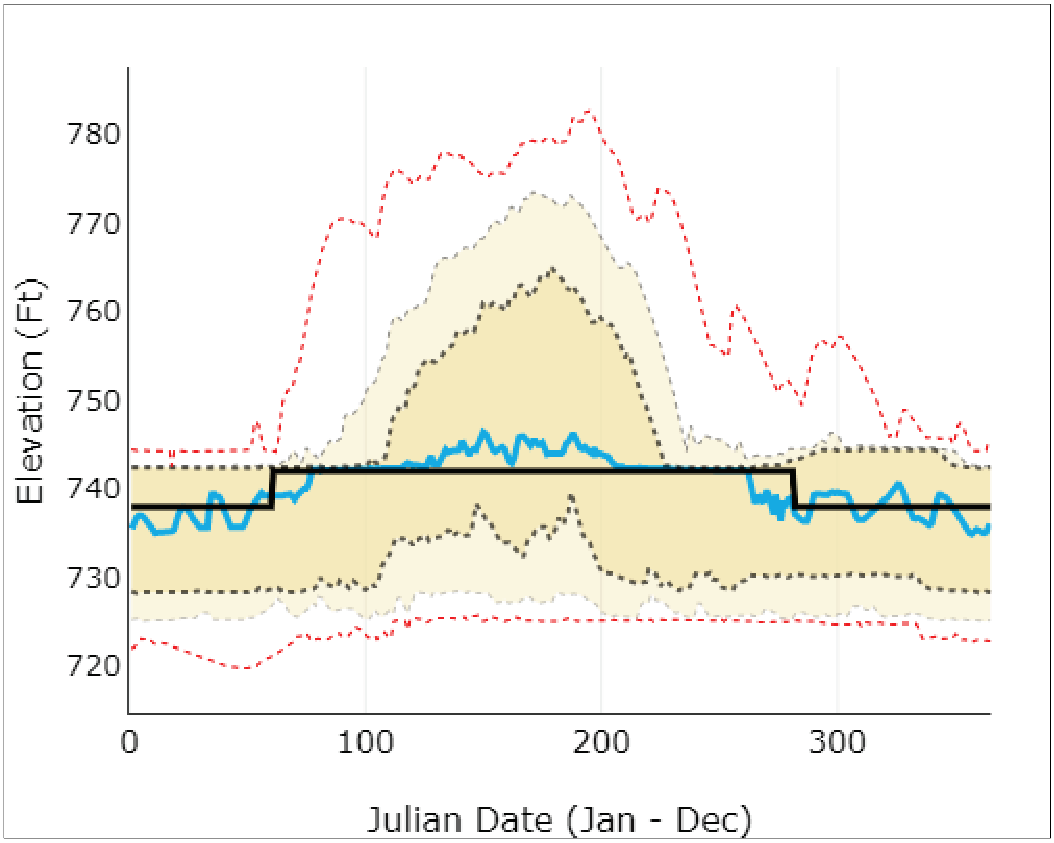
The standard deviation of pool elevation can indicate short-term (e.g., diurnal) and long-term (e.g., seasonal variability). A statistical analysis of observed in situ pool elevation data collected at multiple locations across the US will be performed and used to determine the statistic that best describes the variability, and this will be used to refine the classes listed in Table 2.

It is a daunting challenge to effectively assess the vast network of hydrologic information at USACE dam projects, yet this has been achieved within the USACE Hydrologic Engineering Center's (HEC), Corps Water Management System (CWMS), and in Duke University's reservoir data visualization tool.* Some hydrologic and water quality data available to USACE users via the CWMS national database is publicly available via Access to Water.† The Duke data service tool provides access to USACE dam project operating purposes, daily elevation data and statistics (Figure 2), and pool storage volume data, the reservoir operation plan and deviations from it for the period of record until 30 September 2015. These open-source data can be summarized and classified by their range and frequency of stage variation during the growing season as indicators of wetland or riparian plant communities. Lakes with moderate range of variation and seasonal predictability may be better candidates for water management than highly variable lakes.

* https://nicholasinstitute.duke.edu/reservoir-data/

† http://water.usace.army.mil

Figure 2. An example of the USACE reservoir data visualization tool reservoir target operations (*black*), long-term average median (*blue*), and percentiles (others = min, 10th, 25th, 75th 90th, max; source: https://nicholasinstitute.duke.edu/reservoir-data/).



Patterson and Doyle (2019a) reviewed environmental and social drivers influencing USACE dam operations including changes in precipitation since 1970. Their analysis (Figure 3) provides an overview of the hydrologic environment in each USACE Division in the Continental United States (CONUS). Each USACE Division has a different temperature, precipitation, and hydrologic regime, which together with other social drivers influenced the development of flood control, hydropower, water supply, and recreational dams, which in turn control hydrology and ecological connectivity in many river reaches.

The USACE Divisions are large geographic designations based largely on river basins that can cross climate regions. The Northwest Division, for example, encompasses a large region including both the Pacific Northwest and Great Plains climate regions, which show starkly different precipitation trends (Figure 3). The Mississippi Valley Division (MVD) stretches 1,500 miles and crosses three climate regions north to south. The northern MVD districts resemble the Great Lakes, climatologically, while climate of the southern districts is more like the South Atlantic Division in the Southeast climate region. US climate regions (Figure 4; Karl and Koss 1984) can help classify regional hydrology that more closely matches the precipitation change mapped in Figure 3. The climate map, when overlaid on the USACE dam database, will associate dam sites more effectively and accurately with regional climate expectations and trends.

Figure 3. USACE Districts shaded by percent change in precipitation and outlined in bold by division boundaries. Inset plots show annual deviations from the long-term (1900–2010) mean precipitation driving reservoir hydrology (Source: Patterson and Doyle 2019a).

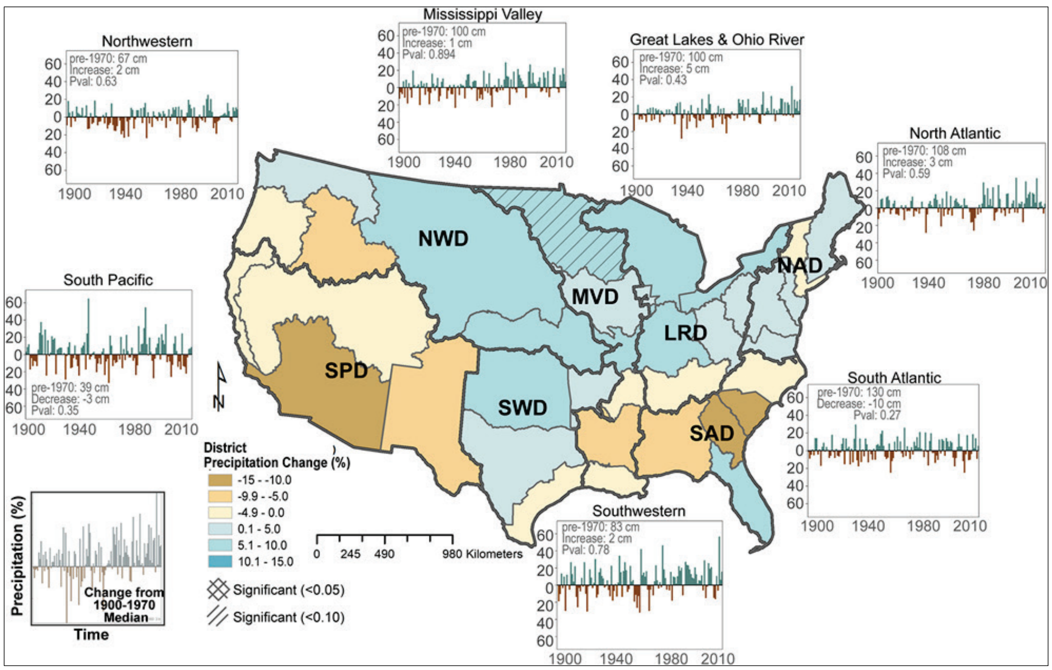
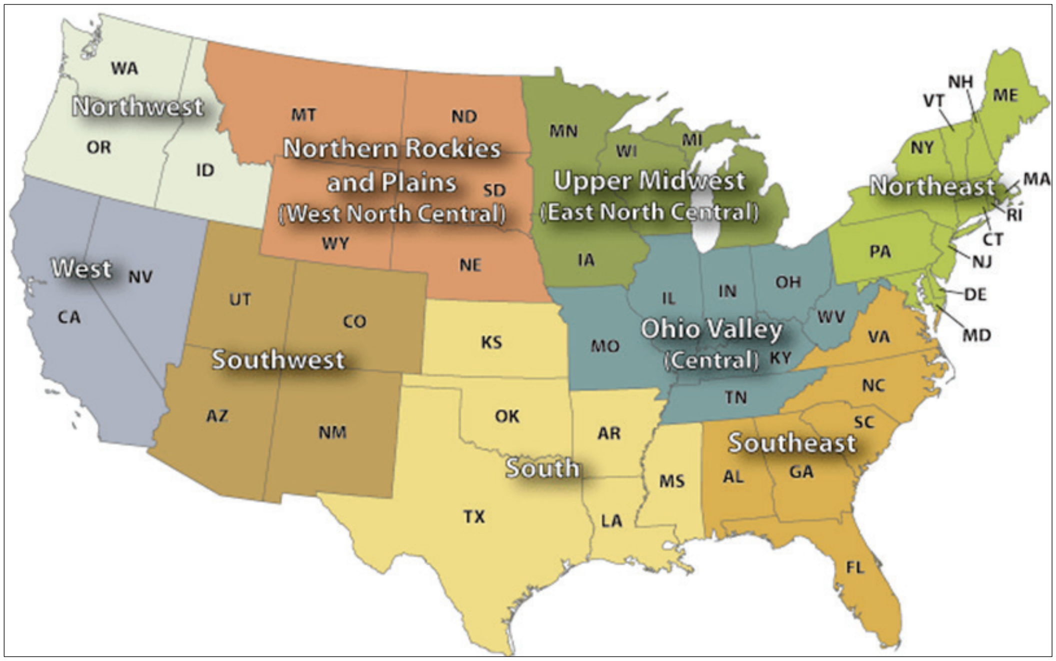


Figure 4. US climate regions (Source: Karl and Koss 1984).

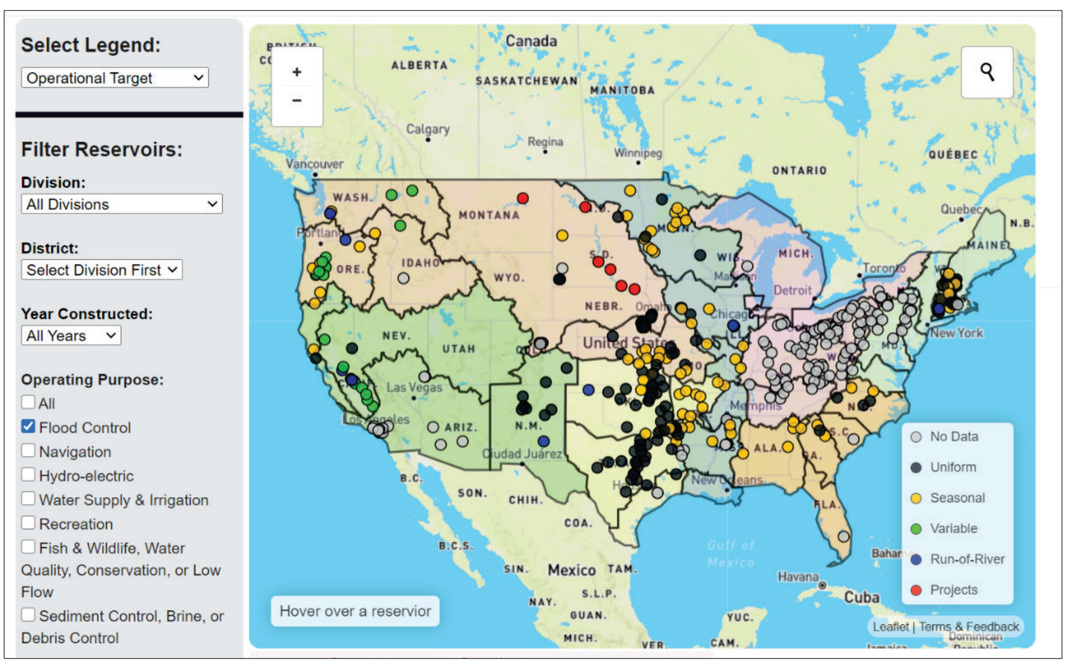


4 Dam Design Constraints

The Duke reservoir data inventory of USACE dams includes their operating purposes: flood control, navigation, hydro-electric, water supply and irrigation, fish and wildlife/water quality/conservation/flow augmentation, and sediment/debris control. While operations classifications can help refine the dams considered for EPM, each site's operations are unique and require careful coordination when evaluating water control changes. This spatial screening is meant to provide a high-level assessment of the best sites for EPM implementation.

The reservoir data visualization tool provides access to individual dam site operational targets – or operating rules (Figure 5), statistical analysis of long-term pool elevation data (see Figures 2 and 3), and target versus actual departure analysis. The classes of dam operation (Figure 5) can help determine sites with the operational flexibility necessary to implement water management changes. Dams with uniform control targets may have strict management constraints, while run-of-the-river sites may not permit any constraints on flow. Sites with seasonal and variable dam operations may be best suited to alternative water management.

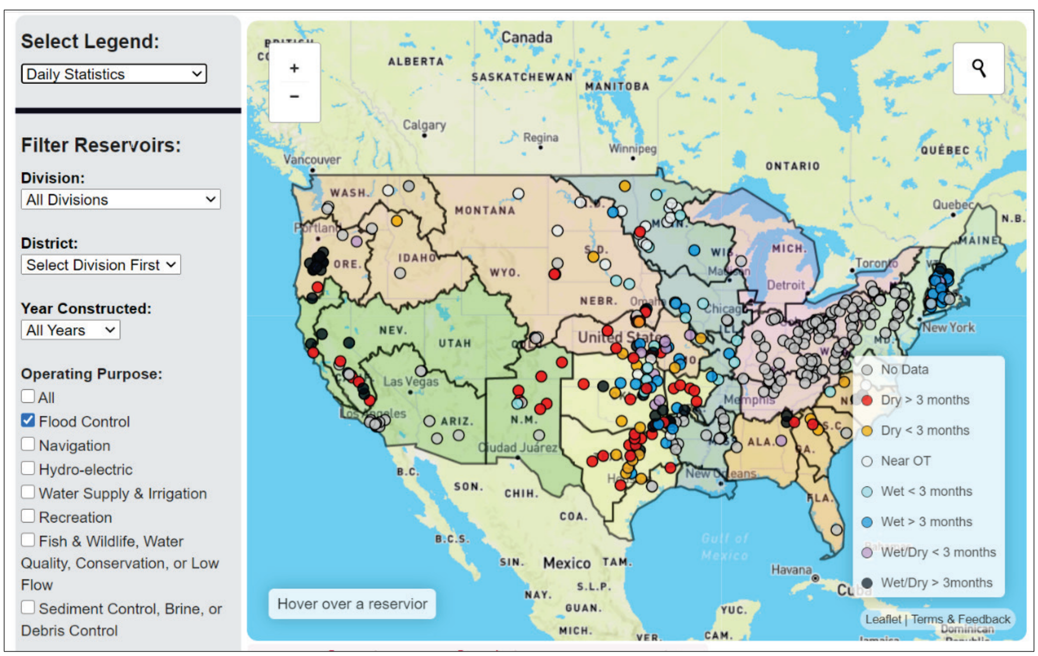
Figure 5. Duke University USACE dam data visualization tool output for the operational target of flood control projects in the continental US.



The quantity and seasonality of water supply are important determinants of operational constraints and ecological outcomes. The reservoir data visualization tool uses daily operating statistics to determine the frequency with which dams meet their annual operating target (Figure 6). Sites with too little water to achieve existing targets will have a much different range of management alternatives than wetter regions that meet or exceed operational targets. Long-term average hydrology with moderate and predictable seasonal variation can be much different than the annual hydrology that determines ecological conditions in any particular year.

Daily pool elevation data will be acquired and summarized to provide more insight into reservoir hydrologic magnitude and frequency of variation affecting wetland and riparian plant community outcomes. The pool stage classification will be layered on the spatial mapping to characterize the pool level range variability in the seasonal reservoir zone mapped for each lake. Lakes with large deltas and stable water levels achieving their operational targets may be ideal candidates for increased water management capability. Lakes that cannot achieve their operational targets on a regular basis should also be reviewed.

Figure 6. Duke University USACE dam data visualization tool output for the daily statistics achieving operational target of flood control projects in the continental US.



5 Ecoregion Considerations and Applications

USACE property extends throughout the US and therefore requires regional subdivisions to apply management actions because climate, hydrology, flora, fauna, and socioeconomics vary widely from coast to coast. As Omernik (2014) described, effective assessment and management decisions cannot be made without understanding these regional differences and without using a geographic framework that recognizes them at multiple scales or levels of detail.

An “ecoregion” is a conceptual tool used by environmental managers in which landscapes are grouped into units and subunits by their ecologically relevant characteristics (Harper-Lore et al. 2013). The EPA describes ecoregions as areas of the landscape that have generally similar characteristics such as landforms, soils, vegetation, climate, land use, wildlife, and hydrology.* Many land management agencies and government departments in the US, such as the EPA, US Forest Service (USFS), US Geological Survey (USGS), and state resource management agencies, utilize ecoregions to implement management actions. Ecoregions are designed to serve as a spatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem components (Griffith et al. 2016). Because the mission is to view and interpret patterns of as many ecological factors that reflect spatial differences in ecosystems and delineate areas of similarity, as noted by Omernik and Griffith (2014), ecoregions are fitting delineations to begin regional management delineations.

There are several major ecoregional classification systems developed and used by Federal land management agencies in the US. These classifications are similar in their basic concepts but differ in their environmental focus. Examples of ecoregional classification systems include (1) Soil focused - US Department of Agriculture Natural Resources Conservation Service, Major Land Resource Areas, (2) Climate Focused - USFS/ Robert Bailey, Ecoregions, and (3) Aquatic ecosystem focused – EPA / James Omernik, Ecoregions (Harper-Lore et al. 2013). There are numerous papers available that outline and debate differences between

* https://www.epa.gov/eco-research/ecoregions

these approaches and the characteristics emphasized in each. For highlights and a brief history of ecosystem components and ecological region designations, see Omernik and Griffith (2014). For this study, the "EPA approach" was selected.

Level II ecoregion classifications will be used as the starting point to delineate USACE project sites and group them for further research and management applications. This decision is based on the definition of Level II as useful for national overviews, as well as the application of Level II by the EPA to classify waterbodies and report stream, river, and lake assessments in the National Rivers and Streams Assessment (USEPA 2016), the National Wadeable Stream Assessment (USEPA 2006), and the National Lake Assessment (USEPA 2009; Omernik and Griffith 2014).

Application of Level II to the USACE project sites will allow grouping of locations with similar abiotic, biotic, terrestrial, and aquatic characteristics. ArcGIS files along with metadata and symbology for Level II ecoregions areas were downloaded from http://www.cec.org/north-american-environmental-atlas/terrestrial-ecoregions-level-ii/ and https://www.epa.gov/eco-research/ecoregions-north-america.

6 Bird Conservation Regions and Context of Application

The North American Bird Conservation Initiative (NABCI) used ecoregions on the continental scale for structuring biological conservation research and planning (US NABCI Committee 2000). These spatial framework units for bird conservation in North America are known as Bird Conservation Regions (BCR) adopting the hierarchical framework of nested ecological units delineated by the CEC.

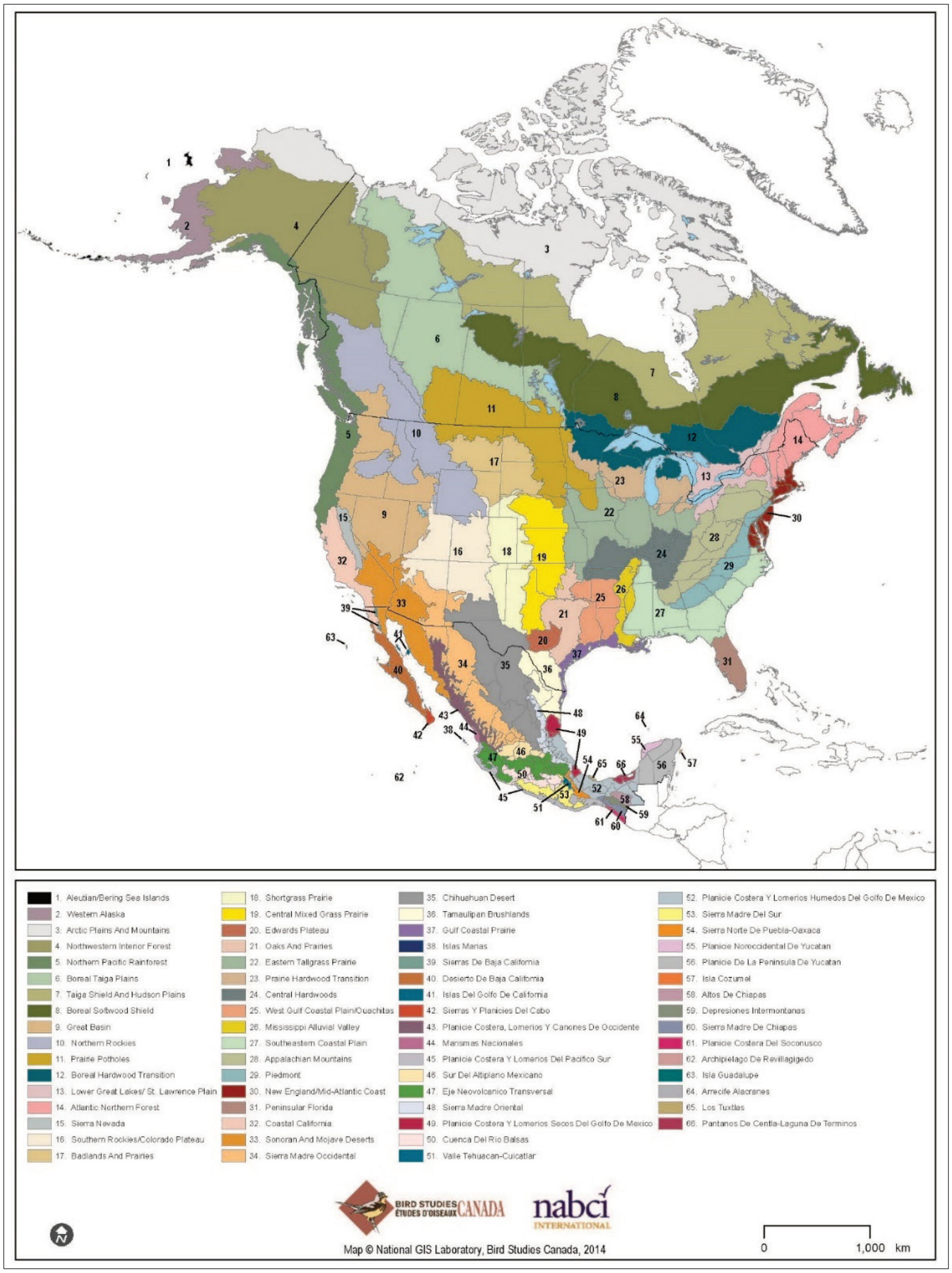
Per NABCI, BCRs are ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues. BCRs were created by aggregating CEC Level II, III, and IV ecoregions in combinations that reflect current understanding of bird species distribution and life history requirements. Moreover, Bird Conservation Regions serve to

- facilitate communication among the bird conservation initiatives;
- systematically and scientifically apportion the US into conservation units;
- facilitate a regional approach to bird conservation;
- promote new, expanded, or restructured partnerships, and;
- identify overlapping or conflicting conservation priorities (Schmidt et al. 1998).

After an ecoregion is assigned to each USACE project site meeting the criteria for EPM, it will also be assigned to a BCR (Figure 7). Layers for BCRs are downloadable from https://www.birdscanada.org/bird-science/nabci-bird-conservation-regions/. The 35 BCRs within the US will be used to identify USACE projects with potential regional importance as breeding or stopover habitat for use by riparian songbirds, shorebirds, and waterfowl with the highest conservation concern or listed as threatened and endangered species.

A list of birds will be created for management action within each BCR, to include species identified within the following conservation programs along with potential EPM actions that would have a positive or negative impact on these species.

Figure 7 . North American Bird Conservation Initiative's map delineating the Bird Conservation Regions across North America (Bird Studies Canada and NABCI 2014).



6.1 Threatened and endangered species

Under Section 7 of the Endangered Species Act (ESA) of 1973, all federal agencies are required to use their authority to help conserve species listed under the ESA. Riparian areas are one habitat declining in many areas of the country. Many ESA species are tied to riparian areas and need to be considered when looking to utilize EPM actions. For example, Lott and Fischer (2019) states conservation efforts for the endangered and riparian-dependent Southwestern Willow Flycatcher have been proposed for several thousands of stream kilometers intended to benefit, or at least cause no harm to, 85 other federally listed and candidate species in Arizona, California, Colorado, New Mexico, Texas, and Utah (USFWS 2015).

6.2 Birds of Conservation Concern

USFWS developed the Birds of Conservation Concern 2008 (BCC 2008) due to their mandate to "identify species, subspecies, and populations of all migratory nongame birds that, without additional conservation actions, are likely to become candidates for listing under the ESA." This list includes species requiring the highest conservation priorities and breaks them into three spatial frameworks, including BCRs. The BCC 2008 found that, on average, priority species make up about 10 to 15 percent of native bird species in any given geographic unit (USFWS 2008). The report also includes all of the species' groups: landbirds, shorebirds, and waterbirds. BCC includes species from Partners in Flight North American Landbird Conservation Plan (PIF; Rich et al. 2004), the United States Shorebird Conservation Plan (USSCP; Brown et al. 2001; USSCP 2004), and the North American Waterbird Conservation Plan (NAWCP; Kushlan et al. 2002; USFWS 2008).

6.3 Management applications

Bird communities are indicators of ecological integrity in a variety of habitats (Bradford et al. 1998; Canterbury et al. 2000; O'Connell et al. 2000). At-risk bird species act as barometers for ecosystem threats (Beissinger et al. 1996; USFWS 2008). With 50 percent of breeding birds in the western US nesting only in riparian areas (Skagen et al. 2005), the focus needs to be on limited conservation funds and efforts on maximizing riparian ecosystems.

The mapping exercise will determine the most probable areas for developing sediment deltas within the USACE project portfolio. The ecoregion and BCR delineations and subsequent list of birds for conservation action will outline the next steps for EPM to increase habitat across spatial and temporal scales and manage for the identified species.

Avian guilds that are predicted to benefit from temporal and spatial EPM include: riparian-dependent songbirds, by increasing sediment deltas and riparian vegetation; shorebirds, by drawing down water during critical migration period to expose mudflats and alluvium sediment; and waterfowl, by increasing water levels to flood emergent marsh vegetation. EPM will allow for a dynamic system that provides habitat for the different guilds under varying scenarios.

This grouping approach allows visualization of the spatial patterns of the EPM criteria (i.e., temperature, precipitation, discharge, pool variability) across ecosystems. This allows more accurate environmental assessments and application of the proposed management and research activities that will cross multiple aspects and characteristics of each ecoregion. This also allows for integrating these activities across programs while focusing on the weighted interests for each geographic area. With similar environmental characteristics within ecoregions, responses to EPM should also be similar. Grouping by ecoregion and BCR allows for more efficient management across land areas but also provides a degree of predictability for management actions.

7 Recommendations and Summary

7.1 Recommendations

These reservoir water level management spatial screening methods provide a rapid assessment of EPM opportunities across the USACE dam portfolio. Geomorphic and hydrologic drivers can be assessed to identify reservoir projects with conditions suitable for delta wetland management. This analysis should be implemented to identify cost-effective environmental management opportunities at appropriate USACE reservoir projects.

7.2 Summary

USACE reservoirs can be managed to support multiple objectives; however, water management plans were developed before widespread understanding of environmental flows principles. There is a need to review USACE reservoir operations to increase environmental opportunities, and the methods outlined in this report support a CONUS-level screening analysis to identify suitable sites. Geomorphic assessments leveraging Landsat imagery and high-resolution terrain data can be used to identify delta land areas suitable for management. Water level analysis using historic pool level data can help screen sites with suitable hydrologic characteristics. Because the nation is large and complex, regional climate, ecoregion, and wildlife conservation regions should be used to subdivide USACE lakes into groups with similar physical and ecological characteristics. Lake managers can use these results to incorporate environmental flow considerations to meet their sites' environmental objectives.

References

Arthington, Angela H., Stuart E. Bunn, N. Leroy Poff, and Robert J. Naiman. 2006. “The Challenge of Providing Environmental Flow Rules to Sustain River Ecosystems.” *Ecological Applications: A Publication of the Ecological Society of America* 16, no. 4: 1311–18. https://doi.org/10.1890/1051-0761(2006)016[1311:tcopef]2.0.co;2.

Bailey, R. G. 1996. *Ecosystem Geography*. Springer, New York.

Bunn, Stuart E., and Angela H. Arthington. 2002. “Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity.” *Environmental Management* 30, no. 4: 492–507. https://doi.org/10.1007/s00267-002-2737-0.

Beissinger, Steven R., Eric C. Steadman, Timothy Wohlgenant, Geoffrey Blate, and Steve Zack. 1996. “Null Models for Assessing Ecosystem Conservation Priorities: Threatened Birds as Titers of Threatened Ecosystems in South America.” *Conservation Biology: The Journal of the Society for Conservation Biology* 10, no. 5: 1343–52. https://doi.org/10.1046/j.1523-1739.1996.10051343.x.

Bird Studies Canada and NABCI. 2014. *Bird Conservation Regions*. Published by Bird Studies Canada on behalf of the North American Bird Conservation Initiative. https://www.birdscanada.org/bird-science/nabci-bird-conservation-regions

Bradford, D. F., S. E. Franson, G. R. T. Miller, A. C. Neagle, G. E. Canterbury, and D. T. Heggem. 1998. “Bird Species Assemblages as Indicators of Biotic Integrity in Great Basin Rangeland.” *Environmental Monitoring and Assessment* 49: 1–22.

Canterbury, G. E., T. E. Martin, D. R. Petit, L. J. Petit, and D. F. Bradford. 2000. “Bird Communities and Habitat as Ecological Indicators of Forest Condition in Regional Monitoring.” *Conservation Biology* 14:544-558.

Farr, T. G., P. A. Rosen, E. Caro, R. Crippen, R. Duren, S. Hensley, M. Kobrick, M. Paller, E. Rodriguez, L. Roth, D. Seal, S. Shaffer, J. Shimada, J. Umland, M. Werner, M. Oskin, D. Burbank, and D. E. Alsdorf. 2007. “The shuttle radar topography mission.” *Reviews of Geophysics* 45(2) RG2004. https://doi.org/10.1029/2005RG000183.

Graf, W. L. 2006. “Downstream hydrologic and geomorphic effects of large dams on American Rivers.” *Geomorphology* 79:336-360.

Griffith, Glenn E., James M. Omernik, David W. Smith, Terry D. Cook, Ed Tallyn, Kendra Moseley, and Colleen B. Johnson. 2016. “Ecoregions of California.” *Open-File Report*. US Geological Survey. https://doi.org/10.3133/ofr20161021.

Harper-Lore, B., M. Johson, and W. Ostrum. 2013. *Vegetation management: An ecoregional approach*. Washington, DC: US Department of Transportation, Federal Highway Administration.

Johnson, W. C. 2002. “Riparian vegetation diversity along regulated rivers contribution of novel relic habitats.” *Freshwater Biology* 47:749-759.

NASA JPL. 2021. NASADEM Merged DEM Global 1 arc second V001. Distributed by OpenTopography. https://doi.org/10.5069/G93T9FD9. Accessed: 2022-02-10.

O'Connell, T. J., L. E. Jackson, and R. P. Brooks. 2000. "Bird Guilds as Indicators of Ecological Condition in the Central Appalachians." *Ecological Applications* 10:1706-1721.

Omernik, J. M. 1995. "Ecoregions: A framework for managing ecosystems." T*he George Wright Forum* 12(1): 35-50.

Omernik, J. M., and G. E. Griffith. 2014. "Ecoregions of the conterminous United States: Evolution of a hierarchical spatial framework." *Environmental Management* 54: 1249–1266.

Pekel, J-F, A. Cottam, N. Gorelick, and A. S. Belward. 2016. "High-resolution mapping of global surface water and its long-term changes." *Nature* 540:7633, 418 - 422. https://doi.org/10.1038/nature20584.

Poff, N. LeRoy, J. David Allan, Mark B. Bain, James R. Karr, Karen L. Prestegaard, Brian D. Richter, Richard E. Sparks, and Julie C. Stromberg. "The Natural Flow Regime." *BioScience* 47, no. 11 (1997): 769–84. https://doi.org/10.2307/1313099.

Poff, N. L., and J. K. H. Zimmerman. 2010. "Ecological responses to altered flow regimes: a literature review to inform the science and management of environmental flows." *Freshwater Biology 55*(1): 194–205.

Richter, B. D., J. V. Baumgartner, J. Powell, and D. P. Braun. 1996. "A method for assessing hydrologic alteration within ecosystems." *Conservation Biology* 10:1163-1174.

Schmidt, P., G. Myers, and D. Pashley. 1998. A Proposed Framework for Delineating Ecologically-based Planning, Implementation, and Evaluation Units for Cooperative Bird Conservation in the United States. Commission for Environmental Cooperation, Montreal, QC, Canada. http://digitalmedia.fws.gov/cdm/ref/collection/document/id/214/ 25 pp.

Skagen, S. K., R. Hazlewood, and M. L. Scott. 2005. "The Importance and Future Condition of Western Riparian Ecosystems as Migratory Bird Habitat." In Ralph, C. John; Rich, Terrell D., editors. 2005. *Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference*. 2002 March 20-24; Asilomar, California, Volume 1 Gen. Tech. Rep. PSW-GTR-191. Albany, CA: U.S. Dept. of Agriculture, Forest Service, Pacific Southwest Research Station: p. 525-52

Soulliere, G. J., M. A. Al-Saffar, R. L. Pierce, M. J. Monfils, L. R. Wires, B. W. Loges, B. T. Shirkey, N. S. Miller, R. D. Schultheis, F. A. Nelson, A. M. SidieSlettedahl, C. M. Tonra, and D. J. Holm. 2018. *Upper Mississippi River and Great Lakes Region Joint Venture Waterbird Habitat Conservation Strategy – 2018 Revision*. U.S. Fish and Wildlife Service, Bloomington, Minnesota, USA.

Theiling, C. H., B. McGuire, G. Benjamin, D. Busse, J. Hendrickson, K. Kenow, K. Landwehr, T. Schlagenhaft, and M. Stefanski. 2021a. *Water level management for enhanced fish and wildlife habitat production in Upper Mississippi River navigation pools: An Engineering with Nature® review of practice*. Vicksburg, MS: US Army Engineer Research Development Center. ERDC/EL SR-21-8. https://hdl.handle.net/11681/42204

Theiling, C. H., A. Strelzoff, A. Ross, and A. Calomeni. 2021b. *Environmental Pool Management: The 25-year evolution of an Engineering With Nature practice*. US Army Corps of Engineers, Engineering With Nature, GIS StoryMap: https://storymaps.arcgis.com/stories/edf81c5fa2e5460dba273c848690f8bf

US Environmental Protection Agency (USEPA). 2006. Wadeable Streams Assessment. EPA-841-R-09-001. Washington, DC: US Environmental Protection Agency, Office of Research and Development.

US Environmental Protection Agency (USEPA). 2009. National Lakes Assessment: A Collaborative Survey of the Nation's Lakes. EPA 841-R- 09-001. Washington, DC: US Environmental Protection Agency, Office of Water and Research and Development.

US Environmental Protection Agency (USEPA). 2016. National Rivers and Streams Assessment 2008-2009: a Collaborative survey. EPA/841/R-16/007. Washington, DC: US Environmental Protection Agency, Office of Research and Development.

US Fish and Wildlife Service. 2015. Final Biological Opinion on Natural Resources Conservation Services' Working Lands for Wildlife Project for the Southwestern Willow Flycatcher. 144pp.

US Fish and Wildlife Service. 2008. Birds of Conservation Concern 2008. Arilington, VA: United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management. 85 pp.

US North American Bird Conservation Initiative Committee. 2000. North American Bird Conservation Initiative: Bird Conservation Region Descriptions. Arlington, VA: US Fish and Wildlife Service.

Weekley, David, and Xingong Li. 2019. "Tracking Multidecadal Lake Water Dynamics with Landsat Imagery and Topography/Bathymetry." *Water Resources Research* 55 (11): 8350–67. https://doi.org/10.1029/2019wr025500.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
September 2023	Final	

4. TITLE AND SUBTITLE

Spatial Screening for Environmental Pool Management Opportunities

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Elizabeth S. Neipert, Todd E. Steissberg, and Chuck Theiling

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Environmental Laboratory
US Army Engineer Research and Development Center
3909 Halls Ferry Rd
Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER

ERDC/EL TR-23-9

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

US Army Corps of Engineers
Washington, DC 20314-1000

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

Project SON 2019-1365/1409, "Evaluate Ecosystem Restoration (ER) Benefits of Reservoir Manipulations"

14. ABSTRACT

US Army Corps of Engineers (USACE) reservoir projects significantly alter river ecosystem structure and function. Each project adheres to a defined set of operating rules to achieve primary objectives, which typically include flood risk management, hydropower, or navigation along with ancillary objectives for drinking water/irrigation, recreation, and natural resources management. Environmental flows (E-Flows) planning under the Sustainable Rivers Program has demonstrated new opportunities for environmental pool management (EPM; Theiling et al. 2021a, 2021b) that have no negative impact on other reservoir functions. In some locations, water level drivers can be managed to improve ecological outcomes, like wetlands, waterbirds, reptiles, and water quality, by altering the magnitude, timing, frequency, and duration of pool level changes that affect riparian and shoreline plant communities. Reservoirs with large delta areas may provide particularly important wetland or riparian habitat management along avian migratory pathways or in wildlife conservation regions (Johnson 2002). These large deltas can be identified and characterized using available satellite imagery, which along with water level habitat drivers available in hydrology databases, can be used to identify USACE reservoirs with good potential for EPM. A spatial analysis of USACE reservoirs capable to support EPM can be developed utilizing estimates of water occurrence, transition, and seasonality as well as surface elevation data derived from satellite imagery to assess geomorphology drivers. USACE water management records can be used to assess wetland drivers. Nationwide screening will be broken down into ecoregions to establish the anticipated geographic range of variation for wetland and riparian habitat drivers. Southwestern US reservoirs, for example, will have much different hydrology and fauna than Midwest and Eastern US reservoirs.

15. SUBJECT TERMS

Reservoirs--Water levels
Wetlands--Effect of water levels on
Riparian areas--Effect of water levels on
Restoration ecology
Environmental management
Remote sensing
Remote-sensing images

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
Unclassified	Unclassified	Unclassified	SAR	32	