Mississippi Valley Division,
Regional Planning and Environment Division South

Yazoo Backwater Area Water Management Project

APPENDIX K - MONITORING AND ADAPTIVE MANAGEMENT PLAN USACE Constructed Mitigation and Groundwater Wells

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SECTION 1 INTRODUCTION

The United States Department of the Army (Army), the United States Environmental Protection Agency (EPA), and the United States Fish and Wildlife Service (USFWS) are committed to a collaborative and expeditious path forward to establish a flood risk reduction solution in the Yazoo Backwater Area; several Memorandum of Agreements are being developed to establish procedures regarding efficient and effective coordination in the development, review, approval, and oversight of Pump Operations, Monitoring and Adaptive Management and Compensatory Mitigation. In addition to monitoring of the pump operations, monitoring and adaptive management is being proposed related to wetlands and shorebird habitat as discussed in this monitoring and adaptive management plan.

Basis of Monitoring and Adaptive Management (M&AM): For restoration and mitigation activities, the U.S. Army Corps of Engineers (USACE) is required to develop a Monitoring and Adaptive Management Plan (WRDA 2007 Section 2036(a) and 2039). The USACE is the lead agency for implementation of three actions in the National Action Plan (2011) associated with the recommendation to support Integrated Water Resources Management (IWRM):

1. Work with States and interstate bodies (*e.g.*, Levee Boards, The Nature Conservancy, Lower Mississippi River Conservation Committee) to provide assistance needed to incorporate IWRM into their planning and programs, paying particular attention to climate change adaptation issues.

2. Working with States, review flood risk management and drought management planning to identify “best practices” to prepare for hydrologic extremes in a changing climate.

3. Develop benchmarks for incorporating adaptive management into water project designs, operational procedures, and planning strategies.

In reference to the Yazoo Backwater Area Water Management Project, management actions are defined as proposed or potential actions to be taken by the USACE to address the overall goal: Develop a M&AM plan that supports multiple functions and values of the Yazoo Backwater Area Water Management Project including socio- economic benefits, flood control, recreation, aquatic biota, water quality, environmental flows, connectivity, and ecological sustainability. M&AM plans contain both a monitoring component and an adaptive management component that is based on the results and interpretation of monitoring efforts as discussed herein.

SECTION 2 MAPPING AND REMOTE MONITORING OF INUNDATION EXTENT IN THE YAZOO STUDY AREA (YSA) OF MISSISSIPPI

The USACE ERDC has developed and promulgated data for better describing the hydrology of the Yazoo Study Area (YSA). These data underpin much of the analysis of the potential long-term impacts of the Proposed Plan to decrease flooding across almost 400,000 acres (>140,000 ha) in the YSA. EPA Office of Research and Development (ORD) scientists have been providing technical expertise to facilitate the analysis. USACE engineering models have described the watershed and in-channel hydrology of the system, and potential backwater flooding regimes have been approximated through GIS-based hydrological tools. Soil-water-table depth sampling have produced data indicating surface soil saturation and inundation in locations located across the YSA and across a variety of different flooding regimes (Berkowitz et al. 2020). These valuable spatial and hydrological data help better understand wetland hydrology within the YSA and provide data which could be used to quantify the potential influence of groundwater on surface water inundation, soil saturation and wetland characteristics at the select locations. However, interpolation of watershed-scale hydrology from a limited number of field-based data points can potentially provide an incomplete understanding of watershed hydrology.

Watershed and in-channel models rely on site-specific gauges to calibrate the model to water levels and elevation models. These models are able to produce spatial extents of surface-water inundation for specific events but are only verified at the stage data locations (i.e., limited points within the channel) and thus the estimated surface water inundation extent remains unverified. Similarly, field measures of soil saturation and surface water inundation are essential to model validation and calibration but can reflect highly localized moisture patterns and are sensitive to fine-scale elevation measures so that the application of observations to basin hydrology, inundation extent and duration are difficult. Complementary remotely sensed data that is continuous in extent will strengthen the understanding of YSA hydrology and is critical to informed decision-making and needed for facts-based adaptive management. This component of the basin-wide assessment plan proposes the use of highly refined and accurate satellite-based remote sensing products (Vanderhoof et al. 2023) to: 1) validate and calibrate estimates of surface water inundation extents of existing USACE hydrology models and tools, 2) leverage field-based measurements of surface-water inundation and soil saturation with remote sensing data via machine learning models to allow for watershed-scale (i.e., beyond individual site) investigation of soil inundation and saturation patterns, and 3) facilitate the monitoring of existing conditions of surface water inundation and/or soil saturation, providing real-time responses to both emergent flood-extent determinations and water management decisions.

2.1 CAPABILITIES OF REMOTELY SENSED DATA

The EPA ORD and USGS Geoscience and Environmental Change Science Center (GECSC) have developed and published multiple inundation algorithms for a set of diverse areas across the conterminous United States using multi-source remote sensing together with auxiliary datasets (Vanderhoof et al. 2023). These novel inundation algorithms developed for Sentinel-1 and Sentinel-2 satellite missions quantify open water and vegetated waters (*e.g.*, bottomland hardwood and forested riverine backwater wetlands) with a high degree of accuracy (see Vanderhoof et al. 2023). With frequent passes of the two satellites, biweekly to monthly estimates of surface inundation patterns have been generated for multiple areas of interest across CONUS, including the lower Mississippi River alluvial valley (Vanderhoof et al. 2024): inundation algorithms have been used to map surface water extent across the YSA from 2017-2023 and can be summarized in a variety of ways to indicate patterns of inundation over a single year or for the entire time frame of available imagery (Figure 1).

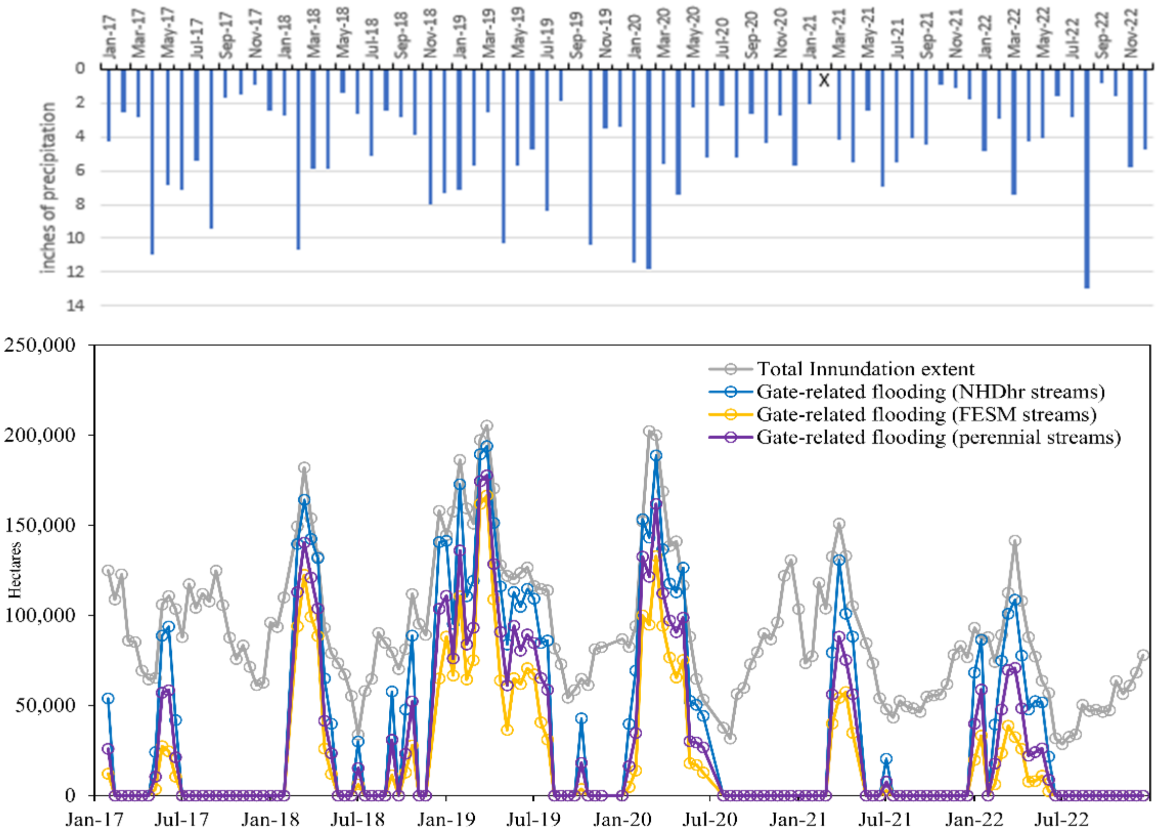

Figure 1. Temporal time pattern of inundation duration for the years 2017-2022 with the grey line representing total inundation. Colored lines represent varying amounts of inundation connected to the stream/river network.

2.2 VALIDATING EXISTING BASIN-WIDE MODELS

Long-term inundation patterns of flooding frequency, extent, and duration are crucial to understand how the Yazoo Study Area rivers and streams, wetland systems, agricultural areas, and residential zones, and wildlife respond to seasonal variability, extreme climate events, and management actions. Remotely sensed surface water inundation products can be compared with the USACE modeling efforts to validate and potentially assist in future calibration of models. At least one model year from the HEC-HMS and HEC-RAS models used to quantify the changes in flood duration and extent overlaps with imagery dates for the year 2019 (see Appendix G – Engineering Report). Comparisons of the 2019 model-predicted inundation with the 2019 remotely sensed surface water inundation can help quantify uncertainty or conversely confidence, in the data. Potential discrepancies can help target where additional field-based data collection and or additional collaborative analyses that might be needed in the future.

2.3 LINKING FIELD DATA AND REMOTE SENSING FOR BASIN-WIDE APPLICATION

USACE ERDC water table monitoring data provides important localized information on surface water inundation and soil saturation at select locations (see, e.g., Berkowitz et al. 2020). Remote sensing inundation products will be statistically related to field-based soil-saturation and surface-water measures as well as ancillary datasets to expand the interpretation of field data to larger areas. Machine learning models, developed with overlapping water-table monitoring data from the USACE, remotely sensed surface water inundation imagery from the USGS and EPA, and ancillary dataset like existing high-resolution elevation data, precipitation data, water management data, and soils data will be used to improve predictions of soil saturation duration and frequency under current conditions. This information will facilitate a better understanding of the broader utility of the water table monitoring wells and also potentially identify areas within the YSA that lack representation within the water table monitoring data. Through machine learning approaches (e.g., neural networks, Long Short-Term Memory Network, etc.), the analysis will define the patterns of surface water inundation and soil saturation under current water management conditions and set the baseline for proposed future changes.

2.4 USE FOR FUTURE MONITORING AND ADAPTIVE MANAGEMENT

As the water management project progresses, remote sensing can be a critical component of monitoring and adaptive management. Within this monitoring effort, biweekly to monthly inundation products can continue to map inundation and responses of surface water inundation to water management can be documented (Figure 1). Such frequent monitoring up to and throughout the proposed water management project would provide a near real-time collaborative monitoring and assessment of surface water levels, important to meeting management goals and adaptive approaches. As USACE continues to monitor and produce water table saturation and inundation data, these inundation products will continue to refine the relationship between the field sites and remote sensing as both document the effects of water management on the YSA and help to refine the tools used to make large-scale management decisions.

2.5 SUMMARY

Overall, this portion of the basin-wide Assessment would include scientific monitoring efforts to support and enhance adaptive management plans by providing:

- Data on the timing, frequency, and extent of open and vegetated surface water extents across the YSA derived from high resolution satellite imagery at a 2-week time step, currently reaching from 2017-2023, and extended to include future years as data becomes available.

- Satellite- and engineering model-based estimates of surface water inundation to improved calibration and validation, as well as application to stakeholder derived data products (*e.g.*, improved 2-, 5-, 25-, 50-yr flood prone extent derivation, improved estimates of agricultural and residential inundation frequency and extent, etc.).

- A machine learning model relating water-table monitoring well saturation and inundation to basin-wide measures of inundation, topography, soil characteristics, and precipitation to identify current patterns of surface saturation and inundation.

Long-term monitoring of inundation patterns and wetland hydrology in response to future operational water management actions (*i.e.*, floodgate closures and surface water pumping) in the YSA.

SECTION 3 WETLANDS COMPENSATORY MITIGATION MONITORING AND ADAPTIVE MANAGEMENT (M&AM) PLAN

3.1 PURPOSE

The following describes a M&AM strategy to document the benefits of a project-specific constructed compensatory mitigation implemented to offset unavoidable impacts to wetland resources. The proposed mitigation plan is described in Appendix J. If USACE constructs a mitigation project to meet the compensatory mitigation needs for the Yazoo Backwater Area Water Management Project a monitoring and adaptive management plan for wetlands will be required. This M&AM plan for Wetlands outlines the procedures used to verify that mitigation activities are restoring the wetland functions with the project area. Once a specific mitigation site is selected (See Appendix J Compensatory Mitigation) site specific M&AM will be outlined based on the site conditions using the general framework described in this Section. The following also identifies restoration milestones (performance criteria or success criteria) designed to ensure that projected wetland mitigation benefits are being generated and discusses strategies (Adaptive Management) to adjust if mitigation targets are not achieved. A discussion of the need for robust water table monitoring within the study area is also included.

3.2 OBJECTIVE

Utilize established monitoring techniques and published scientific resources to 1) document increases in wetland functions as a result of compensatory mitigation, 2) identify data-driven mitigation success trajectories and milestones, and 3) adaptively manage wetland conditions within the project area based upon observed data related to changes in wetland functional capacity over time. The M&AM plan also addresses the need to monitor wetland hydrology conditions within the study area to evaluate the effects of the proposed plan on wetland hydroperiods.

3.3 APPROACH

The M&AM plan 1) describes how restoration milestones/thresholds were identified for wetland mitigation lands used to offset unavoidable impacts associated with implementation of the proposed Yazoo Backwater Project; 2) provides a detailed monitoring plan and protocol to document changes in wetland functions using the Hydrogeomorphic (HGM) methodology (Smith and Klimas 2013); 3) outlines a monitoring plan to evaluate potential changes in wetland hydrology across flood duration and frequency intervals and associated implications for wetland functional capacity in the study area; and 4) discusses corrective adaptive management actions that would be implemented if the mitigation areas fail to offset impacts to wetland resources as intended.

3.4 DEVELOPMENT OF MITIGATION RESTORATION TRAJECTORIES AND MILESTONES

The M&AM plan assumes that compensatory mitigation would be initiated under the proposed plan using similar approaches applied at previously completed projects within the Yazoo Basin. This includes the acquisition of parcels currently managed as active agricultural land, fallow land, pastureland, or other non-forested land cover types. The parcels would exhibit hydric soils and would be planted a mixture of hydrophytic saplings that typically include a mixture of *Fraxinus pennsylvanica*, *Quercus texana*, *Quercus lyrata*, *Carya aquatica*, and other flood-tolerant hydrophytes associated with high wetland habitat values described in Smith and Klimas (2002). Afforestation typically occurs via row planting at seedling spacings of three to four meters.

Although the specific locations of all compensatory mitigation locations have not been finalized, data from existing mitigation sites in the Yazoo Basin can be used to estimate ecological conditions expected on new mitigation lands and how those conditions will change over time. This data informs the inputs for the HGM variables used to determine both wetland functional impacts and mitigation requirements under the proposed plan. Additionally, the established forested wetland mitigation chrono sequence detailed in Berkowitz (2018) provides inputs for other HGM variables up to 20 years and estimated variable metric scores for areas > 20 years post restoration are described in Smith and Klimas (2002).

Collectively, these resources provide data to conduct the HGM assessment across the 50-year period of analysis and identify wetland functional milestones to incorporate into the M&AM plan. Tables 5 through 9 in the Wetlands Appendix display the subset of HGM variables that are not expected to change over the 50-year period of analysis. These variable inputs serve as guidance for the final site selection, which should exhibit the following characteristics where possible: areas with large interconnected forested tracts (V_{TRACT}), forested areas adjacent to the mitigation properties ($V_{CONNECT}$), large interior areas (V_{CORE}), occur within the ≤ 4-year floodplain (V_{FREQ}), and experience wetland hydroperiods for ≥ 5.0% of the growing season (V_{DUR}). If the criteria cannot be met during the acquisition of compensatory mitigation areas, the acreage required for compensatory mitigation would be adjusted accordingly.

A subset of the HGM variables is expected to change over time in response to patterns of forest succession. As a result, they provide mitigation success criteria and monitoring milestones that can be tracked over the 50-year period of analysis (Tables 5 through 21 in the Wetlands Appendix). Visual representations of the variable metric values and variable subindex scores are provided in Figure 6 in the Wetland Appendix. These monitoring milestones provide a quantitative procedure to document the performance of compensatory mitigation sites over time, ensuring that impacts to wetland functions are being recovered and will be used as the performance/success criteria for a migration site.

The HGM functional scores associated with each target year are similarly reported in Table 22 in Wetlands Appendix. A visual representation of the HGM FCI values is presented in Figure 2, providing another way to track and report the functional improvements generated at compensatory mitigation sites. The monitoring milestones outlined for the variable metric values, subindex scores, FCI values, and AAFCUs provide for a robust quantitative procedure to document the performance of compensatory mitigation sites over time, ensuring that impacts to wetland functions are being offset by functional increase in mitigation areas.

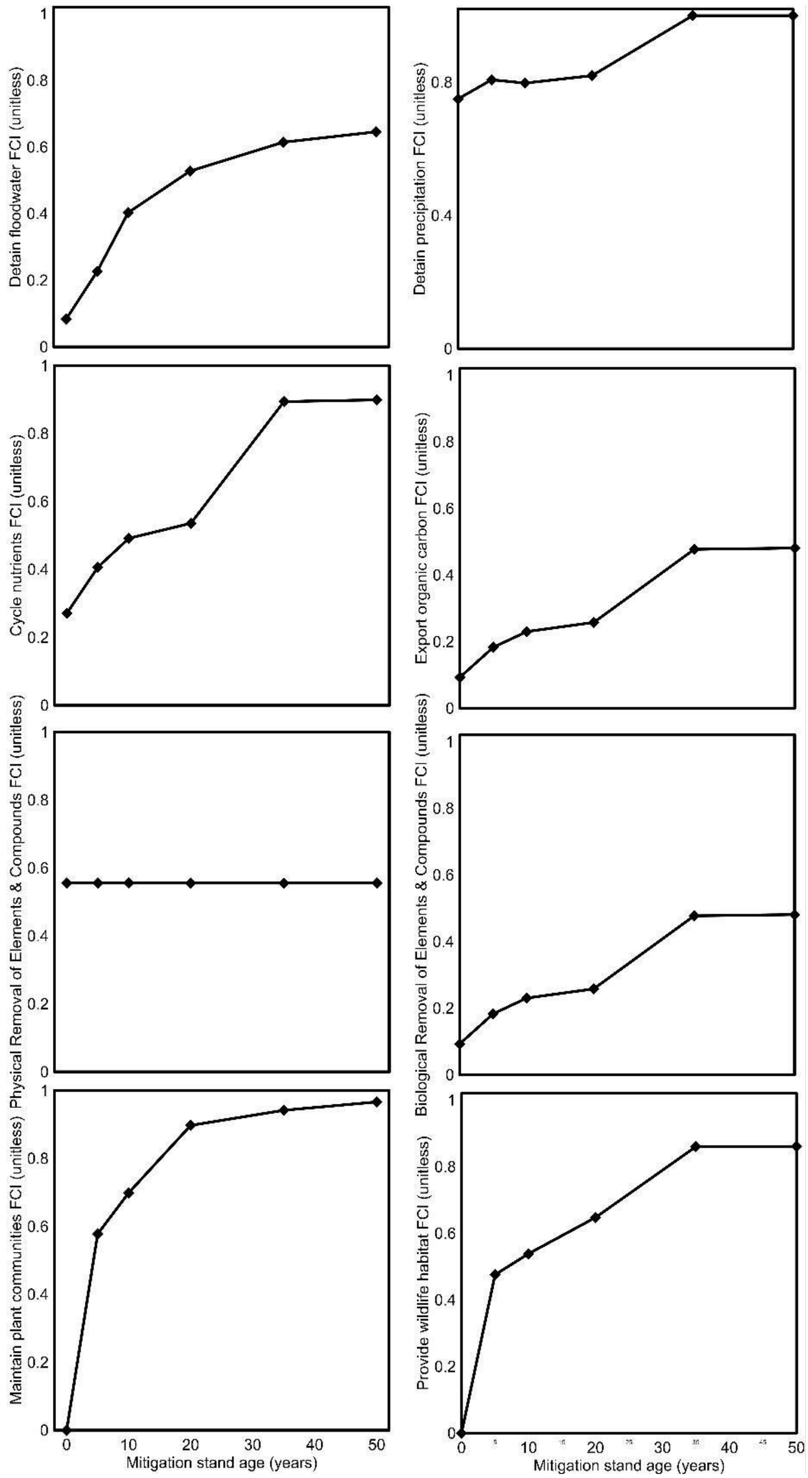

Figure 2. Compensatory mitigation milestones for HGM functions over the period of analysis.

3.5 MONITORING MITIGATION RESTORATION TRAJECTORIES AND MILESTONES

The HGM approach should be applied as part of the M&AM plan to establish baseline conditions at mitigation locations and document changes in wetland function over time. The method proven effective for identifying shifts in wetland functional capacity over multiple time intervals including short- (*e.g.*, 0 - 5 year), mid- (*e.g.*, 5 - 10 year) and long (*e.g.*, > 20 year) and implementation of a multi-year HGM assessment protocol will document functional capacity changes over the period of analysis (Berkowitz 2018).

A repeated measures approach of data collected using the HGM wetlands assessment within mitigation sites will include data gathered at mitigation sites upon acquisition and at a minimum frequency of five-year intervals during the 0 - 20-year post mitigation period and at 10-year intervals during the 20 - 50-year post mitigation period. This approach ensures that the compensatory mitigation efforts effectively offset impacts to wetland resources and inform adaptive management strategies if the mitigation sites fail to meet the milestones outlined above. The sampling design would follow the conventions outlined in Berkowitz (2018), which included the establishment of transects at each mitigation location and an average sampling rate of approximately one HGM sample plot per 50 acres. At each sampling interval, the HGM variable metrics will be determined in addition to the HGM subindex scores, FCI values and FCUs. In cases where the mitigation areas fail to meet the wetland functional milestones outlined above, adaptive management can be initiated.

3.6 MONITORING CHANGES IN WETLAND HYDROLOGY IN THE YAZOO STUDY AREA

In addition to the documentation of HGM functional responses to implementation of the proposed plan and the associated compensatory mitigation, an evaluation of potential changes in wetland hydroperiods will be conducted. The hydrology of wetlands within the study area has been identified as an area of concern, including the potential to decrease the duration or frequency of wetland hydroperiods and periods of flood water inundation. Other portions of this document identify anticipated shifts in flood durations under the proposed plan.
While hydrologic studies have been completed in the region (Berkowitz et al., 2019), additional hydrologic monitoring are needed. Hydrologic monitoring conducted using shallow groundwater wells has proven effective in identifying both hydroperiod and hydro patterns within wetlands in the study area. The goal of water table monitoring is to acquire data related to potential hydrologic changes resulting from operation of the project, provide explanatory data related to observed changes in forested wetland function, and support adaptive operation of the project to improve wetland conditions if required.

The location of monitoring sites would consider multiple factors including: 1) flood duration and frequency, 2) proximity to surface waters and other hydrologic sources, 3) availability of historic or ongoing data collection efforts, 4) site access and continuity considerations, 5) forest successional stage and substrate (*i.e.*, soils), and forested wetland condition (*e.g.*, restored vs mature second growth wetlands).

Although establishment of probabilistic sampling approaches to groundwater monitoring studies are challenging, efforts should be made to incorporate representative and/or statistically derived monitoring location selection where possible. At a minimum of 120 groundwater monitoring wells would be installed throughout the study area and triplicate monitoring locations would be established at each mitigation area. In order to link hydro patterns with measures of wetland function the HGM assessment would be conducted at five-year intervals at the location of all monitoring wells. All well installation and monitoring activities would follow the recommendations of USACE (2005). The estimated period of groundwater monitoring would extend from pre-project conditions through the project implementation, and across multiple periods of project operation.

3.7 ADAPTIVE MANAGEMENT FOR WETLAND COMPENSATORY MITIGATION

A number of adaptive management strategies exist to address wetland functional gaps identified following implementation of the proposed plan based upon data collected during monitoring activities. These strategies would be initiated if 1) the impacts to wetlands within the impact area are more severe than anticipated or 2) the estimated benefits of mitigation activities fail to achieve the milestones outlined above. The data collection and monitoring activities outlined above provide opportunities to identify the need for remedial action and determine what type of corrective actions are required to address a wetland functional shortfall. For example, if the hydrologic monitoring detects shifts in flood duration or frequency that exceed the estimates described in Table 53 in Wetlands Appendix then the unanticipated decrease in AAFCUs can be determined and addressed through implementation of additional compensatory mitigation. Also, if repeated measures HGM monitoring data demonstrates that the compensatory mitigation areas are not achieving the milestones outlined above adaptive management can conducted. For example, if mitigation locations do not display sufficient microtopography the soil surface can be contoured to create depressions that would retain water, improve habitat, and increase the wetland functional outcomes.

Three options exist to conduct adaptive management to address unanticipated impacts to wetland resources or shortfalls in mitigation performance. First, forested wetland conditions at established mitigation areas can be improved to increase functional capacity, generating additional FCUs and increasing the amount of AAFCUs provided by the mitigation lands over the period of analysis. Second, additional mitigation areas can be acquired and restored, increasing the AAFCUs generated over time. The third potential approach to increasing the performance of mitigation areas involves identifying opportunities to alter the operation of the project to increase wetland functional capacities.

A number of adaptive management techniques are available to improve wetland functions in established compensatory mitigation areas. Mitigation areas offer many opportunities for manipulation prior to seedling installation because most mitigation occurs on agricultural tracts devoid of native vegetation. For example, newly acquired fields can be shaped to increase microtopography and improve surface water storage capacity. Local hydrology can be manipulated to increase connectivity with surface water sources or decrease drainage rates through alteration of existing ditches. At a landscape perspective wetland functional score can be improved by linking forested tracts to increase connectivity with adjacent habitat. Once mitigation areas are established, active management of forest conditions may include re-planting areas subject to poor survival; selective removal or girdling trees to decrease stand density, improving conditions for adjacent tree growth, and provide for recruitment of snags/woody debris into forest stands.

Examples of specific actions that would improve functional outputs include: improved connectivity with sources of wetland hydrology (e.g., resizing culverts, maintenance of natural drainage features) to increase V_{FREQ} and V_{DUR}; expansion of adjacent forested tracts to increase V_{TRACT}, V_{CORE}, and $V_{CONNECT}$; planting of desirable flood tolerant vegetation species and select species management (e.g., invasive/nuisance species control) to increase V_{COMP}; manipulation of ground conditions to increase ponding and storage of flood/rain water to increase V_{POND}, selective thinning to improve conditions for tree growth to increase V_{TBA}, V_{SNAG}, and other variables; and the removal/incorporation of carbon sources into the system to increase V_{WD}, V_{LOG}, V_{OHOR} and other variables. Each of these activities alone would increase the functional status of wetlands. Implemented collectively have the potential to significantly improve functional wetland status within the compensatory mitigation tracts. However, the remedy selected should incorporate components which individually or collectively address the specific shortcomings identified in the HGM and hydrology monitoring phases described above. For example, if the mitigation tracts already display variable subindex score of 1.0 for V_{COMP}, additional manipulation of species composition will not result in additional increases in FCI values. One major benefit of these ground-level adaptive management strategies is that they increase the generation of FCUs without requiring the acquisition of additional mitigation acres. Also, these activities can be accomplished without altering the operation of the project.

The acquisition of additional mitigation lands may be necessary if sufficient increases in wetland functions cannot be achieved through the active management of existing mitigation areas. Any additional land acquisitions should target the landscape conditions described above and adhere to the monitoring protocols, trajectories, and milestones herein. Mitigation areas are estimated to provide 4.78 AAFCUs per acre over the 50-year period of analysis (Table 23 and 24 in the Wetlands Appendix). As a result, a wetland functional shortfall of -478 AAFCUs would require establishment of 100 acres of additional compensatory mitigation. In some cases, alternative operation of the pump station may have the potential to result in higher levels of wetland function. Considering alternative pump station operation scenarios is complex due to the competing interests of flood risk reduction, water quality management, and natural resource benefits (including wetland functions). However, in some cases changing operational procedures may be applicable to the adaptive management of wetlands. For example, the project may have the capacity to maintain water levels during excessive drought periods to support wetland hydrology without increasing flood risk to infrastructure. Also, there may be benefits to alternating higher and lower water levels to increase the export of organic carbon to downstream environments, remove additional pollutants from surface waters, and improve habitat for floral and faunal communities. Whether remedial activities occur the adaptive management of existing mitigation areas, the acquisition of additional mitigation parcels, or innovative operation of the pump station or other structures, the HGM and hydrology monitoring data provides valuable insight into the effect of any action. This targeted approach provides the best possible scenario under which to implement an adaptive management plan.

3.8 SUMMARY

A robust monitoring approach incorporating ground water hydrology and wetland functional assessment is required to conduct effective adaptive management. These approaches will need to be conducted both within the study area and at compensatory mitigation sites. Fortunately, there is substantial published data available to inform establishment of restoration trajectory milestones in support of the adaptive management approach for wetlands described above. This includes specific quantitative milestones for HGM variable inputs and forest wetland functional capacities at various stages of forest succession. Additionally, numerous management strategies exist at both landscape and field scales to increase wetland functional outcomes. The combination of available existing data and strategies for targeted remedial interventions provides an ideal opportunity to implement a M&AM plan.

SECTION 4 SUPPLEMENTAL LOW FLOW GROUNDWATER WELLS

4.1 BACKGROUND

Land-use alterations in the Big Sunflower–Steele Bayou drainage are environmental disturbances culminating over a century and resulting in stream degradation. The loss of forested riparian corridors, fine sediment accumulation in the channels, and reduction of surface flows are the principal or primary stressors to aquatic life in low-gradient warm water streams (Wang et al.1997, Wood and Armitage 1997). These stressors influence other parameters (e.g., nutrients, dissolved oxygen) in a hierarchical organization of environmental influences that determine fish composition (Dembkowski and Miranda 2012). Management of land-use disturbances, or the principal environmental variables impacting fish communities, can reverse or possibly restore stream habitat condition and recovery of the fish community.

The approach to developing measures that could potentially benefit recovery of the fish community relies on consideration of the life cycle of fishes and associated anthropogenic impairments to each life stage. Flood-induced hypoxia during the spring and early summer likely impacts successful spawning and rearing regardless of reforestation. Next, the juvenile and adult life stages that do survive through the flood season are faced with extreme low flows during the fall. Land use disturbances (i.e., accretion of sediment, lack of riparian buffers) and intermittent discharge during the fall present significant challenges across fish life cycles which can be better addressed by alternative actions.

A conceptual model is presented that addresses three principal stressors on fish communities in the Big Sunflower-Steele Bayou drainage, three management actions that can reduce or reverse the perturbations, and new associated ecological endpoints resulting from the management actions (Figure 3).

In conclusion, reforestation is only one of several methods to improve the ecological function and structure of the Big Sunflower-Steele Bayou drainage. Hypoxia during backwater events limits the value of reforesting the floodplain. Low survival of fish during hypoxic floods followed by high mortality in the fall from low water and sedimentation prevents recovery. Reforestation alone does not address other impairments in the drainage such as sedimentation and low flows. Specific management actions described herein can be implemented either independent of reforestation, or as an integrated plan of reforestation and other land management practices to improve survival and growth of the overall aquatic community during all life stages. Water level management is the focus of this plan.

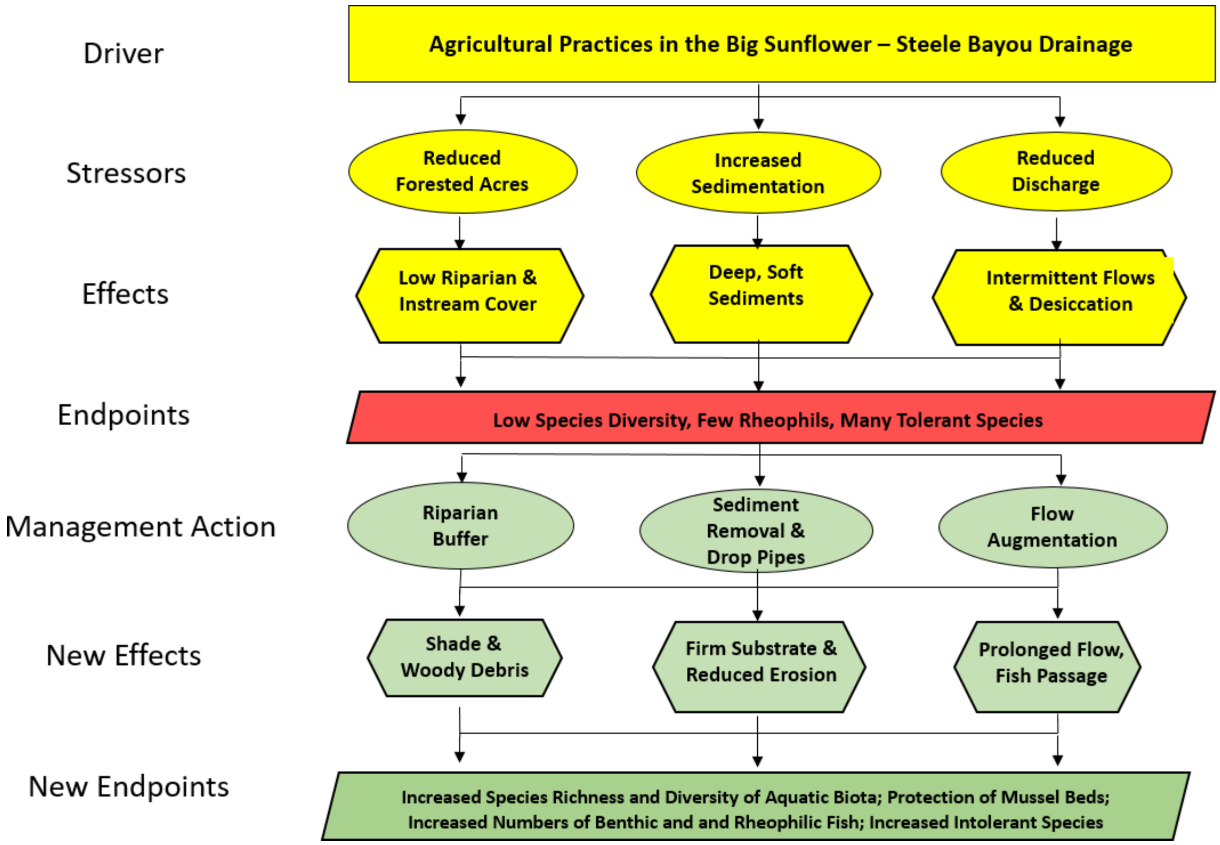

Figure 3. A conceptual model of the effect of agricultural practices and flood control in the Big Sunflower - Steele Bayou drainage on fish communities, along with management options and the endpoints of restoration or mitigation activities (Adapted from Hoover et al. 2008, Killgore et al. 2008).

The first management action addressed herein is flow augmentation, or creation of environmental flows by pumping from re-charged aquifers. Restoring environmental (perennial) flows in the Big Sunflower-Steele Bayou drainage should consider at least three criteria in an adaptive management plan:

1. Provide adequate water to avoid desiccation of established mussel beds. Mussels are widespread and abundant in the Big Sunflower-Steele Bayou drainage and include regional and federally protected species (Jones et al. 2005). Empirical relationships between river stage and wetted perimeter of mussel beds can establish minimum discharge requirements for successful life cycles or recruitment.
2. Ensure periodic fish passage flows over weirs for spawning movements and recolonization. The old Lock and Dam on the Sunflower River and other weirs in the

drainage are impediments to upstream/downstream movements of fish during low water. Environmental flows should consider the minimum water depth over the weir crest for passage of target species. The 10% elevation (90% exceedance) is 83.34, the 25% is 83.83, and the 50% is 84.77. The weir crest elevation is 83.5. Hence 75% of the year the water is 0.33 feet above the weir, and 50% it is 1.27 feet above the weir.

3. Manage hydraulic connectivity between the river channel and low-elevation floodplains or tributary mouths. Slight increases in discharge can potentially re-connect large areas of floodplains otherwise isolated during non-flowing conditions.

4.2 PURPOSE AND OBJECTIVES

The following describes the M&AM plan for a proposed supplemental low flow groundwater wells (SLFG well) installation within the YSA. It includes a brief historic perspective on the ground and surface water interaction, an objective to restore baseflow similar to twentieth century conditions, and an approach to implement the objective.

A series of SLFG wells will be installed and operated during historic low flow periods to prevent desiccation of mussel beds and improve survival and year-class strength of fishes. The goal of the wells is to restore the unregulated rivers in Big Sunflower-Steele Bayou watershed to their historical observed low flow state of the twentieth century (Figure 4). The supplemental low flow groundwater wells will ideally contribute up to 100 cfs to the streams during low flow periods that will increase wetted surface, aquatic habitat and “living space” for mussels, fishes and other aquatic invertebrates including species of special concern in the basin. Installation of the wells will be phased with one site being initially implemented and the design and implementation of subsequent wells refined based on initial site’s lessons learned.

4.3 HYDROLOGIC SETTING

Historically, rivers and tributaries within the Yazoo Basin extend down into the top of the alluvial aquifer, allowing them to supplement their baseflow during dry periods. However, the lowering of the water levels of the aquifer due to agricultural withdrawals for irrigation has impeded the capture of baseflow into the channels, especially during dry periods in unregulated streams including the Big Sunflower- Steele Bayou drainage. Streams regulated by releases from the four upstream reservoirs (Arkabutala, Sardis, Enid, and Grenada) result in perennial flows in the Coldwater-Tallahatchie- Yalobusha-Yazoo Rivers during typically dry periods. Historically, environmental flow within the unregulated streams in the Yazoo Delta has declined from the twentieth century to the twenty-first century. Figure 4 shows the annual minimum flow of the Big Sunflower River at the Sunflower gage from 1937 through 2019.

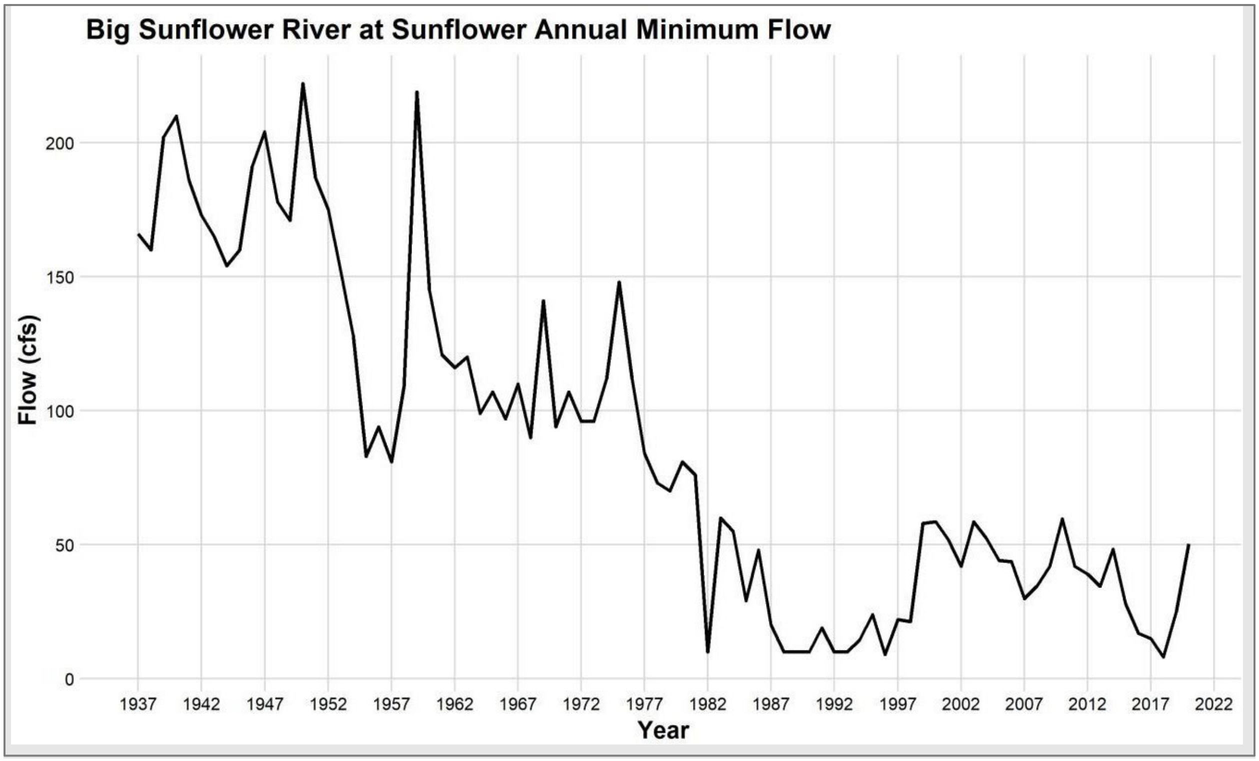

Figure 4. Annual minimum flow at the Big Sunflower River at Sunflower from 1937 through 2019.

Big Sunflower River at Sunflower was chosen as a control location because it is along one of the Yazoo Basin's major rivers and it is upstream of sensitive habitats that require significant environmental flow. From 1937 through 1975, the annual minimum flow fell below 100 cubic feet per second (cfs) only six times. After 1975, the annual minimum flow dramatically decreased and typically ranges between 10 and 60 cfs. Annual precipitation, however, has not declined over this time period. In addition to the decline in the observed minimum flow, the Yazoo Basin typically experiences a dry period during the fall season, from July through November. July through November had the lowest median flow compared to spring months. The highest median flow, 1,910 cfs, occurred in March, whereas, the lowest median flow, 115 cfs, occurred in October. The extremely low baseflows, especially during already dry periods, have been dewatering mussel beds, reducing fish diversity, and impacting other sensitive environments within the Yazoo Basin (Killgore et al. 2024). In addition, the low baseflows cause a reduction in instream wetted habitat that can directly impact fisheries and other aquatic communities in addition to dewatering portions of affected mussel beds. This aspect highlights the needs of the entire aquatic community and not just the mussel community alone. Empirical relationships between river stage and wetted perimeter of mussel beds can establish minimum discharge requirements to maintain an adequate wetted surface within the stream channel.

As a result of inadequate environmental flow, mussel beds within the Big Sunflower River are being dewatered and exposed. Supplemental well fields located in the upper watershed will provide environmental flows to the middle and lower Big Sunflower River where impacts have accrued for decades (see Aquatic Appendix, Parts 3 and 4). Mussels are widespread and locally abundant in the Big Sunflower-Steele Bayou drainage and include regional and federally protected species (Jones et al. 2005). Rheophilic fish species have declined due to low flows, the fish assemblage is highly altered compared to reference watersheds, and the majority of the fish assemblage now consists of habitat-tolerant species. Establishment of environmental flows is intended to improve the overall aquatic assemblages in the unregulated rivers of the Yazoo Basin.

4.4 APPROACH

The proposed locations of the supplemental low flow groundwater wells were chosen based on two criteria: 1) the wells are within 30,000 feet of the Mississippi River and have access to its abundant water supply and 2) the wells reside on the landside of the Yazoo Backwater levee and can provide water downstream to the mussel beds. The supplemental low flow groundwater wells would pull from the alluvial aquifer adjacent to the Mississippi River which is recharged annually. Each well is designed to pump up to 5 cfs. The locations of the proposed wells are provided in Figure 5 and the name of the watershed each well resides in is provided in Table 1.

Table 1. The names of the proposed SLFG wells and the watersheds in which they reside.

Supply Well	Watershed
Harris Bayou	Harris Bayou – Big Sunflower River
Hushpuckena	Hushpuckena River
Bogue Phalia	Snake Creek – Bogue Phalia
Deer Creek	Rolling Fork Bayou – Deer Creek
Main Canal	Granicus Bayou

Three reaches in the Big Sunflower were established to reflect benefits of low flows to endangered mussels (*i.e.*, Rabbitsfoot and Sheepnose) that occur in the upper reach between Clarksdale and Indianola. Eleven wells in Harris Bayou and Hushpuckena River watersheds would supplement low flows in this reach. Eleven wells in the Bogue Phalia Basin watershed would augment flows in the middle Big Sunflower River from just above the Little Callao gage near the Old Lock and Dam to below the Anguilla gage near Holly Bluff. Established mussel beds occur in this reach, particularly below the Old Lock and Dam, although the two endangered species have been collected in this reach. Five wells in the Deer Creek watershed would augment flows in the lower Big Sunflower reach between the Steele Bayou structure and the Old Lock and Dam through Rolling Fork Creek. Recent sampling in the lower reach did not detect the two endangered species and they are unlikely to occur. In addition, five wells in Main Canal and two in upper Black Bayou (Fish Lake Bayou) will augment flows in the Steele Bayou watershed.

The wells would only be operated during the fall low flow period after irrigation return flows cease. Irrigation returns flows from the agricultural fields maintain summer low flows in most of the stream channels. Minimum flow targets will be established for downstream locations based on the number of wells operated and will vary so that the target flows are met. The minimum flows will be established through the Monitoring and Adaptive Management Program for this project. The wells will be located in areas near the Mississippi River levee to minimize possible impacts to the alluvial aquifer. The groundwater elevation will be monitored at all sites to evaluate the impact of well usage to the aquifer. All wells will be located outside of the current zone of depression in the groundwater table. Wells will not be operated during major flood events.

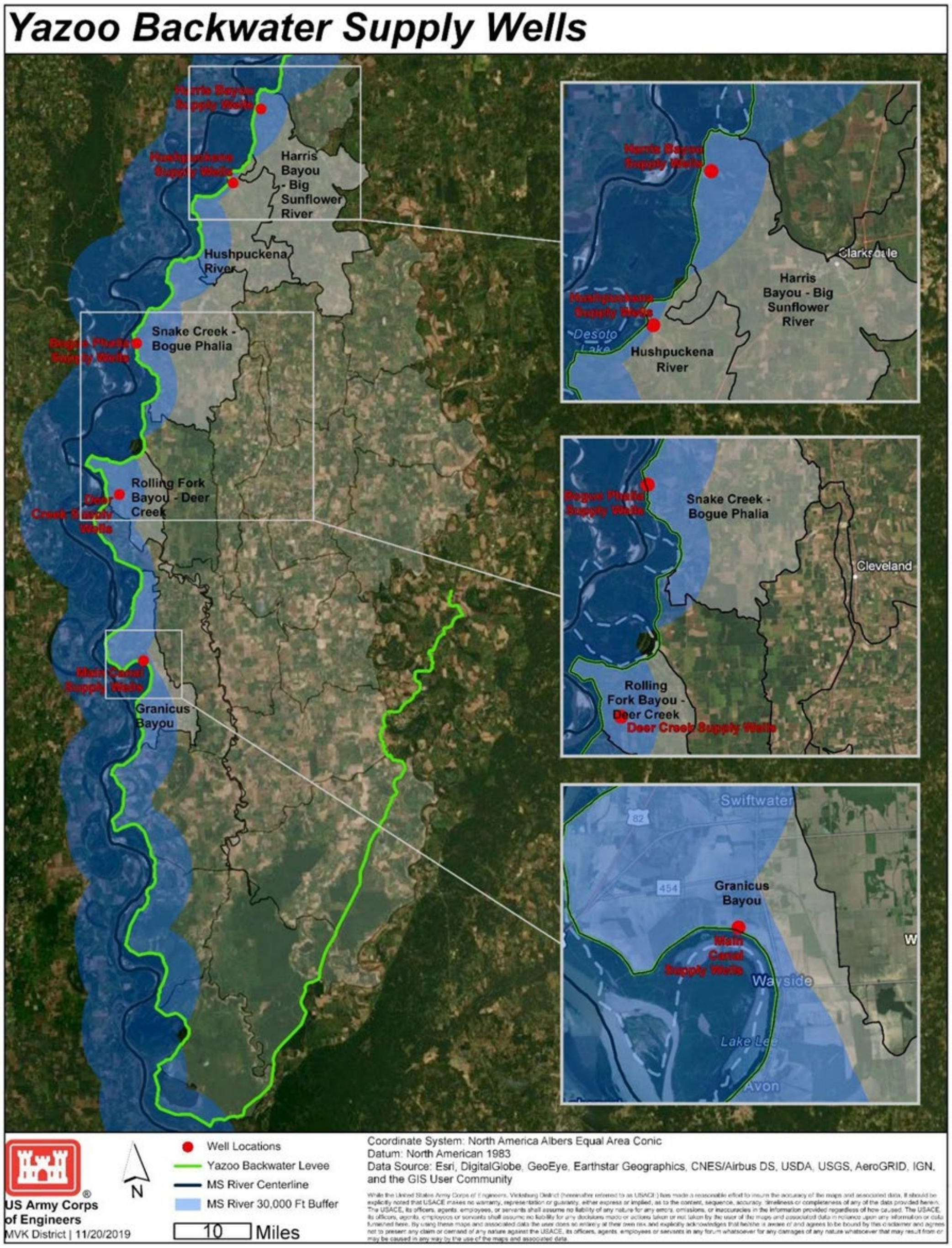

Figure 5. Favorable locations for SLFG wells were based on close proximity to the Mississippi River and residing on the east side of the Yazoo Backwater Levee.

SECTION 5 SHOREBIRDS

Compensatory mitigation measures for shorebirds primarily include seasonally inundating farmland during peak shorebird migration periods. Within a portion of the future mitigation sites, water management for shorebirds would be assessed by measuring the depths and durations of inundation during shorebird migration periods (*e.g.,* the number and length of time that agricultural areas would be covered by less than 3 inches of water, less than 6 inches of water, and deep water) and by counting shorebirds during migration periods. The assessment would occur at least once prior to each adaptive management report and cover a representative sample of seasonally inundated agricultural fields used for mitigation.

Invertebrate density would also be sampled at a portion of the mitigation sites as well as naturally inundated sites. Results would be compared to baseline data to determine if overall invertebrate density is consistent. If a deficiency occurs, adaptive management options include adjusting water holding regimes at the mitigation sites and retaining water for longer durations within the shorebird migration period. However, as the model used to determine impacts does not base impacts on food availability, any increase in mitigation acreage would be the result of a habitat availability deficiency.

SECTION 6 HUMAN ENVIRONMENT – EJ COMMUNITIES-MITIGATION MONITORING AND ADAPTIVE MANAGEMENT (M&AM) PLAN

6.1 PURPOSE

This section presents a proposed plan for mitigating the unavoidable impacts of the proposed action on the human aspects of the environment. Those impacts which could not be fully avoided or minimized are compensated for through adaptive management and mitigation. Compensatory mitigation will be provided during PED and after engaging with the affected communities. This will allow USACE to engage other agencies in the whole of government approach, account for program requirements, and meaningfully engage with EJ communities to define mitigation measures. This document will be updated with the results of the meaningful engagement.

The authority for mitigation of impacts to areas of environmental justice concerns can be found in E.O. 12898, E.O. 13985, E.O. 14008, and E.O. 14096. Further, USACE's Policy for Conducting Civil Works Planning Studies (ER 1105-2-103) identifies "Environmental Justice and Equity" as one of its guiding principles. The policy states: "Agencies should ensure that federal actions are focused on achieving environmental justice by identifying and addressing the distribution of benefits, and identifying any disproportionately high and adverse public safety, human health, or environmental burdens of projects on communities impacted by environmental justice concerns in decision documents. *Agencies must seek alternatives that would eliminate or avoid disproportionate adverse effects on these communities.* Specific efforts must be made to provide opportunities for effective public participation by communities impacted by environmental justice concerns in federal water resource planning by improving access to USACE Civil Works technical services and maximizing the reach of Civil Works projects to benefit communities impacted by environmental justice concerns" (ER 1105-2-103, 1-20 e. (2). *emphasis added.* This is further specified when addressing the avoidance of adverse impacts. "Formulation should seek to avoid adverse environmental, economic, and/or social impacts; however, trade-offs involved in addressing complex water resources problems mean that some alternatives may involve actions that produce unavoidable impacts. In these cases, alternatives should seek to avoid, minimize, and compensate these impacts. Social impacts — particularly those impacting Tribal and Indigenous populations, *or communities impacted by environmental justice concerns* — should also be avoided, minimized, and mitigated to ensure benefits accrue to those communities." (ER1105-2-103 2-4 c. (7). *emphasis added.*

6.2 OBJECTIVE

The Monitoring and Adaptive Management Plan has 4 primary goals:

1. Engagement and Outreach
2. Equitable distribution of benefits
3. Continued Community Cohesion
4. Monitoring and Adjustment to ensure goals 1-3 are being acceptably realized.

Goals number 1 and 2 are based on USACE policy guidance for engagement and outreach that "…should seek to proactively increase the communication with and participation by communities impacted by environmental justice concerns in the process to ensure that their needs are included and that benefits can be equitably distributed" (ER 1105-2-103 2-4 a. (1)(c). Goal 3 is set to maintain the benefits of the social network that was in place at the time of project implementation. The final goal (#4) is a means to stay active with this engagement and to continually evaluate if the first three goals are being met.

Success criteria for the M&AM Plan for EJ Communities are not just removing risk from the floodplain, but also transitioning those left out of the recommended plan, and already impacted by environmental and social burdens, to a less flood prone area while maintaining current cultural practices.

6.3 DEVELOPMENT OF MITIGATION ACTIONS, MILESTONES, AND METRICS

The M&AM plan assumes that compensatory mitigation would be initiated under the proposed plan using similar approaches applied under previously authorized and Implemented NS Plans (e.g., Neuse River Basin Flood Risk Management Integrated Feasibility Study and Environmental Assessment, Fire Island Inlet to Montauk Point Reformulation Study General Reevaluation Report and Environmental Impact Statement Suffolk County, New York, etc.). This includes leveraging national assets, using best management practices, and utilizing the standard implementation milestones to both inform the engagement with EJ Communities and as a guide to formulating metrics to evaluate the success of the to-be-developed Mitigation Measures.

1. First comes the development of Mitigation Measures based on EJ Community engagement aimed at meeting the goals M&AM goals.

2. As the measures/actions are developed, USACE will fold the milestones of existing Implementation Plans: 1) Defining the Target Design Elevation, 2) Determining Eligibility: the Two Step Eligibility Process, 3) Execution of Recordation of Agreement to Elevate, 4) Review of Eligible and Ineligible Project Costs, 5) Commencement of Structure Elevation/Floodproofing/Acquisition/Relocation, 6) Notice of Construction Complete, 7) Conclude Federal Action.

3. Leveraging National Assets for Success: The U.S. Army Corps of Engineers (USACE) recognizes that there are unique challenges related to implementing a relatively large nonstructural plan. Because of this, USACE has proactively leveraged national experts in the planning, design, and construction of nonstructural measures. Within the enterprise, these groups include the USACE National Nonstructural Committee, Flood Risk Management Center of Expertise, as well as project teams that are currently working to implement similar projects (e.g., Fire Island Inlet to Montauk Point General Reevaluation Study, authorized in the Water Resources Development Act of 2020). The non-Federal (NFS), the North Carolina Department of Environmental Quality (NCDEQ), have also provided valuable information pertinent to the project. The USACE places a priority on continuing this coordination during Preconstruction Engineering and Design (PED) and construction, and sharing lessons learned with other USACE teams.

4. Formulate Metrics to track the successful implementation of the Mitigation Measures. An example may be recording the number of residents in areas of EJ concern whose homes relocated, elevated, or acquired. These metrics will be developed through engagement to ensure they capture the intent of the mitigation measures.

6.4 MONITORING IMPLEMENTATION AND SUCCESS OF MITIGATION MEASURES

Establish a Point of Contact within USACE who is responsible for tacking implementation and provide regular updates to the EJ Community to ensure long-term success of the defined mitigation measures.

It should be anticipated that there is a mechanism to provide corrective action if the metrics are not being achieved or if otherwise the program is not being implemented in accordance with the current plan.

Monitoring should occur over the lifetime of project implementation and periodically assessed to determine if it is still meeting the needs.

6.5 ADAPTIVE MANAGEMENT OF EJ MITIGATION MEASURES

Adaptive Management will center around evaluating if the program is on-track to meet the establish metrics in a manner that accounts for USACES commitments to EJ Communities.

Some specific issues to be aware of are:

- Evaluating the impact of voluntary buyouts upon the place-based values of communities, acknowledging that buyouts are usually arranged around an individual basis, rather than a whole community basis.

- Ensuring that buyouts provide equitable benefit. To become more equitable, benefits need to be for the whole community--property owners, renters, those without title—how it can the community look the same afterwards?

- Ensuring that those individuals who are bearing the burden of project implementation shape a part of the outcome.

- Asking the question: what might re-settlement support look like if it takes into account on-going cultural practices? Consider affects to “receiving” communities, as well.

- Not learning from the history of forced relocations, for example the Department of Housing and Urban Development’s Hope VI program. Renters never returned and the success/failure of outcome was never tracked to feedback into program success/failure.

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