Appendix B
Civil Engineering

PAGE INTENTIONALLY LEFT BLANK

Table of Contents

1 Existing Conditions

1.1 Project Location and History

The Oakwood Bottoms, consisting of approximately 13,500 acres of bottomland forest and wetlands, is located within the Shawnee National Forest in the Mississippi River floodplain on the left descending bank of the Mississippi River between River Miles (RM) 73-84 in Jackson County, Illinois. The Oakwood Bottoms HREP focuses on the 4,700-acre Greentree Reservoir portion of Oakwood Bottoms (Oakwood Bottoms Greentree Reservoir, or OBGTR). (Figure 1).

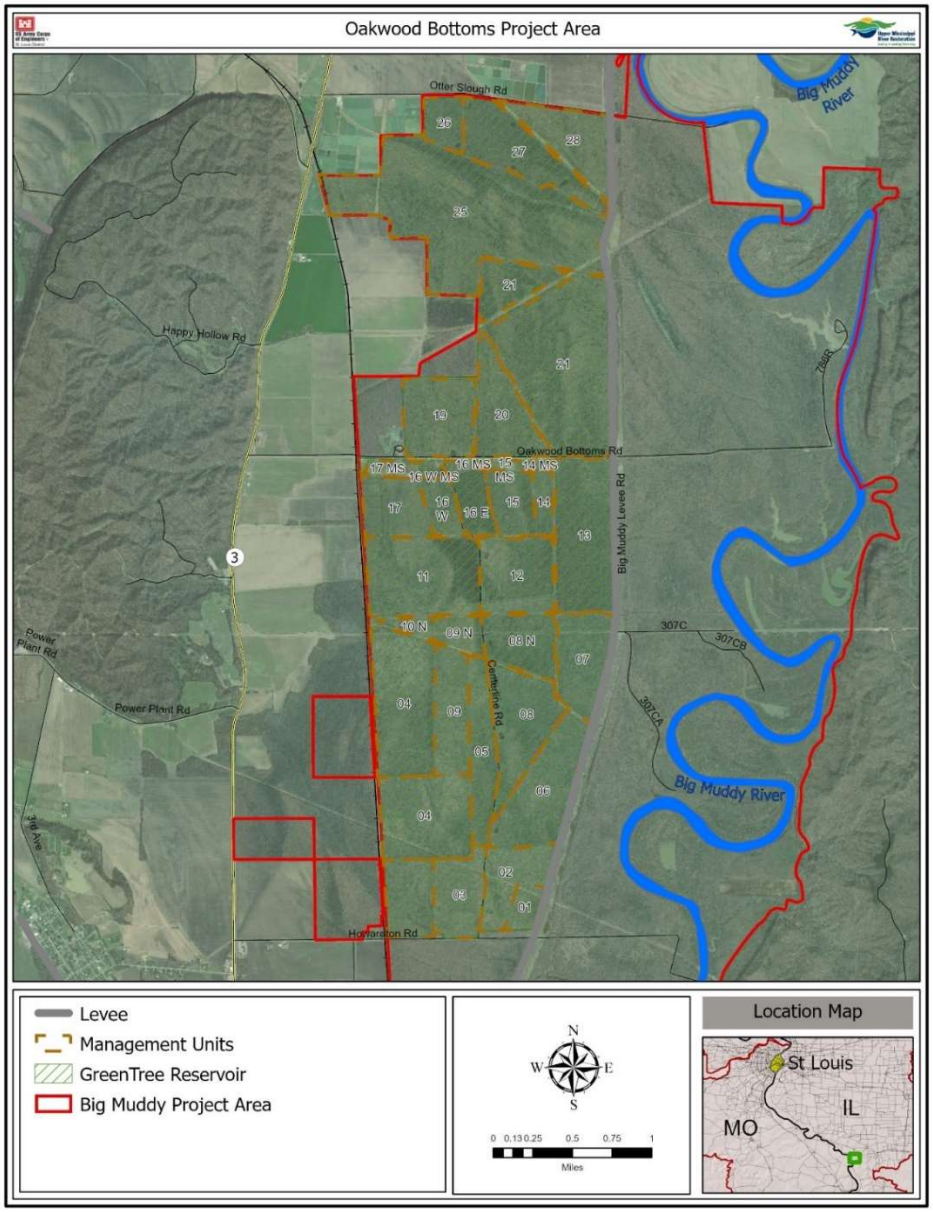

Figure 1 – Study Area Map

The majority of Oakwood Bottoms Study Area was intensively farmed and or grazed prior to USFS acquisition in the late 1930s. As part of the early agricultural development, drainage ditches, fences and buildings were constructed by the landowners. The Grand Tower Levee, built in 1945, separated the current-day OBGTR from the Big Muddy River floodplain, which initiated a hydrologic functionality change for lands west of the newly constructed levee system.

1.2 Existing Features

The Forest Service utilizes the management units created by the construction of berms around the perimeter of the management units along with channels, ditches, and water control structures to manage water levels within the OBGTR. Additional details on the existing features, not described in the following paragraphs can be found in the other engineering appendices.

1.2.1 Berms

The existing berms vary in height and width. They are all wide enough for vehicle access and are used by maintenance staff to access drainage structures for operation and to access other areas of the reservoir for maintenance. Many of the berms have ditches adjacent to them and in some locations there are two berms with a channel in the center of them. Only one of the existing berms has surfacing which is the berm that also functions as Centerline Road. Figure 2, Figure 3, Figure 4, and Figure 5 show the typical existing berms found in OBGTR.

Figure 2 – Existing Berm with Adjacent Ditch

During a field site visit, Operation and maintenance (O&M) staff for the Forest Service reported issues with the berms “melting” or eroding away. From observations during the site visit and further discussions with Forest Service staff it was determined the erosion is likely caused by two events. One event is overtopping of the berms. The Forest

Service has limited staff to operate the large number of management units within OBGTR, combined with limited to no freeboard on the berms. This results in overtopping of the berms if adjustments are not made in time to the water control structures as the management units are flooded. Overtopping can also occur if the units are flooded, when the levee district gravity drains are closed due to high water, thus not allowing water out, and interior rain causes the level of waters to increase within the management units, overtopping the berms. Providing adequate free board and access to the berms and water control structures will reduce the occurrence of the first event causing erosion to the berms. The second event which causes erosions is due to the vehicles and maintenance equipment (mowers, backhoes, etc.) traversing the berms often times during a saturated condition. Many of the berms rarely dry out due to the tree canopy shading which leads to a saturated condition most of the time. Providing surfacing on berms used for access as detailed in section 2.3 will reduce the occurrence of the second event causing erosion of the berms.

Figure 3 – Existing Berm

Figure 4 – Existing Berms with Channel in Center

Figure 5 - Centerline Road

1.2.2 Channels and Ditches

The dimensions of the existing channels and ditches vary. They are typically either v-shaped or trapezoidal. Many of the existing ditches have berms adjacent to them. The material excavated to create the ditches was used to construct the berms and it provides a means to convey water out of the units. Existing channels are used for both

drainage and to convey water to fill management units. See Figure 6 and **Error! Reference source not found.** for photos of existing channels.

Figure 6 - Existing Channel

Figure 7 - Existing Channel, Undersized and Overgrown with Vegetation & Trees

1.3 Survey Data

1.4 Surveys

The existing ground surface used for this report was obtained in 2015. The survey was

completed by aerial Light Detection and Ranging (LiDAR) equipment by a third-party contractor. The data was collected in the horizontal datum of North American Datum of 1983 (NAD83) and the vertical datum of North American Vertical Datum of 1988 (NAVD88). The projection was the Universal Transverse Mercator (UTM) Zone 15 North with meters as the unit of length. To utilize the bare earth ground surface data for the project, the ground surface was converted to Illinois State Plane West Zone in units of US Survey Foot.

A planimetric and topographic survey was also conducted by Bowen Engineering & Surveying to identify and provide data for all of the culverts and existing water control structures. The survey was conducted in July of 2018. The data was collected in the horizontal datum of North American Datum of 1983 (NAD83) and the vertical datum of North American Vertical Datum of 1988 (NAVD88). The projection was the Illinois State Plane West Zone with units of US Survey Foot.

Additional surveys will need to be obtained during PED. The Ducks Unlimited Organization has modified some of the berms and added other features since the 2015 LiDAR was obtained. The additional surveys will need to include land based topographic surveys to better define existing berm toes, channel bottoms, water control structures, other planimetric features, etc.

1.5 Access

Existing access to OBGTR is available from several public roadways. On the North end access can be made into OBGTR from several locations off of Otter Slough Road. Oakwood Bottoms Road provides access to the reservoir in the center. Howardton Road is on the south end of OBGTR and provides access into the reservoir through its connection to Centerline Road and the Levee Road. Centerline road is located in the center of OBGTR and runs from Howardton Road on the south end to Oakwood Bottoms Road. The Levee Road is located on top of the Grand Tower Levee and is located on the east end of the project area. OBGTR can also be accessed at various location from the Levee Road. See Figure 1 for a general location of the roadways which can be used for access.

All of the existing roadways will used for access during construction. If needed, use of the Levee Road for construction access would need to be coordinated with the Grand Tower Drainage and Levee District. In addition, existing berms and berms to be constructed will also be utilized for access. Surfacing will need to be added to harden the surface for construction traffic if it does not already exist. The surfacing used for construction that will also be needed for future operation and maintenance purposes will be left in place at the completion of construction.

2 Measures

2.1 General Design Information

All feature designs were developed using Bentley OpenRoads Designer Software, from which hydraulic models were developed and quantities were calculated. For the features in each alternative, the cross sectional areas, lengths, and areas were

calculated from OpenRoads to determine quantities for each feature. Quantities for each alternative can be found at the end of this appendix. The Feasibility Level Design (FLD) on the Tentatively Selected Plan (TSP) utilized additional 3-D modeling in OpenRoads Designer to develop more accurate quantity estimates and to ensure constructability of the features. Refinements made to the TSP as part of the FLD are described in the below paragraphs. Further refinement of the 3-D model will be completed during PED.

All features of the project will be designed according to the applicable USACE Engineering Manuals and standard engineering practice. Lessons learned from prior UMRR projects and UMRR design handbook will be incorporated.

2.2 Berm Modifications

2.2.1 Berm Removal

Berm removals consist of removing the berm down to the elevation of the surrounding grade to allow for water to sheet flow across the degraded berm footprint. Berms will be stripped prior to degrading and the stripped material will be stockpiled for use as final dressing on the degraded berm footprint. The degraded berms will not be seeded as they will naturally vegetate as seeding and other organic material is deposited when the units are flooded. Material from the berm removals will be used to fill in adjacent ditches and elsewhere on the site to construct other embankment features.

Table 1 - Summary of Berm Removal Quantities

Alternative	Length (Linear Feet)	Cut Volume (CY)	Fill Volume (CY)	Stripping (Acre)
Minimum	33,800	75,500	38,000	29
Maximum	71,700	138,600	101,700	64
Forest Service Preferred (TSP)	61,900	116,600	69,000	53
FLD on TSP	59,200	82,700	70,000	94

The decrease in cut volume and increase in stripping quantity for the FLD was due to differences in the assume section for the TSP alternative and the actual quantities determined from the 3-D model for FLD.

2.2.2 Berm Enhancements

Berm enhancements will consist of additional embankment being added to existing berms to allow for appropriate inundation depths with adequate free board within the management units to prevent overtopping of the berms. Berms will have a minimum top width of 12 feet. Berm side slopes will be a minimum of 1 Vertical to 3 Horizontal to allow for maintenance equipment to traverse the slopes. 1 Vertical to 4 Horizontal slopes were assumed for quantities. The side slope grades will be further refined and determined during PED when further geotechnical analysis is completed. Trees and

other large diameter vegetation will be removed within the berm raise footprint along with grubbing of the foundation soils. Berms will be stripped prior to raising and the stripped material will be stockpiled for use as final dressing on the raised berms. The berm raise footprint and other associated disturbed areas will be seeded.

Table 2 - Summary of Berm Enhancement Quantities

Alternative	Length (Linear Feet)	Fill Volume (CY)	Clearing & Grubbing (Acre)	Stripping (Acre)	Seeding (Acre)
Minimum	0	0	0	0	0
Maximum	39,000	19,100	5	20	20
Forest Service Preferred (TSP)	40,100	18,300	5	20	21
FLD on TSP	86,300	60,000	14	55	21

The increase in length, cut volume, clearing and grubbing, and stripping quantities for the FLD was due to an increase in length of the berms requiring enhancement and additional berms which needed to be raised due to refinement of the hydraulics model and design, and due to differences in the assume section for the TSP alternative and the actual quantities determined from the 3-D model for the FLD.

2.2.3 Berm Additions

Berm additions will consist of embankment placement to create berms for management unit boundaries. Embankment will be constructed to the required elevation to allow for appropriate inundation depths and adequate free board in the sub-units to prevent overtopping of the berms. Berms will have a minimum top width of 12 feet. Berm side slopes will be a minimum of 1 Vertical to 3 Horizontal to allow for maintenance equipment to traverse the slopes. 1 Vertical to 4 Horizontal slopes were assumed for quantities. The slope of the side slopes will be further refined and determined during PED when further geotechnical analysis is completed. Trees and other large diameter vegetation will be removed within the new berm footprints along with grubbing of the foundation soils. New berms footprints will be stripped and the stripped material will be stockpiled for use as final dressing on the new berms. The berm additions and other associated disturbed areas will be seeded.

Table 3 - Summary of Berm Addition Quantities

Alternative	Length (Linear Feet)	Fill Volume (CY)	Clearing & Grubbing (Acre)	Stripping (Acre)	Seeding (Acre)
Minimum	700	14,400	1	2	2
Maximum	22,600	47,700	14	16	16

Forest Service Preferred (TSP)	13,000	26,100	8	9	9
FLD on TSP	10,700	10,100	5	6	6

The decrease in quantities for the FLD was due to a decrease in length of the berms additions as a result of refinement of the design during FLD.

2.3 Surfacing

Surfacing will be added to the top of all berms which will be utilized to access water control structures. The surfacing will consist of 4 inches of crushed stone surfacing on top of 12 inches of a larger crushed stone base. The two layers of stone construction method has been used successfully on other ecosystem restoration projects in the St. Louis area to provide a more resilient surface that is able to resist some overtopping. During PED the risk of berms overtopping will be further considered and surfacing type will be adjusted if necessary. The width of the embankment at the top of the berms which have surfacing will be increased to maintain a minimum 12 foot wide drivable surface.

Table 4 - Summary of Surfacing Quantities

Alternative	Length (Linear Feet)	Crushed Stone Base (TONS)	Crushed Stone Surface (TONS)
Minimum	34,000	31,000	10,600
Maximum	44,000	40,000	13,800
Forest Service Preferred (TSP)	33,000	30,000	10,300
FLD on TSP	48,500	40,000	14,000

The increase in length and stone for the FLD was due to an increase in length of the berms requiring surfacing due to refinement of the design.

2.4 Channels to Increase Water Conveyance

Channels, both new and with modifications, are required to increase water conveyance. Construction of channels will consist of excavation of material to the required depth and grades. Channels will vary in dimensions but will be either v-shaped or trapezoidal. Dimensions will be based on the required capacity of the channel. Assumptions were made for the dimensions of the channel based on output from the hydraulic model and engineering experience. Those assumptions are documented in the quantities. Slopes will be 1 Vertical to 3 Horizontal or flatter to meet operation and maintenance requirements. Trees and other large diameter vegetation will be removed within the

footprints along with grubbing of the foundation soils. New channel footprints will be stripped and the stripped material will be stockpiled for use as final dressing. The channels will not be seeded as they will natural vegetate as seeding and other organic material is deposited when the management units are flooded.

Table 5 - Summary of Channels to Increase Water Conveyance

Alternative	Length (Linear Feet)	Cut Volume (CY)	Clearing & Grubbing (Acre)	Stripping (Acre)
Minimum	0	0	0	0
Maximum	9,300	54,200	6	10
Forest Service Preferred (TSP)	11,300	51,600	5	10
FLD on TSP	111,400	60,500	19	40

The northern units will not drain to the pump station. Their only means of draining is the northern most gravity drain in the project areas. The team considered adding a channel to drain the northern units to the pump station. The channel was not included for several reasons. The northern most gravity drain is closed less frequently making drainage of the northern units through it more frequent. The UFW stated “the northern units are of higher ground and usually drain off faster and are not impacted in the same way as the southern units are.” Construction of ditch from the northern units to the pump station would have required removal of large number of trees offsetting the benefit gained. Placing the ditch adjacent to the levee would not be possible as it would adversely affect the performance of the levee.

During FLD, additional berms were added adjacent to the south and east berms within many of the units. These berms were added to ensure drainage of the units as the projects site generally drains toward the south-east. The decision to include the additional berms was based on results from the refined hydraulics model and from observational feedback from USFS, O&M staff. The increase in all quantities for channels for the FLD was due to the additional channels added to ensure drainage of the sub-units and due to differences in the assume section for the TSP alternative and the actual quantities determined from the 3-D model for FLD.

2.5 Water Control Structures

Water control structures will consist of reinforced concrete pipe and flared end sections or gates if needed to control water within the management units. For this report it was assume concrete pipe would be used due to O&M considerations, unknown soil conditions, and other considerations. All of the existing pipes are corrugated metal and the Forest Service has reported issues with the ends of them being collapsed due to mowers and other maintenance equipment running over the ends. This damage was

observed during site visits and it reduces the capacity of the pipes. Concrete pipe would limit the damage caused by mowers and other equipment. Corrosion of the existing corrugated metal pipes was observed during the site visit which impacts the life span of corrugated metal pipes without the proper coatings. Concrete pipe is not subject to corrosion and will ensure the pipes last the life or the project if corrosive soils are present. Soil test can be conducted during PED to determine the corrosiveness of the soil and to determine the appropriate coating to use for corrugated metal pipe. Cost, sponsor preference, soil conditions, and O&M considerations of the pipe materials will be considered during PED and other materials for pipe such as corrugated metal pipe will be considered. Plastic pipe such as HDPE will not be utilized due to the controlled burns that are utilized by the Forest Service. Plastic pipe could potentially melt during a controlled burn. The water control structures will be constructed by excavating down to the required grades, placing the pipe and structures, backfilling, and seeding the disturbed areas. Since the reservoir is fairly flat and the berms are not very tall, multiple pipes or the height of the embankment may need to be increased over the top of the pipes to prevent live loads from crushing the pipes. This will be evaluated further during PED.

Table 6 - Summary of Water Control Structures

Alternative	Each	Diameter of Pipes	Length (Linear Feet)	Excavation (CY)	Backfill (CY)	Bedding (CY)	Headwalls	Flared End Sections
Minimum	14	36"	560	900	700	60	9	19
Maximum	37	18"-48"	1,470	1,900	1,400	140	28	46
Forest Service Preferred (TSP)	35	18"-48"	1,430	1,900	1,400	140	28	42
FLD on TSP	30	12”-48”	1,750	2,300	1,700	170	11	49

The decrease in the number of water control structures for the FLD was due to refinements in the design and optimization of system due to further refinement of the hydraulics model. The increase in length, excavation, backfill, and bedding quantities was due to changes in locations of structures and refinement in the actual lengths of structures as part of the FLD.

2.6 Removal of Existing Water Control Structures

Removal of existing water control structures will consists of excavating down to the structures and removing them. They will be salvaged or hauled off site and disposed of in accordance with all state and federal regulations. In some locations the diameter of the existing pipe is undersized which will require removal and replacement of the pipe with a larger diameter pipe. New structures will be constructed in place of the existing

structure or the area will be backfilled with embankment and seeded if a new structure is not needed at the same location as the old structure.

Table 7 - Summary of Removal of Existing Water Control Structures

Alternative	# of Structures
Minimum	14
Maximum	62
Forest Service Preferred (TSP)	62
FLD on TSP	62

2.7 Pump Stations

Pump stations will require excavation and grading for access, pump station pad, discharge pipes, and intake channels. Site layouts will be further defined as design progresses during PED. See Mechanical, Electrical, and Structural Appendices for additional details on the pump stations.

Table 8 - Summary of Pump Station Quantities

Alternative	# of Pump Stations
Minimum	0
Maximum	2
Forest Service Preferred (TSP)	1
FLD on TSP	1

2.8 Well Pumps

There are 11 existing well pumps which provide water to the units. In addition to the existing well pumps, additional well pumps will be constructed to provide the needed water supply to fill the management units. The hydrologic analysis determined how many additional wells pumps are needed to supplement the existing well pumps for each alternative. The additional well pumps are needed to fill the units within the acceptable time frame. See Appendix K, Hydrologic and Hydraulic, for additional information on the analysis to determine the number of additional well pumps needed for each alternative. Table 9 below summarizes the number of well pumps needed for each alternative. Water supply wells will require access for operation and maintenance. All of the well pumps are located adjacent to berms. The berms will be used to access

the well pumps. The areas surrounding the well pumps may need to be elevated to prevent inundation and to maintain access to the well pumps when the management units are flooded. Site layouts for well pumps will be further defined during TSP refinement and PED. Some piping will be required to distribute the water from the well pumps to the correct units. Piping will be buried under ground and in berms where feasible. The location of piping will be determined as the design is more detailed during PED. See the Mechanical and Electrical Appendices for additional details on the water supply well pumps.

Figure 8 – Recently Constructed Water Supply Well

Table 9 - Summary of Well Pump Quantities

Alternative	# of New Well Pumps
Minimum	0
Maximum	5
Forest Service Preferred (TSP)	4
FLD on TSP	6

The increase in the number of well pumps for the FLD was due to refinement of the hydraulics model during FLD.

2.9 Wildlife Openings

Wildlife opening areas will consists of selected removal of trees and removing of woody debris. Specific trees to be removed in the wilidlife openings. Individual trees for removal will be finalized during construction and will be identified by the contractor based on specifications or by USACE and USFS foresters during construction. The trees will be cutoff at ground level and stumps will be ground if necessary. None of the

trees below the surround grade will be removed. Existing vegetated debris and any debris created by tree removal will be removed from the site or mulched on site. Removing of debris is necessary to provide access for O&M equipment after completion of the project. The boundaries of the open wetland areas were identified based on aerial photograph and USFS ground based knowledge. The boundaries will need to be refined during PED.

Table 10 - Summary of Open Wetland Areas

Alternative	Selective Clearing & Debris Removal (Acre)
FLD on TSP	124

Open Wetland Areas were added during FLD due to refinement of the design.

2.10 Moist Soil Unit Enhancement Areas

The USFS has issues with maintaining the existing moist soil enhancement areas due to poor drainage. The moist soil enhancement areas will need regarded to drain toward the south-east. They are relatively flat and more precise grading will be required. The tolerance for grading will have to be adjusted in the earthwork specification during PED to ensure the tolerances are tight enough to achieve drainage toward the south-east. Sub-units F-3MS, F-4, and F-4MS will incorporate a tree screen on the northern side to provide a buffer for wildlife between the roadway and the sub-units. The buffer is assumed to be 50 feet wide and will be refined during PED. The ensure survivability, the trees will be placed on berm to elevate them out of the moist soil enhancement areas.

Alternative	Regrade to Drain (Acre)	Clearing & Grubbing (Acre)
TSP	87	34

Moist soil enhancement areas were added during FLD due to refinement of the design.

3 Borrow and Disposal

All borrow is anticipated to come from onsite material. Excavated material from berm degrades, ditches, and other excavations will be used for embankment material. Any excess or unsuitable material from excavations will be wasted on site. Material will be spread adjacent to the features it was excavated from in a manner that will not inhibit the flow of water across management units.

4 Utilities and Relocations

No utility relocations are anticipated. Utility Geographic Information System (GIS) Databases of the area were reviewed and the only known utilities are overhead power lines. One line goes north-east across the top third of the project area. A second line

runs east-west across the bottom third of the project area. A third lines runs north-east across the bottom of the project area. Further investigation and surveys will be needed during PED to determine if any other utilities are located within the footprint of constructed features.

5 Right of Way

It is not anticipated any right of way will need to be acquired for the project. All project features will be constructed on property owned by the Forest Service. All access to the project will be from public roadways. A railroad runs along the west side of the project area. Feature alignments will be located so none of footprint of the features are on the railroad right of way. Coordination will be needed with the levee district for pump station discharges over the levee and any new accesses from the levee road. Potential contractor staging areas have been identified. They are all located on existing lands owned by USFS. Areas were chosen based on susceptibility to flooding, location within the refuge and to project features, accessibility, size, and areas already cleared of trees and vegetation. See Figure 9 below for location of the staging areas.

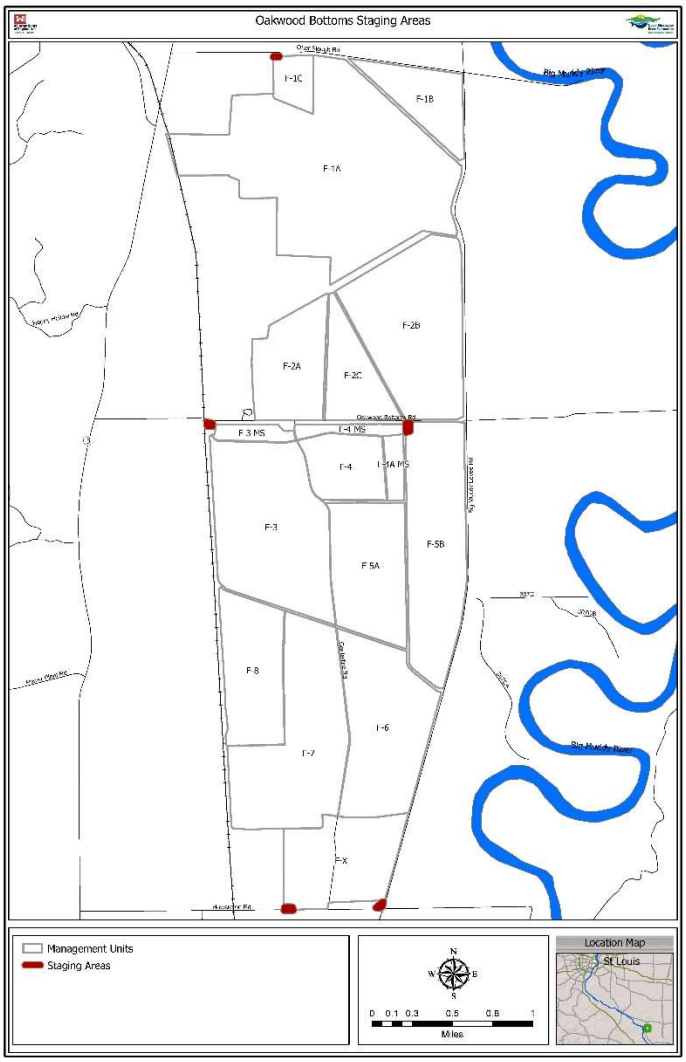

Figure 9 - Contractor Staging Areas

6 Cultural Areas

There are several culturally sensitive areas that will need to be avoided. Two of the areas are located in unit F-3MS. F-3MS will be graded to drain as detailed in paragraph 2.10 outside of those 2 areas. The other area is located unit F-X. The new berm will be constructed around the culturally sensitive area.

7 Other Items to Address During Preconstruction Engineering and Design (PED)

There are several items, not stated in the above paragraphs, which will need further investigation as more detailed design is performed and will be addressed during PED. Those items include the following:

- In the moist soil units the hydraulics model shows water flowing to the north but the Forest Service Personnel have observed it flowing to the south. A site visit

confirmed water ponding on the south end of the moist soil units. This will need to be investigated further during PED to determine if ditches should be placed on the north or south ends. An alternative would be to re-grade the moist soil units to get them to drain toward the desired direction.

- The northern end of the Centerline Road is not elevated and floods frequently, making it inaccessible when needed for operation and maintenance. During PED it will need to be evaluated to see if raising the road, adding ditches, or relocating it to adjacent berms will be the most economical solution to provide the accessibility the Forest Service needs to operate and maintain the project.

REFERENCES

US Army Corps of Engineers. (1998, March). Engineer Manual 1110-2-2902. *Engineering and Design Conduits, Culverts and Pipes*.