NAVIGATION AND ECOSYSTEM SUSTAINABILITY PROGRAM

LOCK AND DAM 22 FISH PASSAGE IMPROVEMENT PROJECT PROJECT IMPLEMENTATION REPORT WITH INTEGRATED SUPPLEMENTAL ENVIRONMENTAL ASSESSMENT

SEPTEMBER 2021

US Army Corps
of Engineers®
Rock Island District

Lock and Dam 22 Fish Passage Improvement Project
Project Implementation Report and Integrated Supplemental Environmental Assessment

ERRATA
April 2022

1. Executive Summary, page 2, second and last two sentences in last paragraph have been deleted and replaced with the following sentences:

The Project First Cost for Alternative 9 is $138,731,000 at a FY 2022 price level (Oct 2021). When interest during construction is added, the total investment cost is $142,842,000.

2. Section 6.6.1, page 117, paragraph has been deleted and replaced with the following:

The project first cost for Alternative 9 is $138,731,000 at a FY 2022 price level (Oct 2021). The costs are expressed as Project First Costs and include construction, contingencies, engineering, preconstruction engineering, and design, and construction management. When interest during construction is added, the total investment cost is $142,842,000. The more refined cost estimate also involved refining quantities, an Abbreviated Risk Analysis to determine contingencies, Micro-Computer Aided Cost Estimating System (MCACES), and Total Project Cost Summary (TPCS) to determine present value costs. Table 15 shows the estimated cost by account. The total project cost fully-funded amount is $156,246,000 which is the project first cost escalated to the mid-point of construction. The detailed estimate of the project design and construction costs are provided in Appendix C, *Cost Estimate*; however, due to the sensitivity of providing this detailed cost information, this material will be omitted in the public document. (Note: The values between MCACES and TPCS reports have a negligible difference due to rounding calculations in the MCACES program.).

3. Section 6.6.1, page 118, Table 15 has been deleted and replaced with the following:

Account	Item	Project First Cost
06	Fish and Wildlife Facilities	$98,233,000
01	Lands and Damages	$0
	Subtotal	$98,233,000
30	Preconstruction, Engineering & Design	$28,889,000
31	Construction Management	$11,609,000
	Subtotal	$138,731,000
	Interest During Construction	$4,110,000
	Total Investment Cost	$142,842,000
	Annualized Project Costs	$4,788,000
	Annual OMRR&R	$208,000
	Total Annual Costs	**$4,996,000**
	AAHU Gain	234.6
	Cost per Average Annual Habitat Unit	$21,294

4. Section 6.6.2, page 118, second sentence in the first paragraph has been deleted and replaced with the following:

The estimated annualized present value (PV) cost is $208,000.

5. Table 16 in Section 6.6.2, page 119, has been deleted and replaced with the following:

Table 16. Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) Costs for the Recommended Plan

Description - OMRR&R	UOM	QTY	Annualized PV Cost
Rock Structure Site Inspection	LS	1	$6,300
O&M Dam Safety Inspection	LS	1	$9,400
O&M Bridge Inspection	LS	1	$1,700
O&M Security and Public Coordination	LS	1	$1,400
O&M Debris Boom Inspection	LS	1	$800
O&M Stoplog Structure Inspection	LS	1	$800
O&M Stoplog Structure Replace Seals-15 yr Frequency	LS	1	$3,800
O&M Stoplog Structure Sand Blast and Repaint- 30 yr Frequency	LS	1	$2,100
O&M Fixed Debris Boom Repair-15 yr Frequency	LS	1	$2,200
Rock Realignment and Replace Rock Lost in Riffles - 10 year High Flow Event	LS	1	$5,100
Fence, Gate, and Guardrail repair-10 yr frequency	LS	1	$6,100
Resurface Asphalt-15 yr frequency	LS	1	$1,100
Patch Asphalt-2 yr frequency	LS	1	$3,300
O&M Concrete Surface Repair-10yr Frequency	LS	1	$15,300
Debris Removal on an Annual Basis	LS	1	$106,900
Subtotal			**$166,300**
Contingency at 25%			$41,600
Total Annual OMRR&R Costs			**$207,900**

Period of Evaluation (Project Life): 50
Discount Rate (FY2022): 2.25%
Interest During Construction: Not considered

6. Section 6.6.3, page 120, Table 17 has been deleted and replaced with the following:

Monitoring Costs	$7,058,000
Adaptive Management Construction	$11,988,000
Subtotal Adaptive Management and Monitoring	**$19,046,000**
PED and Construction Management	**$6,669,000**
Contingency, 31%	$7,971,000
Total Adaptive Management and Monitoring Cost	**$33,686,000**

7. Recommendation, second paragraph, first sentence has been deleted and replaced with the following:

The Recommended Plan, a *200-foot Bottom Width Rock Ramp,* located adjacent to the storage yard, downstream of the spillway, had a calculated output of 234.6 AAHU at an annualized economic cost of $21,294 per AAHU.

8. Recommendation, fourth paragraph has been deleted and replaced with the following:

The effective project first cost at the fiscal year 2022 price level is $138,731,000. The project is 100% Federal funded. The project includes monitoring and adaptive management, which could total $33,686,000 for which USACE would be responsible. The total average annual project cost is $4,996,000. The fully funded cost estimate is $156,246,000.

9. Appendix C – Cost Estimate, Section 2.6 on page C-5, the last sentence has been deleted and replaced with the following:

This TPCS includes October 2021 price level and the fully-funded costs with escalation and contingency. The TPCS fully-funded amount that includes funds spent as of April 2022, is $156,246,000[1]. [1] The values between MII and TPCS reports have a negligible difference due to rounding calculations in the TPCS.)

10. Appendix C – Cost Estimate, Section 2.7 on page C-5, first paragraph, second to last sentence has been deleted and replaced with the following:

The OMRR&R costs were prepared using the Federal Discount Rate for fiscal year 2022 (2.25%) from USACE Economic Guidance Memorandum, 22-01.

11. Appendix C – Cost Estimate, Section 2.7 on page C-5, second paragraph, last sentence has been deleted and replaced with the following:

The total annualized OMRR&R costs for the Recommended Plan is approximately $207,900 which includes a 25% contingency.

12. Appendix C – Cost Estimate, Section 2.8 on page C-8, Table C-1 has been deleted and replaced with the following:

Monitoring Costs	$7,058,000
Adaptive Management Construction	$11,988,000
Subtotal Adaptive Management and Monitoring	**$19,046,000**
PED and Construction Management	**$6,669,000**
Contingency, 31%	$7,971,000
Total Adaptive Management and Monitoring Cost	**$33,686,000**

13. Appendix C – Cost Estimate, Appendix C-A, the table has been deleted and replaced with the following:

Description - OMRR&R	UOM	QTY	Annualized PV Cost
Rock Structure Site Inspection	LS	1	$6,300
O&M Dam Safety Inspection	LS	1	$9,400
O&M Bridge Inspection	LS	1	$1,700
O&M Security and Public Coordination	LS	1	$1,400
O&M Debris Boom Inspection	LS	1	$800
O&M Stoplog Structure Inspection	LS	1	$800
O&M Stoplog Structure Replace Seals-15 yr Frequency	LS	1	$3,800
O&M Stoplog Structure Sand Blast and Repaint- 30 yr Frequency	LS	1	$2,100
O&M Fixed Debris Boom Repair-15 yr Frequency	LS	1	$2,200
Rock Realignment and Replace Rock Lost in Riffles - 10 year High Flow Event	LS	1	$5,100
Fence, Gate, and Guardrail repair-10 yr frequency	LS	1	$6,100
Resurface Asphalt-15 yr frequency	LS	1	$1,100
Patch Asphalt-2 yr frequency	LS	1	$3,300
O&M Concrete Surface Repair-10yr Frequency	LS	1	$15,300
Debris Removal on an Annual Basis	LS	1	$106,900
		Subtotal	**$166,300**
		Contingency at 25%	$41,600
		Total Annual OMRR&R Costs	**$207,900**

Period of Evaluation (Project Life): 50
Discount Rate (FY2022): 2.25%
Interest During Construction: Not considered

14. Appendix C – Cost Estimate, Appendix C-B, page C-B-1, the table has been deleted and replaced with the following:

	Pre-Project Monitoring			Construction Period			Post Project Monitoring and Adaptive Management Monitoring						Total
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	
Monitoring Objective 1. Obtain information needed for project planning and design													
Study 1.1 - Geotech Recon													$ -
Study 1.2 – Fish aggregations in tailwater							$ 126		$ 126	$ 126			$ 379
Study 1.3 – Hydraulic conditions in fish aggregation		$ 150							$ 150		$ 150		$ 449
Study 1.4 – Hydraulic analysis of extending fish passage through dam gate operation													$ -
Monitoring Objective 2. Monitor fish movement through Lock 22 and Fishway													
Study 2.1 – Fixed hydroacoustic fish monitoring system		$ 1,074	$ 78	$ 78	$ 78	$ 78	$ 78	$ 78	$ 78	$ 78	$ 78		$ 1,779
Study 2.2 – Carp capture (if needed)							$ 315	$ 315	$ 315	$ 315	$ 315	$ 315	$ 1,888
Study 2.3 – Monitor upriver movements of fish through Lock and Dam 22							$ 47	$ 47	$ 47	$ 47			$ 187
Monitoring Objective 3. Monitor systemic ecological response by migratory fishes													
Study 3.1 – Fish telemetry		$ 138	$ 138	$ 138	$ 138	$ 138	$ 138	$ 138	$ 138	$ 138	$ 138	$ 138	$ 1,518
Study 3.2 – Migratory fish and mussel occurrence data					$ 8	$ 8	$ 8	$ 8	$ 8	$ 8	$ 8	$ 8	$ 65
Study 3.3 – Mussel surveys – Pool 22						$ 110					$ 110		$ 220
Study 3.4 – System ecological model			$ 173										$ 173
Monitoring Objective 4. Monitor physical performance of the fish passage improvement features													
Study 4.1 – Physical performance survey							$ 23		$ 23	$ 23	$ 23		$ 94
Study 4.2 – Post flood condition survey of the fishway									$ 23				$ 23
Monitoring Objective 5. Monitor effects of the project on structural integrity, navigation operations, water quality													
Study 5.1 – 2-D hydraulic model		$ 32					$ 133		$ 23				$ 188
Study 5.2 – Physical model to assess effects on													$ -
Study 5.3 – Water quality monitoring				$ 8	$ 8	$ 8							$ 25
Study 5.4 – As built survey						$ 23							$ 23
Study 5.5 – Structural survey of fishway toe							$ 23		$ 23				$ 47
Subtotal Monitoring Costs	**$ -**	**$ 1,393**	**$ 389**	**$ 225**	**$ 233**	**$ 366**	**$ 892**	**$ 586**	**$ 955**	**$ 736**	**$ 822**	**$ 461**	**$ 7,058**
Contingency (31%)	$ -	$ 432	$ 121	$ 70	$ 72	$ 113	$ 277	$ 182	$ 296	$ 228	$ 255	$ 143	$ 2,188
Total Monitoring Costs	**$ -**	**$ 1,825**	**$ 510**	**$ 294**	**$ 305**	**$ 480**	**$ 1,169**	**$ 768**	**$ 1,252**	**$ 964**	**$ 1,077**	**$ 604**	**$ 9,246**
Adaptive Management Construction/Testing													
Experiment 1 - Fishway performance													$ -
Experiment 2 – Fishway width and flow								$ 4,795					$ 4,795
Experiment 3 – Fishway entrance										$ 837			$ 837
Experiment 4 – Riffle configuration											$ 1,136		$ 1,136
Restore fishway to optimum configuration												$ 5,220	$ 5,220
Subtotal Management Costs	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 4,795**	**$ -**	**$ 837**	**$ 1,136**	**$ 5,220**	**$ 11,988**
Contingency (31%)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,486	$ -	$ 260	$ 352	$ 1,618	$ 3,716
Total Management Costs	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 6,281**	**$ -**	**$ 1,097**	**$ 1,488**	**$ 6,838**	**$ 15,704**
Adaptive Monitoring and Management - PED and CM													
30 Planning, Engineering, and Design (PED)	$ -	$ 323	$ 90	$ 52	$ 54	$ 85	$ 207	$ 1,248	$ 222	$ 365	$ 454	$ 1,318	$ 4,418
31 Construction Management (CM)	$ -	$ 165	$ 46	$ 27	$ 28	$ 43	$ 105	$ 636	$ 113	$ 186	$ 231	$ 671	$ 2,251
Subtotal,PED and CM	**$ -**	**$ 488**	**$ 136**	**$ 79**	**$ 81**	**$ 128**	**$ 312**	**$ 1,884**	**$ 335**	**$ 551**	**$ 686**	**$ 1,989**	**$ 6,669**
Contingency (31%)	$ -	$ 151	$ 42	$ 24	$ 25	$ 40	$ 97	$ 584	$ 104	$ 171	$ 213	$ 617	$ 2,067
Total PED and CM	**$ -**	**$ 639**	**$ 179**	**$ 103**	**$ 107**	**$ 168**	**$ 409**	**$ 2,468**	**$ 438**	**$ 722**	**$ 898**	**$ 2,606**	**$ 8,736**
Total for Adaptive Management and Monitoring	**$ -**	**$ 2,464**	**$ 689**	**$ 397**	**$ 412**	**$ 647**	**$ 1,578**	**$ 9,517**	**$ 1,690**	**$ 2,782**	**$ 3,463**	**$ 10,047**	**$ 33,686**

Note: Prices shown are $K ($1,000) and at FY 2022 price level.

15. Appendix C – Cost Estimate, Appendix C-F, page C-F-1, the tables have been deleted and replaced with the following:

	Spent Thru 2022	Year					Sum of Years
		2022	2023	2024	2025	2026	2022 to 2026
06 Fish and Wildlife	$ -	$ 1,392,897	$ 389,450	$ 16,983,748	$ 28,211,534	$ 11,570,059	$ 58,547,688
30 PED	$ 6,101,000	$ 2,710,357	$ 4,864,840	$ 3,466,304	$ 1,768,465	$ 771,470	$ 13,581,435
31 CM	$ -	$ 164,625	$ 46,029	$ 2,007,074	$ 3,333,928	$ 1,367,308	$ 6,918,964
Subtotal	$ 6,101,000	$ 4,267,879	$ 5,300,318	$ 22,457,125	$ 33,313,927	$ 13,708,837	$ 79,048,087
31% Contingency		$ 1,323,043	$ 1,643,099	$ 6,961,709	$ 10,327,318	$ 4,249,739	$ 24,504,907
Total		$ 5,590,922	$ 6,943,417	$ 29,418,834	$ 43,641,245	$ 17,958,577	$ 103,552,994

	Sum of Years	Year						Sum of Years
	2022 to 2026	2027	2028	2029	2030	2031	2032	2022 to 2032
06 Fish and Wildlife	$ 58,547,688	$ 892,343	$ 5,381,446	$ 955,497	$ 1,572,424	$ 1,957,626	$ 5,680,737	$ 74,987,762
30 PED	$ 13,581,435	$ 206,995	$ 1,248,321	$ 221,644	$ 364,751	$ 454,106	$ 1,317,747	$ 17,395,000
31 CM	$ 6,918,964	$ 105,465	$ 636,028	$ 112,929	$ 185,843	$ 231,370	$ 671,401	$ 8,862,000
Subtotal	$ 79,048,087	$ 1,204,803	$ 7,265,795	$ 1,290,071	$ 2,123,019	$ 2,643,102	$ 7,669,885	$ 101,244,762
31% Contingency	$ 24,504,907	$ 373,489	$ 2,252,396	$ 399,922	$ 658,136	$ 819,362	$ 2,377,664	$ 31,385,876
Total	$ 103,552,994	$ 1,578,292	$ 9,518,191	$ 1,689,993	$ 2,781,155	$ 3,462,464	$ 10,047,550	$ 132,630,638

16. Appendix M – Monitoring and Adaptive Management Plan, Section 6, Table M-8 on page M-35, has been deleted and replaced with the following:

	Pre-Project Monitoring			Construction Period			Post Project Monitoring and Adaptive Management Monitoring						Total
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	
Monitoring Objective 1. Obtain information needed for project planning and design													
Study 1.1 - Geotech Recon													$ -
Study 1.2 – Fish aggregations in tailwater							$ 126		$ 126	$ 126			$ 379
Study 1.3 – Hydraulic conditions in fish aggregation		$ 150							$ 150		$ 150		$ 449
Study 1.4 – Hydraulic analysis of extending fish passage through dam gate operation													$ -
Monitoring Objective 2. Monitor fish movement through Lock 22 and Fishway													
Study 2.1 – Fixed hydroacoustic fish monitoring system		$ 1,074	$ 78	$ 78	$ 78	$ 78	$ 78	$ 78	$ 78	$ 78	$ 78		$ 1,779
Study 2.2 – Carp capture (if needed)							$ 315	$ 315	$ 315	$ 315	$ 315	$ 315	$ 1,888
Study 2.3 – Monitor upriver movements of fish through Lock and Dam 22							$ 47	$ 47	$ 47	$ 47			$ 187
Monitoring Objective 3. Monitor systemic ecological response by migratory fishes													
Study 3.1 – Fish telemetry		$ 138	$ 138	$ 138	$ 138	$ 138	$ 138	$ 138	$ 138	$ 138	$ 138	$ 138	$ 1,518
Study 3.2 – Migratory fish and mussel occurrence data					$ 8	$ 8	$ 8	$ 8	$ 8	$ 8	$ 8	$ 8	$ 65
Study 3.3 – Mussel surveys – Pool 22						$ 110					$ 110		$ 220
Study 3.4 – System ecological model			$ 173										$ 173
Monitoring Objective 4. Monitor physical performance of the fish passage improvement features													
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Contingency (31%)	$ -	$ 432	$ 121	$ 70	$ 72	$ 113	$ 277	$ 182	$ 296	$ 228	$ 255	$ 143	$ 2,188
Total Monitoring Costs	**$ -**	**$ 1,825**	**$ 510**	**$ 294**	**$ 305**	**$ 480**	**$ 1,169**	**$ 768**	**$ 1,252**	**$ 964**	**$ 1,077**	**$ 604**	**$ 9,246**
Adaptive Management Construction/Testing													
Experiment 1 - Fishway performance													$ -
Experiment 2 – Fishway width and flow								$ 4,795					$ 4,795
Experiment 3 – Fishway entrance										$ 837			$ 837
Experiment 4 – Riffle configuration											$ 1,136		$ 1,136
Restore fishway to optimum configuration												$ 5,220	$ 5,220
Subtotal Management Costs	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 4,795**	**$ -**	**$ 837**	**$ 1,136**	**$ 5,220**	**$ 11,988**
Contingency (31%)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,486	$ -	$ 260	$ 352	$ 1,618	$ 3,716
Total Management Costs	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 6,281**	**$ -**	**$ 1,097**	**$ 1,488**	**$ 6,838**	**$ 15,704**
Adaptive Monitoring and Management - PED and CM													
30 Planning, Engineering, and Design (PED)	$ -	$ 323	$ 90	$ 52	$ 54	$ 85	$ 207	$ 1,248	$ 222	$ 365	$ 454	$ 1,318	$ 4,418
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Subtotal, PED and CM	**$ -**	**$ 488**	**$ 136**	**$ 79**	**$ 81**	**$ 128**	**$ 312**	**$ 1,884**	**$ 335**	**$ 551**	**$ 686**	**$ 1,989**	**$ 6,669**
Contingency (31%)	$ -	$ 151	$ 42	$ 24	$ 25	$ 40	$ 97	$ 584	$ 104	$ 171	$ 213	$ 617	$ 2,067
Total PED and CM	**$ -**	**$ 639**	**$ 179**	**$ 103**	**$ 107**	**$ 168**	**$ 409**	**$ 2,468**	**$ 438**	**$ 722**	**$ 898**	**$ 2,606**	**$ 8,736**
Total for Adaptive Management and Monitoring	**$ -**	**$ 2,464**	**$ 689**	**$ 397**	**$ 412**	**$ 647**	**$ 1,578**	**$ 9,517**	**$ 1,690**	**$ 2,782**	**$ 3,463**	**$ 10,047**	**$ 33,686**

Note: Prices shown are $K ($1,000) and at FY 2022 price level.

NAVIGATION AND ECOSYSTEM SUSTAINABILITY PROGRAM

LOCK AND DAM 22 FISH PASSAGE IMPROVEMENT PROJECT PROJECT IMPLEMENTATION REPORT WITH INTEGRATED SUPPLEMENTAL ENVIRONMENTAL ASSESSMENT

EXECUTIVE SUMMARY

This Project Implementation Report with Integrated Supplemental Environmental Assessment (SEA) is to present the findings of the study conducted for fish passage improvements at Lock and Dam 22 as part of the Navigation and Ecosystem Sustainability Program (NESP).

The need for action for this study was identified in the *Final Integrated Feasibility Report and Programmatic Environmental Impact Statement for the UMR-IWW System Navigation Feasibility Study* U.S. Army Corps of Engineers, September 24, 2004 (2004 Feasibility Study). The fish passage structure at Lock and Dam 22 is one of the measures identified in the 2004 Feasibility Study to meet the ecosystem restoration needs of the system and this SEA is tiered from the 2004 Feasibility Study. The Lock and Dam 22 Fish Passage Improvement Project (Project) is the first of a series of projects to restore longitudinal habitat connectivity for the many species of native migratory fishes in the Upper Mississippi River (UMR). Enabling long distance migration is important to fulfill seasonal and life stage requirements for river fishes. Fish undergo seasonal movements in rivers for reproduction, feeding, and for finding thermal refugia during winter. Fish migrations are the annual movements of fish populations between different habitat areas. Fish passage is the movement of fish past an obstacle, such as a dam in a river, and fishways are constructed channels designed to provide hydraulic connections suitable for fish to pass dams without undue stress, delay or injury.

The primary purpose of the Lock and Dam 22 Fish Passage Project is to increase opportunity for upriver fish passage, thereby increasing access to upstream mainstem river and tributary habitats. Increased access to upriver habitat should result in an increase in the size and distribution of native migratory fish populations. The secondary purpose of this project is to monitor, evaluate, learn from, and adapt future fish passage projects using lessons learned from this initial project. There are significant gaps in knowledge for this project given our limited understanding of: natural fish movements, fish movements in response to flow conditions, the diversity of fish species and their habitat requirements, and the novelty of a fish passage for the UMR. This information is needed for project planning and design to determine if the project objectives are met and to apply lessons learned to future fish passage projects through adaptive management.

The study was initiated in the mid-2000s. At the time, significant coordination was conducted in the early project stages to identify, minimize, avoid, and develop monitoring and adaptive management frameworks and strategies to address concerns and potential impacts associated with native fisheries, invasive fish passage, and freshwater mussel resources. The study has been re-coordinated with pertinent resource agencies and no issues have been identified.

Lock and Dam 22 is located at river mile 301.2 on the UMR near Saverton, Missouri, between Ralls County, Missouri, and Pike County, Illinois. The average lift at Lock and Dam 22 is approximately 11 feet. The project area is located in Congressional District 9 in Missouri and District 17 in Illinois. The project is 100% Federal funded and there is no non-Federal sponsor.

Ten alternatives, including the No Action Alternative, were evaluated and compared to determine what alternative should be recommended for implementation. Alternative 9, *Rock Ramp with 200-Foot Bottom* Width (Figure ES-1), was identified as the Recommended Plan. Alternative 9 would result in a gain of 234.6 average annual habitat units. The Project First Cost for Alternative 9 is $122,110,000 at a FY 2021 price level (Oct 2020). The costs are expressed as Project First Costs and include construction, contingencies, engineering, preconstruction engineering, and design, and construction management. When interest during construction is added, the total investment cost is $126,712,000.

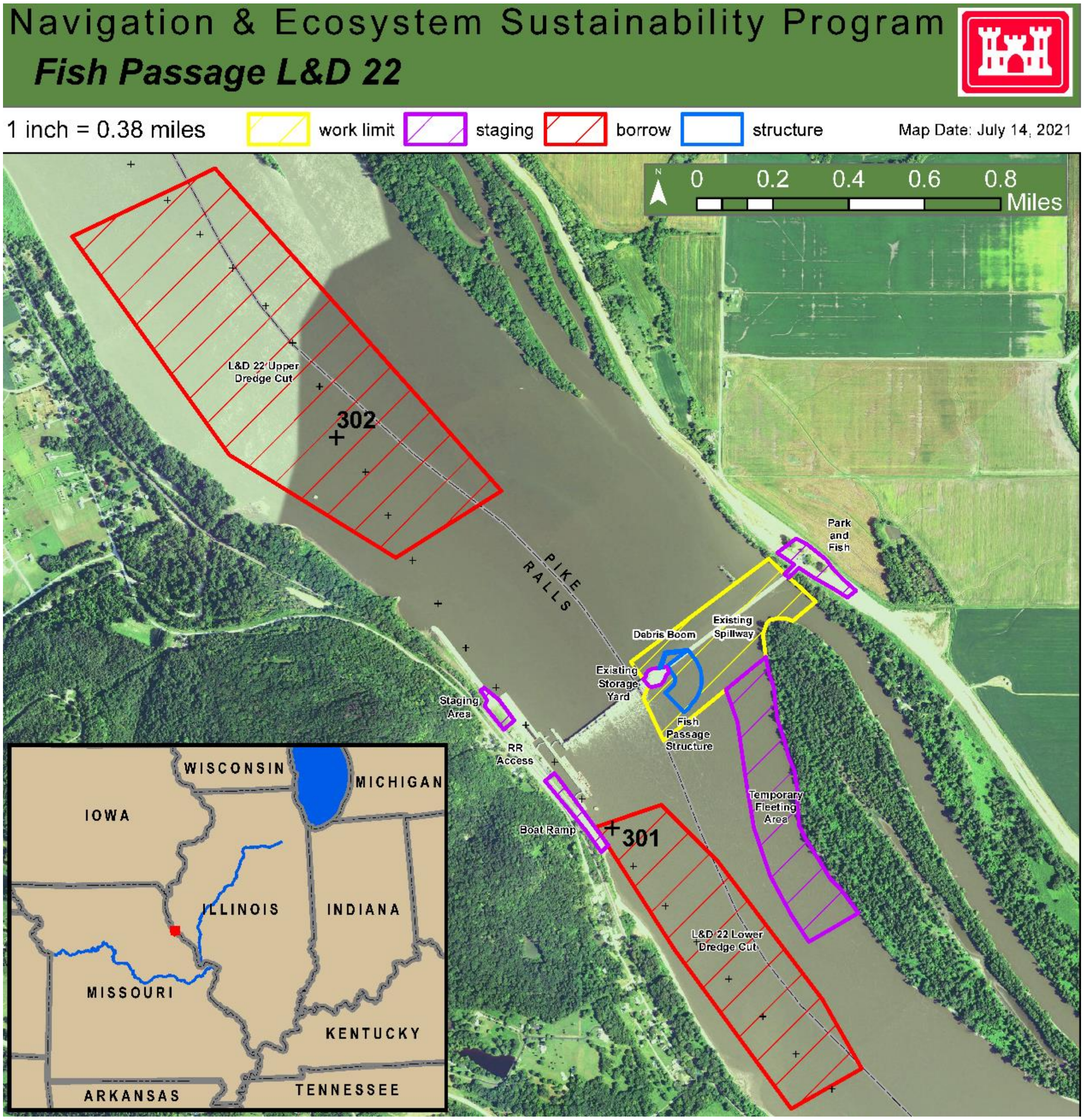

Figure ES-1. Recommended Plan, Alternative 9 Rock Ramp with 200-Foot Bottom Width.

NAVIGATION AND ECOSYSTEM SUSTAINABILITY PROGRAM

LOCK AND DAM 22
FISH PASSAGE IMPROVEMENT PROJECT
PROJECT IMPLEMENTATION REPORT
WITH INTEGRATED SUPPLEMENTAL ENVIRONMENTAL ASSESSMENT

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NAVIGATION AND ECOSYSTEM
SUSTAINABILITY PROGRAM

LOCK AND DAM 22
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1 INTRODUCTION

The Navigation and Ecosystem Sustainability Program (NESP) area comprises the Upper Mississippi River System (UMRS), as defined by Congress in the Water Resources Development Act of 1986 (WRDA 1986), which includes the Upper Mississippi River (UMR) from Minneapolis, Minnesota to Cairo, Illinois; the Illinois Waterway from Chicago to Grafton, Illinois; and navigable portions of the Minnesota, St. Croix, Black and Kaskaskia Rivers. This multi-use resource supports an extensive navigation system (comprising 1,200 miles of 9-foot channel and 37 lock and dam sites); a diverse ecosystem (2.7 million acres of habitat supporting hundreds of fish and wildlife species); floodplain agriculture, recreation and tourism. Based on the recommendation of the *Final Integrated Feasibility Report and Programmatic Environmental Impact Statement for the Upper Mississippi River – Illinois Waterway (UMR-IWW) System Navigation Feasibility Study* U.S. Army Corps of Engineers, September 24, 2004, that examined system needs over a 50-year planning horizon, the NESP was authorized to achieve the dual purposes of UMRS ecosystem restoration and navigation improvements. Fish passage at Lock and Dam 22 is one of 23 initial NESP ecological component projects being planned under this new UMRS program. This Project Implementation Report (PIR) with Supplemental Environmental Assessment (SEA) is tiered from the 2004 Feasibility Study and the Record of Decision signed June 4, 2008.

1.1 Project Authority

This site-specific evaluation was initiated as a follow-up component of the Upper Mississippi River and Illinois Waterway System Navigation Study (Sept 2004), which was a General Investigation study authorized by Section 216 of the Flood Control Act of 1970. Subsequent authorization was received in the Water Resources Development Act (WRDA) of 2007, Title VIII, Section 8004, authorizes implementation of Ecosystem Restoration projects to attain and maintain the sustainability of the ecosystem of the UMR and Illinois River. The complete authorization can be found in Appendix L, *Project Authority*.

1.2 Overview of Study Timeline

The Lock and Dam 22 Fish Passage study was started in 2004 and paused in 2010 due to lack of NESP funding. Pre-construction biological monitoring studies were conducted from 2004 to 2008. The study is being performed by the U.S. Army Corps of Engineers (USACE), Rock Island District (District), in cooperation with numerous Federal and State agencies. Prior to the study being paused in 2010, the plan formulation process was completed, and a Tentatively Selected Plan (TSP) was identified. Funding for the NESP was received in 2020 and the study was re-started. The design for potential measures and alternatives has not been revised and quantities have not been updated. The costs for alternative plans and the Recommended Plan have been updated to current dollars. The design for the Recommended Plan will continue to use best available data, practices, and make changes to the design as appropriate.

1.3 Project Location

Lock and Dam 22 is located at river mile (RM) 301.2 on the UMR near Saverton, Missouri, between Ralls County, Missouri, and Pike County, Illinois (Figure 1). The average lift at Lock and Dam 22 is approximately 11 feet. The project area is located in Congressional District 9 in Missouri and District 17 in Illinois.

Figure 1. Lock and Dam 22 Project Location

1.4 Purpose and Need

Purpose: The District proposes improving fish passage at Lock and Dam 22 near Saverton, Missouri, on the UMR at RM 301.2.

The primary purpose of the Lock and Dam 22 Fish Passage Project is to increase opportunity for upriver fish passage, thereby increasing access to upstream mainstem river and tributary habitats. Increased access to upriver habitat should result in an increase in the size and distribution of native migratory fish populations.

The secondary purpose of this project is to monitor, evaluate, learn from, and adapt future fish passage projects using lessons learned from this initial project. There are significant gaps in knowledge for this project given our limited understanding of: natural fish movements, fish movements in response to flow conditions, the diversity of fish species and their habitat requirements, and the novelty of a fish passage for the UMR. This information is needed for project planning and design to determine if the project objectives are met and to apply lessons learned to future fish passage projects through adaptive management. An adaptive management plan was developed collaboratively with stakeholders and the NESP Science Panel to gain information needed for project planning and design, monitor and evaluate project performance, learn about fish migration behavior in the UMR, and to plan and design future fish passage projects (Appendix M, *Adaptive Management & Monitoring*).

The Lock and Dam 22 Fish Passage Project is the first of a series of projects to restore longitudinal habitat connectivity for the many species of native migratory fishes in the UMRS. Longitudinal connectivity is important to fulfill seasonal and life stage requirements for river fishes. Fish undergo seasonal movements in rivers for reproduction, feeding, and for finding thermal refugia during winter. Fish migrations are the annual movements of fish populations between different habitat areas. Fish passage is the movement of fish past an obstacle, such as a dam in a river. Fishways are constructed channels designed to provide hydraulic conditions suitable for fish to pass dams without undue stress, delay or injury.

Need: This project directly addresses the loss of habitat connectivity for upriver fish movements and the loss of rock rapids habitat. The loss of aquatic habitat connectivity has been dramatic since European settlement. The restoration of connectivity is widely recognized as critical to maintaining biodiversity and ecosystem functions. Caley and Schluter (1997) and Noss (1990) described connectivity as a factor that structures diversity patterns of local species assemblages.

Connectivity affects the turnover, or movement of species between habitat patches and ultimately the number of species in a region. Local biotic communities in rivers are in dynamic equilibrium and are often altered by disturbance events such as floods and droughts. Lack of connection between habitats has significant implications for redistribution, recolonization, and local extinctions of fish and other biota within rivers.

Numerous native fish have life history requirements that involve upstream and downstream migratory movements (Figure 2). Improvements in fish passage would benefit uncommon migratory species including fishes such as the Skipjack Herring, Paddlefish, and sturgeons. For example, large schools of Skipjack Herring once migrated up the river system to spawn as far as Lake Pepin and Lake St. Croix on the Minnesota-Wisconsin border but are now restricted to below Lock and Dam 19. Young-of-year Skipjack Herring may have once been an important component of the forage fish base. In addition to the purely ecological benefits, economic benefits from mussel and fish harvest have been important for centuries (Photograph 1 and Photograph 2).

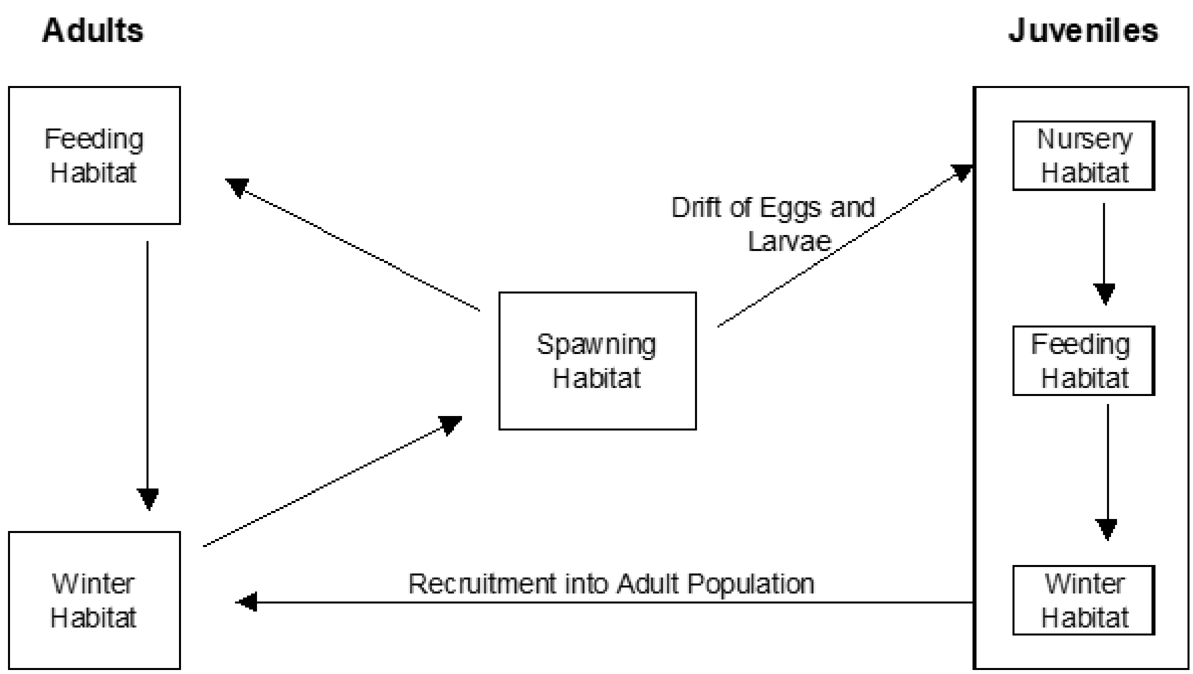


Figure 2. Pattern of Seasonal Movements of Many Upper Mississippi River System Fishes (McKowen, 1984)

Photograph 1. Mussel Harvesting Operation in the Upper Mississippi River Basin

Photograph 2. Fishing Boats Coming into Port, Upper Mississippi River Basin, 1898

Commercial and sport fishing on the UMRS is still a popular and important part of the regional economy (Carlson et al. 1995). Restricted movements of fish through the navigation dams are a contributing factor limiting the abundance of game fish, thereby limiting fishing opportunities. Indirect effects of restricted fish movements, such as reduced prey abundance, could have significant effects on sport and commercial fisheries in the UMRS.

The fish communities of tributaries are influenced by seasonal influx of spawning fish from the UMRS. Migratory fish provide concentrations of biomass for fish-eating birds and mammals, and the eggs, larvae and juveniles of seasonal migratory fishes greatly affect the trophic structure of tributary communities.

In addition to the potential restoration of connectivity, most types of fish passage structures themselves will restore historically significant rock riffle substrates. The historic riffle reaches of the UMR (Rock Island rapids, Des Moines rapids, etc.) were flooded out by the dam impoundments to allow for improved navigation. Riffle reaches have been important for spawning of numerous native species including species of concern such as the state-listed Blue Sucker and Lake Sturgeon.

Access for fish to freely move upstream and downstream in river systems is called longitudinal connectivity. Removing barriers in the river system is the ideal solution – connecting different habitat types are key aides to restoring the longitudinal ecosystems that rivers provide. Longitudinal connectivity is a measure of how connected all of the various ecosystems required to support a certain species' lifelong needs. In the case of the UMRS, this could mean connecting several pools in sequence or connecting a pool with all of its blocked tributaries with fish passage structures, depending on the needs of the specific species being targeted for improvement.

The UMR navigation dams clearly impose barriers to upriver fish movements (Wilcox et al. 2004). However, due to their design their low head, the dams do not impose significant barriers to downriver fish movements. Fish can pass downriver through the dam gates or navigation locks without injury or mortality imposed by pressure change or impingement. There are no records of fish mortality caused by downriver passage through the UMR navigation dams except through those dams with hydropower turbines, St. Anthony Falls and Lock and Dams 1, 2, 14 and 19. Fish tagging and telemetry studies on the UMR have demonstrated that fish can pass downriver even during low flow conditions when the dam gates are controlling flow through the dams (Wilcox et al. 2004). Acoustic tagging and tracking experiments coupled with high-resolution three-dimensional numerical hydraulic modeling have indicated that fish detect and respond to certain hydraulic conditions around them in a predictable way (Nestler 2003). Fish may have behavioral inhibitions to passing through or over the UMRS navigation dams that could restrict their upriver and downriver movements. Given the generally unrestricted nature of downriver fish passage through UMR dams, the goal of this project is to increase longitudinal habitat connectivity for fish moving upriver.

Saverton, MO, experiences an annual average high and low temperature of 64°F and 45°F respectfully. Average high temperatures take place in July at 88°F with peak high temperatures occasionally reaching 100°F. Average low temperatures take place in January at 20°F with extreme cold temperatures occasionally reaching the negatives. On average Saverton receives 38 inches of precipitation with about 5 inches coming from snowfall. Average streamflow for the Mississippi is on the order of 100,000 cfs with flood flows reaching upwards of 380,000 cfs. Increases in temperature will not impact the design/operation of the fish passage. Changes in precipitation patterns and the resulting changes in river flows directly impact the fish passage. Large increases in peak streamflow and flood duration could change the size/configuration of fish passage building materials. Climate change considerations will be made to ensure a robust and resilient fish passage. A more detailed discussion of climate change can be found in Appendix H-A, *Climate Change Impact Assessment*.

The first dam that was constructed on the UMR was referred to as the Keokuk Dam (later known as Lock and Dam 19), which was built between Keokuk, Iowa, and Hamilton, Illinois, between 1911 and 1913 by the Keokuk and Hamilton Water Power Company. It was at this dam where the first observation of blocked fish migrations in the Mississippi was documented by Dr. Robert E. Coker, Director of the United States Biological Station at Fairport, Iowa (Coker 1914). Dr. Coker wrote:

> *The writer (Dr. Coker) visited Keokuk April 15, 1914, when the water was still cool, and practically no movement of fishes had occurred. It was learned that the river immediately below the dam had remained open all the winter, although as a whole below the bridge at Keokuk and above the dam it had been frozen over with thick ice. In the exposed water the wall-eye or "jack salmon" had been present all the winter and fished abundantly with hook and line. Practically the only fish then in evidence were perch and crappie in the slues. A few perch were noted in the lock, and the lock master stated that a large number had been taken at the first locking, about April 10.*
>
> *A local informant, Mr. Joe MacAdams, was requested to write me of the first appearance of the herring. After a card from him, I visited Keokuk again April 29. He stated that the herring first appeared April 20, and that they became enormously abundant within a few days; on the 27th, according to several informants, during a warm day, one could at any moment see hundreds of them breaking the water in every part of the river below the plant.*
>
> *The day of my arrival, April 29, was cold, windy, and cloudy, and at first view very few herring were observable. After closer observation, however, they were seen to be present in immense numbers, and congregated in certain locations exactly as had been predicted. A large number were soon just below the short section of dam between the upper end of the lock and the lower end of the power house; many were observed along the outer wall of the tail-race, hut in the angle between the power house and the dam and from*

> *this point to the nearest open spillway, a short distance away, the herring were fairly massed. Such a close aggregation of fish can rarely be seen in fresh water. They had evidently followed up along the outer edge of the tail-race until they could go no farther.*

Dams disrupt the movements and migrations of fishes in river systems by imposing physical and hydraulic barriers. In the UMRS, several migratory fish species that appear to be affected are considered endangered, threatened, or at-risk, including Pallid Sturgeon, Lake Sturgeon, Paddlefish, Skipjack Herring, Blue Sucker, Goldeye, Black Redhorse, and Yellow Bass. Dams on the UMRS have contributed to the extirpation of some migratory fishes and mussels in the upper reaches of the river system, notably including Skipjack herring, Blue Catfish, and Elephant ear mussel.

Many mussel glochidia (larval mussels) can only survive on a specific species of fish and are therefore known as obligate parasites or “host specific” (Figure 3). Glochidia will not survive if they attach to a fish that is not the host species. Being host specific can make a mussel extremely sensitive to human impacts. For example, the construction of the Keokuk Dam blocked the migration of Skipjack Herring up the Mississippi River. The Skipjack Herring is the only host for the Ebonyshell and Elephant ear mussels. These two mussels, once so abundant that they were major taxa in the UMR ecosystem, are no longer found in the Mississippi River watershed above Keokuk, Iowa, since their host can no longer migrate above the dam at Keokuk, Iowa.

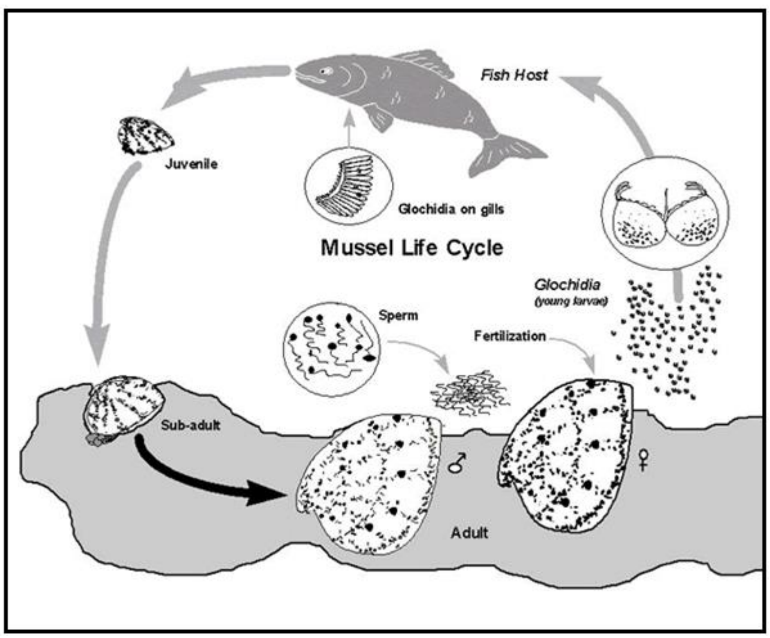


Figure 3. Freshwater Mussel Life Cycle (Cedar Valley Resource, Conservation and Development Int. 2002)

Based on discussion and data gathers over the years for Skipjack Herring, Lake Sturgeon, and other long-distance migratory fish, it may require many fish passage structures throughout the entire UMRS to successfully aid herring and sturgeon recovery. Lock and Dam 19 impose a nearly complete barrier to upriver fish movements. An effective fishway at Lock and Dam 19 will be needed to restore long-distance migrating fishes like Skipjack Herring and Lake Sturgeon. During the 1993, 2008, and 2019 floods, Skipjack Herring found their way upriver through the lock at Lock and Dam 19. All the other dams had their gates raised out of the water to allow the maximum discharge of flood waters, which inadvertently allowed the Skipjack Herring to slip through and travel upriver all the way north to Lake Pepin in Minnesota and Wisconsin. This indicates that migratory fishes may be able to quickly extend their ranges once connectivity past the navigation dams is restored.

Lock and Dam 22 was selected as the first fish passage structure on the UMRS through a collaborative process started by the Navigation Environmental Coordinating Committee (NECC[1]). The NECC was an interagency work group that reviewed and commented on environmental studies during the alternatives formulation stage for the 2004 Feasibility Study. A fish passage sub-group of the NECC comprised of fisheries biologists and engineers, was formed to conduct a systemic analysis of fish passage needs on the UMRS. The sub-group recognized that all dams restrict upstream movements of fish, but some offered greater benefits in terms of existing opportunity for fish passage, access to habitat in the navigation pool, access to tributaries, and cost. This analysis led to the recommendation for the installation of fishways at 18 dams with others to be considered later (Wilcox et al 2004).

The District worked with the NECC to fit this recommendation into the array of ecosystem restoration measures being considered in the 2004 Feasibility Study. The group discussed the juxtaposition of fish passage projects within the basin, the risk of accelerating the spread of invasive species, the adaptive management opportunities, and the complexity of the individual fish passage projects. As a result, fish passage measures were included in two alternatives of the 2004 Feasibility Study. Alternative D* included fish passage at Locks and Dams 2, 4, 5, 8, 9, 10, 11, 13, 14, 18, 19, 22, 26, and the Kaskaskia River. Alternative E included these 14 Locks and Dams with 19 additional locations. Alternative D* was selected as the Recommended Plan for ecosystem restoration.

The Recommended Plan for the 2004 Feasibility Study included a 15-year implementation option which was developed with the stakeholders to address critical ecosystem needs and to provide insight into the response of the environment to the various navigation project modification and measures. The 15-year plan emphasized measures that provide: 1) the greatest return on investment; 2) best gains in diversity; and 3) additional knowledge required to guide future investments. The 15-year plan included fish passage projects at Locks and Dams 4, 8, 22, Mel Price, along with the initial Engineering and Design at 19. At the time, the NECC recommended the first project should be located where invasive carp were already

1 The NECC no longer exists.

found above and below the dam to reduce the risk of accelerating their upstream expansion. Lock and Dam 22 and Mel Price Locks and Dam were the only sites the met the criteria. These sites were recommended as the first proposed fish passage projects on the UMRS.

The benefits of fish passage are incremental because the first individual fishways have fewer substantial benefits to the migratory fish population than a series of fishways. The NECC fish passage sub-group estimated that the systemic benefits of fish passage will not be realized until there is free fish movement through at least 18 specific Locks and Dams. Some reproduction-limited fish species that spawn infrequently and require specific spawning habitat conditions, such as Lake Sturgeon, Shovelnose Sturgeon, and Paddlefish, will benefit only if fish passage improvements allow more of them to reach suitable habitat areas and to spawn more successfully. Auer (1996) suggested that Lake Sturgeon need a barrier-free, 155-to-188-mile combined river and lake range as a minimum for a self-maintaining population. However, a single fish passage at Lock and Dam 22 will have localized benefits to growth-limited fish species if fish passage improvements enable them to reach more suitable foraging habitats. Tributary fish communities, such as the Fabius River system, could also benefit from increased seasonal abundance of migratory fishes and their young-of-year from fish passage at Lock and Dam 22.

The Lock and Dam 22 Fish Passage Project was endorsed again in 2020 for continued study and implementation by the UMRBA and UMRCC Fish Tech Section.

1.5 Resource Significance

When determining Federal interest, it is important to clearly identify the significance of the resources being studied for restoration. The Corps of Engineers' Planning Guidance Notebook defines significance in terms of institutional, public, and technical recognition of the resources. For years, the UMR states (Illinois, Iowa, Minnesota, Missouri, and Wisconsin), non-governmental organizations, and other agencies have been engaged in activities that clearly demonstrate the institutional, public, and technical recognition of the resources of the Upper Mississippi River Basin.

1.5.1 Institutional Significance

The formal recognition of the Upper Mississippi River Basin in laws, adopted plans, and other policy statements of public agencies and private groups illustrate the significance of the basin to a variety of institutions. The U.S. Congress recognized the UMRS as a unique, "…nationally significant ecosystem and a nationally significant commercial navigation system…" in Section 1103 of the WRDA 1986. This was not the first Federal recognition of the UMR.

On the mainstem rivers there is a long and storied history of river development (Anfinsen 2003). The first Federal legislation in 1824 authorized clearing snags and other obstructions in the river. Opening individual rapids or other obstructions and dredging was conducted under many authorities, but the River and Harbor Act of 1878 authorized the USACE to establish a 4.5-foot channel from St. Louis to Minneapolis. That was followed by authority for a 6-foot channel in the 1907 Act. The existing 9-ft channel project was authorized in the 1927 River and Harbor Act. The Illinois River was developed by the State of Illinois until the development of the 9-foot channel project when the Federal government assumed responsibility for the waterway. The UMRS Navigation System was complete by 1940 and worked efficiently until the 1960s, when system capacity was being strained. The need for a new expanded Lock and Dam 26 was identified in the 1960s; it was planned and approved by 1978. The last major addition to the lock and dam system occurred when a second lock was added to the Melvin Price Locks and Dam (formerly Lock 26) in 1990.

Because the UMRS is so large, and so prominent in the social development and structure of the Upper Midwest, there are many agencies and institutional arrangements supporting river and water-related activities in the region. For example, strong Federal, state, and local institutional support has resulted in the U.S. Department of Agriculture (USDA) and Natural Resources Conservation Service (NRCS) being able to implement the highly successful Conservation Reserve Enhancement Program in the Illinois and Minnesota River Basin which has resulted in hundreds of thousands of acres of floodplain and highly erodible lands being put into conservation. The NRCS has also been active in the restoration of wetlands, through its Wetland Reserve Program, with the notable enrollment and restoration of approximately 8,000 acres of Illinois River Floodplain as part of its joint restoration efforts with The Nature Conservancy at its Emiquon and Spunky Bottoms Preserves.

Environmental conservation awareness was active and competing with economic interests by the turn of the 20^{th} century (Carlander 1954, Anfinsen 2003). By 1900, the U.S. Bureau of Fisheries was concerned with the viability of commercial fish stocks because river fish were an important food source, with fish shipped to fine restaurants in the East. The Izaak Walton League was instrumental in generating Congressional support for the Upper Mississippi River Fish and Wildlife Refuge. The refuge was established in 1924 specifically for the protection of fishes. Legislation establishing the 9-foot channel project included the prospect that fishways might be added to the navigation dams if adverse effects of impeded fish movement were demonstrated (War Department 1932).

Conservation awareness has been prominent throughout the development of the UMRS and became increasingly coordinated over time. Biologists on the UMR established the Upper Mississippi River Conservation Committee (UMRCC) in 1943 composed of state and Federal biologists to proactively work on UMR issues. The Great River Environmental Action Team (GREAT) Studies during the 1970s were the first regional assessment and planning process on channel management (GREAT I, II & III 1980). The GREAT helped stop environmentally damaging practices and recommended changes for better environmental management of the navigation system. The *Comprehensive Master Plan for the Management of the Upper*

Mississippi River System prepared by the Upper Mississippi River Basin Commission (UMRBC 1982) included many recommendations that expanded assessments to other cumulative effects and made recommendations for future programs.

The *Upper Mississippi River Restoration (UMRR) program– (formerly known as Environmental Management Program*) was established in 1986 to conduct monitoring and habitat restoration activities along portions of the main stem of the Mississippi and Illinois Rivers. The UMRR program is one of the nation's first large-scale restoration efforts and brings together the expertise of the USACE, the U.S. Fish and Wildlife Service (USFWS), the U.S. Geological Survey, the U.S. Environmental Protection Agency (USEPA) and numerous state agencies. Congress reaffirmed the significance of the UMRS and the success of the program by reauthorizing the EMP in 1999. The program has completed almost 50 ecosystem restoration projects and refined techniques for large river restoration (USACE 2004a). The Long-Term Resource Monitoring Program is one of the largest and longest lasting ecosystem monitoring programs in the nation.

The *Upper Mississippi River and Illinois Waterway System Navigation Study* effort was the latest evaluation of large-scale navigation capacity needs and ecosystem restoration planning. As described previously, it was a massive institutional effort involving many standing committees and significant coordination; as an example, one of the interagency committees associated with the study met more than 50 times. The recommended plan is an ambitious one. It seeks to improve the navigation and environmental problems addressed, but it also seeks to make system management more efficient and effective. The plan's authorization included $2.2 billion in navigation improvement and $1.7 billion in ecosystem restoration features in the WRDA of 2007, further demonstrating the strong institutional support and significance of the UMRS to the nation.

1.5.2 Public Significance

The UMRS and associated environments have a rich record of human history spanning over 12,000 years, and it is increasingly being documented as one of the most archeologically and historically significant regions in the country. The abundant and diverse ecological resources found along the UMR-IWW have attracted and sustained human populations for thousands of years - providing food, water, shelter, and transportation. The Mississippi and Illinois Rivers are significant in their role in the development of the nation.

The region hosts a sizable population, serving as home to more than 30 million people. Nearly 80 percent of the region's population lives in urban areas along the rivers. These urban areas include: Minneapolis-St. Paul, MN; La Crosse, WI; Dubuque, IA; Davenport-Bettendorf, IA and Rock Island-Moline, IL (the Quad Cities); Muscatine, IA; Quincy, IL; St. Louis, MO; Hannibal, MO; Cape Girardeau, MO; Chicago, IL; and Peoria, IL. These communities developed because of the transportation provided by the river; they are sustained by the water supply and waste assimilation capabilities of the river. Many industries depend on the system's commerce route and water supply.

The navigable portions of these rivers, and the locks and dams that allow waterway traffic to move from one pool to another, are integral parts of a regional, national, and international transportation network. The system is significant for certain key exports and the nation's trade balance. For example, in 2000, the UMRS carried approximately 60 percent of the nation's corn and 45 percent of the nation's soybean exports. Corn and soybeans are shipped via the waterway at roughly 60 to 70 percent of the cost of shipping over the same distance by rail. Other commodities shipped on the system include coal, chemicals, petroleum, materials (sand, gravel, iron ore, steel, and scrap), and manufactured goods. The existing navigation system generates an estimated $1 billion of transportation cost savings to the nation. These benefits compare with the annual operation and maintenance costs of approximately $115 million (USACE 2004a).

Recreation is important to the modern economy, and it is another important economic force in the UMRS. Over $6.6 billion in revenue are generated annually from some 12 million visitor-days of use by people who hunt, fish, boat, sightsee or otherwise visit the UMR (Black et al. 1999). That recreation supports almost 150,000 jobs along the UMR corridor.

An example of the broad range of national and local non-government organizations interested in UMRS issues was observed during the development of the NESP. Some of the members involved were American Rivers, American Waterway Operators, Audubon Society, Illinois Stewardship Alliance, Midwest Area River Coalition 2000, Mississippi River Basin Alliance, National Corn Growers Association, The Izaak Walton League of America, The Nature Conservancy, The Sierra Club, Upper Mississippi, Illinois and Missouri River Association, and the Upper Mississippi River Conservation Committee. Many other organizations were less formally involved, yet active.

Public involvement in river related issues, programs, and studies has been very positive. The public has helped identify and prioritize important resources. In public opinion surveys and focus panels, the public has supported the multiple use nature of the river and emphasized water quality, sedimentation, and habitat degradation as continuing problems.

1.5.3 Technical Significance

Numerous scientific analyses and long-term evaluations of the Upper Mississippi River Basin have documented its significant ecological resources. Since the early 20th century, researchers, government agencies, and private groups have studied the large river floodplain system and proposed ecosystem restoration in the Upper Mississippi River Basin.

In a 1995 report, the U.S. Department of the Interior (DOI) listed large streams and rivers as endangered ecosystems in the United States. The U.S. DOI documented an 85 to 98 percent decline in this ecosystem type since European settlement (NRC 1995). In particular, large floodplain-river ecosystems have become increasingly degraded worldwide. Two of the world's largest floodplain-river ecosystems lie within the UMRS, namely the Upper Mississippi and Illinois Rivers. These two ecosystems still retain seasonal flood pulses, and more than half of their original floodplains remain unleveed and open to the rivers (Sparks et al. 1998). The UMRS is one of the few areas in the developed world where ecosystem restoration can be implemented on large floodplain-river ecosystems (Sparks 1995).

The UMRS ecosystem consists of hundreds of thousands of acres of bottomland forest, islands, backwaters, side channels and wetlands—which support more than 300 species of birds; 57 species of mammals; 45 species of amphibians and reptiles; 150 species of fish; and nearly 50 species of mussels. More than 40 percent of North America's migratory waterfowl and shorebirds depend on the food resources and other life requisites (shelter, nesting habitats, etc.) that the system provides. It also provides boating, camping, hunting, trapping and other recreational opportunities. The following is a sample of characteristics that are of particular importance in the UMRS or are rarely found in other areas.

- The Mississippi River is the largest riverine ecosystem in North America.
- 300,000 acres of the floodplain are within the National Wildlife Refuge System.
- It is a migratory flyway for 40 percent of all North American waterfowl.
- It is a globally important flyway for 60 percent of all bird species in North America.
- 25 percent of all freshwater fish species in North America are found in the UMRS.
- The system includes a variety of scarce habitats identified in the UMRS Habitat Needs Assessments (USACE 2000; McCain et al 2018) and in the 2004 Feasibility Study.
- The river system and its potential restoration would contribute significantly to the lateral and longitudinal connectivity of habitats for feeding, reproduction, migration, growth, and overwintering for fish, waterbirds, reptiles, amphibians, and mammals. Some examples of impacted species are: sturgeons, Paddlefish, canvasback ducks, and swans. Proposed projects will be able to make critical direct physical connections between existing habitat areas within migration corridors and larger landscapes, thereby reducing population isolation, expanding home ranges, and providing access to areas supporting life requisites.

- The system is important habitat for 286 state-listed or candidate species and 26 federally listed or candidate species of rare, threatened, or endangered plants and animals native to the UMR Basin. The project will directly and indirectly improve habitat conditions and fulfill life cycle requisites for three Federally Endangered mussels (Higgins Eye pearlymussel, Spectaclecase, and Sheepnose mussel) and many Federal trust species, notably Shovelnose Sturgeon, Lake Sturgeon, and Paddlefish.

Ecosystem services are the benefits humans receive, directly or indirectly, from ecosystems (Costanza et al. 1997, Dailey 1997). The NESP Science Panel has identified a set of ecosystem services provided by the UMRS, drawing from Farber et al. (2006), the 2004 Feasibility Study, the Millennium Ecosystem Assessment (2005) and a NESP ecosystem services workshop (Lubinski et al. 2007). Ecosystem services can be classified into supporting functions and structures, regulating services, provisioning services and cultural services. The benefits of fish passage improvements incurred through increased abundance and geographic range of migratory fishes in the UMRS would include benefits in each of these categories.

The UMR is an amazingly productive and significant national and international resource. However, existing habitat quality is degraded throughout the system (USGS 1999). In order to maintain and improve this essential resource, action is necessary. Stakeholders have identified over 2,600 restoration objectives from more than 1,000 separate potential restoration sites (USACE 2000). This gives an indication of the overall level of awareness and need for ecosystem restoration on the UMRS.

1.6 Prior Studies, Reports, and Existing Water Projects

Numerous studies have been completed on navigation improvements and ecosystem restoration on the UMRS. Applicable studies, reports, and projects are listed below.

1.6.1 Studies and Reports

Operation and Maintenance – Upper Mississippi River 9-Foot Navigation Channel, Final Environmental Impact Statement, Pools 11 thru 22. *U.S. Army Corps of Engineers,* Rock Island District, Rock Island, Illinois, July 1974 (USACE 1974).

This report deals with the environmental impacts of the continued operation and maintenance of the existing 9-foot channel navigation system on the Upper Mississippi within the Rock Island District.

Ecological Status and Trends of the Upper Mississippi River System, 1998: A Report of the Long Term Resource Monitoring Program. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, 1999 (USGS 1999).

This was the first report following the inception of the Environmental Management Program and the beginning of data collection under Long Term Resource Monitoring Program in which the monitoring data are summarized into one report, alongside historical observation and other scientific findings. This report also serves as background material for the U.S. Army Corps of Engineers' Report to Congress that provided recommendations for future environmental management of the UMRS. The report provided a timely assessment of river conditions.

A River That Works and a Working River: A Strategy for the Natural Resources of the Upper Mississippi River System. The Upper Mississippi River Conservation Committee (UMRCC), Rock Island, Illinois, 2000 (UMRCC 2000).

This report was collaboratively developed by the State and Federal agencies responsible for managing the natural resources of the UMRS. It describes the critical elements of a strategy for the operation and maintenance of the natural resources of the UMRS and its tributaries, including the setting of restoration goals and objectives. One of the recommended goals is providing native fish passages at dams.

Upper Mississippi River System Habitat Needs Assessment: Summary Report 2000. U.S. Army Corps of Engineers, St. Louis District, St. Louis, Missouri, 2000 (USACE 2000).

The summary report and its supporting technical report were the result of a system-wide analysis of historical, existing, and forecasted habitat conditions. The information in the report was developed to help guide future habitat projects on the UMRS.

Indicators of Ecosystem Structure and Function for the Upper Mississippi River System. U,S. Geological Survey, LaCrosse, Wisconsin (USGS 2018)

This report describes the development of indicators of ecosystem structure and function the UMRS. Indicators were developed that quantify ecosystem characteristics of the UMRS and the characteristics of a resilient river system. These indicators focus on the major drivers of change in a river system. This report provides a broader scale context for the Habitat Needs Assessment-II.

Habitat Needs Assessment-II for the Upper Mississippi River Restoration Program: Linking science to management perspectives. U.S. Army Corps of Engineers, Rock Island District, Rock Island, Illinois (McCain et al 2018).

This report combines data and surveys to evaluate how the existing conditions in the UMR compare to desired conditions identified by the UMRR partnership. The region's resource managers evaluated the twelve indicators from the Indicators Report, identified where existing conditions differ from desired conditions, and provided rankings on which indicators were most important to target for future restoration activities. The HNA-II and the Indicators Report are used to inform habitat restoration activities.

Conservation Priorities for Freshwater Biodiversity in the Upper Mississippi River Basin, R. Weitzell, E. McKhoury, P. Gagnon, B. Schreurs, D. Grossman, and J. Higgins, Nature Serve and The Nature Conservancy, July 2003 (Weitzell et al. 2003).

This study evaluates the components and patterns for the freshwater biodiversity of the Upper Mississippi River Basin and identifies the most significant places to focus conservation opportunities to maintain it.

Environmental Report 54, Interim Report for the Upper Mississippi River – Illinois Waterway System Navigation Study, Improving Fish Passage Through Navigation Dams on the Upper Mississippi River System, Rock Island, IL (Wilcox et al, 2004)

This plan was developed for improving fish passage at the 29 navigation dams on the Mississippi River and 7 navigation dams on the Illinois River. This report was prepared to provide information for use in the Upper Mississippi River – Illinois Waterway Navigation Study.

Integrated Feasibility Report and Programmatic Environmental Impact Statement for the UMR-IWW System Navigation Feasibility Study, September 2004. U.S. Army Corps of Engineers, Rock Island District, St. Paul District, and St. Louis District, Rock Island, Illinois (USACE 2004a).

The feasibility study examines multiple navigation and environmental restoration alternatives and contains the preferred integrated plan as a framework for modifications and operational changes to the UMR-IWW Navigation System to provide for navigation efficiency and environmental sustainability. The purpose of this study was to provide a comprehensive documentation of the Navigation Study process and final recommendations for action including a full disclosure of decision process and compliance with Corps policy and guidance in addition to applicable Federal and state laws. The study recommended conducting detailed planning for fish passage improvements at a number of locks and dams, beginning with Locks and Dams 4, 8, 22, and Mel Price Locks and Dam and beginning design work at Lock and Dam 19 in the first 15-year increment of the NESP. Lock and Dam 22 and Mel Price Locks and Dam were the initial sites selected for further study. The SEA within this PIR will tier from this study because this project has site-specific characteristics that were not addressed in the 2004 study. After public review comments on the SEA are reviewed and considered and the Record of Decision is signed, the FONSI for this SEA will be signed. If public review determines a SEA/FONSI is not appropriate, an

Environmental Impact Statement/Record of Decision will be prepared for signature.

Biological Opinion of the Upper Mississippi River Illinois Waterway System Navigation Study, August 2004. U.S Fish and Wildlife Service, Rock Island, Illinois (USFWS 2004)

This Tier I Biological Opinion evaluated the effects to listed species at the program or ecosystem level.

Improving Fish Passage Through Navigation Dams on the Upper Mississippi River System, Interim Report for the Upper Mississippi River – Illinois Waterway System Navigation Study, October 2004. U.S. Army Corps of Engineers, Rock Island, St. Louis and St. Paul Districts, Rock Island, Illinois (Wilcox et al. 2004)

This reconnaissance level report was prepared as part of the Navigation Study to provide information for plan formulation of that study. It examined the need for fish passage and potential projects on UMRS navigation dams. This report recommended fish passage improvements at 18 dams on the UMRS for the 34 species of migratory native fishes. It also recommended that these projects be monitored to evaluate the ecological and engineering effectiveness of the fish passage improvements.

2005 Monitoring Report – Fish Passage Melvin Price Locks and Dam, Alton, Illinois, and Lock and Dam 22, Saverton, Missouri, Hydroacoustic Identification and Sampling of Fish Aggregations in Tailwater Areas, NESP ENV Report 1, U.S. Army Corps of Engineers, Rock Island, Illinois, 2006. (Cornish et al. 2006)

This data report described the findings of pre-construction monitoring studies performed during 2005. These studies involved hydroacoustic monitoring and capture of fish in the tailwaters of Lock and Dam 22. The purpose of this work was to identify a suitable location to situate a fishway entrance.

Environmental Science Panel Report: Establishing System-wide Goals and Objectives for the Upper Mississippi River System. D. Galat, J. Barko, S. Bartell, M. Davis, B. Johnson, K. Lubinski, J. Nestler, and D. Wilcox, Upper Mississippi River System Navigation and Ecosystem Sustainability Program, NESP ENV Report 6, U.S. Army Corps of Engineers, Rock Island, Illinois, 2007. (Galat et al. 2007)

The report presents suggested refinements to system-wide ecosystem goals and objectives and proposed steps to take in the further development of objectives for the system.

2005-2008 Fish Passage Monitoring Summary Report Melvin Price Locks and Dam, Alton, Illinois, and Lock and Dam 22, Saverton, Missouri. NESP ENV Report 11, U.S. Army Corps of Engineers, Rock Island, Illinois, 2010. (Caswell 2010)

This report describes the results of preconstruction monitoring performed in 2005 through 2008 at Melvin Price Locks and Dam and at Lock and Dam 22. The purpose of this collection effort was the evaluation of fisheries prior to construction of the fish passageways.

Fish Passage in the Upper Mississippi River System, Annual Report. Sara Tripp and Jim Garvey, Fisheries and Illinois Aquaculture Center Department of Zoology Center for Ecology Southern Illinois University Carbondale, IL, 2011 (Tripp and Garvey 2011)

This report describes the results of preconstruction monitoring performed in 2010 at Melvin Price Locks and Dam and at Lock and Dam 22.

Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States. Asian Carp Working Group. Aquatic Nuisance Species Task Force, Washington, DC, 2007 (Conover et al 2007)

This report describes the national control plan for invasive carp in the United States

Upper Mississippi River Master Plan. U.S. Army Corps of Engineers, Rock Island District, Rock Island, IL

The Master Plan conceptually establishes and guides the orderly development, administration, maintenance, preservation, enhancement, and management of all natural, cultural, and recreational resources of the Upper Mississippi River water resource project. The project areas and adjacent areas are owned and managed by the Rock Island District. Park and Fish is designated Recreation- intensive use and the spillway and immediate project area are designated Project Operations.

Mark Twain National Wildlife Refuge Complex Comprehensive Conservation Plan. U.S. Fish & Wildlife Service, Washington DC, 2004

The plan articulates management goals and specifies the objectives and strategies needed to accomplish the National Wildlife Refuge System's wildlife, habitat and public use goals on the nearby Edward Anderson Conservation Area and the Ted Shanks Conservation Area located downstream of the project area or other nearby public lands managed under the Cooperative Agreement.

Environmental Assessment, Material Placement Sites for Maintenance Dredging, Mississippi River Pools 22 and 24 Behind the Sny Island Levee, Pike County, Illinois and Ralls County, Missouri. 2003

This Environmental Assessment addresses the National Environmental Policy Act compliance for channel maintenance dredging and placement in the vicinity of Lock and Dam.

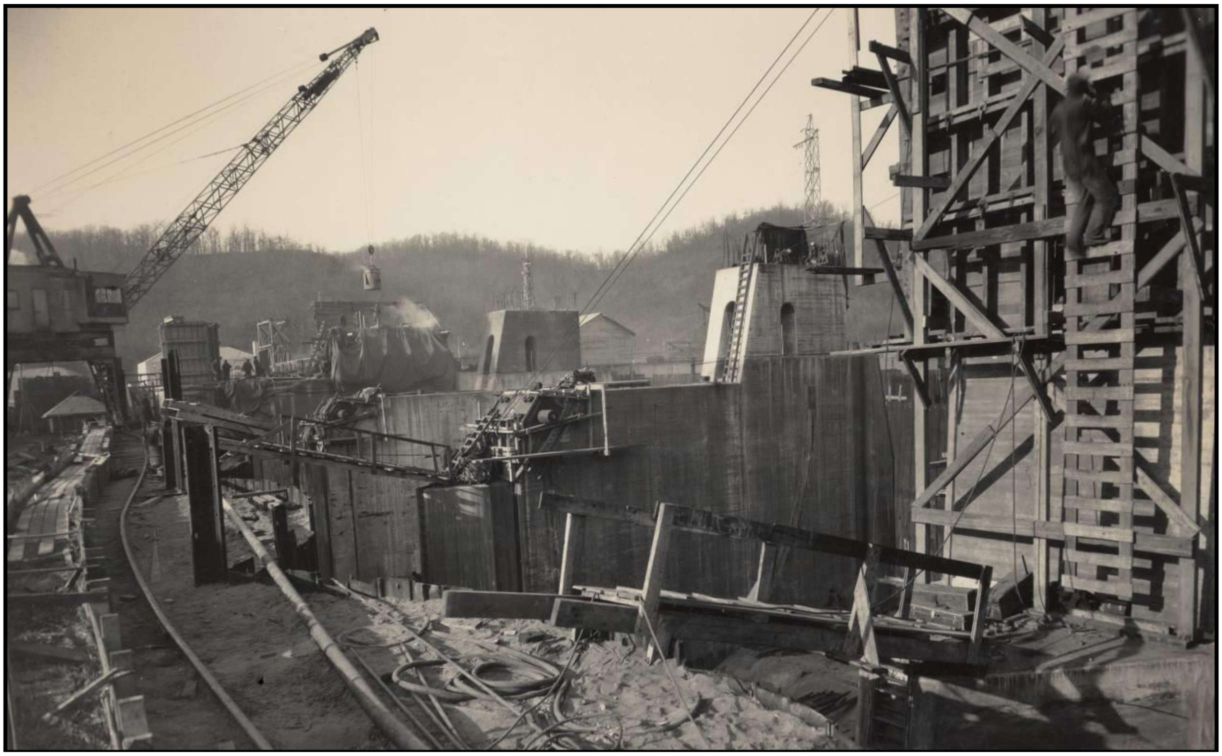
Dredged Material Management Plan for Dredged Material Placement, Upper Mississippi River Miles 300.2-303.4, Pools 22 and 24 Site Plan form the Lock and dam 22 Reach, Lock and Dam 22 Upper and Lower Approach Dredge Cuts, January 2003

The plan proposes to place dredged material from the Lock 22 Upper and Lower dredge cuts on a number of existing (historic) and new dredged material placement sites in the vicinity of River Miles (RM) 296.4-305.3 on the Mississippi River. This plan was developed to meet the projected dredging and placement needs for 40 years. Material from this plan may be used as fill for the fishway.

1.6.2 Water Resource Projects

Lock and Dam 22: Construction on Lock and Dam 22 began in the early 1930s and was completed in 1938 as part of the 9-foot navigation project (Photograph 3 and Photograph 4) created new opportunities for commerce, but it also contributed to the greatly reduced abundance of long-distance migratory fishes such as Skipjack Herring, American Eel, Alabama Shad, Lake Sturgeon, Paddlefish, Blue Sucker, and Blue Catfish. Coker (1914) was the first to observe changes in the migration pattern of fish at the Keokuk dam (Lock and Dam 19). Since then, over 100 studies have documented the effects on dams on fish movement in the UMR (Holland et al. 1984; Ickes et al. 2001).

Photograph 3. Main Lock Construction, October 1934



Photograph 4. Dam Construction, January 1938

Lock and Dam 22 is a low-head navigation dam constructed to provide a 9-foot-deep navigation channel (Photograph 5). The dam was not constructed to reduce flooding damages downriver. It has a design typical of UMR navigation dams with moveable gates extending to a sill on the riverbed.

The dam at Lock and Dam 22 is 3,084 feet long including 1,024 feet of gated structure and a 2,060-foot-long overflow spillway. The structure has 13 gates. Three are submersible roller gates (100 feet wide by 25 feet high), one submersible tainter gate (60 feet wide by 25 feet high), and nine non-submersible tainter gates (60 feet wide by 27 feet high).

Lock and Dam 22 operates using *dam point* control meaning the pool water level immediately behind the dam is maintained within a narrow operating band while the dam gates are in the water. When higher volumes of water flow down the river, the roller and tainter gates on the dam are lifted out of the water because the pool no longer requires regulation (Photograph 6.), and the tail water is allowed to flow naturally. This is important for fish passage because the brief period of open river is the best opportunity for fish to move upstream under the existing dam operating procedures.

Photograph 5. Lock and Dam 22 Looking East Toward Illinois

Photograph 6. Roller Gates at Lock and Dam 22 During Open River Conditions

2 ALTERNATIVE PLAN FORMULATION

2.1 Problems

The primary problem being addressed by this project is restricted longitudinal habitat connectivity for upriver fish movements through Lock and Dam 22. Other problems affecting fish and mussel populations in the UMR were identified at an interagency fish passage workshop early in the study process. The identified problems included:

- historic decline in indigenous fish populations in the UMR
- introduction of exotics
- decline of mussel populations
- loss of longitudinal habitat connectivity
- loss of rock and gravel riffle habitat
- locks and dams disrupt natural fish migration patterns

Many native UMR fishes are migratory and historically traveled throughout the system to seek optimal spawning, foraging, nursery, and overwintering habitats. Under current conditions, fish passage on the system is constrained at 29 mainstem dam locations on the UMR and 8 dam locations on the Illinois Waterway. In addition, passage is typically possible only during the highest flow conditions, which further limits the types of species and ability to pass. Lock and Dam 22 is in open river condition with all gates out of the water only 13 percent of the time over 60 years (Figure 4).

Even with all the gates out of the water, current velocities through the gate openings are high. Only larger and stronger-swimming fishes are able to pass upriver through the dam during open river conditions. At other times, velocities through the dam gates are very high, preventing upriver movements of all fish. The following sections detail the problems regarding fish passage.

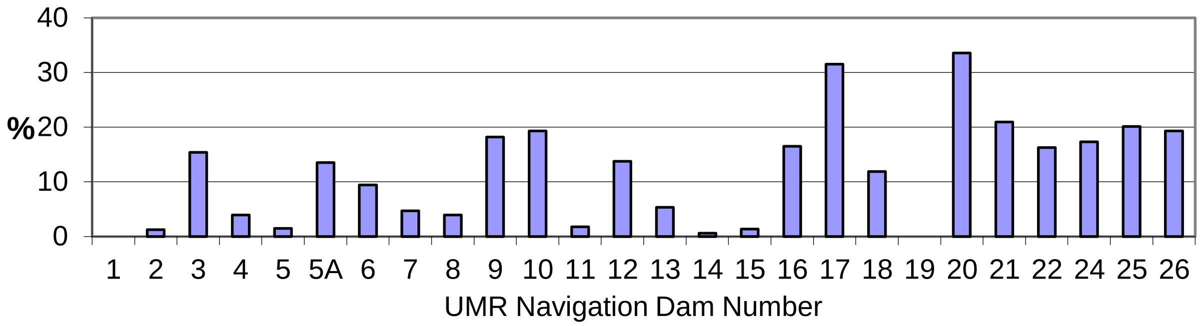


Figure 4. Comparison of Average Annual Time That Dam Gates Are in Open River Condition

2.1.1 Historic Decline in Indigenous Fish Populations

Large populations of Lake Sturgeon, Paddlefish, Channel Catfish, Blue Catfish, and buffalo in the Upper Mississippi River (UMR) once sustained a nationally significant commercial fishery (Townsend 1902, Wagner 1908). Impoundment of the river system changed habitat conditions, fish community composition and the fishing experience for both sport and commercial fishers. Reduced abundance of commercially harvested fish in the UMR in the last century has resulted in considerably fewer fishers working the fishery, markedly reduced catches, and marginalized economic importance of the fishery. Restricted movements of fish through the UMR navigation dams were not the only cause for decline of the commercial fishery but were a contributing factor. Navigation, industrialization, and levees have also been factors, but pollution has been the largest factor in the decline of commercial fishing. By the early 1950s, there was practically no commercial fishing in the middle Mississippi River between St. Louis and the Kaskaskia River (Barnickol and Starrett 1951), and commercial fishermen in the vicinity of St. Louis complained about a gassy or oily flavor to the fish caught in that region (Carlander 1954). A series of environmental laws and ecosystem restoration programs have greatly improved the water quality throughout the Mississippi River, but the pooled portions of the river are experiencing the same sediment-induced aging processes that are found in reservoirs. Restoration efforts through the Environmental Management Program have made positive impacts on the fisheries habitat in parts of the river. The pooled portion of the UMR is presently in better environmental condition than the middle Mississippi River (Pitlo and Rasmussen 2004).

2.1.2 Introduction of Invasive Species

Aquatic invasive species use rivers to expand their range. Invasive species can occupy the same ecological niche as native species. In the end, one will out-compete the other and retain sole possession of the niche in question. The UMR navigation dams presently limit the upstream spread of invasive carp (Bighead and Silver carps) in the same way they limit the movement of native migratory fish species. Invasive carp became established in the Mississippi River basin in the early 1980s (Freeze and Henderson 1982) and have steadily increased in abundance over time (Conover et al 2007). A fish passage structure would enable the movement of native species and invasive carp. In theory, the invasive carp could eventually displace native fish species like buffalo and Paddlefish in the areas where they co-exist; however, there is no evidence that native species have been extirpated from the areas of the UMR where invasive carp are abundant. Lock and Dam 22 was selected as one of the first fish passage projects by natural resource managers because it would have minimal effect on the northern expansion of invasive carp. Reproducing populations of invasive carp have already been found both upstream and downstream of the dam. Monitoring studies of invasive carp on the Illinois River found that flood pulses appear to trigger dispersal; however, movements were in both an upstream and downstream direction. The lack of strongly directed upstream migration instinct and the presence of navigation dams may explain why invasive carp have been caught only occasionally in the upper pools of the UMR. During initial planning (2009), the northernmost collection of adult Bighead Carp was in Lake Pepin, in Pool 4; for Silver Carp, the northernmost collection of juveniles was in Pool 18 and adults in Pool 8. As of 2020, adults of both species have been captured in Pool 2, and spawning has been documented in Pool 16.

2.1.3 Loss of Longitudinal Habitat Connectivity

River ecosystems are complex systems of energy, water, and material flows interacting with a diverse set of organisms. These ecosystems can be characterized by lateral (river/floodplain), longitudinal (upstream/downstream), vertical and temporal relationships. A “healthy” river maintains its connectivity as determined by the geomorphologic characteristics of the watershed. These physical connections allow river ecosystems to be resilient to external stresses within a certain range of natural variation, maintaining a self-sustaining condition of the ecosystem. Disruption of these relations can lead to degradation of the river ecosystem. The dams on the UMR and its tributaries disrupt the longitudinal connectivity of the river corridor and alter the distribution and abundance of many river organisms, including migratory fish.

2.1.4 Loss of Rock and Gravel Riffle Habitat

Prior to dam construction there were three major rapids on the UMR: 1) in the gorge between Minneapolis and St. Paul, Minnesota; 2) the Des Moines rapids located upstream of the confluence of the UMR and the Des Moines River in Iowa; 3) the Rock Island rapids located upriver of the confluence of the UMR and the Rock River in Illinois. These three rapids were flooded by construction of Lock and Dam 1 in 1917; Lock and Dam 19 in 1914; and Lock and Dam 15 in 1934, respectively. The area of these rapids can only be approximated, but they were extensive:

- St. Paul to Minneapolis gorge - 8 miles long, 800 ft channel width, 870 acres
- Rock Island Rapids - 14 miles long, 1600 ft channel width, 2715 acres

- Des Moines Rapids - 11 miles long 4500 ft channel width, 6000 acres

Riffle habitat is important for rare large river fish species such as Lake Sturgeon and Blue Sucker that use these areas for spawning.

2.1.5 Locks and Dams Disrupt Natural Fish Migration Patterns

Navigation dams on the UMR restrict movements of river fishes and reduce access to aquatic resources. Under normal operation the velocities of water going through the gate bays at Lock and Dam 22 are faster than fish can swim against. Impeded fish movements resulting from dams have been implicated in altered fish community structure and the decline of many fish populations in rivers throughout the world (Northcote 1998, Pringle et al. 2000). Prior to dam construction on the UMR, Wagner (1908) observed that Skipjack Herring were once exceedingly abundant in Lake Pepin (Pool 4), whereas now they are considered rare (Pitlo et al. 1995, Steuck et al. 2010). Coker (1914, 1923, 1929a, 1929b) documented changes in the distribution and abundance of fish in the Upper Mississippi following the construction of the Keokuk Dam (Lock and Dam 19). Restrictions on movements of migratory fish in a river system limit the extent and quality of habitats that they can occupy. Effects of reduced access to habitats can be expressed at the individual, population, and community levels.

2.1.6 Decline of Mussel Populations

Migratory fish play a key role in the life history and reproductive success of Unionid mussels in the UMR. The near extirpation of a formerly common Unionid mussel, the Ebonyshell, in the northern reaches of the UMR has been attributed to the reduced upriver migration of the Ebonyshell’s glochidial host fish, the Skipjack Herring (Eddy and Surber 1943, Fuller 1980). Restricted movements of fish between navigation pools may restrict gene flow within mussel species that are dependent on a single fish species as their glochidial host (Romano et al. 1991).

2.2 Opportunities

This project presents numerous opportunities to address the previously stated problems. Opportunities are documented in the following sections.

2.2.1 Address Historic Decline in Indigenous Fish Populations in the Upper Mississippi River

Fish passage through navigation dams is critical to the long-term sustainability of the ecological integrity of the UMR. Improving fish passage at the UMR navigation dams provides an opportunity to adaptively manage the fish community to benefit native species. Facilitating fish passage for all species increases available habitat and may provide access to seasonal habitats that were previously disconnected and limited success during a key life history stage.

2.2.2 Assist in Invasive Species Management

Fish passage offers the opportunity to restore and enhance native fish populations so they can better compete with invasive species such as invasive carp. Restoration of fish passage may also offer ways to reframe invasive species management in a way that broadens the set of values it considers and empowers participants to discover more successful and inclusive solutions (Gobster 2005). For example, fish passage structures may provide the opportunity for monitoring, managing, and removing invasive aquatic nuisance species. Future management of a fishway may require focus on sorting and selectively passing a mixed fish assemblage by predetermined categories of desirable and undesirable species by exploiting or overcoming differences in phenological, behavioral, physiological, social, and morphological attributes/traits of each fish at the individual and species-level (Great Lakes Fishery Commission 2021).

2.2.3 Restore Longitudinal Habitat Connectivity

A fish passage improvement at UMR navigation dams offers the opportunity to restore access to upstream habitats (longitudinal connectivity) for numerous fish species at all times of the year. This project provides the opportunity to identify measures that would enhance fish migration and restore connectivity. This knowledge could then be applied to other locks and dams on the UMR.

2.2.4 Restore Rock and Gravel Riffle Habitat

Fishways offer the opportunity to recreate riffle habitat within the fishway itself.

2.2.5 Minimize Disruption of Locks and Dams on Natural Fish Mitigation Patterns

Fish passage at Lock and Dam 22 provides the unprecedented opportunity to study the behavior and response of large river fish species to the restoration of longitudinal connectivity on the Upper Mississippi River.

2.2.6 Restore Mussel Populations

Restoration of fish passage at Lock and Dam 22 would enable greater numbers of migratory fish to move mussel glochidia upstream, thereby broadening the distribution of mussels and reversing the decline of mussel populations that rely upon migratory fish for glochidia dispersal. For example, a fishway would allow more infested Skipjack Herring to migrate upstream, restoring populations of Ebonyshell, into areas where they were formerly common, but now extirpated.

2.3 Goals and Objectives

This site-specific restoration project was identified and evaluated with the primary purpose of contributing to the restoration of the Upper Mississippi River and Illinois

Waterway. The NESP has developed a vision statement and overarching system-wide ecosystem goals for the restoration of habitat in the UMRS. The site-specific goals and objectives are nested within the context of the system goals and objectives as described below.

2.3.1 Vision Statement

To seek long-term sustainability of the economic uses and ecological integrity of the Upper Mississippi River System.

2.3.2 System-Wide Ecosystem Goals

The overarching ecosystem goal is to conserve, restore, and maintain the ecological structure and function of the UMRS to achieve the vision. The goal and vision statement imply conserving the UMRS's remaining structure and function while restoring the degraded components to realize a sustainable UMRS. Galat et al., 2007, identified five system-wide objectives:

1. Manage for a more natural hydrologic regime (hydrology and hydraulics).

2. Manage for processes that shape a physically diverse and dynamic river-floodplain system (geomorphology).

3. Manage for processes that input, transport, assimilate, and output material within UMR basin river-floodplains: e.g., water quality, sediments, and nutrients (biogeochemistry).

4. Manage for a diverse and dynamic pattern of habitats to support native biota (habitat).

5. Manage for viable populations of native species within diverse plant and animal communities (biota).

2.3.3 Site-Specific Objectives

The project addresses system-wide goals 2, 3, 4, and 5.

In addition, the following site-specific objectives developed for Lock and Dam 22 Fish Passage are:

1. Increase the abundance and spatial distribution of all native migratory fish populations (biota).

2. Provide rock rapids and riffle habitat for fish spawning and for macroinvertebrates (geomorphology and biochemistry).

3. Increase habitat corridors and connectivity opportunities for migration of native fish and mussel populations (habitats).

4. Implement a science-based monitoring and adaptive strategy for all project phases:

    - Develop improved design criteria for future UMR fish pathways to be more ecologically effective in passing fish, including appropriate channel width, depth, flow, hydraulic conditions, and size and placement of stone riffles.

    - Develop improved design criteria for future UMR fish pathways to be less costly and more easily constructed.

    - Develop improved design criteria for operation and maintenance of future UMR fish pathways.

    - Develop improved design criteria for future UMR fish pathways to avoid interference with navigation and water control functions of the locks and dams.

Table 1 summarizes the relationship among objectives, performance evaluation criteria, and the rationale. It should be noted that not all criteria must be met in order to achieve the objective; the criteria are indicators of ideal conditions. Additional information on the indicators and units of measurement is presented as part of the Adaptive Management & Monitoring Plan found in Appendix M, *Monitoring & Adaptive Management*.

Table 1. Study Objectives, Performance Indicators, and Units of Measurement

Site Specific Objectives	Performance Indicators	Units of Measurement
Increase the abundance and spatial distribution of native migratory fish populations	Increase the time that fish can pass upriver.	Relative abundance, geographic range (number of individuals/ha, CPUE, presence)
	Provide increased upriver fish passage opportunity through Lock and Dam 22 that allows adult individual migratory fishes occurring in the tailwaters to pass upriver through the dams during their upriver migration periods.	Relative abundance, geographic range (number of individuals/ha, CPUE, presence)
	Increase the numbers of Skipjack Herring passing upriver within 5 years post construction.	Relative abundance, geographic range (number of individuals/ha, CPUE, presence)
Provide rock rapids and riffle habitat for fish spawning and for macroinvertebrates	Create rock rapids and riffles in a fish pathway that provides year-round habitat for fish and macroinvertebrates.	Current velocity, hydraulic strain, area and volume within target ranges contiguous with fish pathway entrance location (m/sec, Δ x, y, z m/sec/m)
Increase habitat corridors and connectivity opportunities for migration of native fish and mussel populations (habitats)	Increase populations of native migratory fishes upriver as demonstrated by range extensions and increases in relative abundance [catch per unit of effort (CPUE)] from those described in Pitlo (1995).	Relative abundance, geographic range (number of individuals/ha, CPUE, presence)

Adaptive Management & Monitoring. Adaptive ecosystem management was recommended by the Navigation Study Science Panel (Lubinski and Barko 2003), in the National Research Council reviews of the Navigation Study (NRC 2001, 2004), in the 2004 Feasibility Study (USACE 2004a), and by the NESP Science Panel (Barko et al. 2006) and was considered during the development of measures and evaluation of alternatives.

The NESP Science Panel recommended an adaptive management framework including these six activities:

1. refining and clarifying ecosystem objective;

2. developing evaluation criteria for outcomes including ecosystem services;

3. evaluating and sequencing proposed ecosystem restoration projects;

4. monitoring, including selection of response variables appropriate to different scales;

5. evaluating relevant ecological indicators, metrics, and outcomes for an UMRS ecosystem condition report card; and

6. integrating ecological models and using information technology to facilitate the adaptive management process (Barko et al 2006).

The fish passage (Lock and Dam 22 and Mel Price Locks and Dam) Product Delivery Teams (PDT) held two workshops with the NESP Science Panel during the early development of project measures and the monitoring plan. There were five main themes to these discussions:

1. clearly articulate project objectives and design criteria;

2. utilize systemic and site-specific monitoring to fill information gaps;

3. draw upon multiple lines of evidence to detect change;

4. incorporate non-structural measures into the alternatives; and

5. design flexibility for experimentation into constructed features.

As a result of these workshops, the NESP Science Panel provided the following broad but important recommendations for consideration to the PDT and the NESP management in a letter dated November 6, 2006:

- Allow for the development and selection of project alternatives that provide flexibility for experimentation in locating and operating the structures, both during and after construction. The ability to learn through experimentation at

Lock and Dam 22 and Melvin Price Locks and Dam, despite additional initial costs, will provide valuable information to help reduce costs and increase fish passage effectiveness at future project locations throughout the UMRS.

- Encourage the inclusion of performance evaluations both pre- and post-construction. Because these projects are the first attempts at fish passage structures on the UMRS, there are many unknowns and much to learn. Adequate evaluation of fish passage performance is critical. Learning, for the purpose of reducing uncertainty, cannot be achieved without an effective performance evaluation plan.

- Remain mindful that increased fish passage in the UMRS, although absolutely critical to migration, may not alone result in the expanded distribution and/or increased abundance of migratory fishes throughout the system. Other factors, such as the availability of suitable habitat features upriver, will need to be considered to assess fish passage success systemically. A systemic monitoring effort will be needed to assess system-wide responses to fish passage. It is not clear how and when such a monitoring plan will be developed.

- Implement a modeling study to explore the numbers of fish passages required to produce a measurable response in fish distribution and abundance.

Based upon these recommendations, the PDTs broadened the monitoring plan to seek multiple lines of scientific evidence to detect environmental change from increasing fish passage at both a site-specific level and a system level, and to include a systemic modeling study to explore the potential effects of improved fish passage through UMR dams on fish populations. The PDTs also gave greater consideration to those project measures which increased the flexibility for experimentation to answer specific questions about fish migration and fishway design for later projects.

2.4 Constraints and Assumptions

The following constraints have been identified for the system and individual projects:

- **Navigation:** Avoid significant adverse effects on navigation of the UMR and the IWW to include:
    - continuing to operate and maintain the 9-foot channel navigation project for the life of the Fish Passage Improvement Project
    - not interfering with water control for navigation
    - not interfering with dam operations, including access to dam for equipment, etc.
    - maintaining the structural and geotechnical integrity of the dam

- **Flood Elevations:** Avoid increases in flood elevations that would require mitigation of adverse effects. Due to the potential high cost associated with mitigation actions, efforts will be made to avoid this threshold.

- **Land Acquisition:** Any land acquisition by the Secretary for ecosystem restoration projects will be from willing sellers.
    - landside structures and landforms limit viable fish passage options (buildings, roads, Illinois levee, Missouri bluff)

- **Legal Compliance:** All efforts conducted in the implementation of the proposed project shall comply with all Federal regulations pertaining to the activities undertaken by the Corps of Engineers.
    - maintain the historical and architectural integrity of the dam at Lock and Dam 22
    - maintain safety for people (operational and recreational users)
    - maintain security
    - minimize operation and maintenance costs

During the development of this project, the following assumptions were made:

- Extensive pre- and post-project monitoring will be conducted. Results will be evaluated to help design the project, determine project performance, experiment with fishway dimensions, and the lessons learned will be applied to the design of future fish passage improvement projects.

- During the early scoping phase on the project there was extensive public involvement and agency coordination. Public and agency coordination will continue as the study progresses.

2.5 Potential Measures

2.5.1 General

Potential measures are actions that could contribute to achieving the project objectives. A measure is a feature (a structural element that requires construction or assembly on-site) or an activity (a nonstructural action) that can be combined with other management measures to for alternative plans. Both nonstructural and structural measures were considered to improve upriver fish passage at Lock and Dam 22. The measures considered are in Table 2, and are shown in the plates attached to this report (Appendix Q, *Plates*).

Table 2. Potential Measures Considered

Measure	Measure Description
Nonstructural Measures	
Measure A	No Action
Measure B	Fish Lockage
Measure C	Extended Period of Open River Conditions
Measure D	Fish Stocking
Structural Measures	
Measure E	Nature-like Fishways
Measure E.1	Rock Ramp Adjacent to the Storage Yard, Downstream of the Spillway, 50 ft Bottom Width
Measure E.2	Rock Ramp Adjacent to the Storage Yard, Downstream of the Spillway, 100 ft Bottom Width
Measure E.3	Rock Ramp Adjacent to the Storage Yard, Downstream of the Spillway, 200 ft Bottom Width
Measure E.4	Rock Ramp Adjacent to the Storage Yard, Downstream of the Spillway, 300 ft Bottom Width
Measure E.5	Rock Ramp Adjacent to the Storage Yard, Upstream of the Spillway, 100 ft Bottom Width
Measure E.6	Rock Ramp Adjacent to the Illinois Shoreline, Upstream of the Spillway, 100 ft Bottom Width
Measure E.7	Bypass Channel on the Illinois Shoreline, Bisecting the Spillway, 82 ft Bottom Width
Measure E.8	Rock Ramp through Gate 13, Upstream of the Dam
Measure F	Technical Fishway
Measure F.1	Pool Pass
Measure F.2	Slot Pass
Measure F.3	Denil Pass
Measure F.4	Fish Elevator
Measure G	Dam removal
Measure H	Siphons
Measure I	Notches through the spillway

2.5.2 Potential Measures and Increments

2.5.2.1 Non-Structural Measures

Measure A: No Action. *No action* includes no change to the existing structures or the operation and maintenance (O&M) at Lock and Dam 22. If no action is taken at Lock and Dam 22, populations of migrating fish will most likely be maintained at existing levels in Pool 22 and 24. These populations are well short of the populations the UMR is able to support. Taking no action would not meet the goals and objectives of the project and the UMR would be unable to return to a condition when large groups of migratory fish were plentiful.

Measure B: Fish Lockage. This measure involves modification to the locking procedures to pass more fish around the dam. Fish lockage has been used with mixed success at a minimum of four locks in the U.S.

This operational measure could be applied at Lock and Dam 22 through the 600 ft lock if a new 1,200 ft lock is constructed as is proposed through the NESP. The following assumptions were made for locking fish through Lock and Dam 22:

- Fish lockage would occur during the primary migration periods for UMRS fish, which are April through June and October through November (152 days total or approximately 40 percent of the year).
- All commercial and recreational navigation traffic would have precedence. Fish lockage would occur during low traffic periods.
- A maximum of five fish lockages per day would occur during low traffic periods.
- Each fish lockage cycle would take one hour to complete.
- Fish lockage would require staff for lock operations and maintenance.
- The increase in lock operations for fish passage would accelerate the lock rehabilitation schedule.

At the start of the fish lockage cycle, both the lower and upper miter gates of the lock would be closed. The water level in the lock would be lowered to the tailwater elevation. The lower end miter gates would be opened completely into the miter recesses. To attract fish, the tainter valves in the lock filling culverts would be cracked open to allow water to flow out of the completely opened lock chamber at a no-head condition. After a period of one-half hour, the tainter valves would be closed to stop the attractant flow and the lower miter gates would be immediately closed to trap the fish in the lock. The lock would be operated to raise the surface level to the upper pool elevation. The upper miter gates would be opened completely into the miter gate recesses for 1/2 hour to allow the fish into the upper pool. The lock draining conduits would be opened to set up currents in the lock chamber that would induce the fish to leave the lock. Opening the lock-draining conduits with the upper miter gates is possible but may require modifications to the lock operating controls to accomplish routinely. The upper miter gates would be closed, completing the process. Attractant flow could be further enhanced by installing a minimum of four sluice gates in the upper miter gates to attract fish to the upstream end of the lock. Any modification to the miter gate would be designed to avoid impacting the structural integrity of the gates.

At Lock and Dam 22, fish could be attracted into the navigation lock by first closing the upper and lower miter gates, then lowering water level in the lock chamber to the tail water level. Opening the lower miter gate would allow the fish to enter the lock chamber. Fish could be attracted in the lock chamber by allowing the attracting flow through small size sluice gates in the upper miter gate. A minimum of four sluice gates would be installed on the upper miter gate so as to allow sufficient attracting flow. After allowing fish time to enter, the lower miter gate could be closed, the lock chamber filled, and then the upper gate could be opened to allow the fish to leave the lock into the upstream pool. Fish lockage could be done during the late April through June and the October through November periods of fish migration in the UMRS.

There is no construction cost associated with the measure. Rather there is only an operation and maintenance (O&M) cost for this measure. These costs are in addition to the existing operational costs at the lock.

Assisted lockages may not be sufficient to routinely pass large numbers or whole populations of fish in the UMRS. The limitations of using navigational locks as fishways include: the considerably greater attracting flows for fish at the gated parts of the dams than at the locks; mixed rheotactic cues for fish within the lock chambers; the potential for disorientation and propeller entrainment as commercial vessels enter and leave the locks (Keevin et al. 2005); the wear of lock machinery; and potential additional labor cost from additional lockage cycles. Construction of a second lock would make the original main lock chamber available more often for passing fish.

Zigler et al. (2004) suggested that modeling studies should be conducted to study the flow patterns in tailwaters and evaluated alternatives in gate operation to enhance fish passage. A computer simulation of flow patterns below Lock and Dam 22 showed flows around the lower lock entrance were different than those below the storage yard. Fish monitoring data, described in Chapter 7, *Adaptive Management & Monitoring*, shows that fish aggregate on the opposite side of the dam, below the storage yard. Creating similar flows near the lock by manipulating dam gates is not possible at this dam.

Additionally, there is another NESP project that would construct a new lock in the auxiliary lock bay, between the existing lock and the main channel. This new lock and guidewall will extend 2,000 feet downstream of the tailwater area, effectively separating it from the tailwater environment. Migrating fish that are milling in the tailwaters would be unable to find the existing lock because the entrance is too far downstream.

Measure C: Extend Period of Open River Conditions. Lock and Dam 22 has 13 moveable gates that extend to a sill on the river bottom and are operated to maintain a 9-foot-deep navigation channel in Pool 22. At higher levels of river discharge, all the gates are raised out of the water and open river conditions occur. Larger and stronger swimming fish can pass upriver through the dam gates during open river conditions. Extending the period of open river conditions involves changing gate operation to extend the time that fish can pass upriver through the dam.

Dam operation can be modified to extend the period of open river conditions when open channel flow occurs through the gate openings (Figure). The current velocities through the dam gate openings at open channel flow are low enough for some fish to pass. However, when the dam gates are in the water, orifice flow conditions create high current velocities through the dam gate openings that they are impassable by fish.

Changing the dam operation involves drawing down the pool. While the magnitude of the drawdown can vary, the greater the drawdown, the more difficult it would be to maintain the 9-foot navigation channel. A 2-foot drawdown was chosen because it reduces velocities enough to have some positive impact for fish while having a chance to maintain the 9-foot channel with some dredging anticipated.

One way to extend the time period of open river conditions is to operate the dam with a longer 2-foot drawdown at the dam. Numerical hydraulic modeling (Figure) results indicate that during a 2-foot drawdown, current velocities through gate bays 2 through 12 range between 6 and 7 feet per second. Velocities through the end gate bays 1 and 13 vary widely, but overall, the cross-sectional area of suitable velocities for upriver fish passage would not increase significantly over the normal dam gate operation. Even if there were significantly lower current velocities through the dam gate openings, the additional amount of time that a 2-foot drawdown could be maintained is small.

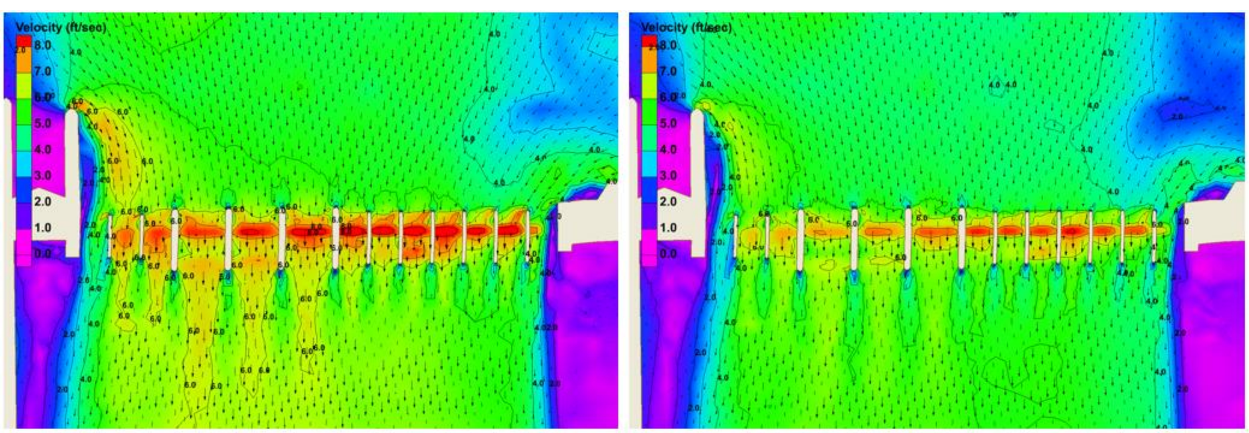


Figure 5. Image on the left - Dam Out of Operation at 458.5 Ft MSL 1912 (Normal Operation Plan). The gates are numbered sequentially with Gate 1 closest to the lock chamber on the left and Gate 13 on the right. Image on the right - Dam Out of Operation at 456.5 Ft MSL 1912 (2-Foot Drawdown Condition)

Open river conditions currently exist 13 percent of the time in a typical year (a typical year is based on a 60-year period of record, from 1947 through 2006). With a 2-foot drawdown, open river conditions would exist 16 percent of the time, again given a typical year. Therefore, the difference of 3 percent is the percentage of time when any drawdown down to a 2-foot drawdown condition could exist during a year. That would assume other variables would be conducive, such as ability to dredge in order to maintain a navigable 9-foot channel.

Modifying river regulation at Lock and Dam 22 with increased drawdown of Pool 22 would require further hydraulic analysis and revising the Master Water Control Plan with approval by the Mississippi Valley Division. Drawdowns of navigation pools on the UMR are done as part of routine river regulation at the dams with mid-pool control points. Growing season drawdowns of navigation pools have successfully been used to restore emergent aquatic plants.

It is also important to mention that just keeping one or two gates out of operation while the rest stay in operation is not an option. The other gates would maintain Pool 22, creating a waterfall through the open gate bays for tailwater levels below 458.5 MSL 1912. These velocities would be too high for fish passage. If more gates were opened, the ability to maintain pool depth would quickly be diminished, and the effect would be the same as if all gates were open.

Measure D: Fish Stocking. The fish stocking alternative involves supplementing wild stocks with hatchery grown fish to mitigate for the effect of the dam on fish populations. A fish hatchery would be constructed in the vicinity of Pool 22. Fish stocking would occur upstream of the dam in Pool 22. Fish would be released from stocking trucks at boat ramps. This measure involves stocking fish in Pool 22 annually with 28 species of migratory fish.

There are two examples of where fish stocking has been successful in the UMR, Exelon Quad Cities Generation Station, Cordova, Illinois, and Missouri Department of Conservation (MDC) Lake Sturgeon stocking. In Pool 14, at the Exelon Quad Cities Generating Station, Walleye and hybrid striped bass have been stocked since 1984 to mitigate for cooling water discharge from the nuclear power facility, providing sport anglers with additional harvest opportunities. Beginning in 1988, MDC stocked Lake Sturgeon in Pools 20, 21, 22, 24, and 25 to restore depleted populations as part of a long-term sturgeon recovery program. There have also been numerous unintentional and sometimes harmful stockings, the most noteworthy of these being the release of Bighead and Silver carps, which were inadvertently released from fish hatcheries into the wild in the 1970s.

A warmwater multi-species fish hatchery would cost approximately $20.7 million to construct based upon the recently constructed Fort Peck warmwater fish hatchery in Montana (Ted Streckfuss, Omaha District, USACE pers. com, 2007). The annual costs to rear and stock fish include those associated with collecting eggs from fish and transporting them to the hatchery; operational costs for the hatchery itself including personnel, utilities, fish food, maintenance; and the cost to distribute the fish. The annual costs to rear and stock fish in Fort Peck were estimated to be $750,000 for four species of fish. Costs for rearing 28 species would be expected to be higher because of the complexity of raising these additional species to stocking size.

Fish stocking as a restoration measure is contrary to the NESP's goals and objectives, which include maintaining viable population in situ and restoring and maintaining evolutionary and ecological processes. The debate over hatchery fish versus wild fish has gone on for decades among fisheries professionals and has been the subject of many journal articles. Stocking is an inherently artificial means for managing natural systems and requires a long-term financial commitment. Some species of fish, especially migratory fish, exhibit homing instincts during spawning, which may be unique to specific genetic strains of fish. Stocked fish may not possess this instinct and may not be capable of establishing naturally reproducing populations in the wild.

2.5.2.2 Structural Measures

Structural measures included nature-like fishways, technical fishways, dam removal, siphons, and notches through the spillway. Although these measures have distinct differences, there are some base requirements that apply for all constructed structural measures. The first is to maintain access to the storage yard across the spillway. The second is to protect the structures from significant ice and debris found in this portion of the UMR.

All structural measures would require an ice and debris boom structure upstream of the constructed fishway. The boom would reduce the amount of debris which would have to be removed to maintain fishway functionality. The boom would also reduce damage to the fishway from ice and debris, which would reduce the number and frequency of repairs to the fishway. A description of the ice and debris booms considered and selected is contained in Appendix I, *Structural Considerations* and Appendix H, *Hydrology and Hydraulics*. A fixed boom was selected for protection of structures. The Rock Island District has had success with this type of boom in the Mississippi River in deflecting ice and debris similar to what will be encountered at Lock and Dam 22. A review of the boom by the District's Structural Engineering Section, Design Branch, Engineering Division, determined that a structural engineering inspection will be required every 5 years in accordance with ER 1110-2-100, "Periodic Inspection and Continuing Evaluation of Completed Civil Works Structures", dated February 15, 1995. This review will be part of the structural engineering periodic inspections. It is not anticipated that there will be significant O&M costs with either type of debris boom unless there is a major event.

All constructed structural measures located along the spillway would require a crossing to access the storage yard. These crossings are required for the O&M of the lock and dam. The crossings must include water control structures to allow for further manipulation of the fishway for adaptive management purposes. A description of the crossings considered is contained in Appendix I, *Structural Considerations,* and Appendix H, *Hydrology and Hydraulics*. A prefabricated bridge system was determined to be the preferred system since it met the requirements for crossing, reduced floodplain impacts, and was less expensive than other alternatives. For operation and maintenance, a bridge inspection and a water control structure inspection would be required every 5 years in accordance with ER 1110-2-100, *Periodic Inspection and Continuing Evaluation of Completed Civil Works Structures*, dated February 15, 1995. This review will require a separate report and input by the District’s Structural Engineering Section. The prefabricated bridge system would not need to be repainted or resealed, but any eroded material on the bridge deck would need to be replaced, and guide rails may need to be replaced after major events. The debris boom should deflect debris from this structure, but if it fails the arch opening of the bridge should be cleared of tree trunks and bulky debris. The water control structure will need to have seals replaced every 15 years, and steel components and stoplogs will need repainting every 30 years.

Measure E: Nature-Like Fishway. A nature-like fishway is a broad term for several styles of structures constructed with natural materials, with rock being the most common. Nature-like fishways have proven effective for a wide range of fish species with varying swimming abilities (DVWK 1996; 2002; Gaboury et al. 1995). The purpose of these nature-like fishways is to simulate natural river channels. In addition to improving fish passage past dams, nature-like fishways provide benefit for many aquatic organisms. Figure shows conceptual layout of a partial-width rock ramp fishway (additional conceptual layouts can be found in Appendix E, *Engineering*). Aadland (2010) described the advantages of emulating natural channel geomorphology and materials in a fishway as:

1. Fish react to complex current and bathymetry cues, and channels similar to natural channels are less likely to cause disorientation than channels that are not.

2. Natural channel design allows fishways to provide important spawning habitat as well as passage.

3. Use of natural substrates, rather than concrete or other smooth materials, provides roughness and interstitial spaces that allow small fishes and benthic invertebrates to pass and, in many cases, colonize the fishway.

4. A fishway built with natural channel design techniques provides habitat that in some cases may be rare due to reservoir inundation.

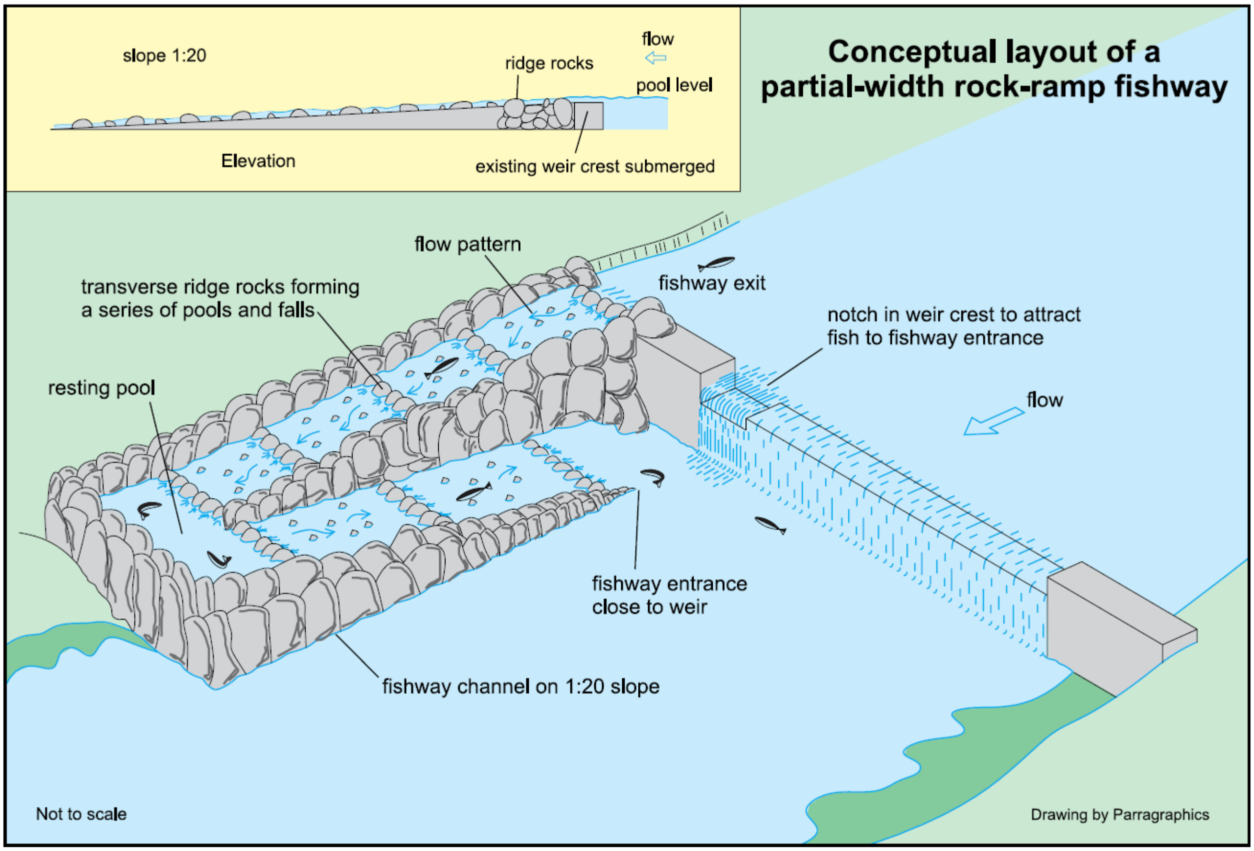


Figure 6. Conceptual Layout of a Partial-Width Rock Ramp Fishway (Throncroft and Harris, 2000)

Rock ramps are nature-like fishways that simulate conditions of natural rapids. While rapids are not naturally abundant on the Mississippi River, prior to navigation project work, rapids were present at the Des Moines Rapids (Keokuk, Iowa), the Rock Island Rapids (Rock Island, Illinois), and St. Anthony Falls (Minneapolis, Minnesota). Rapids still exist at the “Chain of Rocks” near St. Louis, Missouri, and at a number of locations on Mississippi River tributaries. Rock ramps can be constructed to create continuous rapids where most of the ramp is fairly turbulent and has higher velocities or they can be constructed to create pool/riffle conditions where the head loss occurs at steps with resting pools in between those steps. Rock ramps have been used effectively to restore Lake Sturgeon spawning habitat (Aadland et al. 2005) and enhance macroinvertebrate communities (Litvan et al. 2006).

In addition to improving fish passage past dams, nature-like fishways provide year-round habitat for fish and macroinvertebrates adapted to higher gradient river conditions. Rock riffles provide important spawning habitat for a number of native species including Lake Sturgeon (Wilcox et al. 2004) and Walleye (Dustin and Jacobson 2003, Leblanc et al. 2017), as they provide the gradient, substrate, and flow preferred for spawning (Daugherty et al. 2009, Lyons et al. 2016). Riffles provide a boundary layer very near the streambed or other surface that has zero or very low flow and a viscous sublayer (Vogel 1994) that combine to form a three dimensional flow microenvironment that is critical to the recruitment of microbes and invertebrate larvae to surfaces of all kinds (Nowell and Jumars 1984). Edwards et al. (1984) reported higher total macroinvertebrate densities on artificial riffles; however, these densities can vary annually (Walther and Whiles 2008).

Nature-like fishways are gradually sloping open channels with a rough bottom or a series of riffles and pools (Wildman et al. 2003, Acharya et al. 2004). The closer a nature-like fishway matches the morphological characteristics of natural river habitat for the species present, the less likely hydraulic conditions will reach thresholds that limit fish passage (Parasiewicz et al. 1998). Nature-like fishways have proven effective for a wide range of fish species with varying swimming abilities (Katopodis and Aadland 2006). Rock rapid weir designs enable passing of large-bodied fish (Lake Sturgeon) in both the upstream and downstream directions when strategically placed in an area of optimal flow (Bruch 2008). Cooke et al 2020, identified this as an area where more science is needed.

Design Criteria. The rock ramp fishways being considered for Lock and Dam 22 are pool/riffle structures. The riffles serve as the steps of the fishway. The pool and riffle details are shown on Plate C14. The riffles were designed with 4H:1V slopes or flatter for stability from a geotechnical standpoint and a riffle top length of 5 feet to ensure stability, and more than 2 feet of depth between the boulders at the riffles. The space between the boulders would be graduated from tightly spaced near the shores to wider gaps between boulders in the middle of the fishway. This creates lower flow areas near the bank and higher flow areas in the middle to accommodate the swimming ability of both small and large fish. The bed of the fishway would have an elliptical shape, being deepest in the middle section of each riffle. The layout of the riffles extends across the bottom of the fishway and may extend slightly up the side slopes. While curved riffles were evaluated for structure layouts during the study phase, other layouts could be as successful. However, straightening the shape of the riffles too much may oversimplify the velocity profile created by the riffle, making the fishway less suitable for passing both large and small fish. Fish orient their body in flowing water using the helical flow pattern found in channels to identify the upstream direction and using current breaks (eddies) for resting and feeding. The arched configuration with the associated complex flows through the riffle step is desirable in emulating a natural stream and has been effective in other fishways. The pool between the riffles was designed to be 20 feet in length at 5 feet deep to ensure that there was adequate resting room for fishes before and after each riffle passage.

Ideally, the slope of any nature-like fishway would be gradual, with few very low vertical drops and bed materials to replicate the riverbed found below the dam (Wilcox et al. 2004). At Lock and Dam 22, the rock ramp drops approximately 10 feet in elevation over an approximately 500-foot-long structure at the centerline. Typical profiles are shown on Plate C13.

The optimal size of the fishway was based upon the Larinier (2000) recommendation that fishways should be designed with an attraction flow of around 10 percent of the minimum flow of the river and between 1 and 1.5 percent of the higher design flow for a well located fishway on large rivers. Using these criteria, the optimal fishway discharge at Lock and Dam 22 at low flow was a minimum of 1,800 cfs.

Bedload transport of sediment should be insignificant based upon the location, height, and flows through the rock ramp structure.

The typical section of the rock ramp is shown on Plate C15. Fill material would build the rock ramp to the appropriate elevations, and then riprap would be placed on top of the fill material. Slopes for the rock ramps were designed to ensure stability during various flow conditions. The riprap would require some choking with dredged material to ensure that the appropriate water levels can be maintained. For nomenclature purposes in this report, the width was taken as the bottom width of the fishway pools in the structure, as shown on Plate C15. More details regarding the design criteria can be found in Appendix G, *Geotechnical Considerations*, Appendix H, *Hydrology and Hydraulics*, and Appendix I, *Structural Considerations*.

Location: The location of nature-like fishways at Lock and Dam 22 must be situated in an area where fish congregate and in a location which minimizes impact to navigation and the O&M of the dam. Other factors involved with the layout of the structures included minimizing ice and debris damage by using existing structures (such as the storage yard) as deflection devices and reducing costs by minimizing fill material required or reducing the amount of sheet pile used in the structure. Additionally, dam safety was a significant concern when making modifications to the dam gates or the spillways.

Hydroacoustic surveys were completed in 2006 and determined that most fish congregate downstream of the storage yard. See Section 3.3 for additional information. To ensure that fish can find the fishway, it is imperative to place the structure in a location where fish are present or in an area which can attract fish. Therefore, the location adjacent to the storage yard or near dam gate 13 would be an optimal spot for fish passage as fish are already attracted to this location. Fishways located further away from the navigation channel were also considered, with an option located adjacent to the Illinois shoreline and a bypass channel through the Illinois shoreline. However, very few fish congregate in these areas, and it would be difficult to get enough attractive flow through these fishways to draw the fish away from the dam to this area.

Size: The closer a fishway recreates the natural habitat of a species, the greater the likelihood that species will be able to use the fishway. Velocities will be similar to that of natural river conditions so that fish will be able to use the fishway as if it was part of the original stream. Larger fishways would be a benefit to the project. A larger fishway could pass more fish, could have greater attracting flows, and could be less likely to behaviorally deter fishway usage due to crowding. A smaller fishway could form a bottleneck for fish and could make the fish vulnerable to predation by birds.

A review of successful fishways (including small alpine rivers and larger lowland rivers) has found that around 10 percent of the minimum flow of the river passes through the fishways. These fishway projects passed a variety of fish species with different migration behaviors and swimming performance. In the UMRS, there are a large number of migratory fish species and large numbers of individuals migrating.

The fishway size was selected to ensure that there is an attractive flow of around 10 percent of the minimum flow of the river (for the lower design flow), and between 1 and 1.5 percent of the higher design flow for a well located fishway (more details are provided in Appendix H, *Hydrology and Hydraulics*). A fishway which meets these design guidelines would be similar in size to a 200-foot bottom width rock ramp.

Some fishways throughout the world are designed with 5 percent of the competing flow or the mean annual flow passing through the fishway. Parasiewicz, et al (1996, 1998) recommends a minimum functional discharge of 5 percent of the natural river discharge to provide the attractive flow to get fish to the fishway. To get to 5 percent of the mean annual flow, which is about 81,000 cubic feet per second at Lock and Dam 22, would require a fishway with a bottom of 540 feet. A fishway of that size would be cost prohibitive. (Appendix H, *Hydrology and Hydraulics*).

One of the important project constraints for fish passage is to ensure that any fish passage measure must not impact commercial navigation. Hydraulic analysis determined that it is not necessarily the width of the structure which would impact navigation as much as the location of the structure within the river. Physical and numerical models determined that fishways with a flow of 1980 cubic feet per second (cfs) or less located near the storage yard would not adversely impact navigation at any river flow. A 1980 cfs fishway corresponds to a fishway that is 300 feet wide using the design criteria previously discussed. (Appendix H, *Hydrology and Hydraulics*, Plates).

Site visits were conducted at the beginning of the project to determine appropriate fish passage sizes to evaluate for this project. These visits were at both Lock and Dam 22 and other fish passage projects in the United States. Numerous national meetings which discussed fish passage were attended, and research into successful fish passage projects was considered. The PDT, consisting of biologists, engineers, resource agencies, archaeologists, planners, and fish passage specialists considered the size of Lock and Dam 22, while envisioning positioning the mouth of the fishway at a location where fish were present. A 300-foot bottom width fishway was selected by the PDT as the largest size structure to evaluate, since it appeared to fit into the site, yet it was not so large that it was an apparent dam safety or navigation concern.

While a 200-foot wide fishway appeared to meet design guidelines, and a 300-foot wide fishway selected as the largest structure to be considered, it was important to evaluate smaller rock ramps to determine if they could improve fish passage at a lesser cost. A 100-foot-wide rock ramp was selected as a reasonably smaller size which could still allow for limited adaptive management and monitoring, and a 50-foot rock ramp was selected which would allow for the minimum size that could be constructed which might still effectively pass fish.

Operation and Maintenance: Corps personnel (engineers and biologists) would inspect the site annually to determine if the structure is meeting the project goals and objectives. If these inspections determine that debris within the structure is impacting fish passage, then Operation Division personnel would work on debris removal within the structure. This does not include debris removal after a major event which would fall under the area of rehabilitation. Time for debris removal would be approximately 20 hours/year for a 50-foot bottom width structure, 40 hours/year for a 100-foot bottom width structure, 80 hours/year for a 200-foot bottom width structure, and 120 hours/year for a 300-foot bottom width structure. If there is a major event, it may be possible that rock or boulders are displaced or removed, or the sand fill is scoured. These major events will be addressed under the area of rehabilitation.

Based on the location of the rock ramp and the width of the fishway, the following measures were selected for evaluation:

Measure E.1 Rock Ramp Adjacent to the Storage Yard, Downstream of the Spillway, 50-foot Bottom Width

Measure E.2 Rock Ramp Adjacent to the Storage Yard, Downstream of the Spillway, 100-foot Bottom Width

Measure E.3 Rock Ramp Adjacent to the Storage Yard, Downstream of the Spillway, 200-foot Bottom Width

Measure E.4 Rock Ramp Adjacent to the Storage Yard, Downstream of the Spillway, 300-foot Bottom Width

Measure E.5 Rock Ramp Adjacent to the Storage Yard, Upstream of the Spillway, 100-foot Bottom Width

Measure E.6 Rock Ramp Adjacent to the Illinois Shoreline, Upstream of the Spillway, 100-foot Bottom Width

Measure E.7 Bypass Channel on the Illinois Shoreline, Bisecting the Spillway, 82-foot Bottom Width

Measure E.8 Rock Ramp Through Gate 13, Upstream of the Dam

The rock ramps evaluated for this project were of a pool and riffle design, with a rock bottom. Details for these designs are shown in the plates attached to this report.

Measure E1, E2, and E3: Rock Ramps. These measures were rock ramps of varying bottom widths located downstream of the storage yard and adjacent to the spillway. Figure shows a rock ramp layout with a 100-foot bottom width, additional figures showing different bottom widths can be found in Appendix E, *Engineering*. The measures are located in an area where fish congregate, would not impact commercial navigation, require a shallower cut into the spillway than an upstream fishway (a factor for dam safety), and can use the storage yard to assist with ice and debris deflection into the fishway. Additionally, Measures E2 and E3 are wide enough that they could be used for the adaptive management studies to test the proper width and flow of fishways on the UMRS and the appropriate location of the downstream entrance.

These measures would provide: a pathway for migratory fishes past Lock and Dam 22, rock rapids habitat for macroinvertebrates, and an opportunity for monitoring and learning for adaptive management. Measures E2 and E3 are large enough to serve as a platform for future experiments to test the design and configuration of fishways through adaptive management experiments.

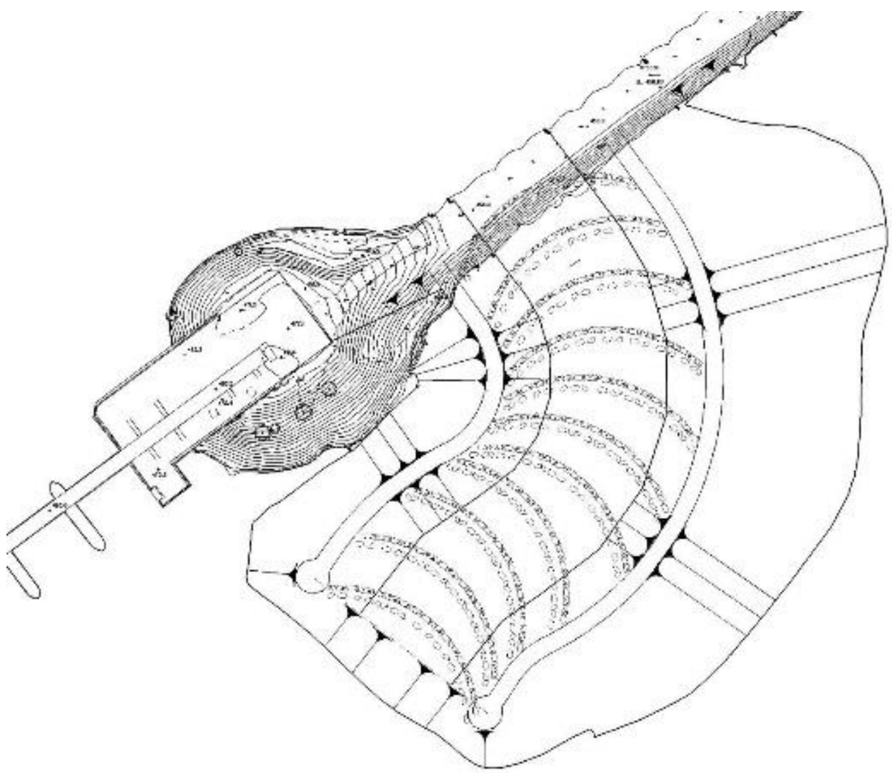


Figure 7. Rock Ramp Adjacent to the Storage Yard, Downstream of the Spillway, 100-foot Bottom Width

Measure E4: 300-Foot Bottom Width Rock Ramp. The 300-foot bottom width rock ramp, located downstream of the storage yard and adjacent to the spillway, was the largest width fishway evaluated. This measure would not impact navigation based on numerical modeling. The fishway was positioned so that the downstream entrance was located where fish aggregate, near Gate 13, using the same 500-foot centerline design criterion that was used for the other rock ramp measures. Under these conditions, the structure had a severe bend in the middle. This bend caused the riffle structures to converge near the inner angle leaving little or no room for resting pools (Figure). 3D computer simulations confirmed that this measure was not feasible under these design constraints. While these constraints could be changed by creating a longer structure or repositioning the downstream end, the PDT determined that these changes would increase the cost.

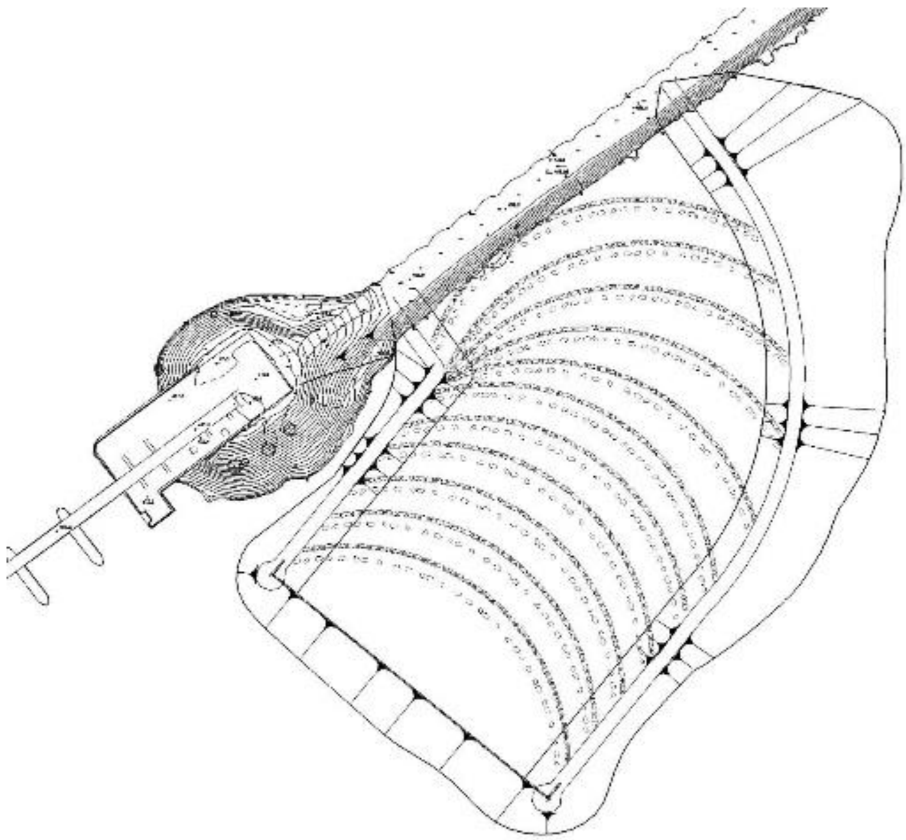


Figure 8. Measure E4: Rock Ramp Adjacent to the Storage Yard, Downstream of the Spillway, 300-foot Bottom Width

Measure E5: Rock Ramp Located Upstream of the Spillway. This measure would provide a pathway for migratory fishes past Lock and Dam 22, provide rock rapids habitat for macroinvertebrates, and would provide an opportunity for monitoring and learning for adaptive management. The location of this rock ramp (Figure) would avoid filling a deep hole downstream of the spillway but would require a deeper notch through the spillway. Deeper notches may have a greater impact on dam safety. It was assumed that hydrostatic pressure from the outside will be large enough to induce significant flow through the side walls of the structure unless there is sheet pile. For ramps located downstream, the hydrostatic pressure produced by flow inside of the fishway will not be as great due to shallow depths in the fishway. Therefore, those designs did not include sheet pile.

The perimeter of the fishway upstream of the spillway requires two feet of freeboard above elevation 459.5, so this version of the measure effectively raises the spillway 1.5 to 2.0 feet for the along-spillway component of the fishway length. In addition to this increase in the effective spillway height, a barrier would need to extend along the entire upstream perimeter to keep ice and debris out of the fishway once it overtops.

Adaptive Hydraulics Modeling System (ADH) modeling of the pool with the fishway located upstream of the spillway showed impacts to the velocity field in the upstream lock approach (something not observed when the fishway was located downstream of the spillway). This model also showed that the fishway would increase the flood stage greater than 0.1 feet. (Appendix H, *Hydrology and Hydraulics*). Navigation impacts may be reduced if the structure is moved further east along the spillway (towards the Illinois shoreline). However, this movement would increase the flood stage.

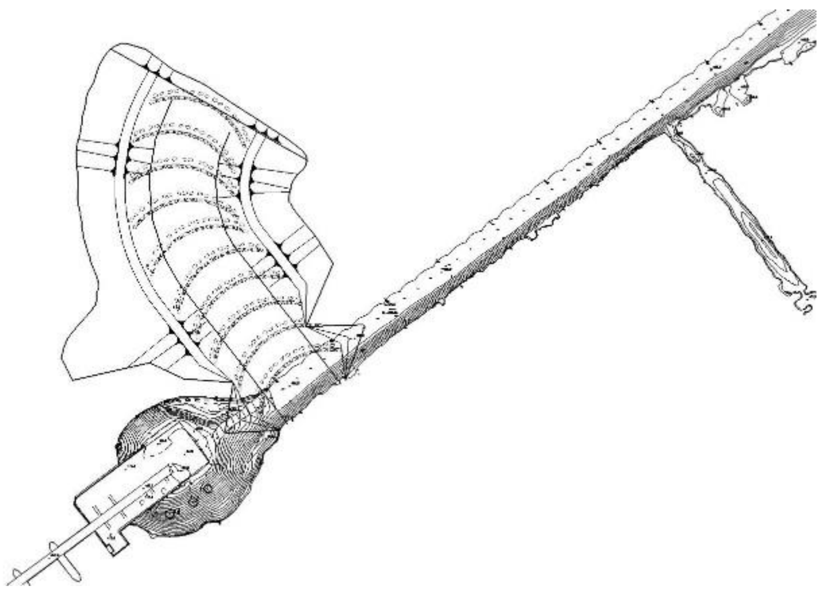


Figure 9. Measure E5: Rock Ramp Adjacent to the Storage Yard, Upstream of the Spillway, 100-foot Bottom Width

Measure E6: Rock Ramp Located Along the Illinois Shoreline. Early in the planning process, a rock ramp along the shoreline (Figure 10) was considered as an alternative measure because it would be further from the navigation channel and would possibly have fewer impacts to navigation. However, navigation impacts were not modeled at this location due to other concerns with this site. If a structure were constructed in this location, rock would be placed in the area to displace existing soft riverbed material until it reached a firmer subsurface. The rock would then be built up until it met design elevations (refer to borings in the plates or attached to Appendix G, *Geotechnical Considerations*). Placement in this area was constricted by upstream and downstream islands, not allowing for a curved structure which might reduce ice and debris concerns, and not allowing for a structure much larger than a 100-foot bottom width. Pre-construction monitoring showed that few fish aggregate in this location, therefore significant populations of fish are unlikely to find the entrance or use any fishway located in this area. Some fish will move to the Illinois shoreline, but this would be a small part of the entire community.

Figure 10. Measure E6. Rock Ramp Adjacent to the Illinois Shoreline, Upstream of the Spillway, 100-foot Bottom Width

Measure E7: Bypass Channel. Bypass channels were considered on both the Missouri and Illinois shorelines. The Missouri shoreline would not be feasible due to a high bluff, a railroad track, the lockhouse, and other constructed buildings in the area. A bypass channel (Figure 11) was further evaluated along the Illinois shoreline. The Federal government owns the property, but the Sny Levee runs across the area. A dredged material placement site, a roadway, and parking lot are in the area where the bypass channel fishway would have to be located. The Sny Levee is a federally constructed project that is now locally maintained by the Sny Island Levee and Drainage District (Levee District). It would be possible to relocate the levee to construct a bypass channel fishway; however, it would require coordination and permission from the Levee District.

Pre-construction monitoring showed that few fish aggregate in this location, therefore significant populations of fish are unlikely to find the entrance or use any fishway located in this area.

Figure 11. Measure E7: By-pass Channel

Measure E8: Rock Ramp Located Through Dam Gate 13. This rock ramp (Figure), was considered for the gate bay furthest from the lock chamber due to results of fish monitoring and the need to minimize impacts to navigation. Although not shown on the figure below, this structure would be a pool/riffle design similar to the other rock ramps. The design could be altered to allow full use of existing bulkhead slots by raising the elevation of the concrete sill to equal the surrounding new derrick stone and then the tainter gate and trunnion would be removed and salvaged. In order to maximize the use of gate bay 13 without impacting the adjacent gate bay 12, a sheetpile cell wall was assumed necessary for the right descending boundary of the structure. However, the section of the right descending boundary that runs parallel to the dam could be formed using rock instead of a sheetpile cell wall. The entire upstream facing perimeter would need to be protected from ice, debris, and scour.

Using a design similar to the rock ramp would create a bottom width of 4 feet and a discharge of 180 cfs, which is not a very high percentage of the total river flow. Operations Division personnel expressed concern with the loss of one gate bay and the limits it could impose with controlling operations at Lock and Dam 22. Numerical modeling was not conducted for this measure; however, it is likely that it would cause a 100-year flood stage increase of more than 0.05 feet.

Figure 12. Measure E8: Rock Ramp Through Gate 13, Upstream of the Dam

Measure F: Technical Fishways. The proposed location of the fishways was determined to be across the spillway adjacent to the storage yard due to the aggregation of fish monitored in this location.

Most technical fishways are specially designed concrete, steel, or wooden channels that dissipate the energy of flowing water, creating hydraulic conditions that enable fish to swim past barriers. Other technical fishways use locks or traps which move fish past barriers. Technical fishways are designed to be effective for target fish species, given their migration behavior and swimming performance. They range in size, but most are small, easy to site, and often have viewing windows that are useful in educating the public about fish movements.

Technical fishways such as Denil troughs, eel paths, baffled troughs, and pool and orifice troughs are designed to be effective at passing the average bodied, strong swimming portions of the fish population. Technical fishway often use baffles, weirs, or other engineered elements to increase roughness and slow down water movements to produce average flows which fall within the swimming speeds for the target fish species. These engineered elements also create turbulence, increasing the energy expenditure that a fish must use to maintain position in the water (Pavlov et al 1994) and disorienting small fish due to swirling flows (Pavlov and Tyuryukov 1993; Odeh et al 2002), which may cause avoidance by certain species and sizes of fish. Fish locking and fish elevators are semi-successful at passing a wide variety of large and small fish (Carter 1954; Scott and Hevel 1991), but they require frequent O&M and require fish to respond to prescribed attractant flows usually during normal working (daylight) hours.

The likelihood of sustainable populations of warmwater fish successfully migrating past a series of dams using only technical fishways is small, yet at some dams a technical fishway may be the only option or may be useful as part of a suite of fish passage measures (Katapodis 1995). The “Salmon 2000” ecosystem restoration program used a combination of fishway types to pass salmon through the Rhine River system, including the world’s largest modified vertical slot fishway found at the Iffezheim Dam, which was constructed in 2000 (Heimerl et al. 2001). These types of fishways can be roughened to provide suitable microhabitats and to slow down velocities for a greater variety of fish species.

There are several types of technical fishways used throughout the world for fish passage of various species. Those considered included:

Measure F.1 Pool Pass
Measure F.2 Slot Pass
Measure F.3 Denil Pass
Measure F.4 Fish Elevator

Operation and Maintenance for technical fishways varies somewhat depending on the type of fishway selected. A review of literature and interviews with operators of technical fishways found that the type which has the least O&M requirements is the slot pass fishway. Corps personnel (engineers and biologists) would inspect the site annually to determine if the structure is meeting the project goals and objectives. It’s expected that time for this should total four days per year. Debris removal is anticipated to be higher than that required for the rock ramps, based in part on the size of the structure openings. Smaller debris may have a greater negative impact on a technical fish passageway. Therefore, Operations Division personnel would conduct debris removal on average one day per week. The schedule of debris removal would vary, more debris removal expected during the fish passage season than in the winter months. A review of these structures by the Structural Engineering Section, Design Branch, Engineering Division of Rock Island District, determined that a structural engineering inspection would be required every 5 years in accordance with ER 1110-2-100, *Periodic Inspection and Continuing Evaluation of Completed Civil Works Structure*s, dated February 15, 1995. This review would require a separate report and Structural Engineering Section input.

Measure F1: Pool Pass Fishways. This is a series of vertical walls that create pools with overflow cascades between them (Photograph 7). The pool and weir fishway is considered a technical fishway. It is generally used where the head pool levels can be closely regulated. This type of fishway has a limited operating capability under fluctuating operational pool levels unless a special regulating section is provided at the upper end of the fishway system. Sturgeon have not been passed successfully in pool type fishways (Bell 1990). A variation of the pool pass fishway is to add a hole (orifice) to the vertical wall, though shad generally reject bottom types of orifice openings and may become trapped in square corners of the fishway (Bell 1990). There are increased maintenance issues with an orifice pool pass design because orifices become obstructed with debris, and the fishway has to be drained to remove the clog.

Photograph 7. Pool Pass Fishway (www.michigan.gov)

Measure F2: Vertical Slot Pass Fishways. This measure (Figure) is a technical fishway that consists of a series of boxes with baffled vertical slots between them. A dual-slot fishway design was selected for consideration at Lock and Dam 22. The fishway would be constructed with concrete and steel, consisting of a series of 15 boxes (pools) with two baffled slots between the pools. There would be relatively low velocity water within each pool for fish to rest. The slots for the structure can be pre-fabricated offsite to facilitate the construction of the fishway. These pre-fabricated slots can also be removed just as easily for maintenance purposes which could include removal of debris jams.

While this type of technical fishway would have a small construction footprint when compared to the larger nature-like fishways, there are several disadvantages to this type of fishway at this location. The technical fishway would only pass certain fish species (not a broad range), would have a high level of O&M, and would be very susceptible to debris jams. Also, the slot fishways do not have as much resting room as the rock ramps discussed earlier in this chapter. However, this type of technical fishway was determined to have the best chance of success when compared to other technical fishways at Lock and Dam 22. Vertical slot fishways are somewhat better at passing diverse species because the slots span the whole water column of the fishway, attracting both bottom swimmers and surface swimmers. The slot fishway has the best chance of success because slot fishways are more successful at passing fish with a variety of swim speeds; are somewhat less prone to debris jams than other technical fishways; and have been used successfully throughout the United States.

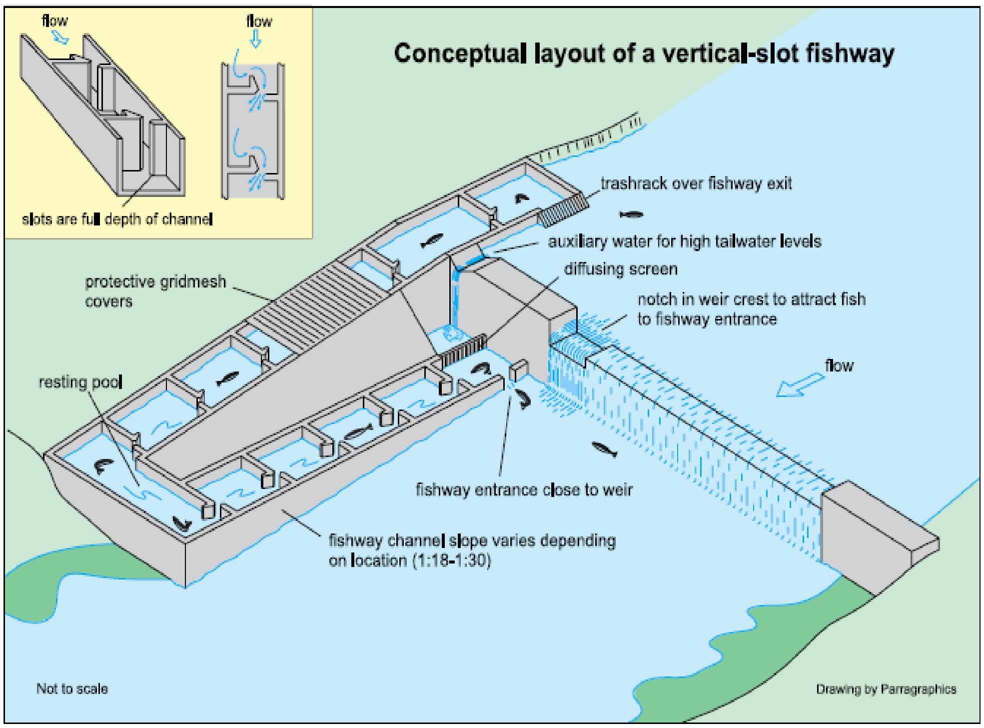


Figure 13. Conceptual Layout of a Vertical Slot Fishway (Throncroft and Harris, 2000)

Measure F3: Denil Fishways. These technical fishways use closely spaced baffles to create rapid energy dissipation to control flow through a sloping trough, therefore allowing high velocities to dissipate quickly. Denil fishways are generally used for passing salmon. However, variations of these fishways have been tested on warmwater fishes with some success (Katapodis et al 1997, McLeod and Nemenyi 1941). The largest disadvantage to this fishway is that higher velocities are encountered due to the steeper slope and fish must traverse the entire fishway in one pass without a resting area. The slotted fish fishway was chosen over the Denil fish passage because it is more capable of handling changes in flows, head differences and other factors associated with conditions at Lock and Dam 22. Denil fishways are very susceptible to these types of changes and only pass a limited number of fish species because of the strong turbulence. The Denil fishway would only pass certain fish species (not a broad range); would have a high level of operation and maintenance; and would be susceptible to debris jams.

Measure F4: Fish Elevator. The fish elevator (Figure) is a technical fishway that involves physically lifting fish over the dam using an elevator. Attractant flow is used to lure fish into the elevator where they are trapped until they are raised into either a holding tank above the dam or released upstream immediately above the dam. Fish elevators have been used at the Holyoke Dam on the Connecticut River in Massachusetts to pass American shad, and at the Winooski River in Vermont to move salmon. A fish elevator at Lock and Dam 22 would be designed similarly to the Holyoke dam, using a bucket or a hopper style of elevator. The contents of the bucket or hopper would be released immediately upstream of the dam. Fish elevators are usually raised three times a day throughout the spring migration period. Regular O&M of the equipment would be required. Fish elevators are inefficient at moving populations of fish over barriers. In the Connecticut River, between 200,000 and 600,000 American shad pass through the Holyoke Dam fish passage elevator annually out of a total population of 1-2 million returning adults. (Barry and Kynard 1986). Half of the population of one species of fish was moved past the dam. Returns are much worse at other dams.

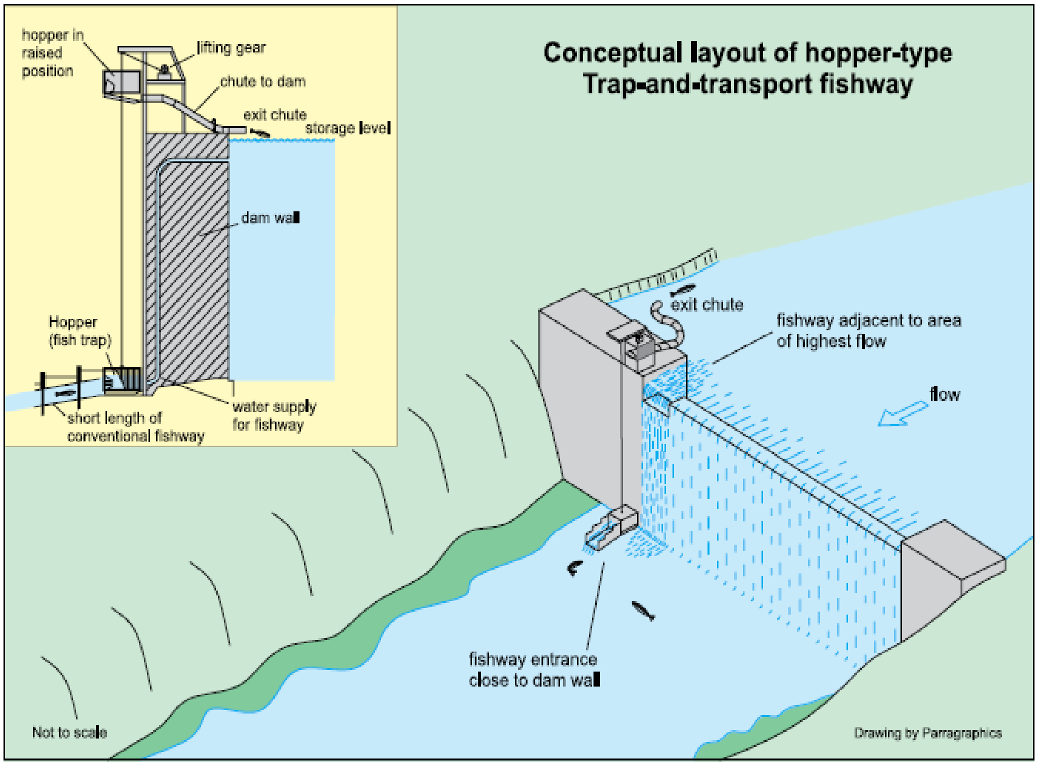


Figure 14. Conceptual Layout of a Fish Elevator (Throncroft and Harris, 2000)

Measure G: Dam Removal. Dam removal would effectively eliminate the fish barrier imposed by Lock and Dam 22, allowing free movement of fish and other aquatic life in both upriver and downriver directions. Dam removal has been used to restore fish passage, eliminate maintenance costs, and reduce liability of ageing dams (KCI Technologies 2013) and provides an opportunity for managers to rethink how rivers are regulated (Brown et al 2013).

Measure H: Siphons. Fish siphons are technical fishways that have been used experimentally in the Netherlands in small waterways (Photograph). The fish siphon has a series of evenly spaced baffles used to control water depth within a sloping tube. The siphon will pull the water out of the pool until the level of the tailwater equals the level of the pool. A vacuum pump is used to start (prime) the siphon creating a cascade of water through the baffles and a hydraulic path for upstream migrating fish. The pump is also used to control the rate of flow by adjusting the size of the air bubble at the head end of the siphon. There are several disadvantages to this type of fishway. Like a technical fishway, the siphon only passes certain fish species (not a broad range) because of the turbulent flows created by the baffles and the darkness and negative pressure of the enclosed siphon can deter some fish species. The downstream entrance of the siphon must be below the surface of the water to maintain the siphon and stationery, yet the tailwater at Lock and Dam 22 fluctuates by over 10 feet. Littoral and pelagic fish species would not find the fishway entrance during high tailwater stages. Operation and maintenance of the siphon are problematic. Removal of debris requires the structure to be disassembled to gain access to obstructions within the siphon.

Photograph 8. Fish Siphon (FishFlow Innovations)

Measure I: Notches Through the Spillway. This measure would include one or more large notches into the existing spillway in an effort to provide enough flow to attract fish while maintaining the pool above the dam for navigation. Flow would be provided via flow through the new notch(es) without any active manipulation. Flow through new notches in the spillways would be directly governed by the elevation and width of the notch, and upstream water elevations resulting from the operation of the upstream pool (Figure).

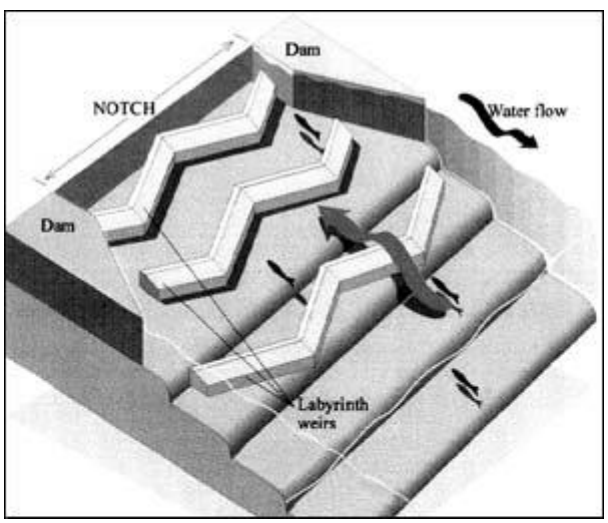


Figure 15. Notches Through the Spillway (USGS, Conte Andromous Fish Lab drawing)

The velocity of water flowing through a notch would be too high for most fish to pass unless the tailwater was less than one foot below the poolwater level. Since the tailwater is more than one foot below the poolwater a large percentage of time, it would be impractical to use notches for fish passage.

Another possible modification is to operate the submersible roller gates (Gates 4, 5 and 6) in a lower position to provide lower current velocities over time so that fish may be able to pass.

A waterfall effect would be created using notches, especially when the tailwater level is at least 1 foot below the poolwater level. This effect would cause severe scour problems at the downstream toe of the spillway. Notch fishways would only be functional a small period of time. Additionally, this type of fishway would be susceptible to debris jams unless the notch was large, or a debris boom was constructed.

2.5.3 Measure Screening

These measures were compared to the system-wide goals and project constraints to determine if they should be retained for further consideration. Table 3 includes a summary of each measure and explanation of how it met or failed to meet the primary screening criteria of:

- It meets system-wide goals, and
- It is feasible within project constraints

Table 3. Screening of Potential Measures

Nonstructural Measures	Feasible Within Project Constraints	Ecosystem Objectives	Retained	Justification
Measure A – No Action	Yes	Low likelihood of meeting system goals of restoring habitats and biota	Yes	No Action is always carried forward for alternative plans to be compared against.
Measure B. Fish Lockage	Yes	Low likelihood of meeting system goals of restoring geomorphology, biogeochemistry, habitats and biota	Yes	Pre-construction monitoring showed that few fish aggregate in this location, therefore significant populations of fish are unlikely to find the entrance or use any fishway located in this area. However; fish lockage would meet project goals and objectives.
Measure C. Extend Period of Open River Conditions	Yes	Low likelihood of meeting system goals of restoring geomorphology, biogeochemistry, habitats and biota	No	This measure does not meet project goals and objectives and cannot be used in conjunction with other measures; therefore, it will not be screened from further evaluation.
Measure D: Fish Stocking	Yes	Low likelihood of meeting system goals of restoring geomorphology, biogeochemistry, and habitats and moderate likelihood of meeting the goals of restoring biota	No	Fish stocking was screened from further evaluation based upon its incompatibility with system goals and objectives.
Measure E. Nature Like Fishways				
Measure E.1. Rock Ramp Adjacent to the Storage Yard, Downstream of the Spillway, 50 ft Bottom Width	Yes	High likelihood of meeting system goals of restoring geomorphology, biogeochemistry, habitats and biota	Yes	Would provide pathway for upriver fish passage for a wide range of native migratory fishes; would provide rapids habitat for macroinvertebrates, resident fishes and for fish spawning; and would provide opportunity for learning through experimentation, monitoring and adaptive management.

Table 3. Screening of Potential Measures

Nonstructural Measures	Feasible Within Project Constraints	Ecosystem Objectives	Retained	Justification
Measure E.2. Rock Ramp Adjacent to the Storage Yard, Downstream of the Spillway, 100 ft Bottom Width	Yes	High likelihood of meeting system goals of restoring geomorphology, biogeochemistry, habitats and biota	Yes	Would provide pathway for upriver fish passage for a wide range of native migratory fishes; would provide rapids habitat for macroinvertebrates, resident fishes and for fish spawning; and would provide opportunity for learning through experimentation, monitoring and adaptive management.
Measure E.3. Rock Ramp Adjacent to Storage Yard, Downstream of Spillway, 200 ft Bottom Width	Yes	High likelihood of meeting system goals of restoring geomorphology, biogeochemistry, habitats and biota	Yes	Would provide pathway for upriver fish passage for a wide range of native migratory fishes; would provide rapids habitat for macroinvertebrates, resident fishes and for fish spawning; and would provide opportunity for learning through experimentation, monitoring and adaptive management.
Measure E.4. Rock Ramp Adjacent to the Storage Yard, Downstream of the Spillway, 300 ft Bottom Width	No	High likelihood of meeting system goals of restoring geomorphology, biogeochemistry, habitats and biota	No	Technically infeasible based upon design constraints. The bend in the ramp caused the arched riffle structures to converge in the inside bend, creating a pool and riffle slope that exceeded the acceptable slope for fish passage. Therefore, measure E4 was not retained for further evaluation.
Measure E.5. Rock Ramp Adjacent to the Storage Yard, Upstream of the Spillway, 100 ft Bottom Width	No	High likelihood of meeting system goals of restoring geomorphology, biogeochemistry, habitats and biota	No	This measure does not meet the project constraints for navigation and flood elevations. Computer simulation models of flow indicated that this design would either impact navigation or cause increases in flood elevations that would require mitigation.

Table 3. Screening of Potential Measures

Nonstructural Measures	Feasible Within Project Constraints	Ecosystem Objectives	Retained	Justification
Measure E.6. Rock Ramp Adjacent to the Illinois shoreline, Upstream of Spillway, 100 ft Bottom Width	Yes	Low likelihood of meeting system goal of restoring biota	No	Pre-construction monitoring showed that few fish aggregate in this location, therefore significant populations of fish are unlikely to find the entrance or use any fishway located in this area. This measure would not meet system-wide goals. Therefore, measure E.6 was not retained for further consideration.
Measure E.7. Bypass Channel on the Illinois shoreline, bisecting the Spillway, 82 ft Bottom Width	No	Low likelihood of meeting system goal of restoring biota	No	Based on site real estate constraints with a local levee district (the Sny), Dredged Material Management Plan site, and road as well as the absence of fish in this location, this measure was eliminated from further consideration. This measure would violate the constraints. Therefore, measure E.7 was not retained for further consideration.
Measure E.8. Rock Ramp through Gate 13, Upstream of the Dam	No	Moderate likelihood of meeting system goals of restoring geomorphology, biogeochemistry, habitats and biota	No	Based on scour potential along upstream edge of sheet pile wall at the bend, likelihood of increased 100-year flood stage, debris issues due to orientation of ramp, and loss of the additional flexibility in dam operations one more gate allows this measure would violate the constraints. Therefore, measure E.8 was not retained for further consideration.
Measure F. Technical Fishways				
Measure F.1. Pool & Orifice Pass	Yes	Moderate likelihood of meeting system goals of restoring habitats and biota. Low likelihood of meeting	No	The technical fishway would only pass certain fish species (not a broad range), would have a high level of O&M, and would be very susceptible to debris jams. This measure would not meet the system-wide goals. Therefore,

Table 3. Screening of Potential Measures

Nonstructural Measures	Feasible Within Project Constraints	Ecosystem Objectives	Retained	Justification
		geomorphology, biogeochemistry		measure F.1 was not retained for further consideration.
Measure F.2. Slot Pass	Yes	Moderate likelihood of meeting system goals of restoring habitats and biota. Low likelihood of meeting geomorphology, biogeochemistry	Yes	Slot fishways are more successful at passing fish with a variety of swimming abilities and are somewhat less prone to debris jams. Unconsolidated materials such as rock can be added to the bed to increase the effectiveness for passing benthic species. The slots span the whole water column attracting both surface and bottom swimmers.
Measure F.3. Denil Pass	Yes	Moderate likelihood of meeting system goals of restoring habitats and biota. Low likelihood of meeting geomorphology, biogeochemistry	No	The technical fishway would only pass certain fish species (not a broad range), would have a high level of O&M, and would be very susceptible to debris jams. This measure would not meet the system-wide goals. Therefore, measures F.3 was not retained for further consideration.
Measure F.4. Fish Elevator	Yes	Low likelihood of meeting system goals of restoring geomorphology, biogeochemistry, habitats and biota	No	Fish elevators were screened from further evaluation based upon inefficiency in moving fish and expense of O&M. This measure would not meet the system-wide goals. Therefore, measures F.4 was not retained for further consideration.
Measure G. Dam Removal	No	High likelihood of meeting system goals of restoring geomorphology, biogeochemistry, habitats and biota	No	This does not avoid significant adverse effects on Navigation of the Upper Mississippi River and Illinois Waterway. Dam removal is not an option because Lock and Dam 22 is an essential part of the navigation system on the Mississippi River. This measure would violate the constraints.

Table 3. Screening of Potential Measures

Nonstructural Measures	Feasible Within Project Constraints	Ecosystem Objectives	Retained	Justification
				Therefore, measure G was not retained for further consideration.
Measure H. Siphons	Yes	Low likelihood of meeting system goals of restoring geomorphology, biogeochemistry, habitats and biota	No	Since it is much more practical and cheaper to use gravity between the pools of these fishways, the use of siphons is not a feasible alternative. A siphon creates low pressures which are sensed by the lateral line of the fish and actively avoided. This measure would not pass a variety of species and would not meet the system-wide goals. Therefore, this measure was not retained for further evaluation.
Measure I. Notches Through Spillway	Yes	Low likelihood of meeting system goals of restoring geomorphology, biogeochemistry, habitats and biota	No	Notch fishways would only pass certain fish species (not a broad range), would have a high level of O&M, and would be very susceptible to debris jams if the notch were not large and no debris boom was used. Notches can only be used by fish when the tailwater level is only slightly lower than the pool water level, which occurs only a small percentage of the time. This measure would not meet the system-wide goals. Therefore, measures I was not retained for further consideration.

Shading indicates measures were screened from further consideration.

2.6 Alternative Plans

This section describes how the measures retained were combined into alternative plans.

2.6.1 Final Array of Measures

Measures which were retained for alternative plan formulation include the following:

Measure A. No Action
Measure B. Fish Lockage
Measure E.1. Rock Ramp Adjacent to the Storage Yard, Downstream of the Spillway, 50-foot Bottom Width
Measure E.2. Rock Ramp Adjacent to the Storage Yard, Downstream of the Spillway, 100-foot Bottom Width
Measure E.3. Rock Ramp Adjacent to Storage Yard, Downstream of Spillway, 200-foot Bottom Width
Measure F.2. Slot pass

2.6.2 Measure Combinability

For alternative plan formulation, Measure B can be combined with Measures E.1, E.2, E.3 and F.2. Measures E.1, E.2, E.3 and F.2 cannot be combined because they share the same project footprint. Measure A, *No Action*, is a standalone alternative.

2.6.3 Final Array of Alternatives

Table 4 shows the alternative plans that were developed from the remaining measures.

Table 4. Alternatives Plans

Alternative		Measures Included in Alternative
1	No Action	A
2	Fish Lockage	B
3	Slot Pass	F.2
4	Fish Lockage and Slot Pass	B, F.2
5	50-foot Rock Ramp Adjacent to Storage Yard	E.1
6	Fish Lockage and 50-foot Rock Ramp Adjacent to Storage Yard	B, E.1
7	100-foot Rock Ramp Adjacent to Storage Yard	E.2
8	Fish Lockage and 100-foot Rock Ramp Adjacent to Storage Yard	B, E.2
9	200-foot Rock Ramp Adjacent to Storage Yard	E.3
10	Fish Lockage and 200-foot Rock Ramp Adjacent to Storage Yard	B, E.3

3 AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

This chapter is organized by relevant resource topic. Per the Rivers and Harbors Act Section 122 (PL 91-6110), the planning process considered 15 resources; however, this section is not a comprehensive discussion of every resource within the study area but focuses on environmental aspects identified as relevant during scoping or had potential to affect or be affected by the considered alternatives. For each resource, discussion begins with the baseline (existing conditions), including reasonably foreseeable trends and planned actions in the affected area, followed by the environmental consequences of each reasonable alternative, including the No Action Alternative. The environmental consequences discussion forms the scientific and analytic basis for comparing the alternatives and the significance of those impacts on the following alternatives:

- Alternative 1: No Action (Future Without Project)
- Alternative 2: Fish Lockage
- Alternative 3: Slot Pass
- Alternative 4: Fish Lockage and Slot Pass
- Alternative 5: 50-foot Rock Ramp Adjacent to Storage Yard
- Alternative 6: Fish Lockage and 50-foot Rock Ramp Adjacent to Storage Yard
- Alternative 7: 100-foot Rock Ramp Adjacent to Storage Yard
- Alternative 8: Fish Lockage & 100-foot Rock Ramp Adjacent to Storage Yard
- Alternative 9: 200-foot Rock Ramp Adjacent to Storage Yard
- Alternative 10: Fish Lockage & 200-foot Rock Ramp Adjacent to Storage Yard

Assessing potential significant effects requires consideration to the potentially affected environment (physical, ecological and socioeconomic aspects) and degree to which the resources of the human environment are affected both short and long-term. *Short-term* effects include those impacts that would occur during implementation of any reasonable alternative, as well as transient ecological effects that can be expected to occur during the first 1 to 3 years. *Long-term* effects might be expected to persist for up to ten years and beyond. For purposes of this analysis, significance definitions (*i.e.,* unaffected, less than significant, and significant) have been developed to assess the magnitude of effects for all of the affected resource categories resulting from implementing any of the reasonable alternatives:

- **Unaffected:** A resource was not affected, or the effects were not appreciable; changes were not of any measurable or perceptible consequence.
- **Less Than significant:** Effects on a resource were detectable, although the effects were localized, small, and short-term.
- **Significant:** Effects on a resource were readily detectable and obvious, localized or regional, large, and long-term.
- **Beneficial:** Positive effects on a resource that are localized or regional, large, and long term.

Environmental impacts of alternatives that are the same are discussed collectively. Public interest factors and projected impacts are summarized in Table 5.

T**able 5.** Summary of Projected Effects for Each Measure

Public Interest Factors	**Impacts**					
	Measure A – No Action	**Measure B. Fish Lockage**	**Measure E.1. Rock Ramp, 50 ft Bottom Width**	**Measure E.2. Rock Ramp 100 ft Bottom Width**	**Measure E.3. Rock Ramp, 200 ft Bottom Width**	**Measure F.2. Slot Pass**
Air Quality	U	U	-T Associated with construction	-T Associated with construction	-T Associated with construction	-T Associated with construction
Aquatic Resources/Wetlands	U	+P Improved spawning habitat	++P Improved spawning habitat	++P Improved spawning habitat	++P Improved spawning habitat	+P Improved spawning habitat
Invasive Species	U	-P Addressed through Adaptive Management	-P Addressed through Adaptive Management	-P Addressed through Adaptive Management	-P Addressed through Adaptive Management	-P Addressed through Adaptive Management
Fish and Wildlife Habitat	U	++P	++P	++P	++P	++P
Threatened/Endangered Species/Critical Habitat	U	+P Expanded range fish & mussels	+P Expanded range fish & mussels	+P Expanded range fish & mussels	+P Expanded range fish & mussels	+P Expanded range fish & mussels
Historic Properties	U	U	UM	UM	UM	UM
Other Cultural Resources	U	U	U	U	U	U
Floodplains	U	U	U	U	U	U
Hazardous, Toxic & Radioactive Waste	U	U	U	U	U	U
Hydrology	U	U	U	U	U	U
Land Use	U	U	U	U	U	U
Navigation	U	-P Shared use O&M	U	U	U	U
Noise Levels	U	U	-T Associated with construction	-T Associated with construction	-T Associated with construction	-T Associated with construction
Public Infrastructure	U	U	+P	+P	+P	+P
Socio-Economics	U	U	U	U	U	U
Environmental Justice	U	U	U	U	U	U
Soils	U	U	U	U	U	U
Tribal Trust Resources	U	U	U	U	U	U
Water Quality	U	U	-T From turbidity associated with placement operations	-T From turbidity associated with placement operations	-T From turbidity associated with placement operations	U
Climate Change	U	U	U	U	U	U

Major Adverse (- -)
Minor Adverse (-)
Resource Unaffected (U)
Resource Unaffected through Mitigation (UM)
Minor Beneficial (+)
Major Beneficial (++)

Temporary (T)
Permanent (P)

3.1 Future Without Project Condition

The National Environmental Policy Act (NEPA) requires Federal agencies to consider the option of no action as one of the alternatives. The No Action alternative assumes no action is taken by the Corps to achieve the planning objectives and is synonymous with the future without project (FWOP) condition. The No Action alternative is the basis against which all alternatives plans are measured.

The FWOP condition is developed to describe the most likely condition in the study area if no Federal action is taken to address the identified problems. It forms the baseline for identifying the effects of the alternatives. The future is inherently uncertain, and conditions change over time.

The FWOP conditions will continue not to realize potential fish populations in the UMR. These populations are well short of the populations the UMR is able to support.

The FWOP condition will be very similar to present, where migratory fish are impeded at the Lock and Dam 22 and little genetic flow with upstream populations occurs for fish or mussels. Small-bodied, benthic oriented, and slower-swimming fishes will continue to have reduced to no ability to migrate from Pool 24 to Pool 22 for spawning or seasonal habitat usage, which could impact fish and mussel communities in Pool 22 and its tributaries. At least two mussel beds in upper Pool 24 host diverse mussel communities and would not be able to serve as source populations to help bolster populations or reestablish beds of these species in Pool 22 without fish passage implementation.

The FWOP condition will allow the climate to change as nature intends. This includes increases in temperatures, duration and frequency of precipitation events with periods of drought, and duration and magnitude of river flows. These are further discussed in section 3.8.1 and Appendix H-A, *Climate Change Impact Assessment*.

3.1.1 Fish and Wildlife Habitat

The Habitat Needs Assessment (USACE 2000) describes how habitat connectivity would remain fragmented in the future without a project condition for geomorphic reach 7 (which includes Pool 22). The future desired condition identified by river managers in Habitat Needs Assessment-II (McCain et al 2018) includes improved gate management for native fish passage for the lower impounded cluster which also includes Pool 22. River resource managers in both the Fish and Wildlife Interagency Committee (FWIC) and River Resources Action Team (RRAT) desired increased connectivity to facilitate the movement of native fishes which links to the Longitudinal Aquatic Connectivity Indicator (USGS 2018). The UMRS navigation dams are used to maintain low flow navigation only, so high flows pass freely through the dams with all gates open. Lock and Dam 19 presents a nearly complete barrier to upriver fish movements because it is a high-head hydropower dam. Fish cannot swim upriver through the dam gates at any time. Limited numbers of fish may be able to pass upriver through the lock chamber. The other UMR navigation dams (2 through 25 and

Melvin Price Locks and Dam) have dam gates extending to sills on the riverbed. The gates on these navigation dams are raised entirely out of the water during times of higher river discharge, from 1 to 34 percent of the time depending on the number of gates at each dam. Main stem navigation dams alter hydraulic conditions in impounded reaches and inhibit fish movement throughout the river system. The dams increase connectivity of permanent aquatic areas throughout the river by raising low flow river stages, though the effects are most pronounced in geomorphic reach 3. At the same time, dams decrease connectivity with the floodplain by not allowing terrestrial floodplain communities to develop in permanently inundated areas and by maintaining conditions that reduce the area subject to seasonal flooding. Fish movement in the river is related to spawning, overwintering, and feeding requirements. Where fish migrations are blocked, fish may be trapped in river reaches that do not provide required habitats.

3.2 Unaffected Resources

The project alternatives would not affect the following resources because they are not present or all actions as part of the potential project would not affect the resource.

Wetlands: Wetlands are not present in the project activity area, as it is riverine and experiences dynamic flows, and thus would not be affected.

Water Quality: The Fish Passage Project would have very little or no effect on water quality, however water quality conditions may improve through continued watershed management efforts in the UMR Basin, and progress on restoring aquatic habitats is expected through the UMRS Environmental Management Program and through implementation of other ecosystem restoration components of NESP. While the ongoing efforts to protect, maintain, and restore habitat would be beneficial for some native species and some specific locations, the current level of effort would not be sufficient to counteract the cumulative impacts affecting the river ecosystem without the continuation of ongoing local, state and Federal ecosystem protection and restoration efforts. Water quality would not be affected, as the project activities would not impact nutrient inputs, create sedimentation, or increase flood heights.

Floodplain Forest: Floodplain forests are not present in the project area, and therefore would not be affected.

Migratory Birds: Migratory birds would not be affected, as no perching areas will be impacted and suitable habitat for waterfowl and piscivorous birds is available nearby.

- **Migratory Waterfowl.** Migratory or resident waterfowl should avoid the project area during construction. Those waterfowl that would use the spillway for feeding and resting would be impacted but would find suitable habitat for these activities nearby.

- **Wading and Shore Birds.** Wading birds and shore birds should not be significantly impacted. This category of birds will likely benefit from the construction of the fishway, because the structure will increase wading and feeding habitat. Fish-eating birds would benefit from foraging in the fishway.

- **Neotropical Migrants**. Neotropical migrants should not be significantly impacted since the bottomland hardwoods will not be disturbed. Fleeting activity may cause some disruption in the area by Cottel Island during construction, though this would be temporary.

Mammals: Mammals will not be affected, as the project area lacks suitable habitat.

Aquatic Resources - Plants: No aquatic plants exist within the construction footprint of the project and hydraulic modeling indicates that the change in flow patterns from the project will not affect the near-shore habitats where aquatic vegetation grows.

Social Factors: No people would be displaced, or residential properties affected as part of any of the alternatives. Property values or taxes would not be affected. There would be no effect on farms or farm displacement.

Land Use: A trend in land use in parts of Midwest has been the loss of some prime farmland to industrial and urban uses. The loss of prime farmland to other uses puts pressure on marginal lands, which generally are more erodible, droughty, and less productive and cannot be easily cultivated. Since this project is focused in the center of the river, there would be no effect on land use. Use of dredged material for construction may extend the use of existing dredged material placement areas, which could reduce the need to convert agricultural land around the project area in the future.

Sediment Transport and Bed Load: The project will have minor impacts on sediment transport and bedload due to the comparatively small flow through the fishway as compared to the combined flow through the gated sections of the dam and over the spillway.

Soils: Prime farmland is of major importance in meeting the Nation's short- and long-range needs for food and fiber. Because the supply of high-quality farmland is limited, the U.S. Department of Agriculture recognizes that responsible levels of government, as well as individuals, should encourage and facilitate the wise use of our Nation's prime farmland. The proposed project would not result in the conversion of any prime, unique, or State or locally important farmland to nonagricultural uses.

3.3 Fishery Resources

3.3.1 Potentially Affected Environment

The UMRS supports 143 indigenous fishes (Pitlo et al. 1995) and both recreational and commercial fisheries. At least 34 native migratory fishes occur in the UMRS, but many other species likely make movements to habitats that meet seasonal and life history needs. A recent project providing fish passage around a lowhead dam on the

Eel River, IN, found 43 of the 53 species known in the watershed successfully used a technical fish ladder to move upstream (Holmes 2020), including many small-bodied glochidial host species. On the UMRS, dams impose at least partial barriers to fish passage (Fremling et al. 1989). Improving upriver fish passage through the navigation dams is a recognized way to restore and manage the UMRS toward a more sustainable river ecosystem (UMRCC 2000, USACE 2004a, Wilcox et al. 2004, USGS 2018). Though strong anecdotal evidence exists for the location of spawning aggregations in the UMR, the actual location or locations of successful spawning contributing to annual cohorts is unknown (Colombo et al 2007). Large numbers of individuals in close proximity created spawning aggregations and may have contributed to the reproductive success of large schools of long-distance migrating fishes that were observed spawning in the northern reaches of the UMR prior to dam construction (Wagner 1908, Coker 1914, Forbes and Richardson 1920, Jordan and Evermann 1923, Coker 1929a). State and Federal natural resources agencies have identified “providing opportunities for native fish passage at dams” as a restoration objective for the Upper Mississippi River (UMRCC 2000). An abbreviated list of UMR fishes as provided in Wilcox et al. (2004) is included in Table 6, but many more species are probably migratory than are indicated in the table. Life history and seasonal movement information are not available for many of the lesser-studied small-bodied fishes.

Some fish species exhibit regular migration behavior, homing to specific locations year after year (Pitlo 1989, Osborn and Schupp 1985). Occasionally passable dams, like many of the navigation dams on the UMRS, limit reliable access to habitats and the potential for inter-annual reinforcement of learned migration behavior. Some fish, like the Skipjack Herring, have experienced a dramatic and sustained decline in abundance due to the construction of the dams. Fish migrations are important in maintaining genetic diversity of fish populations. High genetic diversity makes populations resilient to disturbances. Sufficient inter-pool movement of most UMR fishes may still occur to prevent genetic isolation, although opportunity for upriver gene flow is limited.

Hydroacoustic fish surveys of the tailwater indicated most fish aggregated in the area below the spillway and between the main channel and Cottel Island on the Illinois side (Cornish et al. 2006). Fish sizes commonly ranged to over 40 inches in total length. Tailwater population estimates of fish abundance varied by season with greater abundance of fish appearing in the spring and summer and fewer fish in the fall. Fish location and abundance varied by river discharge.

3.3.2 No Action Alternative

The existing opportunity for upriver fish passage through the navigation dams is not expected to change the future without project condition. The geographic ranges and population sizes of native migratory fishes and fish host-dependent native mussels would continue to be restricted. From a genetics standpoint, sufficient inter-pool movement of most UMR fishes may still occur to prevent genetic isolation, although opportunity for upriver gene flow is limited by restricted fish passage through mainstem navigation dams and tributary dams. Skipjack herring populations are expected to remain low in the UMR. MDC has been stocking lake sturgeon in the UMR for about 20 years. Lake sturgeon numbers are increasing, and some natural reproduction is evident. Exotic species like Bighead, Silver, and Black carp (invasive carp) have been increasing in numbers since their introduction into the Mississippi River in the late 1970s. Invasive carp are of particular concern in the UMR because of their potential to adversely affect the river ecosystem by physically crowding out native fishes and competing for plankton resources. A wide range of size classes of invasive carp now occurs in the project area and reproducing populations have increased their range as far north as Pool 18. All species of invasive carp will probably expand their range northward throughout the UMR and become more abundant.

The 2004 Feasibility Study's Cumulative Effect Study (WEST Consultants, Inc. 2000) found that fish mitigation and longitudinal connectivity are fragmented without fish passage improvements. The ecosystem would continue to be degraded and lotic (river dwelling) fish species would experience little net change in habitat availability because migratory corridors are restricted.

3.3.3 Effects on Fishery Resources

Implementing any of the action alternatives would be beneficial to the migratory fish community. Improving upriver fish passage through the navigation dams is recognized as a way to restore and manage the UMRS toward a more sustainable river ecosystem. Construction activities associated with any of the action alternatives would have short-term negative impacts on the fish community, as fish would avoid the area due to constant disturbance, however these are less than significant given the present conditions that preclude or inhibit fish passage and brevity of impacts.

Fish lockage and technical fishways provide passage to most species but have swimming performance requirements that preclude some fishes from efficacious passage. Fish lockage would require volitional movement into and out of the lock chamber without a controllable attraction flow. Technical fishways rely on fish ability to navigate higher velocity seams between resting areas and can produce too great a velocity for fishes to pass or physically constrain fish of too great a length or width.

Implementation of a nature-like fishway project would change habitat conditions in the immediate tailwater and would provide a pathway for fish movements upriver past Lock and Dam 22. Hydraulic models and hydroacoustic fish survey data indicate that similar hydraulic conditions would occur at the downstream entrance of the fishway once the project is built. Migratory fish that used the storage yard as a waiting area until the dam was passable would likely migrate out of the tailwater and move upstream through the fishway. The fishway would also provide spawning habitat for some species like Lake Sturgeon.

A fish passage structure would enable the movement of native species and invasive carp, but the risk of increasing the northern expansion of invasive carp is low, as they have been established in the Mississippi River for over twenty-five years and have steadily increased in abundance. See Section 6.6 for more detail on the status of invasive carp in the Upper Mississippi River.

The proposed action alternatives are anticipated to have a positive long-term benefit to the fisheries resources.

Table 6. Upper Mississippi River Fishes

Family (Common Name)	Species	Indigenous	Introduced	Probable Stray From Tributaries or Ocean	Known To Move Through UMR Dam	Known To Be Migratory in UMR	Probably Migratory in UMR
Petromyzontidae							
Silver Lamprey	*Ichthyomyzon unicuspis*	X					X
Acipenseridae							
Lake Sturgeon	*Acipenser fulvescens*	X			X	X	
Pallid Sturgeon	*Scaphirhynchus albus*	X					X
Shovelnose Sturgeon	*Scaphirhynchus platorynchus*	X			X	X	
Polydontidae							
Paddlefish	*Polyodon spathula*	X			X	X	
Ammiidae							
Bowfin	*Amia calva*	X					
Hiodontidae							
Goldeye	*Hiodon alosoides*	X					X
Mooneye	*Hiodon tergisus*	X					X
Anguillidae							
American Eel	*Anguilla rostrata*	X			X	X	
Clupeidae							
Alabama Shad	*Alosa alabamae*	X				X	
Gizzard Shad	*Dorosoma cepedianum*	X					
Skipjack Herring	*Alosa chrysochloris*	X			X	X	
Cyprinidae							
Bighead Carp	*Hypophthalmichthys nobilis*		X		X	X	
Common Carp	*Cyprinus carpio*		X				
Goldfish	*Carassius auratus*		X				
Grass Carp	*Ctenopharyngodon idella*		X				
Silver Carp	*Hypophthalmichthys molitrix*		X		X	X	
Castostomidae							
Bigmouth Buffalo	*Ictiobus cyprinellus*	X			X		X
Smallmouth Buffalo	*Ictiobus bubalus*	X			X		X
Black Buffalo	*Ictiobus niger*	X					

Table 6. Upper Mississippi River Fishes

Family (Common Name)	Species	Indigenous	Introduced	Probable Stray From Tributaries or Ocean	Known To Move Through UMR Dam	Known To Be Migratory in UMR	Probably Migratory in UMR
Black Redhorse	*Moxostoma duquesnei*	X					X
Blue Sucker	*Cycleptus elongatus*	X				X	
Golden Redhorse	*Moxostoma erythrurum*	X					X
Highfin Carpsucker	*Carpiodes velifer*	X					X
Northern Hog Sucker	*Hypentelium nigricans*	X					X
Quillback	*Carpiodes cyprinus*	X					X
Shorthead Redhorse	*Moxostoma macrolepidotum*	X					X
Silver Redhorse	*Moxostoma anisurum*	X					X
Spotted Sucker	*Minytrema melanops*	X					X
White Sucker	*Catostomus commersoni*	X					X
Ictaluridae							
Blue Catfish	*Ictalurus furcatus*	X				X	
Channel Catfish	*Ictalurus punctatus*	X			X	X	
Flathead Catfish	*Pylodictis olivaris*	X			X	X	
Esocidae							
Northern Pike	*Esox lucius*	X			X		X
Percichthyidae							
hybrid striped bass	*Morone saxatilis x chrysops*		X		X		
White Bass	*Morone chrysops*	X			X	X	
Yellow Bass	*Morone mississippiensis*	X					X
Centrarchidae							
Bluegill	*Lepomis machrochirus*	X			X		
Smallmouth Bass	*Micropterus dolomieu*	X			X		X
Largemouth Bass	*Micropterus salmoides*	X				X	
Sauger	*Sander canadensi*	X			X	X	
Walleye	*Sander vitreus*	X			X	X	
Sciaenidae							
Freshwater Drum	*Aplodinotus grunniens*	X			X		X

3.4 Freshwater Mussel Resources

3.4.1 Potentially Affected Environment

Freshwater mussels in the UMRS are part of one of the richest mussel communities in the world. The UMRS once supported an abundant and diverse assemblage of 51 mussel species. Freshwater mussels are currently the most threatened aquatic resource and the number of species has declined to about 44 species. Freshwater mussels have been adversely affected by a number of factors: overharvesting, pollution, siltation, restricted movements of glochidial (larval stage) host fish by mainstem navigation dams and tributary dams, and the exotic Zebra Mussel. Upper Mississippi River migratory fishes are hosts to the larval stages of native mussels and are important in maintaining their genetic diversity and spatial dispersal.

Dams have limited UMR mussel distribution. Mussel habitat has remained stable or increased above Pool 12 and decreased somewhat in Pools 13 through 26 (USACE 2004a). Numerous site-specific mussel studies have been conducted, but systemic data and monitoring remains incomplete. Pool-wide mussel estimates for Pools 5 and 18 indicate that mussel communities may be as high as hundreds of millions of individuals in these pools (USGS 2008). However, the Ebonyshell was a dominant mussel taxa in the upper pools and now it has been almost completely eliminated because Skipjack Herring, its host species, can no longer move to its traditional spawning areas.

Lock and Dam 22 is located in a reach with a diverse freshwater mussel assemblage. MDC has monitored the mussel sanctuary from RM 300.2 downstream to RM 299.6 for 20 + years (Moore and Corgiat 2007). There are records of 30 species of mussels in Pool 24. Freshwater mussel densities in Pool 24 on the right descending side of the channel below the dam have ranged from 74.4 mussels per square meter to 16.2 mussels per square meter (Koch, 1990; Winterringer and Dunn 2008); 24 mussel species were found above the dam on the right descending side of the channel at a density of 9.2 individuals per square meter (McClane 2007).

3.4.2 No Action Alternative

Without action, the mussel community is expected to maintain their existing community structure and distribution. The zebra mussel will remain a threat to native mussel populations. Black Carp (*Mylopharyngodon piceus*), an invasive carp that feeds on mollusks and is commonly used in aquaculture to control snails, has invaded the system, and may be further stressing native mussels. Reduced geographic range and abundance of fish may have other ecological effects. The UMR migratory fishes are hosts to the larval stages of native mussels and are important in maintaining their genetic diversity and spatial dispersal. Genetic isolation, near-complete interruption of recruitment, and near extirpation of the Ebonyshell mussel in the northern reaches of the UMR has been attributed to the markedly reduced upriver migrations of the Ebonyshell's fish host, the Skipjack

Herring. The no action alternative would perpetuate the current conditions, where not all fishes have the swimming performance to pass Lock and Dam 22, and some that may be able to during certain seasonal conditions may not experience passable conditions during the seasons they may host mussel glochidia.

3.4.3 Reasonable Action Alternatives

Construction activities for the action alternatives would leave the mussel community unaffected as there is not suitable habitat within the project footprint due to dynamic flow patterns and unstable bed materials. Geotechnical borings show that the general substrate is sand over bedrock. Water levels at the construction site routinely fluctuate up to 12 feet and tailwater flow patterns shift as dam operation and discharge changes.

A temporary fleeting area will be used to moor barges for delivery to/from the construction site. The District's initial coordination letter for natural resources for this project (Appendix A, *Correspondence*) showed a barge fleeting area would be required along the main channel side of Cottel Island during construction. This initial fleeting area extended from approximate RM 300.0 to 301.1L. The Illinois Natural Heritage Database contains several records of a mussel bed, including State listed species downstream of the proposed fleeting area. This bed supports the State-threatened Black Sandshell (*Ligumia recta*), Federally- and Illinois-endangered Spectaclecase (*Margaritifera monodonta*), State threatened Butterfly (*Ellipsaria lineolata*), and state-threatened Ebonyshell (*Reginaia ebenus*) at RM 300.2 to 300.6L. Fleeting activity is not anticipated to create bed disturbance, but if any listed mussels are encountered during the dewatered portion of the construction for the bridge and water control structure, they will be relocated to this bed and appropriate monitoring would occur. A contingency plan will be coordinated with USFWS before initiation of construction activities.

The Cottel Island fleeting area was reduced to approximately RM 300.6 to 301.1 to avoid this mussel bed. Bathymetry data collected March 2007 in this new fleeting area shows deep water extending very close to shore, which reduces the potential for significant adverse impacts to mussels from fleeting activity. The District will require the construction contractor to use on-shore anchorage/pilings for barge fleeting/mooring along the Cottel Island shoreline. This should eliminate tie-off to large trees and minimize adverse impacts to long-term vegetation.

The State of Missouri has identified a mussel sanctuary along the right descending bank (RM 299.6 to 300.2) near the project area, which would not be affected by this project.

Mussels use fish hosts to carry their glochidia and facilitate transformation to the shelled juvenile stage. Mussels in the beds near the project area could provide source populations to reestablish or bolster populations in Pool 22 and its tributaries if fish passage would be facilitated. Enabling upstream genetic flow would increase the genetic diversity and population resiliency of the receiving mussel beds.

A nature-like fishway would provide stable substrate with areas of laminar flow and riffle habitat, which is preferred by some mussels. Small-bodied riverine fishes, especially darters and minnows, would use the fishway as habitat and could facilitate mussel colonization of this preferable habitat.

Long-term effects on the mussel community should be positive using any of the action alternatives, because the action alternatives proposed would facilitate fish passage (including mussel hosts carrying glochidia) throughout the year. As a result of continuous feasible passage, glochidial hosts would be able to facilitate mussel range expansion and genetic flow for all mussels.

3.5 Endangered Species

Federally-listed species occurring in the project counties were determined using the USFWS Information for Planning and Consultation (IPAC) website (Consultation codes: 03E18000-2020-SLI-2667; 03E14000-2020-SLI-3468) on September 10, 2020 to initiate coordination and shown in Table 7. An IPAC search was done on April 28, 2021, resulting in the addition of a candidate species, Monarch (*Danaus plexippus*); IPAC searches would continue until construction initiation to ensure that all listed species are identified so potential impacts are avoided or minimized and properly coordinated.

3.5.1 Potentially Affected Environment

The Endangered Species Act consultation for the 2004 Feasibility Study used a tiered Endangered Species Act consultation framework. The Tier I Biological Opinion (BO), *Biological Opinion of the Upper Mississippi River Illinois Waterway System Navigation Study,* was completed in August 2004 (USFWS 2004a). This BO evaluated the effects to listed species at the program or ecosystem level. The Corps determined that a Tier II biological assessment was not needed because the project would have no effect on federally-listed species. Federally-and State-listed species are listed in Table 7.

The Illinois Department of Natural Resources (ILDNR) and the MDOC informed the District of the potential for the project to affect the numerous species and sensitive resources. A mussel bed is located along Cottel Island at approximate RM 300.5L containing Illinois-threatened and Missouri-imperiled Black Sandshell (*Ligumia recta*). This area would not be designated as a fleeting area for fish passage construction.

3.5.2 No Action Alternative

The No Action Alternative would not have any additional impacts on endangered species, but would continue impeding migrations for state listed fishes and reducing upstream genetic flow of mussels.

3.5.3 Effects on Threatened or Endangered Species and Critical Habitat

The Endangered Species Act consultation for the 2004 Feasibility Study used a tiered Endangered Species Act consultation framework. The Tier I Biological Opinion (BO), *Biological Opinion of the Upper Mississippi River Illinois Waterway System Navigation Study*, was completed in August 2004 [US Fish and Wildlife Service (USFWS 2004a)]. This BO evaluated the effects to listed species at the program or ecosystem level. The Corps determined that a Tier II biological assessment was not needed because the project would have no effect on federally listed species. Considering that listed mussels and Pallid Sturgeon have not been found in recent surveys and habitats for the listed bats and plants are not present in the affected area, the proposed project would not affect any federally-listed threatened or endangered species. In compliance with the Bald and Golden Eagle Protection Act, construction activities would only have negligible impacts on any wintering bald eagles, as there would be a reduced hunting area, and the nearest nest is one river mile downstream of any project activities. The USFWS recommended that the District maintains a written record of the "no effect" determination in a letter dated October 30, 2020 and in the Coordination Act Report (Appendix A, *Correspondence*). Several state-listed fish species will benefit from this project including the Lake Sturgeon (*Acipenser fulvescens* - Illinois and Missouri endangered); Blue Sucker (*Cycleptus elongatus*-Missouri rare); and Paddlefish (*Polyodon spathula*-Missouri rare).

Nature-like fishway construction would provide stable substrates that could be inhabited by mussels, including federally listed Spectaclecase and Sheepnose. These species would benefit from fish passage by increasing genetic flow to upstream populations.

MDC informed the District that several common mudpuppies (*Necturus maculosus*) were found in the main lock chamber in 2002 when the lock was down for repairs. They may be present in the area below the spillway and could be encountered during fishway construction. If, during the dewatered portion of the construction of alternatives 4-10 of the bridge and water control structure, any mudpuppies are encountered, they will be captured and relocated to nearby suitable habitat. Mudpuppies would be relocated upstream in the vicinity of the mussel bed at approximate RM 302.0 to 302.5R.

The proposed alternatives would benefit endangered mussels by improving genetic flow and habitat availability and would have no effect on other listed species.

Table 7. Federally- and State-Listed Species in the Vicinity of Lock and Dam 22

		Listing		
	Species	**Federal**	**Illinois**	**Missouri**
Mussel	Black Sandshell (*Ligumia recta*)	-	threatened	imperiled
	Rock Pocketbook (*Arcidens confragosus*)	-	-	Vulnerable
	Hickorynut (*Obovaria olivaria*)	-	-	Vulnerable
	Wartyback (*Cyclonaias nodulata*)	-	-	vulnerable
	Monkeyface (*Theliderma metanevra*)	-	threatened	-
	Spectaclecase (*Margaritifera monodonta)*	endangered	endangered	endangered
	Butterfly (*Ellipsaria lineolata)*	-	threatened	-
	Ebonyshell (*Reginaia ebenus*)	-	endangered	endangered
	Higgins' eye pearly mussel (*Lampsilis higginsii*)	endangered	endangered	endangered
	sheepnose (*Plethobasus cyphyus*)	endangered	endangered	endangered
	Elephant ear (*Elliptio crassidens*)	-	endangered	-
	Salamander mussel (*Simpsonaias ambigua*)	-	endangered	endangered
Fish	Lake Sturgeon (*Acipenser fulvescens*)	-	endangered	endangered
	Pallid Sturgeon (*Scarphirhynchus albus*)	endangered	endangered	endangered
	Western Sand Darter (*Ammocrypta clara)*	-	endangered	imperiled to vulnerable
	Bigeye Shiner (*Notropis boops*)	-	endangered	-
	American Eel (*Anguilla rostrata*)	-	threatened	-
	Starhead Topminnow (*Fundulus dispar*)	-	threatened	imperiled-
	River Redhorse (*Moxostoma carinatum*)	-	threatened	--
Mammal	Indiana Bat (*Myotis sodalis*)	endangered	endangered	endangered
	Northern Long-eared Bat (*Myotis septentrionalis*)	endangered	threatened	endangered
	Gray Bat (*Myotis grisescens*)	endangered	endangered	endangered
Bird	Eastern Black Rail	threatened	endangered	Species of Concern
Amphibian	Mudpuppy (*Necturus maculosus*)	-	threatened	species of concern – status undetermined
Insect	Monarch (*Danaus plexippus*)	candidate	-	-
Plant	Decurrent False Aster (*Boltonia decurrens)*	threatened	threatened	endangered
	Eastern Prairie Fringed Orchid *(Platanthera leucophaea)*	threatened	endangered	endangered

3.6 Aquatic Resources

3.6.1 Potentially Affected Environment

At present, other aquatic biota in the project area are macroinvertebrates. The dynamic flow velocity and depth conditions in the tailwater preclude aquatic vegetation establishment. The macroinvertebrate community is limited to flow-tolerant species that utilize woody debris or burrow into the sediment.

3.6.2 No Action Alternative

With no action, aquatic biota would not change. The macroinvertebrate community currently present would not change without systemic change upstream of the project area.

3.6.3 Effects on Aquatic Biota

Construction activity and the placement of construction materials for alternatives involving the fishway and coffer dam should not cause significant reductions in levels of light penetration that could lower photosynthesis and plant growth. Sight-feeding species should not suffer a reduction in feeding ability, growth rate, or resistance to disease. Invertebrates in the upstream and downstream footprint would be buried during construction, but these communities are not unique to these specific areas of the lower pool and tailwater. A new structure would recolonize overcoming any losses due to construction.

Fish lockage would have no impact on macroinvertebrate populations. A technical fishway may cover some invertebrates during construction, but stabilizing materials may increase habitat diversity and provide a slight potential increase in habitat quality.

Construction of a nature-like fishway would provide a channel with stable substrate and shallow water, which would increase benthic habitat diversity and provide suitable habitat for a greater diversity of macroinvertebrates. Substrate stability would provide safe areas for exposed clinging species to colonize without being removed during erosive events and would allow periphyton to grow and provide a useful food source.

3.7 Historic and Cultural Resources

3.7.1 Potentially Affected Environment

For over 10,000 years, the Upper Mississippi River was an important waterway for transportation, resource gathering, and trade by the Native American tribes that settled nearby. The long history of human occupation in this region has resulted in numerous prehistoric, architectural, and submerged sites, attributed to Native American, European, Colonial, and American cultures. The archaeology and historic architecture of Pool 22 is representative of these Upper Mississippi River occupational periods and cultures. None of the historic properties identified within the project area will be adversely affected by the project as proposed.

Lock and Dam 22 is part of the Upper Mississippi River Navigation Project (built between 1931 and 1948). The Project comprises 25 National Register Historic Districts within the Upper Mississippi River 9-Foot Navigation System. Each of these historic districts has national significance under 36 Code of Federal Regulations (CFR) Part 60.4, National Register of Historic Places Criteria A (that are associated with events that have made a significant contribution to the broad patterns of our history) and C (embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction).

3.7.2 No Action Alternative

Under the no action alternative, the affects would be similar to the existing conditions.

3.7.3 Effects on Historic Properties and Other Cultural Resources

The District conducted an archival search for historic properties following the *Policy and Procedures for the Conduct of Underwater Historic Resource Surveys for Maintenance Dredging and Corps Activities* (DGL-89-01, March 1989). The District queried the online Illinois and Missouri Geographic Information Systems site file database for standing, buried, or submerged historic properties potentially affected by this project and reviewed summary reports on historic properties within the Upper Mississippi River, Pool 22 (Custer and Custer 1997, Benn, et al. 1995, Benn and Anderson 1997). No submerged historic properties are documented within the area proposed for fish passage improvements. Two previously reported or recorded sites - 23RA132 and 23RA863 - are located in agricultural fields to the north and south of the proposed staging area on the Illinois side of the river. While these areas were previously approved for dredged material placement and equipment staging in 2004, the areas will not be used for dredged material placement or borrow during construction phases for the Fish Passage improvements.

The 2004 *Programmatic Agreement Among the U.S. Army Corps of Engineers Mississippi Valley Division, St. Paul District, Rock Island District, and St. Louis District, the U.S. Fish and Wildlife Service, the Illinois, Iowa, Minnesota, Missouri, and Wisconsin State Historic Preservation Officers, and the Advisory Council Historic Preservation, Regarding Implementation of the Upper Mississippi River-Illinois Waterway System Navigation Feasibility Study* (Agreement) expired January 20, 2012 as per Stipulation VII (Termination) of the Agreement (see Appendix A). The District is therefore coordinating this individual undertaking in compliance with 36 CFR §§ 800.3 through 800.7, as per Stipulation VII of the expired Agreement. This proposed project exists in both Illinois and Missouri and is being coordinated with the

State Historic Preservation Office for each state, as well as 22 federally-recognized Tribes identified to have a potential interest in the project area.

Archeological Impacts. Those staging, borrow, and access areas for the Fish Passage project deemed to have potential for surface or buried archeological properties have been previously surveyed. The District has made a determination of No Adverse Effect to archaeological historic properties within the Project area.

Architectural and Engineering Impacts. Pending design finalization of the Recommended Plan for this Project, the District will review any additional structural and visual effects to above ground historic properties prior to the Public Review process, as per phased identification and evaluation efforts specified by 36 § 800.4(b)(2). As specific aspects or locations of the alternative are refined, the District shall proceed with the identification and evaluation of historic properties in accordance with paragraphs (b)(1) and (c) of § 800.4.

Based on the results of archival review of state site files and previous archaeological investigations conducted for the currently proposed NESP Project, the Corps recommends a finding of No Adverse Effect to historic properties for the planned Project in accordance with 36 CFR 800.4(d). This determination of No Adverse Effect was submitted to the Illinois and Missouri SHPOs as well as the interested Tribes in a letter dated October 27, 2020, by electronic correspondence on November 2, 2020, with a request for comment (see Appendix A, *Correspondence*). The Missouri SHPO provided concurrence with the determination made regarding effects to archaeological properties on December 1, 2020. No structural elements contributing to the NRHP-eligibility of the Lock & Dam that could potentially be affected by this proposed project are located within the Missouri portion of the APE, however the Missouri SHPO requested to receive information on any additional structural and visual effects to above ground historic properties as it becomes available. The Illinois SHPO provided concurrence with the determination made regarding effects to both archaeological and structural properties on December 1, 2020. The Ho-Chunk Nation of Wisconsin and the Miami Tribe of Oklahoma also provided concurrence with the District's determination, on November 2, 2020 and December 18, 2020, respectively. Comments and concurrence received from the consulting parties have been appended to the final project report within the Appendix A, *Correspondence.*

3.8 Climate

3.8.1 Potentially Affected Environment

Available literature suggests a wetter and warmer climate in the future for the Project area. Over the next 50 years, temperatures are predicted to rise anywhere between 2.7 – 11.7 °F (Liu et al, 2013 and Kunkel et al, 2010). The temperature increase does not apply equally throughout the year. Winter, Spring, and Summer are expected to become warmer, while Fall will become colder (Wang et al., 2009). During this same time period, precipitation on average is expected to increase between 2.4 – 4.0

inches annually (Pryor et al, 2014). Fewer storms with higher intensity are predicted to take place interspersed with longer periods of dry weather. Seasonally, more precipitation is expected to come in the Spring while Summer is expected to become drier (Pryor et al, 2014). Hydrologically, the area immediately surrounding the project has statistically significant trends of increasing flood frequency, peak magnitude, duration, and volume (Archfield, 2016).

Analyses conducted in accordance with Engineering and Construction Bulletin 2018-14 and Engineering Technical Letter 1100-2-3, included in Appendix H-A, suggest some increasing trends in climate variables. Over the next 50 years, annual maximum monthly Mississippi River flows could increase by 1,100 cfs. Since typical flows are around 100,000 cfs and flood flows can reach about 350,000 cfs, the slight upwards trends in peak flow, duration, etc. will be negligible compared to conditions currently experienced and is not considered to have any operational impact. Nonstationarity analyses, which seek to find point in data where trends change, mildly indicated upward trends in annual peak streamflow and duration of L&D 22 spillway overtopping. Out of 12 statistical tests, only three indicated a nonstationarity for annual peak streamflow around 1990. For duration of spillway overtopping six out of 12 statistical tests indicated a nonstationarity around 1970. Environmental vulnerability assessments (VA) indicate that Hydrologic Unit Code (HUC) 0711, where the project is located, is relatively less vulnerable to climate change compared to the other 202 HUC 04 watersheds in the United States. VA study a HUC's potential threat of exposure to its freshwater resources due to climate change using multiple weather and climate models.

Regardless of the conditions projected above, the design of the fish passage structure will not be impacted, because the structure, as designed, is robust enough to resist damage in times of higher and longer duration flows. Rather, higher and longer duration flows will only impact the usefulness of the fish passage structure, as stronger-swimming species would have greater opportunity to move upstream over the inundated spillway and be less reliant on the structure.

3.8.2 No Action Alternative

With no action, climate trends will continue to progress as summarized in Section 3.8.1.

3.8.3 Effects on Climate

The construction of any fish passage alternative would not impact the climate of the surrounding area.

3.9 Socioeconomic Resources and Human Use

3.9.1 Potentially Affected Environment

Economic Base: American Community Survey data (2018, data.census.gov) show Pike County, IL residents have a median household income of $42,664 and a poverty rate of 13.9%. The data for Ralls County, MO show median income as $55,546 with 12.5% of residents below the poverty line.

Education: Highest level of education estimates for Pike County indicate that 15% of residents hold a Bachelor's degree or higher, another 32% attended some college, and an additional 41% graduated high school or hold an equivalent degree. In Ralls County, the highest education level estimates are 14% of residents hold at least a bachelor's degree, 26% more attended some college, and another 49% graduated high school or have an equivalent degree.

Employment/Unemployment: Employment rate estimates of the labor force (16 to 64 years old) for Pike County and Ralls county, respectively, are 55.1% and 60.5%; the unemployment rate (fred.stlouisfed.org) in September 2020 was 4.9% in both counties. Primary occupation fields in Pike County include: educational services, health care and social assistance (23.8%); manufacturing (11%); retail trade (10.5%); agriculture, forestry, fishing and hunting, and mining (8.6%); and construction (8%). Ralls County primary occupation fields include: management, business, science, and arts occupations (29.5%); sales and office occupations (22.2%); production, transportation, and material moving occupations (21.2%); and service occupations (16%).

Population Demographics: Pike County has a population of 17,254 people, of whom 96.8% are white, 1.5% are black, 1.2% are Hispanic or Latino, 0.3% are American Indian or Alaska Native, and 0.3% are Asian. Median age of Pike County residents was 42.3, 20.3% of the population was 65 or older, and 6.1% were under the age of 5. Ralls County has a population of 10,217 who are 96.7% white, 1.3% black, 1.2% Hispanic or Latino, 0.5% American Indian or Alaska Native, and 0.5% Asian. Median age was 45, 20.4% of the population was 65 or older, and 4.9% were under age 5.

Visual Resources: Visual resources of the study area include the Lock and Dam no. 22 historic district, forested islands that support charismatic wildlife including Bald Eagles, and general riverine habitat that provides valued scenery.

Recreational Resources: The Mississippi River provides excellent recreational and commercial fishing, hunting, camping, and pleasure boating opportunities. The project area hosts a locally important recreational fishery, especially from late fall through early spring when walleye and sauger are staging in the tailwater ahead of their spring migration.

Environmental Justice: Under Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations, a Federal agency "shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations in the United States." An Environmental Justice (EJ) analysis provides data about potential to disproportionately impact these population segments during the construction and normal operation of the Federal action. If this analysis indicates that an impact is appreciable more severe on minority or low-income populations than other segments after accounting for offsetting benefits, it will trigger a disproportionate impact finding and require avoidance and mitigation. An EJ analysis using the USEPA EJSCREEN tool (https://ejscreen.epa.gov/mapper) of the project area found a lower than median minority (13th percentile in Missouri) and low-income (35th percentile in Missouri) population within the study area. While this precludes adversely impacting a largely minority population, this area is a somewhat low-income population; as this project provides environmental restoration, no adverse impacts are expected.

Public Infrastructure: The Project area infrastructure is largely limited to the dam and the recreational area adjacent to the dam on the Illinois shoreline. The Mississippi River's navigation channel and supporting elements such as wing dams, closing dams, and locks and dams help maintain the channel's depth. Nearby towns and counties have roads, schools, police stations, etc that would be temporarily affected during construction.

3.9.2 No Action Alternative

The no action alternative would not change any of these socioeconomic resources.

3.9.3 Effects on Socioeconomic Resources and Human Use

The primary purpose of the Fish Passage Project is to increase opportunity for upriver fish passage, ancillary recreational benefits in the areas of commercial and sport fishing would likely be realized.

Action Alternative 2 would not require construction, rather changing operation of the lock. Therefore, there would be no affects to business or industrial opportunities.

Alternatives 3–10: An increase in business and industrial activity would occur during the construction process. A portion of the increase would be attributable to the purchase of materials and supplies for the construction of the fish passage. The remaining increase would result from purchases made by construction workers. No long-term impacts are anticipated in the project vicinity.

There would be short-term positive impacts from an increase in area employment and local income during construction for action Alternatives 3-10. An estimate of the average number of workers that would be employed for construction cannot be determined at this time; however, workers would likely be local or patronizing local lodging and restaurants. Action Alternatives 3-10 would anticipate less than significant effects on construction jobs, as they would be temporary.

Potential staging areas for barge fleeting, temporary storage of construction equipment and materials, and for parking purposes have been identified for action Alternatives 3-10. One area is on the northwest portion of Cottel Island, located adjacent to and downstream of the Lock and Dam 22 spillway. The other area is located directly east of the Lock and Dam 22 spillway, at the Corps' managed Park 'N Fish recreation area on the Illinois side of the river. It is anticipated the Park 'N Fish location would experience temporary periods of restricted access during project construction; however, the site would return to recreational usage following project completion.

Heavy machinery would temporarily increase noise levels during project construction. The immediate project area is located in the middle of the river with the nearest residential properties located about one-half mile downstream, and the town of Saverton, Missouri, is approximately 2 miles upstream of the construction site. No sensitive receptors are nearby. The Park 'N Fish recreation area is on the Illinois side of the river approximately 1,500 feet east of the construction site. This public use area would be closed intermittently during project construction, so it is unlikely that the increased noise levels would be a major disturbance to users of this recreation area.

Traffic increases from construction workers commuting could occur during the construction phase and to a lesser extent during the modification portions of any adaptive management actions.

The Lock and Dam No. 22 Historic District would be impacted as a visual resource for Alternatives 3-10, as they would provide a fish passageway through part of a contributing element. As a visual resource, the gates and lock would remain as they are at present, but a portion of the auxiliary spillway would be converted to host a technical or nature-like fishway. This would provide a new and attractive visual resource to some individuals, as it would be the first fish passageway over a navigation dam in the UMRS. Cultural and historic preservation information can be found in section 3.7.

3.10 Hazardous, Toxic, and Radioactive Waste

3.10.1 Potentially Affected Environment

A Phase I Environmental Site Assessment (ESA) was performed in 2008 to conform with the scope and limitations of ASTM Practice E 1527-05 for the Lock and Dam 22 Fish Passage Project. See Appendix J, *Hazardous Toxic and Radioactive Waste* for the complete 2006 assessment.

An ESA Transaction Screening Process was completed in October 2020 for the Fish Passage Project at Lock and Dam 22, Missouri in accordance with ASTM Practice E1528-06 and ER 1165-2-132. See Appendix J, *Hazardous Toxic and Radioactive Waste* for more information.

These inquiry activities revealed no evidence of Recognized Environmental Conditions (REC), hazardous substances, hazardous, toxic, and radioactive waste (HTRW), or other regulated contaminants in connection within the proposed easement area.

The Phase I ESA states that no excavated soils shall be removed from the site without first testing for contaminants. Demolition activities along the spillway are not anticipated to include any soils material and will not require HTRW testing prior to disposal.

There are no REC's associated with the Target Areas, therefore no further HTRW assessment is required. Recommend inclusion of specification 01 57 19 Temporary Environmental Controls in project specification set. No other environmental or HTRW specification swill be required.

3.10.2 No Action Alternative

If no action is taken, HTRW would be expected to be similar to existing conditions into the future.

3.10.3 Effects of Hazardous, Toxic, and Radioactive Waste

Any of the action alternatives would be similar to the no action alternative.

3.11 Irretrievable and Irretrievable Commitments of Resources

Irreversible commitments are those that cannot be reversed, except perhaps in the extreme lone ruin (The Shipley Group, 2010). Simply stated, one the resource is removed it can never be replaced. For the action alternatives considered, there are no irreversible commitments.

Irretrievable commitments are those that are lost for a period of time (The Shipley Group, 2010). Construction activities of all action alternatives would temporarily disrupt natural resource productivity. The purchase of materials and the commitment of man-hours, fuel, and machinery to perform the study signal an irretrievable loss in exchange for the benefit of fish passage and habitat improvement.

3.12 Probable Adverse Environmental Impacts Which Cannot Be Avoided

Benthos: Given the nature of this Project, it is unavoidable that some existing substrate will be altered. With construction of Alternatives 3-10, a rock ramp fishway would replace the current sand substrate macroinvertebrate community in the section of river below the spillway and storage yard. A multiple-cell coffer dam would be constructed, and the interior dewatered for construction of the concrete bridge and water control structure. The fishway would be rapidly colonized by macroinvertebrates like caddisflies adapted to fast current and hard substrate.

Traffic: Some increase in barge/truck/equipment traffic would be inevitable during the construction period. Traffic should increase over existing levels from the staging areas to the lock and dam area of construction. At this time, a precise estimate of the increase is not possible.

Noise: Heavy machinery would temporarily increase noise levels during project construction and some low-level blasting may be used for the rock excavation and concrete demolition. Noise from the periodic blasting of concrete could be diminished by appropriate means, such as the use of blast mats.

Aesthetics: The aesthetic appeal of any type of construction activity is low; however, impacts would be minimized for any of the action alternatives based on the rural setting and frequent operations and maintenance activities utilizing heavy equipment at the lock and dam.

Exhaust Fumes: The increase in exhaust fumes from tows, truck traffic, heavy machinery, etc. during new lock construction is unavoidable. This impact would not be permanent and would not be of such quantities and of such duration as may be or tend to be injurious to human, plant, or property. This project would not unreasonably interfere with the comfortable enjoyment of life, or property, or the conduct of business.

Air Quality: Minor, temporary increases in airborne particulates are anticipated to occur as a result of mobilization and use of construction equipment. Disturbances to nearby residents during workdays would be minimal, and no air quality standard violations are anticipated.

The District anticipates any impacts to the above resources would be minor.

3.13 Relationship of the Proposed Projects to Other Planning Efforts

Other projects and management actions are being planned for implementation in the NESP that would contribute to both navigation improvements and ecosystem restoration on the UMRS. Ecosystem restoration activities include restoring lateral connectivity between channels and the floodplain, restoring backwater areas, secondary channels and tributary deltas. These other ecosystem restoration measures should, in combination and over time, also contribute to restoring migratory fish populations. There have been no other planning efforts that address fish passage on the Upper Mississippi River and the implementation of the Monitoring and Adaptive Management components of this project would provide the information needed to inform future discussions on this technique as a restoration measure. The success of this project is not dependent on the implementation of any other ecosystem restoration projects immediately upstream or downstream of the project area, however the goal of systemic fish passage will not be achieved until fish passage is addressed at other dams in the system.

NESP Lock 22. The new 1200-foot lock at Lock and Dam 22 is one of eight initial NESP navigation efficiency component projects being implemented under this new UMRS program. This project involves the creation of a new 1200-foot lock in the existing auxiliary lock area, the removal of the tips of three wing dams on the Illinois side of the channel, the construction of a vane dike near the downstream approach wall, and the construction of one wing dam on the Missouri side of the channel. Recycling the rock removed from the Lock 22 project for use as fill material for the fishway would lower costs and recycle materials, reducing natural resource effects. The habitats affected most by these projects include main channel and the main channel border. The biotic communities most at risk from these projects include fish and mussels. The Fish Passage Project at Lock and Dam 22 would not affect the NESP Lock 22 project. An SEA was prepared for the NESP Lock 22 project and a FONSI signed 22 October 2008.

NESP Mooring Cells: Mooring Cells are being designed at locations near lock approaches to improve navigation efficiency. These structures provide waiting areas closer to the locks where they can wait clear of an existing tow. Navigation efficiency is improved by reduced entrance and exit times. Mooring cells may be constructed above and below the dam on the Missouri side of the channel and switchboats will be operated above and below the new lock chamber. The habitats affected most by these projects include main channel and the main channel border and the biotic communities most at risk from these projects include fish and mussels. The Fish Passage Project at Lock and Dam 22 would not affect the NESP Mooring Cells. A separate SEA will be prepared for the NESP Mooring Cells project.

NESP Fish Passage. The fishway at Lock and Dam 22 is the first of four fishways scheduled for construction on the Upper Mississippi. The others will be at Mel Price Locks and Dam, Lock and Dam 4 and Lock and Dam 8. The fishway at Lock and Dam 22 is being designed to be adjustable for experimentation. The findings of this experimentation and research will be applied to optimize the design of later projects.

Dredged Material Management Plans (DMMP). In the DMMP for the Lock and Dam 22 Reach dredged material could be used beneficially as fill material for the fishway at Lock and Dam 22. If dredged material is removed from DMMP sites, the project would extend the effective capacity of the DMMP placement site (USACE, Rock Island District 2003; 2004; 2021). Should the use of historic or current dredged material placement sites be used for fill borrow or in-water placement of material, the District would coordinate with the On-Site Inspection Team (OSIT) to avoid and minimize potential adverse impacts to natural resources.

Invasive Carp Control Plan. The project is consistent with the recommendations made in the Asian Carp Working Group's Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States (Conover et al. 2007). The USFWS and other natural resource agencies provided technical assistance and biological information to the Corps and participated in collaborative planning for this project. This information led to the determination that a new fishway at Lock and Dam 22 will not accelerate the northward invasion of invasive carp because Bighead and Silver carp have already established reproducing populations upriver of Lock and Dam 22, but will enhance aquatic environments for the sustainability of native biological communities.

Upper Mississippi River Master Plan. The project areas and adjacent areas are owned and managed by the Corps of Engineers. Park and Fish is designated Recreation- intensive use and the spillway and immediate project area are designated Project Operations. The Fish Passage Project is consistent with the Master Plan.

Mark Twain National Wildlife Refuge Complex Comprehensive Conservation Plan. This project is consistent with the USFWS' Conservation plan and not effect on the nearby Edward Anderson Conservation Area and the Ted Shanks Conservation Area located downstream of the project area or nearby public lands managed under the Cooperative Agreement.

4 EVALUATION AND COMPARISON OF ALTERNATIVE PLANS

For environmental planning, where traditional benefit-cost analysis is not possible because costs and benefits are expressed in different units, two analytical methods are used to assist Corps planners in the decision process. First, cost effectiveness (CE) analysis is conducted to ensure that the least cost solution is identified for each possible level of environmental output. Subsequent incremental cost analysis (ICA) of the cost-effective solutions is conducted to reveal changes in costs for increasing levels of environmental outputs. In the absence of a common measurement unit for comparing the non-monetary benefits with the monetary costs of environmental plans, cost effectiveness and incremental cost analysis are valuable tools to assist in decision making.

To perform the CE/ICA, of the District used the Institute of Water Resources (IWR) Planning Suite Decision Support Software (version 2.0.9.1). The IWR Planning Suite has been developed to assist with plan comparison by conducting cost effectiveness and incremental cost analyses, identifying the plans which are the best financial investments ("Best Buys"), and displaying the effects of each on a range of decision variables. The latest version (2.0.9.1) has been certified for use by USACE Headquarters, meaning it has been reviewed and certified by the appropriate Planning Center of Expertise (PCX) and represents a corporate approval the model is sound and functional.

CE/ICA is a multi-step process: (1) calculate the environmental outputs for each alternative, (2) determine a cost estimate for each alternative, and (3) compare and evaluate the alternatives based on habitat benefits and costs. The following sections document the multi-step process used to perform the CE/ICA and the results of the analysis.

4.1 Environmental Benefit Analysis

In ecosystem restoration planning, traditional benefit cost analysis is not done because the Corps does not express ecosystem benefits monetarily. However, cost effectiveness and incremental cost analysis can provide decision makers with relative benefit-cost relationships of various enhancements or restoration solutions. While these analyses are not intended to lead to a single best solution, they do improve the quality of decision making by ensuring that a rational, supportable, focused, and traceable approach is used for considering and selecting alternative methods to produce environmental outputs. These tools aid the decision-makers in selecting the plans to pursue in more detail. In this section we describe cost effectiveness and incremental analysis of the alternative plans, compare the plans, and identify a Recommended Plan.

The ecosystem benefits were developed by a sub-group of the PDT. The analysis of existing conditions, future conditions without the project, and the proposed measures was completed using a multi-agency, collaborative team with representatives from the Corps of Engineers, the USFWS, the MDOC, and the ILDNR.

The Fish Passage Connectivity Index (FPCI) model was used to quantify the ecosystem restoration benefits of the alternative plans. The model used a Microsoft Excel worksheet that evaluates the potential effectiveness of alternative fish passage improvement measures for 30 migratory fishes (Table 8) and calculated the increase in benefits for each alternative measure when compared to the No Action FWOP condition. See Appendix D, *Environmental Benefits* for a full description and documentation of the model and assumptions used to calculate alternative benefits.

The FPCI model was certified for use by the National Ecosystem Planning Center of Expertise (ECO-PCX) in 2010. The model was recertified for regional use by the ECO-PCX in 2021.

The benefits used to quantify the ecosystem restoration benefits were calculated prior to the study being paused in the early 2000s. It is assumed that the existing and future without project conditions haven’t changed and the benefits calculated previously would remain the same. No new calculations for habitat benefits were done as part of the 2020 study restart.

Table 8. Migratory Fishes of the UMRS at Lock and Dam 22

Silver Lamprey	Smallmouth Buffalo	Channel Catfish
Lake Sturgeon	Blue Sucker	Flathead Catfish
Shovelnose Sturgeon	White Sucker	Northern Pike
Paddlefish	Spotted Sucker	White Bass
Longnose Gar	Golden Redhorse	Yellow Bass
Mooneye	Highfin Carpsucker	Largemouth Bass
Goldeye	Quillback	Smallmouth Bass
American Eel	Shorthead Redhorse	Walleye
Skipjack Herring	Silver Redhorse	Sauger
Bigmouth Buffalo	Blue Catfish	Freshwater Drum

The FPCI is a simple arithmetic index that incorporates characteristics of migratory fishes present at Lock and Dam 22 and characteristics of fish passage alternative measures (Equation 1). The FPCI indicates the potential for alternative measures to allow fish passage through Lock and Dam 22. A complete discussion of the FPCI can be found in Appendix D, *Environmental Benefits*. The index is calculated as:

$$Є = \frac{\Sigma_{i\,n} [(E_i \times U_i \times D_i)/25]}{n}$$

Equation 1. FPCI arithmetic index.

Where,

- Є = Fish Passage Connectivity Index
- i = A migratory fish species that occur in Pool or reach below the dam
- n = Number of fish species included in the index
- E_i = Chance of encountering the fishway entrance is a calculated value ranging from 1 to 5 (5=Highly Likely, 3= Moderate Probability, 1=Unlikely)
- U_i = Potential for *species i* to use the fish passage pathway or fishway considering adult fish swimming performance and hydraulic conditions within the fishway or fish travel pathway (5 = Good, 3 = Moderate, 1 = Poor, 0 = None)
- D_i = Duration of availability; the fraction of the upriver migration period for fish species i that the passage pathway is available. D_i incorporates a risk component (i.e., the potential failure of an alternative to perform or be available during a critical fish movement period.)

The major components used for the habitat benefit evaluation and the general scoring criteria of the FPCI included:

- The migratory fish species guilds in the project area.
- The quantity of available habitat in the upstream pool (Pool 22) using a standardized aquatic habitat classification system.

4.1.1 Summary of Environmental Benefits

Habitat units (HU) were derived from the relationship of the effectiveness of the fishway and the amount of habitat available in the Pool above the dam for each species. HU were calculated by multiplying the FPCI by the total acres of available preferred habitat in Pool 22 for each species. The total area of available habitat is the same for all alternatives.

Table 9 documents the HU for each measure. The HUs are then annualized across the project’s 50-year period of analysis, referred to as Average Annual Habitat Units (AAHU). The AAHU for each alternative is shown in Table 10. A complete discussion of the benefits can be found in Appendix D, *Environmental Benefits*.

Table 9. Summary of Benefits for Fish Passage Improvement Measures at Lock and Dam 22

Measure	Fish Passage Connectivity Index	HU
Measure A: No Action	0.00	0
Measure B: Fish Lockage	0.03	403
Measure E.1: Rock Ramp 50-ft Bottom Width	0.62	8,901
Measure E.2: Rock Ramp 100 ft Bottom Width	0.72	10,379
Measure E.3: Rock Ramp 200 ft Bottom Width	0.81	11,730
Measure F.2: Slot Pass	0.15	2,214

Table 10. Summary of Benefits for Fish Passage Improvements Alternative Plans at Lock and Dam 22

Alternative	Total HUs	AAHU
1 – No Action	0	0
2 – Fish Lockage	403	8.1
3 – Slot Pass	2,214	44.3
4 – Fish Lockage and Slot Pass	2,617	52.3
5 – Rock Ramp 50 ft Bottom Width	8,901	178.0
6 – Fish Lockage and Rock Ramp 50 ft Bottom Width	9,304	186.1
7 – Rock Ramp 100 ft Bottom Width	10,379	207.6
8 – Fish Lockage and Rock Ramp 100 ft Bottom Width	10,782	215.6
9 – Rock Ramp 200 ft Bottom Width	11,730	234.6
10 – Fish Lockage and Rock Ramp 200 ft Bottom Width	12,133	242.7

4.2 Cost Effectiveness / Incremental Cost Analysis

The results of the CE/ICA are shown in Table 11 and Table 12. Of the 10 alternatives, 9 were considered cost effective, of which five were considered Best Buys, including the No Action Alternative (Figure). The estimated first cost include the construction cost, Preconstruction Engineering and Design (PED), Monitoring & Adaptive Management and Supervisory and Administration. These costs are in 2021 pricing and include 25% contingency. The interest during construction (IDC) was calculated for each alternative based on the estimated years to construct. Alternative 1 is the No Action Plan and therefore has no construction period or IDC. Although Alternative 2 has no construction, there are adaptive management costs which are represented in the IDC. Alternative 3 and 4 would take 2 years to construct, and Alternatives 5 -10 would take 3 years to construct. The average annual costs were determined using the fiscal year 2021 discount rate of 2.5 percent. Alternative 10 has the greatest net benefits, but the lowest incremental increase of AAHUs, and the highest incremental cost per AAHU.

Based on the results of the CE/ICA only the Best Buy alternatives were carried forward to further evaluation and comparison. Since the Best Buy alternatives represent the most cost-effective alternatives the alternatives that were not-cost effective (Alternative 2) or cost effective (Alternatives 3, 4, 6, and 8) were screened from further evaluation and will not be further discussed.

Table 12 documents the estimated costs and benefits (AAHU) of the Best Buy alternatives as well as the cost-effectiveness and incremental cost analysis for the Best Buy alternatives. The Best Buy alternatives presented provide the information necessary to make well-informed decisions regarding desired project scale and features. Progressing through the increasing levels of output for the alternatives helps determine whether the increase in output is worth the additional cost (Figure). If decision makers consider a level of output to be “worth it,” subsequent levels of output are considered. When a level of output is determined to be “not worth it,” then subsequent levels of output would also likely be “not worth it,” and the final decision regarding desired project scale and features for environmental restoration would be reached.

Table 11. Summary of Outputs (AAHU) and Costs[1].

Name of Alternative	First Cost	Interest During Construction	Average Annual Cost[2]	AAHU	Cost Effective
1. No Action	$-	$-	$-		**Best Buy**
2. Fish Lockage	$2,537,800	$217,830	$729,564	8.1	No
3. Slot Pass	$6,165,494	$332,966	$440,839	44.3	Yes
4. Fish Lockage and Slot Pass	$6,165,494	$332,966	$1,018,262	52.3	Yes
5. Rock Ramp 50 ft Bottom Width	$28,271,156	$1,468,435	$1,422,461	178.0	**Best Buy**
6. Fish Lockage and Rock Ramp 50 ft Bottom Width	$28,271,156	$1,468,435	$1,999,884	186.1	Yes
7. Rock Ramp 100 ft Bottom Width	$42,493,256	$2,253,004	$2,064,721	207.6	**Best Buy**
8. Fish Lockage and Rack Ramp 100 ft Bottom Width	$42,493,256	$2,253,004	$2,642,144	215.6	Yes
9. Rock Ramp 200 ft Bottom Width	$74,561,099	$3,853,351	$3,453,914	234.6	**Best Buy**
10. Fish Lockage and Rock Ramp 200 ft Bottom Width	$74,561,099	$3,853,351	$4,031,337	242.7	**Best Buy**

[1] Costs are shown at the 2021 price level and were annualized using the current FY21 Federal discount rate of 2.5 percent over a 50-year period of analysis.

[2] OMRR&R costs are included in the calculation of average annual costs.

Table 12. Best Buy Plans and Incremental Costs (AAHU).

Name of Alternative	AAHU	First Cost	Interest During Construction	Average Annual Cost	Average Annual Cost per AAHU	Additional Average Annual Cost	Additional Output (AAHU)	Incremental Cost (per AAHU)
1. No Action	-	$-	$-	$-	$-	$-	-	$-
5. Rock Ramp 50 ft Bottom Width	178.0	$28,271,156	$1,468,435	$1,422,461	$7,991	$1,422,461	178.0	$7,991
7. Rock Ramp 100 ft Bottom Width	207.6	$42,493,256	$2,253,004	$2,064,721	$9,946	$642,260	29.6	$21,698
9. Rock Ramp 200 ft Bottom Width	234.6	$74,561,099	$3,853,351	$3,453,914	$14,723	$1,389,193	27.0	$51,452
10. Fish Lockage and Rock Ramp 200 ft Bottom Width	242.7	$74,561,099	$3,853,351	$4,031,337	$16,610	$577,423	8.1	$71,287

Note: Costs are shown at the 2021 price level and were annualized using the current FY21 Federal discount rate of 2.5 percent over a 50-year period of analysis.

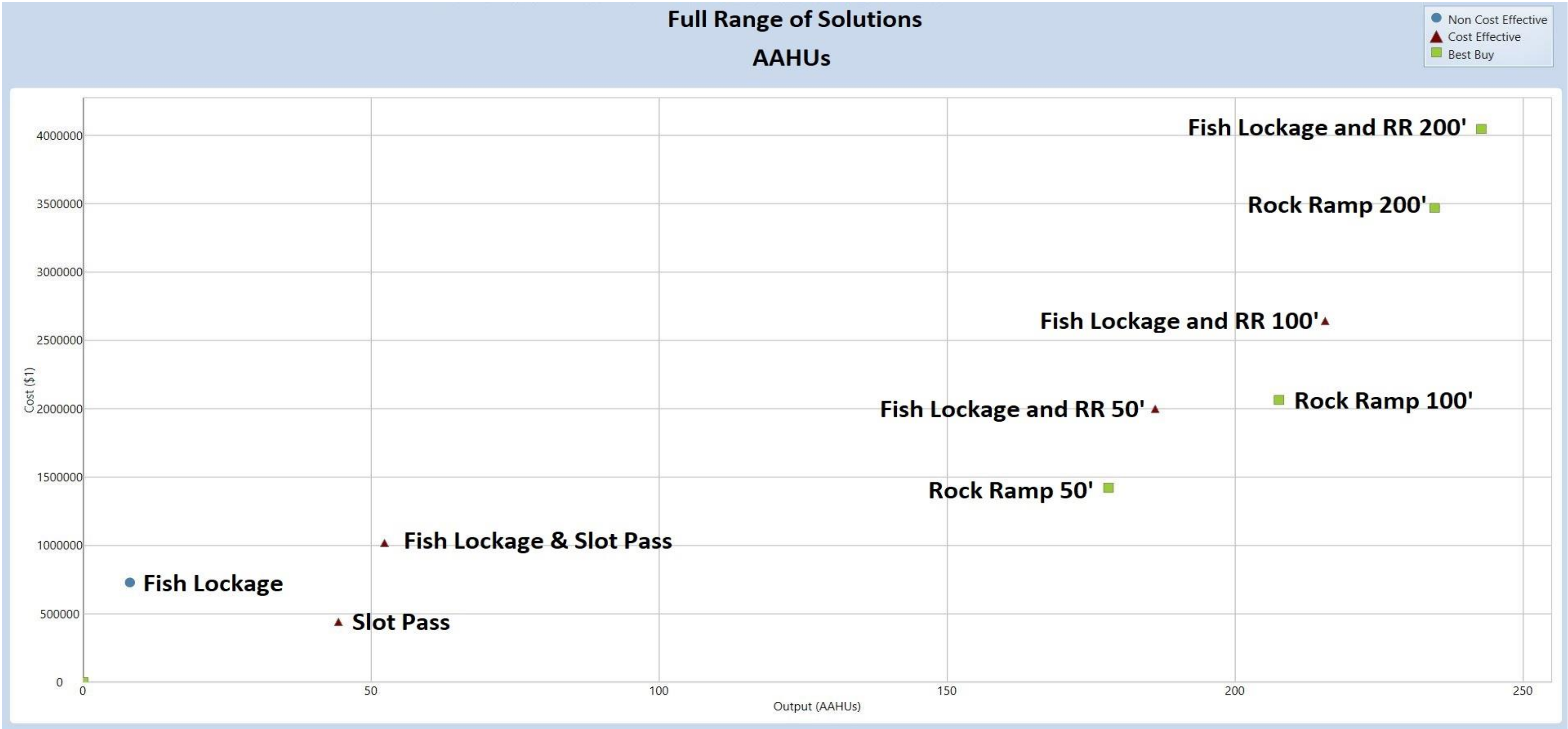


Figure 16. Cost Effectiveness of All Alternatives

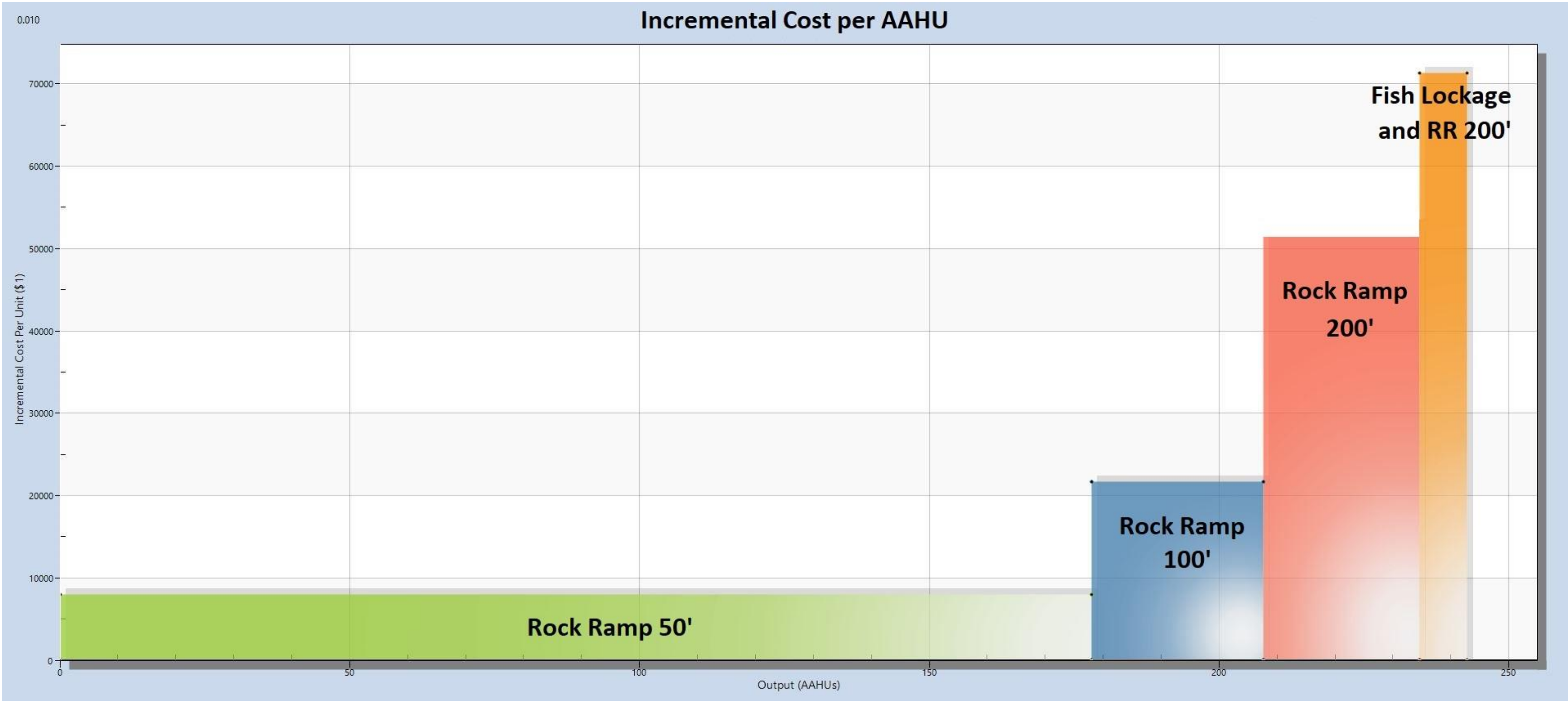


Figure 17. Incremental Cost Analysis of Best Buy Alternatives

4.3 Alternatives' Ability to Meet Project Goals and Objectives

The five Best Buy alternatives were evaluated to determine their ability to meet the project goals and objectives.

Alternative 1 – No Action. This alternative results in no Federal investment. This alternative does not meet any of the project objectives.

Alternative 5 – Rock Ramp 50 ft Bottom Width. This alternative would likely meet all four goals for this project. This alternative would provide riffle habitat to replace spawning habitat that was lost due to the construction of the navigation channel, create a more physically diverse and dynamic river system (Goal 2). By providing pathways for migratory fish movements through dams, the flow of energy, nutrients, and genetic materials of fish migrations can be restored (Goal 3). Rock rapids and riffle habitat can be provided with the fishway (Goal 4). Restoring habitat connectivity and fish migrations can lead to increased spatial extent and abundance of migratory fish populations and native mussels (Goal 5).

This alternative meets three of the four objectives for this project: by increasing the abundance and special distribution of native migratory fish populations (Objective 1), providing rock rapids and riffle habitat, and increasing the habitat corridors (Objective 2), and connectivity opportunities for fish and mussel species (Objective 3). However, this alternative would not provide the opportunity for learning through experimentation (Objective 4), monitoring and adaptive management because it would not provide enough space to adequately assess a variety of fishway entrances and flows.

Alternative 7 – Rock Ramp 100 ft Bottom Width. This alternative would be very similar to Alternative 5 and would likely meet the four project goals and three of the four objectives. In line with Alternative 5, Alternative 7 would not provide the opportunity for learning through experimentation, monitoring and adaptive management because it would not provide enough space to adequately assess a variety of fishway entrances and flows.

Alternative 9 – Rock Ramp 200 ft Bottom Width. This alternative would be very similar to Alternatives 5 and 7. This alternative would likely meet all four project goals. The difference between Alternative 9 and Alternatives 5 and 7 is that it would meet Objective 4. In that this alternative would provide the opportunity for learning through experimentation, monitoring and adaptive management. According to the NESP Science Panel, the ability to learn through experimentation at Lock and Dam 22, despite the additional costs, will provide valuable information to help reduce costs and increase fish passage effectiveness in future project locations throughout the UMRS. The 200-foot Bottom Width Rock Ramp design combined with the monitoring and adaptive management studies would answer several key fish passage effectiveness questions about riffle configuration, spacing, drop, and width that could not be addressed in a laboratory or by narrower fishway alternatives. A 200-foot fishway provides learning opportunities not present in a 100- or 50-foot wide fishway because its size can be reduced relatively easily to test the appropriate width and discharge that will be needed at this and other dams to effectively pass fish in the UMR.

Alternative 10 – Fish Lockage and Rock Ramp 200 ft Bottom Width. This alternative would be very similar to Alternative 9, but with the addition of fish lockage. This alternative would likely meet all four project goals and all four objectives, through the construction of the rock ramp. The fish lockage feature has a low likelihood of meeting system goals of restoring geomorphology, biogeochemistry, habitats and biota. because pre-construction monitoring showed that few fish aggregate in this location, therefore significant populations of fish are unlikely to find the entrance or use any fishway located in this area. Therefore, the addition of the fish lockage is anticipated to provide only a small increase in habitat units for a large increase in additional operating costs. Alternative 10 has the highest incremental cost per unit of habitat compared to the other best buy plans and that the AAHUS increase provided by Alternative 10, is much less than the incremental increases of the previous alternatives.

4.4 Evaluation of Alternatives Using Principles and Guidelines Criteria

The five Best Buy alternatives were evaluated against the four P&G evaluation criteria identified in ER 1105-2-100 **(Table 13).** The four evaluation criteria are acceptability, completeness, effectiveness, and efficiency. Definitions of the criteria are as follows:

- **Acceptability** refers to the workability and viability of the alternative with respect to acceptance by state and local entities and the public compatibility with existing laws.
    - A score of Low or High was used for this criterion. A score of low indicates that the alternative is not acceptable or implementable, high indicates that it is implementable and acceptable.
- **Completeness** is the extent to which the alternative plans provide and account for all necessary investments or other actions to ensure the realization of the planned effects. This may require relating the plan to other types of public or private plans if these plans are crucial to the outcome of the restoration objective. To establish the completeness of a plan, it is helpful to list those factors beyond the control of the planning team that are required to make the plan’s effects (benefits) a reality.
    - A score of Low, Moderate, and High was used for this criterion. A score of low indicates that none of the objectives were met, moderate indicates that some of the objectives were met, and high indicates that all the objectives were met.

- **Effectiveness** is the extent to which an alternative plan alleviates the specified problems and achieves the specified objectives.
    - A score of Low, Moderate, and High was used for this criterion. A score of low indicates that none of the objectives were met, moderate indicates that some of the objectives were met, and high indicates that all the objectives were met.

- **Efficiency** is the extent to which an alternative plan is the most cost-effective means of alleviating the specified problems and achieving the specified objectives.

Table 13. Fish Passage Best Buy Alternatives Comparison to the Planning Principles and Guidelines (P&G) Criteria

	Acceptability	Completeness	Effectiveness	Efficiency
Alternative 1 No Action	Low	Low	Low	No monetary investment, but the objectives are not met and there are no habitat benefits are gained.
Alternative 5 Rock Ramp 50 ft Bottom Width	High	Moderate	Moderate	Yes. This alternative is cost effective at achieving the objectives and gains 178.0 AAHU.
Alternative 7 Rock Ramp 100 ft Bottom Width	High	Moderate	Moderate	Yes. This alternative is cost effective at achieving the objectives and gains 207.6 AAHU.
Alternative 9 Rock Ramp 200 ft Bottom Width	High	High	High	Yes. This alternative is cost effective at achieving the objectives and gains 234.6 AAHU.
Alternative 10 Fish Lockage and Rock Ramp 200 ft Bottom Width	High	High	High	Yes. This alternative is cost effective at achieving the objectives and gains 242.7 AAHU.

4.5 Comparison of Best Buy Alternatives

Alternative 1 – No Action. This alternative results in no Federal investment, but this alternative does not meet any of the project objectives. This alternative yield no net gains in habitat units. This alternative is the basis for which the action alternatives are compared against.

Alternative 5 – Rock Ramp 50 ft Bottom Width. This alternative would likely meet all four goals for this project. This alternative meets three of the four objectives for this project. However, this alternative would not provide the opportunity for learning through experimentation. This alternative yield 178.0 AAHU and the average annual cost is $1,422,461. The average annual cost per AAHU is $7,991. The incremental cost per AAHU above Alternative 1 is $7,991 and the incremental AAHU is 178.0.

The wider fishway would have greater attracting flows and pass more fish; however, the risk and uncertainty associated with this alternative is high because the attractant flow of 525 cfs is less than the 1,800 cfs minimum attractant flow that was recommended. This size of fishway may concentrate fish; however, the rocks that make up the fishway will provide cover that will make fish of all sizes less susceptible to predation.

Alternative 7 – Rock Ramp 100 ft Bottom Width. This alternative would likely meet all four goals for this project. This alternative meets three of the four objectives for this project. However, this alternative would not provide the opportunity for learning through experimentation. This alternative yield 207.6 AAHU and the average annual cost is $2,064,721. The average annual cost per AAHU is $9,946. The incremental cost per AAHU above Alternative 5 is $21,698 and the incremental AAHU is 29.6.

The wider fishway would have greater attracting flows and pass more fish; however, the risk and uncertainty associated with this alternative is high because the attractant flow of 525 cfs is less than the 1,800 cfs minimum attractant flow that was recommended. This size of fishway may concentrate fish; however, the risk and uncertainty associated with this alternative was considered moderate because the attractant flow discharge is 900 cfs, which is half of the recommended design flow. Fish using this structure will be less susceptible to predation because of its larger size and abundant cover.

Alternative 9 – Rock Ramp 200 ft Bottom Width. This alternative would be very similar to Alternative 5 and Alternative 7. This alternative would likely meet all four project goals. This alternative would yield 234.6 AAHU and the average annual cost is $3,453,914. The average annual cost per AAHU is $14,723. The incremental cost per AAHU above Alternative 7 is $51,452 and the incremental AAHU is 27.0.

This structure’s width will ensure that there is an attractive flow of 1,650 cfs, which is lower than the recommended design flow of 1,800 cfs yet is the largest attractive flow that meets all project constraints. Fishways with similar percentages of flows have successfully passed a variety of fish species with similar migration behaviors and swimming performance. Larger width fishways were considered by the PDT; however, they failed to meet the constraints described in Chapter 2. Fish using this structure would be least susceptible to predation because of the large size of the fishway and abundant cover provided by the rock ramp fishway.

Alternative 10 – Fish Lockage and Rock Ramp 200 ft Bottom Width. This alternative would be very similar to Alternative 9, but with the addition of fish lockage. The construction of the rock ramp would likely meet all four project goals and all four objectives. However, the fish lockage feature has a low likelihood of meeting system goals. This alternative would yield 242.7 AAHU and the average annual cost is $4,031,337. The average annual cost per AAHU is $16,610. The incremental cost per AAHU above Alternative 9 is $71,287 and the incremental AAHU is 8.1.

This alternative is cost effective, but the incremental output gained over Alternative 9 (8.1 AAHU) is not worth the additional investment. The addition of fish lockage has no construction cost, but the increased operation and maintenance of the lock contributes to an overall cost increase for this alternative.

4.6 Evaluation of Comprehensive Benefits

In January 2021, a policy memorandum was issues by the Assistant Secretary of the Army for Civil Works (ASA(CW)) directing PDTs to identify and analyze benefits in total and equally across a full range of benefit categories. The intent of this directive is for teams to comprehensively evaluate benefits including equal consideration for economic, environmental, and social categories. To meet the intent of this memo, the Best Buy alternatives were assessed to identify benefits across four categories: National Economic Development (NED), Environmental Quality (EQ), Regional Economic Development (RED), and Other Social Effects (OSE).

NED: The NED account displays changes in economic value of the national output of goods and services.

All action alternatives would have an economic cost to the nation to achieve the non-monetized environmental output of goods and services provided by the improvement of fish connectivity. The average annual cost for the best buy alternatives is as follows:

Alternative 1	0
Alternative 5	$1,422,461
Alternative 7	$2,064,721
Alternative 9	$3,453,914
Alternative 10	$4,031,337.

EQ: The EQ account displays non-monetary effects on significant natural and cultural resources.

EQ of alternatives is scored based on AAHU output. The AAHU output for the best buy alternatives is as follows:

Alternative 1	0
Alternative 5	178.0
Alternative 7	207.6
Alternative 9	234.6
Alternative 10	242.7

All action alternatives would provide positive long-term effects for fish and other aquatic species in the study area. Implementation of a nature-like fishway project would change habitat conditions in the immediate tailwater and would provide a pathway for fish movements upriver past Lock and Dam 22. A fishway structure would also provide spawning habitat for some species like the Lake Sturgeon and would enable the movement of native species and invasive carp. Alternatives 9 and 10 provide the greatest net gain in AAHU, but Alternative 10 provides minimal gains in AAHU over Alternative 9 and the additional cost for Alternative 10 were not deemed worth the investment.

RED: The RED account registers changes in the distribution of regional economic activity.

All action alternatives would have a positive impact on the regional economy. It is assumed the percentage of Federal expenditure to regional benefits are similar across the best buy action alternatives. Examples of regional economic benefits could include, but are not limited to, increase in employment opportunities in the region during construction, increase in visitation to the region due to monitoring and adaptive management activities. The No Action alternative would not produce any RED benefits since there would be no action taken by the Federal government.

OSE: The OSE account registers effects from perspectives that are relevant to the planning process but are not reflected in the other three accounts.

All action alternatives assume positive social impacts since there was an increase in AAHU. All action alternatives would increase recreational fishing opportunities due to the improvement of fish species above the dam. The No Action alternative would not produce any OSE benefits since there would be no action taken by the Federal government.

4.6.1 Summary of Comprehensive Benefits

Based on the primarily qualitative evaluation presented above, Alternatives 5, 7, 9, and 10 provide similar benefits across the accounts.

Alternative 9 reasonably maximizes benefits across all categories. Alternative 9 also reasonably maximizes benefits in relation to the study purposes: to increase opportunity for upriver fish passage and monitor, evaluate, and learn from and adapt future fish passage projects using lessons learned from this project (done through monitoring and adaptive management).

When compared, Alternative 9 is the plan that maximizes net total befits across all benefit categories.

5 PLAN SELECTION

Selecting the National Ecosystem Restoration (NER) plan requires consideration of the plan that meets the project objectives, doesn't violate project constraints, and reasonably maximizes environmental benefits while passing the test of cost-effectiveness and incremental cost-analysis (CE/ICA).

5.1 National Ecosystem Restoration Plan

Based on the CE/ICA, the Best Buy alternative that would meet all project objectives and reasonably maximizes environmental benefits is Alternative 9 (Rock Ramp 200-foot Bottom Width). In addition to the rock ramp, a prefabricated bridge system with water control structure, and a fixed debris boom would also be constructed. A coffer dam would be used to construct concrete features associated with the debris boom, bridge, and water control structure in the dry. This alternative has on overall output of 234.6 AAHU at an average annual cost of $3,453,914. Alternative 9 is selected as the NER and Recommended Plan. A full description of the Recommended Plan, including an updated cost estimate, is outlined in Chapter 6.

5.2 Consistency with USACE Campaign Plan

USACE has developed a Campaign Plan with a mission to "deliver vital public and military engineering services, partnering in peace and war to strengthen our Nation's security, energize the economy, and reduce risks from disasters." Alternative 9 is consistent with the Campaign Plan by producing lasting benefits for the Nation, by using innovative solutions in pursuit of a sustainable, environmentally beneficial, and cost-effective ecosystem restoration design (USACE 2017).

5.3 Consistency with USACE Environmental Operating Principles

USACE has reaffirmed its environmental commitment by formalizing Environmental Operating Principles (EOP) applicable to all of its decision-making and programs. The formulation of alternatives considered for implementation met all of the EOPs.

The EOPs are: foster sustainability as a way of life throughout the organization; proactively consider environmental consequences of all USACE activities and act accordingly; create mutually supporting economic and environmentally sustainable solutions; continue to meet our cooperate responsibility and accountability under the law for activities undertaken by USACE, which may impact human and natural environments; consider the environment in employing a risk management and systems approach throughout the life cycles of projects and programs; leverage scientific, economic, and social knowledge to understand the environmental context and effects of USACE actions in a collaborative manner; and employ an open, transparent process that respects views of individuals and groups interested in USACE activities (USACE 2002). The EOPs were considered during the plan formulation process. Alternative 9 promotes sustainability and economically sound measures by incorporating the most natural and least cost methods for restoring fish connectivity.

6 DESCRIPTION OF RECOMMENDED PLAN

6.1 Plan Components

The Recommended Plan for the Lock and Dam 22 Fish Passage Improvement Project is Alternative 9 – Rock Ramp 200 ft Bottom Width, which includes a rock ramp adjacent to storage yard, downstream of spillway, 200-foot bottom width, a prefabricated bridge system with water control structure, and a fixed debris boom (Figure 5.). This plan is also shown on Plate C1 with additional details on other plates.

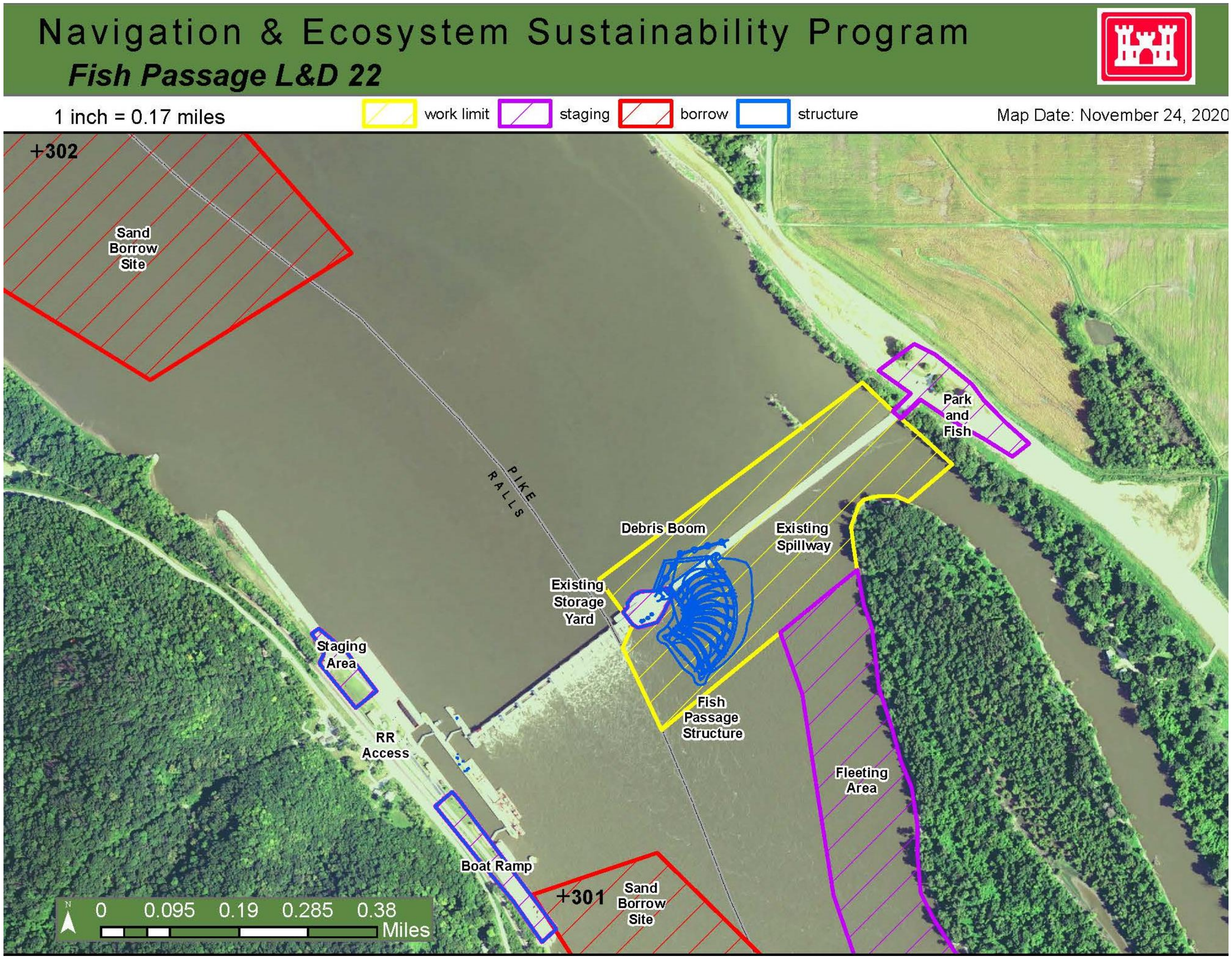


Figure 6. Alternative 9 – Recommended Plan

6.2 Design Considerations

This fishway has been developed to a feasibility level of design. Significant design details are included in Appendices G, *Geotechnical Consideration,* Appendix H, *Hydrology and Hydraulics*, Appendix K, *Real Estate Plan* and Appendix Q, *Plates*. As with all feasibility level studies, these details will be refined in the Preconstruction Engineering and Design (PED) phase.

The fishway would be located adjacent to the storage yard, with the majority of the structure built downstream of the spillway. The largest concentration of fish has been observed in this location. It is possible that during the PED phase, the location may move slightly in either direction along the spillway to address design constraints.

6.2.1 Real Estate

The lands needed for the Project are owned in fee by the United States and managed by the United States Corps of Engineers (USACE). See Appendix K, *Real Estate Plan* for additional information.

6.2.2 Pool and Riffle Design

The fishway will be constructed generally of various sizes of sand, rock, and boulders, and will be of a pool and riffle design to emulate natural fishways. A series of riffles would be used in the fishway to control the water surface elevation and velocity of the pools. In general, there will be a 1-foot drop in water surface elevation between pools. The boulders will be staggered along the top of the riffle and along the downstream side of the structure so that the fish will not encounter the entire head loss at the crest of the weir. This will effectively create a two-step drop within sections of each riffle weir. The boulders will be arranged so that passing fish can position their bodies to burst through the higher velocities associated with the weirs. Long bodied fish, such as Lake Sturgeon, Paddlefish, and large catfish, will require considerable room downstream of the gaps to navigate through them. Detailed information is contained in Appendix H, *Hydrology and Hydraulics* and in Appendix G, *Geotechnical Considerations.*

The pool and riffle details are shown on Plate C14. The riffles were designed with 4H:1V slopes or flatter for stability from a geotechnical standpoint, a riffle top length of 5 feet to ensure stability, and more than 2 feet of depth between the boulders at the riffles. The layout of the riffles extends across the bottom of the fishway and may extend slightly up the side slopes. While curved riffles were evaluated for structure layouts during the study phase, other layouts could be as successful. However, straightening the shape of the riffles too much may oversimplify the velocity profile created by the riffle, making the fishway less suitable for passing both large and small fish. Fish orient their body in flowing water using the helical flow pattern found in channels to identify the upstream direction and using current breaks (eddies) for resting and feeding. The arched configuration creates complex flows through the riffle step and is desirable in emulating a natural stream. This design has been effective in other fishways. The pool between the riffles was designed to be 20 feet in length at 5 feet deep to ensure that there was adequate resting room for fishes before and after each riffle passage. The design of the riffle and pool structures was extensively researched by the PDT and fish passage experts. The correspondence regarding this topic was documented in Appendix A, *Correspondence* with feasibility-level hydraulic modeling results presented in Appendix H, Section 5.4, *Geometry.*

Riffle weirs will serve as the steps of the fishway. Large boulders will be embedded in the top of the riffles and along the approach slope which will create conditions to allow the fish to swim between them. Spaces between boulders would be graduated from tightly spaced near the shores to wider gaps between boulders in the middle of the fishway. This creates lower flow areas near the bank and higher flow areas in the middle to accommodate the swimming abilities of all fishes. The bed of the fishway would have an elliptical shape, being deepest in the middle section of each riffle. It is important to use irregular stones to increase roughness and to have a variety of spaces between the boulders. To ensure an adequate design for the riffles and boulder configuration, the following items must be considered in the design phase of the project:

- velocities achieved by the riffle structure are appropriate to pass all fish
- there is a varied, non-uniform flow regime
- past constructed fishways that have been successful are considered in the final design
- consider a closer boulder spacing near the banks with a wider spread between boulders in the center
- consider the radius of the arch in order to concentrate flow more
- there is a channel of flow through the center of the structure
- consider structural stability during floods for the design of the structure

6.2.3 Construction Materials

Along with providing an environment conducive to fish passage, the fishway must be stable enough to ensure functionality, and minimize maintenance costs. To satisfy both requirements, stone will be used for the upper layer of the fishway. The stone must be sized to protect against flow velocity, and, while an ice and debris barrier will be located upstream of the fishway, the stone must also be sized considering that some ice and debris may make it past the barrier. Fishway materials would consist of riprap for the exterior portion of the structure, large boulders embedded in the riffles, and fill material to bring the rock ramps up to grade. More information is included in the Appendix G, *Geotechnical Considerations* and Appendix H, *Hydrology and Hydraulics*.

The entire fish passage embankment structure will be designed to protect against destructive current action. For the feasibility analysis a 4-foot thickness of riprap was selected for cost estimating purposes. Further analysis will occur during PED.

Geotechnical evaluations determined that it was unlikely that the rock fill would become a critical seepage path; however, it was recommended that the riprap be choked with sand or other material to reduce any seepage concerns. These seepage paths will be further evaluated during PED.

From initial surveys, a scour hole was observed within the footprint of the fishway. To bring this area to grade, rock fill was used for feasibility level cost estimate. The rock fill is well graded, quarry-run shot rock, with a nominal top size of 500 pounds, and not more than 10 percent by weight finer than 1 pound blasted off the quarry face and delivered without any additional processing. Fill at this location could include sand, shot rock, graded rock, waste rock from the lock expansion project or wing dam shortening, dredged material, or geotubes and will be selected during PED. It is imperative that construction considerations such as constructability of the top layers of the fishway and the potential of the spillway overtopping are considered in the final selection of the fill material. Multiple locations for sand borrow sites are shown in Figure 18. These locations were provided in this study as potential locations for borrowing sand if it is selected as a more cost-effective method during the PED phase. As previously mentioned for cost estimating purposes, rock fill is the assumed fill for this report.

Historic bathymetry could provide some insights into how the scour hole has progressed through the years. Some effort could be spent on researching and obtaining past bathymetric surveys, although the information may not be particularly useful in predicting future trends with a fish passage structure where the hole currently exists. 2D hydraulic modeling likely provides the best indication of velocity patterns after a structure is built over the scour hole. Without going into detailed analysis, a fish passage structure would attenuate the higher velocities associate with an overtopping event by dissipating energy across most of the length of structure. Current 2D model simulations already show this. In the case of rock ramp designs, the rock sizing has already been designed for existing condition overtopping events. By constructing a rock ramp, overtopping severity should be no more than existing condition events.

The riprap rock size should withstand the eddy movements and will be designed accordingly. Protection of sediments below the structure’s foundation can be accomplished with additional riprap, concrete grout, or sheet piles if a scour threat is perceived.

A comparison of with and without project velocities from 2D modeling can provide an indication of potential new scour areas if a project is built. A comparison shows the most likely location for erosive conditions for a rock ramp alternative would occur near the inside bend of the structure. Much of this area would already be covered with rock, although the extent of the rock will be verified during the PED phase.

The 2D model simulations of sediment movement for the 2-year and 10-year flood events indicate that the potential for erosion or deposition are not significantly different with the fishway in place. There will be localized differences, without a doubt, but the
modeling does not suggest changes that can't be addressed through typical monitoring activities.

The boulders in each riffle are large enough to provide the desired 2 to 3 feet of flow depth between boulders and to withstand some impact from ice and debris. With an ice and debris boom upstream, an embedment depth of 1.5 feet is considered sufficient for 4 to 5-foot diameter boulders. An embedment of 1.5 feet is 30 percent of the diameter of a 5-foot diameter stone. With 1.5 feet of embedment, these boulders would stand 2.5 to 3.5 feet above the bed. These boulders would provide the desired 2 to 3 feet of depth between boulders. Boulders having a diameter of 4 to 5 feet have been used successfully at the Riverside Dam rock fish passage structure in Grand Forks, ND. At the Riverside Dam, the boulders were placed closer together than what is proposed at Lock and Dam 22, but an ice and debris boom does not exist at Riverside Dam.

6.2.4 Prefabricated Bridge System With Water Control Structure

The bridge over the fish passage and dam is a prefabricated bridge system. The preliminary design is based on HS20-44 loading assuming head wall and wing walls are designed to withstand earth pressure and lateral water pressure of the flow. The design fill height varies from 2 feet minimum to 6 feet maximum. The bridge will have 16 precast 15-inch wide parapet headwalls; 4 precast wing walls; 14 nosecones, and openings to allow sunlight through. Bridge design during PED will develop methods to allow sunlight to pass through the bridge in order to reduce shadows. The final design must ensure that impacts to the floodplain are minimized. Hydraulic requirements to allow appropriate water conveyance through the bridge are described in Appendix H, *Hydrology and Hydraulics*. Design considerations to ensure that fish were not impacted included: ensuring that there was a minimal shadow over the passageway, no steel was located along the bottom of the structure, and concrete pads or sills were minimized (although rock or boulders could be placed on or along these pads). Any bridge structure must be strong enough to support truck-mounted cranes in order to manipulate stoplogs or bulkheads in the fishway. Geotechnical borings will be required for all bridge footings. More details are contained in the Appendix I, *Structural Considerations*.

6.2.5 Fixed Debris Boom

The fixed debris boom consists of five beams supported on six cells, which are supported on steel piles forming a triangular configuration. The debris boom will be further refined during PED. The boom was designed to withstand an ice thrust of 5000 lb per square foot to handle the pack ice conditions encountered at Lock and Dam 22. The top elevation of the debris boom is set at 467.5 (MSL 1912). More details are contained in the Appendix I, *Structural Considerations* and Appendix H, *Hydrology and Hydraulics*. In general, the boom is to be configured to minimize maintenance, deflect debris and ice towards the dam gates, and not impact the floodplain or navigation. The final design must fit within hydraulic engineering design parameters, or additional modeling may be required during the design phase.

6.2.6 Dam Safety

Modifications to existing dams impose additional dam safety risks to people and property upstream and downstream of the project. Risk is defined as a function of the loading condition, expected performance of the dam, likelihood of failure, and the expected consequences. Risk increases with an increase in the likelihood of failure or an increase in the potential consequences. Modifications to existing dams should not increase the risks associated with the project.

USACE has implemented a Periodic Assessment program to assess the risks associated with a dam failure at all projects across the inventory. The results of the periodic assessment are used to re-evaluate the DSAC rating assigned during the previous Screening for Portfolio Risk Analysis (SPRA) process. Dam safety risks include life loss and economic consequences associated a dam failure. The Periodic Assessment program also informs the hazard potential classification, the classification for each dam based on the potential consequences of failure. Dams classified as High Hazard Potential will result in the loss of life as a result of failure. Significant Hazard Potential dams will result in a disruption of essential or critical facilities or access, major or extensive property losses to public and private facilities, or major or extensive environmental losses where mitigation is required or impossible.

Lock and Dam 22 went through a Periodic Assessment in 2018 as a Significant Hazard Potential dam and the results of that risk assessment can be found in the Lock and Dam 22 (MO10305) Mississippi River, Missouri Navigation Lock & Dam Periodic Inspection No. 11 Periodic Inspection Assessment NO. 01 report. The Periodic Assessment re-evaluated the deficiencies and failure modes identified in the 2008 SPRA and identified additional potential failure modes (PFMs) that could result in the loss of damming surface (i.e., loss of pool) or a loss of navigation due to an emergency closure of the lock for an extended period of time. The Periodic Assessment identified 44 PFMs during the risk assessment. Those PFMs with the highest risk were carried forward as risk drivers and used to create a risk matrix and inform the DSAC. The risk driver PFMs identified at Lock and Dam 22 include a barge/vessel accident that blocks one or more dam gates from closing, a trunnion friction failure of a Tainter gate, a barge impact of the main lock chamber miter gates resulting in a loss of service of the lock, and a miter gate embedded anchorage fatigue failure resulting in a loss of service of the lock. None of the risk drivers were associated with the overflow spillway or the storage yard embankment.

The 2018 Periodic Assessment conducted at Lock and Dam 22 did not include an assessment of the fish passage feature as this feature was not a part of the project at the time of the risk assessment. To address the dam safety concerns of the fish passage feature for this feasibility report, a Potential Failure Mode Analysis (PFMA) was performed to identify PFMs associated solely with the fish passage project. This analysis follows the USACE risk-informed design process but was completed using only Rock Island District personnel and did not determine the potential consequences associated with these PFMs. The PFMs were identified and justification for excluding them as risk drivers were documented or design considerations were listed to be addressed by the design team. The fish passage structure does not increase the risks at the dam and does not change the hazard potential classification.

This PFMA for the Fish Passage Project at Lock and Dam 22 identified 25 PFMs. The PFMA team determined that none of the PFMs identified were deemed risk drivers to the Lock and Dam 22 Project. Each PFM provides details as to why they would not be considered risk drivers or describes design considerations that should be addressed by the design team. Consequences were not formally considered as a part of this effort. The finished fish passage structure does not increase the overall risk at Lock and Dam 22 as determined by the 2018 PA. Dam safety risk during construction should not increase the overall risk as long as sound construction practices are followed. The project remains a Significant Hazard project with no incremental life loss consequences resulting from a dam failure.

6.2.7 Navigation Impacts

Navigation impacts are a concern for any ramp due the change in velocity patterns near the lock induced by water going down the ramp. The location and orientation that was assumed to have the worst impact on navigation was a 300-foot-wide ramp extending downstream of the spillway, with the downstream end bending approximately 90 degrees so that the water velocity vectors coming down through the ramp is perpendicular with the water velocity vectors coming through the gates. This situation was studied using both a numerical hydraulic model and a physical hydraulic model. No impacts to commercial navigation were observed.

As the velocity patterns were relatively unchanged, it is not anticipated that there will be any safety concerns for recreational navigation. The rock ramp will not easily be accessible to the public. From the upstream end, the fishway will be blocked by debris boom. From the downstream end, a recreational boater would have to travel almost immediately downstream of the dam, an already unsafe position, to enter the fishway. Though the fishway is relatively inaccessible, it is possible that curious boaters, adventure seekers, and fishermen would be attracted to the site. Lighting, signs and fencing would be used to warn and discourage unauthorized access to the fishway. Further information on these models is contained in Appendix H, *Hydrology and Hydraulics*.

6.2.8 Floodway / Floodplain Impacts

The complex flow conditions were modeled two-dimensionally using the ADH model using the frequencies determined in the Flow Frequency Study (USACE, Rock Island 2004). With the prefabricated bridge and a fixed debris boom, the computed 100-year flood stage increase for a fishway having a 200-foot bottom width was 0.04 foot for the 1 percent annual event. This analysis assumes non-blocked conditions at the ice-debris barrier, which is common for National Flood Insurance Program studies. The final plan will be re-modeled with updated survey information and presented to the state regulatory agencies to assure that state and Federal requirements are satisfied. Additional information is provided in Appendix H, *Hydrology & Hydraulics*.

6.2.9 Public Access and Security

Safety and security are important parameters which will be detailed during the PED phase. Creating an attractive nuisance—the possibility of people fishing off of the top of the bridge—was a concern. Additionally, vandalism and safety issues were also considered. Some type of locked fence prohibiting unauthorized access to the bridge was considered. Coordination with the District's Safety Office and Office of Counsel will be required in this area.

6.3 Project Implementation Timeline

The timeline is subject to change based on approvals of the PIR and funding. This timeline represents the best-case scenario.

The project is likely to be implemented in two stages. Stage I includes design and construction of the cofferdam, bridge, and debris boom. Stage II includes the design and construction of the rock ramp. Monitoring and adaptive management would occur prior to construction (pre-construction monitoring) and after construction is complete (post-construction monitoring and adaptive management).

It is assumed construction duration will last 12 months for Phase 1 and 21 months for Phase 2. This duration assumes that no work activities can occur during the winter months between December and March. A refined construction schedule will be developed during PED.

6.4 Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R)

Table 14 documents the OMRR&R for the major components and frequency. See Appendix C, *Cost Estimate*, for full documentation of proposed OMRR&R activities.

Table 14. OMRR&R Components and Frequency

COMPONENT	FREQUENCY
Rock Structure Site Inspection	Annually
O&M Dam Safety Inspection	Annually
O&M Bridge Inspection	Every 5 years
O&M Debris Boom Inspection	Every 5 years
O&M Stoplog Structure Inspection	Every 5 years
Replace Rock in Riffles and Realign Rock[1]	Every 10 years
Repair Steel Stoplog Structure Seals	Every 15 years
Repair Steel Stoplog Structure Paint Surfaces	Every 30 years
Remove Debris in Fishway	Annually
Repair Asphalt Surfaces with Patch	Every 2 years
Repair Asphalt Surfaces with Complete Resurfacing	Every 15 years
Repair Gates, Guard Rails, Stoplogs	Every 10 years
Repair Debris Boom	Every 15 years
Repair Concrete Surfaces	Every 10 years
Rehab Steel Stoplog Structures	Every 60 years
Rehab Debris Boom	Every 60 years
Rehab Concrete Bridge	Every 75 years

[1] Due to the potential for federally listed species to colonize and utilize the rock ramp structure following construction, future maintenance of the fish passage structure, including replacing rock in riffles, rock re-alignment, and any other actions that may have the potential to affect protected species be coordinated with State and Federal partners to inform and identify timeframes and/ or other measures to avoid and minimize potential impacts to natural resources, as identified.

6.5 Risk and Uncertainty

Risk is the chance that something negative could occur as the result of project implementation. *Uncertainty* is defined as the degree to which we are not sure that the expected results will actually occur. The following paragraphs describe the risk and uncertainty associated with the Lock and Dam 22 Fish Passage Project.

Risk. There is a relatively low level of risk to human safety associated with the implementation of this project. Some risks the PDT considered were dam safety, navigation, flood impacts, climate impacts, and constructability. Dam safety was reviewed by the PDT and the dam safety officer, and it was determined that it would not be compromised. Monitoring will ensure that dam safety measures will be put into place before, during, and after construction. Navigation impacts were assessed in the physical and numerical hydraulic models and the results were reviewed by navigation experts and industry. No impacts to navigation will occur from the proposed project. Flood impacts from constructing a large structure were also reviewed. The flood stage increase was calculated and is contained in Appendix H, *Hydrology and Hydraulics.* Climate impacts were determined to not impact the design of the structure, but rather the usefulness of the structure to fish and would not affect human safety. A table of risks posed by climate change is discussed further in Appendix H-A, *Climate Change Impact Assessment.* The project design is consistent with the ILDNR for flood stage increases. Constructing this project has several challenges as the fishway will be constructed in water. Cost estimating has accounted for constructability issues, and the Plans and Specifications will describe the challenges to the contractor.

Because this is the first fishway installed on the UMR, there is a moderate risk that it will not work exactly as expected. To account for this risk, the plan includes a series of studies that will help the Corps optimize the design for this project and other fishways through adaptive management. Adaptive management measures will address various fishway widths and velocities, downstream entrances to the fishway, and riffle configurations. Performance monitoring will be used to determine the effectiveness of these various configurations.

A fish passage structure would enable the movement of native species and invasive carp, but the risk of increasing the northern expansion of invasive carp is low, as they have been established in the Mississippi River for over twenty-five years and have steadily increased in abundance. Recruiting populations of invasive carp have been found upstream and downstream of Lock and Dam 22. Minnesota DNR reported Bighead and Silver carp in Pool 2 in 2014 and catches have continued in Wisconsin and Minnesota border waters into 2021. Invasive carp eggs have been found as far upstream as Pool 16 (Larson et al. 2017), and consistent reproduction has been documented as far as Pool 18. The Wisconsin DNR reported commercial catches in 2008 of Bighead Carp and the first captured Silver Carp as far north as LaCrosse, Wisconsin, 396 river miles and 14 dams upstream of the project area (Benjamin and Culhane 2008). Natural resources managers believe that fish passage facilitation would do more benefit to native species by expanding access to previously unavailable habitat to native species, than harm from allowing more invasive carp to move into Pool 22.

Ecosystem sustainability can be achieved through greater understanding of threats to native fish populations. Managing the river for multiple and sometimes contradictory purposes is an ongoing challenge for resource managers. The need for fish passage has been acknowledged in the UMRCC Upper Mississippi River Fisheries Plan (Janvrin et al. 2010), as has the need to consider limiting invasive carp movements when planning fishways (Conover et al. 2007). Providing connectivity for native species while managing the distribution of invasive species has stymied biologists and managers since invasive carp were identified as a problem in the lower impounded reaches of river (Chick and Pegg 2001). Because fishways are non-species selective, meaning they pass both native and non-native species, they can be used for dual purposes, reconnecting native fish to upstream habitats while serving as a physical platform for research and capture and invasive species removal. Well-designed fishways offer the opportunity for:

- **Research** – Fishways provide a safe, controlled environment to study the status of non-native fish fauna to establish reasonable goals and objectives for use at the reach, pool and project scale. Fishways would serve as a platform to test deterrent technologies and the effects on target and non-target organisms under controlled conditions.
- **Monitoring** – Both passive and active capture techniques could be used to determine relative abundance and richness of fish fauna and determine the success of management actions for key recreational and commercial fishes.
- **Removal** – Fishways would be designed to facilitate capture and removal of invasive fish species to protect aquatic resources from further degradation. Harvest statistics from removal actions would be used to increase public awareness of aquatic nuisance species. A single capture point would centralize handling and processing of harvested fish.

By designing features that allow for the concentration and capture of non-native species, fishways offer the unprecedented opportunity to fill information gaps regarding fish movement and abundance in the Upper Mississippi River. Monitoring would allow characterization of timing, numbers, and relative size of fish passing upriver and downriver through both a fixed-point hydroacoustic monitoring system and through capture. If managers determine that invasive carp capture at the fishway is ecologically desirable, fish would be captured, sorted and processed at the fishway.

***Uncertainty**.* A degree of uncertainty is inherently associated with the models used to generate estimates of benefits (habitat units). These models involve estimates of environmental conditions for the project site over the project life. Given the dynamic nature of riverine ecosystems and biological populations in general, predictions into the future will always involve some degree of uncertainty. The best scientific judgment of biologists with extensive experience on the UMR was utilized in the development of restoration benefits in order to minimize uncertainty as much as can reasonably be expected. Additionally, uncertainty in future duration and magnitude of flood flows also exists due to climate change.

Adverse river conditions can be divided into two categories: short and long duration high flow events. Temporary blocking of dam gates or the spillway from regular dam maintenance or localized upstream flashy precipitation events can induce a high head condition. High head conditions produce the highest velocities and shear stress on rocks that make up the fish passage structure. These events do not occur often but are unavoidable. Current USACE climate tools do not evaluate likelihood of localized heavy precipitation events. Longer duration high flow events can be caused by increased upstream tributary flows, heavy rain over long durations of time, and from widespread upstream snowmelt and can result in the fish passage or prefabricated bridge being inundated for extended periods of time. When the structures are inundated, the fish passage is not usable to fish for a longer period of time and at least part of the bridge may not be useable for a longer period of time. Longer duration events should not impose a significant risk to the stability of the fish passage structure due to flow, but may make the more structure susceptible to debris and ice impacts. Current fish passage designs were made to accommodate both short and long duration events as best as possible. See Appendix H for the table of Identifying Climate Risks to the Project by feature.

There is some uncertainty on the size, location, and design of the most effective fishway. The optimal size of the fishway was based upon the Larinier (2000) recommendation that fishways should be designed with an attraction flow of around 10 percent of the minimum flow of the river and between 1 and 1.5 percent of the higher design flow for a well located fishway on large rivers. Using these criteria, the optimal fishway discharge at Lock and Dam 22 at low flow was a minimum of 1,800 cfs. The optimal location was determined through pre-project monitoring and hydraulic modeling in the tailwater below the storage yard. The tailwater is where fish aggregate because an eddy that forms below the spillway under normal flow conditions. The design was based upon successful fishways used on different rivers. The fishway may be less effective if any of these assumptions are incorrect.

6.6 Cost Estimates

Cost estimates for the Recommended Plan were completed using MII4.4.2 A detailed description can be found in Appendix C, *Cost Estimate*. The following sections document the components of the project.

6.6.1 Total Project Costs

The project first cost for Alternative 9 is $122,110,000 at a FY 2021 price level (Oct 2020). The costs are expressed as Project First Costs and include construction, contingencies, engineering, preconstruction engineering, and design, and construction management. When interest during construction is added, the total investment cost is $126,712,000. The more refined cost estimate also involved refining quantities, an Abbreviated Risk Analysis to determine contingencies, Micro-Computer Aided Cost Estimating System (MCACES), and Total Project Cost Summary (TPCS) to determine present value costs. Table shows the estimated cost by account. The total project cost fully-funded amount is $137,053,000 which is the project first cost escalated to the mid-point of construction. The detailed estimate of the project design and construction costs are provided in Appendix C, *Cost Estimate*; however; due to the sensitivity of providing this detailed cost information, this material will be omitted in the public document. (Note: The values between MCACES and TPCS reports have a negligible difference due to rounding calculations in the MCACES program.).

Table 15. Project First Cost and Benefits Summary

Account	Item	Project First Cost
06	Fish and Wildlife Facilities	$83,995,000
01	Lands and Damages	$0
	Subtotal	$83,995,000
30	Preconstruction, Engineering & Design	$26,776,000
31	Construction Management	$11,339,000
	Subtotal	$122,110,000
	Interest During Construction[1]	$4,603,000
	Total Investment Cost[2]	$126,712,000
	Annualized Project Costs[3]	$4,468,000
	Annual OMRR&R[4]	$178,000
	Total Annual Costs	**$4,645,000**
	AAHU Gain	234.6
	Cost per Average Annual Habitat Unit	$19,800

Notes
1. Interest During Construction is calculated thru year 2026.
2. Total Investment Cost includes 31% contingency & number has been escalated. It also includes Adaptive Management costs thru 2032.
3. Annualized Project Costs include Adaptive Management costs thru 2032.
4. OMRR&R includes 25% contingency & number has not been escalated

6.6.2 Operation, Maintenance, Repair, Replacement & Rehabilitation Costs

Table 15 is a summary of the annualized OMRR&R costs for the Recommended Plan. Appendix C, *Cost Estimate*, details the development of the OMRR&R annualized costs. The estimated annualized present value (PV) cost is $177,800. It is assumed there is no operation cost for the Recommended Plan. Rehabilitation of any structures is anticipated beyond the 50-year life of the project; those costs are not provided.

Table 156. Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) Costs for the Recommended Plan

Description - OMRR&R	UOM	QTY	Annualized PV Cost
Rock Structure Site Inspection	LS	1	$5,400
O&M Dam Safety Inspection	LS	1	$8,000
O&M Bridge Inspection	LS	1	$1,400
O&M Security and Public Coordination	LS	1	$1,200
O&M Debris Boom Inspection	LS	1	$700
O&M Stoplog Structure Inspection	LS	1	$700
O&M Stoplog Structure Replace Seals-15 yr Frequency	LS	1	$3,200
O&M Stoplog Structure Sand Blast and Repaint- 30 yr Frequency	LS	1	$1,700
O&M Fixed Debris Boom Repair-15 yr Frequency	LS	1	$1,800
Rock Realignment and Replace Rock Lost in Riffles - 10 year High Flow Event	LS	1	$4,400
Fence, Gate, and Guardrail repair-10 yr frequency	LS	1	$5,300
Resurface Asphalt-15 yr frequency	LS	1	$900
Patch Asphalt-2 yr frequency	LS	1	$2,800
O&M Concrete Surface Repair-10yr Frequency	LS	1	$13,000
Debris Removal on an Annual Basis	LS	1	$91,700
Subtotal			**$142,200**
Contingency at 25%			$35,600
Total Annual OMRR&R Costs			**$177,800**

Period of Evaluation (Project Life): 50
Discount Rate (FY2021): 2.5%
Interest During Construction: Not considered

6.6.3 Monitoring and Adaptive Management Costs

Monitoring activities are broken into three general categories: 1) pre-construction planning and design; 2) construction; and 3) post-construction performance evaluation. Pre-construction monitoring focused on establishing project evaluation baselines and identifying site-specific information to aid in planning. Construction monitoring was designed to assess the impact of construction on the surrounding environment. Post-construction monitoring would be used to measure project performance.

Adaptive management encompasses five types of adaptive work that are organized as five experiments. Adaptive management is not expected to be applied until after the base construction project is closed out. Each experiment is expected to include three years of monitoring analysis and a fourth year for construction modification to the structure. It is assumed that Experiment 1, to begin in 2027, does not include any construction modification costs. Subsequent experiments will include construction modification costs.

Table 16 shows the summary of adaptive management costs that includes the base project costs for the Recommended Plan, the total adaptive management construction costs for each experiment, and the total monitoring cost for pre-monitoring, during construction monitoring, post construction monitoring, and adaptive management monitoring. These costs were initially developed with a 2008 price level. The costs have been updated to the 2021 price level and include a 31% contingency from the Project CSRA. See Chapter 7, Appendix M, *Monitoring & Adaptive Management,* and Appendix C, *Cost Estimate* for additional details.

Table 17. Monitoring and Adaptive Management Costs

Monitoring Costs	$6,035,000
Adaptive Management Construction	$10,250,000
Subtotal Adaptive Management and Monitoring	**$16,285,000**
PED and Construction Management	**$6,514,000**
Contingency, 31%	$7,068,000
Total Adaptive Management and Monitoring Cost	**$29,867,000**

6.6.4 Cost Risk Analysis

A cost risk analysis was completed in 2021. The following documents the 2021 cost risk analysis.

A cost risk analysis was performed in accordance with EC Bulletin No. 2007-17, *Application of Cost Risk Analysis Methods to develop Contingencies for Civil Works Total Project Costs*. A project cost and schedule risk analysis is the process of identifying and measuring the cost and schedule impact of project uncertainties on the estimated total project cost. The results of this analysis showed that the greatest factors contributing to schedule uncertainty included; limited control of staffing priorities, inadequate future funding, untimely approvals, accelerated schedules, contracting issues, permit delays, design uncertainties, and floods. These concerns were largely due to the preliminary nature of a feasibility level analysis. The project cost and schedule risk analysis also described the uncertainty associated with the cost estimate. This uncertainty included; contract acquisition issues, future market conditions, quantity estimates, and flooding. The Project Cost and Schedule Risk Analysis Report indicated that appropriate total project cost contingency rate was 30 percent. A complete description of this analysis can be found in Appendix C, *Cost Estimate*.

6.7 Compliance with Environmental Quality Statutes

Compliance is as follows:

Federal Policy	**Compliance**
Bald and Golden Eagle Protection Act of 1940	Full compliance
Clean Air Act, as amended, 42 U.S.C. 1857h-7, et seq.	Full compliance
Clean Water Act, Sections 404 and 401	Full compliance
Endangered Species Act, 16 U.S.C. 1531, et seq.	Full compliance
Environmental Justice (EO 12898)	Full compliance
Farmland Protection Act (CEQ Memorandum, 11 Aug 80)	Full compliance
Federal Actions to Address Environmental Justice in Minority Populations	Full compliance
Federal Water Project Recreation Act, 16 U.S.C. 460-1(12), et seq.	Full compliance
Fish and Wildlife Coordination Act, 16 U.S.C. 601, et seq.	Full compliance
Flood Plain Management (EO 11988)	Full compliance
Hazardous Wildlife Attractants near Airports	Full compliance
Invasive Species (EO 13112)	Full compliance
Migratory Bird Treaty Act of 1918	Full compliance
National Environment Policy Act, 42 U.S.C. 4321, et seq.	Full compliance
National Historic Preservation Act, 16 U.S.C. 470a, et seq.	Full compliance
Protection of Children from Environmental Health Risks and Safety Risks	Full compliance
Protection of Wetlands (EO 11990)	Full compliance
Responsibilities of Federal Agencies to Protect Migratory Birds (EO 13186)	Full compliance
Recreational Fisheries (EO 12962)	Full compliance
Wild and Scenic Rivers Act, 16 U.S.C. 1271, et seq.	Not Applicable

Full compliance - having met all requirements of the statute for the current stage of planning (either pre-authorization or post-authorization)

Noncompliance - violation of a requirement of the statute. Noncompliance entries should be explained in appropriate places in the report and referenced in the table.

Bald and Golden Eagle Protection Act of 1940. The USFWS removed bald eagles from protection under the ESA on August 8, 2007. However, they remain protected today under the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act (Eagle Act). The Eagle Act prohibits take which is defined as, “pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, destroy, molest, or disturb” (50 CFR 22.3). Disturb is defined in regulations as, “to agitate or bother a bald or golden eagle to a degree that causes, or is likely to cause, based on the best scientific information available, 1) injury to an eagle, 2) decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or 3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior.” There are several active bald eagle nests within the vicinity of the project area. In accordance with the avoidance measures described within the Bald and Golden Eagle Protection Act (16 U.S.C. 668-668c), any activities resulting in potential disturbance should be restricted within 660 feet of any identified active eagle nest to dates outside of the nesting season. As identified in the draft EA, there are currently no identified active eagle nests within 660 feet of the proposed project. However, should a new nest be constructed or the project be modified resulting in potential disturbance of a new or existing nest, please contact the Region 3 Migratory

Bird Office (https://www.fws.gov/Midwest/eagle/contactus.html). This project would be in full compliance.

Clean Air Act, as amended. It is not anticipated that the proposed ecosystem restoration project would result in either short- or long-term violations to air quality standards. It is not anticipated that the outdoor atmosphere would be exposed to contaminants/pollutants in such quantities and of such duration as may be or tend to be injurious to human, plant, or property, or which unreasonably interferes with the comfortable enjoyment of life, or property, or the conduct of business. If implemented, the proposed project would be in full compliance.

Clean Water Act (Sections 404 and 401), as amended. The District will perform this work in accordance with the general and special conditions of Nationwide Permit (NWP) No. 27 (Aquatic Ecosystem Restoration) in order to be compliant with Section 404 of the CWA. Section 401 Water Quality Certification conditions have already been coordinated and documented as a part of the NWP. This Project will abide by all conditions of the NWP and Water Quality Certification permits. No significant adverse impacts to water quality would result. The NWP No. 27 documentation can be found in Appendix B, *Clean Water Act Compliance*.

Endangered Species Act of 1973, as amended. The proposed action has been coordinated with USFWS, Missouri DNR, MDC, Illinois DNR, and other interested conservation groups. The District's initial coordination letters in Appendix A, *Correspondence* show the organizations and individuals contacted. If implemented, the proposed project would be in full compliance.

Farmland Protection Policy Act of 1981. The proposed project would not result in the conversion of any prime, unique, or State or locally important farmland to nonagricultural uses. If implemented as proposed, the project would be in full compliance.

Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (Executive Order 12898). This executive order (EO) requires the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations and policies. Fair treatment means that no group of people, including a racial, ethnic, or a socioeconomic group, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of Federal, state, local, and tribal programs and policies. Meaningful involvement means that:

1) potentially affected community residents have an appropriate opportunity to participate in decision-making about a proposed activity that could affect their environment and/or health;

2) the public's contribution can influence the regulatory agency's decision;

3) the concerns of all participants involved will be considered in the decision-making process; and

4) the decision-makers seek out and facilitate the involvement of those potentially affected.

The District has complied with the provisions of the EO through: two public meetings held in Saverton, Missouri; newsletters; coordination; and the NEPA review process. No concerns regarding this EO surfaced during this process. While this area is below mean income, the project would not have adverse environmental effects.

Federal Water Project Recreation Act. At this time, it is anticipated that the existing boat ramp will not be affected by the construction or operation of the fishway. However, the use of the boat ramp will be prohibited during construction of the new lock, which may coincide with construction of the fishway. The ramp will be available for public use after the lock is constructed. If implemented as proposed, the project would be in full compliance.

Fish and Wildlife Coordination Act. Project plans have been coordinated with the USFWS, the Missouri DNR and the Illinois DNR. Coordination responses and the Coordination Act Report can be found in Appendix A, *Correspondence*. If implemented as proposed, the project would be in full compliance. Recommendations and Conclusions from the Coordination Act Report from the USFWS are summarized as follows:

- The USFWS recommends a team comprised of natural resource managers, experts, and partner agencies be convened to reassess and provide input on the monitoring and adaptive management plan and objectives. Re-development of the Science Team could play a critical role in facilitating re-evaluation and ensuring development of a comprehensive plan. Further, we recommend the plan include a detailed schedule and defined roles with responsible parties to ensure monitoring begins in a timely manner to collect the pre- and post-construction data necessary to effectively assess the biotic response to and success of the project.

- The project location and design will provide for an opportunity to monitor use of the fishway and passage by invasive carp and other aquatic invasive species. This will result in the ability to experiment and adaptively manage the structure in response to monitoring results. The USFWS recommends the Corps investigate opportunities to reduce passage of invasive carp during timeframes of key life stages (i.e., spawning) and experiment with fish capture and removal systems. Collectively, these components of monitoring and adaptive management have the potential to control/reduce local invasive carp passage, with the ability to apply lessons learned systemically.

- Finally, although a fish population effect assessment is not a project-specific monitoring objective, the USFWS recommends a broader population/reach scale assessment study plan be developed through a coordinated effort of the NESP partner agencies and a dedicated Science Team. Such an assessment would provide substantial information towards the next steps of restoring longitudinal connectivity throughout the UMR system, building from the LD 22 fish passage project to inform and assess future fish passage projects systemically. In addition to informing future fish passage projects, a reach or systemic scale monitoring plan would enable the program to gauge and evaluate the benefits of other program fish and wildlife habitat improvements projects as a whole. The USFWS urges the Corps to develop monitoring plans in a timely fashion so that program habitat benefits reflected at the project, reach, and ecosystem scales will not be overlooked. We recommend this effort begin yet this fiscal year or early next fiscal year depending upon the availability of program funds. It is critical that baseline data and information gaps be identified and addressed to ensure long-term project and program benefits can be determined.

- Through the draft FWCAR (2020), the USFWS concluded that we support the TSP (Alternative 9) (*referred to in this report as the Recommended Plan*) and believe that combined with a robust monitoring and adaptive management plan, the TSP will successfully meet the project objectives.

Flood Plain Management (EO 11988). Implementation of the Recommended Plan would avoid, to the extent possible, long- and short-term adverse impacts associated with the occupancy and modification of the base floodplain. It also avoids direct and indirect support of development or growth (construction of structures and/or facilities, habitable or otherwise) in the base floodplain wherever there is a practicable alternative. Therefore, the project, as proposed, would be in full compliance.

Invasive Species (EO 13112). Implementation of the Recommended Plan is not likely to cause or promote the introduction or spread of invasive species in the United States or elsewhere. The invasive fish species of greatest risk to the UMR are the silver and bighead carps. Reproducing populations of silver and bighead carps have been found both upstream and downstream of Lock and Dam 22. The Wisconsin DNR has reported commercial catches of feral bighead and silver carps as far north as LaCrosse, Wisconsin, 396 miles and 14 dams upstream of the project area. This project would provide for restoration of native species and habitat conditions in ecosystems that have been invaded by silver and bighead carps. This project would be in full compliance.

Migratory Bird Treaty Act of 1918, as amended. The purpose of this Act is to protect birds that have common migration patterns between the United States and

Canada, Mexico, Japan, and Russia. It regulates the taking and harvesting of migratory birds. The USFWS will be provided this SEA for review and will work with the District for compliance with this Act. This project will be in full compliance.

National Environmental Policy Act of 1969, as amended. The signing of the Finding of No Significant Impact (FONSI), based upon the environmental assessment integrated into this report, would constitute NEPA compliance.

National Historic Preservation Act of 1966, as amended (NHPA) Upper Mississippi River Navigation Project, 1931-1948, Lock and Dam No. 22 Historic District. The proposed fish passage improvements project has been coordinated with the Illinois and Missouri State Historic Preservation Officers (SHPOs) and tribes who have identified an interest in the project area.

In compliance with the NHPA, if any construction activities and ancillary actions result in the discovery of, or potentially affect, significant or undocumented historic properties, the District shall discontinue the undertaking and resume coordination with the appropriate SHPOs and tribes to identify the significance of the historic property and determine any potential effects. All consulting parties must be aware of the specific locations of historic and archaeological properties are subject to protection through nondisclosure under Section 304 of the National Historic Preservation Act. All maps subject to public review/access shall not contain any information on archeological sites. This information is not to be released in order to protect the resources at the sites.

The District is concerned about impacts to traditional cultural properties and sacred sites potentially affected by the fish passage improvements. Those on the consulting parties list (this list included 22 federally-recognized tribes) were asked to please notify the District of any concerns about or potential effects to, traditional cultural properties. Presently, the District is unaware of any traditional cultural properties or sacred sites within this reach of the UMRS.

If human remains, funerary objects, sacred objects, or objects of cultural patrimony are encountered or collected, the District will comply with all provisions outlined in the appropriate State acts, statutes, guidance, provisions, etc., and any decisions regarding the treatment of human remains will be made recognizing the rights of lineal descendants, Tribes, and other Native American Indians and under consultation with the SHPO(s)/THPO(s) and the other consulting parties, designated Tribal Coordinators, and/or other appropriate legal authority for future and expedient disposition or curation. Should finds of human remains, funerary objects, sacred objects, or objects of cultural patrimony be encountered or collected from Federal lands or federally recognized tribal lands, the District will coordinate with the appropriate federally recognized Native American Tribes, pursuant to the Native American Graves Protection and Repatriation Act of 1990 (25 U.S.C. § 3001 *et seq*.) and its implementing regulations (43 CFR Part 10).

Protection of Wetlands (EO 11990). The project, as proposed, would not impact wetlands. If implemented as proposed, the project would be in full compliance.

Responsibilities of Federal Agencies to Protect Migratory Birds (EO 13186). Implementation of the Recommended Plan, to the extent appropriate and practicable, would promote the conservation of migratory birds. This project is not likely to have a measurable negative impact on migratory bird populations. This project would be in full compliance.

Wild and Scenic Rivers Act of 1968, as amended. The UMRS within the District is not listed in the National Rivers Inventory (NRI); this act is not applicable to this project.

7 ADAPTIVE MANAGEMENT & MONITORING

Adaptive ecosystem management is a process wherein management activities can be changed in relation to their efficacy in restoring and/or maintaining an ecological system in a specified desired state or ecological potential (Gunderson and Holling 2002). The desired state may specify some precisely defined structural condition, or more realistically, a range of structural conditions. Desired state can also specify rates of ecological processes or some description of biotic potential (e.g., energy capture and processing or production). A key component in adaptive management is the establishment of a feedback mechanism wherein characterization of current conditions (monitoring) can be used in conjunction with an understanding (model) of the system to alter management actions, if necessary, to produce future system conditions compatible with the desired state (Lubinski and Barko 2003). Because this is the first fish passage on the Mississippi River, despite the additional initial costs, a robust adaptive management and monitoring plan would provide valuable information to help reduce costs and increase fish passage effectiveness at future project locations throughout the UMRS.

The adaptive management implementation strategy will increase understanding of the behavior of migratory fishes in the Mississippi River, effectiveness of the fishway in improving upriver passage through a navigation dam, ecological response of migratory fish populations, and will provide design criteria for future fishway projects. The adaptive management experiments will provide valuable information for design of future fishway projects on the Mississippi River. Insights gained on design criteria for an effective fishway should lead to significant cost savings in implementation of future fishway projects. The monitoring plan was developed within the context of the system-wide ecosystem goals, the ecosystem objectives, and the project objectives to answer science-based questions at both the system and project level.

The NESP allows for up to $300 million to be spent on adaptive management and monitoring. There is no specific value for each individual project. The full authority can be found in Appendix L, *Project Authority*. The Corps would be responsible for all monitoring and adaptive management actions.

7.1 Adaptive Management & Monitoring Objectives and Implementation Schedule

The adaptive management, monitoring and evaluation plan was prepared collaboratively with the NESP science panel, USFWS, USGS, and state partner agencies. There are three phases to the monitoring plan: pre-project monitoring, construction monitoring, and post-project monitoring and evaluation spread over approximately 15 years (Table 18). Implementation of this schedule is contingent upon funding, river conditions, and study design. Pre-project monitoring was conducted at Lock and Dam 22 to develop information needed for project planning and design and to obtain “without project” baseline information about upriver fish passage through the dam. Construction monitoring will determine if the project is performing to design specifications. Post-project monitoring and evaluation would be conducted to assess if the ecological objectives of the project are met; to monitor physical performance of the fishway; to learn from the adaptive management studies; and to monitor effects of the project on navigation and lock and dam operations. All monitoring studies are tied to the following project objectives:

(1) obtain information needed for project planning and design

(2) monitor fish movement through Lock and Dam 22

(3) monitor ecological response of migratory fishes and mussels

(4) monitor physical performance of the fish passage improvement features

(5) monitor effects of the project on structural integrity, navigation operations, water quality

The adaptive management experiments were developed to answer questions that will aid in the design of future fishways on the UMR by addressing the following learning objectives:

(1) develop improved design criteria for future UMR fishways to be more ecologically effective in passing fish, including appropriate channel width, depth, flow, hydraulic conditions, and size and placement of stone riffles

(2) develop improved design criteria for future UMR fishways to be less costly and more easily constructed

(3) develop improved design criteria for operation and maintenance of future UMR fishways

(4) develop improved design criteria for future UMR fishways to avoid interference with navigation and water control functions of the locks and dams

Monitoring and adaptive management are fundamentally intertwined. The adaptive management experiments are designed to re-adjust the internal structure of the fishway and the post-construction monitoring will determine the biological and physical change resulting from these adjustments. Some adaptive management experiments may require replicate samples (years) to achieve scientifically relevant answers. Obviously, less post construction monitoring would be needed if the adaptive management experiments were not funded, but there would be greater risk and uncertainty in the design of future fishway projects.

As new information guides future decisions, the adaptive management experiments will require additional planning and changes. Experimental design and features will be further developed by the Project Delivery Team with support from the River Management Team and the Science Panel during the project design and implementation phases. The River Management Team would be comprised of engineers, scientists, and resource managers from the Army Corps of Engineers, U.S. Fish and Wildlife Service, U.S. Geological Survey, U.S. Environmental Protection Agency, the U.S. Coast Guard, the USDA Natural Resource Conservation Service, state natural resource management agencies, and state departments of transportation. The Science Panel would be comprised of nationally recognized ecologists, engineers and planners.

A complete description of the adaptive management and monitoring plan can be found in Appendix M, *Monitoring & Adaptive Management*.

Table 18. Adaptive Management Implementation Schedule*

	Pre-Project Monitoring			Construction Period			Post-Project Monitoring & Adaptive Management					
	2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**
Monitoring Objective 1. Obtain Information Needed for Project Planning and Design												
Study 1.2 – Fish aggregations in tailwater							X		X	X		
Study 1.3 – Hydraulic conditions in fish aggregation area		X							X		X	
Monitoring Objective 2. Monitor Fish Movement through Lock 22 and Fishway												
Study 2.1 – Fixed hydroacoustic fish monitoring system		X	X	X	X	X	X	X	X	X	X	
Study 2.2 – Carp capture							X	X	X	X	X	X
Study 2.3 – Monitor upriver movements of fish through L/D 22							X	X	X	X		
Monitoring Objective 3. Monitor Systemic Ecological Response by Migratory Fishes												
Study 3.1 – Fish telemetry		X	X	X	X	X	X	X	X	X	X	X
Study 3.2 – Migratory fish and mussel occurrence data					X	X	X	X	X	X	X	X
Study 3.3 – Mussel surveys – Pool 22						X					X	
Study 3.4 – System ecological model			X									
Monitoring Objective 4. Monitor Physical Performance of the Fish Passage Improvement Features												
Study 4.1 – Physical Performance Survey							X		X	X	X	
Study 4.2 – Post flood condition survey of the fishway									X			
Monitoring Objective 5. Monitor Effects of the Project on Structural Integrity, Navigation Operations, Water Quality												
Study 5.1 – 2-D hydraulic model		X					X		X			
Study 5.3 – Water quality monitoring				X	X	X						
Study 5.4 – As built survey						X						
Study 5.5 – Structural survey of fishway toe							X		X			
Adaptive Management Construction/Testing												
Experiment 1 - Fishway Performance							X					
Experiment 2 – Fishway width and flow								X				
Experiment 3 – Fishway entrance										X		
Experiment 4 – Riffle configuration											X	
Restore fishway to optimum configuration												X

*Contingent upon funding

7.2 Evaluation and Reporting

Documentation of the monitoring activities would be made routinely through NESP Environmental Technical Reports. Meetings with state agency biologists, academic biologists, and other interested stakeholders would be conducted between adaptive management experiments to share initial findings, upcoming plans, and lessons learned. Evaluation of the ecological effectiveness of the project and results of the experimental manipulations of the fishway will be documented in a NESP Environmental Technical Report and in the NESP Reports to Congress.

Based on the construction “Lessons Learned” report and the Lock and Dam 22 fish passage monitoring and evaluation reports, a Fishway Design Manual will be prepared to help guide design, construction, and O&M of future UMRS fish passage projects.

7.3 Reducing Risk and Uncertainty

Reducing the risk of adverse outcomes from construction and operation of a Fish Passage Project is an important reason for adaptive management and monitoring of the Lock and Dam 22 fish passage project. Monitoring the physical performance of the fishway, its effects on the structural integrity of the dam, the hydraulic effects of the fishway on pool stage and navigation conditions will help guide future fish passage projects and reduce risk.

The uncertainty about the ecological effectiveness of a rock ramp fishway on the Mississippi River in passing fish will be reduced by monitoring fishway performance. The adaptive management experiments will help analyze the relationship between fishway sizing and efficacy of passage for the large number of migratory fish in the Mississippi River. Monitoring fish passage through the dam and the fishway and acoustic tracking of fish movements will enable examination of the ecological response of fish populations to increased habitat connectivity.

8 IMPLEMENTATION RESPONSIBILITIES

8.1 U.S. Army Corps of Engineers

The Rock Island District is responsible for project management and coordination with USFWS; MDC; ILDNR; and other affected agencies. The Rock Island District of the Corps will submit this Project Implementation Report and Integrated Supplemental Environmental Assessment to the Corps of Engineers Headquarters for final review and approval. Upon approval, the Corps will complete Plans and Specifications, administer contracts for construction, supervise construction, and conduct project monitoring, evaluation, and adaptive management.

8.2 Non-Federal Sponsor

There is not a non-Federal cost share sponsor. The Water Resource Development Act of 2007, Title VIII, Section 8004(b)(3)(B) states that ecosystem restoration project features shall be 100 percent Federal cost if the project features are located below the ordinary high-water mark or in a connected backwater, modified the operation of structures for navigation, or is located on federally-owned land. The Lock and Dam 22 Fish Passage Project Recommended Plan features include modifying the navigation related structures of Lock and Dam 22 and are located within the Mississippi River on federally-owned lands. As a result, the Federal share of the cost of carrying out the project shall be 100 percent. The O&M, including monitoring, data collection, and adaptive management as outlined in the monitoring plan, will be a Corps responsibility. Any major rehabilitation of the project required due to major flooding or other events will be performed by the Corps of Engineers.

8.3 Views of Other Agencies Having Implementation Responsibilities

The USFWS, the ILDNR, and the MDOC have provided technical and other advisory assistance during all phases of the project and would continue to provide assistance during project implementation. Specific opinions of these agencies can be found in Chapter 9, *Coordination and Views* and Appendix A, *Correspondence*.

9 COORDINATION AND VIEWS

Extensive coordination was done in the early 2000s, when the study was first initiated. Pertinent coordination from the initial coordination actions from Federal and State agencies, Native American Tribes, and the public can be found at the end of in Appendix A, *Correspondence*.

The study was re-initiated in 2020 and the following sections document the recent coordination activities, with additional information in Appendix N, *Public Involvement*.

9.1 Federal Agencies

The United States Department of the Interior, Fish and Wildlife Service, Rock Island Field Office has worked with the District both before and after the project was paused in 2010. Most recently the USFWS provided the following recommendations in the draft USFWS CAR dated 30 November 2020:

- The Service recommends a team comprised of natural resource managers, experts, and partner agencies be convened to reassess and provide input on the monitoring and adaptive management plan and objectives. Re-development of the Science Team could play a critical role in facilitating re-evaluation and ensuring development of a comprehensive plan. Further, we recommend the plan include a detailed schedule and defined roles with responsible parties to ensure monitoring begins in a timely manner to collect the pre- and post-construction data necessary to effectively assess the biotic response to and success of the project.

- The project location and design will provide for an opportunity to monitor use of the fishway and passage by invasive carp and other aquatic invasive species. This will result in the ability to experiment and adaptively manage the structure in response to monitoring results. The Service recommends the Corps investigate opportunities to reduce passage of invasive carp during timeframes of key life stages (i.e., spawning) and experiment with fish capture and removal systems. Collectively, these components of monitoring and adaptive management have the potential to control/reduce local invasive carp passage, with the ability to apply lessons learned systemically.

- Finally, although a fish population effect assessment is not a project-specific monitoring objective, the Service recommends a broader population/reach scale assessment study plan be developed through a coordinated effort of the NESP partner agencies and a dedicated Science Team. Such an assessment would provide substantial information towards the next steps of restoring longitudinal connectivity throughout the UMR system, building from the LD 22 Fish Passage Project to inform and assess future fish passage projects systemically. In addition to informing future fish passage projects, a reach or systemic scale monitoring plan would enable the program to gauge and evaluate the benefits of other program fish and wildlife habitat improvements projects as a whole. The Service urges the Corps to develop monitoring plans in a timely fashion so that program habitat benefits reflected at the project, reach, and ecosystem scales will not be overlooked. We recommend this effort begin yet this fiscal year or early next fiscal year depending upon the availability of program funds. It is critical that baseline data and information gaps be identified and addressed to ensure long-term project and program benefits can be determined.

In their 2020 response, the Illinois-Iowa Field Office recommended reviving the NESP Science Team, coordinating with the revived team and other experts in the field to guide or update adaptive management and monitoring projects, assessing invasive carp movement through the fishway with the goal of implementing carp removal, and implementing a broader population assessment of the reach and ecosystem to serve as a baseline against which project impact could be measured. While USFWS did not express objections with the No Effect determination on the nine listed species in the Section 7 coordination, they did request coordination in the event Spectaclecase habitat would be impacted or any listed mussels were discovered during project activities.

The USEPA, Region VII, NEPA Reviewer, Environmental Services Division responded by letter dated April 13, 2006. Their main environmental and human health concerns include wetlands, water quality, and cumulative floodplain impacts. They suggest the project area may have potential for neighborhoods that are minority and/or low income and should be duly considered with respect to disproportionate impacts under EO 12898, *Environmental Justice*. They recommend that the SEA also address any project-related impacts or improvements to water quality in the UMRS or its tributaries currently listed on the Missouri or Illinois 303(d) list as impaired water bodies. They request the SEA evaluate the cumulative impacts for potential increased flooding risk both upstream and downstream during high storm events.

9.2 State Agencies

The Illinois Department of Natural Resources, Office of Realty and Environmental Planning, responded by letter dated April 12, 2006. This office provided the District with requested information on sensitive resources in the vicinity of Lock and Dam 22 that may be impacted by the proposed new lock project. The letter references the following:

1. an identified mussel bed supporting state-threatened black sandshell near the flank of Cottel Island at RM 300.5L (the vicinity where the District is currently proposing fleeting during construction);
2. other listed mussel species in the Lock and Dam vicinity such as state-endangered spectacle case, and state-threatened Butterfly and Ebonyshell;
3. Federally-endangered Higgins Eye 0.5 mile downstream of the Lock and Dam in the 1990s;
4. Federally-threatened active Bald Eagle nest near the tip of Taylor Island at RM 299.0;
5. state-endangered Lake Sturgeon has been collected from the tailwaters within the last year; and
6. the Missouri State mussel sanctuary along the right descending bank downstream of the Lock and Dam.

The MDC responded by letter dated May 15, 2006. A diverse/important mussel bed/mussel sanctuary exists in the area of the proposed downstream staging area. They believe that additional surveys are warranted. The species of concern are:

- Sheepnose (state endangered);
- Fat Pocketbook (state endangered);
- Spectaclecase (state rare);
- Ebonyshell (*Fusconaia ebena*) (state endangered);
- Hickorynut (*Obovaria olivaria*) (state rare);
- Wartyback (*Quadrula nodulata*) (state rare);
- Black Sandshell (*Ligumia recta*) (state imperiled); and
- Rock Pocketbook (*Arcidens confragosus*) (state rare).

Several common mudpuppies (*Necturus maculosus*) (Missouri species of concern-status undetermined) were found in 2002 in the lock during repairs.

MDC also requests that any mudpuppies encountered during dewatering during lock construction be salvaged and relocated. Fish species of concern include:

- Lake Sturgeon (*Acipenser fulvescens*) (state endangered);
- Blue Sucker (*Cycleptus elongatus*) (state rare);
- Mississippi Silvery Minnow (*Hybognathus nuchalis*) (state rare to uncommon);
- Western Sand Darter (*Ammocrypta clara*) (state imperiled to rare); and
- Paddlefish (*Polyodon spathula*) (state rare).

In addition, MDC questions how new lock construction, including access and barge fleeting, would impact the Robert H. Thompson Conservation Area at RM 300.5R. They also request that the District notify them if project construction impacts the Edward Anderson Conservation Area at RM 299.3R. Finally, they express concern that the boat ramp below the lock would be closed during and following construction. If so, they request the District consider providing alternative access in that part of the river.

The Minnesota DNR requested that Black Carp, as a species later in its invasion than the other carps and less understood, receive separate discussion about its range, potential to expand, and potential impacts to native species. They are also concerned that fish passage projects may facilitate range expansions of other invasive species, like Round Goby and Northern Snakehead, and requested that more attention be paid to their present distribution and range expansion trends when assessing potential effects.

The Illinois Historic Preservation Agency requested a hard copy of the District's November 2, 2020 electronic correspondence on November 16, 2020. Following submission of hard copy documentation, the Illinois Deputy State Historic Preservation Officer (SHPO) provided concurrence with the District's determination of No Adverse Effect to archaeological and structural properties within the project area, via electronic correspondence dated December 18, 2020.

The Missouri DNR provided concurrence with the District's determination of No Adverse Effect to archaeological properties within the project area, via electronic correspondence dated December 2, 2020. Further consultation on the effects of the project to the built environment has been requested when these effects have been determined.

9.3 Native American Tribes

The currently planned project details were coordinated with 22 Tribes (the Citizen Potawatomi Nation; Forest County Potawatomi Community; Ho-Chunk Nation; Iowa Tribe of Kansas and Nebraska; Iowa Tribe of Oklahoma; Kaw Nation; Kickapoo Tribe in Kansas; Kickapoo Tribe of Oklahoma; Menominee Indian Tribe of Wisconsin; Meskwaki Nation; Miami Tribe of Oklahoma; Omaha Tribe of Nebraska; Osage Nation; Otoe-Missouria Tribe; Peoria Tribe of Indians of Oklahoma; Ponca Nation; Ponca Tribe of Nebraska; Prairie Band Potawatomi Nation; Prairie Island Indian Community; Sac & Fox Nation of Missouri in Kansas & Nebraska; Sac and Fox

Nation of Oklahoma; and Upper Sioux Community Minnesota) identified to have an area of interest overlapping the project area, via electronic correspondence dated November 2, 2020.

The Ho-Chunk Nation responded to the October 27, 2020, coordination letter, sent via email on November 2, 2020 on the same day, providing concurrence with the Corps' determination and asking to remain on the consulting party list for the project as it moves forward.

The Miami Tribe of Oklahoma responded to the October 27, 2020, coordination letter, sent via email on November 2, 2020, on December 28, 2020, in concurrence with the Corps' determination and asking to remain on the consulting party list for the project as it moves forward.

The Kaw Nation submitted a comment during the public review period and noted that they believe the Corps was safe to continue with the project. If, however, any cultural materials or human remains are uncovered the tribe expects to be notified within 24 hours.

9.4 Public Involvement

Public involvement activities were conducted early in the planning phase for the proposed Fish Passage Project at Lock and Dam 22. Two public meetings were held in May 2005. Additional information related to the 2005 public involvement meetings can be found in Appendix N, *Public Involvement*. In general, at the time there was public support for the proposed project.

The Draft Project Implementation Report with Integrated Supplemental Environmental Assessment was released for 30-day public review and comment period on May 15, 2021. The review period closed on June 19,2021. Comments received and responses to the comments can be found in Appendix A, *Correspondence* and Appendix N, *Public Involvement*.

The draft report was made available on the Rock Island District public website. A link to an online comment form was also provided on the website, additionally the District mailing address was also provided for written comments. A live virtual public meeting was held on May 21, 2021, via WebEx. The virtual meeting included a live presentation on the proposed project and a live question and answer session. Files from the public meeting are contained in Appendix N, *Public Involvement*. Elevation persons representing resource agencies, and other interested parties were in attendance.

In general, the comments received on the draft report were positive and supportive in nature. One comment did not support the fish passage project or the rock ramp fishway.

9.5 Coordinating Parties

Coordination has been ongoing throughout the study. Coordination letters were sent between 2006 and 2011 when the study was last active. All correspondence from this time period can be found at the end of Appendix A, *Correspondence*. Current coordination occurring since 2020 is cataloged in the front end of Appendix A, *Correspondence*. A full distribution list for this report is included as Appendix P, *Distribution*.

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NAVIGATION AND ECOSYSTEM SUSTAINABILITY PROGRAM

LOCK AND DAM 22 FISH PASSAGE IMPROVEMENT PROJECT PROJECT IMPLEMENTATION REPORT WITH INTEGRATED SUPPLEMENTAL ENVIRONMENTAL ASSESSMENT

RECOMMENDATION

I have weighed the outputs to be obtained from the full implementation of the *Navigation and Ecosystem Sustainability Program Lock and Dam 22 Fish Passage Improvement Project, Project Implementation Report With Integrated Supplemental Environmental Assessment* project against its estimated cost and have considered the various alternatives proposed, impacts identified, and overall scope.

The Recommended Plan, a *200-foot Bottom Width Rock Ramp,* located adjacent to the storage yard, downstream of the spillway, had a calculated output of 234.6 AAHU at an annualized economic cost of $19,047 per AAHU. This alternative has a high likelihood of meeting the system goals of restoring geomorphology, biogeochemistry, habitats, and biota. In addition, this alternative has a high likelihood of meeting the project goals of: providing a pathway for upriver fish passage for 34 species of native migratory fishes; providing rapids habitat for macroinvertebrates, resident fishes and for fish spawning; and providing an opportunity for learning through experimentation, monitoring and adaptive management. This structure's width will ensure that there is an attractive flow of around 10 percent of the minimum flow of the river (for the lower design flow), and between 1 and 1.5 percent of the higher design flow for a well located fishway. Fishways with similar percentages of flows have successfully passed a variety of fish species with similar migration behaviors and swimming performance. The Recommended Plan has been sized large enough to perform adaptive management experiments which would not be possible on smaller width rock ramps.

The fishway at Lock and Dam 22 is the first of four fishways proposed for construction on the Upper Mississippi River. The others would be at Mel Price Locks and Dam, Lock and Dam 4, and Lock and Dam 8. These collectively are only the first increment in a system-wide restoration effort to restore longitudinal connectivity to the entire UMRS. USACE designed the fishway at Lock and Dam 22 to be adjustable for experimentation. The findings of this experimentation and research will be applied to optimize the design of these later projects. The cost of future fishways on the Mississippi River could be reduced by approximately 50 percent based on the findings of the adaptive management experiments with the fishway at Lock and Dam 22.

The effective project first cost at the fiscal year 2021 price level is $122,110,000. The project is 100% Federal funded. The project includes monitoring and adaptive management, which could total $29,876,000 for which USACE would be responsible. The total average annual project cost is $4,468,000. The fully funded cost estimate is $137,053,000.

I find this project, as proposed, justifies expenditure of Federal funds and it fully addresses the Corps' Environmental Operating Principles and reasonably maximizes environmental benefits. I recommend the Chief of Engineers approve the proposed project to include constructing a fish passage structure at Lock and Dam 22 and implementing the adaptive management measures at the project site.

30 September 2021
Date

Jesse T. Curry
Colonel, U.S. Army
Commander & District Engineer

FINDING OF NO SIGNIFICANT IMPACT

LOCK AND DAM 22 FISH PASSAGE IMPROVEMENT PROJECT

PROJECT IMPLEMENTATION REPORT WITH INTEGRATED SUPPLEMENTAL ENVIRONMENTAL ASSESSMENT

RALLS COUNTY, MISSOURI, AND PIKE COUNTY, ILLINOIS

The U.S. Army Corps of Engineers, Rock Island District (Corps) conducted an environmental analysis in accordance with the National Environmental Policy Act of 1969, as amended. The final Project Implementation Report/Supplemental Environmental Assessment (PIR/SEA) dated **30 September 2021**, for the Lock and Dam 22 Fish Passage Improvement Project addresses ecosystem restoration opportunities and feasibility in the Lock and Dam 22 is located at river mile 301.2 on the UMR near Saverton, Missouri, between Ralls County, Missouri, and Pike County, Illinois. The final recommendation is contained in the PIR/SEA approved by the Chief of Engineers.

This PIR/SEA is tiered from a Programmatic Environmental Impact Statement titled *Integrated Feasibility Report and Programmatic Environmental Impact Statement for the UMR-IWW System Navigation Feasibility Study,* dated September 24, 2004.

The Final PIR/SEA, incorporated herein by reference, evaluated various alternatives increasing the opportunity for upriver fish passage, thereby increasing access to upstream mainstem river and tributary habitats. The recommended plan is the National Ecosystem Restoration (NER) Plan and includes:

- Rock ramp fishway adjacent to storage yard, downstream of spillway, 200-foot bottom width,
- Prefabricated bridge system with water control structure,
- Fixed debris boom,
- Adaptive management experiments to optimize the design of this fishway and inform subsequent projects at other dams in the system.

In addition to a “no action” plan, the Corps evaluated 9 alternatives. The alternatives included:

- **Alternative 2 - Fish Lockage.** Fish Lockage is the modification of the locking procedures to pass fish through the dam using the existing navigation lock.

- **Alternative 3- Slot Pass.** This alternative includes a dual-slot fishway design. The fishway would be constructed with a series of 15 boxes (pools) with two baffled slots between the pools.

- **Alternative 4 - Fish Lockage and Slot Pass**. This alternative involves the combination of Alternative 2 – Fish Lockage and Alternative 3 – Slot Pass.

- **Alternative 5 - 50-Foot Rock Ramp**. The 50-Foot Ramp alternative includes a debris boom, bridge, and a stoplog structure to control flows within the fishway.

- **Alternative 6 - Fish Lockage and 50-foot Rock Ramp**. This alternative involves the combination of Alterative 2 – Fish Lockage and Alternative 5 – 50-foot Rock Ramp.

- **Alternative 7 - 100-foot Rock Ramp.** The design of this alternative is very similar to Alternative 5 - 50-Foot Rock Ramp. The main differences were that the 100-foot fishway would allow more attractant flow through the fishway.

- **Alternative 8 - Fish Lockage and 100-foot Rock Ramp.** This alternative involves the combination of Alterative 2 – Fish Lockage and Alternative 7 – 100-foot Rock Ramp.

- **Alternative 9 - 200-foot Rock Ramp. This is the Corps' preferred alternative.**

- **Alternative 10 - Fish Lockage and 200-foot Rock Ramp.** This alternative involves the combination Alterative 2 – Fish Lockage and Alternative 9 – 200-foot Rock Ramp

For all alternatives, the potential effects were evaluated, as appropriate. A summary assessment of the potential effects of the recommended plan are listed in Table 1:

Table 1: Summary of Potential Effects of the Recommended Plan

	Insignificant effects	Insignificant effects as a result of mitigation*	Resource unaffected by action
Aesthetics	☒	☐	☐
Air Quality	☐	☐	☒
Aquatic Resources/Wetlands	☒	☐	☐
Invasive Species	☒	☐	☐
Fish and Wildlife Habitat	☒	☐	☐
Threatened/Endangered Species/Critical Habitat	☒	☐	☐
Historic Properties	☒	☐	☐
Other Cultural Resources	☒	☐	☐
Floodplains	☒	☐	☐
Hazardous, Toxic & Radioactive Waste	☐	☐	☒
Hydrology	☒	☐	☐
Land Use	☐	☐	☒
Navigation	☐	☐	☒
Noise Levels	☒	☐	☐

	Insignificant effects	Insignificant effects as a result of mitigation*	Resource unaffected by action
Public Infrastructure	☒	☐	☐
Socio-Economics	☒	☐	☐
Environmental Justice	☐	☐	☒
Soils	☐	☐	☒
Tribal Trust Resources	☐	☐	☒
Water Quality	☒	☐	☐
Climate Change	☐	☐	☒

All practicable and appropriate means to avoid or minimize adverse environmental effects were analyzed and incorporated into the recommended plan. Best management practices (BMPs) as detailed in the PIR/SEA will be implemented, if appropriate, to minimize impacts.

No compensatory mitigation is required as part of the recommended plan.

Public review of the draft PIR/SEA and FONSI was completed on 19 June 2021. All comments submitted during the public review period were responded to in the Final PIR/SEA and FONSI.

Pursuant to section 7 of the Endangered Species Act of 1973, as amended, the U.S. Army Corps of Engineers determined the recommended plan will have no effect on federally listed species or their designated critical habitat.

Pursuant to section 106 of the National Historic Preservation Act of 1966, as amended, the U.S. Army Corps of Engineers determined that historic properties would not be adversely affected by the recommended plan. The Missouri SHPO provided concurrence with the determination on December 1, 2020. The Illinois SHPO provided concurrence with the determination on December 1, 2020. The Ho-Chunk Nation of Wisconsin and the Miami Tribe of Oklahoma also provided concurrence with the District's determination, on November 2, 2020 and December 18, 2020, respectively.

Pursuant to the Clean Water Act of 1972, as amended, the discharge of dredged or fill material associated with the recommended plan has been found to be compliant with section 404(b)(1) Guidelines (40 CFR 230) under Nationwide Permit No. 27: Aquatic Habitat Restoration, Enhancement, and Establishment Activities (NWP 27), as documented in Appendix B of the PIR/SEA.

Water quality certification pursuant to section 401 of the Clean Water Act was obtained from the Illinois Environmental Protection Agency, through a standing certification under NWP 27. A U.S. Army Corps of Engineers evaluation found that this project meets the specified certification conditions for the Illinois Regional Conditions and Illinois Section 401 Water Quality Certification Conditions of NWP 27.

All applicable environmental laws have been considered and coordination with appropriate agencies and officials has been completed.

Technical, environmental, and cost effectiveness criteria used in the formulation of alternative plans were those specified in the Water Resources Council's *1983 Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*. All applicable laws, executive orders, regulations, and local government plans were considered in evaluation of alternatives. Based on this report, the reviews by other Federal, State and local agencies, Tribes, input of the public, and the review by my staff, it is my determination that the Recommended Plan would not cause significant adverse effects on the quality of the human environment; therefore, preparation of an Environmental Impact Statement is not required.

March 22nd, 2022
Date

Jesse T. Curry
Colonel, US Army
Commander & District Engineer