GLMRIS – Brandon Road

Appendix N - Mitigation Plan

FINAL

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SUMMARY

This report describes a species-specific model for evaluating alternative measures to accomplish the project objective of fish passage improvements on the Des Plaines River and tributaries to mitigate potential losses in longitudinal connectivity from the Great Lakes and Mississippi River Interbasin Study (GLMRIS)-Brandon Road ecosystem restoration project. Longitudinal connectivity refers to the aquatic pathway that enables the unconstrained movement of biota, sediment, and nutrients from headwaters to the mouth of rivers. Connectivity is a central factor in shaping aquatic biological communities, particularly fish and mussel species, and is negatively affected by dams and aquatic nuisance species barriers.

The GLMRIS-Brandon Road ecosystem restoration plan is referred to as the Technology Alternative – Complex Noise with Electric Barrier. This ecosystem restoration project involves the construction of barriers and implementation of management actions to prevent the upstream transfer of aquatic nuisance species from the Mississippi River Basin to the Great Lakes Basin through the Chicago Area Waterways at Brandon Road Lock and Dam. Though the upstream movement of native fish and mussels is already restricted by the Brandon Road Dam, the proposed project would further obstruct the upstream movement.

The goal of this mitigation plan is to offset the increment of loss to native species resulting from the project described in the Final Integrated Feasibility Report and Programmatic Environmental Impact Statement for the GLMRIS – Brandon Road Feasibility Study. The benefits and losses are expressed in habitat units as calculated by the Fish Passage Connectivity Index (FPCI) model. The mitigation objective for this project is 110 average annual habitat units (AAHU).

Six alternatives were evaluated using the FPCI model and the Institute of Water Resources Planning Suite decision support software to compare alternatives based upon habitat benefits and costs. The selected mitigation alternative was Alternative B - Trap and Transport. This alternative involves the manual capture of fish below the Brandon Road Dam; sorting of target species and transfer to a location upstream of the Brandon Road Dam for release. Native fish in their native habitat have the potential to carry early life stages (glochidia) of mussels, which would also enhance upstream mussel populations.

Measures within the selected mitigation alternative (Alternative B - Trap and Transport) include:

1) Trap and Transport: The U.S. Army Corps of Engineers (USACE) estimated $132,000 annually for fish collection based upon the U.S. Fish and Wildlife Service (USFWS) Coordination Act Report (CAR) estimate for fish monitoring. Trap and transport will occur annually. USACE estimated $6,000/week for 12 weeks for a collection crew plus time and equipment for fish identification, quarantine (if needed), data analysis, reporting, and transfer upstream of the Brandon Road Dam. Trapping would be done in two periods to coincide with spawning movements for the largest number of a species, a 3 week early spring spawning period (weeks 11-12) and a 9 week late spring-summer (weeks 17-25).

2) Project Performance Monitoring: Performance monitoring is necessary to ensure that fish are responding as expected after the first year of transfer. This effort would focus on optimizing the methods used for fish capture and improving survival during the fish transfer process using caged fish to determine the effects of handling and transfer on translocated fish. The USFWS CAR estimated that fish monitoring costs were $6,000/week for 3 weeks for a collection crew plus time for fish identification, data analysis, reporting, and other necessary components for a total of $35,000.

Measure	Cost
Trap and Transport ($132,000 /year for 50 years)	$6,600,000
1-Time Project Performance Monitoring (Project Year 2)	$35,000
Total	**$6,635,000**

USACE identified the least cost mitigation plan that provides full mitigation of losses specified in mitigation planning objective as required in policy (USACE 2000). The mitigation objective for this project is 110 AAHU. The selected mitigation alternative offsets the loss of these 110 AAHU with the restoration of 235 net AAHU at an average annual cost of $133,000. The cost of mitigation ($6,635,000) is greater than what was presented in the draft report ($2,200,000) after USACE factored in the impacts identified in the FWCAR found in GLMRIS-Brandon Road Feasibility Report and EIS - Appendix A. Changes include the addition of a trap and transport measure to assist with native fish and mussel recovery, project performance monitoring, and an update of contingency costs to achieve certification from the Civil Works Cost Engineering and Agency Technical Review Mandatory Center of Expertise.

The FPCI model was reviewed by a model certification team appointed by the National Ecosystem Planning Center of Expertise (ECO-PCX). The certification team included Shane Simmons, St. Louis District, and Eric Laux and Clayton Ridenour, Omaha District. Nathan Richards, ECO-PCX, U.S. Army Corps of Engineers, oversaw the certification process for GLMRIS-Brandon Road.

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Appendix

Mitigation Appendix A – Fish Passage Connectivity Summary Worksheets

1. Problems and Opportunities

1.1. Purpose and Need

The Great Lakes and Mississippi River Interbasin Study (GLMRIS)-Brandon Road Recommended Plan is Technology Alternative – Complex Noise with Electric Barrier. This plan will protect the Great Lakes basin from aquatic nuisance species by creating barriers at the Brandon Road Lock and Dam (see Chapter 9 Description of the Recommended Plan of the main report for details). Creating this barrier will prevent upstream interbasin transfer of aquatic nuisance species but also obstruct the movement of native fish and mussels and slow the recovery of restored areas above Brandon Road Lock and Dam. Mitigation is needed to offset these losses.

1.2. Problems and Opportunities

Problems and Opportunities for the project are discussed in Chapter 3 in the main report. In addition, the following problems and opportunities were identified for the mitigation plan.

Problems

- Restricting movements of aquatic nuisance species restricts the movement of native species.
- Species diversity would be limited to those species already above the dam once the barrier is in place.
- Development of a mitigation plan which has minimal or no adverse environmental effects.

Opportunities

- Native biota can be restored through management actions.
- Mitigation can offset the incremental losses to native biota in upstream habitats.
- Increased opportunity for upstream fish movements would contribute to increased reproductive success, survival and growth of juveniles, genetic diversity and population-level responses of increased geographic range and abundance.
- Increased habitat utilization could lead to a more diverse, abundant and genetically enriched fish community in the Des Plaines River watershed that is more resistant to environmental disturbances.
- Benefits to society could be realized through ecosystem services provided by increased abundance of fish and mussel populations.
- Policy-compliant methods can be used to assess impacts, evaluate alternatives and select appropriate mitigation to restore lost functions and values.
- The information within the U.S. Fish and Wildlife Service (USFWS) Coordination Act Report (CAR) can be used to inform the alternatives developed for this mitigation plan.

1.3. Mitigation Goals and Objective

The goal of this mitigation plan is to offset the increment of loss in longitudinal connectivity to native aquatic biota resulting from the creation of an aquatic nuisance species barrier at Brandon Road Lock and Dam. The Recommended Plan will benefit the aquatic ecosystem in the Great Lakes and its tributaries by deterring aquatic nuisance species, however there would be localized negative affects to native species within the Des Plaines River watershed.

Once the Recommended Plan is implemented, there will be no upstream passage at Brandon Road Lock and Dam for native fish and mussel species. The mitigation objective is to offset this loss. For this mitigation plan, benefits and losses are expressed in habitat units as calculated by the Fish Passage Connectivity Index (FPCI) model.

1.4. Planning Constraints

USACE considered each of the following in the development of the Recommended Plan:

- Avoiding the impact altogether by not taking a certain action or part of an action;
- Minimizing impacts by limiting the degree or magnitude of the action and its implementation;
- Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
- Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action;
- Compensating for the impact by replacing or providing substitute resources or environments.

Because impacts were unavoidable, USACE formulated a range of mitigation alternatives and used the FPCI to evaluate the net output of all mitigation alternatives. USACE considered the guidance in the following sections the Planning Guidance Notebook (USACE 2000) in the development of this mitigation plan:

- USACE must identify the least cost mitigation plan that provides full mitigation of losses specified in mitigation planning objectives [Paragraph C-3 e.(8)] ;
- USACE must conduct incremental cost analyses to demonstrate that the most cost effective mitigation measure(s) has been selected (Paragraph C-3e. (2) and (8);
- Habitat-based evaluation methodologies shall be used to the extent possible [Paragraph C-3 d.(6)];
- Mitigation planning shall address a range of alternatives up to the full compensation of significant ecological resources losses [Paragraph C-3 E (4)];
- The evaluation of effects is a comparison of the with-project and without project conditions for each alternative [Paragraph 2-3 d.(1)];
- Characterize the effects by magnitude, location, timing and duration [Paragraph 2-3 d.(2);
- USACE must consider monitoring time and cost limits; [Paragraphs C-3 e.(10); G-63 (b)];
- Ecosystem restoration projects should be designed to avoid the need for fish and wildlife mitigation. [Chapter 3-5, Section B(3)];
- Fish and wildlife mitigation costs are subject to cost sharing to the same extent as other project costs. [Paragraph C-3 e. (12)(c)].

2. Inventory and Forecast

2.1. Existing Conditions

The IWW navigation system includes eight locks, seven dams, one controlling works and the main navigation channel between Alton, Illinois and Chicago, Illinois (Figure N-1). The Des Plaines River is the segment of the upper Illinois Waterway (IWW), within the series of maintained rivers and canals collectively known as the Chicago Area Waterway System (CAWS). This mitigation plan examined three reaches within the Des Plaines River watershed including the Des Plaines River at Brandon Road Lock and Dam; Salt Creek at Fullersburg Woods Dam; and the DuPage River at Channahon Dam (Figure N-2). The Salt Creek and the DuPage River tributaries of the Des Planes River, though not commercially

navigable, have dams that are barriers to upstream movements of migratory fishes. Clearing the lowest dam on these tributaries would open access and restore longitudinal connectivity to large parts of the upper watershed. These dams were identified as areas of concern and restoring longitudinal connectivity is consistent with the goals identified by regional stakeholders (DRSCW 2016, 2017; Hammer and Linke 2003; Lake County Stormwater Management Commission 2018; Illinois Department of Natural Resources 2018; USACE 2015).

Though the water quality in the Des Plaines River watershed has steadily improved over the last decade, large sections remain on the U.S. Environmental Protection Agency's (USEPA) Clean Water Act Section 303(d) list as impaired (Table N-1 and Figure N-3) having urban sewer overflows that combine rainwater runoff, domestic sewage, and industrial wastewater into one pipe. Under normal conditions, all of the wastewater goes to a sewage treatment plant, then discharges to the river, but when the volume of wastewater exceeds capacity during heavy rainfall events or snowmelt, untreated stormwater and wastewater discharges directly to rivers, reducing the suitability for aquatic species. Impaired reaches were excluded from the FPCI evaluation because the value of this habitat to migratory fish species and to mussels is questionable. To gauge the effect that improved water quality could have on the selection of alternatives, a sensitivity analysis was conducted that showed that inclusion of impaired reaches would not change the selection of the mitigation plan.

The patchy distribution of unimpaired acres used to evaluate mitigation alternatives reflects the nature of streams in urban environments, where point source and non-point source of pollutants combine to have significant effects on the aquatic community. Though impaired, when conditions are right, these rivers provide a corridor by which tolerant and in some cases intolerant species can access unimpaired reaches that are suitable and become established. An example from the USFWS CAR is the re-establishment of the rosyface shiner in the upper Des Plaines River. These islands of suitable habitat are critical to the long-term establishment of species throughout the system are important to consider when comparing available habitat among mitigation alternatives.

Table N-1. Habitat Quality Above Dams (Clean Water Act Section 303(d) listing status).

Aquatic Habitat	Des Plaines River Reach above Brandon Road Dam (acres)	DuPage River Reach above Channahon Dam (acres)	Salt Creek Reach Above Fullersburg Woods Dam (acres)
Unimpaired[1]	3842	824	833
Impaired[2]	3909	893	406
Total	**7751**	**1717**	**1239**

[1] NHD dataset
[2] US EPA rad_grts_1 feature class queried for event type 10011

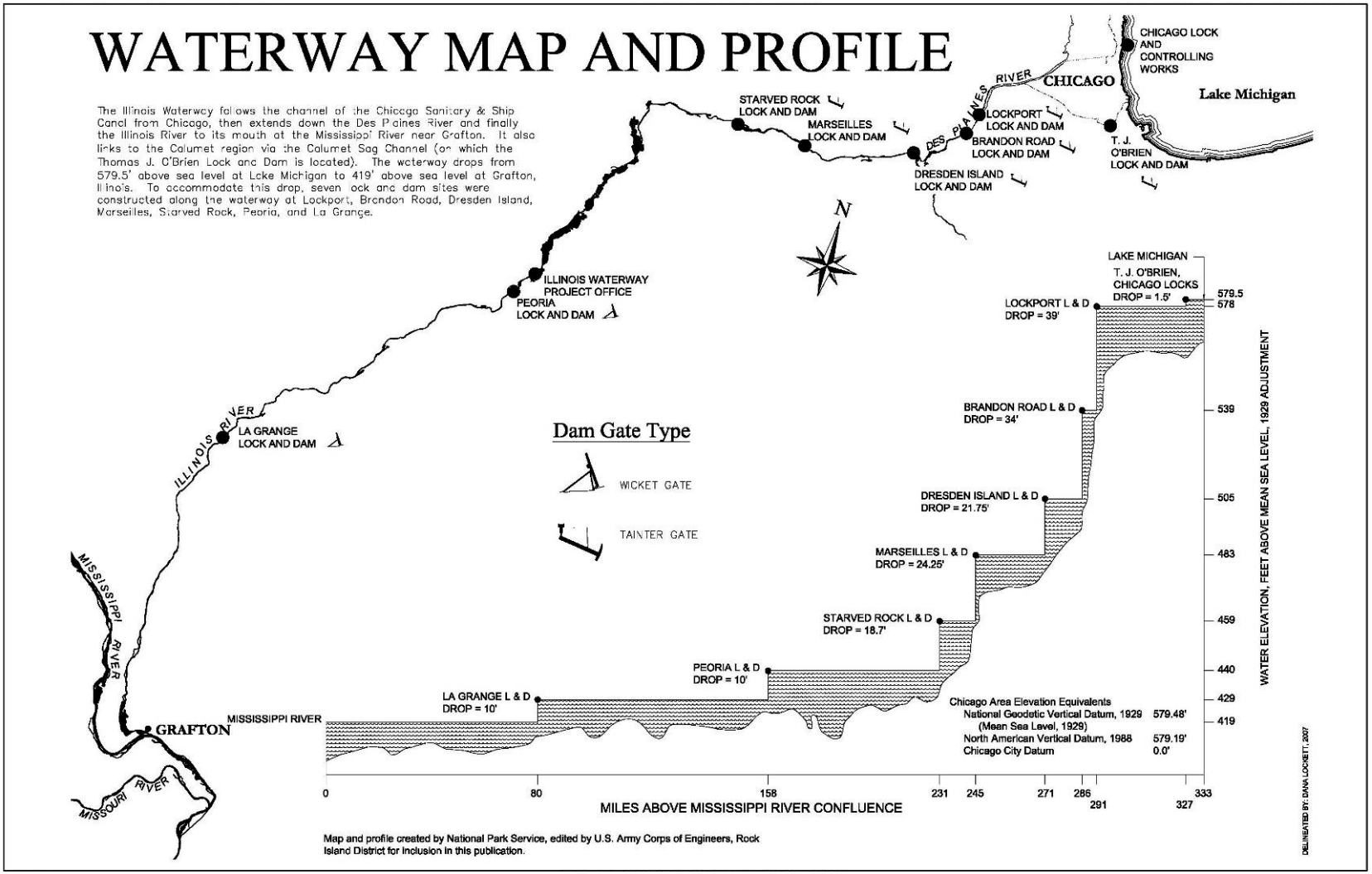


Figure N-1. Location of Brandon Road Lock and Dam on the IWW Navigation System

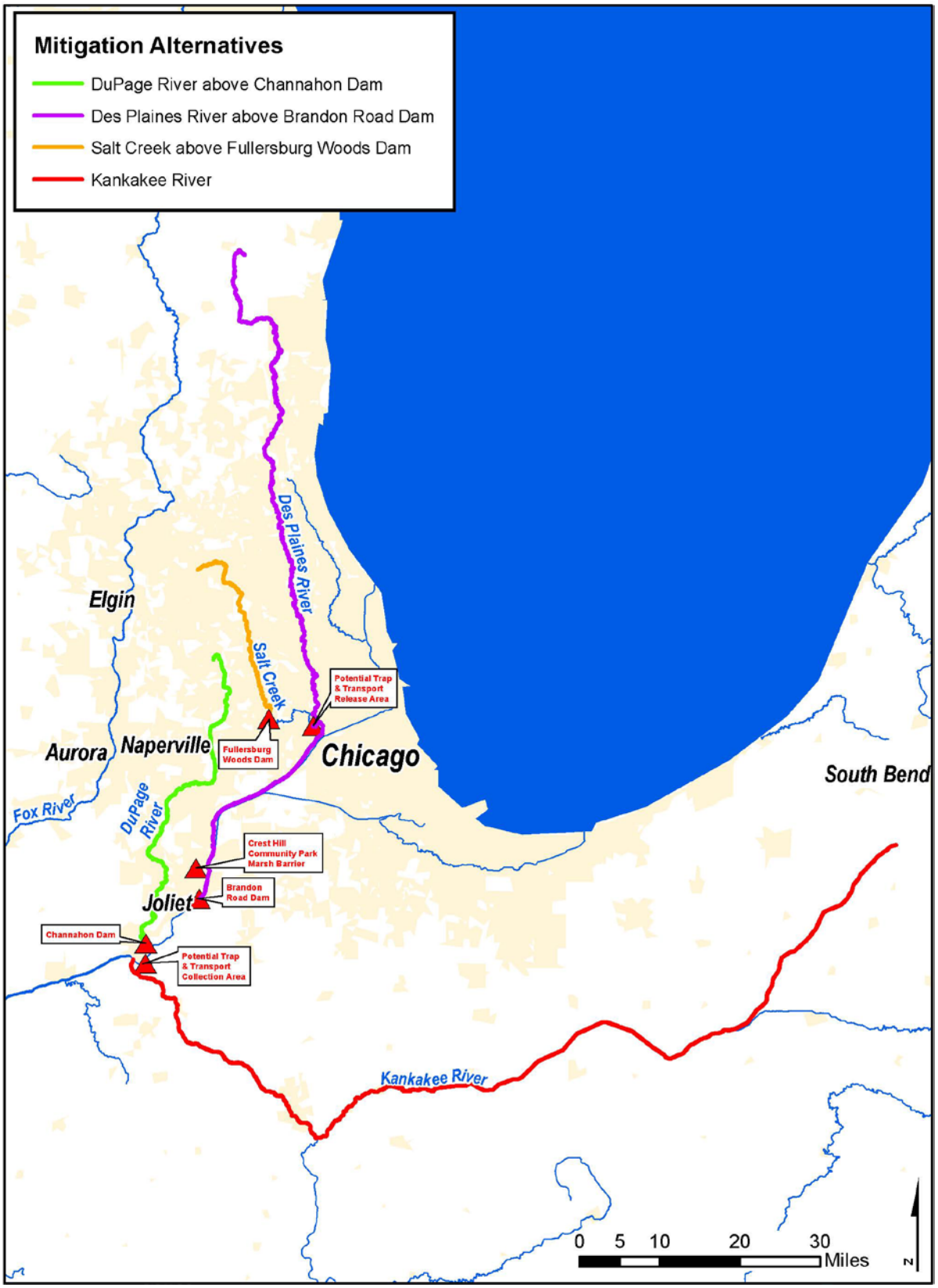


Figure N-2. Location of Alternatives and Measures.

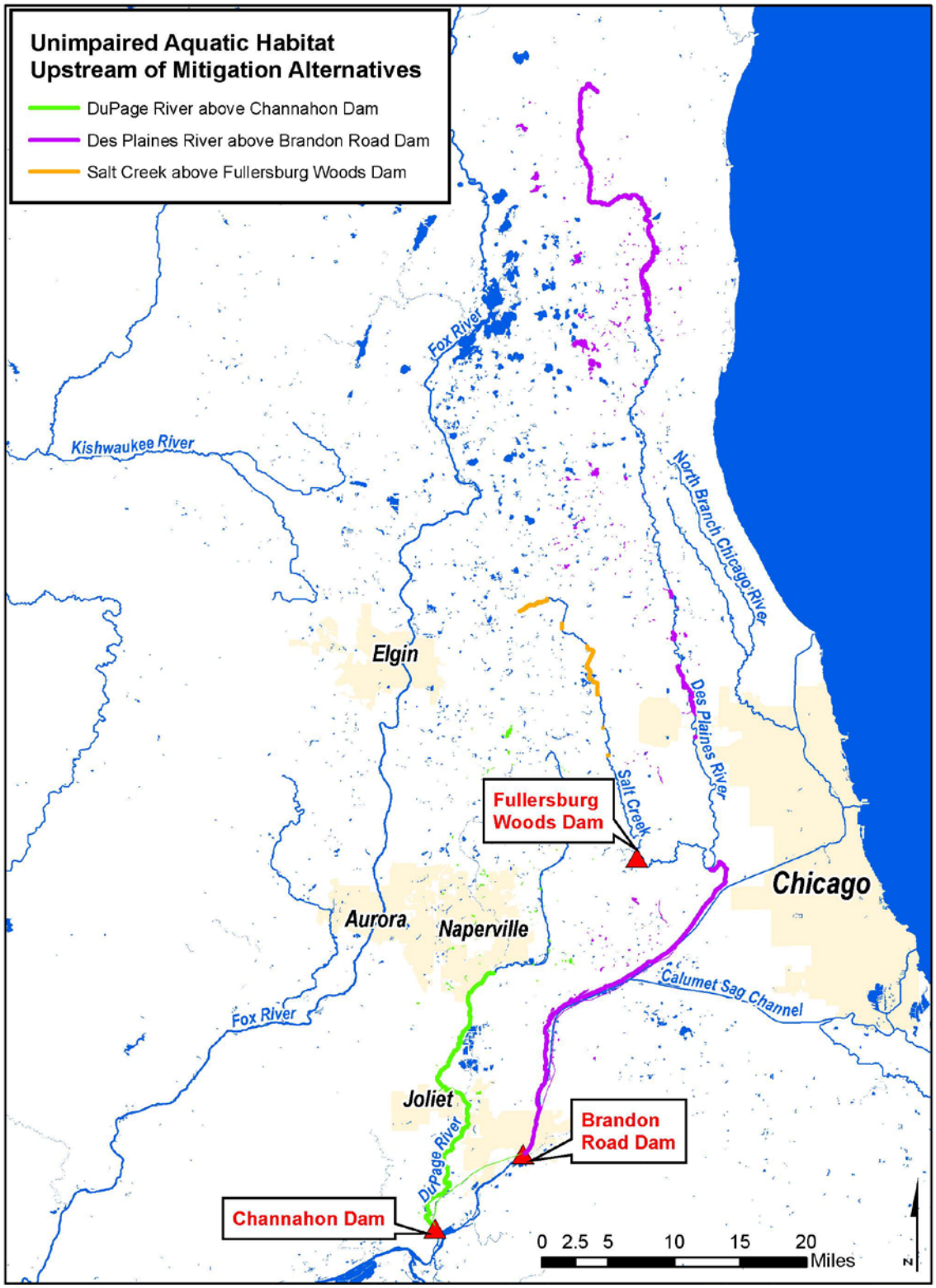


Figure N-3. Location of the Unimpaired Aquatic Habitat Considered for Mitigation in Relation to the GLMRIS- Brandon Road Lock and Dam Project Area.

[Areas not on Clean Water Act Section 303(d) listing (US EPA rad_grts_1 feature class queried for event type 10011)]

Brandon Road Lock and Dam Reach: Brandon Road Lock and Dam is a navigation dam on the IWW located near Joliet, Illinois (Photograph 1). The dam was constructed in 1934 and has a head of 34 ft. at normal pool elevation. Brandon Road Dam has a fixed dam, so the sole passage is through the navigation lock. See "Des Plaines Upstream of Brandon" on Table N-2 for the habitat units used to describe existing conditions for this reach. Fish could pass upstream through the lock chamber on an average of nine times per day as the lock was operated for navigation. The site is owned by the U.S. Government and is on the National Register of Historic Places.

DuPage River Reach: The Channahon Dam on the DuPage River in Illinois was originally constructed in 1848 and replaced in 1935 as part of the Illinois and Michigan (I&M) canal system. The spillway is 11.5 ft. high and 165 ft. long. The dam is located less than 0.5 mile from the DuPage River confluence with the Des Plaines River in the Illinois and Michigan Canal State Park in Channahon. Channahon Dam effectively disconnects the DuPage River from the Des Plaines River from a biological standpoint (Hammer and Linke 2003) and considered a complete obstruction to upstream fish movement in the FPCI model. See "DuPage Upstream of Channahon Dam" on Table N-2 for the habitat units used describe existing conditions for this reach. The site is owned by the State of Illinois, and the I&M canal is listed on the National Register of Historic Places. The rock ramp fishway would be located at the site occupied by the control gates south of the spillway, adjacent to the lock 7 chamber (Photograph 2). Asian carp are found in the Des Plaines River below Channahon Dam. Enhancing longitudinal connectivity at this location would increase access for both native fish and Asian carp into upper parts of the watershed. A supplemental barrier is needed at Crest Hill Community Park marsh to ensure that non-native fish do not bypass Brandon Road Dam during major floods.

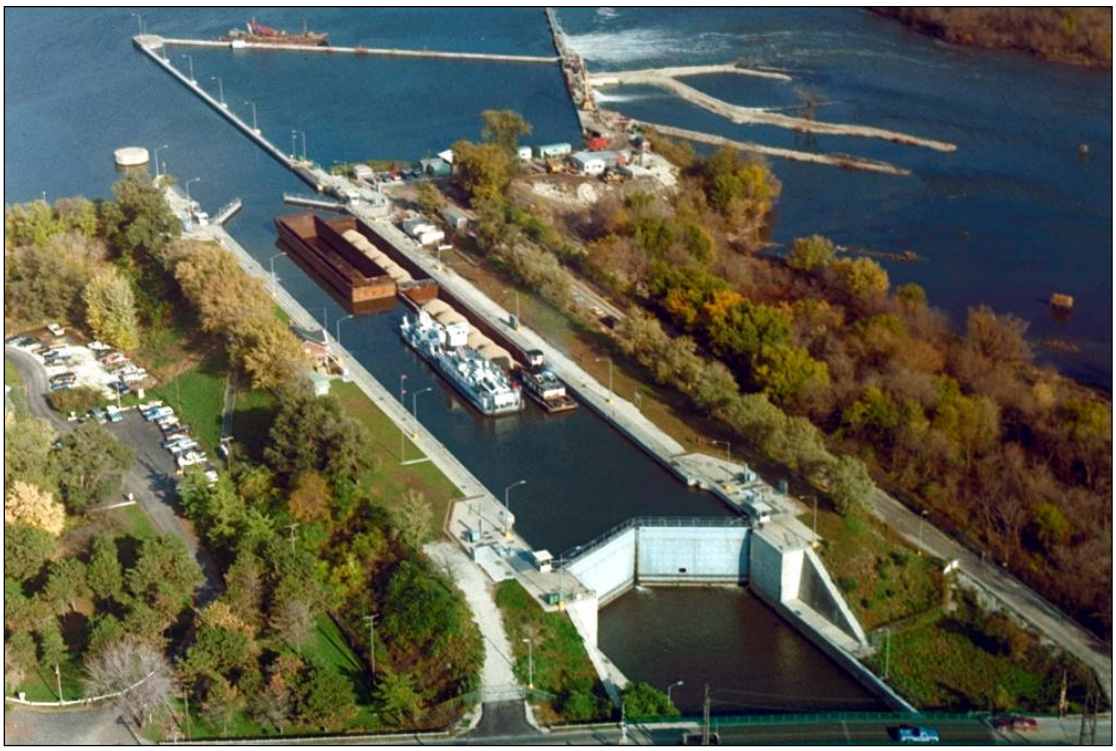
Salt Creek Reach: The Fullersburg Woods Dam is located on Salt Creek in Illinois, a tributary to the Des Plaines River adjacent to Graue Mill in the Village of Oak Brook (Photograph 3). The dam was originally constructed in 1930s and replaced in 1934 with the concrete structure present today. The dam is 132 ft. long and 6.2 ft. high. A dewatering gate was installed in 1991 to allow periodic drawdown for maintenance and inspection. USACE estimated that fish could migrate over Fullersburg Dam when floods equalize the water surface above and below the dam, eliminating the obstruction to upstream fish movement. See "Salt Creek Upstream of Fullersburg Woods Dam" on Table N-2 for the habitat units used to describe existing conditions for this reach. The dam is owned by the Forest Preserve District of DuPage County and the Graue Mill is on the National Register of Historic Places.

Fish Passage Connectivity Index (FPCI): The FPCI model was used to evaluate the potential effectiveness of alternative fish passage improvement measures for use in cost effectiveness and incremental cost analysis for this mitigation plan. The FPCI is capable of estimating the incremental benefit of upstream migration for any fish species that demonstrates migratory behavior. The FPCI is a simple arithmetic index that can be adjusted to fit the characteristics of migratory fishes and the unique characteristics of fish passage alternatives being considered. Connectivity (€) is numerically expressed with zero representing a complete barrier and one representing no barrier to upstream fish movement. A description of the model is presented in Section 4.2.

Table N-2. Available Habitat Within Reaches Considered in This Mitigation Plan.

Reach	Existing Conditions		
	Connectivity (Є)	Available Habitat (acres)	Gross Habitat Units
DuPage Upstream of Channahon Dam	0	824	0
Des Plaines Upstream of Brandon (excluding Salt Creek Upstream of Fullersburg Woods Dam)	0.03*	3842	110*
Salt Creek Upstream of Fullersburg Woods Dam	0.01	833	5
Total			**115**

*Affected by the Recommended Plan



Photograph N-1. Brandon Road Lock and Dam

Photograph N-2. Control Gate on Illinois & Michigan Canal at Channahon Dam, DuPage River

Photograph N-3. Fullersburg Woods Dam on Salt Creek

2.2. Biological Resources

The criteria for determining the significance of resources are provided in the Federal Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (Water Resources Council 1983) and USACE regulations 40 CFR Part 1508.27 and ER 1105-2-100 Appendix C, section d(4).

Significant resources in the study area include natural and cultural resources that are recognized by Federal and state agencies, local institutions, the public, and Native American tribes. The significance of resources is based on both monetary and non-monetary values. Monetary value is based on the contribution of the resources to the Nation's economy. Non-monetary value is based on technical, institutional or public recognition of the ecological, cultural, and aesthetic attributes of resources in the study area. The scientific community and natural resources management agencies recognize the technical and legal significance of resources. In recent years, USACE, the Illinois DNR, and other project sponsors have implemented fish passage projects on the Upper Des Plaines River leading to the reconnection of longitudinal connectivity for the majority of the main stem.

The significance of restoring longitudinal connectivity for fish in an urban environment is affected by the anthropogenic uses of the watershed. The restoration of connectivity of impaired waters was not considered significant for the purposes of this evaluation because access to degraded habitat has minimal benefits (Table N-1). The significance of the project mitigation would increase should these impaired waters improve over the 50-year project life.

There are no Federally Threatened or Endangered fish and mussel species in the project area, however, the USFWS and the Illinois Department of Natural Resources (DNR) consider the fish community of the upper Illinois River as a significant resource (GLMRIS-Brandon Road Feasibility Report and EIS - Appendix A). According to the Illinois Natural Heritage Database, there are 76 state-listed species within Will County. The Illinois DNR has documented state listed mussels downstream of the project site around the Dresden Lock and Dam area and believes these species will not recolonize the upper Des Plaines River and CAWS if their host fish are not able to pass through the proposed project at Brandon Road Lock and Dam. The Illinois DNR also believes that two state listed fish species, the river and greater redhorse, will not recolonize to the upper Des Plaines River with the implementation of the project. Table N-3 provides a summary of the state-listed species considered and the likelihood of establishment rating assigned to each species by the USFWS (Appendix A). Species that have never been captured in the project vicinity were considered not affected.

Table N-3. State-Threatened, Endangered, and Species Within the Vicinity of the Brandon Road Lock and Dam

Common Name	Scientific Name	State Status	Likelihood
American eel	*Anguilla rostrata*	Proposed as Threatened	Rare in area, slight potential
American brook	*Lethenteron appendix*	Proposed as Threatened	Rare in area, slight potential
Banded killifish	*Fundulus diaphanus*	Threatened	Not affected, source Great Lakes
Black sandshell	*Ligumia recta*	Threatened	May, but unlikely
Blacknose shiner	*Notropis heterolepis*	Endangered	Not affected
Blackchin shiner	*Notropis heterodon*	Threatened	Rare in area, slight potential
Brassy minnow	*Hybognathus hankinsoni*	Proposed as Threatened	Rare in area, slight potential
Greater redhorse	*Moxostoma valenciennesi*	Endangered	May, but unlikely
Iowa Darter	*Etheostoma exile*	Threatened	Rare in area slight potential, source
Longnose sucker	*Catostomus catostomus*	Threatened	Not affected
Mudpuppy	*Necturus maculosus*	Threatened	Not affected
Purple wartyback	*Cyclonaias tuberculata*	Threatened	May, but unlikely
River redhorse	*Moxostoma carinatum*	Threatened	Moderately likely/occasional
Pallid shiner	*Hybopis amnis*	Endangered	Not affected
Scaleshell*	*Leptoda leptodon*	Proposed as Endangered	Rare in area, slight potential (nearest capture Marseilles Pool)
Sheepnose*	*Plethobasus cyphyus*	Endangered	Rare in area, slight potential (nearest capture Kankakee River)

*Federally listed

Nine common fish species were selected for FPCI evaluation based upon their potential to be affected by the Recommended Plan, significance as a migratory species, presence in the study area, and unique habitat preferences. This subset was used for project comparison. It is likely that the project will affect all migratory fish species. The USFWS looked at fish assemblages in navigation pools above and below the Brandon Road Lock and Dam to determine what species are likely to pass through the lock and what species have already established above the dam. Fish data from Brandon Road Pool and Dresden Island Pool came from the Asian Carps Monitoring Program, a collaborative research program involving the Illinois DNR, USFWS, and USACE. The USFWS used an expert panel to identify the losses to fish and mussels from the GLMRIS-Brandon Road Technology Alternative – Complex Noise with Electric Barrier based on the likelihood of establishment over the next 50 years. A complete description of this expert panel and the methods used to assess impacts is found in the USFWS CAR, GLMRIS-Brandon Road Feasibility Report and EIS - Appendix A. However, most of the species in Table N-4 are absent or scarce in the Brandon Road project area (above and below the dam) or are already established upstream of the dam. Utilizing the USFWS' approach to assess mitigation was not compliant with USACE policy (see Section 1.4 Planning Constraints for more detail).

Many fishes in the Des Plaines River are hosts to the larval stage of many species of freshwater mussels. Freshwater mussels are recognized by the scientific community and by natural resource management agencies as a significant resource for their role in the river ecosystem providing hard substrate for macroinvertebrates, filter-feeding, and as prey for fish and furbearers.

Fish migrations result in significant annual movements of biomass, energy, nutrients and genetic material within the river system. Migratory fishes and their young-of-year provide forage for other fish species and for fish-eating birds like bald eagles, herons and ospreys.

Table N-4. Fishes Within the Vicinity of the Brandon Road Lock and Dam.

	Common Name	Upstream of Barrier Brandon Road Pool 2010-17 [1]	Downstream of Barrier Dresden Island Pool 2010-17 [1]	USFWS Losses from TSP [2]	USFWS CAR Justification
1	Bullhead minnow	1	195	1	Highly likely to establish
2	Northern hog sucker	0	25	1	Highly likely to establish
3	Shorthead redhorse	0	208	1	Highly likely to establish
4	Golden redhorse	0	347	1	Highly likely to establish
5	Longear sunfish	0	53	1	Highly likely to establish
6	Silver redhorse	0	125	1	Highly likely to establish
7	Flathead catfish	6	154	1	Highly likely to establish
8	Suckermouth minnow	0	1	1	Highly likely to establish
9	Striped shiner	0	3	1	Highly likely to establish
10	Redfin shiner	0	0	0.75	Fairly likely to establish
11	Black redhorse	0	3	0.75	Fairly likely to establish
12	River redhorse	0	1	0.5	Moderately likely to establish
13	Orangethroat darter	0	0	0.5	Moderately likely to establish
14	River carpsucker	1	320	0.5	Occasionally an occupant
15	Mimic shiner	0	1	0.5	Mod. likely already established
16	Smallmouth buffalo	60	11422	0.5	Occasionally an occupant
17	Quillback	5	172	0.5	Mod. likely already established
18	Shortnose gar	0	16	0.25	May but unlikely to establish
19	Skipjack herring	7	11	0.25	May rarely occupy
20	Silverjaw minnow	0	0	0.25	May but unlikely to establish
21	Bigmouth buffalo	3	759	0.25	May rarely occupy
22	Black buffalo	1	333	0.25	May rarely occupy
23	Highfin carpsucker	0	8	0.25	May but unlikely to establish
24	Greater redhorse	0	0	0.25	May but unlikely to establish
25	Slender madtom	0	0	0.25	May but unlikely to establish
26	White bass	12	71	0.25	May rarely occupy
27	Slenderhead darter	0	1	0.25	May but unlikely to establish
28	Banded darter	0	0	0.25	May but unlikely to establish
29	Rainbow darter	0	0	0.25	May but unlikely to establish
30	Rosyface shiner	0	0	0.25	Established but vulnerable
31	Amer. brook lamprey	0	0	0.1	Rare in area, slight potential
32	Spotted gar	0	8	0.1	Rare in area, slight potential
33	American eel	0	2	0.1	Rare in area, slight potential
34	Goldeye	0	1	0.1	Rare in area, slight potential
35	Mooneye	0	4	0.1	Rare in area, slight potential
36	Southern redbelly dace	0	0	0.1	Rare/dated in area, slight potential

	Common Name	Upstream of Barrier Brandon Road Pool 2010-17 [1]	Downstream of Barrier Dresden Island Pool 2010-17 [1]	USFWS Losses from TSP [2]	USFWS CAR Justification
37	Largescale stoneroller	0	0	0.1	Unlikely, unique habitat needs
38	Blacknose dace	0	1	0.1	Unlikely, unique habitat needs
39	Brassy minnow	0	0	0.1	Rare in area, slight potential
40	Steelcolor shiner	0	0	0.1	Rare in area, slight potential
41	Pugnose minnow	0	0	0.1	Rare in area, slight potential
42	Ozark minnow	0	0	0.1	Rare in area, slight potential
43	Weed shiner	0	0	0.1	Rare in area, slight potential
44	Ironcolor shiner	0	0	0.1	Rare in area, slight potential
45	Ghost Shiner	0	0	0.1	Rare in area, slight potential
46	Creek chubsucker	0	0	0.1	Rare in area, slight potential
47	Lake chubsucker	0	0	0.1	Rare in area, slight potential
48	Brown bullhead	4	9	0.1	Rare in area, slight potential
49	Freckled madtom	0	0	0.1	Rare in area, slight potential
50	Trout-perch	0	3	0.1	Rare in area, slight potential
51	Pirate perch	0	0	0.1	Rare in area, slight potential
52	Starhead topminnow	0	0	0.1	Rare in area, slight potential
53	Brook stickleback	0	0	0.1	Rare in area, slight potential
54	Mottled sculpin	0	0	0.1	Unlikely, unique habitat needs
55	Bluntnose darter	0	0	0.1	Rare in area, slight potential
56	Fantail darter	0	0	0.1	Established in UDPR tributary
57	Least darter	0	0	0.1	Rare in area, slight potential
58	Red shiner	0	0	0.1	Rare in area, slight potential
59	Blackchin shiner	0	0	0.1	Rare in area, slight potential
60	Iowa darter	0	0	0.1	Rare in area, slight potential
61	Central stoneroller	1	5	0.1	Established in UDPR tributary
62	Grass pickerel	23	24	0.1	Established
63	White crappie	15	53	0.1	Established
64	Longnose gar	13	591	0.1	Established
65	Stonecat	0	0	0.1	Established
66	Warmouth	7	10	0.1	Established
67	Brook silverside	2	68	0.1	Established
68	Walleye	1	60	0.1	Established
69	Central mudminnow	5	2	0.1	Established
70	Common shiner	2	9	0.1	Established
71	Logperch	0	66	0.1	Established
72	Tadpole madtom	70	12	0.1	Established
73	Freshwater drum	238	1067	0.1	Established
74	Yellow bass	33	16	0.1	Established

	Common Name	Upstream of Barrier Brandon Road Pool 2010-17 [1]	Downstream of Barrier Dresden Island Pool 2010-17 [1]	USFWS Losses from TSP [2]	USFWS CAR Justification
75	Creek chub	1	7	0.1	Established
76	Bowfin	10	22	0.1	Established
77	Sauger	26	3	0.1	Established
78	Emerald shiner	2231	1915	0.1	Established
79	Mosquitofish	1230	52	0.1	Established
80	Blackside darter	0	7	0.1	Established
81	Golden shiner	110	651	0.1	Established
82	Yellow bullhead	323	272	0.1	Established
83	Smallmouth bass	426	612	0.1	Established
84	Northern pike	35	32	0.1	Established
85	Fathead minnow	8	9	0.1	Established
86	Bigmouth shiner	0	0	0.1	Established
87	Spottail shiner	191	1553	0.1	Established
88	Black crappie	19	96	0.1	Established
89	Pumpkinseed	1766	1567	0.1	Established
90	Johnny darter	6	3	0.1	Established
91	Rock bass	32	109	0.1	Established
92	Orangespotted sunfish	184	37	0.1	Established
93	Hornyhead chub	1	1	0.1	Established
94	Spotted sucker	5	34	0.1	Established
95	Channel catfish	464	1817	0.1	Established
96	White sucker	399	165	0.1	Established
97	Largemouth bass	750	3941	0.1	Established
98	Black bullhead	5	8	0.1	Established
99	Green sunfish	695	1481	0.1	Established
100	Gizzard shad	12453	43006	0.1	Established
101	Bluegill	4856	14424	0.1	Established
102	Blackstripe topminnow	61	101	0.1	Established
103	Sand shiner	20	44	0.1	Established
104	Spotfin shiner	155	430	0.1	Established
105	Bluntnose minnow	3161	5938	0.1	Established
106	Unidentified lamprey	0	0	0	Covered by Amer. brook lamprey
107	Banded killifish	339	329	0	Not affected, source Great Lakes
108	Yellow perch	7	13	0	Not affected, source Great Lakes
109	Alewife	19	0	0	Non-native/out of natural range
110	Grass carp	17	74	0	Non-native/out of natural range
111	Bighead carp	0	493	0	Non-native/out of natural range
112	Silver carp	0	615	0	Non-native/out of natural range

	Common Name	Upstream of Barrier Brandon Road Pool 2010-17 [1]	Downstream of Barrier Dresden Island Pool 2010-17 [1]	USFWS Losses from TSP [2]	USFWS CAR Justification
113	Blue catfish	0	1	0	Non-native/out of natural range
114	Burbot	0	0	0	Non-native/out of natural range
115	White perch	7	9	0	Non-native/out of natural range
116	Oriental Weatherfish	89	6	0	Non-native/out of natural range
117	Threadfin shad	1018	2070	0	Non-native/out of natural range
118	Muskellunge	0	2	0	Non-native/out of natural range
119	Redear sunfish	0	0	0	Non-native/out of natural range
120	Goldfish	265	309	0	Non-native/out of natural range
121	Round goby	1421	116	0	Non-native/out of natural range
122	Carp	8185	10502	0	Non-native/out of natural range

[1] Number of fish collected from Lockport Pool below the Electric Dispersal Barrier during standardized sampling for Asian carp. All gears. (USFWS CAR).

[2] Justification for "Losses from TSP" based on area fish sampling data as determined by expert opinion (USFWS CAR).

2.3. Future Without Project

The existing condition is considered the future without project condition for this mitigation plan largely because of the urbanization in the watershed. The Illinois DNR and stakeholders are expected to implement watershed restoration plans to enhance habitats and the Illinois Environmental Protection Agency (IEPA) will continue to slowly advance water quality requirements in the future. However, stormwater, which is typically not treated, will continue to provide sources of fine sediment (roadways, lawns, construction sites, etc.), chemicals (road salt, lawn fertilizer and chemicals, etc.) into the waterway. If urbanization and land modification continues, the amount of hard surfaces and accelerated runoff into these streams will increase. Unless there is a significant increase in the implementation of stormwater best management practices into the future, nothing will impede these discharges to the waterway. Legacy contaminants in the waterway will remain until removed through dredging or other remediation. Continued efforts to implement watershed restoration plans could maintain or improve conditions for fish and mussel communities over time.

The Upper Des Plaines River and tributaries are classified as general use water bodies by the IEPA (USACE 2015). The general use water quality standards apply to almost all waters of the state and are intended to protect aquatic life, wildlife, agricultural, primary contact, secondary contact, and most industrial uses. The general use standards are designed to ensure the aesthetic quality of the aquatic environment and to protect human health from disease or other harmful effects that could occur from ingesting aquatic organisms taken from surface waters.

Some segments of the Des Plaines River and tributaries do not support the aquatic life, fish consumption, or primary contact designated uses (IEPA 2006, Short 1997). The potential causes for aquatic life impairment include elevated levels of chloride, nitrogen, phosphorous, total dissolved and suspended solids, zinc, and silver, and excessive sedimentation and siltation caused primarily from combined sewer overflows, municipal point source discharges, urban runoff, storm sewers, highway/road/bridge runoff, site clearance and land development, hydrostructure flow regulation, and the presence of sediment contaminated with various chemicals. Sediments with elevated concentrations of mercury and PCBs of unknown origin have resulted in fish consumption advisories in several reaches of the study area. Elevated levels of fecal coliform, resulting from combined sewer overflows, urban runoff, and storm sewers have impaired primary contact recreation uses in many areas.

Under the future without project condition, fish passage connectivity will remain low because the Brandon Road Dam will continue to impede upstream movement. Connectivity (Є) was calculated at 0.03 with the dam as compared to 1 if there was no impediment without the dam. Should water quality and habitat conditions improve in the upper Des Plaines River over time, some fish and mussel species may re-establish either from natural unassisted movement through Brandon Road Lock or from human transport (stocking) even with the dam in place.

2.4. Future Conditions with GLMRIS Brandon Road Recommended Plan

Brandon Road Dam is a barrier to fish passage upstream into the Brandon Road Pool, the Des Plaines River above the dam and into its tributaries. Any passage that does occur happens through the navigation lock as gates are opened to pass navigation traffic. Once the Recommended Plan is implemented, there will be no upstream fish passage and it is anticipated that 110 AAHU will be lost. See “Des Plaines Upstream of Brandon” on Table N-5 for the habitat units used describe future conditions for this reach after the Recommended Plan is implemented.

Table N-5. Available Habitat With GLMRIS-Brandon Road Recommended Plan.

	GLMRIS-Brandon Road Recommended Plan (Technology Alternative Complex Noise with Electric Barrier)		
Reach	**Connectivity (Є)**	**Available Habitat (acres)**	**Gross Habitat Units**
DuPage Upstream of Channahon Dam	0	824	0
Des Plaines Upstream of Brandon (excluding Salt Creek Upstream of Fullersburg Woods Dam)	0*	3842	0*
Salt Creek Upstream of Fullersburg Woods Dam	0.01	833	5
	Total		**5**

*Affected by the Recommended Plan (see Table N-2 for a comparison)

2.5. Impacts and Mitigation Objective

The impact of the project was calculated as the available habitat in the Future Without Project (115 Habitat Units) minus the available habitat in the Future Conditions with GLMRIS Brandon Road Recommended Plan and No Mitigation (5 Habitat Units), resulting in an impact of 110 Habitat Units. The Mitigation Objective for this plan is 110 Average Annual Habitat Units (AAHU).

3. Formulation of Alternative Plans

This Section describes the strategy used to formulate the mitigation alternative for GLMRIS-Brandon Road following Planning Guidance (USACE 2000). The formulation strategy for this mitigation plan included:

- Must offset the loss resulting from the project (110 AAHU).
- Must comply with USACE guidance

To assess the full range of alternatives, the mitigation alternatives with the least impact (Alternative A - Project with No Mitigation and the greatest impact Alternative F - USFWS CAR were evaluated. Alternative A - Project with No Mitigation is the Future Without Project Condition for mitigation planning and is the baseline condition by which all other mitigation alternatives were measured.

3.1. Fish Passage Measures Considered for GLMRIS-Brandon Road Mitigation

Six alternatives were developed to illustrate concepts and develop comparisons for this report (Table N-5).

3.1.1. Alternative A – Project with No Mitigation

If the project is constructed with no mitigation, fish would no longer have access to the Upper Des Plaines River through the lock. The habitat assessment for Alternative A – Project with No Mitigation considered that fish would no longer pass through the lock chamber on an average of nine times per day as the lock was operated for navigation and that those fish could migrate over Fullersburg Woods Dam 5% of the time when floods equalize the water surface above and below the dam, eliminating the obstruction to upstream fish movement at the dam. The available habitat in Alternative A – Project with No Mitigation is 5 Habitat Units. The Project with No Mitigation Alternative includes the current and future actions of Federal, state, and local agencies in combating ANS. The Project with No Mitigation alternative is used as a baseline for this evaluation to compare other mitigation measures.

Table N-6. Alternative Fish Passage Improvement Measures and Screening Considerations for GLMRIS Brandon Road Mitigation.

Structural Measures	Feasible Within Project Constraints	Mitigation Objective	Retain for Alternative Plan Formulation	Reasoning
Alternative A - Project with No Mitigation	No	Low likelihood of restoring >110 AAHU	Yes	This measure was retained to provide a point of comparison for other feasible measures. This is standard practice for feasibility level studies.
Alternative B - Trap and Transport	Yes	High likelihood of restoring >110 AAHU	Yes	This measure would restore native fishes to the Upper Des Plaines watershed while not expanding the range of Asian carp.
Alternative C - Upper Des Plaines/Salt Creek	Yes	High likelihood of restoring >110 AAHU	Yes	This measure would restore native fishes to the Upper Des Plaines watershed, including full access to Salt Creek; would provide rapids habitat for macro invertebrates, resident fishes and for fish spawning. Would not expand the range of Asian carp in the Des Plaines River watershed.
Alternative D - DuPage River Rock Ramp	Yes	High likelihood of restoring >110 AAHU	Yes	This measure would restore native fishes to the DuPage River. Increased risk of range expansion of Asian carp in the DuPage watershed.
Alternative E - Brandon Road Dam Native Fish Passage	Yes	Moderate likelihood of restoring >110 AAHU	Yes	Fish elevators are inefficient in moving fish and costly to operate and maintain.
Alternative F - USFWS CAR	No	High likelihood of restoring >110 AAHU	Yes	Retained as a point of comparison of feasible alternatives. Alternative F was not consistent with USACE guidance (Planning Guidance Notebook USACE 2000).

3.1.2. Alternative B – Trap and Transport

This alternative would involve manual capture of fish below the Brandon Road Dam by trapping, netting or electrofishing; sorting and documenting target species in a boat or on-shore, and manual transfer of fish to a location upstream of the Brandon Road Dam via transport trailer or boat live well for release. Indigenous fish have the potential to carry glochidia of mussels, thereby this measure could enhance mussel populations. Many minnow and darter species are difficult to field identify, so it may be necessary to hold some fish temporarily until proper identification can be assured. Table N-2 is a comprehensive list of the fish species found in the Brandon Road Lock and Dam area. Emphasis would be placed on transferring desirable species that have potential for establishment above Brandon Road Lock and Dam.

Care must be taken to ensure that transferred stocks do not contain invasive species. The USFWS CAR expressed concern over the potential to inadvertently transfer unwanted organisms. To address this risk, procedures for handling captured fish to prevent the spread of unwanted organisms upstream will need to be developed and updated as new aquatic nuisance species arrive below Brandon Road Lock and Dam. Since Asian carp are the current threat, this risk is low because Asian carp are easily identifiable from native species by trained fisheries staff and can be immediately culled upon capture. Water can be exchanged to removing eggs and larvae of fish and the scud, *Apocorophium lacustre*. In the future, a quarantine or temporary suspension of trap and transfer activities may be needed if there is a new aquatic nuisance species that is more difficult to separate from native fish stocks until a new aquatic nuisance species-free harvest (trapping) site is identified.

USACE estimated $132,000 annually for fish collection based upon the USFWS CAR estimate for fish monitoring. Trap and transport will occur annually. USACE estimated $6,000/week for 12 weeks for a collection crew plus time and equipment for fish identification, quarantine (if needed), data analysis, reporting, and transfer upstream of the Brandon Road Dam. Trapping would be done in two periods to coincide with spawning movements for the largest number of a species, a 3 week early spring spawning period (weeks 11-12) and a 9 week late spring-summer (weeks 17-25).

Project Performance Monitoring: Performance monitoring is necessary to ensure that fish are responding as expected after the first year of transfer. This effort would focus on optimizing the methods used for fish capture and improving survival during the fish transfer process using caged fish to determine the effects of handling and transfer of translocated fish. The USFWS CAR estimated that fish monitoring costs were $6,000/week for 3 weeks for a collection crew plus time for fish identification, data analysis, reporting, and other necessary components for a total of $35,000.

These costs were annualized over the 50-year project life to $133,000.00 for the incremental analysis.

Table N-7. Estimated Costs for Alternative B.

Measure	Cost
Trap and Transport ($132,000 /year for 50 years)	$6,600,000
One-Time Project Performance Monitoring (Project Year 2)	$35,000
Total	**$6,635,000**

3.1.3. Alternative C – Upper Des Plaines/Salt Creek

This alternative involves the improvement of longitudinal connectivity upstream of Brandon Road Lock and Dam to improve the access of native fish and mussels to more and higher quality habitats. Alternative C involves the removal of a dam to improve access within Salt Creek, a major tributary to the Des Plaines River.

Measures:

- **Fullersburg Woods Dam Modification and Channel Restoration:** The DuPage River Salt Creek Workgroup (DRSCW) identified this project on the Salt Creek mainstem to modify this dam to eliminate ponding, allow fish passage, and rebuild stream habitat for both fish and invertebrates for 1.5 miles of river. DRSCW has engaged the public extensively and will be collaborating with the Forest Preserve District of DuPage County and DuPage County Stormwater Management on this project. DRSCW budgeted $2,985,000 for this project and USACE applied a 20% contingency for an estimated cost of $3,582,000.

- **Trap and Transport:** Dam removal at Fullersburg Woods Dam restores some of the ecological functions and values lost by the project. Trap and transport over Brandon Road dam completes this alternative by enabling desirable fish species to access the restored Salt Creek and the upstream portions of the Des Plaines watershed. See description in Alternative B.

- **Project Performance Monitoring:** Performance monitoring is necessary to ensure that fish are responding as expected after the first year of operation. The USFWS CAR estimated that fish monitoring costs were $6,000/week for 3 weeks for a collection crew plus time for fish identification, data analysis, reporting, and other necessary components for a total of $35,000.

  The Fullersburg Woods Dam Modification and Channel Restoration will be self-sustaining in perpetuity; however, USACE would take advantage of information collected by partner agencies and other interested parties to inform decisions on mitigation over the project lifecycle.

Table N-8. Estimated costs for Alternative C.

Measure	Cost
Fullersburg Woods Dam Modification and Channel Restoration (add 20% contingency)	$3,582,000[a]
Trap and Transport ($132,000 /year for 50 years)	$6,600,000
One-Time Project Performance Monitoring – Salt Creek (Project Year 2)	$35,000
Total	**$10,217,000**

[a] DRSCWG 2016 and 2017.

3.1.4. Alternative D – DuPage River Rock Ramp

- **Fish Passage – Channahon Dam:** Installation of a Rock Ramp fishway at the Channahon Dam site and placement of a protective berm at Crest Hill Community Park marsh. This alternative improves longitudinal connectivity within the Des Plaines River Watershed and provides access to habitats. Fish passage does not currently occur at this dam.

- **Permeable Berm at Flow Divide:** A berm across the Crest Hill Community Park Marsh would topographically separate the upper part of the I&M canal from the headwaters of Rock Run Creek, preventing Asian carp from moving between these areas during floods. This berm would seal a potential aquatic bypass of a barrier at Brandon Road Lock and Dam during a 100 year discharge event. Large stone would be used to enable flow through the rocks but prevent adult fish from crossing the berm. Eggs and larvae are unlikely pass through the berm because spawning habitat is absent at this location.

- **Trap and Transport:** The rock ramp at Channahon Dam restores some of the ecological functions and values lost by the project. Trap and transport over Brandon Road dam completes

this alternative by enabling desirable fish species to access the upstream portions of the Des Plaines watershed. Same as Alternative B.

- **Project Performance Monitoring:** Same as Alternative C.

Table N-9. Estimated Costs for Alternative D

Measure	Cost
Permeable Berm at Flow Divide - Crest Hill Community Park Marsh	$884,000
Fish Passage – Channahon Dam	$6,000,000
Trap and Transport ($132,000 /year for 50 years)	$6,600,000
One-Time Project Performance Monitoring – DuPage River (Project Year 2)	$35,000
Total	**$13,519,000**

3.1.5. Alternative E – Brandon Road Dam Native Fish Passage

Fish Lift and Sorting Station: Construction of a fish lift and sorting station at Brandon Road Dam near the tailrace of the Brandon Road Dam. Fish would be lifted from the tailrace area and passed into the river upstream from an angled fish guidance rack/fish diversion structure. A fish lift consists of a small vertical lock chamber constructed as part of the dam. Fish are encouraged to enter the lock with attraction flow, the gates are closed, then fish are lifted into a sorting station where invasive fish are removed and native fish are released into the upper Pool.

Sorting Station Operation: Fish lift would be operated during the peak migratory period April through June, three times daily, five days a week. Operations include 12 weeks for operation and maintenance of fishway and a sorting crew for fish identification, sorting, data analysis, and reporting.

Table N-10. Estimated Costs for Alternative E

Measure	Cost
Fish Lift and Sorting Station ($4,390,000[1] 2009 dollars – escalated to 2018: $5,269,756, add 20% contingency)	$6,323,707
Sorting Station Operation (5% of the capital cost[2];$316,185 annually)	$15,809,250
Total	**$22,132,957**

[1] U.S. Fish and Wildlife Service 2011.
[2] Noonan *et al*. 2011.

3.1.6. Alternative F – USFWS CAR

This Alternative involves the implementation of all alternatives identified in the USFWS CAR. The Salt Creek tributary was selected as a proxy to calculate benefits for habitat restoration for the FPCI evaluation of Alternative F because it closely represents the scope and cost of restoration efforts identified in Habitat Restoration. This alternative is discussed in detail in the USFWS CAR, GLMRIS-Brandon Road Feasibility Report and EIS - Appendix A).

- **Oversight:** A managing River Biologist will be responsible for the overall management of all activities on the Des Plaines River including coordination between all DNR staff and liaison with the USFWS as well as other external partners and shareholders. This will be a full time need and position requiring funds for salary and operations. $150,000 salary and benefits. This is for a senior level biologist that will provide oversight for all years where intensive activities and monitoring are underway.

- **Propagation:** Rearing and stocking 24 fish and 15 mussel species above Brandon Road Lock and Dam. Approximately three species of fish and three species of mussels will be raised concurrently using existing infrastructure at DNR, USFWS, commercial, or other hatcheries whenever practical. Each species would be reared for 5 years.

- **Habitat Restoration:** The success of stocking efforts for several species of interest will be greatly enhanced by providing key habitat features that are currently limited in the upper Des Plaines River including: backwater reconnection/restoration; emergent vegetation; tributary reconnection; rock bars; riffles in tributaries or mainstem; re-meandering; deep runs and pools; and woody debris. In addition, there are other habitat restoration efforts in downstream reaches that will have a very direct benefit for target species in mitigation planning. Habitat planning and engineering services will contribute to the successful identification and implementation of these efforts and will likely be contracted due to the limited nature of the work. Early in that planning effort, key habitat features and best locations to restore them will be identified. Then project design, cost, and timeframe can be addressed and projects can commence. It is likely that habitat projects will be a larger part of mitigation in the earlier years with a general lessoning over time. Given project specific information is needed to generate costs, USFWS request a fixed allocation of funding to support these efforts (no inflation applied).

- **Monitoring and Research:** A Monitoring and Research Plan for fish and mussels will be developed to identify key questions to be answered and to determine the most effective methods for pursuing those answers. Monitoring and research may be done with a combination of staff as well as contracting projects with Illinois Natural History Survey, universities and/or others. These efforts are distinct from other monitoring efforts identified in the TSP, with the latter designed to assess the effectiveness of the selected alternative rather than to assess the effectiveness of mitigation efforts. The primary performance measures are self-sustaining populations of target fish that trend toward comparison streams and for IBI scores calculated from basin-wide surveys to trend in a positive direction.

- **Outreach:** Building support in the community and among key partners is important to complete habitat projects and other watershed improvements that cannot be done without private and/or public landowners. Also, angling and environmental groups can be key partners in generating support for efforts from local citizens and governments as well as in providing additional labor/funds for projects. This less than a full-time need and may use staff, contracted assistance, or a combination of both. This outreach is distinct from other outreach identified in the TSP which uses aquatic nuisance species targeted messages rather than the community support and outreach needed for improved water quality and habitat.

The cost of the measures that are included in Alternative F without inflation are summarized in Table N-11 for equal comparison with the other alternatives (total $42,120,000). The USFWS' total cost of Alternative F with full inflation is $100,400,000. The USFWS describes how the Alternative F cost estimate was indexed for inflation in the USFWS CAR.

Table N-11. Estimated Costs for Alternative F (USFWS CAR, GLMRIS-Brandon Road Feasibility Report and EIS - Appendix A)

Measure	Total Cost [1]	Comments [2]
Oversight - Salary & Ops	$6,750,000	Est. $150,000/yr. Managing River Biologist
Propagation	$10,000,000	Est. $2,400,000 upgrades, ~$99,000/species/yr.
Habitat Restoration	$10,000,000	Flat $10,000,000 total, spread over 12 years
Monitoring & Research	$5,625,000	Covers initial needs, annual needs, and periodic needs
Outreach	$1,000,000	Est. $25,000/yr.
Subtotal	$39,000,000	
Indirect	$3,120,000	16% of salaries and benefits (assumed to be 50% of total costs)
Total	**$42,120,000**	

[1] Costs are spread over 50-year time horizon for planning effort.
[2] Costs in "Comments" reflect 2018 values.

4. Evaluating Alternative Plans

The FPCI was developed to evaluate ecosystem outputs of alternative measures for fish passage improvements on the GLMRIS-Brandon Road Ecosystem Restoration Project for cost effectiveness and incremental analysis of mitigation measures. The model was originally developed for use in the plan formulation process for the Navigation and Ecosystem Sustainability Program (NESP) for the Upper Mississippi River System Lock and Dam 22 fish passage improvement project and was adapted to the Des Plaines River for this project. This report was developed in compliance with the planning model certification process as required for USACE projects (USACE 2007).

4.1. Model Constraints

The FPCI model is a simple logic construct used to evaluate the potential effectiveness of alternative fish passage improvement measures for use in cost effectiveness and incremental cost analysis.

1. Capabilities

Habitat Benefit Quantification. The estimation of FPCI units provides a surrogate that enables a habitat-based alternatives evaluation for migratory fishes in the project area. Because we currently lack population-level response predictive capabilities, this habitat-based approach provides a planning tool to evaluate the alternative measures.

Upstream Migration. The FPCI is capable of estimating the incremental benefit of upstream migration for any fish species that demonstrates migratory behavior.

2. Limitations

System-Level Analyses. The FPCI was not developed for a system-wide analysis of alternative fish passage improvement measures or for project sequencing. The model was developed to assess how well the alternative measures would improve connectivity for upstream fish movements.

Downstream and Lateral Migration. The FPCI addresses upstream movements of adult migratory fishes. It does not address downriver or lateral fish movements (between channels and floodplain). It does not address fish migrations to wintering areas, which are typically in a downstream direction in the fall.

Ichthyoplankton and Juvenile Fish. The FPCI does not address movements of non-adult life stages of fish like downriver drift of ichthyoplankton or lateral and longitudinal movements of juveniles.

Invasive Species. The FPCI does not address movements of invasive species like Asian carp and it does not address the risk of enabling the range expansion of invasive species. The risk of enabling the spread of invasive species was a screening consideration for the alternatives developed for this mitigation plan.

Predation. The FPCI does not include consideration of the potential for increased predation of fish by concentrating fish and predators near fishways.

Secondary Benefits. The FPCI does not consider the indirect or secondary benefits of fish passage. Secondary benefits should be identified early in the plan formulation process to ensure that all aspects of the project contribute to the project objectives. Secondary benefits of dam removal may include recreational benefits from restored small boat access and elimination of future maintenance cost.

4.2. Model Description

The FPCI is a simple arithmetic index that can be adjusted to fit the characteristics of migratory fishes present at all locks and dams on the Upper Mississippi river system including the Illinois Waterway and characteristics of fish passage alternative measures. The index is calculated as:

Equation

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

Where,

- Є = Fish Passage Connectivity Index.
- i = a migratory fish species that occurs 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 indicates highly likely, 3 indicates moderate probability, 1 indicates unlikely.
- U_i = Potential for species i to use the fish passage pathway or fishway (5 = Good, 3 = Moderate, 1 = Poor, 0 = None). Considering adult fish swimming performance and hydraulic conditions within the fishway or fish travel pathway.
- D_i = Duration of availability; fraction of the upstream 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.)

4.3. Description of the Input Data

1. Navigation Study Fish Passage Report. The input data used in the FPCI were primarily from the report, *Improving Fish Passage Through Navigation Dams on the Upper Mississippi River System* (Wilcox et al. 2004). This report summarized pertinent scientific, operational and economic information, drawing from the literature resources and experience of the GLMRIS-Brandon Road Project Delivery Team.

2. Grouping Fish Species into Guilds. Migratory fishes were grouped into guilds and classified by their behavior and swimming performance (Table N-11). A subset of migratory fish species were selected

to represent populations that could be found in the Des Plaines River, Salt Creek and the DuPage River and to limit bias toward river reaches that have greater species diversity. All guilds were used to provide an unbiased comparison of alternatives. Representative guild species have been collected in the vicinity of Brandon Road Lock and Dam (Table N-12) and have certified life history and swimming performance data available within the FPCI model. This information was used to estimate the chance of encountering the fishway entrance (E_i) and the potential to use the fishway (U_i) in the FPCI.

Table N-12. Guilds and Representative Fish Species That Occur at Brandon Road Lock & Dam

Swimming Performance	Behavior		
	Benthic	**Littoral**	**Pelagic**
Strong	channel catfish	walleye	white bass
Medium	black redhorse	largemouth bass	mooneye
Weak	quillback	American eel	longnose gar

Benthic = swims near the river bottom,
Littoral = swims in shallow water
Pelagic = swims throughout the water column, often near the surface

3. Estimating the Potential for Fish to Encounter the Fishway Entrance (E_i). It is generally not difficult to pass a significant portion of the total river flow through a fishway on a small river due to scale. On a larger river like the Illinois River, it becomes more difficult to pass a large percentage of river discharge through a fishway simply due to the expense of building a larger fishway. On large rivers, Larinier (2000) recommended an attraction 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.

E_i was designed to simulate the relationship between discharge and location mathematically within the FPCI. E_i was estimated considering the width of the fishway and the location of fishway entrance in relation to the expected behavior of the fish guild. E_i ranges from 1 to 5 and is unique to each alternative and fish guild. The two components that make up E_i are fishway size (F_s) and fishway location (F_l). The relationship between E_i, F_s and F_l is expressed in the equation:

$$E_i = (F_s+F_l)/2$$

Where,
E_i = the potential for fish to encounter the fishway entrance
F_s = the size of the fishway relative to the discharge of the river under low flow conditions
F_l = the location of the fishway entrance in relation to the expected behavior of the fish guild

Fs was used to classify measures based upon the percentage of discharge of the river under low flow conditions on a 1-5 scale. A value of 5 was assigned to fishway designs that pass 10 percent of the low flow discharge, 4 = 8 percent, 3 = 5 percent, 2 = 2 percent, and 1 = less than 2 percent (Table N-13).

Table N-13. Classification of Fishway Measures Based Upon the Percentage of Discharge of the River Under Low Flow Conditions (F_s)

Measure	% of Minimum Flow	F_s
Alternative A - Project with No Mitigation	1	1
Alternative B - Trap and Transport	1	1
Alternative C - Upper Des Plaines/Salt Creek	100	5
Alternative D - DuPage River Rock Ramp	25	5
Alternative E - Brandon Road Dam Native Fish Passage	1	1
Alternative F - USFWS CAR	100	5

F_l was used to determine if the measures were well located for each fish guild based on swimming performance and behavior. Swimming performance is important because it indicates the flow conditions that a fish prefers and behavior is important because it indicates the vertical and horizontal position within the flow field that a fish would generally select. F_1 is influenced by river geomorphology and fish ecology. Guilds represent species that select similar habitats with respect to distance from thalweg, edge habitat, substrate, rheotactic preference and migration pathways. These values fell into three categories; 5 indicates that the entrance would be encountered by a significant portion of the population, 3 indicates that the entrance may be encountered, and 1 indicates that it was unlikely that the entrance would be encountered (Table N-14). A measure that extends across the entire channel, such as a dam removal, would have the highest likelihood of passage. A measure that provides a migratory corridor through a bypass channel, but leaves part of the dam impassible was considered more difficult for some fish guilds to use successfully. Navigation lock chambers are the most difficult for migratory fish to use successfully due to the presence of vertical sills on the upstream side and lack of rheotactic cues to guide fish into the lock and out of the upper gates and successfully pass into the upstream pool. Trap and transport was assigned a value of 3 because passage by all species is assured but it is considered less effective than dam removal at passing fish.

Table N-14. Estimated Suitability of Fishway Locations (F_l) for Fish Guilds Based Upon Swimming Performance and Behavior

	F_l for Potential Fishway Locations			
Guild	**Entire Channel**	**Side Channel and Bypass Channel**	**Trap and Transport**	**Lock**
Benthic – Strong	5	3	3	1
Littoral – Strong	5	3	3	1
Pelagic – Strong	5	3	3	1
Benthic – Medium	5	5	3	1
Littoral – Medium	5	5	3	1
Pelagic – Medium	5	5	3	1
Benthic – Weak	5	5	3	1
Littoral – Weak	5	5	3	1
Pelagic – Weak	5	5	3	1

4. Estimating the Potential (U_i) for Fish to Use Alternative Fish Passage Measures. An estimate of the potential for fish to use alternative fish passage measures (U_i) based upon the adult fish swimming performance and hydraulic conditions within the fishway or fish travel pathway. The minimum current velocity at the hydraulic steps for each alternative measure was plotted and compared to the swimming ability for each migratory fish species. Generally, if velocities did not exceed sustained speeds the U_i was scored a 5. If velocities exceeded sustained speeds for part of hydraulic step area it was scored a 3, and if velocity exceeded burst speeds for the entire hydraulic step area it was scored a 1.

Some fish have unique characteristics that affect their U_i for fish lockage. For example the paddlefish can detect electrical fields emanating from metal structures in the water and avoid them; therefore, the Ui rating for paddlefish would be 0 for measures that had substantial metal components such as a technical fishway. No species found in the project area possess these unique characteristics. The lock chambers are operated only to pass navigation traffic and are only intermittently available for fish passage (Wilcox et al. 2004). All fish guilds were assigned a Ui value of 3 for the Fish Lockage because even though fish appear in lock chambers (Johnson et al. 2004) and can move through locks (Carter 1954, Kinge 1994), attracting flows into the lock chamber are minimal compared to the attracting flows at the dam gates and fish are less likely to use locks to move upstream (Lubejko et al. 2017). The flow conditions are not restricting to any fish and all would have at similar likelihood of being drawn to the flows or finding their way out of the upstream end of the lock chamber. The U_i for trap and transfer was assigned a value of 1

because even though passage for native fish is assured, the number of fish is limited to the number harvested below the dam. Harvest is affected by the selectivity of the gear used to catch fish and changing environmental conditions (i.e. water temperature and water levels).

Critical current velocities (Ucrit) for prolonged swimming by adult fish of size at first year of reproduction were estimated based on literature reports on fish swimming performance trials (Table N-15). Although information about swimming performance is incomplete, experimental swimming performance data for morphologically similar species were used for species without experimental results. This information was used to estimate the potential (U_i) for species to be physically and behaviorally able to travel upstream through the alternative measures fishways and travel pathways for the FPCI. Table N-15 shows an example of how U_i was calculated for a hypothetical fish species.

Table N-15. Example of Estimating the Potential (U_i) for a Hypothetical Benthic-Strong Fish Species Guild

Measure	Minimum Current Velocity at Hydraulic Step (ft/sec)	Prolonged Swim Speed Ucrit (ft/sec)	U_i
Alternative A - Project with No Mitigation	n/a	1.6	3
Alternative B - Trap and Transport	n/a	1.6	1
Alternative C - Upper Des Plaines/Salt Creek	n/a	1.6	3
Alternative D - DuPage River Rock Ramp	2	1.6	1
Alternative E - Brandon Road Dam Native Fish Passage	n/a	1.6	1
Alternative F - USFWS CAR	n/a	1.6	3

Velocities between the riffle boulders in the rock ramp fishways would range from approximately 6.5 ft/sec at the center of the fishway to <2.0 f/sec between the riffle boulders along the shallower edges of the fishways (Table N-16). This information was compared to fish swim speed (Table N-17) to estimate the potential for species to use the fishway (Ui) in the FPCI equation.

Table N-16. Physical Characteristics of GLMRIS-Brandon Road Alternatives

Measure	Current Velocity (ft/s)	Fishway Pool Length (ft)
Alternative A - Project with No Mitigation	n/a	n/a
Alternative B - Trap and Transport	n/a	n/a
Alternative C - Upper Des Plaines/Salt Creek	n/a	n/a
Alternative D - DuPage River Rock Ramp	<2.0-6.5	11.1-19.0
Alternative E - Brandon Road Dam Native Fish Passage	n/a	n/a
Alternative F - USFWS CAR	n/a	n/a

Table N-17. Estimates of Prolonged Swimming Performance of Select Migratory Fishes (Wilcox et al. 2004)

Species	Length mm TL	TL or FL/SL	*U*crit Model (cm/s)	*n* test fish	Reference	Estimated adult fish *U*crit (cm/s)	Estimated adult fish *U*crit (ft/s)	Comments on *U*crit
Longnose gar	500	TL = FL	4.9FL^0.55 (surrogate: northern pike)	0	3	21	0.7	surrogate, probably low
Mooneye	255	1.25 (estimate)	2.9 SL (surrogate: goldeye)	58	1, 4	59	1.9	surrogate
American eel	900	1.0	none found					unknown
Quillback	300 (estimate)	1.22	25.5 + 0.97 SL (surrogate: smallmouth buffalo)	0	2	49	1.6	surrogate
Black redhorse	230	1.23 (FL=1.1SL	10.03FL^0.55 (surrogate: white sucker)	0	3	50	1.6	surrogate
Channel catfish	330	1.2	3.05 SL	0	1, 4	121	4.0	surrogate
			3.0 TL at 20 degrees C	25	7	99	3.2	temperature response test fish (Mean 14.0 cm to 15.4 cm TL)
			Mean of 3 min. Ucrit tests	4	8	57	1.9	Test fish (Mean 36.25 cm SL)
White bass	313	1.2 (estimate)	4.6SL	13	1, 4	120	3.9	test fish (9.8 cm to 21.8 cm SL)
Largemouth bass	254	1.215	5.0TL @ 20 degrees C	15	7	127	4.2	temperature response test test fish (5.2 cm to 6.4 mm)
			3.41SL	50	8	71	2.3	conditioning response test test fish (10.9 cm to 14.2 cm FL)
			4.5 TL	>100	9	114	3.8	temperature, D.O. response test test fish (Mean 8.2 cm TL)
			3.84SL	21	10	80	2.6	performance repeatability test test fish small (Mean 9.4 cm FL)
Walleye	454	1.2 (estimate)	3.04SL	6	1, 4	115	3.8	test fish (15.4 cm to 40.8 SL)
			13.07FL^0.51	54	3	83	2.7	test fish (8 cm to 38 cm FL)

References:

1. Tunink (1975)
2. Adams and Parsons (1995)
3. Jones, et al. (1974)
4. Schmulbach et al. (1981)
5. Parsons and Bartlett (1997)
6. Parsons and Smiley (1994)
7. Hocutt (1973)
8. Farlinger and Beamish (1977)
9. Dahlberg et al. (1968)
10. Kolok (1992)

5. Estimating the Duration of Availability (Di) of the Alternative Measures. Each migratory fish species has its own unique life history and migration behavior, responding to environmental cues at different times of a year. Information about the migration behavior, swimming performance and seasonal timing of migration is incomplete for the migratory fishes that occur near the project area.

Table N-18 presents information about the seasonal upstream movements of migratory fishes in the Midwest based on fisheries literature, consultations with fisheries managers and water temperature records (adapted from Wilcox et al. 2004). The estimated spawning periods are based on water temperatures reported in the fisheries literature (Becker 1983; Tunink and Crossman 1973). Water temperature for each dam location was not factored into the GLMRIS-Brandon Road analysis because it was considered constant among all alternatives. Pre-spawning movement periods shown in Table N-18 are more uncertain and are based on reports from literature. This information was used to estimate the duration of availability (D_i) in the FPCI.

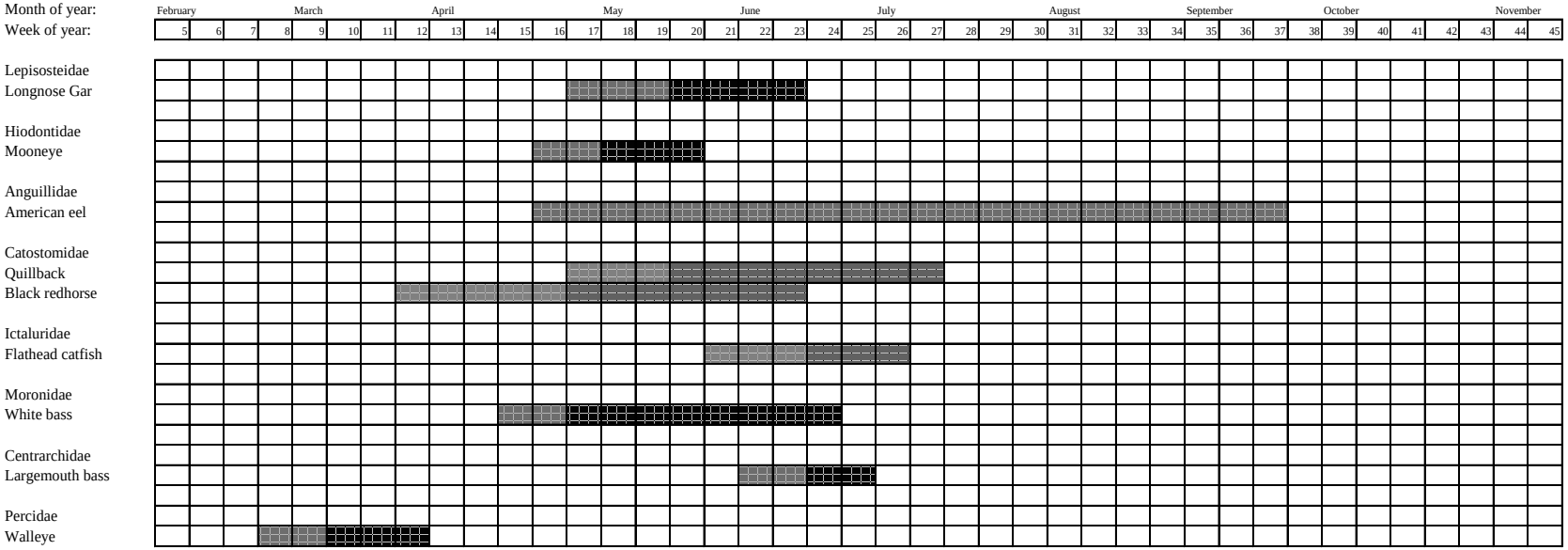
The duration of availability (D_i) was important in assessing the future without project and fish lockage alternatives. It was estimated based on the number of weeks in the migration period that a fish passage measure would be available, divided by the total number of weeks in the migration period for that fish species. Fishways and Trap and Transport estimates were based upon two periods to coincide with spawning movements for the largest number of a species, a 3 week early spring spawning period (weeks 11-12) and a 9 week late spring-summer (weeks 17-25).

Fish can pass upstream through the Brandon Road lock chamber, although that pathway is only intermittently available and is unlikely to allow upstream movements of large numbers of fish, given the lack of attracting flows, orientation of currents in the lock chamber and the presence of commercial tows transiting the lock. Fish lockage was assumed to be done nine times per day during the fish migration period because this is the average number of lockages. A D_i of 0.375 (9 out of 24 hours) was estimated for the Future Without Project because fish could pass through lock when it is operated an average of 9 times per day, and a D_i of 0.125 (3 out of 24 hours) was estimated for Alternative E - Brandon Road Dam Native Fish Passage because the fish lift would be operated 3 times per day to allow time for fish to aggregate in the attractant flow between lift raises.

Table N-18. Seasonal Timing of Upstream Fish Movements in the Midwest (adapted from Wilcox et al. 2004)

Approximate upriver movement and spawning periods of migratory fishes that may occur in the Des Plaines River watershed.

Pre-spawning movement period
Spawning period



Notes:
1) Timing of pre-spawning movements and spawning water temperatures during spawning were obtained from Becker, G.C. 1973. Fishes of Wisconsin. University of Wisconsin Press. Madison, Wisconsin, and other fisheries literature sources.
2) Pre-spawning movements and spawning time periods by week of year at Brandon Road Lock and Dam were assigned based existing model data (long-term weekly water temperature records at Lock and Dam 22 on the Mississippi River (1984 - 1997))
3) Timing of movements into winter habitat is not well documented. Some species (e.g., sturgeons, walleye) migrate in fall to winter aggregation areas that are close to spawning areas. Periods shown for those species are estimated.

4.4. Description of Output Data

Output data is expressed in habitat units which are derived from the relationship of the effectiveness of the fishway (Connectivity (€)) and the amount of unimpaired habitat available above the dam for each species (see Figure N-3 and Mitigation Appendix A). The resulting species habitat units are then averaged for each alternative. Habitat unit gains or losses are annualized by summing the cumulative habitat units across all target years in the period of analysis and dividing the total (cumulative HU) by the number of years in the life of the project (i.e., 50 years). This calculation results in the Average Annual Habitat Units (AAHUs). The averages of fish passage connectivity and corresponding habitat units were summarized in Tables N-19 and N-20. Habitat Units were calculated by multiplying the FPCI by the total acres of available unimpaired habitat for each species. The total area of available habitat varied by the location of the dam and the corresponding upstream unimpaired habitat.

When calculating the AAHU the assumption was made that all of the potential mitigation alternatives were fully implemented by Year 1 and achieving their maximum AAHUs. The average annual cost calculation for the alternatives included the initial construction cost as well as monitoring. Adaptive management, lands, easements, rights-of-way, relocations and disposal areas (LERRDS), Interest During Construction (IDC), and Operation and Maintenance (O&M) were not included in the calculation of the average annual costs since these costs are unknown at this time. Alternatives C through F would require LERRDs and O&M for implementation since they all include habitat restoration as well as other structures (e.g., rock ramp). IDC and adaptive management would be needed for all of the potential mitigation alternatives. While these costs are unknown at this time, it is assumed that including these values would not alter the outcome nor the selection of a mitigation plan.

Table N-19. Comparison of Gross Habitat Units for Each Alternative by Reach

	Alternative A Project with No Mitigation			Alternative B Trap and Transport			Alternative C Upper Des Plaines/Salt Creek		
Reach	**Connectivity (Є)**	**Available Habitat (acres)**	**Gross Habitat Units**	**Connectivity (Є)**	**Available Habitat (acres)**	**Gross Habitat Units**	**Connectivity (Є)**	**Available Habitat (acres)**	**Gross Habitat Units**
DuPage Upstream of Channahon Dam	0	824	0	0	824	0	0	824	0
Des Plaines Upstream of Brandon (excluding Salt Creek Upstream of Fullersburg Woods Dam)	0	3842	0	0.06	3842	237	0.06	3842	237
Salt Creek Upstream of Fullersburg Woods Dam	0.006	833	5	0.006	833	5	1	833	833
Total			**5**			**242**			**1070**

	Alternative D DuPage River Rock Ramp			Alternative E Brandon Road Dam Native Fish Passage			Alternative F USFWS CAR Mitigation		
Reach	**Connectivity (Є)**	**Available Habitat (acres)**	**Gross Habitat Units**	**Connectivity (Є)**	**Available Habitat (acres)**	**Gross Habitat Units**	**Connectivity (Є)**	**Available Habitat (acres)**	**Gross Habitat Units**
DuPage Upstream of Channahon Dam	0.93	824	769	0	824	0	0	824	0
Des Plaines Upstream of Brandon (excluding Salt Creek Upstream of Fullersburg Woods Dam)	0.06	3842	237	0.01	3842	38	1*	3842	3842
Salt Creek Upstream of Fullersburg Woods Dam	0.006	833	5	0.006	833	5	1	833	833
Total			**1011**			**43**			**4675**

*****Alternative F includes many features to restore the Des Plaines River (over $25M in additional habitat restoration, propagation activities for both mussels and fish, oversight, research, and outreach). A Connectivity (Є) value of "1" was assigned to account for these enhancements.

Table N-20. Differences Between Each Alternative With and Without Plan Condition.

Alternative	Gross Habitat Units		Project with No Mitigation		Gross Net Habitat Units	AAHUs
B: Trap and Transport	242	-	5	=	237	240
C: Upper Des Plaines/Salt Creek	1070	-	5	=	1065	1059
D: DuPage River Rock Ramp	1011	-	5	=	1006	1001
E: Brandon Road Dam Native Fish Passage	43	-	5	=	38	43
F: USFWS CAR	4675	-	5	=	4670	4628

5. Comparison of Alternative Mitigation Plans

Cost effectiveness and incremental cost analysis (CE/ICA) are two distinct analyses that must be conducted to evaluate the effects of alternative plans according to USACE policy. First, it must be shown through cost effectiveness analysis that a restoration plan's output cannot be produced more cost effectively by another alternative.

Cost effectiveness means that, for a given level of non-monetary output, no other plan costs less and no other plan yields more output at a lower cost.

Incremental cost analysis means that the subset of cost effective plans are examined sequentially to ascertain which plans are most efficient in the production of environmental benefits. Those most efficient plans are called "best buys." As a group of measures, they provide the greatest increase in output for the least increases in cost. They have the lowest incremental costs per unit of output. In most analyses, there will be a series of best buy plans, in which the relationship between the quantity of outputs and the unit cost is evident. As the scale of best buy plans increases (in terms of output produced), average costs per unit of output and incremental costs per unit of output will increase as well. The incremental analysis by itself will not point to the selection of any single plan. The results of the incremental analysis must be synthesized with other decision-making criteria (i.e., significance of outputs, acceptability, completeness, effectiveness, risk and uncertainty, reasonableness of costs) to help the study team select and recommend a particular plan.

5.1. GLMRIS-BR Mitigation Cost Effectiveness/Incremental Cost Analysis

The USACE's Institute for Water Resources (IWR) developed procedures and software to assist in conducting CE/ICA. The IWR Planning Suite Beta MCDA software package was used to conduct this analysis. Table N-21 shows the values that were put into the IWR Planning Suite and used for cost-effectiveness and incremental cost analysis. Habitat Unit gains or losses are annualized by summing the cumulative HUs calculated across all target years in the period of analysis and dividing the total (cumulative HU) by the number of years in the life of the project (i.e., 50 years). This calculation results in the AAHUs.

Table N-21. Summary of Mitigation Alternative Costs and Outputs Used in CE/ICA

Alternative	Description	Average Annual Cost[1]	AAHUs[2]	Net AAHUs
A	Project with No Mitigation[3]	$0.00	5	0
B	Trap and Transport	$133,000	240	235
C	Upper Des Plaines/Salt Creek	$262,000	1059	1054
D	DuPage River Rock Ramp	$381,000	1001	996
E	Brandon Road Dam Native Fish Passage	$544,000	43	38
F	USFWS CAR	$993,000	4628	4623

[1]Average annual cost includes construction and project performance monitoring only. Adaptive management, LERRDs, interest during construction, and operations and maintenance (O&M) are not included. These costs will be further developed during PED; however, they are not expected to affect the outcome of the CE/IC analysis.
[2] Habitat units were annualized using the Habitat Evaluation Procedure (HEP) annualization formula in the IWR Planning Suite Software.
[3] The AAHUs for the Project with No Mitigation were subtracted from each of the alternatives to calculate the Net AAHUs for each alternative.

5.2. Cost Effectiveness

The cost effectiveness analysis was used to ensure that certain options would be screened out if they produced the same amount or less output at a greater cost than other options with a lesser cost. Six alternatives were analyzed for cost effectiveness, including the Project with No Mitigation. Of these, four cost effective combinations were identified (Table N-22 and Figure N-4), with two of the four plans also being identified as “Best Buys”. Two alternatives were screened out as “Non-Cost-Effective”, alternatives D and E. These alternatives were compared to determine which best met the Mitigation Objective of 110 AAHU at the least average annual cost (Figure N-4).

Table N-22. Cost Effective Analysis on Five Alternative Plans

Alternative	Description	Average Annual Cost[a]	Net AAHUs	Cost Effectiveness
A	Project with No Mitigation	$0.00	0	Best Buy
B	Trap and Transport	$133,000	235	Cost Effective
C	Upper Des Plaines/Salt Creek	$262,000	1054	Cost Effective
D	DuPage River Rock Ramp	$381,000	996	Non-Cost Effective
E	Brandon Road Dam Native Fish Passage	$544,000	38	Non-Cost Effective
F	USFWS CAR	$993,000	4623	Best Buy

[a] Monetary values are expressed at the 2018 price level, assuming a base year of 2021, a 50-year period of analysis, and a Federal Discount Rate of 2.750%. Values rounded to the nearest thousand.

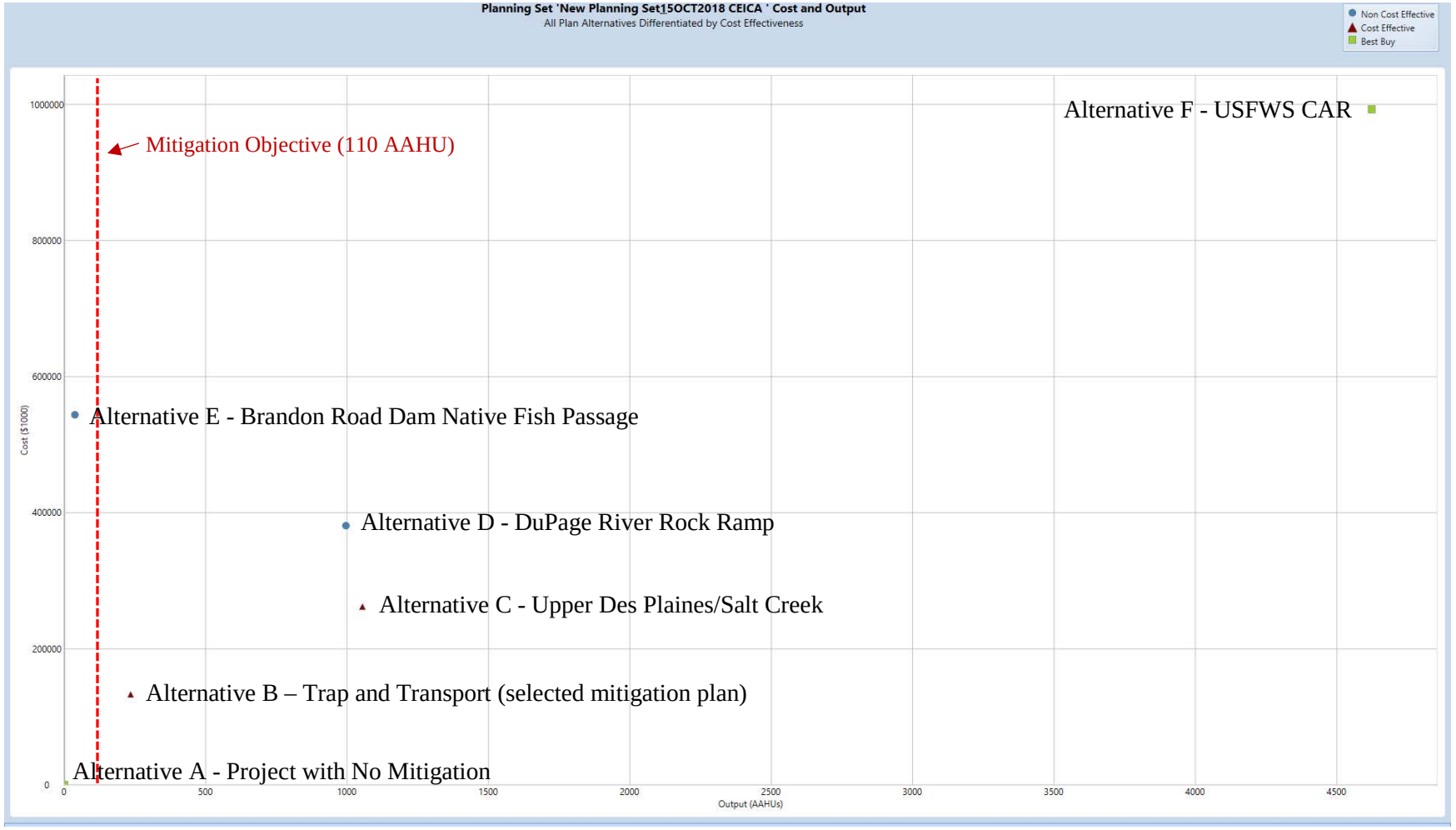


Figure N-4. Summary of Mitigation Alternative Costs and Outputs Used in CE/ICA

Incremental Cost Analysis

An incremental cost analysis was performed on the Best Buy Plans identified from the cost effectiveness analysis, including the No Action plan. The objective of the incremental cost analysis is to assist in determining whether the additional output provided by each successive plan is worth the additional cost. This incremental cost analysis (Figure N-5 and Tables N-23 and N-24) compares the mitigation alternatives that were considered for selection.

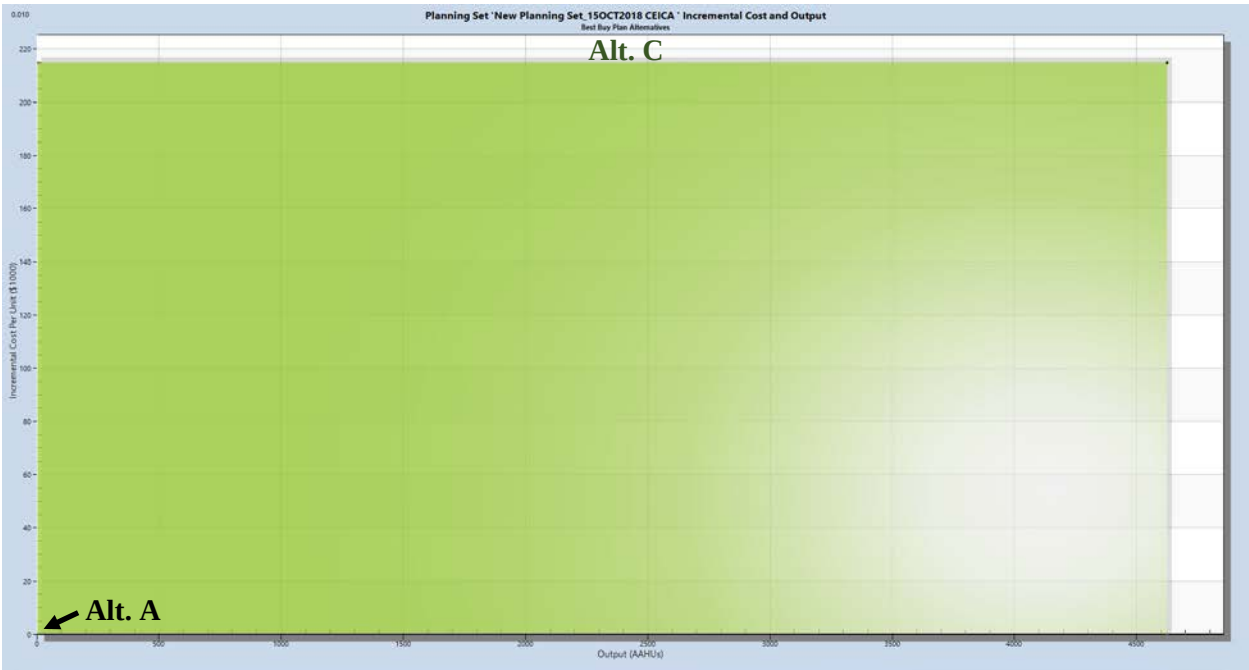


Figure N-5. Incremental Cost and Output of "Best Buy" Alternative Plans

Table N-23. Summary of CE/ICA "Best Buy" and "Cost-Effective" Alternative Plans

Alternative	AAHUs	AA Cost	AA Cost/ AAHUs	Incremental Cost	Incremental AAHUs	Incremental Cost/ Incremental AAHUs
A	0	$0	$0.00	$0.00	0	$0.00
F	4623	$993,000	$214.78	$993,000	4623	$214.78

The least costly "cost effective" plan satisfies the mitigation objective; therefore, it is preferred over the "best buy" plans based upon cost considerations. Alternative F, the only mitigation best buy, significantly over mitigates, providing almost 42 times more output than the impact of 110 AAHUs. Alternative B is the first cost effective plan, which fully mitigates for unavoidable impacts and is therefore the selected mitigation plan. Regardless of the CE/ICA, it is important to look at which alternative plan mitigates for the loss of habitat units from implementation of the Recommended Plan. The implementation of the Recommended Plan would result in the loss of 110 AAHUs. Alternative B - Trap and Transport, was identified as a cost effective plan and offsets the loss of the 110 AAHUs by providing 235 AAHUs; therefore, Alternative B is the selected mitigation plan.

Table N-24. Summary of Benefits and Cost for GLMRIS Brandon Road Mitigation Alternatives

Mitigation Alternative	Measure	Gross Habitat Units	Gross AAHUs	Total Construction Cost	CE/ICA Information		CE/ICA Outcome
					Net AAHU	AA Cost (Cost)	
Alternative A	Project with No Mitigation	5	5	$0	0	$0.00	Best Buy
Alternative B	Trap and Transport	242	240	$6,635,000	235	$133,000	Cost Effective
Alternative C	Upper Des Plaines/Salt Creek	1070	1059	$10,217,000	1054	$262,000	Cost Effective
Alternative D	DuPage River Rock Ramp	1011	1001	$13,519,000	996	$381,000	Non-Cost Effective
Alternative E	Brandon Road Dam Native Fish Passage	43	43	$22,132,957	38	$544,000	Non-Cost Effective
Alternative F	USFWS CAR	4675	4628	$42,120,000	4623	$993,000	Best Buy

6. Selecting a Plan

There are a number of ways to conduct CE/ICA, thereby determining which alternative plans are cost-effective and, from the set of cost-effective plans, identifying those alternative plans that are most efficient in producing outputs (i.e., best buys). In this case, the selected plan, a "cost effective" plan, was chosen over "best buy" alternatives because it the least cost mitigation plan that provided full mitigation of losses specified in mitigation planning objective.

The selected mitigation alternative was Alternative B - Trap and Transport. This alternative involves the manual capture of fish below the Brandon Road Dam; sorting of target species and transfer to a location upstream of the Brandon Road Dam for release. Wild caught fish have the potential to carry early life stages (glochidia) of mussels, which would also enhance upstream mussel populations.

Measures within the selected mitigation alternative (Alternative B - Trap and Transport) include:

1) Trap and Transport: USACE estimated $132,000 annual for fish collection based upon the USFWS CAR estimate for fish monitoring. Trap and transport will occur annually. USACE estimated $6,000/week for 12 weeks for a collection crew plus time and equipment for fish identification, quarantine (if needed), data analysis, reporting, and transfer upstream of the Brandon Road Dam.

2) Project Performance Monitoring: Performance monitoring is necessary to ensure that fish are responding as expected after the first year of transfer. The USFWS CAR estimated that fish monitoring costs were $6,000/week for 3 weeks for a collection crew plus time for fish identification, data analysis, reporting, and other necessary components for a total of $35,000.

Table N-25. Cost of Selected Mitigation Plan, Alternative B – Trap and Transport

Measure	Cost
Trap and Transport ($66,000 /year for 50 years)	$6,600,000
One-Time Project Performance Monitoring (Project Year 2)	$35,000
Total	**$6,635,000**

The mitigation objective for this project is 110 AAHU. The selected mitigation alternative offsets the loss of these 110 AAHU of longitudinal connectivity with the restoration of 235 net AAHU at an average annual cost of $133,000.00. This is the least cost mitigation plan that provides full mitigation of losses specified in mitigation planning objectives as required in policy (USACE 2000).

7. References

Adams, S.R., and Parsons, G.R. 1995. Swimming performance of the smallmouth buffalo, *Ictiobus bubalus*. Report to the U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Becker, G.C. 1983. Fishes of Wisconsin. The University of Wisconsin Press, Madison, WI. 1052 pp.

Bell, M.C. 1991. Fisheries handbook of engineering requirements and biological criteria. U.S. Army Corps of Engineers, North Pacific Division, Portland, OR. 650 pp.

Carter, B.T. 1954. The movement of fishes through navigation lock chambers in the Kentucky River. Transactions of the Kentucky Academy of Science 15(3): 48-56.

Dahlberg, M.L., D.L. Shumway, and P. Doudoroff. 1968. Influence of dissolved oxygen and carbon dioxide on swimming performance of largemouth bass and Coho salmon. Journal of the Fisheries Research Board of Canada 25:49-70.

DRSCWG (DuPage River Salt Creek Workgroup). 2016. Plan to develop consensus for dam modification and channel enhancement at Fullersburg Woods. Bluestem Communications, Chicago, IL. 42 pp.

DRSCWG (DuPage River Salt Creek Workgroup). 2017. DuPage/Salt Creek special conditions report. DuPage River Salt Creek Workgroup, Naperville, IL. 55 pp.

Farlinger, S., and F.W.H. Beamish. 1977. Effects of time and velocity increments on the critical swimming speed of largemouth bass (*Micropterus salmoides*). Transactions of the American Fisheries Society 106:436-439.

Hammer, J., and R. Linke. 2003. Assessments of the impacts of dams on the DuPage River. The Conservation Foundation, Naperville, IL. 48 pp.

Hocutt, C.H. 1973. Swimming performance of three warmwater fishes exposed to rapid temperature change. Chesapeake Science 14(1): 11-16.

Illinois Department of Natural Resources. 2018. Des Plaines River fishery management plan. Office of Resource Conservation, Region II Streams Program, Plano, IL.

Illinois Environmental Protection Agency. 2006. Illinois Integrated Water Quality Report and Section 303(d) list – 2006. Illinois Environmental Protection Agency, Bureau of Water. Springfield, IL.

Johnson, B.J., T.M. Keevin, E.A. Laux, and T.B. Miller. 2005. Seasonal fish densities in the lock chamber at Lock and Dam 25, Upper Mississippi River. ENV Report 57, U.S. Army Corps of Engineers Upper Mississippi River - Illinois Waterway System Navigation Study, Rock Island, IL 15 pp.

Jones, D.R., Kiceniuk, J.W., and Bamford, O.S. 1974. Evaluation of the swimming performance of several fish species from the Mackenzie River. Journal of the Fisheries Research Board of Canada 31: 1641-1647.

Kinge. M. 1994. Fish migration via the shipping lock at the Hagenstein Barrage: Results of an indicative study. Water Science Technology 29(3): 357-361.

Kolok, A.S. 1992. The swimming performance of individual largemouth bass (*Micropterus salmoides*) is repeatable. Short communication. Journal of Experimental Biology 170: 265-270.

Lake County Stormwater Management Commission. 2018. Des Plaines River watershed-based plan. Lake County Stormwater Management Commission, Libertyville, IL.

Larinier, M. 2000. Dams and Fish Migration. Contributing paper to World Commission on Dams, Thematic II.1 Dams, ecosystem functions and environmental restoration. *Edited by* McCartney, M., Dugan, P., McNeely, J., Acreman, M. Institut de Mecanique des Fluides, Toulouse, France. 26 pp.

Lubejko, M., Whitledge, G., Coulter, A.A., Brey, M., Oliver, D., and Garvey, J.E. 2017. Evaluating upstream passage and timing of approach by adult bigheaded carps at a gated dam on the Illinois River. River Research and Applications 33(8): 1268-1278.

Noonan, M.J., J.W.A. Grant, and C.D. Jackson. 2011. A quantitative assessment of fish passage efficiency. Fish and Fisheries 13(4): 450-464.

O'Brien, W.P., M.Y. Rathbun, and P. O'Bannon. 1992. Gateways to commerce: the U.S. Army Corps of Engineers' 9-Foot Channel Project on the Upper Mississippi River. National Park Service, Rocky Mountain Region, Denver, CO. 238 pp.

Parsons, G. R., and Bartlett, J. 1997. Swimming performance of selected freshwater fish species. Report to the U.S. Army Engineer Waterways Experiment Station, Environmental Laboratory, Vicksburg, MS. University of Mississippi, Oxford.

Parsons, G.R., and R. Smiley. 1994. Swimming performance of white crappie, *Pomoxis annularis*. The effect of environmental change. Freshwater Fisheries Report 136. University of Mississippi, Oxford, MS. 62 pp.

Pfleiger, W.L. 1997. The fishes of Missouri, revised edition. Missouri Department of Conservation. Jefferson City, MO. 372 pp.

Pitlo, J. Jr., A. Van Vooren, and J. Rasmussen. 1995. Distribution and relative abundance of Upper Mississippi River fishes. Upper Mississippi River Conservation Committee Fish Technical Section, Rock Island, IL. 20 pp.

Schmulbach, J.C., Tunink, D.H., and Zittel, A.E. 1981. Swimming performance of fishes endemic to the Missouri River in South Dakota. U.S. Department of the Interior.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Bulletin 184. Fisheries Research Board of Canada, Ottawa, Canada. 966 pp.

Short 1997. Evaluation of Illinois sieved stream sediment data, 1982-1995. IEPA/BOW/97 016. Illinois Environmental Protection Agency, Bureau of Water, Division of Water Pollution Control. Springfield, IL.

Tunink, D.H. 1975. The swimming performance of fishes endemic to the middle Mississippi River. M.S. thesis, University of South Dakota, Vermillion, SD. 126 pp.

U.S. Army Corps of Engineers. 2000. Planning guidance notebook. Engineer Circular No. 1105-2-100, U.S. Army Corps of Engineers, Washington, DC.

U.S. Army Corps of Engineers. 2007. Protocols for certification of planning models, planning models improvement program. Engineer Circular No. 1105-2-407, U.S. Army Corps of Engineers, Washington, DC.

U.S. Army Corps of Engineers. 2015. Upper Des Plaines River and tributaries, Illinois and Wisconsin, integrated feasibility report and environmental assessment. U.S. Army Corps of Engineers, Chicago District, Chicago IL. 298 pp.

U.S. Fish and Wildlife Service. 2011. Proposed upstream and downstream fish passage for Lake Sturgeon at Menominee dam and park mill dam on the Lower Menominee River in the cities of Marinette Wisconsin and Menominee Michigan. U.S. Fish & Wildlife Service, Green Bay, WI. 236 pp.

U.S. Fish and Wildlife Service. 2018. Tentative final fish and wildlife coordination act report on U.S. Army Corps of Engineers GLMRIS – Brandon Road project. U.S. Fish & Wildlife Service Midwest Region, Bloomington, MN.

Videler, J.J. 1993. Fish swimming. Chapman and Hall, London, England. 260 pp.

Water Resources Council. 1983. Federal economic and environmental principles and guidelines for water and related land resources implementation studies. U.S. Army Corps of Engineers, Washington, D.C.

Webb, P.W. 1986. Kinematics of lake sturgeon, *Acipenser fulvescens*, at cruising speeds. Canadian Journal of Zoology 64: 2137-2141.

Wilcox, D.B., E.L. Stefanik, D.E. Kelner, M.A. Cornish, D.J. Johnson, I.J. Hodgins, S.J. Zigler, and B.L. Johnson. 2004. Improving fish passage through navigation dams on the Upper Mississippi River System. Upper Mississippi-Illinois Waterway Navigation Study ENV Report 54. Rock Island District, U.S. Army Corps of Engineers, Rock Island, IL. 110 pp. + Appendices.

Great Lakes and Mississippi River Interbasin Study

Appendix N-A
Fish Passage Connectivity Summary Worksheets

Alternative A - Project with No Mitigation

Minimum Current Velocity at Hydraulic Steps (ft/sec): N/A
Fs - Size of Fishway: 1
Discharge: N/A

	Fl Fishway Location	Ei Potential to Encounter	Ui Potential for Species to Use Fishway Type	Di Duration of Migration Period Passable	Ei x Ui x Di	Є = Fish Passage Connectivity at Brandon Road Dam
Longnose gar	1	1	3	0.05	0.2	0.01
Mooneye	1	1	3	0.05	0.2	0.01
American eel	1	1	3	0.05	0.2	0.01
Quillback	1	1	3	0.05	0.2	0.01
Black redhorse	1	1	3	0.05	0.2	0.01
Channel catfish	1	1	3	0.05	0.2	0.01
White bass	1	1	3	0.05	0.2	0.01
Largemouth bass	1	1	3	0.05	0.2	0.01
Walleye	1	1	3	0.05	0.2	0.01
					Avg.	0.01

Alternative B – Trap and Transport

Minimum Current Velocity at Hydraulic Steps (ft/sec): N/A
Fs - Size of Fishway: 1
Discharge: N/A

	Fl Fishway Location	Ei Potential to Encounter	Ui Potential for Species to Use Fishway Type	Di Duration of Migration Period Passable	Ei x Ui x Di	Є = Fish Passage Connectivity at Brandon Road Dam
Longnose gar	3	2	1	1.00	2.0	0.08
Mooneye	3	2	1	0.80	1.6	0.06
American eel	3	2	1	0.41	0.8	0.03
Quillback	3	2	1	0.82	1.6	0.07
Black redhorse	3	2	1	0.67	1.3	0.05
Channel catfish	3	2	1	0.83	1.7	0.07
White bass	3	2	1	0.80	1.6	0.06
Largemouth bass	3	2	1	1.00	2.0	0.08
Walleye	3	2	1	0.60	1.2	0.05
					Avg.	0.06

Alternative C - Upper Des Plaines/Salt Creek

Minimum Current Velocity at Hydraulic Steps (ft/sec): N/A
Fs - Size of Fishway: 5
Discharge: N/A

	Fl Fishway Location	Ei Potential to Encounter	Ui Potential for Species to Use Fishway Type	Di Duration of Migration Period Passable	Ei x Ui x Di	Є = Fish Passage Connectivity at Fullersburg Woods Dam
Longnose gar	5	5	5	1.00	25.0	1.00
Mooneye	5	5	5	1.00	25.0	1.00
American eel	5	5	5	1.00	25.0	1.00
Quillback	5	5	5	1.00	25.0	1.00
Black redhorse	5	5	5	1.00	25.0	1.00
Channel catfish	5	5	5	1.00	25.0	1.00
White bass	5	5	5	1.00	25.0	1.00
Largemouth bass	5	5	5	1.00	25.0	1.00
Walleye	5	5	5	1.00	25.0	1.00
					Avg.	1.00

Alternative D. DuPage River Rock Ramp

Minimum Current Velocity at Hydraulic Steps (ft/sec): N/A
Fs - Size of Fishway: 5
Discharge: N/A

	Fl Fishway Location	Ei Potential to Encounter	Ui Potential for Species to Use Fishway Type	Di Duration of Migration Period Passable	Ei x Ui x Di	Є = Fish Passage Connectivity at Channahon Dam
Longnose gar	5	5	5	1.00	25.0	1.00
Mooneye	5	5	5	1.00	25.0	1.00
American eel	5	5	5	1.00	25.0	1.00
Quillback	5	5	5	1.00	25.0	1.00
Black redhorse	5	5	5	1.00	25.0	1.00
Channel catfish	3	4	5	1.00	20.0	0.80
White bass	3	4	5	1.00	20.0	0.80
Largemouth bass	5	5	5	1.00	25.0	1.00
Walleye	3	4	5	1.00	20.0	0.80
					Avg.	0.93

Alternative E - Brandon Road Dam Native Fish Passage

Minimum Current Velocity at Hydraulic Steps (ft/sec): N/A
Fs - Size of Fishway: 1
Discharge: N/A

	Fl Fishway Location	Ei Potential to Encounter	Ui Potential for Species to Use Fishway Type	Di Duration of Migration Period Passable	Ei x Ui x Di	Є = Fish Passage Connectivity at Brandon Road Dam
Longnose gar	1	1	1	0.13	0.1	0.01
Mooneye	1	1	1	0.13	0.1	0.01
American eel	1	1	1	0.13	0.1	0.01
Quillback	1	1	1	0.13	0.1	0.01
Black redhorse	1	1	3	0.13	0.4	0.02
Channel catfish	1	1	3	0.13	0.4	0.02
White bass	1	1	3	0.13	0.4	0.02
Largemouth bass	1	1	1	0.13	0.1	0.01
Walleye	1	1	3	0.13	0.4	0.02
					Avg.	0.01

Alternative F - USFWS CAR

Minimum Current Velocity at Hydraulic Steps (ft/sec): N/A
Fs - Size of Fishway: 5
Discharge: N/A

	Fl Fishway Location	Ei Potential to Encounter	Ui Potential for Species to Use Fishway Type	Di Duration of Migration Period Passable	Ei x Ui x Di	Є = Fish Passage Connectivity at Brandon Road Dam
Longnose gar	5	5	5	1.00	25.0	1.00
Mooneye	5	5	5	1.00	25.0	1.00
American eel	5	5	5	1.00	25.0	1.00
Quillback	5	5	5	1.00	25.0	1.00
Black redhorse	5	5	5	1.00	25.0	1.00
Channel catfish	5	5	5	1.00	25.0	1.00
White bass	5	5	5	1.00	25.0	1.00
Largemouth bass	5	5	5	1.00	25.0	1.00
Walleye	5	5	5	1.00	25.0	1.00
					Avg.	1.00