Lower Yellowstone Intake Diversion Dam Fish Passage Project, Montana

FINAL - APPENDIX D

Lower Yellowstone Intake Fish Passage EIS

Fish Passage Connectivity Index and Cost Effectiveness and Incremental Cost Analysis

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Attachment 1 Table 4. Estimate Suitability of Fishway Locations (Fl) for Each Fish Guild Based Upon Swimming Performance and Behavior.

Attachment 2 FPCI Model Approval

1.0 Fish Passage Connectivity Index

1.1 Introduction

Intake Diversion Dam has likely impeded upstream fish passage for pallid sturgeon and other fish species in the Yellowstone River since it was completed in approximately 1909. The best available science suggests that the diversion dam is a partial barrier to some fish species including shovelnose sturgeon (Bramblett, et al. 2015; Helfrich et al. 1999; Jaeger et al. 2004; Backes et al. 1994; Stewart 1986, 1988, 1990, 1991; Rugg et al. 2016). It is essentially a total barrier to other fish species, such as pallid sturgeon, due to a high level of turbulence associated with the rocks at the dam crest and in the downstream boulder field and high velocities at the dam crest (Jaeger et al. 2005; Fuller et al. 2007; Helfrich et al. 1999; White and Mefford 2002; Bramblett and White 2001). Pallid sturgeon were tracked passing upstream of the dam via the existing high-flow side channel in 2014 and 2015 (Rugg 2014, 2015; Rugg et al. 2016) during flows greater than 30,000 cfs. It is not known if passage has occurred before 2014 because this was the first year that fish were tracked swimming upstream of the dam.

Improving fish passage at Intake Diversion Dam accomplishes several things from a pallid sturgeon recovery perspective:

- It would provide access to approximately 165 miles of Yellowstone River habitat upstream of Intake Diversion Dam and additional miles on tributaries such as the Powder River that are currently inaccessible to the pallid sturgeon;
- The area to which access would be provided appears to include substantial areas of suitable spawning habitat for pallid sturgeon including bluff pools and other areas of swift water over gravel and cobble substrates (Jaeger, et al. 2005, Rugg 2014, 2015; Bramblett, et al. 2015);
- If 165 more river miles were accessible for spawning, it would provide longer drift distances and a larger area available for larvae to stop dispersal and seek rearing habitat before reaching Lake Sakakawea, which is currently thought to be unsuitable larval settling habitat due to the fine substrates and low dissolved oxygen levels (Braaten et. al. 2008, 2011; Guy et al. 2015; Bramblett & Scholl 2016)

While the primary purpose of a fish passage project at Intake Dam is to improve pallid sturgeon passage, other migratory species of fish are also likely to benefit from the project. This includes fish that are important from a management perspective by the State of Montana, such as shovelnose sturgeon, paddlefish, sauger, and blue sucker, as well as a variety of native fish species that reside in the Yellowstone River and undertake shorter seasonal movements.

Federal agencies are required to evaluate the economic and environmental costs and benefits of water resources projects that it undertakes (CEQ 2013). For a project with environmental benefits, such as this fish passage project, benefits are not reasonably monetized. However, if benefits can be quantified in some dimension, cost effectiveness and incremental cost analysis can be used to assist in selecting a preferred plan. Cost effectiveness analysis evaluates which alternatives are the least-costly way of attaining the project objectives. Incremental analysis is then used to evaluate the change in cost from each measure or alternative to the next to determine their incremental costs and incremental benefits. This type of analysis helps identify which measures or alternatives provide more benefits for lower cost and can be used as one element to inform the selection of a preferred plan.

1.2 Fish Passage Connectivity Index

The Fish Passage Connectivity Index (FPCI) was developed to evaluate ecosystem outputs (i.e. benefits) of alternative measures for fish passage improvements on the Upper Mississippi River and Illinois Waterway System for cost effectiveness and incremental analysis (Corps 2011). The model was developed for use in the plan formulation process for the Navigation and Ecosystem Sustainability Program for the Upper Mississippi River System fish passage improvement ecosystem restoration projects. The model is semi-quantitative in that relative scores are assigned to variables using best professional judgment informed by available literature on fish behavior and swimming abilities. The model is currently in review by the Ecosystem Restoration Center of Expertise as required for use in the U.S. Army Corps of Engineers (Corps) planning context for this project (Corps 2016). This model was used in an assessment of fish passage alternatives at Intake Diversion Dam in 2015 (Corps 2015).

The FPCI is a simple arithmetic index that is calculated as:

$$\epsilon = \frac{\Sigma\, i \ldots n\ [(E_i \times U_i \times D_i)/25]}{n}$$

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.

Ei = Probability of encountering the fishway entrance is a calculated value ranging from 1 to 5, where 5 = highly likely; 3 = moderate probability; 1 = unlikely.

Ui = 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.

Di = Duration of availability, the fraction of the upriver migration period for fish species i that the passage pathway is available. Di incorporates a risk component (i.e., the potential failure of an alternative to perform or be available during a critical fish movement period.)

Although the model was developed to measure benefits of fish passage in the Upper Mississippi River, the model is applicable (with slight adjustments) to fish passage projects on other large river systems, especially those with very similar fish communities. This model, with minor adjustment, was used as a planning tool for comparing benefits of alternative measures for provide fish passage at Intake Dam. It should be recognized that this model is a planning tool that relies on the best professional judgment of users (informed by the published literature on the species) and does not represent a statistical probability of fish passage but a relative comparison of effectiveness. This memo describes the input data used and minor adjustments made to the model to demonstrate ecological benefits of the Yellowstone River Intake Diversion Dam fish passage alternatives.

1.3 Data Required for the Model

1.3.1 Identify fish to be included for analysis, and their associated habitat preferences, swimming behaviors, and swimming abilities.

1.3.1.1 The FPCI model was created with a list of 40 fish species that could be considered for use in the model (Corps 2011). This list does not include pallid sturgeon. Swimming performance data, swimming behavior, and critical current velocities (Ucrit) for prolonged swimming by adult fish used in the creation of the model were sourced from two primary studies on the Upper Mississippi River (Wilcox et al. 2004; Pitlo et al. 1995). More recent data were used to calculate an estimated Ucrit for adult pallid sturgeon (Braaten et al. 2015) and to make one other change to anticipated swimming speeds of other species; walleye Ucrit was reduced to 3.0 feet/second (Peake et al. 2000). The 14 species used in this model are shown in Table 1-1.

1.3.1.2 For ensuring a good comparison of benefits across fish passage alternatives, the fish species selected for use in this FPCI modeling effort, the thirteen (13) species used by the Corps in 2014 with the addition of pallid sturgeon, for a total of 14 species. The inclusion of pallid sturgeon does not change the ranking of alternatives. Because this project is focused on improving fish passage for pallid sturgeon, the project team felt that including it specifically (instead of using shovelnose sturgeon as a surrogate) gives added importance to pallid sturgeon capabilities and provides a better differentiation between similar alternatives. As explained in the Corps (2015) modeling, the other 13 species were selected because they represent the native migratory species typically found in the Yellowstone River at Intake Diversion Dam and the species provide good representation of the various guilds of fish based on their various migration behaviors (benthic (8), pelagic (2), and littoral (3) and swimming abilities (strong (6), medium (5), weak (2)).

1.3.1.3 Habitat preferences/use for each species was considered acceptable as presented in the FPCI with one slight adjustment as noted by the Corps (2015); white sucker, blue sucker and river carpsucker were shown only to be associated with main channel border habitats in the original FPCI. However, for purposes of this study, these species were also assumed to utilize main channel habitats. The “main channel” habitat type in the Upper Mississippi River was defined as a navigation channel, which is very different than main channel habitats in the Yellowstone River, and may be the reason those species were not associated with that habitat type. These three species are known to utilize main channel habitats available in the Yellowstone and Upper Missouri River systems, and as such, were associated with it for purposes of this study. In addition, pallid sturgeon was included and shown with a habitat preference for main channel and main channel border habitats similar to the habitat preferences provided for shovelnose sturgeon.

1.3.1.4 Fish species of concern are well represented. Species of special concern that are included in this analysis include the shovelnose and pallid sturgeon, paddlefish, sauger, and blue sucker. Habitat loss and fish passage barriers have contributed to the decline of these species (Montana AFS 2016). It is important to ensure fish passage alternatives do not reduce passage for these species.

Table 1.1. Species Used in the FPCI Model for Intake Diversion Dam with Swimming Speed and Habitat Preference.

Common Name	Scientific Name	Swimming Behavior	Swimming Performance	Swimming Speed (Ucrit)[1,2,3] (ft/sec)	Habitat Preference
Shovelnose sturgeon	*Scaphirhynchus platorhynchus*	Benthic	Medium	2.7	B,C
Paddlefish	*Polyodon spathula*	Pelagic	Strong	4.2	B,C
Goldeye	*Hiodon tergisus*	Pelagic	Medium	2	A,B,D,E
Smallmouth buffalo	*Ictiobus bubalus*	Benthic	Medium	2.1	B,C,D,E
Blue sucker	*Cycleptus elongatus*	Benthic	Strong	2.6	B,C
White sucker	*Catosomus commersoni*	Benthic	Weak	2.1	B,C
River carpsucker	*Carpiodes carpio*	Benthic	Weak	1.5	B,D,E
Shorthead redhorse	*Moxostoma macrolepidotum*	Benthic	Medium	2	B,C
Channel catfish	*Ictalurus punctate*	Benthic	Strong	2.7	A,B,C,D,E
Smallmouth bass	*Micropterus salmoides*	Littoral	Medium	2.1	A,B,D,E
Walleye	*Sander vitreus*	Littoral	Strong	3[4]	B,C,D
Sauger	*Sander canadensis*	Littoral	Strong	2.6	B,C,D
Freshwater drum	*Aplodinotus grunniens*	Benthic	Strong	2.7	A,B,C,D,E
Pallid sturgeon	*Scaphirhynchus albus*	Benthic	Medium	3.3	B,C

A = Contiguous floodplain lake; B = Main channel border; C = Main channel; D = Secondary channel; E = Tertiary channel; F = Tributary

[1] Pitlo, J., Jr., Van Vooren, A., and Rasmussen, J. (1995). "Distribution and relative abundance of Upper Mississippi River fishes," Upper Mississippi River Conservation Committee Fish Technical Section, Rock Island, IL.

[2] Wilcox, D.B. et al (2004) "Improving fish passage through navigation dams on the Upper Mississippi River system", ENV Report 54, U.S. Army Corps of Engineers, Rock Island, St. Louis, and St. Paul Districts

[3] Braaten, P.J., C.M. Elliott, J.C. Rhoten, D.B. Fuller, & D.J. McElroy. 2015. Migrations and swimming capabilities of endangered pallid sturgeon (*Scaphirhynchus albus*) to guide passage designs in the fragmented Yellowstone River. Restoration Ecology 23(2): 186-195.

[4] Peake, S., R.S. McKinley, & D.A. Scruton. 2000. Swimming performance of walleye (*Stizostedion vitreum*). Canadian Journal of Zoology 78: 1686-1690.

1.3.2 Identify habitat acres made available by passage.

1.3.2.1 Habitat Units are calculated in the model by multiplying the fish passage index by the total acres of available preferred habitat upstream of Intake Diversion Dam for each species. For this analysis, the habitat acres mapped between Intake and Cartersville on low-level aerial photography for the *Yellowstone River Cumulative Effects Analysis* (Corps & YRCDC 2015; Corps 2015; Yellowstone River Corridor Clearinghouse 2016) were used.

1.3.2.2 Habitat types from the Cumulative Effects Analysis (CEA) include the following primary categories:

Scour – (SC) Scour pool occurring in otherwise unconstrained river channel.

Bluff – (BL) Scour pool located at the base of a bedrock bluff. Indicates a relatively permanent pool location bounded by a geologic constraint.

Terrace – (T) Scour pool located at the base of a terrace (Quarternary Alluvium).

Riprap Bottom – (RRB) Scour pool occurring in riprap constrained channel where riprap is located in the middle of the active channel area.

Riprap Margin – (RRM) Scour pool occurring in riprap constrained channel where riprap is located at the edge of the active channel area.

Channel Crossover – (CC) A transitional unit where the river is translating from one bendway or pool to the next.

Bedrock – (BED) Channel is controlled by bedrock bed.

Secondary Channel – (2C) Undifferentiated low flow channel. No additional habitat typing is defined, though the channel likely contains areas of pool and riffle.

Secondary Channel Seasonal – (2CS) Secondary channel High flow channel.

Point Bar – (PB) Areas in the bank full lines that show aggradation associated with the insides of a bendway. Can include exposed gravel, or areas with vegetation, as long as they lie within the bank full area.

Side Bar – (SB) Areas in the bank full lines that show aggradation along the sides of a channel. These bar areas create channel sinuosity at low flows but are inundated at higher or bank full flows. Can include exposed gravel, or areas with vegetation, as long as they lie within the bank full area.

Mid-Channel Bar – (MCB) Areas in the bank full lines that show aggradation, creating islands within the low flow area. Can include exposed gravel or areas with emergent vegetation, as long as they lie within the bank full area.

Dry Channel – (DC) This is a general category for areas within the bank full boundaries that do not fit into Point Bar, Side Bar, Mid-channel Bar, or Island categories. They are generally associated with split flows around islands where there is exposed channel bed at low flow, but does not appear to be strictly depositional in nature, though they could still have some depositional characteristics. Can include exposed gravel or areas with vegetation, as long as they lie within the bank full area.

Dam – Habitat unit is influenced by a dam in the main channel.

1.3.2.3 As depicted in Table 1-2, the CEA habitat categories were cross-walked to the habitat categories as defined for the Upper Mississippi River in the FPCI, allowing Yellowstone River habitat acreages to be compatible with the existing layout as presented in the FPCI model. The habitats for the Upper Mississippi River were defined as:

- Contiguous Floodplain Lake
- Main Channel Border
- Main Navigation Channel
- Secondary Channel
- Tertiary Channel
- Tributary Channel

1.3.3 Identify Windows of Opportunity for Upstream Fish Passage

A window of opportunity, or the timing of when fish passage is physically possible at a dam due to typical peak flows (and suitable depths and velocities), compared with the timeframe of when fish typically migrate, is used to estimate the duration of availability (Di) for the baseline condition and each alternative in the FPCI. The Corps (2015) modified the "percent probability of open river conditions" in the original model (which referred to when the dam gates were open on the Upper Mississippi River) and used available literature (Jaeger, et al. 2005; Helfrich et. al. 1999), anecdotal information, and best professional judgment, to assign probabilities that passage opportunities exist on a weekly basis as a function of flow, with highest probabilities being associated with the peak of the typical hydrograph, and very small (1%) probabilities being attributable to the timeframes outside of the peak river flow (September-April). These same probabilities were used in this analysis for the existing conditions. Table 1-3 shows the windows of opportunity for fish passage, as entered into the FPCI model to represent the no action alternative (existing condition).

For the rock ramp alternative, the depths and velocities are suitable at most times, but for some species at some flows, depths may be too shallow or velocities too high to have suitable passage. Thus, the 2D model results for the rock ramp were used to indicate the duration of passage availability for the median flows in each month of interest. Table 1-4 shows the opportunity for passage as used in the FPCI model for the rock ramp alternative.

For the other alternatives, an assumption was made both by the Corps in 2015 and for this application that the duration available for fish passage would be 100% during the pre-spawn and spawning migration season for the bypass channel, modified side channel, and dam removal alternatives because suitable depths and velocities would be provided across all typical flows. Table 1-5 shows the opportunity for passage as used in the FPCI model for these remaining alternatives.

1.3.3.1 Seasonality of Fish Migration

Basic information on fish migratory behaviors and timing from the original FPCI model was modified by Corps (2015) because the actual time of year when migration takes place on the Yellowstone River is different than on the Mississippi River. Movement and spawning periods were pushed back 3-4 weeks later in the year as migrations tend to take place later in the year for cooler, more northern latitudes. Other information considered in establishing the migratory timeframes for the Yellowstone River at Intake Diversion Dam included data found in Elser, et al. (1977), anecdotal data from George Jordan (Mike Backes, Montana Fish Wildlife and Parks survey data) and best professional judgment. Migratory timeframes as utilized in the FPCI modeling for the Intake Dam project are shown in Table 1-6.

In addition, for this analysis, the migratory timing was adjusted for four fish species: shovelnose sturgeon, paddlefish, blue sucker, and sauger based on literature available for these species from recent tracking on the Yellowstone River (Rugg 2014, 2015; Rugg et al. 2016; Bramblett et al. 2014). Pallid sturgeon timing was also adjusted based on recent tracking data for the Yellowstone River (Delonay et al. 2015; Rugg 2014, 2015; Rugg et al. 2016).

Table 1.2. Habitat crosswalk for area between Intake and Cartersville (Yellowstone River Corridor Clearinghouse 2016).

Low Flow Fisheries Habitat	Acres	Habitats as Defined in UMRC FPCI Model					
		Contiguous Floodplain Lake	Main Channel Border	Main Nav Channel	Secondary Channel	Tertiary Channel	Trib Channel
2C - Secondary low flow channel	1,251				1,251		
2CS - Secondary high flow channel	1,930				1,930		
CC - Channel crossover	3,152			3,152			
DC - Dry Channel not meeting PB, SB, MCB or I categories	1,348					1,348	
I - Islands - vegetated	6,589						
MCB - Mid Channel Bar aggradation area within bankfull lines	772		772				
PB - Point Bar area in bankfull line showing aggradation	1,062		1,062				
SB - Side Bar area in channel showing aggradation at high flow lines at bank	0						
RRB - Scour at riprap - mid active channel	722			723			
RRM - Scour at riprap - margin of active channel	723		723				
SC - Scour in unconstrained river	3,099			3,099			
T - Scour at base of terrace	1,762		1,762				
BL - Scour at base of bedrock bluff	1,293		1,293				
Trib - Large tributary confluences	10						10
Dam	51			51			
TOTAL		0	5,612	7,025	3,181	1,348	10

Table 1.3. Opportunity for Fish Passage at Intake Diversion Dam for the No Action (existing conditions; associated primarily with peak runoff).

Month	Jan-Apr			May			June			July			Aug-Dec		
Week	1-17	18	19	20	21	22	23	24	25	26	27	28	29	30	31-52
% Opportunity for Passage	1	1	1	25	50	100	100	100	100	100	50	25	1	1	1

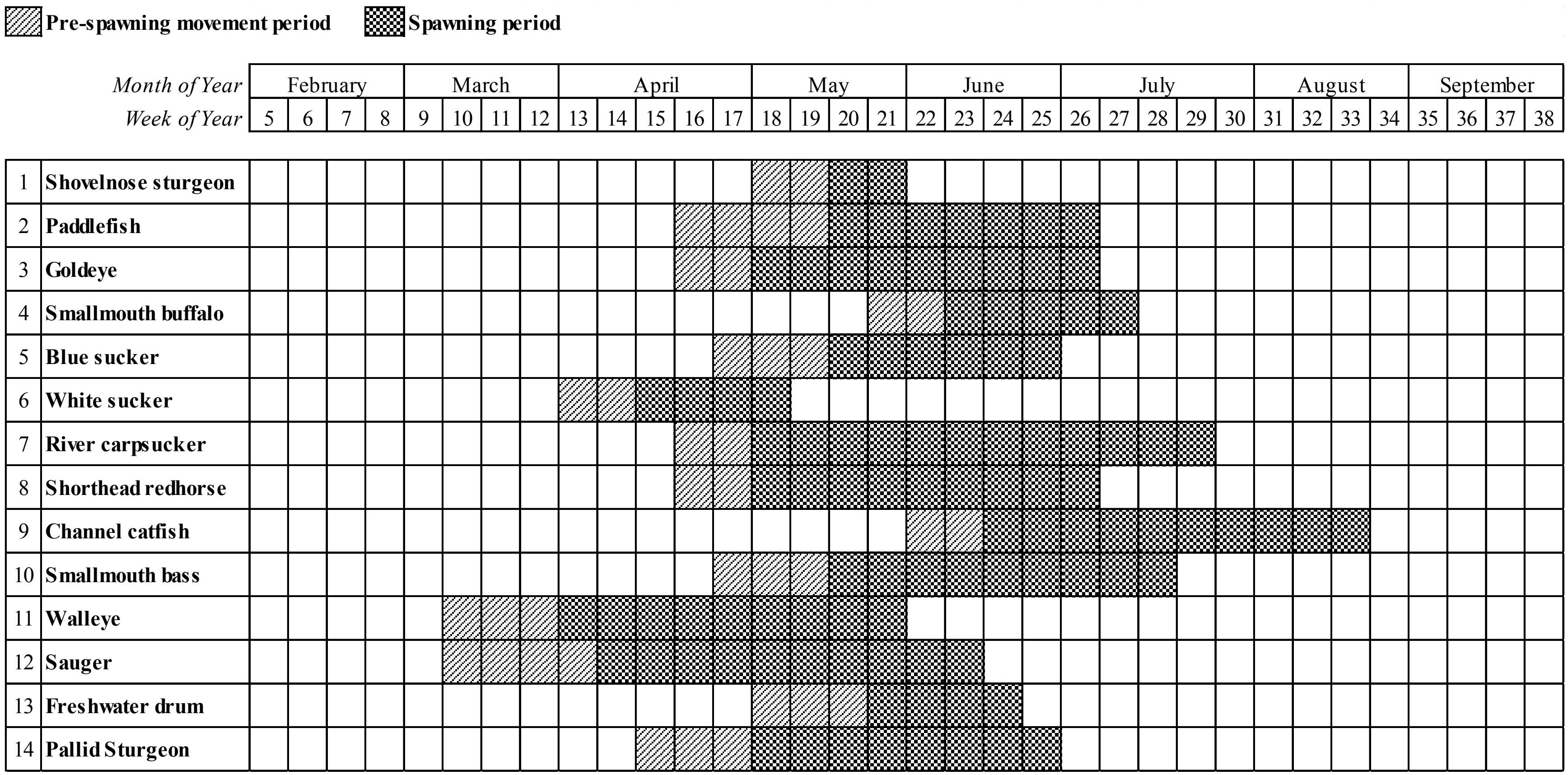
Table 1.4. Opportunity for Fish Passage for Rock Ramp Alternative

Month	Jan-Mar	Apr	May	June	July	Aug	Sept	Oct-Dec
Week	1-13	14-17	18-21	22-25	26-30	30-34	35-38	39-52
% Opportunity for Passage	1	95	97	100	97	95	95	1

Table 1.5. Opportunity for Fish Passage for the Bypass Channel, Modified Side Channel, and Multiple Pump Alternatives

Month	Jan-Mar	Apr	May	June	July	Aug	Sept	Oct-Dec
Week	1-13	14-17	18-21	22-25	26-30	30-34	35-38	39-52
% Opportunity for Passage	1	100	100	100	100	100	100	1

Table 1.6. Migratory Timing for Species Used in FPCI.



1.3.4 Identity Potential Fish Passage Connectivity

1.3.4.1 Probability that Fish Encounters Fish Passage Alternative **(Ei)**

E_i simulates the relationship between fishway size (F_s) and ability of a fish to encounter the fishway entrance location (F_l) within the FPCI. (E_i) is expressed as a value ranging from 1 to 5, with 5 being highly likely, and 1 being unlikely. The relationship is represented by the following equation: $E_i = (F_s+F_l)/2$

1.3.4.2 Determine Potential for Fish to Encounter Passage Alternative **(Fl)**

Fl is used to assess the suitability of the fishway entrance location for each fish guild based on swimming performance and behavior. As described in the FPCI, swimming performance and migration behavior are important because they indicate the route as well as vertical and horizontal position within the flow field that a fish would generally select. Guilds of fish species, as defined by swimming performance and behavior. Table 4 in the Corps (2011) model documentation assigned values for the potential for fish species to encounter a fish passageway located in main channel, main channel border (near channel), main channel border (near shore) and lock locations (Table 4 attached). Species that primarily use main channel habitats are highly likely to encounter a main channel passageway (received a score of 5, indicating that the fish passageway entrance would be encountered by a significant portion of the population of that species). Species that primarily use channel border, side channel, or other habitats would be unlikely to encounter a main channel fish passageway (received a score of 1 indicating that it was unlikely the fish passageway entrance would be encountered). Scores ranging from 1 to 5 were assigned based on the location of the fish passageway in comparison to the primary habitat used by the species.

To assign an Fl value to each guild, the Corps (2015) used the same likelihood that was used in the Upper Mississippi system based on monitoring data and the professional judgment of an interagency group of large river fisheries biologists. For this analysis, as additional alternatives were included and additional detailed design had been completed for the proposed bypass channel to maximize the orientation and flows from the bypass channel for main channel fish to locate the channel entrance, the scores were re-evaluated and adjusted. The no action and rock ramp scores were not modified from the scores used by the Corps in 2015 (Table 1-8). For the bypass channel, main channel species including pallid sturgeon, shovelnose sturgeon, paddlefish, and blue sucker were assigned a score of 4 as the bypass channel entrance has been further modeled and designed for its attraction flows to be directed towards the main channel thalweg where these main channel species would be present. Additionally, walleye and sauger were assigned a score of 5 as the bypass channel entrance would be located and directed towards the near channel areas used by these species.

1.3.4.3 Determining the Size of Fish Passage Alternative (Fs)

- This parameter is the size of the fishway relative to the discharge of the river under low flow conditions. For the Yellowstone River, Corps (2014) used the recommendation by the BRT that fish passage alternatives should be capable of conveying up to 30% of river flow. Therefore the following range of inputs for Fs were established by Corps (2015) for the

Intake project; 5 was assigned to fishway designs that pass 30 percent or more of the low flow discharge, 4 = 25 percent, 3 = 20 percent, 2 = 15 percent, and 1 = equal to or less than 10%.

- More recent tracking of pallid sturgeon passing upstream of Intake Diversion Dam by pallid sturgeon in 2014 and 2015 (Rugg 2014, 2015) indicates that passage is possible when flow in the existing side channel is only 2-6% of the river flow (based on HEC-RAS modeling for this study of flow splits into the side channel at river flows from 30,000 to 63,000 cfs, which was the rage of river flows when passage occurred).

The size of fishway for each alternative is listed in Table 1-9. The No Action, Rock Ramp, and dam removal alternatives all pass full flows of the river and received inputs of 5, whereas the bypass channel and modified side channel alternatives pass 15% of the flow and received inputs of 2.

Table 1.7. Swimming Performance and Behavior Guilds.

Performance	Behavior		
	Benthic	**Littoral**	**Pelagic**
Strong	Pallid sturgeon	Walleye	Paddlefish
	Shovelnose sturgeon	Sauger	
	Blue sucker		
Medium	Channel catfish	Smallmouth bass	Goldeye
	Freshwater drum		
	Shorthead redhorse		
	Smallmouth buffalo		
Weak	River carpsucker		
	White sucker		

Table 1.8. Estimate of Likelihood of Encountering the Fishway Entrance for Each Fish Guild. (Values: 5 – significant portion of population would encounter, 1 –unlikely that fish would encounter)

Estimated Probability of Encountering Fishway Locations (Fl) for Each Fish Guild				
	Fishway Location			
Guild	**Main Channel – Rock Ramp**	**Main Channel Border –Near Channel Thalweg(Bypass Channel)**	**Main Channel Border – Near Shore or Side Channel (Modified Side Channel)**	**No Dam**
Benthic – Strong -Pallid Sturgeon -Shovelnose Sturgeon -Blue sucker	5	4	2	5
Littoral – Strong -Walleye -Sauger	5	5	5	5
Pelagic – Strong -Paddlefish	5	4	2	5
Benthic – Medium -Channel Catfish -Freshwater Drum -Shorthead Redhorse -Smallmouth Buffalo	3	5	5	5
Littoral – Medium -Smallmouth Bass	1	5	5	5
Pelagic – Medium -Goldeye	1	5	5	5
Benthic – Weak -River Carpsucker -White Sucker	1	5	5	5
Littoral – Weak	1	5	5	5
Pelagic – Weak	1	5	5	5

Table 1.9. FPCI input data for Size of the fishway relative to flow (Fs). (Range of inputs for Fs are as follows: 5 = >30% of low flow discharge of river, 4 = 25% to >20% percent, 3 = 20% to >15% percent, 2 = 15% to >10%, and 1 = < 10%)

Size of Fishway (F_s)					
Measure A: No Action	**Measure B: Rock Ramp**	**Measure C: Bypass Channel 15% Flow**	**Measure D: Modified Side Channel 15% Flow**	**Measure E: Multiple Pumps**	**Measures F: Multiple Pumps with Conservation Measures**
F_s - Size of Fishway: 5	F_s - Size of Fishway: 5	F_s - Size of Fishway: 2	F_s - Size of Fishway: 2	F_s - Size of Fishway: 5	F_s - Size of Fishway: 5

1.3.4.4 Determine the Potential (U_i) for Fish to Use Alternative Fish Passage Measures, and the Duration of Availability (D_i) of the Alternative Measures.

The potential for a fish to pass upriver past an obstacle is dependent on its swimming performance, the hydraulic conditions that are encountered, and the likely pathway a fish would use (i.e. main channel vs. bank zone). Critical current velocities (U_{crit}), or the speed at which a fish can maintain prolonged swimming by adult fish used in this analysis are found in Table 1-1. The average current velocity at specific locations within each alternative (at 30,000 or 40,000 cfs) was compared to the U_{crit} speed for each migratory fish species. Scores can be selected over a range from 1 to 5. If velocities did not exceed the U_{crit} speed, the U_i was scored a 5. If velocities exceed U_{crit} speed, but was not likely to exceed burst speed it was scored a 3, and if velocity was likely to exceed burst speeds in a key location (i.e. inlet or outlet), or was widespread without potential for resting, it was scored a 1.

Scores for Ui can be found in Table 1-10. Explanation of the selection of scores are provided below.

a. Flow velocities over the existing dam are over 10 ft/sec, with turbulent flow. As such, it scores 1 for the U_i variable for most fish, with the exception of shovelnose sturgeon, paddlefish, blue sucker, walleye and sauger that have been documented to pass over the dam occasionally (Rugg et al. 2016; Bramblett, et al. 2015), thus each getting a score of 2.
b. The rock ramp has slightly reduced velocities as compared to the existing condition, but exceeds the U_{crit} of all species over a majority of the ramp (i.e. 8 ft/sec) and would likely have turbulent flow. The only fish likely to be able to pass consistently is paddlefish that have high U_{crit}, thus meriting a 5. Walleye is a strong swimmer that may be able to pass high velocities, but based on data from Peake et al. (2000) indicating walleye do not like to transition from slower to faster water readily, thus meriting a slightly reduced score of 4. Fish that are more littoral or pelagic in behavior that may use the margins of the rock ramp received a 3, and strong benthic swimmers other than paddlefish also received a 3, since passage is likely to be somewhat improved and these species have occasionally shown an ability to pass over the dam. Pallid sturgeon are still unlikely to be able to swim through turbulent flows and uneven rocks over such a long distance, although improved from the existing condition, thus receiving a 2 and river carpsucker are weak swimmers, thus receiving a 1.
c. The bypass channel and modified side channel velocity modeling indicates velocities not greater than the U_{crit} for all species along the sides of the channel, thus allowing passage for all species.
d. While not a consideration in the modeling, both the bypass and modified side channel alternatives would also have much less turbulence associated with them, as they would both provide channels that are very much like existing side channels of the Yellowstone River in terms of width, gradient and substrate.
e. The multiple pump alternatives would return the channel to near natural conditions, thus allowing passage for all species.

1.3.4.5 Duration of Availability (Di) of the fish passage structure is the proportion of time when both the fish passage structure is physically available for passage, and migration is actually occurring for a particular species of fish.

Table 1-11 identifies when fish passage alternatives are available to fish for each alternative.

Di for the existing condition is calculated as the fraction of time that upriver movement may generally occur when the physical conditions at the dam allow for passage, typically during runoff. Thus, the Di is highly variable between each species of fish, depending on their migration timing in relation to the runoff period.

The Di for the rock ramp would be more passable with a low-flow channel through the replacement weir and ramp, but does not necessarily provide suitable depths and velocities at all times for all species and would not necessarily be the location where all species would seek passage. Thus, D_i was calculated from the opportunity for passage and migration timing of the species in relation to the runoff period.

The Di for all the other alternatives is available 100% of the time (ranked a 1) when passage is occurring. This is because the channels are all designed to have 13-15% flows at all flows above 7,000 cfs and also still convey flow down to 3,000 cfs, or lower, in the river.

Scores can be selected on a scale of 1 to 5: If velocities do not exceed the U_{crit} speed for the alternative, the U_i was scored a 5; If velocities exceed U_{crit} speed but did not exceed burst speed it was scored a 3; and if velocities exceed burst speeds at all times it was scored a 1. Scores of 2 or 4 were selected for instances of known, but infrequent passage or limited flows when velocities do not exceed burst speed; or if velocities occasionally exceed U_{crit}, respectively.

Table 1.10. Potential (Ui) for Fish to Use Alternative Fish Passage Measures.

Potential for Species to Use Fishway Type						
	Measure A: No Action	**Measure B: Rock Ramp**	**Measure C: Bypass Channel 15% Flow**	**Measure D: Modified Side Channel**	**Measure E: Multiple Pumps**	**Measure F: Multiple Pumps with Conservation Measures**
Fish Species	Ui	Ui	Ui	Ui	Ui	Ui
Shovelnose sturgeon	1	3	5	5	5	5
Pallid sturgeon	1	2	5	5	5	5
Paddlefish	2	5	5	5	5	5
Goldeye	1	3	5	5	5	5
Smallmouth buffalo	1	3	5	5	5	5
Blue sucker	2	3	5	5	5	5
White sucker	1	3	5	5	5	5
River carpsucker	1	1	5	5	5	5
Shorthead redhorse	1	3	5	5	5	5
Channel catfish	1	3	5	5	5	5
Smallmouth bass	1	3	5	5	5	5
Walleye	2	4	5	5	5	5
Sauger	1	3	5	5	5	5
Freshwater drum	1	3	5	5	5	5

Table 1.11. Duration Of Availability (Di) Of The Fish Passage Structure Is The Proportion Of Time When Both The Fish Passage Structure Is Physically Available For Passage, And Migration Is Likely Occurring For A Particular Species Of Fish.

Potential of Availability of Fishway Alternatives						
	Measure A: No Action	**Measure B: Rock Ramp**	**Measure C: Bypass Channel 15% Flow**	**Measure D: Modified Side Channel**	**Measure E: Pumping**	**Measure F: Ranney Wells**
Fish Species	Di	Di	Di	Di	Di	Di
Shovelnose sturgeon	0.19	0.97	1	1	1	1
Pallid sturgeon	0.44	0.98	1	1	1	1
Paddlefish	0.53	0.98	1	1	1	1
Goldeye	0.53	0.98	1	1	1	1
Smallmouth buffalo	0.86	0.99	1	1	1	1
Blue sucker	0.53	0.98	1	1	1	1
White sucker	0.01	0.95	1	1	1	1
River carpsucker	0.47	0.98	1	1	1	1
Shorthead redhorse	0.53	0.98	1	1	1	1
Channel catfish	0.48	0.98	1	1	1	1
Smallmouth bass	0.54	0.98	1	1	1	1
Walleye	0.07	0.72	1	1	1	1
Sauger	0.20	0.76	1	1	1	1
Freshwater drum	0.54	0.98	1	1	1	1

Table 1.12. Connectivity Index and Habitat Units

Migratory Fish Species		Measure A: No Action		Measure B: Rock Ramp		Measure C: Bypass Channel, 15% Flow		Measure D1: Modified Side Channel		Measure E: Multiple Pump		Measure F: Multiple Pumps w/ Conservati	
Common Name	Total Available Preferred Habitat (acres)	€ = Fish Passage Connectivity	Habitat Units (€ X acres)	€ = Fish Passage Connectivity	Habitat Units (€ X acres)	€ = Fish Passage Connectivity	Habitat Units (€ X acres)	€ = Fish Passage Connectivity	Habitat Units (€ X acres)	€ = Fish Passage Connectivity	Habitat Units (€ X acres)	€ = Fish Passage Connectivity	Habitat Units (€ X acres)
Shovelnose sturgeon	12637	0.08	973.0	0.58	7,354.7	0.60	7,582.2	0.40	5,054.8	1.00	12,637.0	1.00	12,637.0
Paddlefish	12637	0.21	2,660.7	0.98	12,349.8	0.60	7,582.2	0.40	5,054.8	1.00	12,637.0	1.00	12,637.0
Goldeye	10141	0.06	640.5	0.35	3,567.8	0.70	7,098.7	0.70	7,098.7	1.00	10,141.0	1.00	10,141.0
Smallmouth buffalo	17166	0.10	1,765.6	0.36	6,100.3	0.70	12,016.2	0.70	12,016.2	1.00	17,166.0	1.00	17,166.0
Blue sucker	5612	0.21	1,192.2	0.59	3,303.6	0.60	3,367.2	0.40	2,244.8	1.00	5,612.0	1.00	5,612.0
White sucker	5612	0.00	6.7	0.34	1,926.0	0.70	3,928.4	0.70	3,928.4	1.00	5,612.0	1.00	5,612.0
River carpsucker	10141	0.06	569.3	0.12	1,187.4	0.70	7,098.7	0.70	7,098.7	1.00	10,141.0	1.00	10,141.0
Shorthead redhorse	5612	0.06	354.5	0.35	1,974.4	0.70	3,928.4	0.70	3,928.4	1.00	5,612.0	1.00	5,612.0
Channel catfish	17166	0.06	995.6	0.35	6,025.3	0.70	12,016.2	0.70	12,016.2	1.00	17,166.0	1.00	17,166.0
Smallmouth bass	15818	0.07	1,032.9	0.35	5,571.1	0.70	11,072.6	0.70	11,072.6	1.00	15,818.0	1.00	15,818.0
Walleye	15818	0.03	448.2	0.58	9,132.3	0.70	11,072.6	0.70	11,072.6	1.00	15,818.0	1.00	15,818.0
Sauger	15818	0.08	1,288.0	0.46	7,226.6	0.70	11,072.6	0.70	11,072.6	1.00	15,818.0	1.00	15,818.0
Freshwater drum	17166	0.06	1,109.4	0.35	6,073.8	0.70	12,016.2	0.70	12,016.2	1.00	17,166.0	1.00	17,166.0
Pallid sturgeon	12637	0.04	551.4	0.20	2,465.4	0.60	7,582.2	0.40	5,054.8	1.00	12,637.0	1.00	12,637.0
		Avg.	971	Avg.	5,304	Avg.	8,388	Avg.	7,766	Avg.	12,427	Avg.	12,427

Table 1-13 shows the resulting fish passage connectivity index and habitat units for each alternative.

Table 1.13. Fish Passage Connectivity Index Scores and Habitat Units.

Alternative	W/ Pallid, 14 Species		
	Є = Fish Passage Connectivity (Avg.)	**Avg. Habitat Units**	**Δ HUs**
A: No Action	0.08	971	**0**
B: Rock Ramp	0.43	5,304	**4,333**
C: Bypass Channel	0.67	8,388	**7,417**
D: Modified Side Channel	0.61	7,766	**6,795**
E: Multiple Pump Alternative	1	12,427	**11,456**
F: Multiple Pumps with Conservation Measures	1	12,427	**11,456**

2.0 Cost Effectiveness and Incremental Cost Analysis

The plan evaluation process utilized in this study is based upon methods described in the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (U.S. Water Resources Council 1983) referred to as the P&G and the associated Corps implementation guidance found in Engineer Regulation (ER) 1105-2-100 Planning Guidance Notebook (U.S. Army Corps of Engineers 2000). The specific plan evaluation and comparison methods applied are from the *Evaluation of Environmental Investments Procedures Manual, Interim: Cost Effectiveness and Incremental Cost Analysis* document (U.S. Army Corps of Engineers 1995). This methodology consists of a series of steps that provide an orderly and systematic approach to comparing the costs and benefits of a range of alternative plans to inform the selection of a recommended plan. Plan formulation and evaluation is a dynamic process, whereby the steps may be iterated one or more times as new information or new alternatives are developed, or as planning objectives are reevaluated.

When planning for the restoration of environmental resources, cost effectiveness (CE) and incremental cost analyses (ICA) may be used as tools for the comparison of alternative plans (CE/ICA). CE/ICA are comparisons of the effects of alternative plans; more specifically, they involve comparisons between the outputs and costs of different solutions. Information about alternative plans and their effects must be developed in order to conduct the CE/ICA comparisons.

Traditional benefit-cost analyses are not applicable to environmental planning when costs and benefits are expressed in different units; however, CE/ICA offers plan evaluation approaches that are consistent with the P&G evaluation framework. The Institute for Water Resources (IWR) Planning Suite software was used to assist in performing the CE/ICA. Alternative plans were evaluated and compared in terms of cost (e.g. construction, operation, and maintenance) and environmental outputs over a 50-year period of analysis. IWR Planning Suite helps determine and present the relative efficiency and effectiveness of alternative plans at generating environmental outputs. The most efficient plans are referred to as “best buys.” The Corps’ policies for cost effectiveness and incremental cost analysis, ER 1105-2-100, paragraph E.36, states:

> *Cost effectiveness and incremental cost analysis are two distinct analyses that must be conducted to evaluate the effects of alternative plans. First, it must be shown through cost effectiveness analysis that an alternative restoration plan’s output cannot be produced more cost effectively by another alternative. “Cost effective” means that, for a given level of nonmonetary output, no other plan costs less and no other plan yields more output for less money. Subsequently, through incremental cost analysis, a variety of implementable alternatives and various-sized alternatives are evaluated to arrive at a “best” level of output within the limits of both the sponsor’s and the Corps capabilities. The subset of cost effective plans are examined sequentially (by increasing scale and increment of output) to ascertain which plans are most efficient in the production of environmental benefits. The most efficient plans are called “Best Buys.” They provide the greatest increase in output for the least increases in cost. They have the lowest incremental costs per unit of output.*

2.1 Methodology

The CE/ICA analysis utilized the Corps IWR Planning Suite model. The Corps-certified model provides a systematic method for testing all possible combinations of ecosystem restoration measures to identify combinations of measures (alternative plans) which are cost effective, and then ranks cost effective plans according to their efficiency to identify "best buy" plans. Because this analysis considered six complete alternatives which were mutually exclusive, no alternatives were combined in the model. Instead, the software identified which plans were cost effective, and then ranked the cost effective plans by efficiency to identify "best buy" plans. The CE/ICA model required the following inputs:

Average annual habitat units (AAHUs) for each alternative: Because habitat benefits are non-monetary, the outputs are referred to as "units" of output. In order to compare action alternatives to the No Action Alternative, AAHUs are typically converted to "net AAHUs," which is the change in habitat units versus No Action. Thus, the No Action Alternative is always entered as zero net AAHUs, and each action alternative is entered as the additional AAHUs that would be generated compared to this baseline. AAHUs were developed using the FPCI Model as detailed previously in this appendix.

Average annualized cost for each alternative: Costs used in the analysis included construction, PED/CM, real estate, monitoring and adaptive management, interest during construction, and operation, maintenance, and rehabilitation (OM&R). Annualized costs are presented at an FY16 price level, amortized over a 50-year period of analysis using the FY16 Federal interest rate for Corps of Engineers projects of 3.125% (U.S. Army Corps of Engineers 2015). For each action alternative, net costs above the No Action Alternative are calculated for use in the analysis, consistent with the net habitat output calculation. Detailed cost tables are available in Cost Appendix B.

2.1.1 Annualized Costs and AAHU's

Table 2-1 summarizes AAHUs for each alternative, in total and on net. As defined above, AAHUs are average annual habitat outputs, and net AHHUs are the change in output versus the No Action Alternative.

Table 2.1. AAHU's By Alternative

Alternatives	Habitat Output	
	AAHUs	**Net AAHUs**
No Action	971	-
Rock Ramp	5,304	4,333
Bypass Channel	8,388	7,417
Modified Side Channel	7,766	6,795
Multiple Pump	12,427	11,456
Multiple Pumps with Conservation Measures	12,427	11,456

Table 2-2 summarizes the annualized cost for each alternative. Like the habitat output calculation, costs for each action alternative are calculated as the net costs above the No

Action Alternative. For each alternative, inputs to the model were the net AAHUs and the net annualized project cost. Because the only costs which would be incurred in the No Action Alternative would be OM&R and monitoring, the net cost for each action alternative is equivalent to construction-related costs plus the incremental operational costs above the No Action for each alternative, as noted by the row "Net OM&R and Monitoring" in the following table.

Table 2.2. Net Cost by Alternative ($1000s)

	No Action	Rock Ramp	Bypass Channel	Modified Side Channel	Multiple Pump Alternative	Multiple Pumping w/ Cons.
Construction First Cost (PV)	$0	$90,454	$57,044	$54,441	$132,028	$477,925
Interest During Construction (PV)	$0	$1,880	$2,002	$1,123	$6,556	$53,789
Adaptive Management (PV)	$0	$796	$538	$476	$1,153	$4,145
OM&R and Monitoring (PV)	$66,420	$71,370	$70,333	$73,046	$124,395	$114,768
Net OM&R and Monitoring (PV)	**$0**	**$4,950**	**$3,913**	**$6,626**	**$57,975**	**$48,348**
Subtotal - Net Alternative Costs (PV)	$0	$98,081	$63,497	$62,665	$197,712	$584,208
Total Annualized Net Cost (AC)	**$0**	**$3,903**	**$2,527**	**$2,494**	**$7,868**	**$23,247**

IDC – interest during construction
OM&R – operation, maintenance, and rehabilitation
PV – Present Value (FY2016)
AC – Annualized Cost (3.125%, 50 years)

2.2 Cost Effectiveness Analysis

Cost effectiveness analysis is a form of economic analysis designed to compare costs and outcomes (or effects) of two or more courses of action. This type of analysis is useful for environmental restoration projects where the benefits are not measured in monetary terms but in environmental output units such as the Habitat Units developed in this study. The purpose of the cost effectiveness analysis is to ensure that the least cost plan alternative is identified for each possible level of environmental output; and that for any level of investment, the maximum level of output is identified. In short, cost effectiveness means no other plan provides more habitat benefits for the same money. Per IWR 95-R-01, an alternative is ***not*** to be considered cost effective if any of the following rules are met:

1. The same output level could be produced by another plan at least cost;
2. A larger output level could be produced at the same cost; or
3. A larger output level could be produced at less cost.

Table 2-3 provides the results of the cost effectiveness analysis sorted by increasing output. As shown in the table, alternatives were identified as cost effective only when no other alternative provided the same output for less cost, and no other alternative provided larger output at the same or less cost. The No Action, Bypass Channel, Modified Side Channel and Multiple Pump alternatives were identified as cost effective. The Rock Ramp alternative is not cost effective because the Bypass Channel alternative provides greater output for less cost. The Multiple Pumps with Conservation Measures alternative is not cost effective because the Multiple Pump alternative provides the same level of output for less cost.

Table 2.3. Cost Effectiveness by Alternative

Alternative	Annual Cost ($)	Net AAHUs	Cost per AAHU ($)	Cost Effective?
No Action	$0	0	$0	Yes
Rock Ramp	$3,903,000	4,333	$901	No
Modified Side Channel	$2,494,000	6,795	$367	Yes
Bypass Channel	$2,527,000	7,417	$341	Yes
Multiple Pump	$7,868,000	11,456	$687	Yes
Multiple Pumps w/ Conservation Measures	$23,247,000	11,456	$2,029	No

Figure 2-1 provides a graph of the total output and annualized costs for each of the alternatives while differentiating the cost effective plans from the non-cost effective ones. Per IWR 95-R-01, any alternatives that are not found to be cost effective "should be dropped from further analysis" in the CE/ICA process. Therefore, the Rock Ramp and Multiple Pumps with Conservation Measures alternatives are not included in the ICA analysis that follows.

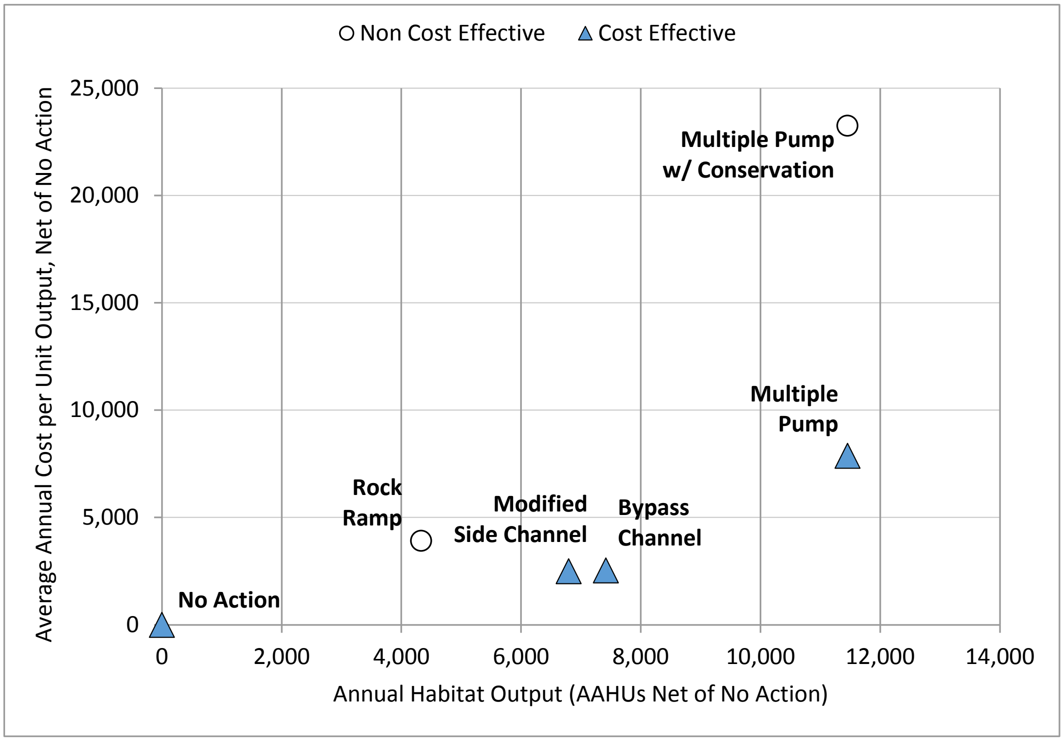


Figure 2.1. Cost Effectiveness Analysis Graph

2.3 Incremental Cost Analysis

The purpose of the ICA is to provide additional information about the cost effective plans previously identified. The ICA reveals changes in costs as output levels are increased, which provides information about how much each successive levels of total environmental output would cost. The term "incremental cost" refers to the additional cost that would be incurred to achieve successive levels of environmental output. Consider the following hypothetical example with two cost-effective action alternatives:

Plan A costs $100 and yields 100 units of output, or $1 per unit output. Plan B costs $200 and yields 150 units of output, or $1.33 per unit. Thus Plan B provides an additional 50 units of output over Plan A, but also costs $100 more. Therefore, the incremental cost of Plan B over Plan A is $100, the incremental output is 50, and the incremental cost per unit output is $2. In summary, the ICA shows that while Plan B outputs are only $0.33 more per unit on average, the true cost of Plans B's extra 50 units of output is $2 per unit. As shown in the example, the ICA provides useful information about the extra cost that would be incurred per unit output for larger and larger cost effective plans.

As previously noted, the cost-effective plans for this study are the No Action, Modified Side Channel, Bypass Channel, and Multiple Pump alternatives. During the ICA, the cost-effective plans are examined sequentially by increasing environmental output (net AAHUs). The horizon of cost effective plans which minimize incremental cost for successive levels of environmental output are called "best buy" plans in the ICA framework. Not all cost effective plans are best buy plans, and the No Action is always considered a best buy.

The first step in identifying best buy plans, other than the No Action, is to identify the plan with the lowest incremental cost per unit output compared to the No Action. Per IWR 95-R-01, this means to "smooth out fluctuations in incremental costs per unit as project scale increases such that incremental cost per habitat unit are continuously increasing." This is first completed by calculating the incremental cost per unit for each plan over the "baseline condition," which is the No Action plan. Once the incremental costs per unit are calculated and sorted by increasing output, the alternative with the lowest incremental cost per unit will be selected as the first "best buy" alternative. Table 2-4 shows the calculation of the incremental costs per unit with the No Action alternative set as the baseline for the cost effective alternatives. As shown in the table, the Bypass Channel alternative has the lowest incremental cost per unit output versus the No Action, and is therefore the first best buy plan among the action alternatives.

Table 2.4. Identification of the First Best Buy Plan

Alternative	Annual Cost ($)	Net AAHUs	Incremental Output vs No Action	Incremental Cost vs No Action	Incremental Cost per Unit Output vs No Action
No Action	$0	0	0	$0	$0
Modified Side Channel	$2,494,000	6,795	6,795	$2,494,000	$367
Bypass Channel	$2,527,000	7,417	7,417	$2,527,000	**$341**
Multiple Pump	$7,868,000	11,456	11,456	$7,868,000	$687

At this step of the ICA the incremental cost per unit is equal to the average annual cost per unit values calculated in Table 2-3 because complete alternatives are being compared, not combinations of measures.

Note that because the Modified Side Channel produced less total output than the Bypass Channel, and the Bypass Channel has already been identified as a best buy plan, the Modified Side Channel cannot be a best buy plan. It is only a cost effective plan. This is consistent with IWR 95-R-01, which states that after each iterations of the incremental calculation, all action alternatives which produce fewer net AAHU's (see last column in Table 2-1) are removed from further iterations of the incremental cost analysis.

Note that because the Modified Side Channel produced less total output than the Bypass Channel, and the Bypass Channel has already been identified as a best buy plan, the Modified Side Channel cannot be a best buy plan. It is only a cost effective plan.

Having identified the three best buy plans (No Action, Bypass Channel, and Multiple Pump), the final step in the ICA process is to analyze the incremental cost per incremental unit of output between these three plans. Like the hypothetical example above, this step illustrates the additional cost that would be incurred per unit output relative to each other. Table 2-5 shows the incremental cost per unit output between the three best buy alternatives.

Table 2.5. Incremental Cost Analysis Summary

Best Buy Alternative	Annual Cost ($)	Net AAHUs	Incremental Cost	Incremental Output	Incremental Cost per Unit Output
No Action	$0	0	$0	0	$0
Bypass Channel	$2,527,000	7,417	$2,527,000	7,417	$341
Multiple Pump	$7,868,000	11,456	$5,341,000	4,039	$1,322

This table shows that the most efficient plan above No Action is the Bypass Channel alternative that provides 7,417 additional habitat units at a cost of $341 each. If more output is desired, the next most efficient plan available is the Multiple Pump alternative that provides an additional 4,039 habitat units, at a cost of $1,322 dollars for each additional unit. Figure 2-2 provides a visual representation of this increase in incremental cost. The figure graphically illustrates the incremental cost and output differences between the two best buy action alternatives. The width of each box in the chart represents the incremental output of that plan, and the height of each box shows the incremental cost per unit of that output. The relatively wide box for the Bypass Channel alternative shows that it provides about 65% of the total output possible at a cost of approximately $341 per unit. The box for the Multiple Pump alternative shows that to achieve the remaining 35% of total possible output would be more expensive per unit than the first 65%. Such breakpoints in incremental cost per unit typically require a higher level of justification if the study team is to recommend the larger output plan.

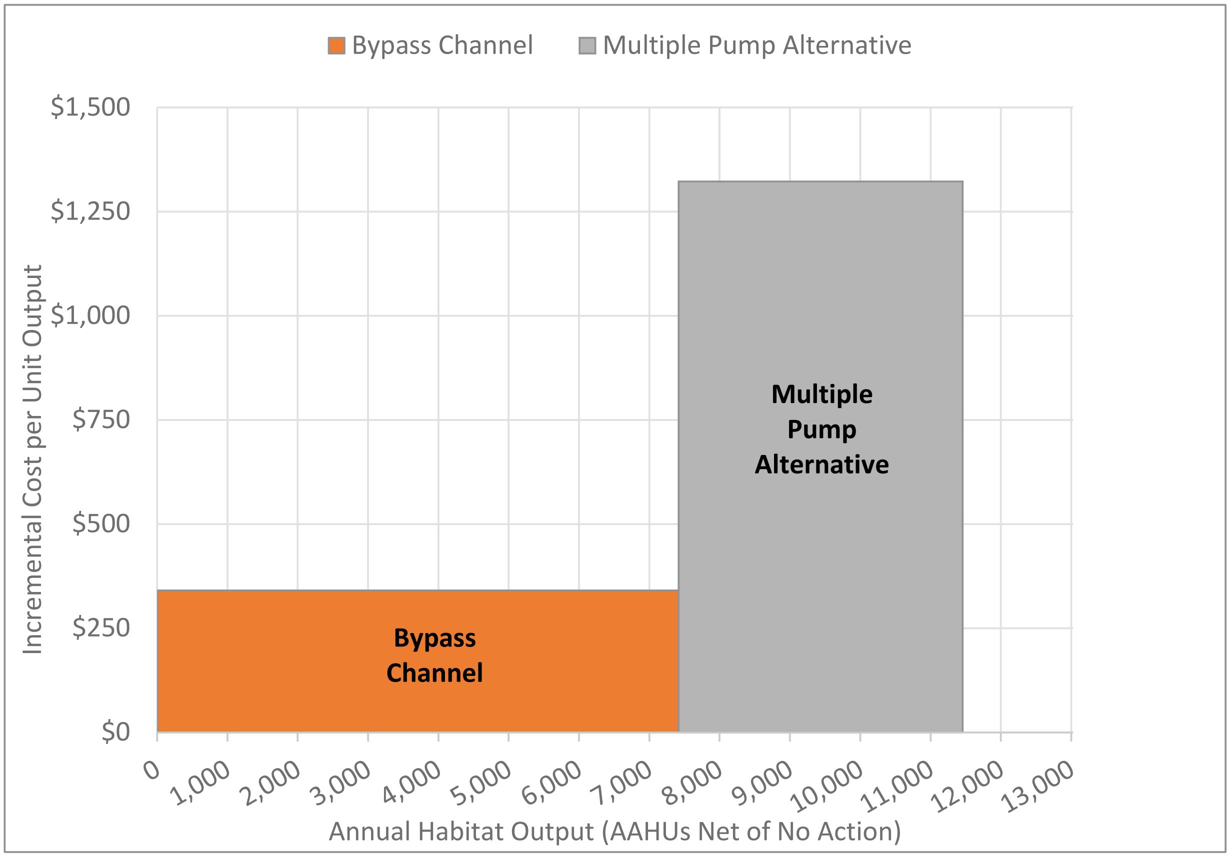


Figure 2.2. Incremental Cost Analysis Chart

2.4 Summary of Conclusions

The results of the CE/ICA do not provide a discrete decision for selecting the preferred plan, but rather they offer organized data on the effectiveness and efficiency of the range of alternatives under consideration to help inform a decision. For Corps ecosystem restoration projects, the selected plan should be the alternative having the maximum excess of non-monetary benefits (habitat output) over costs. This plan occurs where the incremental beneficial effects just equal the incremental costs, or alternatively stated, the recommended plan is selected by identifying the largest plan for which the extra habitat output is still worth the extra costs. Definition of the level of output that is “worth it” is a concern for the study team that will consider specific project factors and information.

Thus, a plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with the Federal objective, can be identified as the selected plan. The selected plan should also be cost effective and justified in achieving the desired level of output. In practice, the selected plan is chosen from the suite of cost effective plans identified in the CE/ICA. While the selected plan is not required to be a best buy plan, this is typically the case.

2.5 Sensitivity Analysis

In order to evaluate the sensitivity of the CE/ICA results to changes in the FPCI model outputs, two sensitivity scenarios were modeled. In the first scenario, the scores for fishway location were reduced for the bypass channel, which reduces that alternative's habitat outputs. In the second scenario, pallid sturgeon only, only the variable for pallid sturgeon was included, which changes the total habitat outputs for all alternatives. These two scenarios reasonably evaluate the possibility of reduced effectiveness for the bypass channel and a focus on pallid sturgeon-specific benefits. In Scenario 1, the score for the fishway location was modified was due to the concern that benefits were overstated for the bypass. The fishway location score was lowered to "3" for pallid sturgeon, shovelnose sturgeon, paddlefish, and blue sucker, which indicates that it is equally likely or unlikely that these fish species could find the fishway due to swimming location/behavior of using the main channel. Scenario 2 was used to evaluate whether using the diversity of native fish species skews the resulting index score, or washes out the importance of pallid sturgeon benefits.

Note that fishway location scores were not lowered to a "1" or "2" because it is not reasonable to suppose that no fish would find a bypass channel located in immediate proximity to the weir (12 to 50 percent of telemetered pallid sturgeon that approached Intake Diversion Dam found the existing side channel in 2014 and 2015 [Rugg 2014, 2015]). Also note that the Modified Side Channel alternative in all scenarios always has been given a lower score of "2" for fishway location as the location of the entrance for upstream migrating fish is approximately 2 miles downstream of Intake Diversion Dam and distant from the main channel so fish are less likely to find it as compared to the bypass channel.

Tables 2-6 and 2-7 summarizes the FPCI revisions for each scenario. Based on these revised habitat output values, and using the same costs, the CE/ICA model was re-run twice. Tables 2-8 and 2-9 provides the cost effectiveness tables for the two scenarios, and Tables 2-10 and 2-11 provide the best buy plans incremental cost tables. Finally, summary graphics are provided for both scenarios side-by-side.

As shown in the tables and figures, even when components of the FCPI scoring are revised, the order of alternatives in terms of average cost per unit output does not change.

- Scenario 1 – Revised Fishway Location Score: the reduced output of the Bypass Channel alternative makes its average cost per unit output more expensive, though it remains less expensive per unit than the Modified Side Channel, resulting in no changes to the identified cost effective and best buy plans.
- Scenario 2 – Pallid Sturgeon Only: by only considering pallid sturgeon in the FPCI, the relative cost effectiveness of the alternatives does not change. The Bypass Channel remains the first best buy plan. However, the total output possible for the Rock Ramp, Modified Side Channel, and Bypass Channel alternatives are all reduced. In this scenario, the Bypass Channel would provide for about 48% of possible habitat output, rather than 65% as in the main analysis which considered 14 species.

In both scenarios, the order of alternatives in terms of average cost per unit output did not change. Based on this analysis, it was determined that there is reasonable confidence that, as currently designed, the Bypass Channel alternative is less costly per unit than the Multiple Pump Alternative, and that the two best buy action alternatives are the Bypass Channel and the Multiple Pump Alternative.

Table 2.6. Scenario 1 – Revised Fishway Location Score, FPCI

Alternative	W/ Pallid, 14 Species		
	€ = Fish Passage Connectivity (Avg.)	Avg. Habitat Units	Δ HUs
No Action	0.08	971	0
Rock Ramp	0.43	5,304	4,333
Bypass Channel	0.64	8,077	7,106
Modified Side Channel	0.61	7,766	6,795
Multiple Pump Alternative	1	12,427	11,456
Multiple Pumping w/ Cons.	1	12,427	11,456

Table 2.7. Sensitivity Scenario 2 – Pallid Sturgeon Only, FPCI

Alternative	Pallid Sturgeon Only		
	€ = Fish Passage Connectivity (Avg.)	Avg. Habitat Units	Δ HUs
No Action	0.04	551	0
Rock Ramp	0.2	2,465	1,914
Bypass Channel	0.5	6,319	5,768
Modified Side Channel	0.4	5,055	4,504
Multiple Pump Alternative	1	12,637	12,086
Multiple Pumping w/ Cons.	1	12,637	12,086

Table 2.8. Scenario 1 – Revised Fishway Location Score, Cost Effectiveness

Alternative	Annual Cost ($)	Net AAHUs	Cost per AAHU ($)	Cost Effective?
No Action	$0	-	$0	Yes
Rock Ramp	$3,903,000	4,333	$901	No
Modified Side Channel	$2,494,000	6,795	$367	Yes
Bypass Channel	$2,527,000	7,106	$356	Yes
Multiple Pump	$7,868,000	11,456	$687	Yes
Multiple Pumps w/ Conservation Measures	$23,247,000	11,456	$2,029	No

Table 2.9. Sensitivity Scenario 2 – Pallid Sturgeon Only, Cost Effectiveness

Alternative	Annual Cost ($)	Net AAHUs	Cost per AAHU ($)	Cost Effective?
No Action	$0	-	$0	Yes
Rock Ramp	$3,903,000	1,914	$2,039	No
Modified Side Channel	$2,494,000	4,504	$554	Yes
Bypass Channel	$2,527,000	5,768	$438	Yes
Multiple Pump	$7,868,000	12,086	$651	Yes
Multiple Pumps w/ Conservation Measures	$23,247,000	12,086	$1,923	No

Table 2.10. Scenario 1 – Revised Fishway Location Score, Incremental Cost

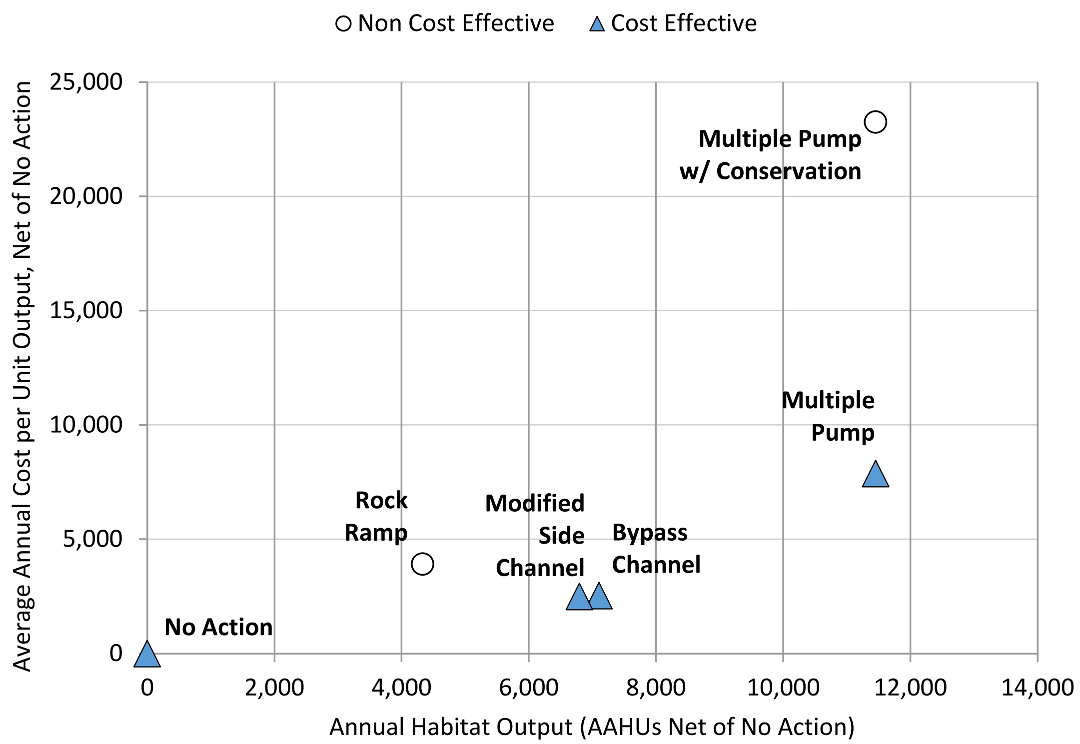
Best Buy Alternative	Annual Cost ($)	Net AAHUs	Incremental Cost	Incremental Output	Incremental Cost per Unit Output
No Action	$0	0	$0	0	$0
Bypass Channel	$2,527,000	7,106	$2,527,000	7,106	$356
Multiple Pump	$7,868,000	11,456	$5,341,000	4,350	$1,228

Table 2.11. Sensitivity Scenario 2 – Pallid Sturgeon Only, Incremental Cost

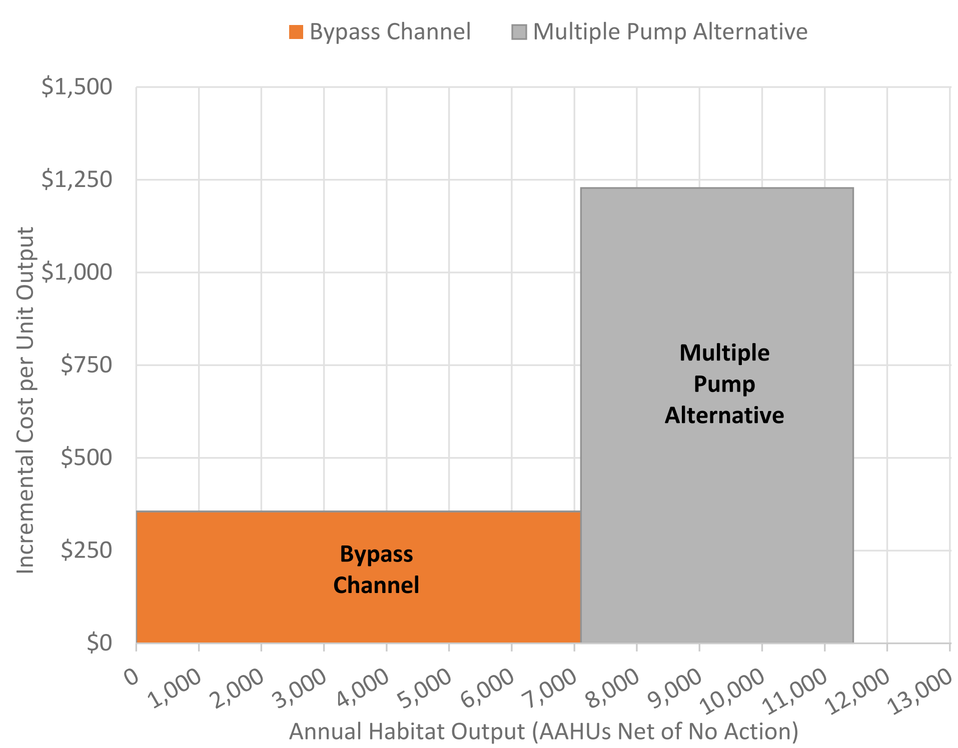
Best Buy Alternative	Annual Cost ($)	Net AAHUs	Incremental Cost	Incremental Output	Incremental Cost per Unit Output
No Action	$0	0	$0	0	$0
Bypass Channel	$2,527,000	5,768	$2,527,000	5,768	$438
Multiple Pump	$7,868,000	12,086	$5,341,00	6,318	$845

Scenario 1 – Revised Fishway Location Score

Cost Effectiveness

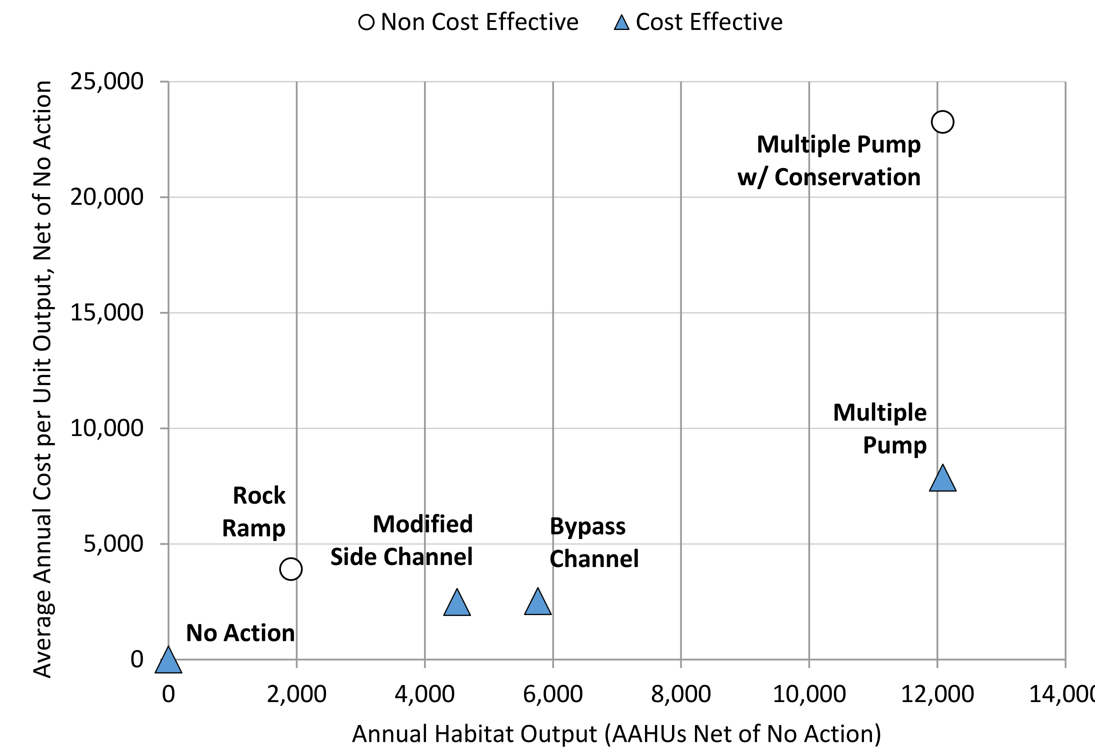


Best Buy Plans

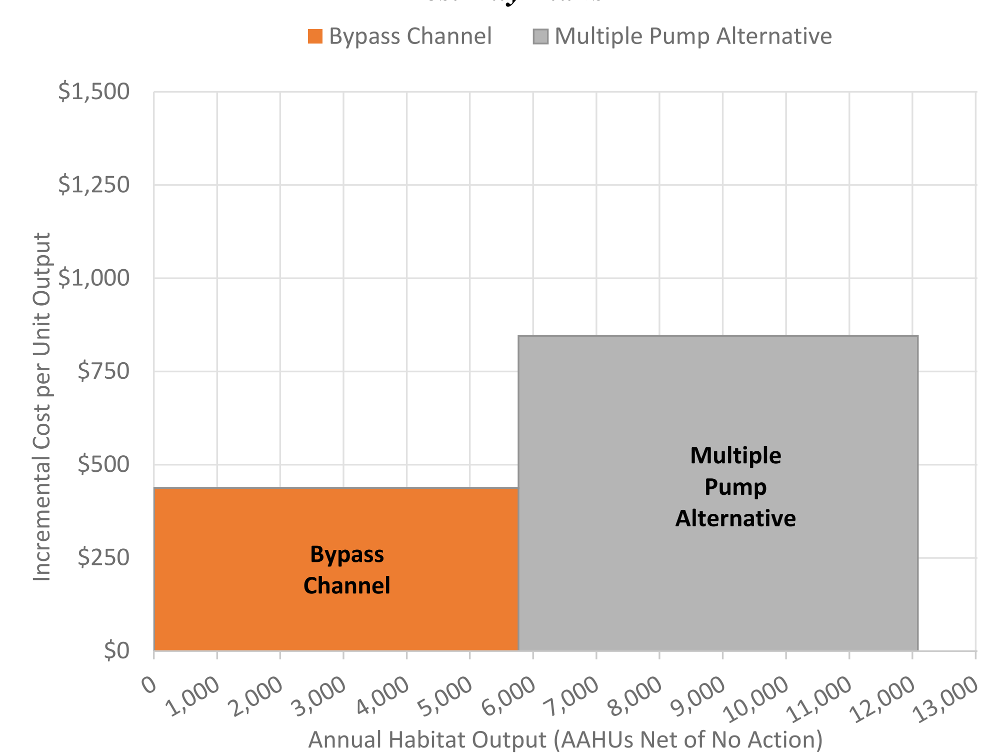


Scenario 2 – Pallid Sturgeon Only

Cost Effectiveness



Best Buy Plans



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Attachment 1

Table 4. Estimate Suitability of Fishway Locations (FI) for Each Fish Guild Based Upon Swimming Performance and Behavior.

	Potential Fishway Location – Lock and Dam 22 example			
Guild	Main Channel	Main Channel Border – near channel	Main Channel Border– near shore; Side Channel; or Bypass Channel	Lock
Benthic – Strong	5	5	3	1
Littoral – Strong	5	5	3	1
Pelagic – Strong	5	5	3	1
Benthic – Medium	1	5	5	1
Littoral – Medium	1	3	5	1
Pelagic – Medium	1	5	5	1
Benthic – Weak	1	5	5	1
Littoral – Weak	1	3	5	1
Pelagic – Weak	1	1	5	1

5 = Entrance would be encountered by a significant portion of the population
3 = Entrance may be encountered
1 = Unlikely that entrance would be encountered

Table 4 is reproduced from Corps (2011) showing the scoring for various guilds of fish relative to general fishway locations.

Attachment 2

DEPARTMENT OF THE ARMY
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REPLY TO
ATTENTION OF:

CEMVD-PD-L 15 September 2016

MEMORANDUM FOR CECW-NWD (Kramer)

SUBJECT: Recommendation for Single Use Approval of the Fish Passage Connectivity Index for the Lower Yellowstone Intake Diversion Dam Fish Passage Project

1. References:
   a. Engineer Circular 1105-2-412: Assuring Quality of Planning Models, dated 31 March 2011.

   b. Fish Passage Connectivity Index, Upper Mississippi River System Fish Passage Improvement Ecosystem Restoration Projects – Regional Certification Memo, dated 16 September 2011 (Encl 1).

   c. Model Documentation, Fish Passage Connectivity Index for the Lower Yellowstone Intake Diversion Dam Fish Passage Project, dated 08 September 2016 (Encl 2).

   d. Model Approval Plan, Fish Passage Connectivity Index for the Lower Yellowstone Intake Diversion Dam Fish Passage Project, dated 19 July 2016 (Encl 3).

   e. Model Review Comment Response Record, Fish Passage Connectivity Index for the Lower Yellowstone Intake Diversion Dam Fish Passage Project, dated 08 September 2016 (Encl 4).

   f. Model Spreadsheet Calculator, Fish Passage Connectivity Index for the Lower Yellowstone Intake Diversion Dam Fish Passage Project, dated 08 September 2016 (Encl 5).

2. The Fish Passage Connectivity Index (FPCI) model is certified for regional use in the Upper Mississippi River System with possible application on other river systems (Encl 1). The National Ecosystem Restoration Planning Center of Expertise (ECO-PCX) received a request from Omaha District (NWO) to use this model on the Yellowstone River for the purposes of evaluating the suitability of various fish passage alternatives for the Lower Yellowstone Intake Diversion Dam Fish Passage Project (Encl 2), and subsequently initiated review of this application following the model certification requirements (Reference 1.a.) and the model approval plan (Encl 3). Based on the review results (Encl 4), the ECO-PCX recommends Single Use Approval of the FPCI for the Lower Yellowstone Intake Diversion Dam Fish Passage Project. Please log in this recommendation with the Office of Water Project Review for the Model Certification Team to consider.

3. The FPCI model was developed by the Navigation and Ecosystem Sustainability Program, Lock and Dam 22 Fish Passage Ecosystem Restoration Project Delivery Team which included fisheries biologists and hydraulic engineers from USACE (MVS, MVR, MVP, ERDC), US Fish and Wildlife Service (USFWS) Ecological Services and Refuges, Illinois Department of Natural Resources, Illinois Natural History, Missouri Department of Conservation, and Iowa Department of Natural Resources. The model calculates Habitat Units (HU) for each migratory fish species and averages HU for all migratory fish species for each fish passage alternative. Model input includes movement periods for each migratory species, likelihood of species to encounter fishway entrance based on location, species potential to use passage route; and availability of suitable passage conditions during movement and spawning periods. The result is a 0-1 index that represents the suitability of the fish passage

alternative measure to a given species. The fish passage connectivity index is multiplied by the acres of connected, upstream habitat types that are suitable to the individual migratory species to get Habitat Units.

4. Prior review concluded the FPCI meets model criteria of technical and system quality and usability. The model addresses the key factors associated with fish passage and is easily modified for application at numerous locations. For a given area, users will input species data such as timing of migration, swimming abilities, swimming behavior, and input on habitat quality available to the migrating fish. Below is a summary of the input data used and minor adjustments made to the model to demonstrate ecological benefits of the Yellowstone River Intake Diversion Dam fish passage alternatives.

   - The certified FPCI model does not include pallid sturgeon, so it was added to the model.

   - Habitat preferences/use for each species was considered acceptable as presented in the FPCI with one slight adjustment as noted by the Corps (2015); white sucker, blue sucker and river carpsucker were shown only to be associated with main channel border habitats in the original FPCI. However, for purposes of this study, these species were also assumed to utilize main channel habitats. The "main channel" habitat type in the Upper Mississippi River was defined as a navigation channel, which is very different than main channel habitats in the Yellowstone River, and may be the reason those species were not associated with that habitat type.

   - The Di variable accounts for the timing of when fish passage is physically possible at a dam compared with the time of when fish typically migrate. NWO modified the "percent probability of open river conditions" in the original model (which referred to when dam gates were open on the Upper Mississippi River) and used available literature (Jaeger, et al. 2005; Helfrich et. al. 1999), anecdotal information, and best professional judgment, to assign probabilities that passage opportunities exist on a weekly basis as a function of flow, with highest probabilities being associated with the peak of the typical hydrograph, and very small (1%) probabilities being attributable to the timeframes outside of the peak river flow (September-April).

   - Information on fish migratory behaviors and timing from the original model was modified because the time of year when migration takes place on the Yellowstone River is different than on the Mississippi River. Movement and spawning periods were pushed back 3-4 weeks later in the year as migrations tend to take place later in the year for cooler, more northern latitudes.

5. Review of the input data and minor adjustments made to the model for this project was conducted by Joe Jordan (MVR) and Elliott Stefanik (MVP). Mr. Jordan is a MVD Biologist Regional Technical Specialist with specific expertise in large river fish passage and is familiar with the structure and use of the FPCI. Mr. Stefanik is the Environmental Planning Section Chief in MVP and is a subject matter expert in large river fish passage and has experience planning fish passage restoration projects. The ECO-PCX managed the review to assess the technical quality, system quality, and usability of the project specific input data. The review results are in Enclosure 4.

   There were three final comments (two moderate significance and one low significance). The first and second comments related to the application of the model for alternative evaluation. Specifically, the reviewers were concerned the inputs leading to the calculated value of the Ei variable within the FPCI may not be appropriate. Both comments were evaluated and closed by providing additional information on why the rock ramp would not be as suitable as a bypass channel for pallid sturgeon. This is also reinforced and documented through consultation and correspondence with the USFWS. The final comment was related to the usability of the model for this project. The reviewer was concerned about the selection of Ui (Potential for Species to Use Fishway) scores of 2 when the model documentation only lists possible scores of 5, 3, or 1. In this case, the PDT's deviation from the original model are relatively minor and are in fact justified with additional documentation and independent professional judgement from the various resource biologists. Documentation on the deviation from the model was included in the project report and model documentation for the project.

All comments were addressed and incorporated to the satisfaction of the ECO-PCX and reviewers.

6. The ECO-PCX finds the input data used and minor adjustments made to the FPCI for this project are technically appropriate, computational correct, and usable for the Lower Yellowstone Intake Diversion Dam Fish Passage Project. The use of the model outside of the certified geographic location is appropriate and the model continued to be used in a policy compliant manner. The ECO-PCX recommends Single Use Approval of the FPCI for the Lower Yellowstone Intake Diversion Dam Fish Passage Project. Please notify the ECO-PCX of the Model Certification Panel's findings.

Encls (5)

Gregory Miller
Operating Director
National Ecosystem Restoration
Planning Center of Expertise

CF (without enclosures)
CECW-PC (Paynes, Coleman, Matusiak, Trulick, Bee)
CECW-NWD (Durham-Aguilera, Dunn)
CENWD-PDD (Combs, Hudson, Fischer)
CENWO-PM (Thompson, Johnson, Laux, Vanosdall)
CEMVP-PD-F (Richards)
CEMVD-PD-L (Chewning, Lachney, Miller, Young)
CELRP-PM-EV (Fleeger)

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET, NW
WASHINGTON, DC 20314-1000

REPLY TO
ATTENTION OF

CECW-P

16 September 2011

MEMORANDUM FOR Director, National Ecosystem Restoration Planning Center of Expertise (ECO-PCX)

SUBJECT: Fish Passage Connectivity Index (FPCI), Upper Mississippi River (UMR) System Fish Passage Improvement Ecosystem Restoration Projects – Regional Certification

The FPCI, which evaluates ecosystem outputs of alternative measures for fish passage improvements for cost effectiveness and incremental analysis, is certified for regional use. Adequate technical reviews have been accomplished and the model meets the certification criteria contained in EC 1105-2-412. The FPCI is an arithmetic index that incorporates characteristics of migratory fishes present at Lock and Dam 22 on the UMR and characteristics of fish passage alternative measures. While originally intended for use for the Lock and Dam 22 project, it is applicable to fish passage projects at other dams on the UMR and has the potential for application to fish passage projects on other river systems. Subject to a demonstration by the ECO-PCX that use of the model is applicable to other river systems, the regional certification will be expanded. This regional certification is based on the decision of the HQUSACE Model Certification Panel which considered the ECO-PCX assessment of the model.

APPLICABILITY: This regional certification is limited to fish passage projects at other dams on the UMR with possible application on other river systems.

EXPIRES: 30 September 2018

HARRY E. KITCH, P.E.
Deputy Chief, Planning and Policy Division
Director of Civil Works

Printed on Recycled Paper

Enclosure 2

Lower Yellowstone Intake Diversion Dam Fish Passage Project, Montana

FINAL - APPENDIX D

Lower Yellowstone Intake Fish Passage EIS

Fish Passage Connectivity Index and Cost Effectiveness and Incremental Cost Analysis

SEPTEMBER 2016

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1.0 Fish Passage Connectivity Index

1.1 Introduction

Intake Diversion Dam has likely impeded upstream fish passage for pallid sturgeon and other fish species in the Yellowstone River since it was completed in approximately 1909. The best available science suggests that the diversion dam is a partial barrier to some fish species including shovelnose sturgeon (Bramblett, et al. 2015; Helfrich et al. 1999; Jaeger et al. 2004; Backes et al. 1994; Stewart 1986, 1988, 1990, 1991; Rugg 2016). It is essentially a total barrier to other fish species, such as pallid sturgeon, due to a high level of turbulence associated with the rocks at the dam crest and in the downstream boulder field and high velocities at the dam crest (Jaeger et al. 2005; Fuller et al. 2007; Helfrich et al. 1999; White and Mefford 2002; Bramblett and White 2001). Pallid sturgeon were tracked passing upstream of the dam via the existing high-flow side channel in 2014 and 2015 (Rugg 2014, 2015, 2016) during flows greater than 30,000 cfs. It is not known if passage has occurred before 2014 because this was the first year that fish were tracked swimming upstream of the dam.

Improving fish passage at Intake Diversion Dam accomplishes several things from a pallid sturgeon recovery perspective:

- It would provide access to approximately 165 miles of Yellowstone River habitat upstream of Intake Diversion Dam and additional miles on tributaries such as the Powder River that are currently inaccessible to the pallid sturgeon;
- The area to which access would be provided appears to include substantial areas of suitable spawning habitat for pallid sturgeon including bluff pools and other areas of swift water over gravel and cobble substrates (Jaeger, et al. 2005, Rugg 2014, 2015; Bramblett, et al. 2015);
- If 165 more river miles were accessible for spawning, it would provide longer drift distances and a larger area available for larvae to stop dispersal and seek rearing habitat before reaching Lake Sakakawea, which is currently thought to be unsuitable larval settling habitat due to the fine substrates and low dissolved oxygen levels (Braaten et. al. 2008, 2011; Guy et al. 2015; Bramblett & Scholl 2016)

While the primary purpose of a fish passage project at Intake Dam is to improve pallid sturgeon passage, other migratory species of fish are also likely to also benefit from the project. This includes fish that are important from a management perspective by the State of Montana, such as shovelnose sturgeon, paddlefish, sauger, and blue sucker, as well as a variety of native fish species that reside in the Yellowstone River and undertake shorter seasonal movements.

Federal agencies are required to evaluate the economic and environmental costs and benefits of water resources projects that it undertakes (CEQ 2013). For a project with environmental benefits, such as this fish passage project, benefits are not reasonably monetized. However, if benefits can be quantified in some dimension, cost effectiveness and incremental cost analysis can be used to assist in selecting a preferred plan. Cost effectiveness analysis evaluates which alternatives are the least-costly way of attaining the project objectives. Incremental analysis is then used to evaluate the change in cost from each measure or alternative to the next to determine their incremental costs and incremental benefits. This type of analysis helps identify which measures or alternatives provide more benefits for lower cost and can be used as one element to inform the selection of a preferred plan.

1.2 Fish Passage Connectivity Index

The Fish Passage Connectivity Index (FPCI) was developed to evaluate ecosystem outputs (i.e. benefits) of alternative measures for fish passage improvements on the Upper Mississippi River and Illinois Waterway System for cost effectiveness and incremental analysis (Corps 2011). The model was developed for use in the plan formulation process for the Navigation and Ecosystem Sustainability Program for the Upper Mississippi River System fish passage improvement ecosystem restoration projects. The model is currently in review by the Ecosystem Restoration Center of Expertise as required for use in the U.S. Army Corps of Engineers (Corps) planning context for this project (Corps 2016). This model was used in an assessment of fish passage alternatives at Intake Diversion Dam in 2015 (Corps 2015).

The FPCI is a simple arithmetic index that is calculated as:

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

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.

Ei = Probability of encountering the fishway entrance is a calculated value ranging from 1 to 5, where 5 = highly likely; 3 = moderate probability; 1 = unlikely.

Ui = 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.

Di = Duration of availability, the fraction of the upriver migration period for fish species i that the passage pathway is available. Di incorporates a risk component (i.e., the potential failure of an alternative to perform or be available during a critical fish movement period.)

Although the model was developed to measure benefits of fish passage in the Upper Mississippi River, the model is applicable (with slight adjustments) to fish passage projects on other large river systems, especially those with very similar fish communities. This model, with minor adjustment, was used as a planning tool for comparing benefits of alternative measures for provide fish passage at Intake Dam. It should be recognized that this model is a planning tool that relies on the best professional judgment of users (informed by the published literature on the species) and does not represent a statistical probability of fish passage but a relative comparison of effectiveness. This memo describes the input data used and minor adjustments made to the model to demonstrate ecological benefits of the Yellowstone River Intake Diversion Dam fish passage alternatives.

1.3 Data Required for the Model

1.3.1 Identify fish to be included for analysis, and their associated habitat preferences, swimming behaviors, and swimming abilities.

1.3.1.1 The FPCI model was created with a list of 40 fish species that could be considered for use in the model (Corps 2011). This list does not include pallid sturgeon. Swimming performance data, swimming behavior, and critical current velocities (Ucrit) for prolonged swimming by adult fish used in the creation of the model were sourced from two primary studies on the Upper Mississippi River (Wilcox et al. 2004; Pitlo et al. 1995). More recent data were used to calculate an estimated Ucrit for adult pallid sturgeon (Braaten et al. 2015) and to make one other change to anticipated swimming speeds of other species; walleye Ucrit was reduced to 3.0 feet/second (Peake et al. 2000). The 14 species used in this model are shown in Table 1-1.

1.3.1.2 For ensuring a good comparison of benefits across fish passage alternatives, the fish species selected for use in this FPCI modeling effort, the thirteen (13) species used by the Corps in 2014 with the addition of pallid sturgeon, for a total of 14 species. The inclusion of pallid sturgeon does not change the ranking of alternatives Because this project is focused on improving fish passage for pallid sturgeon, the project team felt that including it specifically (instead of using shovelnose sturgeon as a surrogate) gives added importance to pallid sturgeon capabilities and provides a better differentiation between similar alternatives. As explained in the Corps (2015) modeling, the other 13 species were selected because they represent the native migratory species typically found in the Yellowstone River at Intake Diversion Dam and the species provide good representation of the various guilds of fish based on their various migration behaviors (benthic (8), pelagic (2), and littoral (3) and swimming abilities (strong (6), medium (5), weak (2)).

1.3.1.3 Habitat preferences/use for each species was considered acceptable as presented in the FPCI with one slight adjustment as noted by the Corps (2015); white sucker, blue sucker and river carpsucker were shown only to be associated with main channel border habitats in the original FPCI. However, for purposes of this study, these species were also assumed to utilize main channel habitats. The “main channel” habitat type in the Upper Mississippi River was defined as a navigation channel, which is very different than main channel habitats in the Yellowstone River, and may be the reason those species were not associated with that habitat type. These three species are known to utilize main channel habitats available in the Yellowstone and Upper Missouri River systems, and as such, were associated with it for purposes of this study. In addition, pallid sturgeon was included and shown with a habitat preference for main channel and main channel border habitats similar to the habitat preferences provided for shovelnose sturgeon.

1.3.1.4 Fish species of concern are well represented. Species of special concern that are included in this analysis include the shovelnose sturgeon, paddlefish, sauger, and blue sucker.

Habitat loss and fish passage barriers have contributed to the decline of these species (Montana AFS 2016). It is important to ensure fish passage alternatives do not reduce passage for these species.

Table 1-1. Species Used in the FPCI Model for Intake Diversion Dam with Swimming Speed and Habitat Preference.

Common Name	Scientific Name	Swimming Behavior	Swimming Performance	Swimming Speed (Ucrit)[1,2,3] (ft/sec)	Habitat Preference
Shovelnose sturgeon	*Scaphirhynchus platorhynchus*	Benthic	Medium	2.7	B,C
Paddlefish	*Polyodon spathula*	Pelagic	Strong	4.2	B,C
Goldeye	*Hiodon tergisus*	Pelagic	Medium	2	A,B,D,E
Smallmouth buffalo	*Ictiobus bubalus*	Benthic	Medium	2.1	B,C,D,E
Blue sucker	*Cycleptus elongatus*	Benthic	Strong	2.6	B,C
White sucker	*Catosomus commersoni*	Benthic	Weak	2.1	B,C
River carpsucker	*Carpiodes carpio*	Benthic	Weak	1.5	B,D,E
Shorthead redhorse	*Moxostoma macrolepidotum*	Benthic	Medium	2	B,C
Channel catfish	*Ictalurus punctate*	Benthic	Strong	2.7	A,B,C,D,E
Smallmouth bass	*Micropterus salmoides*	Littoral	Medium	2.1	A,B,D,E
Walleye	*Sander vitreus*	Littoral	Strong	3[4]	B,C,D
Sauger	*Sander canadensis*	Littoral	Strong	2.6	B,C,D
Freshwater drum	*Aplodinotus grunniens*	Benthic	Strong	2.7	A,B,C,D,E
Pallid sturgeon	*Scaphirhynchus albus*	Benthic	Medium	3.3	B,C

A = Contiguous floodplain lake; B = Main channel border; C = Main channel; D = Secondary channel; E = Tertiary channel; F = Tributary

[1] Pitlo, J., Jr., Van Vooren, A., and Rasmussen, J. (1995). "Distribution and relative abundance of Upper Mississippi River fishes," Upper Mississippi River Conservation Committee Fish Technical Section, Rock Island, IL.

[2] Wilcox, D.B. et al (2004) "Improving fish passage through navigation dams on the Upper Mississippi River system", ENV Report 54, U.S. Army Corps of Engineers, Rock Island, St. Louis, and St. Paul Districts

[3] Braaten, P.J., C.M. Elliott, J.C. Rhoten, D.B. Fuller, & D.J. McElroy. 2015. Migrations and swimming capabilities of endangered pallid sturgeon (*Scaphirhynchus albus*) to guide passage designs in the fragmented Yellowstone River. Restoration Ecology 23(2): 186-195.

[4] Peake, S., R.S. McKinley, & D.A. Scruton. 2000. Swimming performance of walleye (*Stizostedion vitreum*). Canadian Journal of Zoology 78: 1686-1690.

1.3.2 Identify habitat acres made available by passage.

1.3.2.1 Habitat Units are calculated in the model by multiplying the fish passage index by the total acres of available preferred habitat upstream of Intake Diversion Dam for each species. For this analysis, the habitat acres mapped between Intake and Cartersville on low-level aerial photography for the *Yellowstone River Cumulative Effects Analysis* (Corps & YRCDC 2015; Corps 2015; Yellowstone River Corridor Clearinghouse 2016) were used.

1.3.2.2 Habitat types from the Cumulative Effects Analysis (CEA) include the following primary categories:

Scour – (SC) Scour pool occurring in otherwise unconstrained river channel.

Bluff – (BL) Scour pool located at the base of a bedrock bluff. Indicates a relatively permanent pool location bounded by a geologic constraint.

Terrace – (T) Scour pool located at the base of a terrace (Quarternary Alluvium).

Riprap Bottom – (RRB) Scour pool occurring in riprap constrained channel where riprap is located in the middle of the active channel area.

Riprap Margin – (RRM) Scour pool occurring in riprap constrained channel where riprap is located at the edge of the active channel area.

Channel Crossover – (CC) A transitional unit where the river is translating from one bendway or pool to the next.

Bedrock – (BED) Channel is controlled by bedrock bed.

Secondary Channel – (2C) Undifferentiated low flow channel. No additional habitat typing is defined, though the channel likely contains areas of pool and riffle.

Secondary Channel Seasonal – (2CS) Secondary channel High flow channel

Point Bar – (PB) Areas in the bank full lines that show aggradation associated with the insides of a bendway. Can include exposed gravel, or areas with vegetation, as long as they lie within the bank full area.

Side Bar – (SB) Areas in the bank full lines that show aggradation along the sides of a channel. These bar areas create channel sinuosity at low flows but are inundated at higher or bank full flows. Can include exposed gravel, or areas with vegetation, as long as they lie within the bank full area.

Mid-Channel Bar – (MCB) Areas in the bank full lines that show aggradation, creating islands within the low flow area. Can include exposed gravel or areas with emergent vegetation, as long as they lie within the bank full area.

Dry Channel – (DC) This is a general category for areas within the bank full boundaries that do not fit into Point Bar, Side Bar, Mid-channel Bar, or Island categories. They are generally associated with split flows around islands where there is exposed channel bed at low flow, but does not appear to be strictly depositional in nature, though they could still have some depositional characteristics. Can include exposed gravel or areas with vegetation, as long as they lie within the bank full area.

Dam – Habitat unit is influenced by a dam in the main channel.

1.3.2.3 As depicted in Table 1-2, the CEA habitat categories were cross-walked to the habitat categories as defined for the Upper Mississippi River in the FPCI, allowing Yellowstone River habitat acreages to be compatible with the existing layout as presented in the FPCI model. The habitats for the Upper Mississippi River were defined as:

- Contiguous Floodplain Lake
- Main Channel Border
- Main Navigation Channel
- Secondary Channel
- Tertiary Channel
- Tributary Channel

1.3.3 Identify Windows of Opportunity for Upstream Fish Passage

A window of opportunity, or the timing of when fish passage is physically possible at a dam due to typical peak flows (and suitable depths and velocities), compared with the timeframe of when fish typically migrate, is used to estimate the duration of availability (Di) for the baseline condition and each alternative in the FPCI. The Corps (2015) modified the “percent probability of open river conditions” in the original model (which referred to when the dam gates were open on the Upper Mississippi River) and used available literature (Jaeger, et al. 2005; Helfrich et. al. 1999), anecdotal information, and best professional judgment, to assign probabilities that passage opportunities exist on a weekly basis as a function of flow, with highest probabilities being associated with the peak of the typical hydrograph, and very small (1%) probabilities being attributable to the timeframes outside of the peak river flow (September-April). These same probabilities were used in this analysis for the existing conditions. Table 1-3 shows the windows of opportunity for fish passage, as entered into the FPCI model to represent the no action alternative (existing condition).

For the rock ramp alternative, the depths and velocities are suitable at most times, but for some species at some flows, depths may be too shallow or velocities too high to have suitable passage. Thus, the 2D model results for the rock ramp were used to indicate the duration of passage availability for the median flows in each month of interest. Table 1-4 shows the opportunity for passage as used in the FPCI model for the rock ramp alternative.

For the other alternatives, an assumption was made both by the Corps in 2015 and for this application that the duration available for fish passage would be 100% during the pre-spawn and spawning migration season for the bypass channel, modified side channel, and dam removal alternatives because suitable depths and velocities would be provided across all typical flows. Table 1-5 shows the opportunity for passage as used in the FPCI model for these remaining alternatives.

1.3.3.1 Seasonality of Fish Migration

Basic information on fish migratory behaviors and timing from the original FPCI model was modified by Corps (2015) because the actual time of year when migration takes place on the Yellowstone River is different than on the Mississippi River. Movement and spawning periods were pushed back 3-4 weeks later in the year as migrations tend to take place later in the year for cooler, more northern latitudes. Other information considered in establishing the migratory timeframes for the Yellowstone River at Intake Diversion Dam included data found in Elser, et al. (1977), anecdotal data from George Jordan (Mike Backes, Montana Fish Wildlife and Parks survey data) and best professional judgment. Migratory timeframes as utilized in the FPCI modeling for the Intake Dam project are shown in Table 1-6.

In addition, for this analysis, the migratory timing was adjusted for four fish species: shovelnose sturgeon, paddlefish, blue sucker, and sauger based on literature available for these species from recent tracking on the Yellowstone River (Rugg 2014, 2015, 2016; Bramblett et al. 2014). Pallid sturgeon timing was also adjusted based on recent tracking data for the Yellowstone River (Delonay et al. 2015; Rugg 2014, 2015, 2016).

Table 1-2. Habitat crosswalk for area between Intake and Cartersville (Yellowstone River Corridor Clearinghouse 2016).

Low Flow Fisheries Habitat	Acres	Habitats as Defined in UMRC FPCI Model					
		Contiguous Floodplain Lake	Main Channel Border	Main Nav Channel	Secondary Channel	Tertiary Channel	Trib Channel
2C - Secondary low flow channel	1,251				1,251		
2CS - Secondary high flow channel	1,930				1,930		
CC - Channel crossover	3,152			3,152			
DC - Dry Channel not meeting PB, SB, MCB or I categories	1,348					1,348	
I - Islands - vegetated	6,589						
MCB - Mid Channel Bar aggradation area within bankfull lines	772		772				
PB - Point Bar area in bankfull line showing aggradation	1,062		1,062				
SB - Side Bar area in channel showing aggradation at high flow lines at bank	0						
RRB - Scour at riprap - mid active channel	722			723			
RRM - Scour at riprap - margin of active channel	723		723				
SC - Scour in unconstrained river	3,099			3,099			
T - Scour at base of terrace	1,762		1,762				
BL - Scour at base of bedrock bluff	1,293		1,293				
Trib - Large tributary confluences	10						10
Dam	51			51			
TOTAL		0	5,612	7,025	3,181	1,348	10

Table 1-3. Opportunity for Fish Passage at Intake Diversion Dam for the No Action (existing conditions; associated primarily with peak runoff).

Month	Jan-Apr			May			June			July			Aug-Dec		
Week	1-17	18	19	20	21	22	23	24	25	26	27	28	29	30	31-52
% Opportunity for Passage	1	1	1	25	50	100	100	100	100	100	50	25	1	1	1

Table 1-4. Opportunity for Fish Passage for Rock Ramp Alternative

Month	Jan-Mar	Apr	May	June	July	Aug	Sept	Oct-Dec
Week	1-13	14-17	18-21	22-25	26-30	30-34	35-38	39-52
% Opportunity for Passage	1	95	97	100	97	95	95	1

Table 1-5. Opportunity for Fish Passage for the Bypass Channel, Modified Side Channel, and Multiple Pump Alternatives

Month	Jan-Mar	Apr	May	June	July	Aug	Sept	Oct-Dec
Week	1-13	14-17	18-21	22-25	26-30	30-34	35-38	39-52
% Opportunity for Passage	1	100	100	100	100	100	100	1

Table 1-6. Migratory Timing for Species Used in FPCI.

Pre-spawning movement period (P) **Spawning period** (S)

	Month of Year	February				March				April					May				June				July					August				September			
	Week of Year	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1	**Shovelnose sturgeon**														P	P	S	S																	
2	**Paddlefish**												P	P	P	P	S	S	S	S	S	S	S												
3	**Goldeye**												P	P	S	S	S	S	S	S	S	S	S												
4	**Smallmouth buffalo**																	P	P	S	S	S	S	S											
5	**Blue sucker**													P	P	P	S	S	S	S	S	S													
6	**White sucker**									P	P	S	S	S	S																				
7	**River carpsucker**												P	P	S	S	S	S	S	S	S	S	S	S	S	S									
8	**Shorthead redhorse**												P	P	S	S	S	S	S	S	S	S	S												
9	**Channel catfish**																		P	P	S	S	S	S	S	S	S	S	S	S					
10	**Smallmouth bass**													P	P	P	S	S	S	S	S	S	S	S	S										
11	**Walleye**						P	P	P	S	S	S	S	S	S	S	S	S																	
12	**Sauger**						P	P	P	P	S	S	S	S	S	S	S	S	S	S															
13	**Freshwater drum**														P	P	P	S	S	S	S														
14	**Pallid Sturgeon**											P	P	P	S	S	S	S	S	S	S	S													

1.3.4 Identity Potential Fish Passage Connectivity

1.3.4.1 Probability that Fish Encounters Fish Passage Alternative **(Ei)**

E_i simulates the relationship between fishway size (F_s) and ability of a fish to encounter the fishway entrance location (F_l) within the FPCI. (E_i) is expressed as a value ranging from 1 to 5, with 5 being highly likely, and 1 being unlikely. The relationship is represented by the following equation: $E_i = (F_s + F_l)/2$

1.3.4.2 Determine Potential for Fish to Encounter Passage Alternative **(Fl)**

Fl is used to assess the suitability of the fishway entrance location for each fish guild based on swimming performance and behavior. As described in the FPCI, swimming performance and migration behavior are important because they indicate the route as well as vertical and horizontal position within the flow field that a fish would generally select. Guilds of fish species, as defined by swimming performance and behavior. Table 4 in the Corps (2011) model documentation assigned values for the potential for fish species to encounter a fish passageway located in main channel, main channel border (near channel), main channel border (near shore) and lock locations (Table 4 attached). Species that primarily use main channel habitats are highly likely to encounter a main channel passageway (received a score of 5, indicating that the fish passageway entrance would be encountered by a significant portion of the population of that species). Species that primarily use channel border, side channel, or other habitats would be unlikely to encounter a main channel fish passageway (received a score of 1 indicating that it was unlikely the fish passageway entrance would be encountered). Scores ranging from 1 to 5 were assigned based on the location of the fish passageway in comparison to the primary habitat used by the species.

To assign an Fl value to each guild, the Corps (2015) used the same likelihood that was used in the Upper Mississippi system based on monitoring data and the professional judgment of an interagency group of large river fisheries biologists. For this analysis, as additional alternatives were included and additional detailed design had been completed for the proposed bypass channel to maximize the orientation and flows from the bypass channel for main channel fish to locate the channel entrance, the scores were re-evaluated and adjusted. The no action and rock ramp scores were not modified from the scores used by the Corps in 2015 (Table 1-8). For the bypass channel, main channel species including pallid sturgeon, shovelnose sturgeon, paddlefish, and blue sucker were assigned a score of 4 as the bypass channel entrance has been further modeled and designed for its attraction flows to be directed towards the main channel thalweg where these main channel species would be present. Additionally, walleye and sauger were assigned a score of 5 as the bypass channel entrance would be located and directed towards the near channel areas used by these species.

1.3.4.3 Determining the Size of Fish Passage Alternative (Fs)

- This parameter is the size of the fishway relative to the discharge of the river under low flow conditions. For the Yellowstone River, Corps (2014) used the recommendation by the BRT that fish passage alternatives should be capable of conveying up to 30% of river flow. Therefore the following range of inputs for Fs were established by Corps

(2015) for the Intake project; 5 was assigned to fishway designs that pass 30 percent or more of the low flow discharge, 4 = 25 percent, 3 = 20 percent, 2 = 15 percent, and 1 = equal to or less than 10%.

- More recent tracking of pallid sturgeon passing upstream of Intake Diversion Dam by pallid sturgeon in 2014 and 2015 (Rugg 2014, 2015) indicates that passage is possible when flow in the existing side channel is only 2-6% of the river flow (based on HEC-RAS modeling for this study of flow splits into the side channel at river flows from 30,000 to 63,000 cfs, which was the rage of river flows when passage occurred).

The size of fishway for each alternative is listed in

- Table 1-9. The No Action, Rock Ramp, and dam removal alternatives all pass full flows of the river and received inputs of 5, whereas the bypass channel and modified side channel alternatives pass 15% of the flow and received inputs of 2.

Table 1-7. Swimming Performance and Behavior Guilds.

Performance	**Behavior**		
	Benthic	**Littoral**	**Pelagic**
Strong	Pallid sturgeon	Walleye	Paddlefish
	Shovelnose sturgeon	Sauger	
	Blue sucker		
Medium	Channel catfish	Smallmouth bass	Goldeye
	Freshwater drum		
	Shorthead redhorse		
	Smallmouth buffalo		
Weak	River carpsucker		
	White sucker		

Table 1-8. Estimate of Likelihood of Encountering the Fishway Entrance for Each Fish Guild. (Values: 5 – significant portion of population would encounter, 1 –unlikely that fish would encounter)

Estimated Probability of Encountering Fishway Locations (Fl) for Each Fish Guild				
	Fishway Location			
Guild	**Main Channel – Rock Ramp**	**Main Channel Border –Near Channel Thalweg(Bypass Channel)**	**Main Channel Border – Near Shore or Side Channel (Modified Side Channel)**	**No Dam**
Benthic – Strong -Pallid Sturgeon -Shovelnose Sturgeon -Blue sucker	5	4	2	5
Littoral – Strong -Walleye -Sauger	5	5	5	5
Pelagic – Strong -Paddlefish	5	4	2	5
Benthic – Medium -Channel Catfish -Freshwater Drum -Shorthead Redhorse -Smallmouth Buffalo	3	5	5	5
Littoral – Medium -Smallmouth Bass	1	5	5	5
Pelagic – Medium -Goldeye	1	5	5	5
Benthic – Weak -River Carpsucker -White Sucker	1	5	5	5
Littoral – Weak	1	5	5	5
Pelagic – Weak	1	5	5	5

Table 1-9. FPCI input data for Size of the fishway relative to flow (Fs). (Range of inputs for Fs are as follows: 5 = >30% of low flow discharge of river, 4 = 25% to >20% percent, 3 = 20% to >15% percent, 2 = 15% to >10%, and 1 = < 10%)

Size of Fishway (F_s)					
Measure A: No Action	**Measure B: Rock Ramp**	**Measure C: Bypass Channel 15% Flow**	**Measure D: Modified Side Channel 15% Flow**	**Measure E: Multiple Pumps**	**Measures F: Multiple Pumps with Conservation Measures**
F_s - Size of Fishway: 5	F_s - Size of Fishway: 5	F_s - Size of Fishway: 2	F_s - Size of Fishway: 2	F_s - Size of Fishway: 2	F_s - Size of Fishway: 5

1.3.4.4 Determine the Potential (U_i) for Fish to Use Alternative Fish Passage Measures, and the Duration of Availability (D_i) of the Alternative Measures.

The potential for a fish to pass upriver past an obstacle is dependent on its swimming performance, the hydraulic conditions that are encountered, and the likely pathway a fish would use (i.e. main channel vs. bank zone). Critical current velocities (U_{crit}), or the speed at which a fish can maintain prolonged swimming by adult fish used in this analysis are found in Table 1-1. The average current velocity at specific locations within each alternative (at 30,000 or 40,000 cfs) was compared to the U_{crit} speed for each migratory fish species. Scores can be selected over a range from 1 to 5. If velocities did not exceed the U_{crit} speed, the U_i was scored a 5. If velocities exceed U_{crit} speed, but was not likely to exceed burst speed it was scored a 3, and if velocity was likely to exceed burst speeds in a key location (i.e. inlet or outlet), or was widespread without potential for resting, it was scored a 1.

- Scores for Ui can be found in Table 1-10. Explanation of the selection of scores are provided below.
  a. Flow velocities over the existing dam are over 10 ft/sec, with turbulent flow. As such, it scores 1 for the U_i variable for most fish, with the exception of shovelnose sturgeon, paddlefish, blue sucker, walleye and sauger that have been documented to pass over the dam occasionally (Rugg 2016; Bramblett, et al. 2015), thus each getting a score of 2.
  b. The rock ramp has slightly reduced velocities as compared to the existing condition, but exceeds the U_{crit} of all species over a majority of the ramp (i.e. 8 ft/sec) and would likely have turbulent flow. The only fish likely to be able to pass consistently is paddlefish that have high U_{crit}, thus meriting a 5. Walleye is a strong swimmer that may be able to pass high velocities, but based on data from Peake et al. (2000) indicating walleye do not like to transition from slower to faster water readily, thus meriting a slightly reduced score of 4. Fish that are more littoral or pelagic in behavior that may use the margins of the rock ramp received a 3, and strong benthic swimmers other than paddlefish also received a 3, since passage is likely to be somewhat improved and these species have occasionally shown an ability to pass over the dam. Pallid sturgeon are still unlikely to be able to swim through turbulent flows and uneven rocks over such a long distance, although improved from the existing condition, thus receiving a 2 and river carpsucker are weak swimmers, thus receiving a 1.
  c. The bypass channel and modified side channel velocity modeling indicates velocities not greater than the U_{crit} for all species along the sides of the channel, thus allowing passage for all species.
  d. While not a consideration in the modeling, both the bypass and modified side channel alternatives would also have much less turbulence associated with them, as they would both provide channels that are very much like existing side channels of the Yellowstone River in terms of width, gradient and substrate.
  e. The multiple pump alternatives would return the channel to near natural conditions, thus allowing passage for all species.

1.3.4.5 Duration of Availability (Di) of the fish passage structure is the proportion of time when both the fish passage structure is physically available for passage, and migration is actually occurring for a particular species of fish.

Table 1-11 identifies when fish passage alternatives are available to fish for each alternative.

Di for the existing condition is calculated as the fraction of time that upriver movement may generally occur when the physical conditions at the dam allow for passage, typically during runoff. Thus, the Di is highly variable between each species of fish, depending on their migration timing in relation to the runoff period.

The Di for the rock ramp would be more passable with a low-flow channel through the replacement weir and ramp, but does not necessarily provide suitable depths and velocities at all times for all species and would not necessarily be the location where all species would seek passage. Thus, D_i was calculated from the opportunity for passage and migration timing of the species in relation to the runoff period.

The Di for all the other alternatives is available 100% of the time (ranked a 1) when passage is occurring. This is because the channels are all designed to have 13-15% flows at all flows above 7,000 cfs and also still convey flow down to 3,000 cfs, or lower, in the river.

Table 1-10. Potential (Ui) for Fish to Use Alternative Fish Passage Measures.

Scores can be selected on a scale of 1 to 5: If velocities do not exceed the U_{crit} speed for the alternative, the U_i was scored a 5; If velocities exceed U_{crit} speed but did not exceed burst speed it was scored a 3; and if velocities exceed burst speeds at all times it was scored a 1. Scores of 2 or 4 were selected for instances of known, but infrequent passage or limited flows when velocities do not exceed burst speed; or if velocities occasionally exceed U_{crit}, respectively.

Potential for Species to Use Fishway Type						
	Measure A: No Action	**Measure B: Rock Ramp**	**Measure C: Bypass Channel 15% Flow**	**Measure D: Modified Side Channel**	**Measure E: Multiple Pumps**	**Measure F: Multiple Pumps with Conservation Measures**
Fish Species	Ui	Ui	Ui	Ui	Ui	Ui
Shovelnose sturgeon	1	3	5	5	5	5
Pallid sturgeon	1	2	5	5	5	5
Paddlefish	2	5	5	5	5	5
Goldeye	1	3	5	5	5	5
Smallmouth buffalo	1	3	5	5	5	5
Blue sucker	2	3	5	5	5	5
White sucker	1	3	5	5	5	5
River carpsucker	1	1	5	5	5	5
Shorthead redhorse	1	3	5	5	5	5
Channel catfish	1	3	5	5	5	5
Smallmouth bass	1	3	5	5	5	5
Walleye	2	4	5	5	5	5
Sauger	1	3	5	5	5	5
Freshwater drum	1	3	5	5	5	5

Table 1-11. Duration Of Availability (Di) Of The Fish Passage Structure Is The Proportion Of Time When Both The Fish Passage Structure Is Physically Available For Passage, And Migration Is Likely Occurring For A Particular Species Of Fish.

Potential of Availability of Fishway Alternatives						
	Measure A: No Action	**Measure B: Rock Ramp**	**Measure C: Bypass Channel 15% Flow**	**Measure D: Modified Side Channel**	**Measure E: Pumping**	**Measure F: Ranney Wells**
Fish Species	Di	Di	Di	Di	Di	Di
Shovelnose sturgeon	0.19	0.97	1	1	1	1
Pallid sturgeon	0.44	0.98	1	1	1	1
Paddlefish	0.53	0.98	1	1	1	1
Goldeye	0.53	0.98	1	1	1	1
Smallmouth buffalo	0.86	0.99	1	1	1	1
Blue sucker	0.53	0.98	1	1	1	1
White sucker	0.01	0.95	1	1	1	1
River carpsucker	0.47	0.98	1	1	1	1
Shorthead redhorse	0.53	0.98	1	1	1	1
Channel catfish	0.48	0.98	1	1	1	1
Smallmouth bass	0.54	0.98	1	1	1	1
Walleye	0.07	0.72	1	1	1	1
Sauger	0.20	0.76	1	1	1	1
Freshwater drum	0.54	0.98	1	1	1	1

Table 1-12. Connectivity Index and Habitat Units

Migratory Fish Species		Measure A: No Action		Measure B: Rock Ramp		Measure C: Bypass Channel, 15% Flow		Measure D1: Modified Side Channel		Measure E: Multiple Pump		Measure F: Multiple Pumps w/ Conservati	
Common Name	Total Available Preferred Habitat (acres)	€ = Fish Passage Connectivity	Habitat Units (€ X acres)	€ = Fish Passage Connectivity	Habitat Units (€ X acres)	€ = Fish Passage Connectivity	Habitat Units (€ X acres)	€ = Fish Passage Connectivity	Habitat Units (€ X acres)	€ = Fish Passage Connectivity	Habitat Units (€ X acres)	€ = Fish Passage Connectivity	Habitat Units (€ X acres)
Shovelnose sturgeon	12637	0.08	973.0	0.58	7,354.7	0.60	7,582.2	0.40	5,054.8	1.00	12,637.0	1.00	12,637.0
Paddlefish	12637	0.21	2,660.7	0.98	12,349.8	0.60	7,582.2	0.40	5,054.8	1.00	12,637.0	1.00	12,637.0
Goldeye	10141	0.06	640.5	0.35	3,567.8	0.70	7,098.7	0.70	7,098.7	1.00	10,141.0	1.00	10,141.0
Smallmouth buffalo	17166	0.10	1,765.6	0.36	6,100.3	0.70	12,016.2	0.70	12,016.2	1.00	17,166.0	1.00	17,166.0
Blue sucker	5612	0.21	1,192.2	0.59	3,303.6	0.60	3,367.2	0.40	2,244.8	1.00	5,612.0	1.00	5,612.0
White sucker	5612	0.00	6.7	0.34	1,926.0	0.70	3,928.4	0.70	3,928.4	1.00	5,612.0	1.00	5,612.0
River carpsucker	10141	0.06	569.3	0.12	1,187.4	0.70	7,098.7	0.70	7,098.7	1.00	10,141.0	1.00	10,141.0
Shorthead redhorse	5612	0.06	354.5	0.35	1,974.4	0.70	3,928.4	0.70	3,928.4	1.00	5,612.0	1.00	5,612.0
Channel catfish	17166	0.06	995.6	0.35	6,025.3	0.70	12,016.2	0.70	12,016.2	1.00	17,166.0	1.00	17,166.0
Smallmouth bass	15818	0.07	1,032.9	0.35	5,571.1	0.70	11,072.6	0.70	11,072.6	1.00	15,818.0	1.00	15,818.0
Walleye	15818	0.03	448.2	0.58	9,132.3	0.70	11,072.6	0.70	11,072.6	1.00	15,818.0	1.00	15,818.0
Sauger	15818	0.08	1,288.0	0.46	7,226.6	0.70	11,072.6	0.70	11,072.6	1.00	15,818.0	1.00	15,818.0
Freshwater drum	17166	0.06	1,109.4	0.35	6,073.8	0.70	12,016.2	0.70	12,016.2	1.00	17,166.0	1.00	17,166.0
Pallid sturgeon	12637	0.04	551.4	0.20	2,465.4	0.60	7,582.2	0.40	5,054.8	1.00	12,637.0	1.00	12,637.0
		Avg.	971	Avg.	5,304	Avg.	8,388	Avg.	7,766	Avg.	12,427	Avg.	12,427

Table 1-13 shows the resulting fish passage connectivity index and habitat units for each alternative.

Table 1-13. Fish Passage Connectivity Index Scores and Habitat Units.

Alternative	W/ Pallid, 14 Species		
	Є = Fish Passage Connectivity (Avg.)	**Avg. Habitat Units**	**Δ HUs**
A: No Action	0.08	971	**0**
B: Rock Ramp	0.43	5,304	**4,333**
C: Bypass Channel	0.67	8,388	**7,417**
D: Modified Side Channel	0.61	7,766	**6,795**
E: Multiple Pump Alternative	1	12,427	**11,456**
F: Multiple Pumps with Conservation Measures	1	12,427	**11,456**

2.0 Cost Effectiveness and Incremental Cost Analysis

The plan evaluation process utilized in this study is based upon methods described in the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (U.S. Water Resources Council 1983) referred to as the P&G and the associated Corps implementation guidance found in Engineer Regulation (ER) 1105-2-100 Planning Guidance Notebook (U.S. Army Corps of Engineers 2000). The specific plan evaluation and comparison methods applied are from the *Evaluation of Environmental Investments Procedures Manual, Interim: Cost Effectiveness and Incremental Cost Analysis* document (U.S. Army Corps of Engineers 1995). This methodology consists of a series of steps that provide an orderly and systematic approach to comparing the costs and benefits of a range of alternative plans to inform the selection of a recommended plan. Plan formulation and evaluation is a dynamic process, whereby the steps may be iterated one or more times as new information or new alternatives are developed, or as planning objectives are reevaluated.

When planning for the restoration of environmental resources, cost effectiveness (CE) and incremental cost analyses (ICA) may be used as tools for the comparison of alternative plans (CE/ICA). CE/ICA are comparisons of the effects of alternative plans; more specifically, they involve comparisons between the outputs and costs of different solutions. Information about alternative plans and their effects must be developed in order to conduct the CE/ICA comparisons.

Traditional benefit-cost analyses are not applicable to environmental planning because costs and benefits are expressed in different units; however, CE/ICA offers plan evaluation approaches that are consistent with the P&G evaluation framework. The Institute for Water Resources (IWR) Planning Suite software was used to assist in performing the CE/ICA. Alternative plans were evaluated and compared in terms of cost (e.g. construction, operation, and maintenance) and environmental outputs over a 50-year period of analysis. IWR Planning Suite helps determine and present the relative efficiency and effectiveness of alternative plans at generating environmental outputs. The most efficient plans are referred to as “best buys.” The Corps’ policies for cost effectiveness and incremental cost analysis, ER 1105-2-100, paragraph E.36, states:

> *Cost effectiveness and incremental cost analysis are two distinct analyses that must be conducted to evaluate the effects of alternative plans. First, it must be shown through cost effectiveness analysis that an alternative restoration plan’s output cannot be produced more cost effectively by another alternative. “Cost effective” means that, for a given level of nonmonetary output, no other plan costs less and no other plan yields more output for less money. Subsequently, through incremental cost analysis, a variety of implementable alternatives and various-sized alternatives are evaluated to arrive at a “best” level of output within the limits of both the sponsor’s and the Corps capabilities. The subset of cost effective plans are examined sequentially (by increasing scale and increment of output) to ascertain which plans are most efficient in the production of environmental benefits. The most efficient plans are called “Best Buys.” They provide the greatest increase in output for the least increases in cost. They have the lowest incremental costs per unit of output.*

2.1 Methodology

The CE/ICA analysis utilized the Corps IWR Planning Suite model. The Corps-certified model provides a systematic method for testing all possible combinations of ecosystem restoration measures to identify combinations of measures (alternative plans) which are cost effective, and then ranks cost effective plans according to their efficiency to identify "best buy" plans. Because this analysis considered six complete alternatives which were mutually exclusive, no alternatives were combined in the model. Instead, the software will identified which plans were cost effective, and then ranked the cost effective plans by efficiency to identify "best buy" plans. The CE/ICA model required the following inputs:

Average annual habitat units (AAHUs) for each alternative: Because habitat benefits are non-monetary, the outputs are referred to as "units" of output. In order to compare action alternatives to the No Action Alternative, AAHUs are typically converted to "net AAHUs," which is the change in habitat units versus No Action. Thus, the No Action Alternative is always entered as zero net AAHUs, and each action alternative is entered as the additional AAHUs that would be generated compared to this baseline. AAHUs were developed using the FPCI Model as detailed previously in this appendix.

Average annualized cost for each alternative: Costs used in the analysis included construction, PED/CM, real estate, monitoring and adaptive management, interest during construction, and operation, maintenance, and rehabilitation (OM&R). Annualized costs are presented at an FY16 price level, amortized over a 50-year period of analysis using the FY16 Federal interest rate for Corps of Engineers projects of 3.125% (U.S. Army Corps of Engineers 2015). For each action alternative, net costs above the No Action Alternative are calculated for use in the analysis, consistent with the net habitat output calculation. Detailed cost tables are available in Cost Appendix B.

2.1.1 Annualized Costs and AAHU's

Table 2-1 summarizes AAHUs for each alternative, in total and on net. As defined above, AAHUs are average annual habitat outputs, and net AHHUs are the change in output versus the No Action Alternative.

Table 2-1. AAHU's By Alternative

Alternatives	Habitat Output	
	AAHUs	**Net AAHUs**
No Action	971	-
Rock Ramp	5,304	4,333
Bypass Channel	8,388	7,417
Modified Side Channel	7,766	6,795
Multiple Pump	12,427	11,456
Multiple Pumps with Conservation Measures	12,427	11,456

Table 2-2 summarizes the annualized cost for each alternative. Like the habitat output calculation, costs for each action alternative are calculated as the net costs above the No Action Alternative. For each alternative, inputs to the model were the net AAHUs and the net annualized project cost. Because the only costs which would be incurred in the No Action Alternative would be OM&R and monitoring, the net cost for each action alternative is equivalent to construction-related costs plus the incremental operational costs above the No Action for each alternative, as noted by the row “Net OM&R and Monitoring” in the following table.

Table 2-2. Net Cost by Alternative ($1000s)

	No Action	Rock Ramp	Bypass Channel	Modified Side Channel	Multiple Pump Alternative	Multiple Pumping w/ Cons.
Construction First Cost (PV)	$0	$90,454	$57,044	$54,441	$132,028	$477,925
Interest During Construction (PV)	$0	$1,880	$2,002	$1,123	$6,556	$53,789
Adaptive Management (PV)	$0	$796	$538	$476	$1,153	$4,145
OM&R and Monitoring (PV)	$66,420	$71,370	$70,333	$73,046	$124,395	$114,768
Net OM&R and Monitoring (PV)	**$0**	**$4,950**	**$3,913**	**$6,626**	**$57,975**	**$48,348**
Subtotal - Net Alternative Costs (PV)	$0	$98,081	$63,497	$62,665	$197,712	$584,208
Total Annualized Net Cost (AC)	**$0**	**$3,903**	**$2,527**	**$2,494**	**$7,868**	**$23,247**

IDC – interest during construction
OM&R – operation, maintenance, and rehabilitation
PV – Present Value (FY2016)
AC – Annualized Cost (3.125%, 50 years)

2.2 Cost Effectiveness Analysis

Cost effectiveness analysis is a form of economic analysis designed to compare costs and outcomes (or effects) of two or more courses of action. This type of analysis is useful for environmental restoration projects where the benefits are not measured in monetary terms but in environmental output units such as the Habitat Units developed in this study. The purpose of the cost effectiveness analysis is to ensure that the least cost plan alternative is identified for each possible level of environmental output; and that for any level of investment, the maximum level of output is identified. Per IWR 95-R-01, an alternative is ***not*** to be considered cost effective if any of the following rules are met:

1. The same output level could be produced by another plan at least cost;
2. A larger output level could be produced at the same cost; or
3. A larger output level could be produced at less cost.

Table 2-3 provides the results of the cost effectiveness analysis sorted by increasing output. As shown in the table, alternatives were identified as cost effective only when no other alternative provided the same output for less cost, and no other alternative provided larger output at the same or less cost. The No Action, Bypass Channel, Modified Side Channel and Multiple Pump alternatives were identified as cost effective. The Rock Ramp alternative is not cost effective because the Bypass Channel alternative provides greater output for less cost. The Multiple Pumps with Conservation Measures alternative is not cost effective because the multiple pump stations alternative provides the same level of output for less cost.

Table 2-3. Cost Effectiveness by Alternative

Alternative	Annual Cost ($)	Net AAHUs	Cost per AAHU ($)	Cost Effective?
No Action	$0	0	$0	Yes
Rock Ramp	$3,903,000	4,333	$901	No
Modified Side Channel	$2,494,000	6,795	$367	Yes
Bypass Channel	$2,527,000	7,417	$341	Yes
Multiple Pump	$7,868,000	11,456	$687	Yes
Multiple Pumps w/ Conservation Measures	$23,247,000	11,456	$2,029	No

Figure 2-1 provides a graph of the total output and annualized costs for each of the alternatives while differentiating the cost effective plans from the non-cost effective ones. Per IWR 95-R-01, any alternatives that are not found to be cost effective "should be dropped from further analysis" in the CE/ICA process. Therefore the Rock Ramp and Multiple Pumps with Conservation Measures alternatives are not included in the ICA analysis that follows.

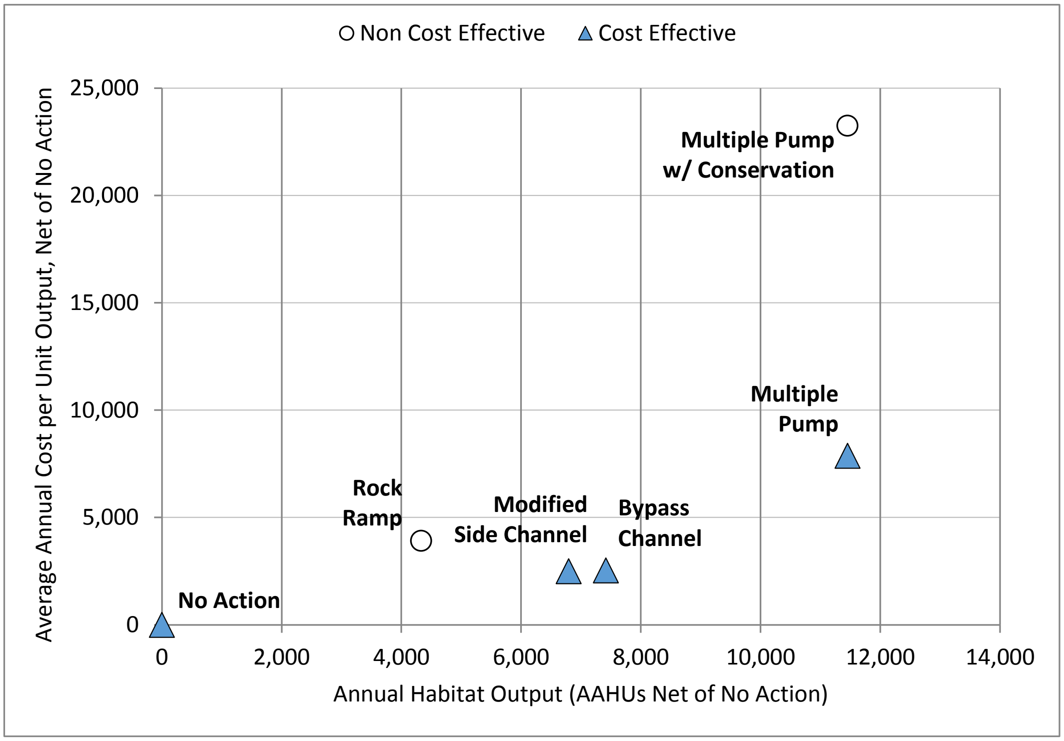


Figure 2-1. Cost Effectiveness Analysis Graph

2.3 Incremental Cost Analysis

Subsequent incremental cost analysis of the cost effective plans is conducted to reveal changes in costs as output levels are increased. Only plans that were deemed as cost effective in the CE analysis have been advanced to ICA. These cost effective plans are the No Action, Bypass Channel, Modified Side Channel and Multiple Pump alternatives. During the ICA, the cost effective plans are examined sequentially (by increasing scale in terms of net AAHUs produced) to ascertain which plans are most efficient in the production of additional environmental benefits.

The first step, per IWR 95-R-01, is to “smooth out fluctuations in incremental costs per unit as project scale increases such that incremental cost per habitat unit are continuously increasing.” This is first completed by calculating the incremental cost per unit for each plan over the “baseline condition,” which is the no action plan. Once the incremental costs per unit are calculated and sorted by increasing output, the alternative with the lowest incremental cost per unit will be selected as the first “best buy” alternative. Table 2-4 shows the calculation of the incremental costs per unit with the no action alternative set as the baseline for the cost effective alternatives.

Table 2-4. Identification of the First Best Buy Plan

Alternative	Annual Cost ($)	Net AAHUs	Incremental Output	Incremental Cost	Incremental Cost per Unit Output
No Action	$0	0	0	$0	$0
Modified Side Channel	$2,494,000	6,795	6,795	$2,494,000	$367
Bypass Channel	$2,527,000	7,417	7,417	$2,527,000	$341
Multiple Pump	$7,868,000	11,456	11,456	$7,868,000	$687

Table 2-4 indicates that the Bypass Channel alternative is the first best buy alternative because it has the lowest incremental cost per unit of output. At this step of the ICA the incremental cost per unit is equal to the average annual cost per unit values calculated in Table 2-3 because complete alternatives are being compared, not combinations of measures.

After selection of this best buy alternative, per IWR 95-R-01, all alternatives which produce fewer net AAHU's (see last column in Table 2-1) are removed from further iterations of the incremental cost analysis. Thus the Modified Side Channel alternative is removed from further analysis in the CE/ICA, and is not considered a best buy plans.

Next, the incremental process should be started anew with the first best buy plan. Thus the Bypass Channel is set as the new baseline. However, for this study only the Multiple Pump alternative is remaining, and is therefore a best buy plan as well, since no other plans can produce more output for lower incremental cost per unit.

The final step in the ICA process is to analyze the incremental cost per incremental unit of output for the best buy alternatives only. This includes the No Action, Bypass Channel, and Multiple Pump alternatives. Incremental costs are calculated between each successive best buy plan. Table 2-5 shows the incremental cost per unit output between the three best buy alternatives.

Table 2-5. Incremental Cost Analysis Summary

Best Buy Alternative	Annual Cost ($)	Net AAHUs	Incremental Cost	Incremental Output	Incremental Cost per Unit Output
No Action	$0	0	$0	0	$0
Bypass Channel	$2,527,000	7,417	$2,527,000	7,417	$341
Multiple Pump	$7,868,000	11,456	$5,341,000	4,039	$1,322

This table shows that the most efficient plan above No Action is the Bypass Channel alternative that provides 7,417 additional habitat units at a cost of $341 each. If more output is desired, the next most efficient plan available is the Multiple Pump alternative that provides an additional 4,039 habitat units, at a cost of $1,322 dollars for each additional unit. Figure 2-2 provides a visual representation of this increase in incremental cost. The figure graphically illustrates the incremental cost and output differences between the two best buy action alternatives. The width of each box in the chart represents the incremental output of that plan, and the height of each box shows the incremental cost per unit of that output. The relatively wide box for the Bypass Channel alternative shows that it provides about 65% of the total output possible at a cost of approximately $341 per unit. The box for the Multiple Pump alternative shows that to achieve the remaining 35% of total possible output would be more expensive per unit than the first 65%. Such breakpoints in incremental cost per unit typically require a higher level of justification if the study team is to recommend the larger output plan.

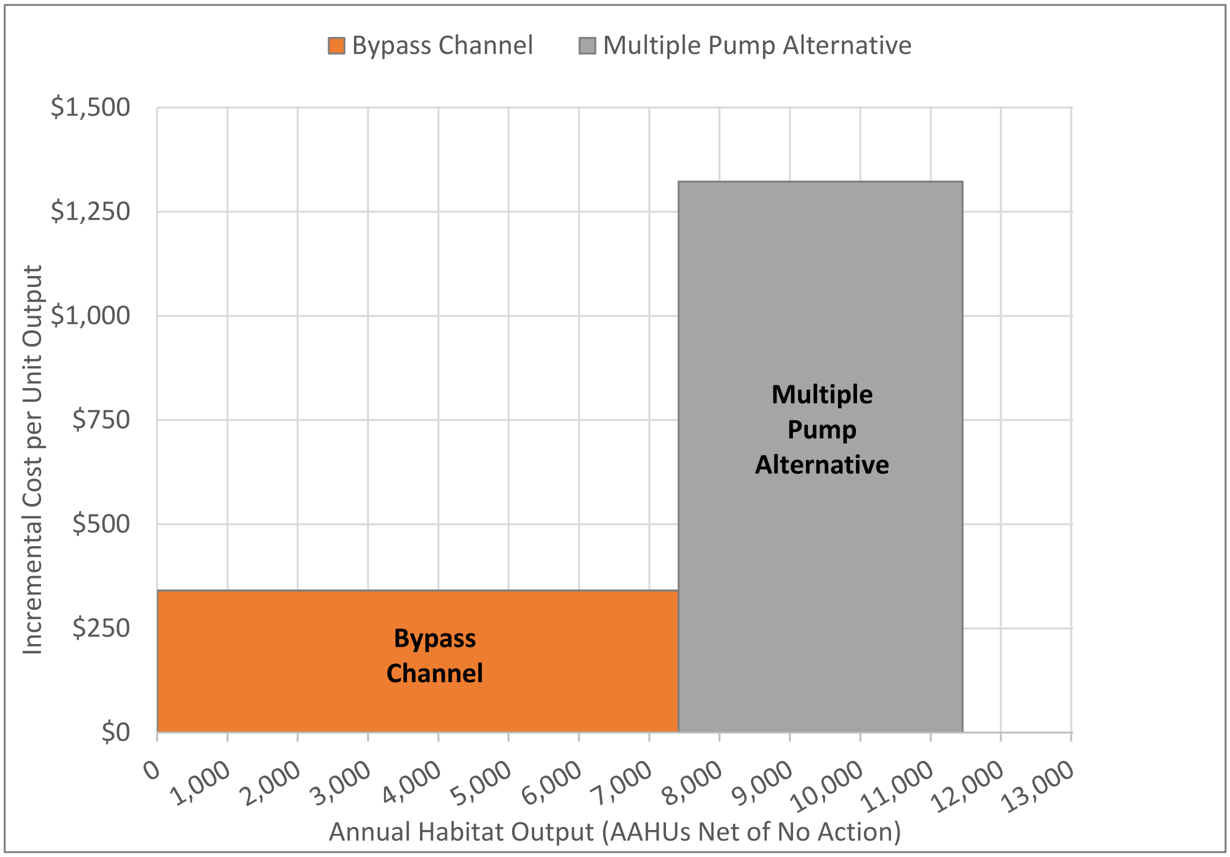


Figure 2-2. Incremental Cost Analysis Chart

2.4 Summary of Conclusions

The results of the CE/ICA do not provide a discrete decision for selecting the preferred plan, but rather they offer organized data on the effectiveness and efficiency of the range of alternatives under consideration to help inform a decision. For Corps ecosystem restoration projects, the selected plan should be the alternative having the maximum excess of non-monetary benefits (habitat output) over costs. This plan occurs where the incremental beneficial effects just equal the incremental costs, or alternatively stated, the recommended plan is selected by identifying the largest plan for which the extra habitat output is still worth the extra costs. Definition of the level of output that is “worth it” is a concern for the study team that will consider specific project factors and information.

Thus, a plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with the Federal objective, can be identified as the selected plan. The selected plan should also be cost effective and justified in achieving the desired level of output. In practice, the selected plan is chosen from the suite of cost effective plans identified in the CE/ICA. While the selected plan is not required to be a best buy plan, this is typically the case.

2.5 Sensitivity Analysis

In order to evaluate the sensitivity of the CE/ICA results to changes in the FPCI model outputs, two sensitivity scenarios were modeled. In the first scenario, revised fishway location, the scores were reduced for the bypass channel, which reduces that alternative's habitat outputs. In the second scenario, pallid sturgeon only, only the variable for pallid sturgeon was included, which changes the total habitat outputs for all alternatives. These two scenarios reasonably evaluate the possibility of reduced effectiveness for the bypass channel and a focus on pallid sturgeon-specific benefits. Note that the Modified Side Channel alternative in both scenarios always has been given a lower score than the Bypass Channel Alternative as the location of the entrance for upstream migrating fish is approximately 2 miles downstream of Intake Diversion Dam and distant from the main channel so fish are less likely to find it as compared to the bypass channel.

Tables 2-6 and 2-7 summarizes the FPCI revisions for each scenario. Based on these revised habitat output values, and using the same costs, the CE/ICA model was re-run twice. Tables 2-8 and 2-9 provides the cost effectiveness tables for the two scenarios, and Tables 2-10 and 2-11 provide the best buy plans incremental cost tables. Finally, summary graphics are provided for both scenarios side-by-side.

As shown in the tables and figures, even when components of the FCPI scoring are revised, the order of alternatives in terms of average cost per unit output does not change.

- Scenario 1 – Revised Fishway Scenario: the reduced output of the Bypass Channel alternative makes its average cost per unit output more expensive, though it remains less expensive per unit than the Modified Side Channel, resulting in no changes to the identified cost effective and best buy plans.
- Scenario 2 – Pallid Sturgeon Only: by only considering Pallid Sturgeon in the FPCI, the relative cost effectiveness of the alternatives does not change. The Bypass Channel remains the first best buy plan. However, the total output possible for the Rock Ramp, Modified Side Channel, and Bypass Channel alternatives are all reduced. In this scenario, the Bypass Channel would provide for about 48% of possible habitat output, rather than 65% as in the main analysis which considered 14 species.

In both scenarios, the order of alternatives in terms of average cost per unit output did not change. Based on this analysis, it was determined that there is reasonable confidence that, as currently designed, the Bypass Channel Alternative is less costly per unit than the Multiple Pump Alternative, and that the two best buy action alternatives are the Bypass Channel and the Multiple Pump Alternative.

Table 2-6. Scenario 1 – Revised Fishway Location, FPCI

Alternative	W/ Pallid, 14 Species		
	€ = Fish Passage Connectivity (Avg.)	Avg. Habitat Units	Δ HUs
No Action	0.08	971	0
Rock Ramp	0.43	5,304	4,333
Bypass Channel	0.67	8,077	7,106
Modified Side Channel	0.61	7,766	6,795
Multiple Pump Alternative	1	12,427	11,456
Multiple Pumping w/ Cons.	1	12,427	11,456

Table 2-7. Sensitivity Scenario 2 – Pallid Sturgeon Only, FPCI

Alternative	Pallid Sturgeon Only		
	€ = Fish Passage Connectivity (Avg.)	Avg. Habitat Units	Δ HUs
No Action	0.04	551	0
Rock Ramp	0.2	2,465	1,914
Bypass Channel	0.5	6,319	5,768
Modified Side Channel	0.4	5,055	4,504
Multiple Pump Alternative	1	12,637	12,086
Multiple Pumping w/ Cons.	1	12,637	12,086

Table 2-8. Scenario 1 – Revised Fishway Location, Cost Effectiveness

Alternative	Annual Cost ($)	Net AAHUs	Cost per AAHU ($)	Cost Effective?
No Action	$0	-	$0	Yes
Rock Ramp	$3,903,000	4,333	$901	No
Modified Side Channel	$2,494,000	6,795	$367	Yes
Bypass Channel	$2,527,000	7,106	$356	Yes
Multiple Pump	$7,868,000	11,456	$687	Yes
Multiple Pumps w/ Conservation Measures	$23,247,000	11,456	$2,029	No

Table 2-9. Sensitivity Scenario 2 – Pallid Sturgeon Only, Cost Effectiveness

Alternative	Annual Cost ($)	Net AAHUs	Cost per AAHU ($)	Cost Effective?
No Action	$0	-	$0	Yes
Rock Ramp	$3,903,000	1,914	$2,039	No
Modified Side Channel	$2,494,000	4,504	$554	Yes
Bypass Channel	$2,527,000	5,768	$438	Yes
Multiple Pump	$7,868,000	12,086	$651	Yes
Multiple Pumps w/ Conservation Measures	$23,247,000	12,086	$1,923	No

Table 2-10. Scenario 1 – Revised Fishway Location, Incremental Cost

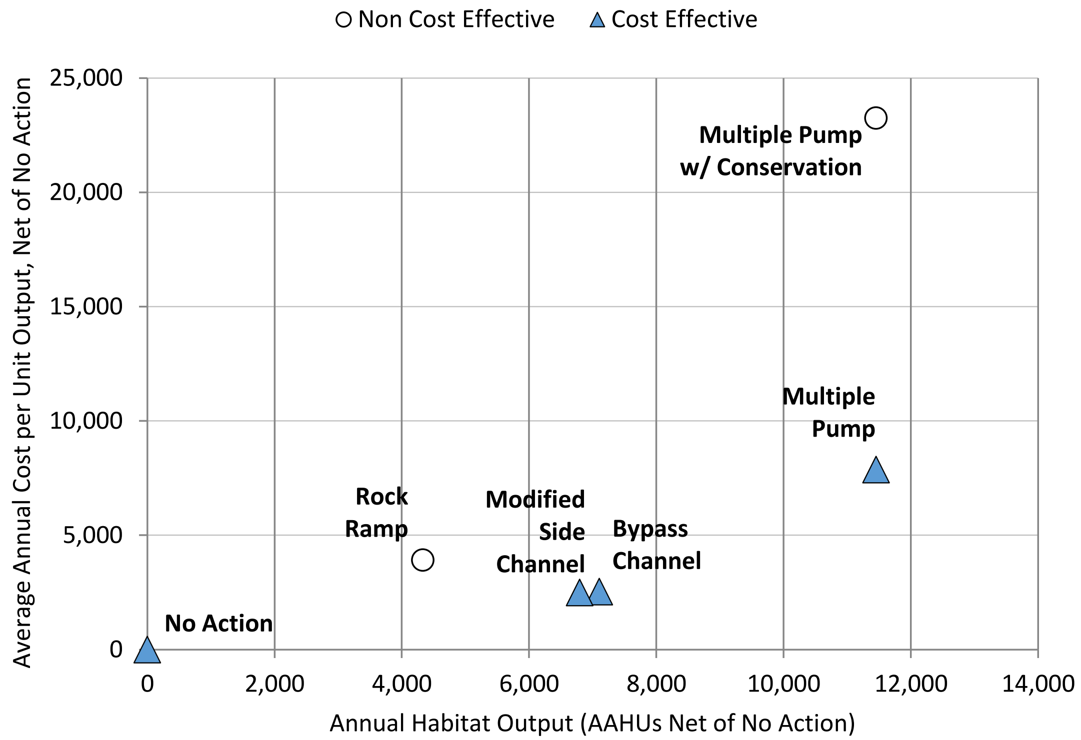
Best Buy Alternative	Annual Cost ($)	Net AAHUs	Incremental Cost	Incremental Output	Incremental Cost per Unit Output
No Action	$0	0	$0	0	$0
Bypass Channel	$2,527,000	7,106	$2,527,000	7,106	$356
Multiple Pump	$7,868,000	11,456	$5,341,000	4,350	$1,228

Table 2-11. Sensitivity Scenario 2 – Pallid Sturgeon Only, Incremental Cost

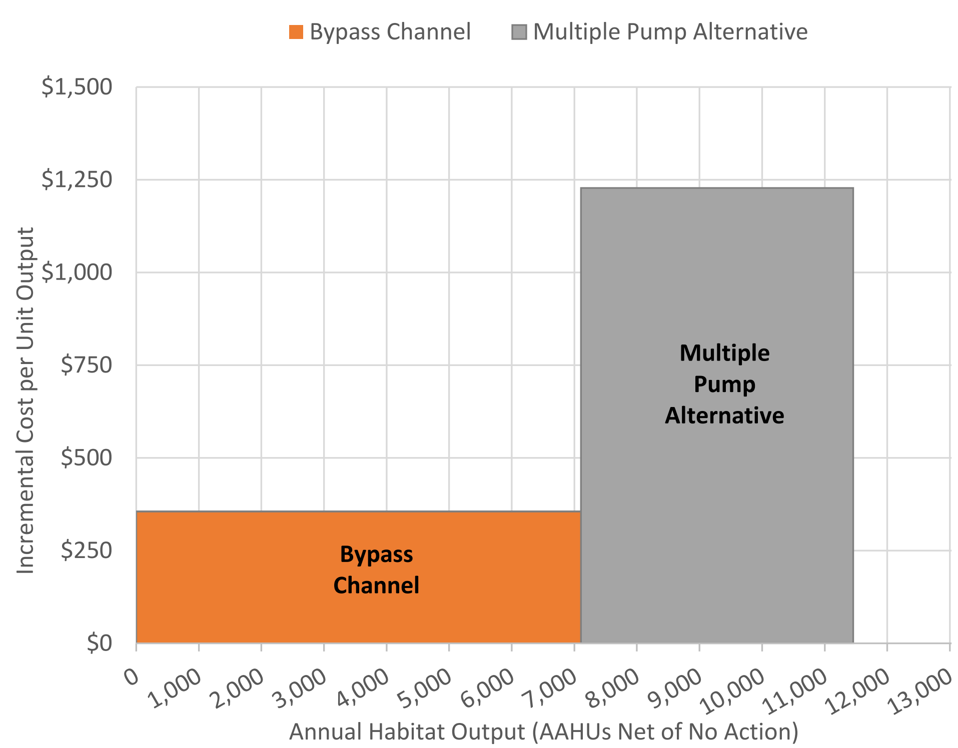
Best Buy Alternative	Annual Cost ($)	Net AAHUs	Incremental Cost	Incremental Output	Incremental Cost per Unit Output
No Action	$0	0	$0	0	$0
Bypass Channel	$2,527,000	5,768	$2,527,000	5,768	$438
Multiple Pump	$7,868,000	12,086	$5,341,00	6,318	$845

Scenario 1 – Revised Fishway Location

Cost Effectiveness

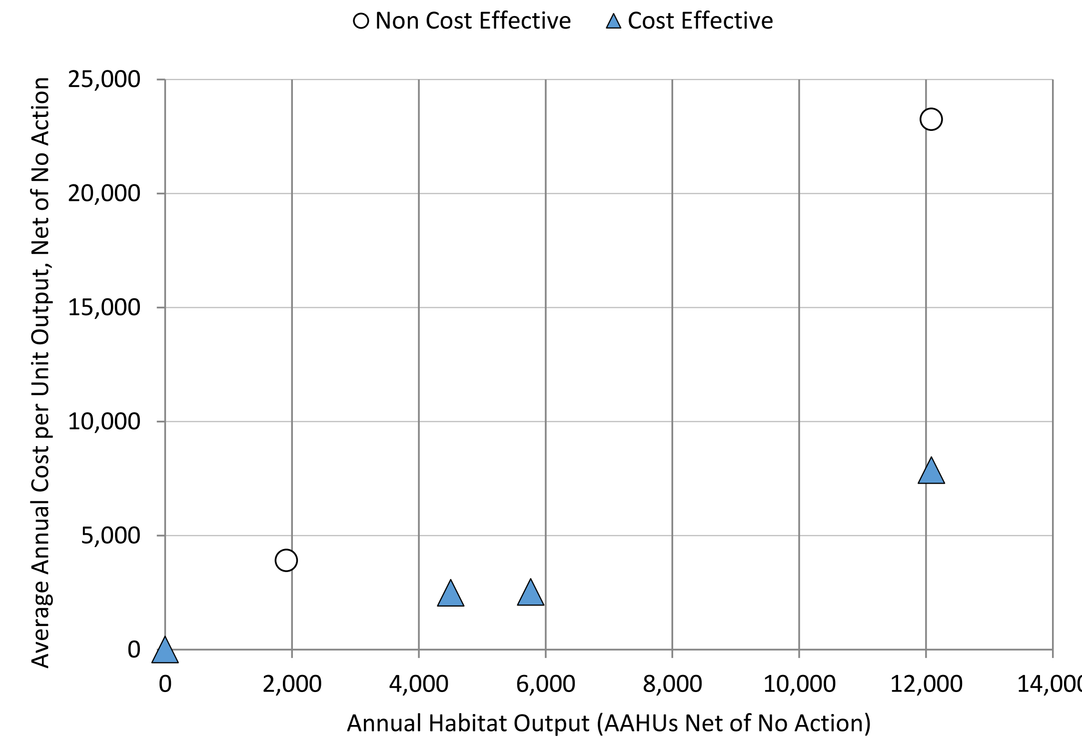


Best Buy Plans

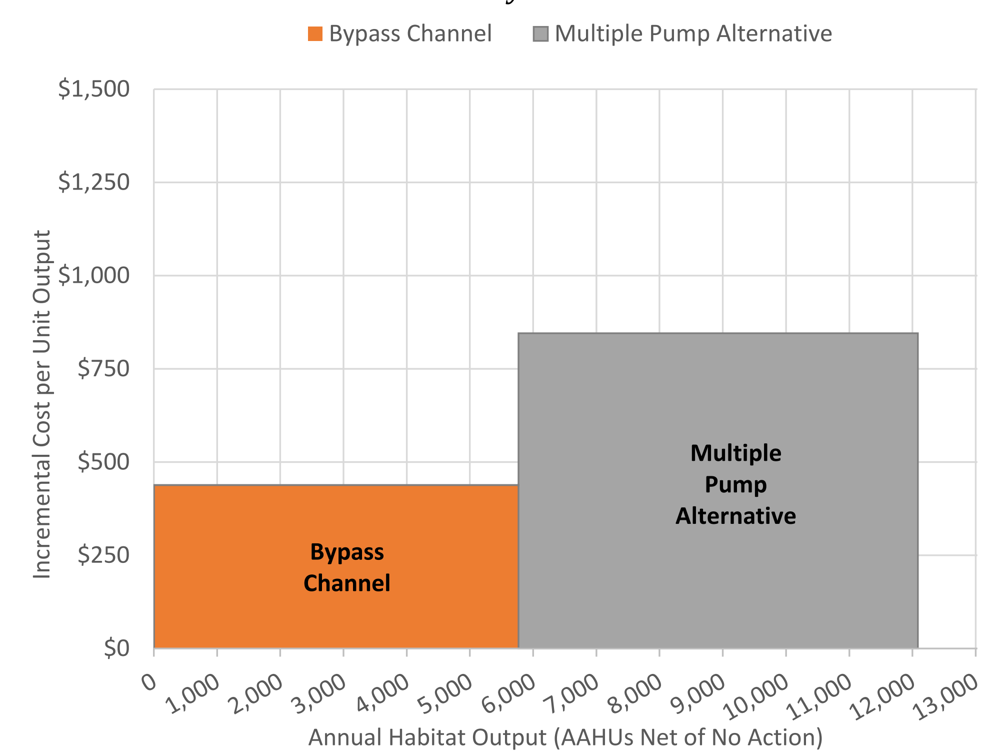


Scenario 2 – Pallid Sturgeon Only

Cost Effectiveness



Best Buy Plans



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ATTACHMENTS

Table 4. Estimate Suitability of Fishway Locations (F_l) for Each Fish Guild Based Upon Swimming Performance and Behavior.

	Potential Fishway Location – Lock and Dam 22 example			
Guild	Main Channel	Main Channel Border – near channel	Main Channel Border– near shore; Side Channel; or Bypass Channel	Lock
Benthic – Strong	5	5	3	1
Littoral – Strong	5	5	3	1
Pelagic – Strong	5	5	3	1
Benthic – Medium	1	5	5	1
Littoral – Medium	1	3	5	1
Pelagic – Medium	1	5	5	1
Benthic – Weak	1	5	5	1
Littoral – Weak	1	3	5	1
Pelagic – Weak	1	1	5	1

5 = Entrance would be encountered by a significant portion of the population
3 = Entrance may be encountered
1 = Unlikely that entrance would be encountered

Table 4 is reproduced from Corps (2011) showing the scoring for various guilds of fish relative to general fishway locations.

MODEL APPROVAL PLAN

FISH PASSAGE CONNECTIVITY INDEX (FPCI)

for

Intake Diversion Dam Fish Passage Project, Lower Yellowstone Project, Montana

Omaha District

July 19, 2016

US Army Corps
of Engineers ®

Model Approval Plan

Fish Passage Connectivity Index

Intake Diversion Dam Fish Passage Project, Lower Yellowstone Project, Montana

Omaha District

1. Purpose

The purpose of this Model Approval Plan is to outline the review process and requirements necessary to assure the applicability of the Fish Passage Connectivity Index, as submitted from the Omaha District to the ECO-PCX in support of the Approval of Single Use of the model in the Intake Diversion Dam Fish Passage Project. Since the model has already been Approved for Use in the Mississippi River Basin, the review will consist of an evaluation of the applicability of the model for the Yellowstone River. The model review will be managed by the Ecosystem Restoration Planning Center of Expertise (ECO-PCX) in accordance with EC 1105-2-412, Assuring Quality of Planning Models. The review team will document the review process and provide an assessment of the technical quality, system quality, and usability of the model.

2. Reference and Guidance

2.1. Engineering Circular 1105-2-412, Assuring Quality of Planning Models, 31 March 2011.

3. Background

The FPCI model was developed by the Navigation and Ecosystem Sustainability Program, Lock and Dam 22 Fish Passage Ecosystem Restoration Project Delivery Team which included fisheries biologists and hydraulic engineers from USACE (MVS, MVR, MVP, ERDC), US Fish and Wildlife Service Ecological Services and Refuges, Illinois Department of Natural Resources, Illinois Natural History, Missouri Department of Conservation, and Iowa Department of Natural Resources. The model calculates Average Annual Habitat Units for each migratory fish species and averages AAHUs for all migratory fish species for each fish passage alternative. Model input includes movement periods for each migratory species, likelihood of species to encounter fishway entrance based on location, species potential to use passage route; and availability of suitable passage conditions during movement and spawning periods. The result is a 0-1 index that represents the suitability of the fish passage alternative measure to a given species. The fish passage connectivity index is multiplied by the acres of connected, upstream habitat types that are suitable to the individual migratory species to get Average Annual Habitat Units. The model documentation includes the model report (Enclosure 1) and an Excel worksheet (Enclosure 2). The worksheet utilizes good spreadsheet practices including protecting cells, data validation, color-coding input/output cells and including a worksheet with instructions on how to use the model.

Prior review concluded that the FPCI meets model criteria of technical and system quality and usability. The model addresses the key factors associated with fish passage and was easily modified for application at any geographic location. The ECO-PCX updated the Excel Workbook to make it applicable for use nationwide. For a given project area, users will input data on migratory species such as timing of migratory movements, swimming abilities and behavior and input data on habitat available to the migrating fish. This input data will be technically reviewed as part of District Quality Control and Agency Technical Review.

Although the model was developed to measure benefits of fish passage in the Upper Mississippi River, the model is applicable (with slight adjustments) to fish passage projects on other large river systems, especially those with very similar fish communities. This model, with minor adjustment, was used as a planning tool for comparing benefits of alternative measures for provide fish passage at Intake Dam. Below is a summary of the input data used and minor adjustments made to the model to demonstrate ecological benefits of the Yellowstone River Intake Diversion Dam fish passage alternatives.

- The approved FPCI model does not include pallid sturgeon as a modeled species, therefore pallid sturgeon were added. The inclusion of pallid sturgeon does not change the ranking of alternatives, but provides a better differentiation between similar alternatives.

- Habitat preferences/use for each species was considered acceptable as presented in the FPCI with one slight adjustment as noted by the Corps (2015); white sucker, blue sucker and river carpsucker were shown only to be associated with main channel border habitats in the original FPCI. However, for purposes of this study, these species were also assumed to utilize main channel habitats. The “main channel” habitat type in the Upper Mississippi River was defined as a navigation channel, which is very different than main channel habitats in the Yellowstone River, and may be the reason those species were not associated with that habitat type.

- The Di variable accounts for the timing of when fish passage is physically possible at a dam compared with the timeframe of when fish typically migrate. The District modified the “percent probability of open river conditions” in the original model (which referred to when the dam gates were open on the Upper Mississippi River) and used available literature (Jaeger, et al. 2005; Helfrich et. al. 1999), anecdotal information, and best professional judgment, to assign probabilities that passage opportunities exist on a weekly basis as a function of flow, with highest probabilities being associated with the peak of the typical hydrograph, and very small (1%) probabilities being attributable to the timeframes outside of the peak river flow (September-April).

- Basic information on fish migratory behaviors and timing from the original FPCI model was modified by because the actual time of year when migration takes place on the Yellowstone River is different than on the Mississippi River. Movement and spawning periods were pushed back 3-4 weeks later in the year as migrations tend to take place later in the year for cooler, more northern latitudes.

4. Documentation Provided by Proponent

4.1. Model Technical Documentation

- Fish Passage Connectivity Index, Upper Mississippi River System Fish Passage Improvement Ecosystem Restoration Projects, 17 August 2011 (Enclosure 1)

4.2. **Model User Documentation**

- Fish Passage Connectivity Index Excel Worksheet, dated 22 March 2013 (Enclosure 2)

4.3. **Model Support Literature**

- N/A

4.4. **Model QA/QC Documentation/Activities**

- District Quality Control and Agency Technical Review has been conducted. Comments and revisions made as a result will be included in the model certification review package.

5. Type/Scope of Review

Per EC-1105-2-412, 31 March 2011, the ECO-PCX recommends a limited review which would include ATR of applicability of use of this model on the Yellowstone River.

The following language defines the scope of the review and will be provided to the model reviewers:

5.1. **Preliminary charge for reviewers of the Fish Passage Connectivity Index**

Input being sought to help the US Army Corps of Engineers ECO-PCX determine the degree to which the subject model can be described as technically sound relative to its design objectives. Reviewers are asked to comment on aspects of the model that potentially affect its applicability on the Yellowstone River as a potential producer of information to be used to influence planning decisions.

While the specific review questions included below are intended to prompt the reviewer for information specific to the efforts to Approve for Single Use, please feel free to offer comments believed relevant and appropriate to any elements of the technical quality and usability of the model as documented in the provided review materials. Accordingly, please provide responses to the sought scientific and technical topics listed below and perform a broad review of the Fish Passage Connectivity Index focusing on your areas of expertise, experience, and technical knowledge. Listed below are the model review charge questions.

Technical Quality:

1. To what extent is the model suitable for the expressed intended uses?
2. Comment on the geographic range/applicability of the model. Is the model applicable for the Yellowstone River considering it was developed for the Mississippi River Basin.
3. Does the model adequately emulate or otherwise address the suite of critical attributes necessary to characterize system/resources?
4. Are the modifications to the model detailed in the analysis and summarized above appropriate?

System Quality:

1. Where changes in the spreadsheet made accurately and without error?

6. Description of Tasks.

The model review tasks are:

6.1. **Kick-Off Meeting.** Once the ECO-PCX has received approval to proceed, a teleconference will be held assure all reviewers understand the scope and the approach for review of the models. The reviewers will review the provided model documentation and, if necessary, identify additional information required to conduct the model review. The meeting will include representatives of the ECO-PCX, the model proponent, and the reviewer. CECW will be notified of the meeting and invited to attend.

6.2. **Conduct Review of Model.** The reviewers will conduct an assessment of the models using all documentation provided by the model proponent and the ECO-PCX. Reviewers will provide comments regarding the model and should follow a four part structure to include: 1) the review concern, 2) the basis for the concern (reviewer should note if the comment relates to technical quality, system quality, or usability), 3) the significance/impact of the concern, and 4) the probable specific action needed to resolve the concern.

6.3. **Meeting to Discuss Initial Findings.** The reviewers will meet with the ECO-PCX, model proponent, and CECW to discuss initial review comments and recommendations, and outline a plan for the Draft Model Review Report.

6.4. **Proponent and ECO-PCX Summary.** Based on the review comments and the Final Model Review Report, the ECO-PCX will identify actions or modifications the proponent needs to undertake in order to gain a recommendation for approval. The ECO-PCX will close-out the review when it determines identified issues have been resolved to its satisfaction.

6.5. **ECO-PCX Recommendation Package to HQ.** Based on the resolution of all comments/issues, the ECO-PCX will compile and send the recommendation package to HQ. This package will include, at a minimum, some combination of the following based on the level of review and whether it is a certification or approval for use.

7. Review Team Composition.

The ECO-PCX proposes review of the model documentation and supporting literature. The review will address all technical quality, system quality and usability certification criteria, including the criteria regarding whether the model properly incorporates Corps policies and accepted procedures.

The ECO-PCX proposes an internal review as part of the EIS ATR consisting of the following disciplines:

The following disciplines are proposed as part of the review team:

- Review Project Manager – The project review manager will be responsible for facilitation of the model review process. This person should have prior experience facilitating ecosystem habitat benefit evaluation reviews.

- Senior Fisheries Biologist – the reviewer should be a senior biologist with familiarity with large river warmwater fisheries. The reviewer shall be familiar with the FPCI model and knowledge of the Mississippi and Missouri River system.

8. Schedule.

The following is a draft schedule for the model review. Revisions to the model to address model deficiencies will require adjustments to the schedule below.

Begin Model Review	30 July – 30 August 2016
Model Review Complete	August 2016
Model Review Report	Sept 2016
ECO-PCX Summary	Oct 2016
ECO-PCX Recommendation Package to HQ	Nov 2016

9. Cost.

The model review is expected to cost $10,000.

10. Points of Contact.

ECO-PCX Point of Contact:	Nathan Richards - MVR	(309) 794-5286
Model Proponent Point of Contact:	Tiffany Vanosdall – NWO	(402) 995-2695

Enclosure 4

UNCLASSIFIED\\FOR OFFICIAL USE ONLY

Comment Report: Comment Evaluation/Backcheck Contribution by Elliott Stefanik
Project: Intake EIS **Review**: Intake DEIS ATR (*00002*)
(sorted by Discipline , ID)

Displaying 15 comments for the criteria specified in this report.

Id	Discipline	Section/Figure	Page Number	Line Number
6558641	Environmental	n/a	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

Concern: It's unclear from Table 2-1 whether this is a list of all alternatives considered, or if it's a refined list.
Reason for Concern: Given concerns with alternative formulation and given the table is a summary of this process, it's important the table clearly explains what is being provided within.
Significance: Moderate.
Recommendation: Clarify in the table heading if this is a list of all alternatives identified or considered (comprehensive list), a refined list that has been paired down, or what exactly this list of alternatives represents. Also the list should probably focus on fish passage alts (remove the "removable rotating drum screen").

Submitted By: Elliott Stefanik (651-290-5260). Submitted On: Jun 14 2016

1-0 Evaluation **Concurred**
As described starting on page 2-25 (Section 2.2 Background and History of Alternatives) this section is a summary of the project history including alternatives that have been developed and analyzed since 2006. Following the table are paragraphs referencing the various documentation (with citations) to the steps of the process. The table includes all of the alternatives including the headworks which were screened to reduce entrainment, and that is why the screens are included in this table.

Submitted By: James Carney (206-728-9655) Submitted On: Jun 30 2016

1-1 Backcheck Recommendation **Close Comment**
Explanation is acceptable.

Submitted By: Elliott Stefanik (651-290-5260) Submitted On: Jul 21 2016.

Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
6558643	Environmental	n/a	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

Concern: Section 1.1.2.3 Collaboration is missing.
Reason for Concern: Discussion of collaboration is important to demonstrate thorough scoping of an eco restoration project.
Significance: Minor
Recommendation: Include this missing section.

Submitted By: Elliott Stefanik (651-290-5260). Submitted On: Jun 14 2016

1-0 Evaluation **Concurred**
This is a typo that will be corrected, section 1.1.2.3 and 1.1.2.4 were combined and this header didn't get deleted for some reason.

Submitted By: James Carney (206-728-9655) Submitted On: Jun 30 2016

1-1	Backcheck Recommendation **Close Comment** Revision will be acceptable when implemented. Revision will be confirmed during the Final ATR. Submitted By: Elliott Stefanik (651-290-5260) Submitted On: Jul 20 2016.
	Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
6558645	Environmental	n/a	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

Concern: Section 1.1.3 discusses other dams and irrigation projects on the Yellowstone River but does not mention any projects or activities related to Pallid sturgeon or ecorestoration. Touch on this briefly, even if there isn't anything (mention that).
Reason for Concern: Demonstrates we are considering all activities related to our project. This is important as project is eco-restoration (at this point, exclusively since the diversion improvements have been made).
Significance: Minor
Recommendation: Include a brief description of any similar efforts or activities in the area or region.

Submitted By: Elliott Stefanik (651-290-5260). Submitted On: Jun 14 2016

1-0	Evaluation **Concurred** Will add brief discussion of on-going studies on the Yellowstone and recommendations from Yellowstone Cumulative Effects Analysis related to broader management of the river. For the most part, there are not other specific actions planned on the Yellowstone for pallid sturgeon. Submitted By: James Carney (206-728-9655) Submitted On: Jun 30 2016
1-1	Backcheck Recommendation **Close Comment** Revision will be acceptable when implemented. Revision will be confirmed during the Final ATR. Submitted By: Elliott Stefanik (651-290-5260) Submitted On: Jul 20 2016.
	Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
6558646	Environmental	n/a	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

Concern: Section 2.3.4 states: Based on rock requirements, rock will need to be purchased from quarries in Wyoming or Minnesota and delivered to Glendive. Be advised that the Fargo-Moorhead FRM project (St. Paul District) will likely use large quantities of field stone for various H&H features, including fish passage. There has been some question if there is enough field stone in the region to meet demand. That project will likely begin construction in 2017.
Reason for Concern: This could actually drive up cost further for the Rock Ramp alternative.
Significance: Low
Recommendation: Given the rock ramp isn't the selected plan this is a minor issue. But if that were to change it could become an issue. Recommend inserting sentence in the section that further evaluation may be needed on rock availability which could influence cost of this alternative.

Submitted By: Elliott Stefanik (651-290-5260). Submitted On: Jun 14 2016

1-0

Evaluation **Concurred**
Comment noted, the costs for hauling of rock made assumptions that it would be obtained from MN or WY so there are already high hauling costs included. For alternative comparison purposes the cost of rock was kept consistent with that used in the 2015 EA, and escalated to current dollars, and approximately a 30% contingency is added to that.

Submitted By: James Carney (206-728-9655) Submitted On: Jun 30 2016

1-1 Backcheck Recommendation **Close Comment**
Response is acceptable.

Submitted By: Elliott Stefanik (651-290-5260) Submitted On: Jul 20 2016.

Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
6558647	Environmental	n/a	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

Concern: Section 2.3.5 states the dam would be replaced with the bypass channel alternative. It's unclear why this is needed.
Reason for Concern: Incorporating a new dam obviously drives up cost of the alternative. It's also unclear why this is needed for ecosystem restoration project. The need for a new dam isn't expressed in the "purpose and need" statement, other than "allow for continued viable and effective operation of the LYP." No where is the need for a new dam discussed.
Significance: Moderate to major, depending on the reasoning for inclusion.
Recommendation: Specify why a new dam needs to be included in this alternative, as well as other similar alts (e.g., side channel alternative). If it's not needed as a specific function of ecosystem restoration it should be removed from the alternative and the EIS revised to reflect this change.

Submitted By: Elliott Stefanik (651-290-5260). Submitted On: Jun 14 2016

1-0 Evaluation **Non-concurred**
Please see the second paragraph of Section 2.3.5 Bypass Channel (Page 2-46) which describes why the dam would be replaced. "A concrete replacement weir would be constructed that would provide water surface elevations similar to no action conditions, which would be adequate for flow into the new bypass channel, ensuring delivery of irrigation water, eliminating concern as to whether continued displacement of rock from the crest of the dam by ice flows could adversely affect the downstream entrance to the bypass channel.. Construction of a replacement weir would eliminate the need to routinely place rock along the crest of the Intake Diversion Dam. While head requirements could theoretically be met through rock placement, a permanent structure provides more reliable flows into the bypass channel, reduces the amount of fill placed into the Yellowstone River, and eliminates concern as to whether continued displacement of rock from the crest of the dam by ice flows could adversely affect the downstream entrance to the bypass channel."

Submitted By: Scott Estergard (602-241-8543) Submitted On: Jul 11 2016

1-1 Backcheck Recommendation **Close Comment**
The response is acceptable provided the costs of a new weir are generally similar to those of continued O&M of existing features. Cost numbers to this end are still in preparation. The ATRT will verify during review of the Final EIS that costs are similar enough to warrant including a new weir as a part of the bypass channel alternative.

Submitted By: Elliott Stefanik (651-290-5260) Submitted On: Aug 22 2016.

Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
6558648	Environmental	n/a	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

Concern: Section 2.4.4.1 and 2.4.4.2 discuss CE/ICA outputs. Although OK for an EIS, it would be helpful to include the CE figure from IWRPlan to help demonstrate how the benefits shake out. Moreover, it's unclear why Modified Sidechannel and Multiple Pumps with Conservation Measures were not included in the Incremental Cost Analysis.
Reason for Concern: We need to ensure all of our alts carried forward for detailed consideration get full consideration.
Significance: Moderate.
Recommendation: First, provide a figure from IWRPlanning Suite show the CE analysis, including demonstration of "Best Buy" plans and "Cost Effective" plans. Then, better explain why only certain alternatives are carried forward for detailed consideration. Table 2-30 does mention "Best Buy" plans, but this concept should be described and identified earlier.

Submitted By: Elliott Stefanik (651-290-5260). Submitted On: Jun 14 2016

1-0 Evaluation **Concurred**
1) The last sentence of Sec 2.4.4 (main report) cites an appendix. The reference was incorrect, and will be revised to cite Appendix D.
2) Apx D Fig 2-1 will be added to main report after Table 2-28 with this text: "Figure 2-1 provides a graph of the total output and annualized costs for each of the alternatives while differentiating the cost effective plans from the non-cost effective ones. Per IWR 95-R-01, any alternatives that are not found to be cost effective "should be dropped from further analysis" in the CE/ICA process. Therefore the Rock Ramp and Multiple Pumps with Conservation Measures alternatives are not included in the ICA analysis that follows."
3) These text and figures from Apx D will be added between paragraphs 2 and 3 of Sec 2.4.4.2:
"The first step, per IWR 95-R-01, is to "smooth out fluctuations in incremental costs per unit as project scale increases such that incremental cost per habitat unit are continuously increasing." This is first completed by calculating the incremental cost per unit for each plan over the "baseline condition," which is the no action plan. Once the incremental costs per unit are calculated and sorted by increasing output, the alternative with the lowest incremental cost per unit will be selected as the first "best buy" alternative. Table 2-4 shows the calculation of the incremental costs per unit with the no action alternative set as the baseline for the cost effective alternatives.
[Apx D Table 2-4]
Table 2-4 indicates that the Bypass Channel alternative is the first best buy alternative because it has the lowest incremental cost per unit of output. At this step of the ICA the incremental cost per unit is equal to the average annual cost per unit values calculated in Table 2-3 because complete alternatives are being compared, not combinations of measures.
After selection of this best buy alternative, per IWR 95-R-01, all alternatives with lower average annual output are removed from further iterations of the incremental cost analysis. Thus the No Action and Modified Side Channel alternatives are removed from further analysis and are not considered best buy plans.
Next, the incremental process should be started anew with the first best buy plan. Thus the Bypass Channel is set as the new baseline. However, for this study only the Multiple Pump alternative is remaining, and is therefore a best buy plan as well since no other plans can produce more output for lower incremental cost per unit.
The final step in the ICA process is to analyze the incremental cost per incremental unit of output for the best buy alternatives only. This includes the No Action, Bypass Channel, and Multiple Pump alternatives. Incremental costs are calculated between each successive best buy cost-effective plans are examined sequentially (by increasing scale in terms of net AAHUs produced) to ascertain which plans are most efficient in the production of additional environmental benefits."

Submitted By: James Carney (206-728-9655) Submitted On: Jun 30 2016

1-1 Backcheck Recommendation **Close Comment**
Revision will be acceptable when implemented. Revision will be confirmed during the Final ATR.

Submitted By: Elliott Stefanik (651-290-5260) Submitted On: Jul 20 2016.

Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
6558650	Environmental	n/a	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

Concern: Sections 2.5.2 spends describes reasoning for section of the recommended plan. But it leaves a lot of uncertainty on whether or not a $54 million dollar project will work.
Reason for Concern: Should be investing such a large amount of federal funding on something with so much uncertainty?
Significance: Moderate
Recommendation: include some type of brief summary sentence that basically states: although there remains uncertainty, biologists on the agency team collectively agree that the preferred alternative represents the best balance of cost, likely benefits, and uncertainty of effectiveness amongst the alternatives considered. It would also meet the needs of the Bureau of Reclamation for ESA compliance (*assuming this last part is in fact true).

Submitted By: Elliott Stefanik (651-290-5260). Submitted On: Jun 14 2016

1-0 Evaluation **Concurred**
Concur, will add a summary paragraph stating that the best available science indicates the preferred alternatives is the best way to achieve passage and continue to provide irrigation diversions/water right. And, the ESA consultation for the project and both interim/future O&M by Reclamation will ensure ESA compliance for both agencies.

Submitted By: James Carney (206-728-9655) Submitted On: Jun 30 2016

1-1 Backcheck Recommendation **Close Comment**
Revision will be acceptable when implemented. Revision will be confirmed during the Final ATR.

Submitted By: Elliott Stefanik (651-290-5260) Submitted On: Jul 20 2016.

Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
6558651	Environmental	n/a	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

Concern: Section 4.4 does briefly discuss influence of alternatives on flood heights. Are there any agency concerns, or potential permit ramifications, of any alternatives on flood heights? Any indication that any of the alternatives might not be permit-able because of flood height impacts.
Reason for Concern: Flood height increases has become an issue in some parts of the country with habitat restoration projects.
Significance: Minor
Recommendation: Mention somewhere whether or not potential changes in flood height would make an alternative more or less likely to be permitted.

Submitted By: Elliott Stefanik (651-290-5260). Submitted On: Jun 14 2016

1-0 Evaluation **Concurred**
While there are anticipated small changes in flood water surface elevations during construction due to coffer dams, etc., they are relatively minor (i.e. less than a foot) and similar for all alternatives.

Submitted By: James Carney (206-728-9655) Submitted On: Jun 30 2016

1-1	Backcheck Recommendation **Close Comment** Comment is closed. However, be advised that in some states flood height increases of less than an inch have been problematic. Encourage the PDT confirms this is not a late issue that causes headaches. Submitted By: Elliott Stefanik (651-290-5260) Submitted On: Jul 20 2016.
	Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
6558653	Environmental	n/a	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

Concern: Under Section 4.6, Effects to Geomorphology, and Section 4.7, Water Quality. The impacts to sediment transport, both erosion and accretion, are not spelled out for both dam removal and dam construction. For alts where this occurs there will be releases of trapped sediments behind the existing dam; and trapping of new sediment from the new dam. This should be discussed for both geomorphology and water quality impacts.
Reason for Concern: Complete geomorphic understanding associated with dam removal and construction.
Significance: Moderate
Recommendation: For applicable alternatives be sure to discuss sediment movement, both erosion and accretion, associated with dam removal and new dam construction.

Submitted By: Elliott Stefanik (651-290-5260). Submitted On: Jun 14 2016

1-0	Evaluation **Concurred** Partially concur. Text will be clarified to ensure the following information is clearly conveyed. The new weir/dam will be constructed at the same elevation as the existing weir so there should not be more than minimal effects to sediment erosion/accretion. During construction, when coffer dams are in place and the river flow is confined to a narrower channel, there could be some localized erosion/accretion, but the river substrate is coarse and the banks are also riprapped in many locations, so this is not anticipated to be more than a minor effect either. For dam removal alternatives, because the dam/weir is fairly low, there is not a large quantity of sediment trapped behind it, and it is primarily coarse material (cobbles). However, this sediment will erode and transport downstream over time, but in the scale of the river channel width this will also only be a minor effect. Submitted By: James Carney (206-728-9655) Submitted On: Jun 30 2016
1-1	Backcheck Recommendation **Close Comment** Revision will be acceptable when implemented. Revision will be confirmed during the Final ATR. Submitted By: Elliott Stefanik (651-290-5260) Submitted On: Jul 20 2016.
	Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
6558656	Environmental	n/a	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

Concern: Impact discussion often doesn't note direct mortality to biota (usually inverts) from disturbance.
Reason for Concern: Disclosure of all anticipated impacts.
Significance: Minor
Recommendation: Include this in the impact discussion, where applicable, for all construction impacts.

Submitted By: Elliott Stefanik (651-290-5260). Submitted On: Jun 14 2016

1-0	Evaluation **Concurred** Concur. Will add additional text to indicate invertebrates would experience direct mortality where construction activities occur in the river. Submitted By: James Carney (206-728-9655) Submitted On: Jun 30 2016
1-1	Backcheck Recommendation **Close Comment** Revision will be acceptable when implemented. Revision will be confirmed during the Final ATR. Submitted By: Elliott Stefanik (651-290-5260) Submitted On: Jul 20 2016.
	Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
6558658	Environmental	n/a	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

Concern: Section 5.2.4 states the Biological Assessment is included as Appendix D. However, Appendix D was never provided for review, and the Table of Contents listed Appendix D as the Fish Passage Connectivity Index and CE/ICA. Thus no review was performed on the BA. Moreover, the impacts discussion in Section 4.10 does not specify the ESA-specific impacts determination. Thus the impacts determination can't be concluded.
Reason for Concern: Final ESA determinations are uncertain and unavailable.
Significance: Moderate to Major.
Recommendation: At a minimum, make the Biological Assessment available for public review. Assuming it has been prepared, bring some of that impact discussion into the EIS, including the ESA-specific effects determinations.

Submitted By: Elliott Stefanik (651-290-5260). Submitted On: Jun 14 2016

1-0	Evaluation **Concurred** The portion of the sentence that references Appendix D will be deleted. This is a typo. The BA is not being provided for public review as part of the Draft EIS. Submitted By: James Carney (206-728-9655) Submitted On: Jun 30 2016
1-1	Backcheck Recommendation **Close Comment** Revision will be acceptable when implemented. Revision will be confirmed during the Final ATR. Submitted By: Elliott Stefanik (651-290-5260) Submitted On: Jul 20 2016.
	Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
6558660	Environmental	n/a	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

Concern: Section 4.11 and elsewhere in the document. Obviously there are some adverse effects from project alternatives, including the preferred alternative. This can include some disturbance, tree clearing, wetland fill, and other actions. Somewhere we should explain why these impacts are acceptable. Not only wetlands but other resource categories.
Reason for Concern: We should provide an explantion why we can perform these activities. The public may be interested why we do this without a need for permits.
Significance: Minor
Recommendation: Include a brief explanation of how this project is collectively better environmentally, even with some of the adverse tradeoffs.

Submitted By: Elliott Stefanik (651-290-5260). Submitted On: Jun 14 2016

1-0 Evaluation **Concurred**
Concur, will add additional text describing collective benefits and how that outweighs the adverse effects (either during construction or long-term).

Submitted By: James Carney (206-728-9655) Submitted On: Jun 30 2016

1-1 Backcheck Recommendation **Close Comment**
Revision will be acceptable when implemented. Revision will be confirmed during the Final ATR.

Submitted By: Elliott Stefanik (651-290-5260) Submitted On: Jul 20 2016.

Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
6558661	Environmental	n/a	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

Concern: Section 4.18.2 References impacts discussion under historic properties extends to ground disturbance in unsurveyed portions of rock quarry. I don't think we should discuss potential impacts with quarries. That's broader than any other impact category we've analyzed. We haven't considered this range of potential effects for other resource categories. If we do that here we would need to do that elsewhere, including consideration of ESA, wetlands and other resource concerns.
Reason for Concern: Consistency with the area of effects and impacts analysis.
Significance: Major
Recommendation: Keep the discussion on historic properties consistent with the rest of the EIS in terms of the focus areas and Area of Potential Effects.

Submitted By: Elliott Stefanik (651-290-5260). Submitted On: Jun 14 2016

1-0 Evaluation **Concurred**
The quarry referenced in Section 4.18.2 is the one adjacent to Joe's Island, not other quarries within the region. It is currently used for rocking and was addressed due to the potential for it to be a source for materials for O&M in the future.

Submitted By: James Carney (206-728-9655) Submitted On: Jun 30 2016

1-1 Backcheck Recommendation **Close Comment**
Per a discussion between ATRT and PDT on 8/19/2016, it was agreed that impacts to other resource categories from use of the quarry would be added to all other resource discussions. This isn't reflected in the DrChecks response above provided 6/30/1016, but is understood as the action moving forward. This revision would satisfy the ATR comment. This revision to the EIS will be confirmed during the ATR of the Final EIS later this year.

Submitted By: Elliott Stefanik (651-290-5260) Submitted On: Aug 22 2016.

Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
6558663	Environmental	n/a	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

Concern: It's uncertain if the FPCI model is approved in this instance for use on the Yellowstone River.
Reason for Concern: EC 1105-2-412 requires that models used in planning studies work through some level of certification or approval for use.
Significance: Moderate
Recommendation: Clarify if in fact the FPCI model has been approved for use here.

Submitted By: Elliott Stefanik (651-290-5260). Submitted On: Jun 14 2016

1-0 Evaluation **Concurred**
The FPCI model is currently undergoing review by the ECO-PCX. For the FEIS, it will be stated that approval has been completed.

Submitted By: James Carney (206-728-9655) Submitted On: Jul 07 2016

1-1 Backcheck Recommendation **Close Comment**
Revision will be acceptable when implemented. Revision will be confirmed during the Final ATR.

Submitted By: Elliott Stefanik (651-290-5260) Submitted On: Jul 20 2016.

Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
6558665	Environmental	n/a	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

Concern: I have concern that the value of Ei within the FPCI may not be calculated correctly. This variable uses an average of two assumed values to compute Ei. The first variable measures the amount of flow conveyed through the fish passage structure. The second variable, Fishway Location, measures the ability of fish to find the fishway. "Finding the fishway" was more of an issue on the Upper Mississippi River where the model was first developed for fishways that wouldn't convey all flow and fish behavior was more important in finding a structure entrance that passes only a portion of total river flow. However, in situations where all flow is provided through the fishway (like on the Yellowstone), the ability to encounter the fishway is the same as the first variable which measures amount of water conveyed through the structure. In my opinion that value may need to be a constant "5" for all species. Fish behavior and their ability to use the structure would be captured in variable Ui.
Reason for Concern: This difference in calculations could undervalue the benefits from the rock ramp alternative. Without the model going through some form of model review for application here it's uncertain if the assumed values are appropriate, or if the concern outlined above is valie.
Significance: Moderate. It's likely that changes to benefits calculations won't impact selection of a recommended plan, but the issue above, along with model certification needs, should be addressed.
Recommendation: Explain if the model, including inputs, will go through some type of detailed review. Also address the concern above and explain whether or not the Ei variable should be calculated as is, or along the line of what is addressed above.

Submitted By: Elliott Stefanik (651-290-5260). Submitted On: Jun 14 2016

1-0 Evaluation **Non-concurred**
The fishway size is not the entire river for either the bypass channel or modified side channel alternatives (they have a fishway size score of 2). Also, the fishway location is not the same for all alternatives, most pronounced for the modified side channel alternative that is located nearly 2 miles downstream of the dam and is on the opposite bank from the river's thalweg, thus having low likelihood for fish that use the main channel (i.e. sturgeon) to encounter it. Do not agree that it should be 5 for all alternatives.

Submitted By: James Carney (206-728-9655) Submitted On: Jun 30 2016

1-1 Backcheck Recommendation **Close Comment**
This comment has been passed on to the EcoPCX for consideration during the model review process. The

	comment above should have been better worded to describe concerns wtih input assumptions between the bypass channel alternative and the rock ramp alternative. The ATR reviewer remains concerned that the assumptions may bias alternatives comparison, and this concern has been passed on to the EcoPCX. The ATR Report also should highlight this concern and the path for resolution as it relates only to closing this ATR. Submitted By: Elliott Stefanik (651-290-5260) Submitted On: Jul 21 2016.
	Current Comment Status: **Comment Closed**

Report Complete

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Comment Report: All Comments
Project: Intake EIS
Review: Intake FPCI Model Review
Displaying 2 comments for the criteria specified in this report.

Id	Discipline	Section/Figure	Page Number	Line Number
6655556	Environmental	n/a	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

REVIEW CONCERN: The ATR comment #6558665 expressed concern that the habitat model undervalued fish encounters with a rock ramp and overvalued fish encounters with the bypass channel. The reviewer felt the PDT's biases favored the bypass channel alternative. The ATR comment concluded that the model reviewer (J. Jordan) should look into this concern and make an independent review and conclusion.

BASIS FOR THE CONCERN: Please reference ATR Comment #6558665 (E. Stefanik). I agree with the ATR comment that a rock ramp spanning a stream or river should be encountered by all fish and there will be fewer fish species recognizing a bypass channel depending on the bypass size, location, and flow. Perhaps the word "encounter" is confusing; a better phrase maybe "passage success". A fish may encounter the rock ramp but will not traverse it due to depth, turbulence, ample resting spots, etc. Likewise a fish may enter a bypass channel but may turn around due to unacceptable physical limitations.

SIGNIFICANCE OF THE CONCERN: The significance of the original comment can be high. Biases should not come into play in a habitat model. The model should be able to be replicated by an independent team of professional fisheries biologists and get similar results. However, after reviewing the literature including the project report and correspondence from then USFWS, I found the species in question (particularly the pallid sturgeon) would encounter the rock ramp, but would find the depths, and turbulence unacceptable to successfully traverse past the dam.

PROBABLE SPECIFIC ACTION NEEDED TO RESOLVE THE CONCERN: No action is necessary. Please consider rewording the word "encounter" if the District proposes to advance the model review for regional or national use.

Submitted By: Joe Jordan (309-794-5791). Submitted On: Aug 31 2016

1-0 Evaluation **Concurred**

At this time, the District is not proposing to advance the model review for regional or national use.

Submitted By: Eric Laux ((402)221-7186) Submitted On: Sep 01 2016

1-1 Backcheck Recommendation **Close Comment**

1-1 Backcheck Recommendation **Close Comment**
No additional action is needed.

Submitted By: Joe Jordan (309-794-5791) Submitted On: Sep 01 2016
Current Comment Status: **Comment Closed**

6655563	Environmental	n/a	15	Table 1-10

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

REVIEW CONCERN: The Lower Yellowstone Intake Diversion fish passage model documentation (page 15, table 1-10 requires Potential (Ui) data scored as 5, 3, or 1, yet a value of 2 is assigned to certain fish for certain measures. This special adjustment was not described in the model description.

BASIS FOR THE CONCERN: The model description states one thing but the spreadsheet does not follow the guidance. Without any explanation why this occurred demonstrates a shortcoming in the model.

SIGNIFICANCE OF THE CONCERN: Weaknesses or gaps in a habitat model tend to be overcome by sensitivity analysis which is code for making the model reflect you bias or professional judgement. This can led to decisions not based on peer review literature or other documented scientific evidence. In this case, the PDT's deviation from the original model are relatively minor and are in fact justified with either documentation or independent professional judgement from the various resource biologists.

PROBABLE SPECIFIC ACTION NEEDED TO RESOLVE THE CONCERN: There are two options to correct this action. 1.) Leave the model as is, and document why you deviated from the model in the project report and in the model documentation. 2.) Modify the model to reflect addition increments such as .5, 2, and 4. In either case you must document the deviation or model revision with enough narrative (and backing) to justify your action. Be sure to check the Ui formula in the Excel spreadsheet to ensure any adjustments are accurately calculated.

Submitted By: Joe Jordan (309-794-5791). Submitted On: Aug 31 2016

1-0 Evaluation **Concurred**
We plan to leave the model as is, and document why we deviated from the model in the project report and in the model documentation.

Submitted By: Eric Laux ((402)221-7186) Submitted On: Sep 01 2016

1-1 Backcheck Recommendation **Close Comment**
Be sure to cite your source of data/coordination supporting your deviation.

Submitted By: Joe Jordan (309-794-5791) Submitted On: Sep 01 2016
Current Comment Status: **Comment Closed**

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