ERDC
Engineer Research and
Development Center

Adaptive Management for Large-Scale Water Infrastructure Projects

The Missouri River Recovery Program

J. Craig Fischenich, PhD, PE
ERDC Environmental Laboratory

Restore the Mississippi River Delta
July 26, 2018
New Orleans, LA

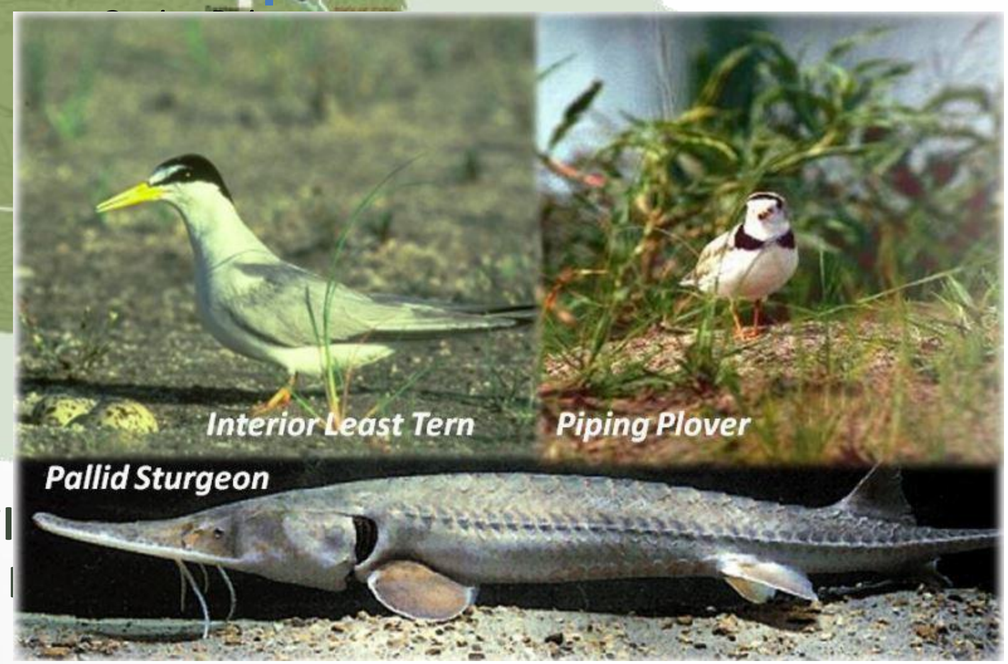
Missouri River Basin

Engineer Research and Development Center

nally
ed
poses

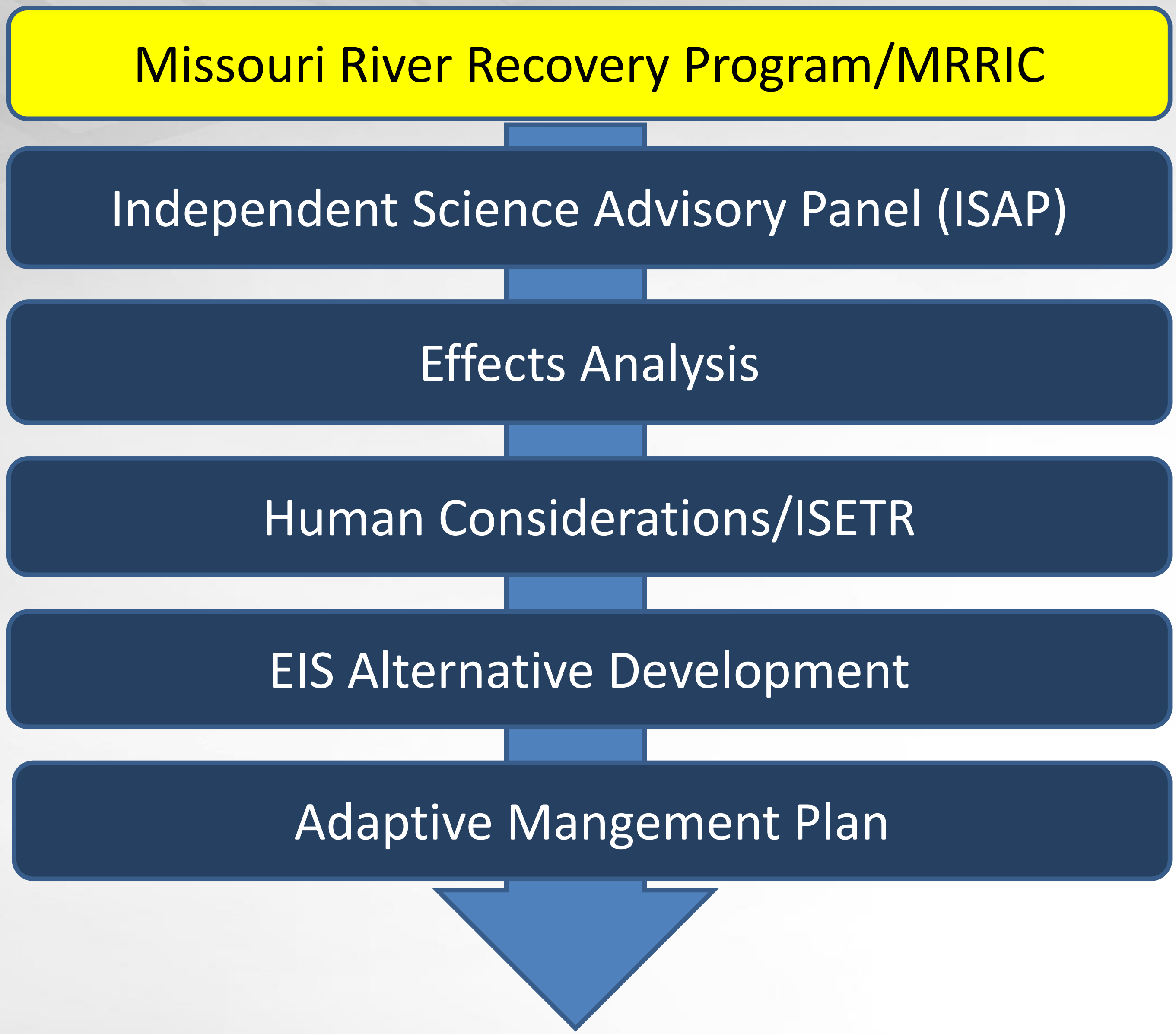
y
life

Bank Stabil
Sioux City, I



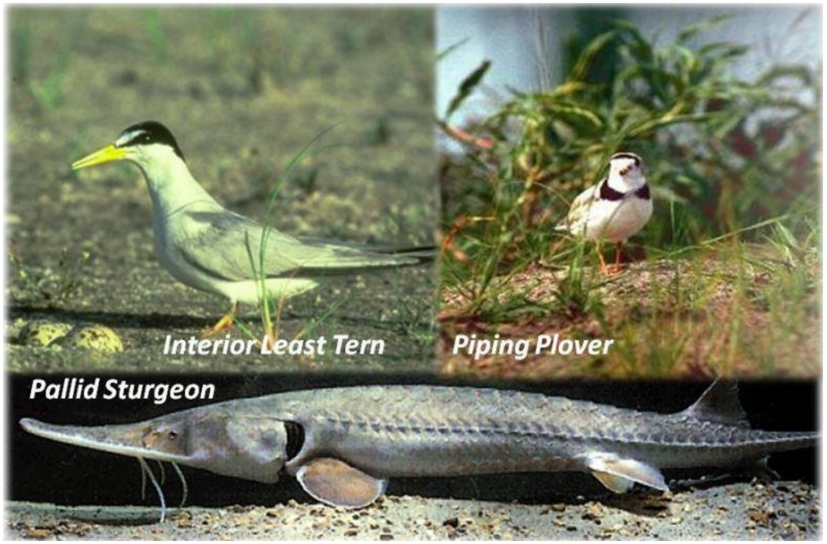
ERDC
Engineer Research and Development Center

Missouri River Recovery Management Plan-EIS Process



BiOp & Missouri River Recovery Program

- USFWS 2000/2003 Biological Opinions (BiOp) found Corps' operations would jeopardize the continued existence of the pallid sturgeon (*Scaphirhynchus albus*), interior least tern (*Sternula antillarum athalassos*) and the piping plover (*Charadrius melodus*)
- Identified a Reasonable and Prudent Alternative (RPA) to jeopardy consisting of several actions, including adaptive management
- Missouri River Recovery Program (MRRP) initiated in 2006 to implement requirements in the BiOp



"The Corps should embrace an adaptive management process that allows efficient modification/implementation of management actions in response to new information and to changing environmental conditions to benefit the species . . ." (USFWS 2000)

MRRP Overview

Engineer Research and Development Center

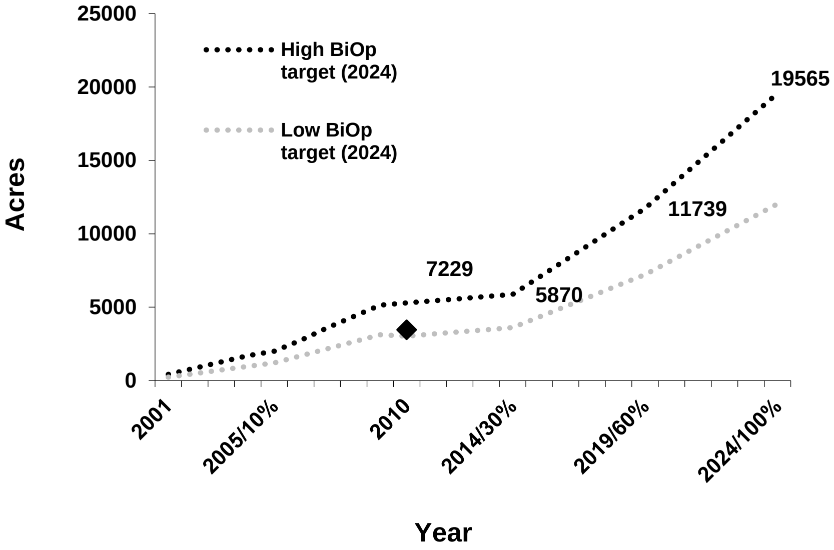
MRRP Purpose:

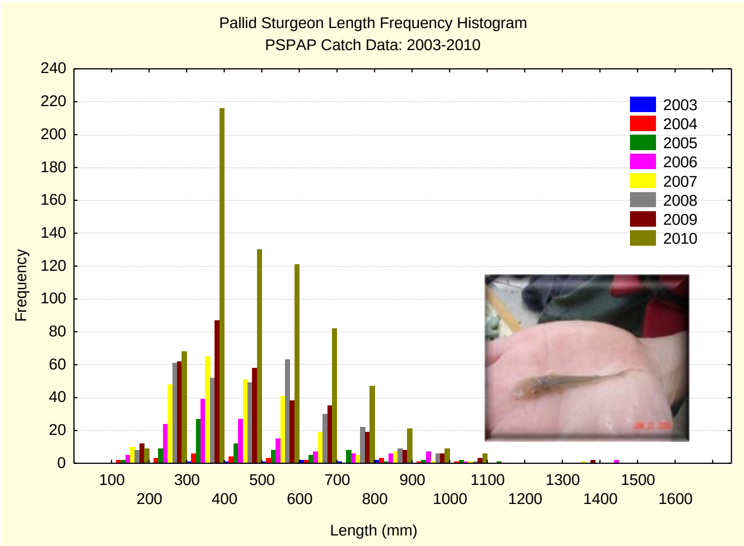
- To implement the requirements of the BiOp and restore a portion of the Missouri River ecosystem and habitat for fish and wildlife, while maintaining the congressionally-authorized uses of the river

MRRP Elements:

- Pallid Sturgeon-
  - Shallow Water Habitat Construction
  - Hatchery Propagation/Stocking
  - Spring Pulse System Release
- Tern and Plover
  - Emergent Sandbar Habitat Construction
  - System Operation to Reduce Nest Damage
- Monitoring and Evaluation

Missouri River Recovery Program





Missouri River Recovery Implementation Committee (MRRIC)

- Authorized by Congress in WRDA 2007
- Provide guidance/recommendations to USACE on MRRP implementation
- Composed of:
  - 28 Stakeholder members
  - 8 States
  - 18 Tribes
  - 15 Federal agencies

Missouri River Recovery Program/MRRIC

Independent Science Advisory Panel (ISAP)

Effects Analysis

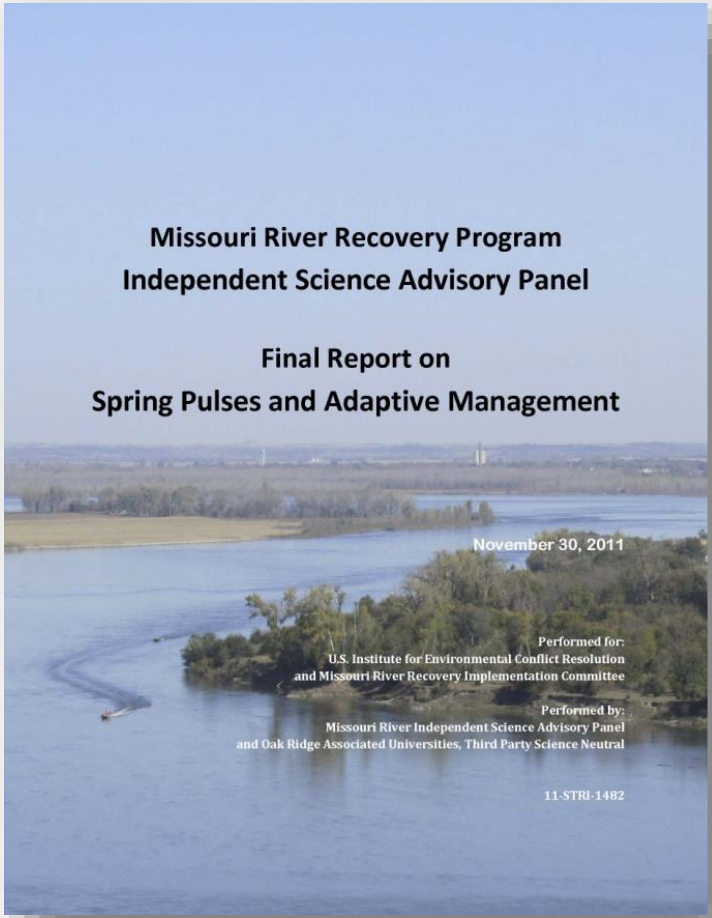
Human Considerations/ISETR

EIS Alternative Development

Adaptive Management Plan

Independent Science Advisory Panel (ISAP)

- 2009 MRRIC selection of independent science advisory panel
- Selection of 6 national experts in:
  - Geomorphology
  - Tern and Plover Biology
  - Pallid Sturgeon Biology
  - Ecology/Statistics
  - Conservation Biology
  - Riverine Ecology



Jan 2011 – MRRIC Finalized Initial Task to Independent Science Advisory Panel (ISAP)

Nov 2011 – ISAP's *"Final Report on Spring Pulses and Adaptive Management"*

2011 Flood

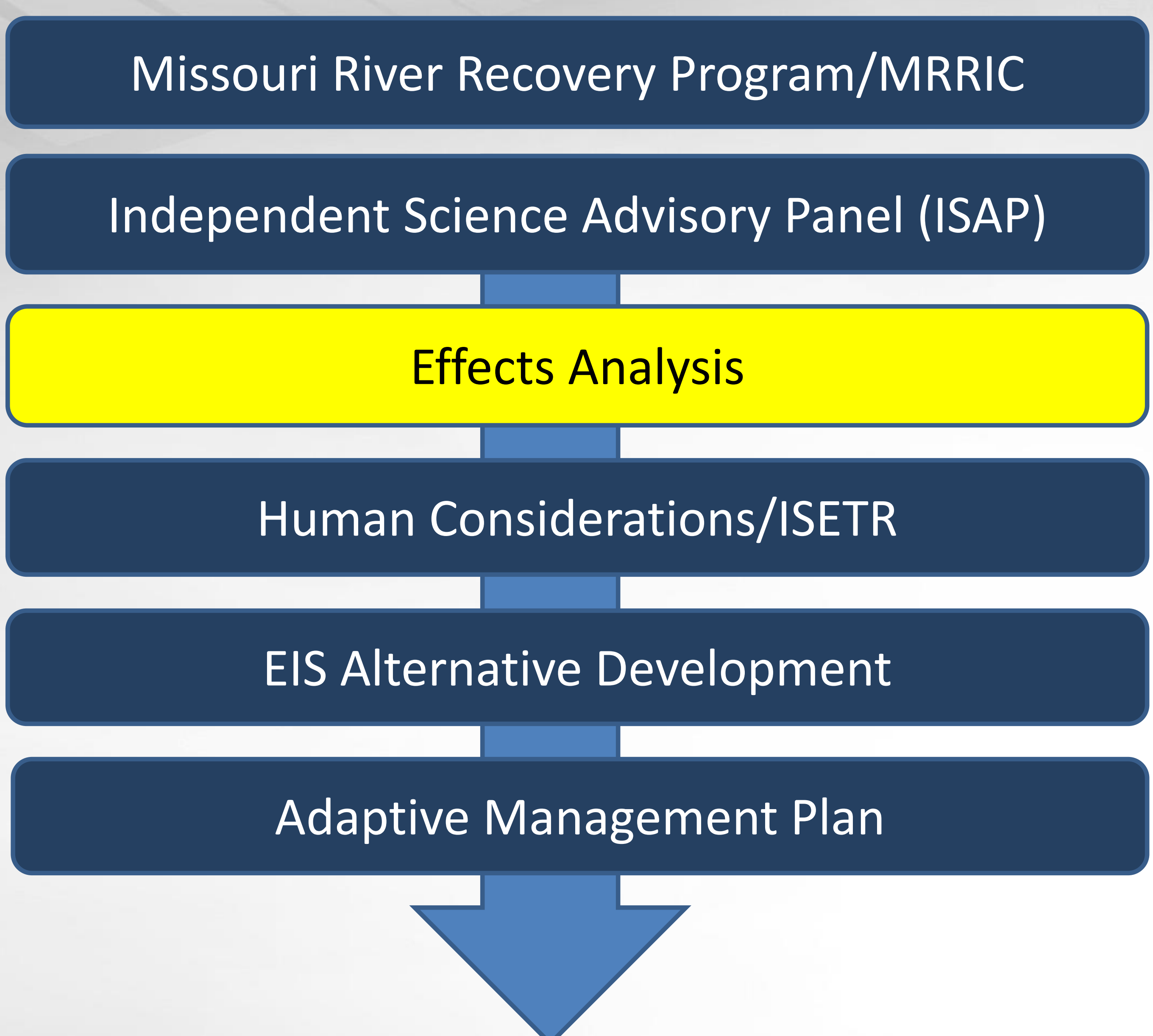
- >210% Normal basin runoff
- Flood of record
- >2X previous maximum reservoir release
- $85M direct impacts
- 5 deaths

(NWS 2012)

ERDC
Engineer Research and Development Center

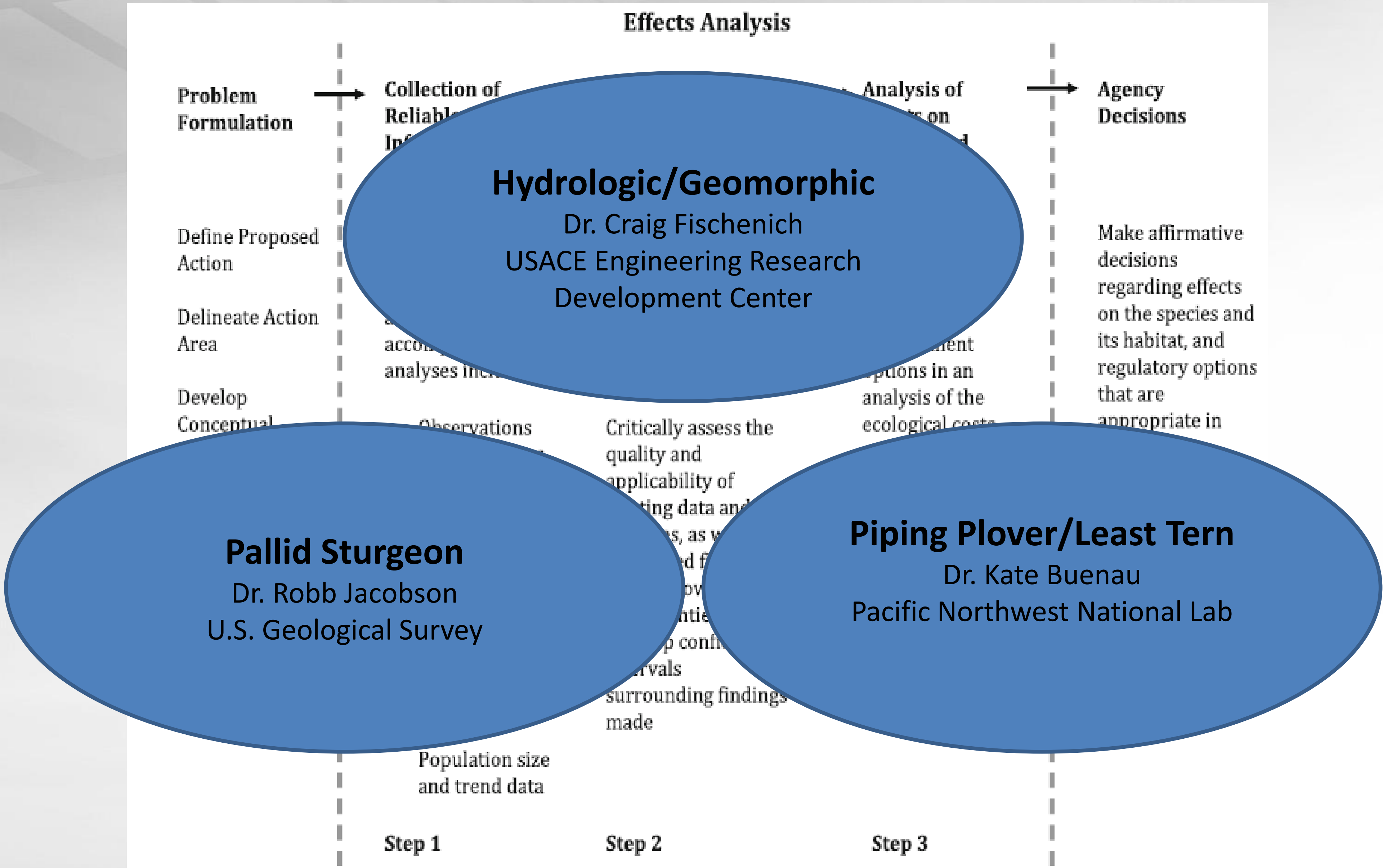
MRRIC Consensus Recommendation: 7 Proposed Actions from ISAP Report

1. Develop Effects Analysis
2. Develop Conceptual Ecological Models for listed species
3. Evaluate other Recovery programs
4. Develop overarching adaptive management strategy
5. Design monitoring programs
6. Identify decision criteria
7. Evaluate entire hydrograph effects on the listed species


Missouri River Recovery Program/MRRIC
Independent Science Advisory Panel (ISAP)
Effects Analysis
Human Considerations/ISETR
EIS Alternative Development
Adaptive Management Plan

Effects Analysis

Engineer Research and Development Center

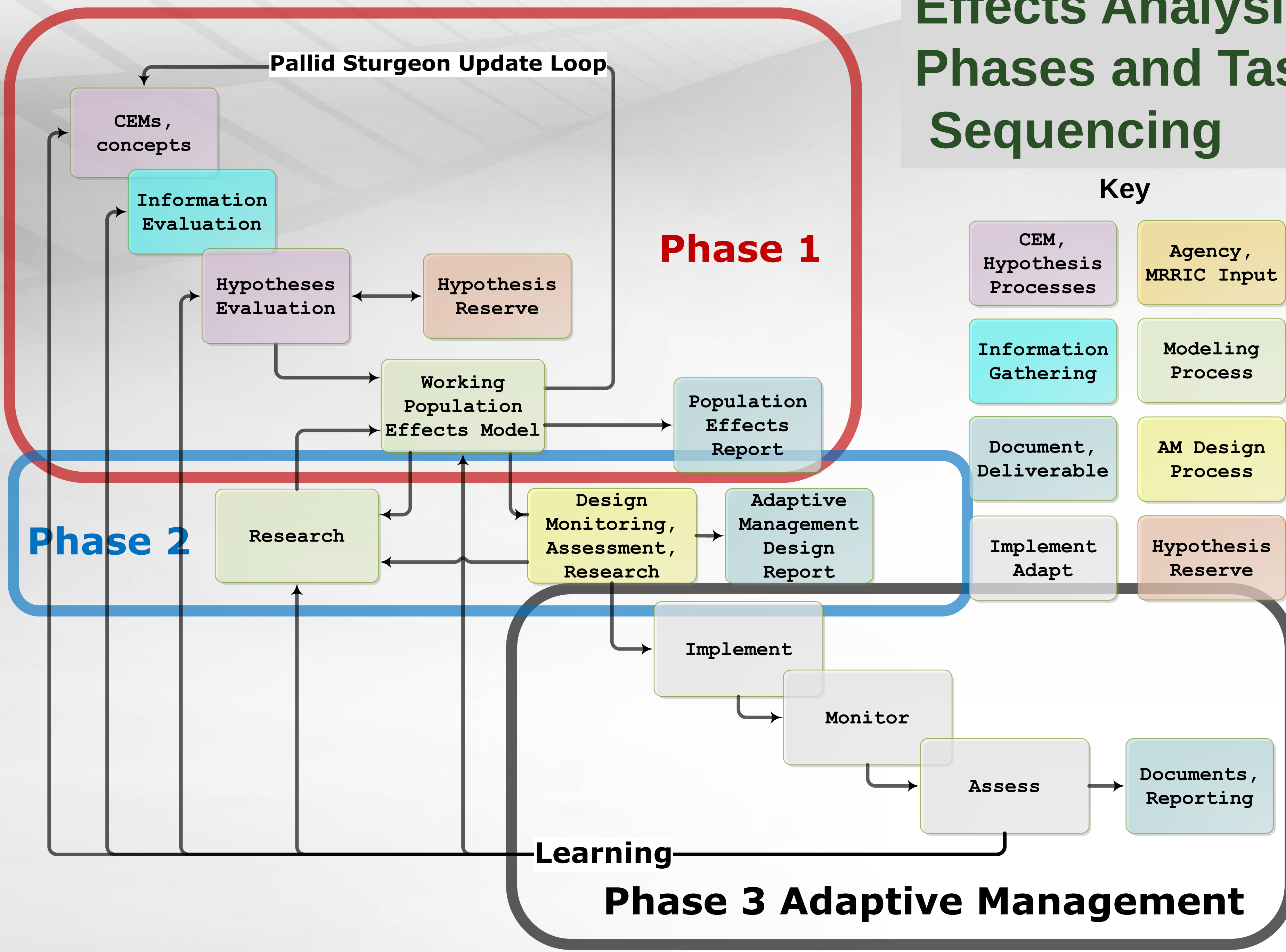


Effects Analysis Activities

ERDC
Engineer Research and Development Center

- Compile and assess ***pertinent scientific and operational information***
- Develop ***conceptual ecological models*** to guide development of hypotheses and quantitative models
- Identify hypothesized ***factors contributing to species population dynamics***
- Develop ***quantitative models for forecasting*** the effect of different actions on listed species performance
- Conduct analyses to inform ***species objectives targets*** and ***management actions***
- Assess ***effectiveness of alternative management strategies*** relative to the No Action condition

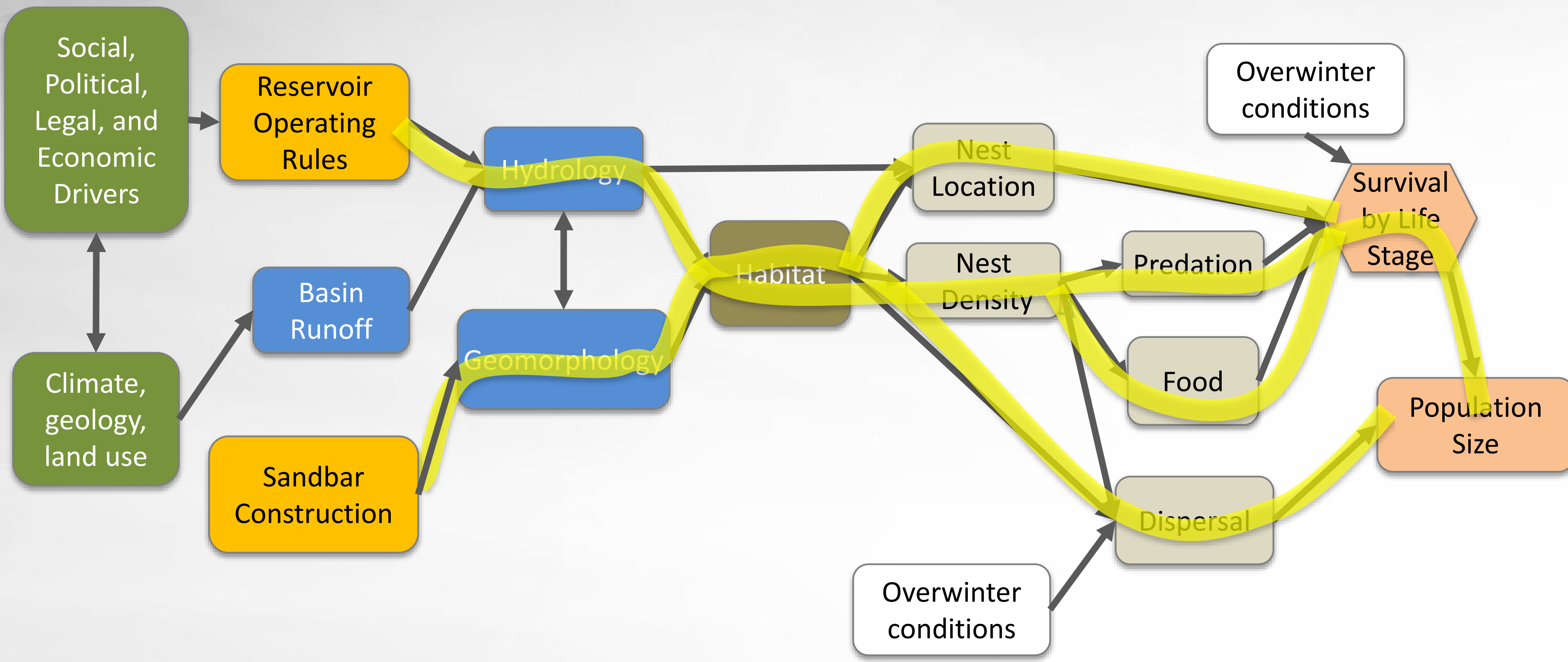
Effects Analysis Phases and Task Sequencing



Sources of information – lines of evidence

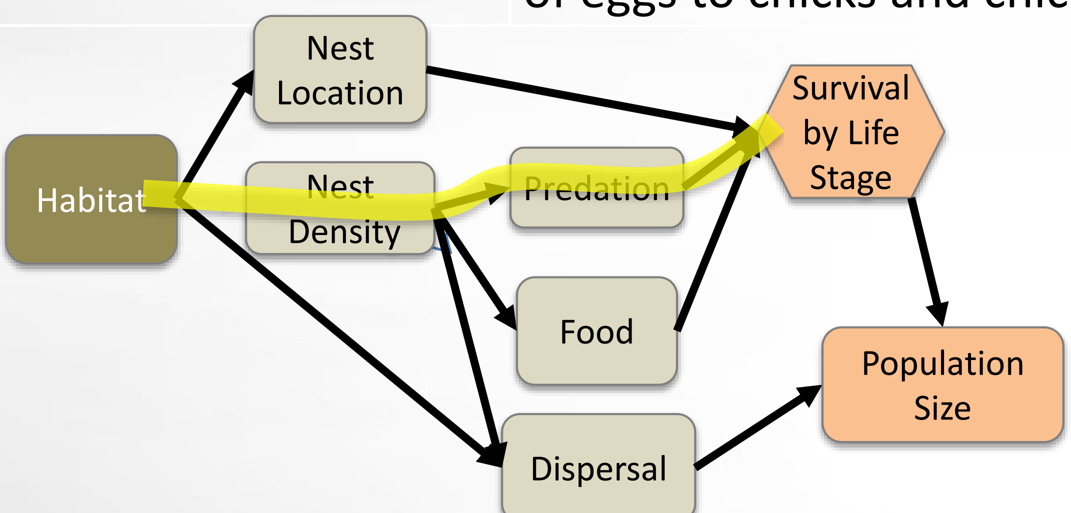
- **Theory**: natural flow paradigm, resource partitioning, niche utilization
- **Expert opinion**: understanding from other rivers, other species, from experience – "professional judgment"
- **Empirical evidence**: laboratory or field evidence of association, habitat selection; developmental rates; behavioral experiments
- **Quantitative models**: models constructed from theory, opinion, and/or empirical data to link management actions to biotic responses
  - We emphasize quantitative models but quantitative models need to be based on a strong theoretical or empirical foundation to be useful.

Pathways from Management Actions to Population Responses



CEM-Derived Hypotheses

Plover biotic hypothesis	Intermediate hypotheses
Increases in area of suitable habitat increases survival of eggs to chicks and chicks to fledglings by reducing predation.	
	For a given population size, increases in habitat area decrease nest density
	Lower nest densities attracts fewer predators, reducing predation.
	Decreases in predation increase survival of eggs to chicks and chicks to fledglings.



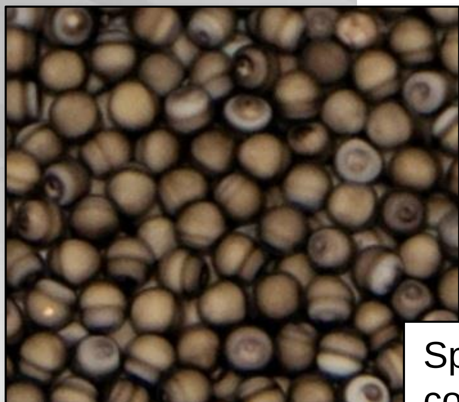
Overarching Critical Uncertainties—Birds

ERDC
Engineer Research and Development Center

- How much habitat is needed to maintain a resilient population of plovers and how should it be distributed?
- How are the Missouri River populations affected by migratory and metapopulation dynamics?
- How will changes in climate and channel morphology affect management effectiveness?
- How can the AM program buffer against natural (especially hydrologic) uncertainty?
- How can the AM program buffer against institutional and socioeconomic uncertainty?
- Management uncertainties: are actions necessary and effective?

Pallid Sturgeon (*Scaphirhynchus albus*)

Migrate upstream hundreds of km



Spawn over hard, coarse substrate, adhesive eggs, fertilize, 4-7 days incubation

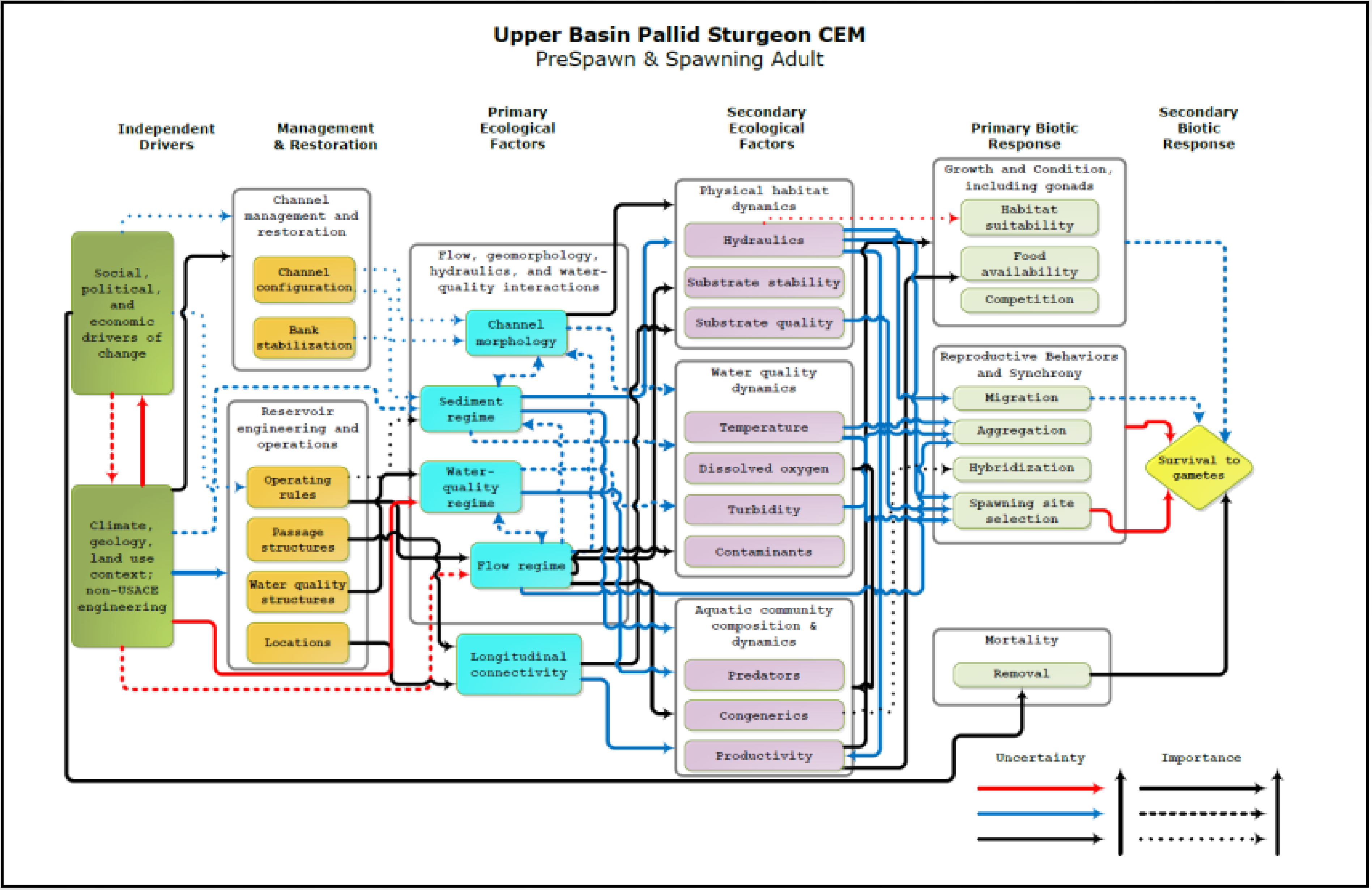
11-14 days drift as free embryo (or 6-9?)

"Settle" into lotic marginal habitats

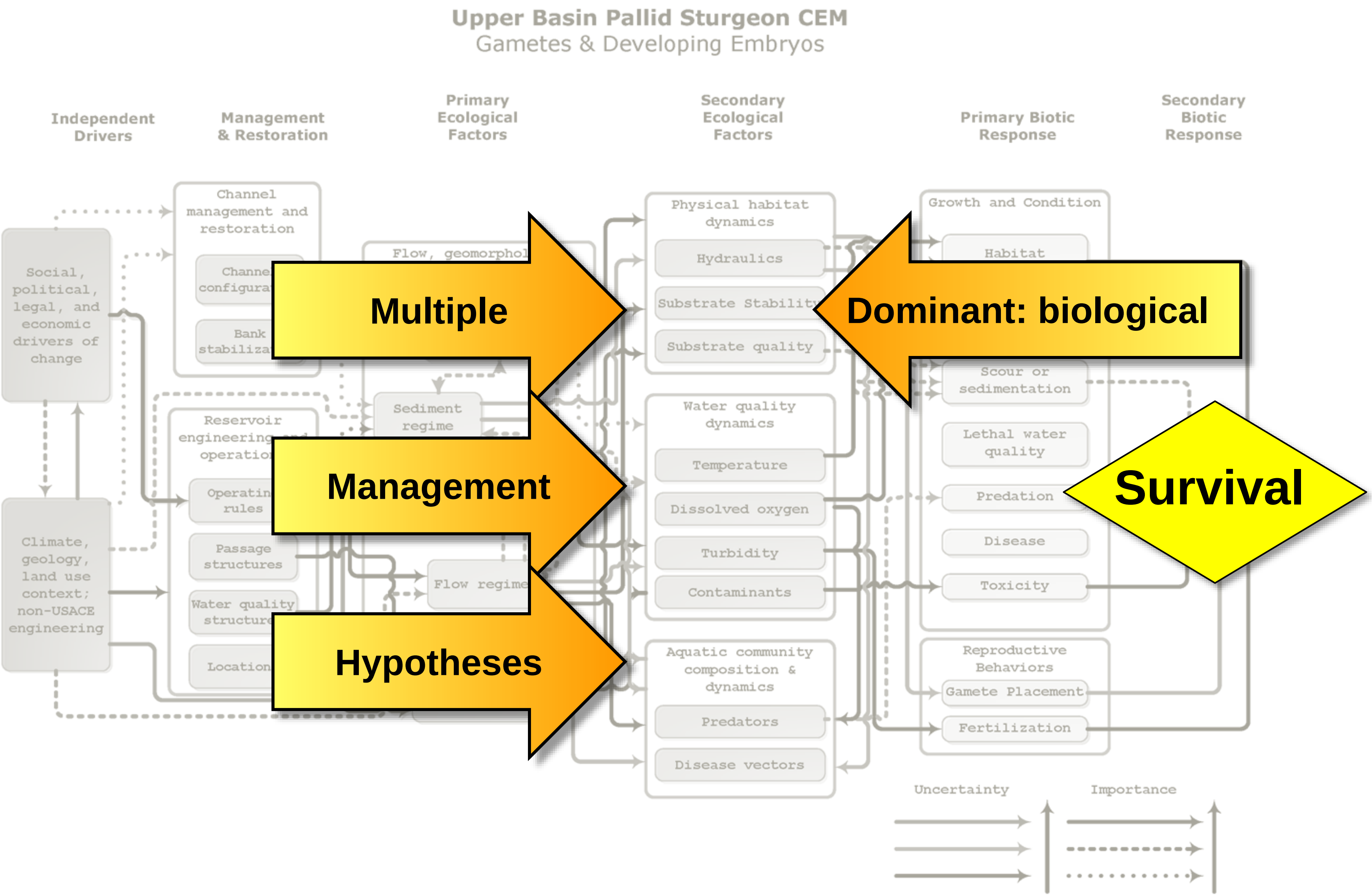
Grow to sexual maturity, 7-14 years

DeLonay and others (2009)

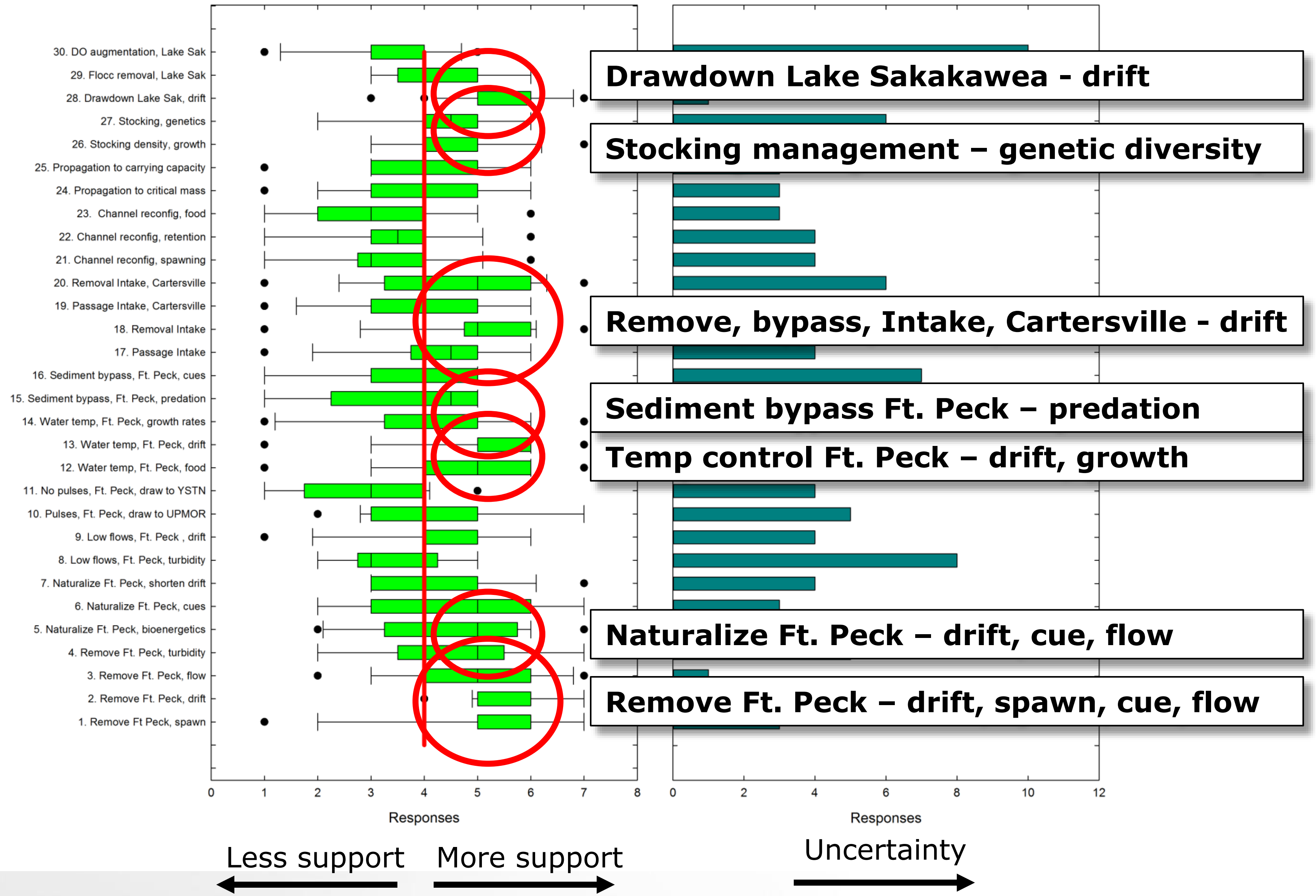
Pallid Sturgeon Conceptual Models



Component-level Conceptual Model



Management Hypotheses Expert Survey



ERDC Engineer Research and Development Center

21 Hypotheses:

Expand by Location, Expand by Life Stage

Five core model types

Working set of management hypotheses and model types.

Where	What	Management Hypothesis	Model Type	Short Name
Upper Missouri River	Alter Flow Regime at Fort Peck	Naturalized flow releases at Fort Peck will result in increased productivity through increased hydrologic connections with low-lying land and floodplains in the spring, and decreased velocities and bioenergetic demands on exogenously feeding larvae and juveniles during low flows in summer and fall.	Flow + Morph -> Habitats -> Food Production, energetic requirements -> Growth, survival	BIOENERGETICS
		Naturalized flow releases at Fort Peck will result in increased reproductive success through increased aggregation and spawning success of adults.	Flow + Morph + Sediment + Temperature -> Behavioral response -> Viable gametes	SPAWNING CUE
		Reduction of mainstem Missouri flows from Fort Peck Dam during free embryo dispersal will decrease mainstem velocities and drift distance thereby decreasing downstream mortaliity of free embryos and exogenously feeding larvae.	Flow + Morph -> Disp Distance; + Temperature -> Destination @ settling; + Destination Quality -> Survival	DRIFT
	Temperature Control, Multilevel-release Device at Fort Peck	Warmer flow releases at Fort Peck will increase system productivity and food resource availability, thereby increasing growth and condition of exogenously feeding larvae and juveniles.	Flow + Morph -> Habitats -> Food Production, energetic requirements -> Growth, survival	BIOENERGETICS
		Warmer flow releases from Fort Peck will increase growth rates, shorten drift distance, and increase survival of free embryos.	Flow + Morph -> Disp Distance; + Temperature -> Destination @ settling; + Destination Quality -> Survival	DRIFT
	Sediment Bypass at Fort Peck or Other Sediment Augmentation.	Installing sediment bypass at Fort Peck will increase and naturalize turbidity levels, resulting in decreased predation on embryos, free embryos, and exogenously feeding larvae.	Flow + Morph + Sediment + Temperature -> Behavioral response -> Mortality	PREDATION
Yellowstone River	Construct Fish Passage at Intake on Yellowstone River	Fish passage at Intake Dam on the Yellowstone will allow access to a additional functional spawning sites, increasing spawning success and effective drift distance, and decreasing downstream mortality of free embryos and exogenously feeding larvae.	If (Passage + migration + spawning); Flow + Morph, Disp Distance; + Temperature -> Destination @ settling; + Destination Quality -> Survival	DRIFT
	Upper Basin Propagation	Stocking at optimal size classes will increase growth rates and survival of exogenously feeding larvae and juveniles.	Stocking decision -> Population model -> Population growth/decrease?	PROPAGATION
		Stocking with appropriate parentage and genetic diversity will result in increased survival of embryos, free embryos, exogenously feeding larvae, and juveniles.		PROPAGATION
Lake Sakakawea	Operate Garrison Dam to draw down Lake Sakakawea	Drawdown of Lake Sakakawea will increase effective drift distance, decreasing downstream mortaliity of free embryos and exogenously feeding larvae.	Flow + Morph -> Disp Distance; + Temperature -> Destination @ settling; + Destination Quality -> Survival	DRIFT
Lower Missouri River	Alter Flow Regime at Gavins Point	Naturalization of the flow regime at Gavins Point will improve flow cues in spring for aggregation and spawning of reproductive adults.	Flow + Morph + Sediment + Temperature -> Behavioral response -> Viable gametes	SPAWNING CUE
		Naturalization of the flow regime at Gavins Point will improve connectivity with marginal habitats and low-lying lands, increase primary and secondary production, and increase growth and condition of exogenously feeding larvae and juveniles.	Flow + Morph -> Habitats -> Food Production, energetic requirements -> Growth, survival	BIOENERGETICS
		Naturalization of the flow regime at Gavins Point will decrease velocities and bioenergetic demands, resulting in increased growth and condition for exogenously feeding larvae and juveniles.	Flow + Morph -> Habitats -> Food Production, energetic requirements -> Growth, survival	BIOENERGETICS
		Alteration of the flow regime at Gavins Point can be optimized to decrease mainstem velocities, decrease effective drift distance, and minimize mortality.	Flow + Morph -> Disp Distance; + Temperature -> Destination @ settling; + Destination Quality -> Survival	DRIFT
	Temperature Management at Fort Randall and Gavins Point	Operation of a temperature management system at Fort Randall and/or Gavins Point will increase water temperature downstream of Gaivns Point, providing spawning cues for reproductive adults.	Flow + Morph + Sediment + Temperature -> Behavioral response -> Viable gametes	SPAWNING CUE
	Channel Reconfiguration	Re-engineering of channel moprhology in selected reaches will create optimal spawning conditions -- substrate, hydraulics, and geometry -- to increase probability of successful spawning, fertilization, embryo incubation, and free-embryo retention.	Flow + Morph + Sediment + Temperature -> Behavioral response -> Viable gametes	BIOENERGETICS
		Re-engineering of channel morphology in selected reaches will increase channel complexity and bioenergetic conditions to increase prey density (invertebrates and native prey fish) for exogenously feeding larvae and juveniles.	Flow + Morph -> Habitats -> Food Production, energetic requirements -> Growth, survival	BIOENERGETICS
		Re-engineering of channel morphology will increase channel complexity and minimize bioenergetic requirements for resting and foraging of exogenously feeding larvae and juveniles.	Flow + Morph -> Habitats -> Food Production, energetic requirements -> Growth, survival	BIOENERGETICS
		Re-engineering of channel morphology in selected reaches will increase channel complexity and serve specifically to intercept and retain drifting free embryos in areas with sufficient prey for first feeding and for growth through juvenile stages.	Flow + Morph -> Habitats -> Food Production, energetic requirements -> Growth, survival	BIOENERGETICS
	Propagation Lower Basin	Stocking at optimal size classes will increase growth rates and survival of exogenously feeding larvae and juveniles.	Stocking decision -> Population model -> Population growth/decrease?	PROPAGATION
		Stocking of fish with appropriate genetic heritage and at river locations with appropriate habitats will increase growth and survival of exogenously feeding larvae and juveniles.		PROPAGATION

- Bioenergetics
- Spawning cues
- Drift/dispersal
- Predation
- Propagation

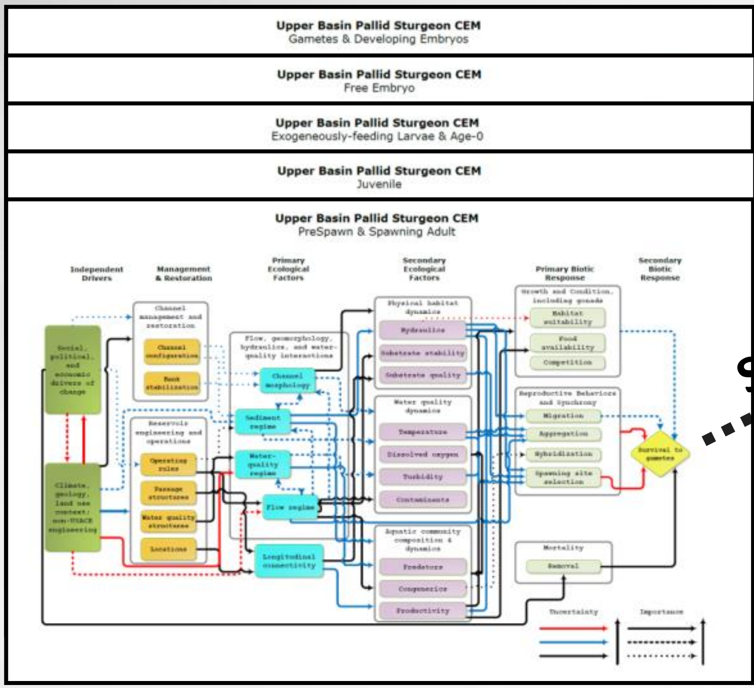
Overarching Critical Uncertainties—Sturgeon

- Are flow manipulations necessary to cue spawning, contribute to effective dispersal of free embryos?
- Are water temperature manipulations necessary for reproductive cues, or increased productivity and growth?
- Is dispersal distance limiting for age-0 pallid sturgeon survival, and if so, what combination of flow manipulation and other engineering actions would remove that limit?
- Are food-producing or foraging habitats limiting for age-0 pallid sturgeon, and if so, what combination of flow manipulation and channel reconfiguration would remove that limit?
- Are spawning habitats limiting for successful reproduction, and if so what combination of flow manipulation and channel reconfiguration would remove that limit?
- Is sediment augmentation necessary to achieve recruitment?
- What approaches to population augmentation are necessary to maintain the population temporarily and will do so with least harm to genetic diversity?

Engineer Research and Development Center

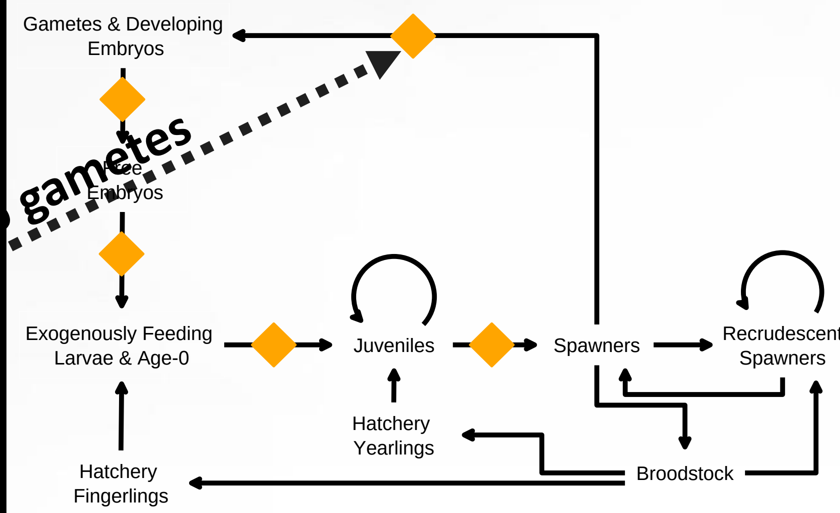
CEMs to Population Viability

Conceptual Ecological Models (CEMs)



Survival to gametes

Stage Structured Population Model



Pallid Sturgeon

ERDC
Engineer Research and Development Center

Stage structured Pallid Sturgeon population model

Number of years to simulate:
10 — 50 — 100

Maximum age:
30 — 41

Initial abundance juveniles (natural):
100 — 5,000 — 20,000

Initial abundance juveniles (hatchery):
100 — 5,000 — 20,000

Initial abundance adults (hatchery):
100 — 5,000 — 20,000

Initial abundance adults (hatchery):
0 — 33,000 — 100,000

Annual hatchery inputs (fingerlings):
0 — 20,000

Annual hatchery inputs (yearlings):
0 — 20,000

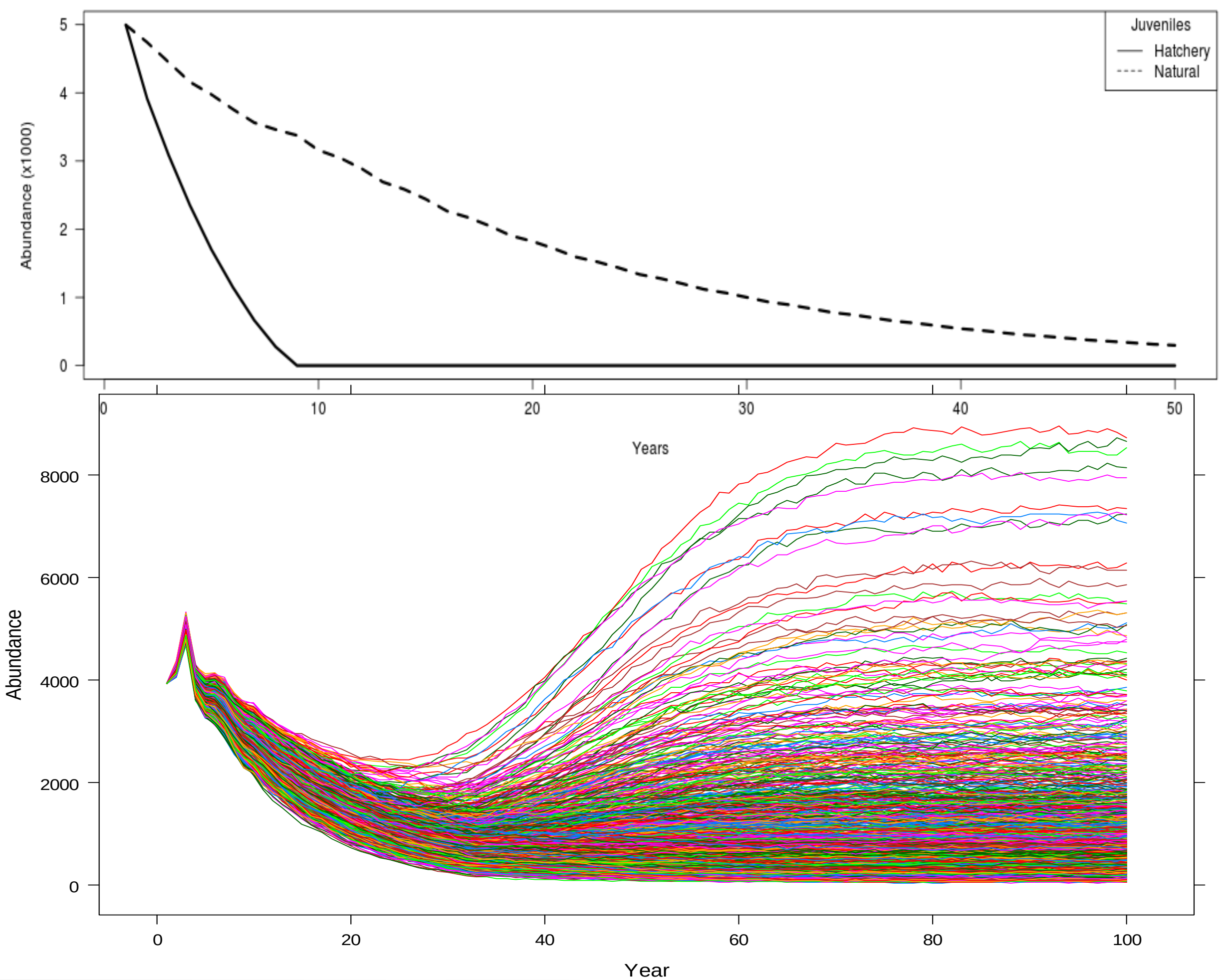
Early life survival (0-365 dph):
0 — 0.0508 — 0.1

Probability of producing viable gametes:
0.0002 — 0.01

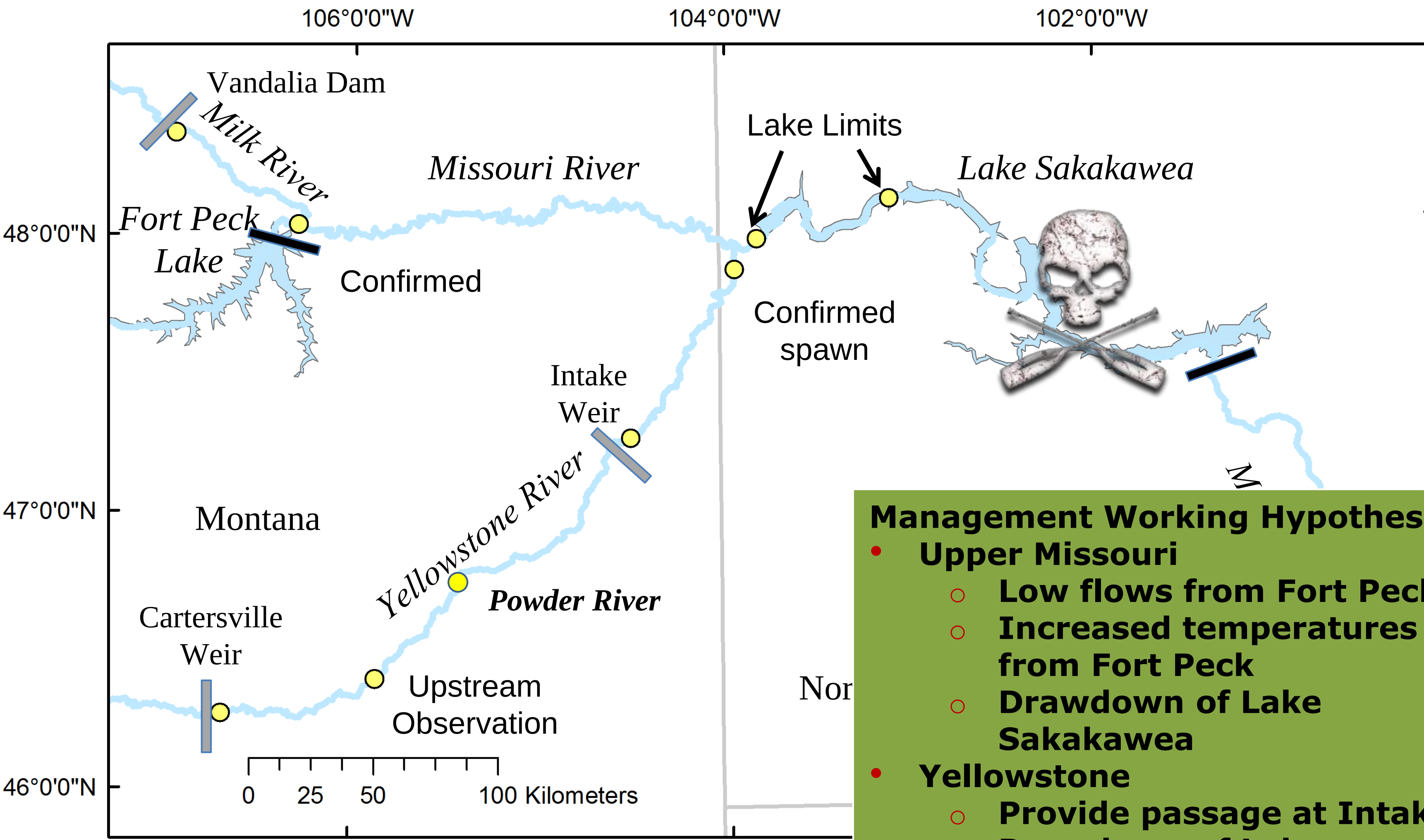
Survival to adult (age-1):
0 — 0.688 — 1

Adult survival (>age-1):
0.5 — 0.922 — 1

Juveniles | Adults



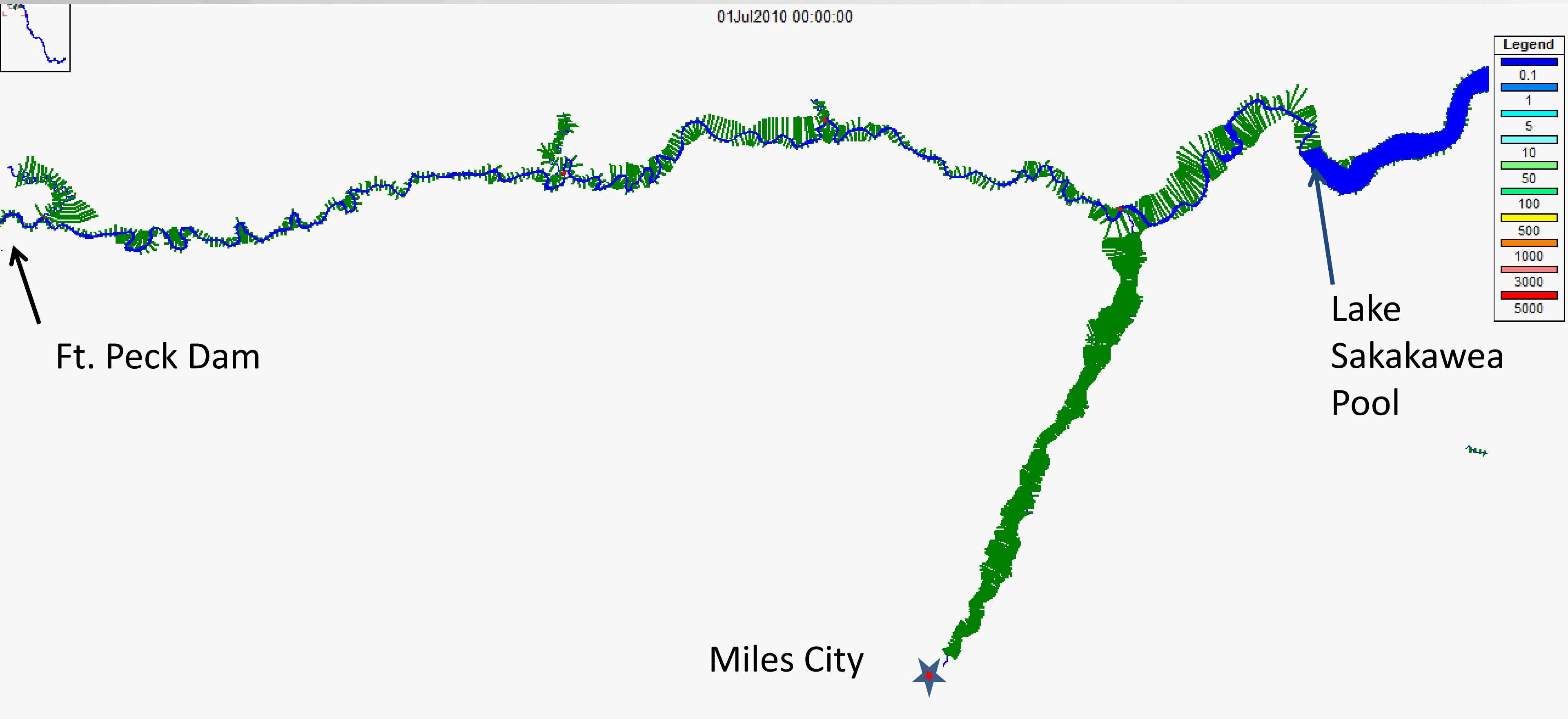
Free Embryo Drift and Survival
Upper Missouri & Yellowstone Rivers



Management Working Hypotheses:

- **Upper Missouri**
  - **Low flows from Fort Peck**
  - **Increased temperatures from Fort Peck**
  - **Drawdown of Lake Sakakawea**
- **Yellowstone**
  - **Provide passage at Intake**
  - **Drawdown of Lake Sakakawea**

1D Advection/Dispersion



Preliminary Effectiveness of Management Actions

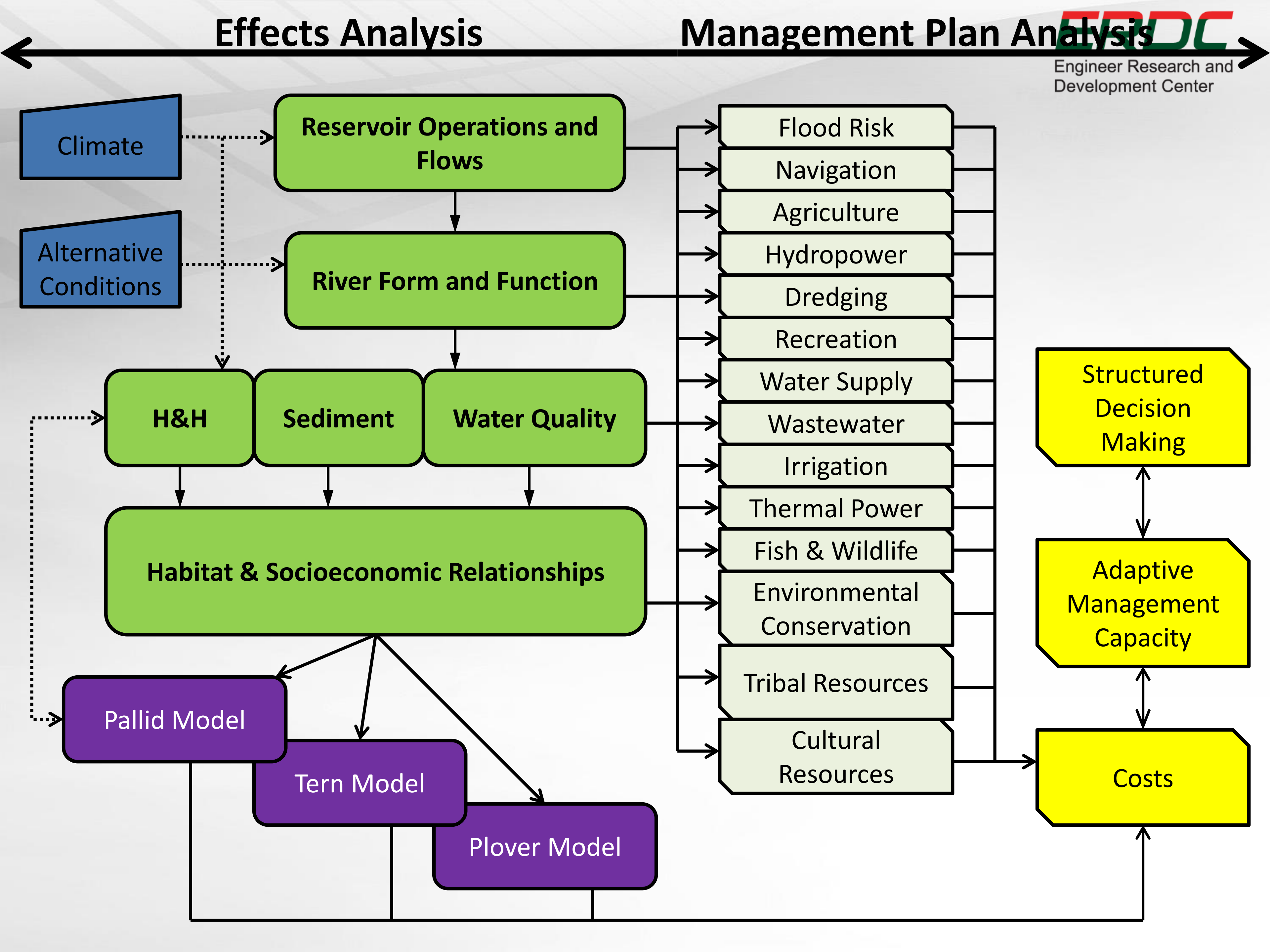
ERDC
Engineer Research and Development Center

Percent Larvae U/S of Pool at T = 4 Days							
		Lake Sakakawea Pool Level					
Flow		HMin	Min	10	50	90	Max
Exceed	Ft. Peck	1805.0	1812.6	1821.6	1843.2	1850.4	1856.0
Min	3000	100%	100%	100%	100%	100%	100%
5	5500	100%	100%	100%	100%	100%	100%
10	6100	100%	100%	100%	100%	100%	100%
25	7150	100%	100%	100%	100%	99%	99%
50	8600	99%	99%	99%	99%	99%	97%
75	11000	100%	100%	100%	100%	98%	92%
90	14400	100%	100%	100%	100%	95%	80%
95	16100	100%	100%	100%	100%	89%	63%

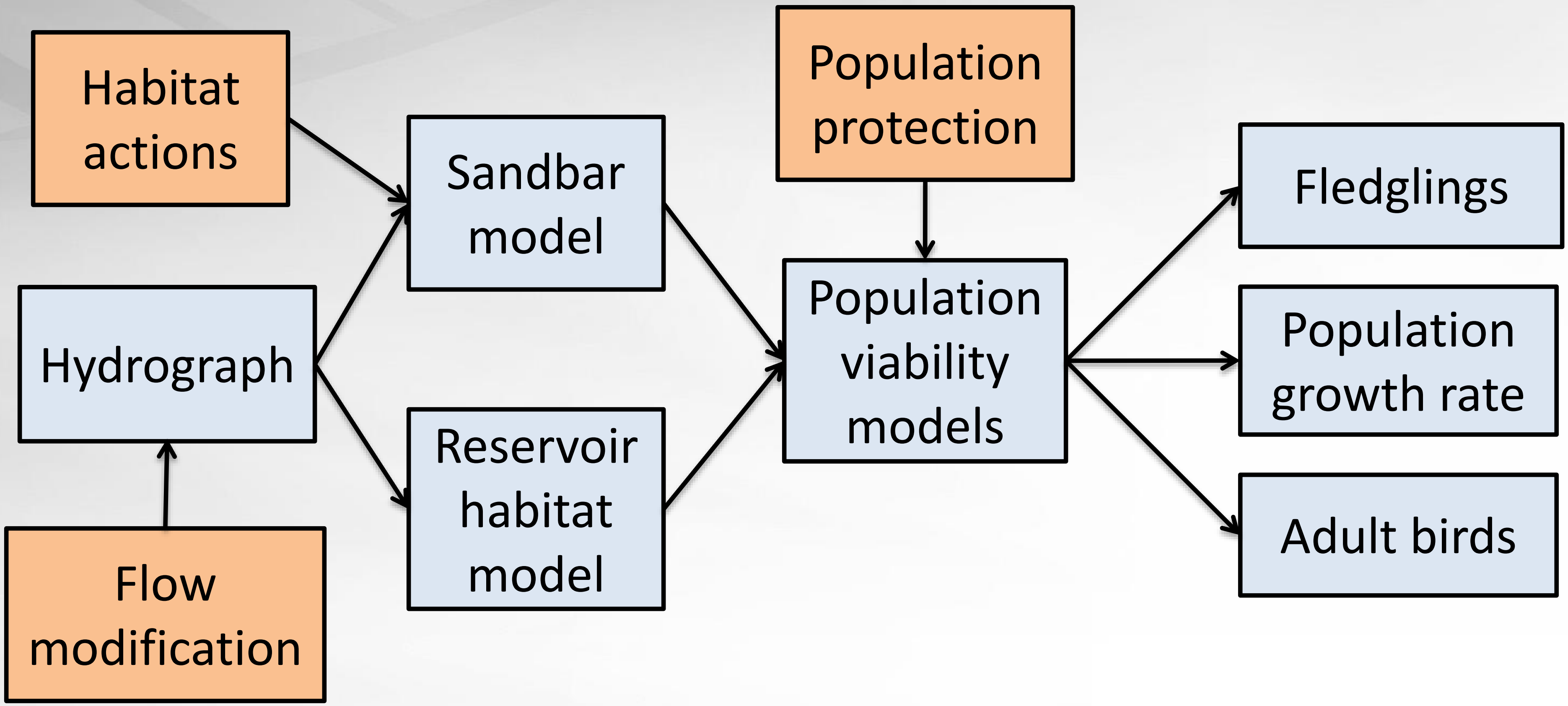
Percent Larvae U/S of Pool at T = 6 Days							
		Lake Sakakawea Pool Level					
Flow		HMin	Min	10	50	90	Max
Exceed	Ft. Peck	1805.0	1812.6	1821.6	1843.2	1850.4	1856.0
Min	3000	100%	100%	100%	98%	85%	70%
5	5500	100%	100%	97%	80%	33%	22%
10	6100	100%	99%	96%	75%	23%	14%
25	7150	99%	98%	91%	60%	11%	6%
50	8600	98%	96%	85%	49%	6%	4%
75	11000	98%	94%	83%	44%	3%	1%
90	14400	92%	86%	68%	30%	2%	0%
95	16100	85%	76%	57%	20%	1%	0%

Percent Larvae U/S of Pool at T = 8 Days							
		Lake Sakakawea Pool Level					
Flow		HMin	Min	10	50	90	Max
Exceed	Ft. Peck	1805.0	1812.6	1821.6	1843.2	1850.4	1856.0
Min	3000	92%	85%	60%	26%	7%	3%
5	5500	53%	41%	14%	6%	1%	1%
10	6100	47%	34%	11%	4%	0%	1%
25	7150	29%	20%	6%	2%	0%	0%
50	8600	16%	11%	3%	1%	0%	1%
75	11000	12%	8%	2%	0%	0%	0%
90	14400	5%	3%	1%	0%	0%	0%
95	16100	3%	2%	1%	0%	0%	0%

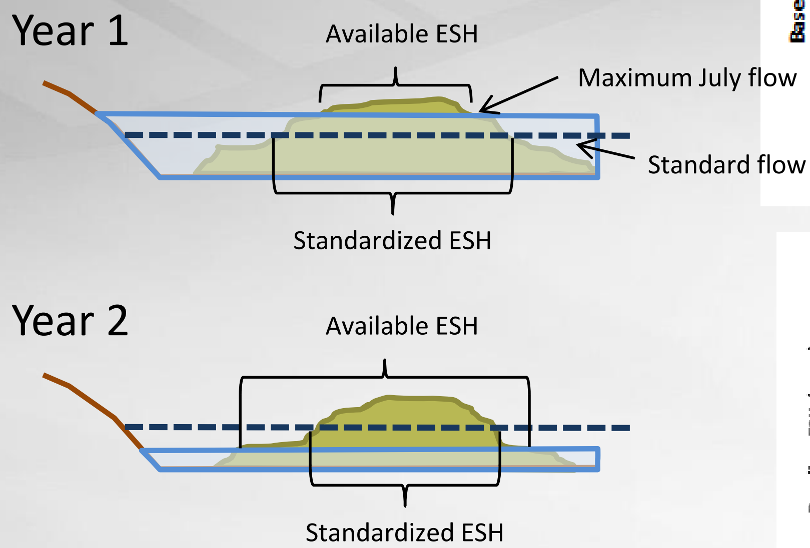
Percent Larvae U/S of Pool at T = 10 Days							
		Lake Sakakawea Pool Level					
Flow		HMin	Min	10	50	90	Max
Exceed	Ft. Peck	1805.0	1812.6	1821.6	1843.2	1850.4	1856.0
Min	3000	21%	19%	6%	3%	1%	1%
5	5500	4%	5%	1%	1%	0%	0%
10	6100	0%	3%	1%	0%	0%	0%
25	7150	1%	1%	1%	0%	0%	0%
50	8600	0%	0%	0%	0%	0%	0%
75	11000	0%	0%	0%	0%	0%	0%
90	14400	0%	0%	0%	0%	0%	0%
95	16100	0%	0%	0%	0%	0%	0%

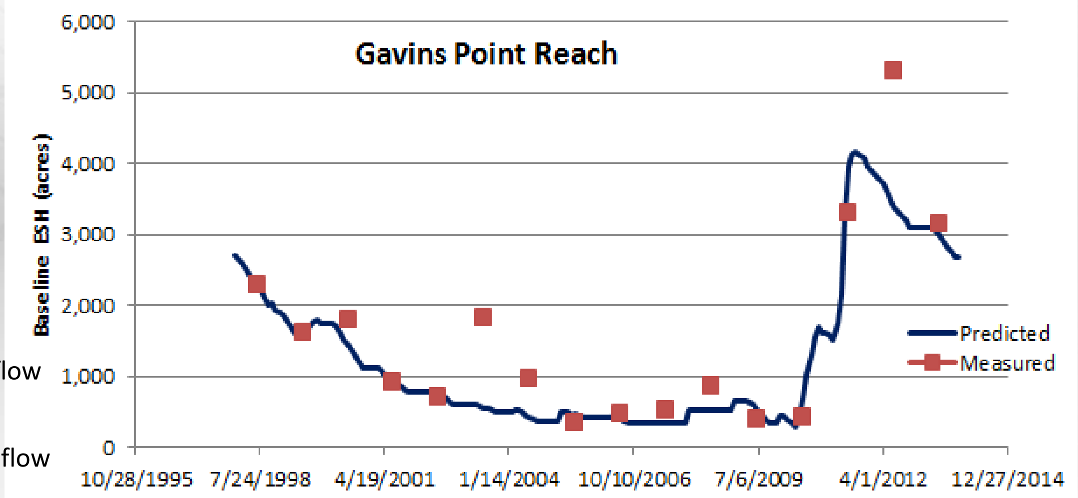

Effects Analysis
Management Plan Analysis
ERDC
Engineer Research and Development Center
Climate
Alternative Conditions
Reservoir Operations and Flows
River Form and Function
H&H
Sediment
Water Quality
Habitat & Socioeconomic Relationships
Pallid Model
Tern Model
Plover Model
Flood Risk
Navigation
Agriculture
Hydropower
Dredging
Recreation
Water Supply
Wastewater
Irrigation
Thermal Power
Fish & Wildlife
Environmental Conservation
Tribal Resources
Cultural Resources
Structured Decision Making
Adaptive Management Capacity
Costs

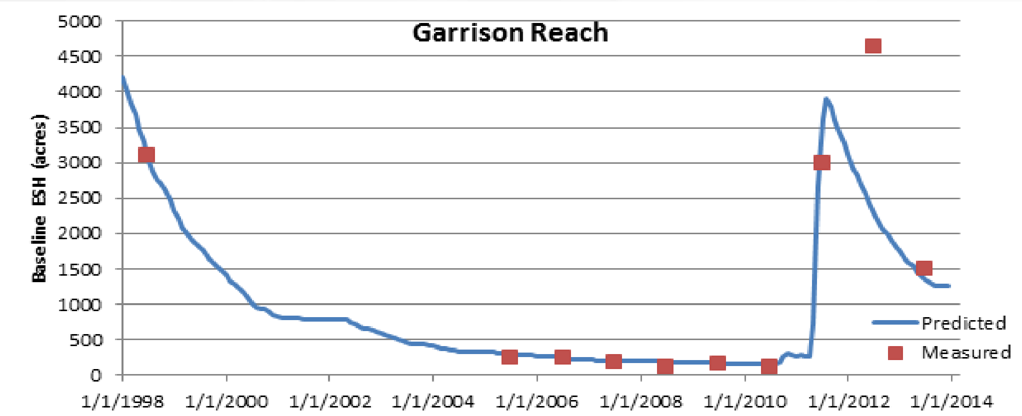
Habitat and population modeling

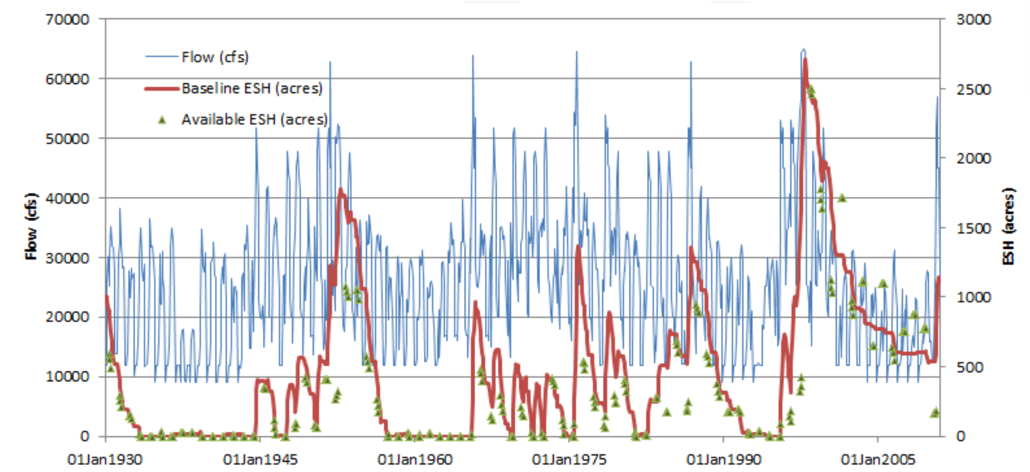


Emergent Sandbar Habitat



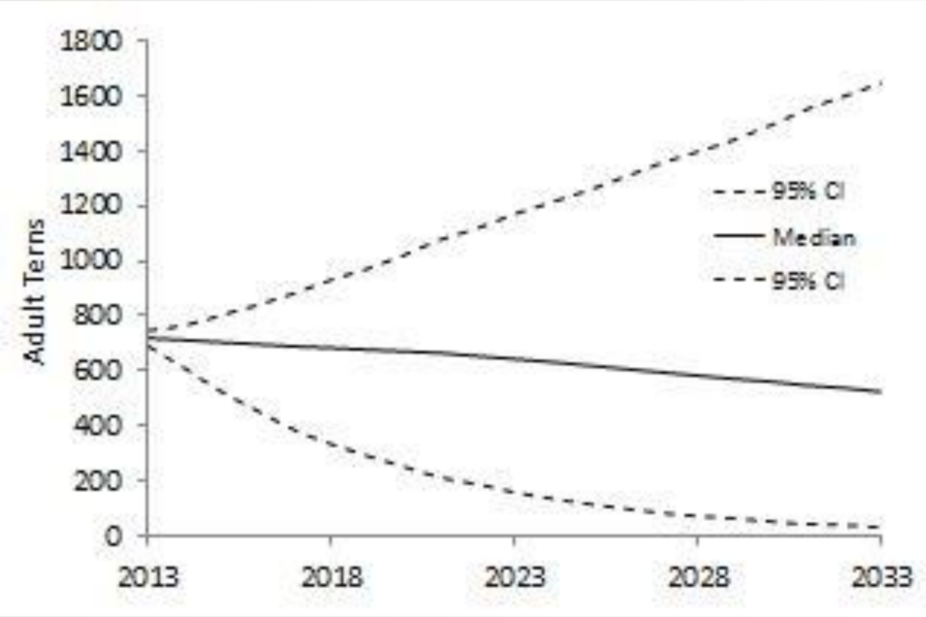


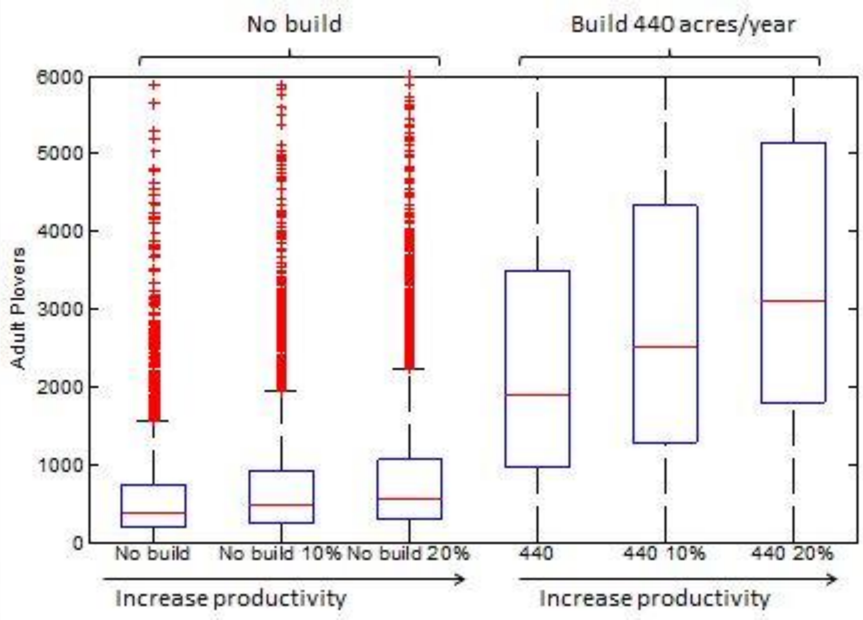




Species Models

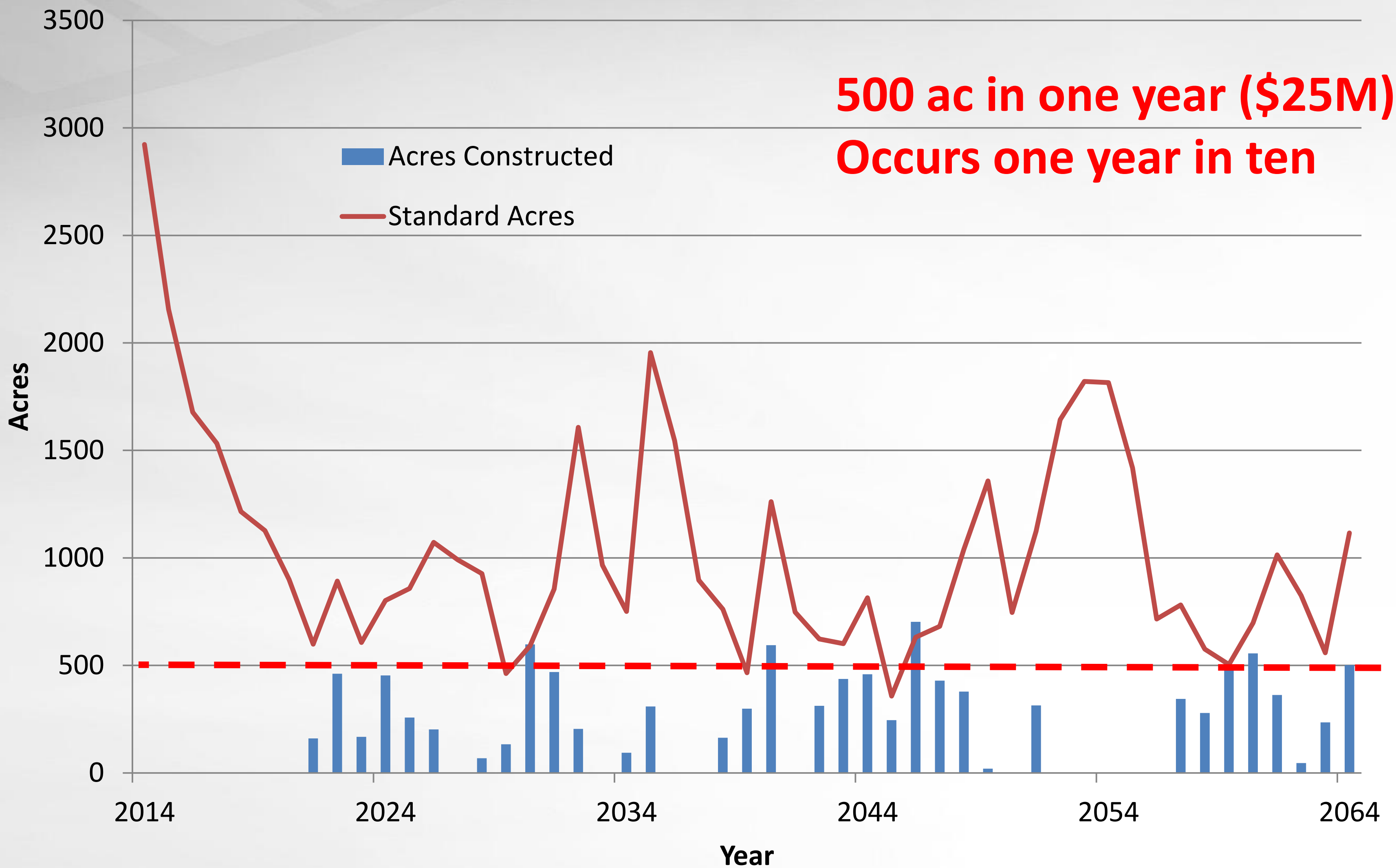
- Species models were developed and are used to forecast population ranges for alternative management scenarios
- Additional modeling is addressing specific biological hypotheses critical to decision making



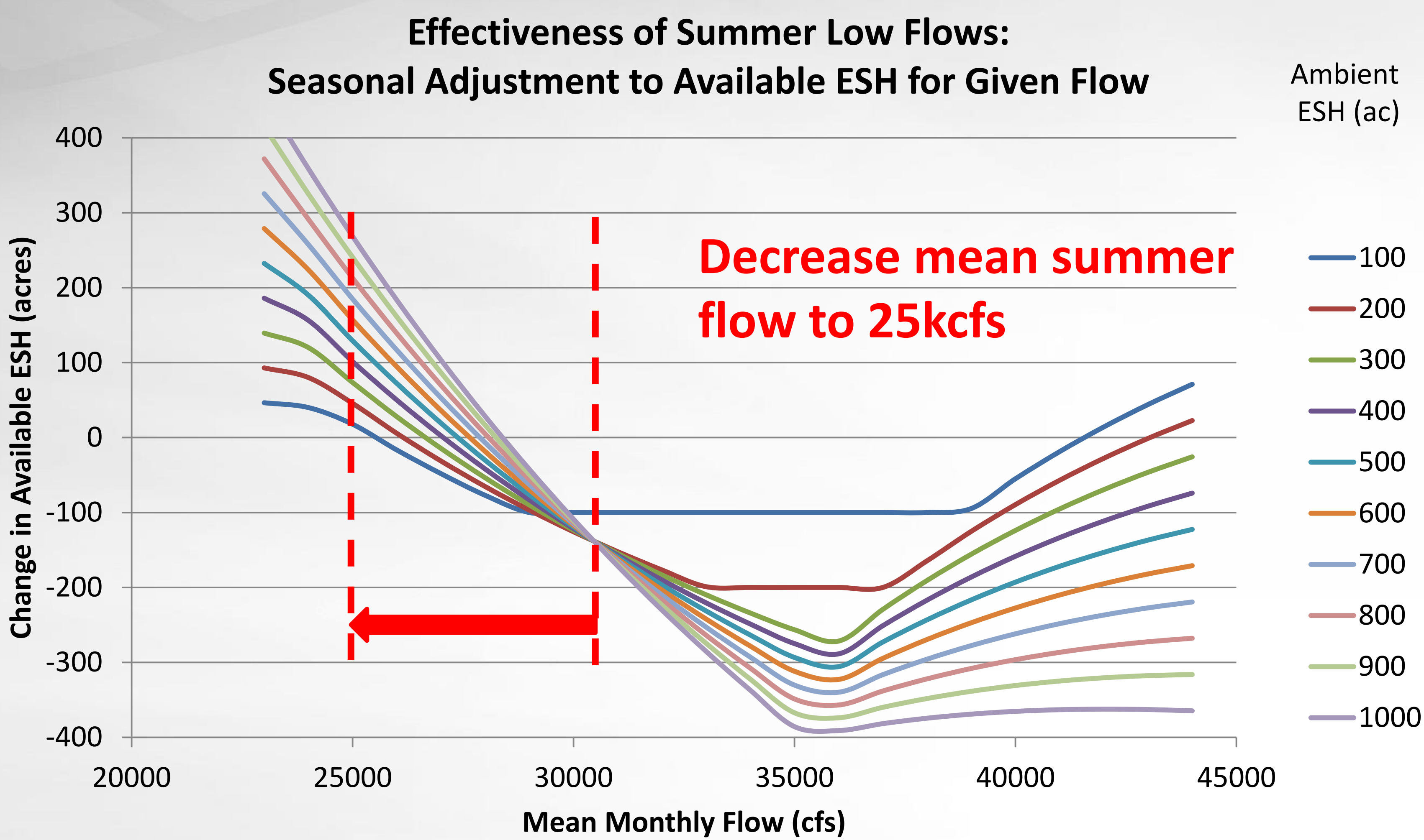


Useful Model Analyses

ERDC
Engineer Research and
Development Center



Useful Model Analyses

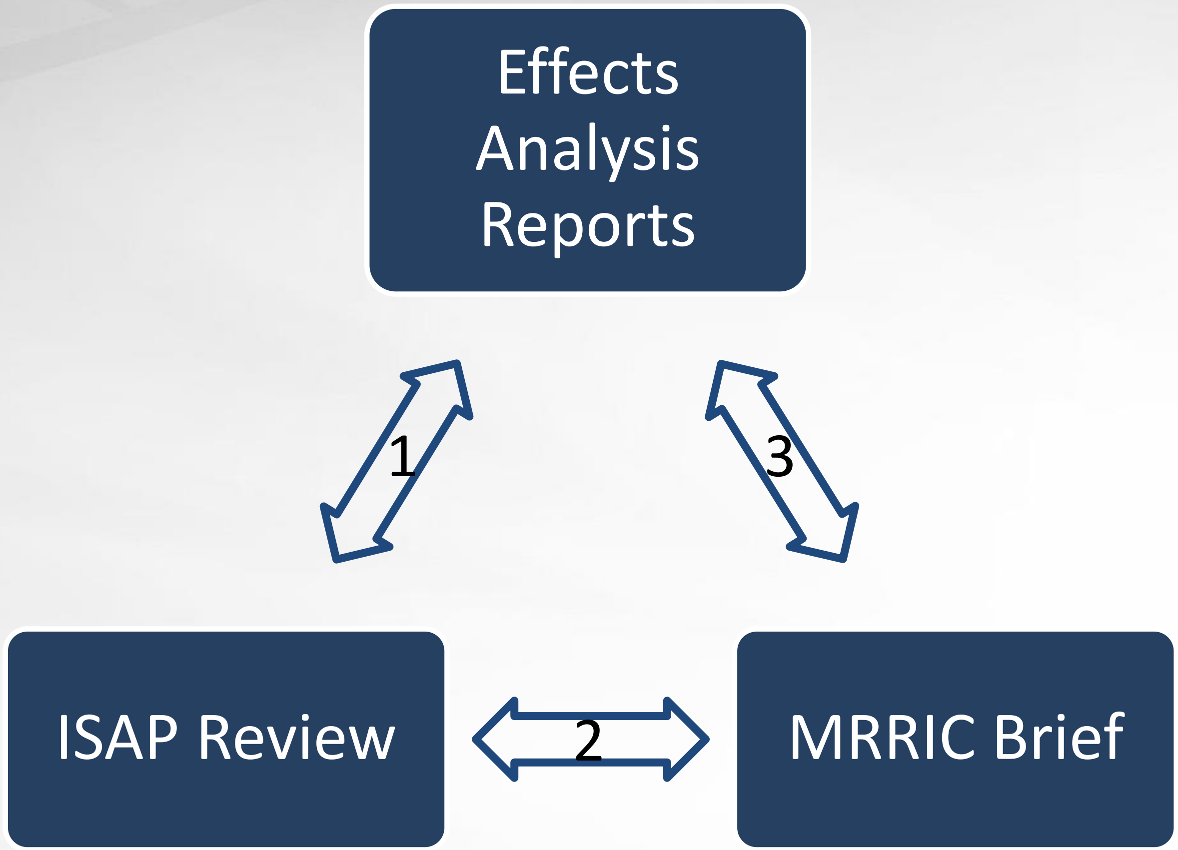


Synthesis: Best Available Science Based on Lines of Evidence and Model Projections

ERDC
Engineer Research and Development Center

Effects Analysis Report Review Process

ERDC
Engineer Research and Development Center



Missouri River Recovery Program/MRRIC

Independent Science Advisory Panel (ISAP)

Effects Analysis

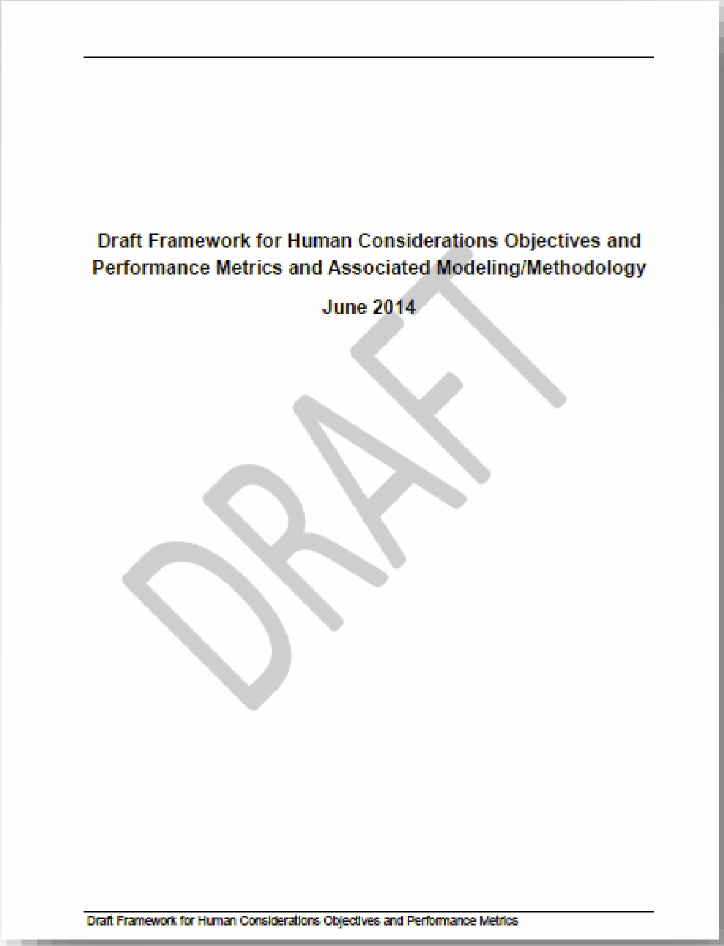
Human Considerations/ISETR

EIS Alternative Development

Adaptive Management Plan

Human Considerations

- Purpose is to assess effects of potential management actions on human interests
- Identified and developed with MRRIC- 2013-2014
- MRRIC Consensus Recommendation- 2014
- PrOACT process truncated in 2015

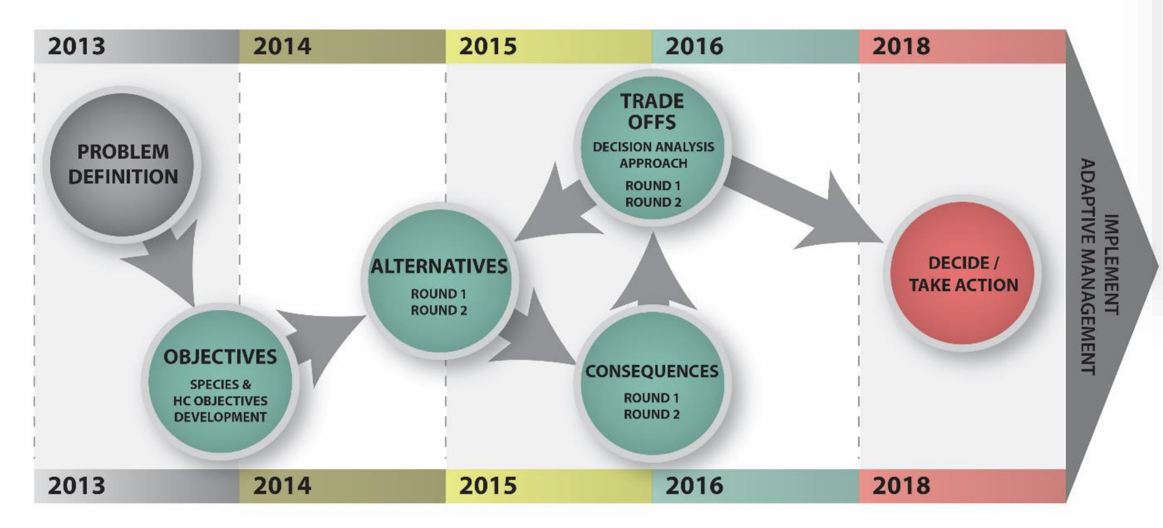


Draft Framework for Human Considerations Objectives and Performance Metrics and Associated Modeling/Methodology

June 2014

DRAFT

Draft Framework for Human Considerations Objectives and Performance Metrics

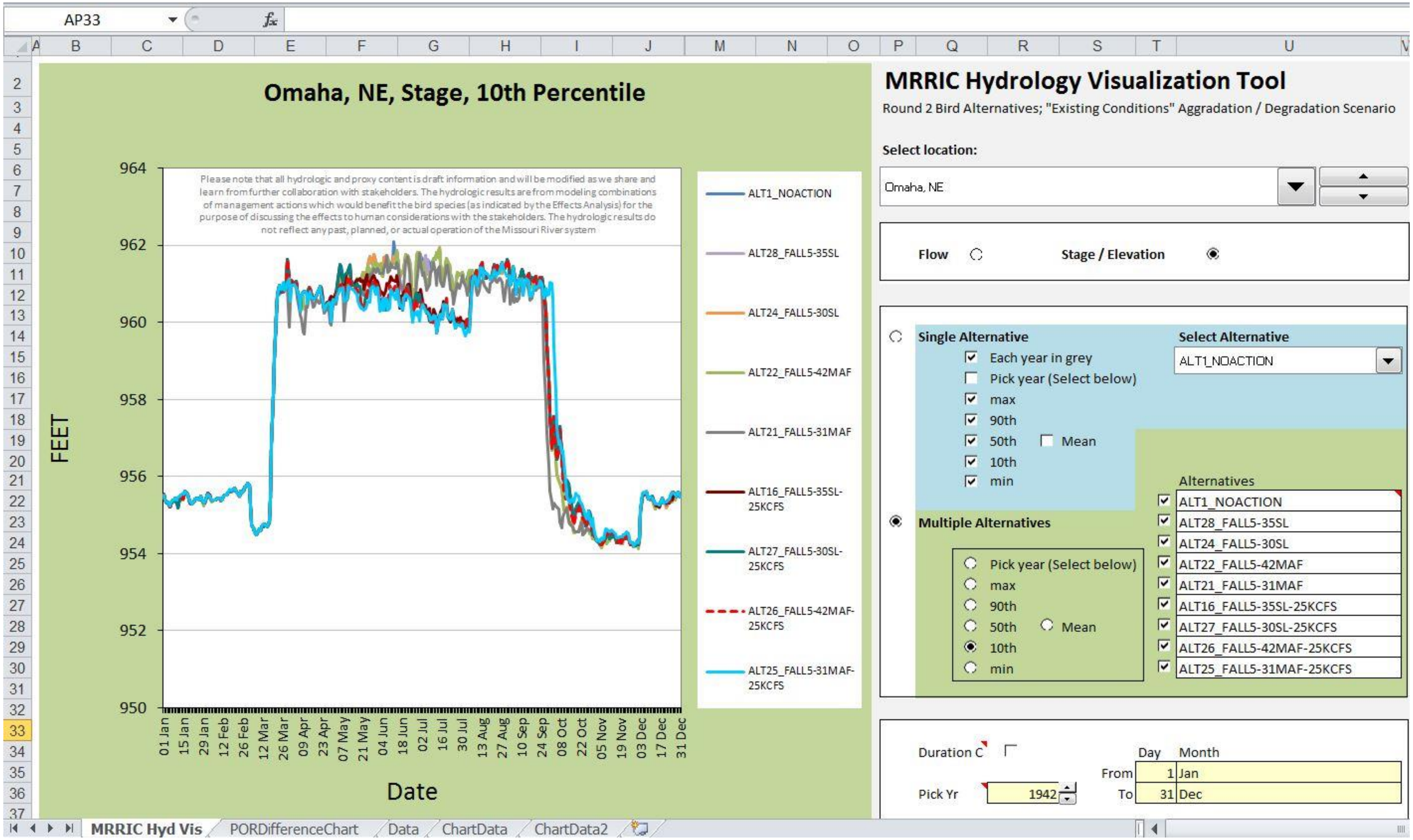


Environmental Impact Categories (Human Considerations)

Engineer Research and Development Center

- Agriculture
- Commercial Sand Dredging
- Cultural Resources
- Environmental Conservation
- Fish and Wildlife
- Flood Risk Reduction
- Hydropower
- Implementation Costs
- Irrigation
- Navigation
- Recreation
- Thermal Power
- Water Supply
- Wastewater

Tools for Stakeholders



Independent Socio-Economic Review Panel & Government to Government Consultation

Engineer Research and Development Center

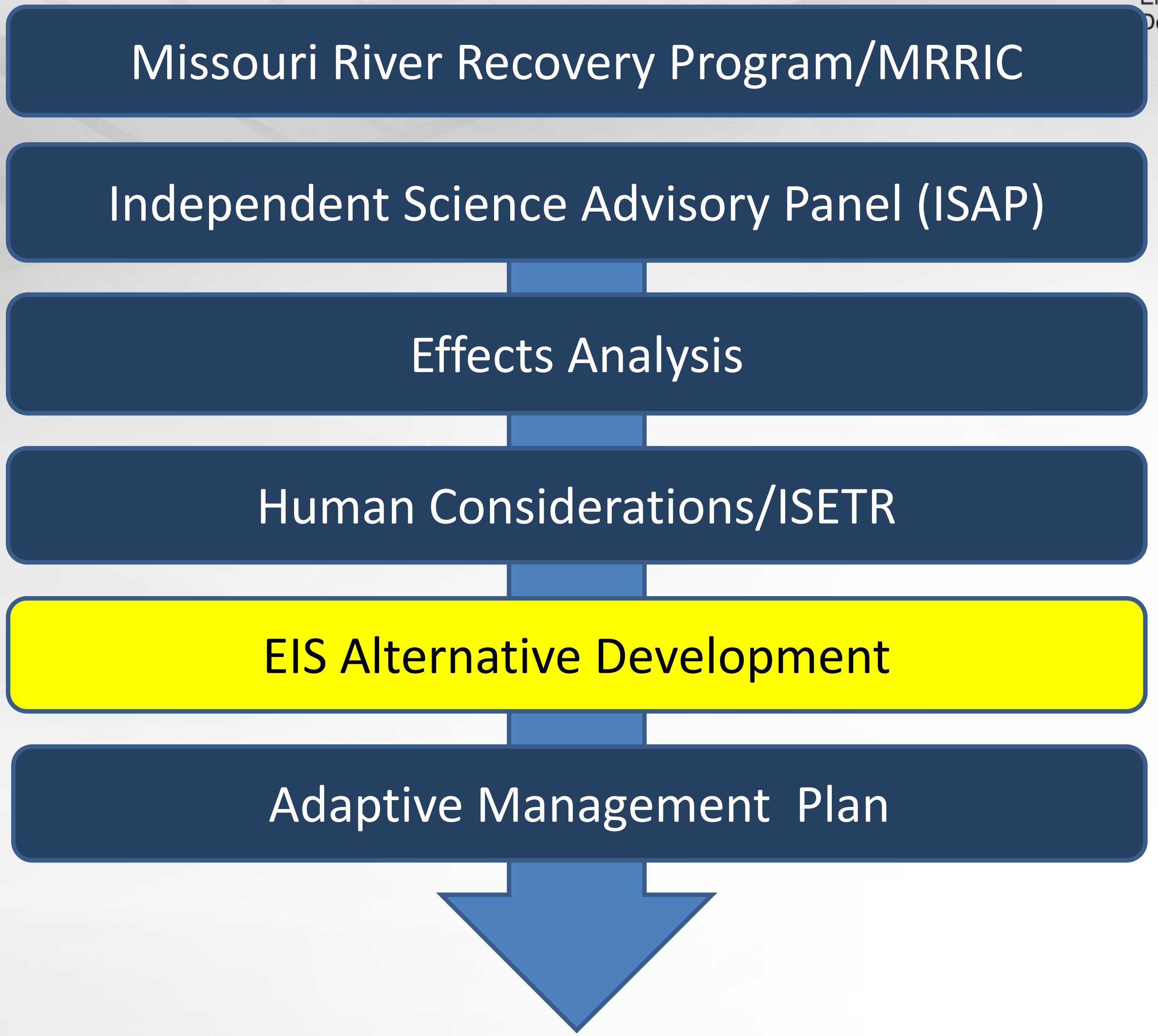
ISETR Engagement

- MRRIC selection of 3 national experts in:
  - Resource Economics
  - Social Science
  - Mathematics and Quantitative Modeling
- Evaluated HC Methods/Models document- Sept 2014 & Reviewed USACE Alternative Development process with MRRIC- 2015

Consultation with Tribes Under Executive Order 13175 (2009)

- Direct engagements to fulfill Trust Responsibilities
- Tribal Working Group for MRRIC

ERDC
Engineer Research and Development Center



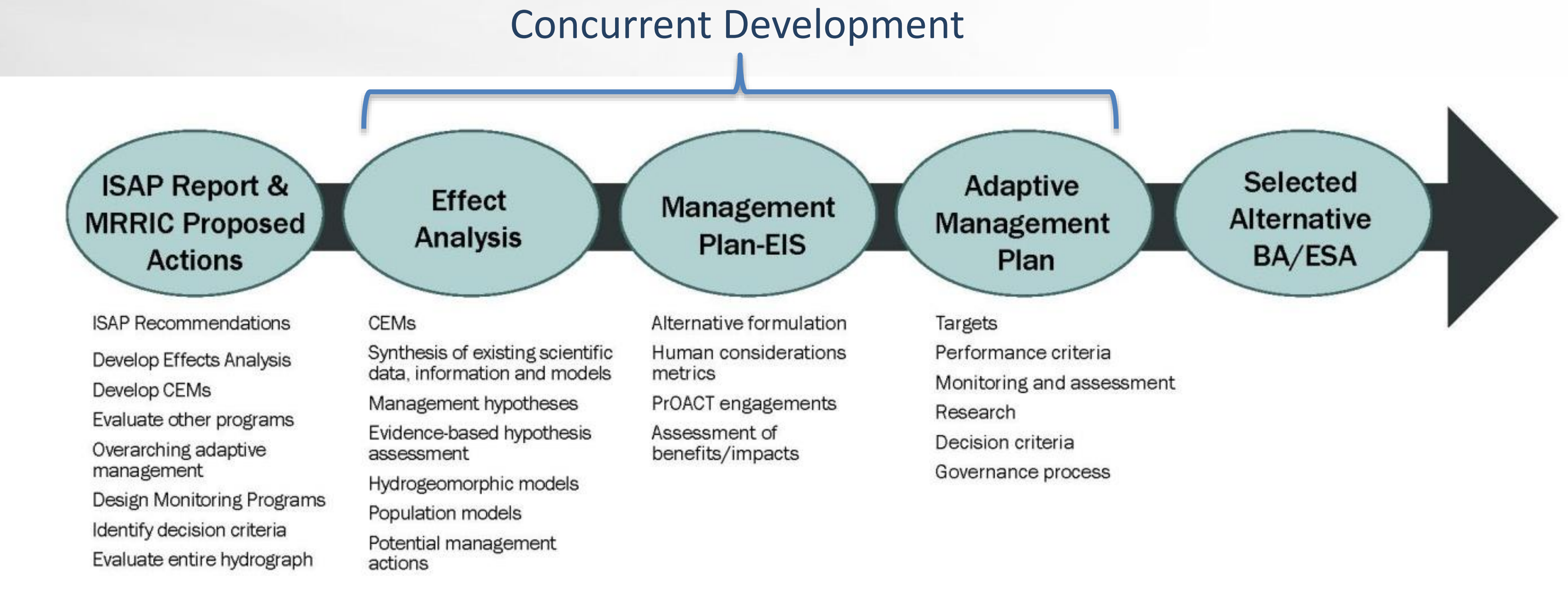
Management Plan EIS

Engineer Research and Development Center

Problem Statement:

Develop a management plan that includes a suite of actions that removes or precludes jeopardy status for the piping plover, interior least tern, and pallid sturgeon, and that

- *Complies with the authorization requirements from Section 601(a) of WRDA 1986, as modified by Section 334(a) of WRDA 1999, and further modified by Section 3176 of WRDA 2007.*
- *Continues to serve the Missouri River authorized purposes and accounts for human considerations; and*
- *Includes an EIS and establishes an AM process for implementing the preferred alternative.*



Pallid Sturgeon Framework

ERDC
Engineer Research and Development Center

- Provides an organizational framework for actions
- Utilizes adaptive management as an essential component
- Incorporates a phased implementation over a reasonable timeframe

Time

Level 1: Research	Population Level Biological Response IS NOT Expected	Studies without changes to the system (laboratory studies or field studies under ambient conditions)
Level 2: In-river Testing		Implementation of actions at a level sufficient to expect a measurable biological, behavioral, or physiological response in pallid sturgeon, surrogate species, or related habitat response.
Level 3: Scaled Implementation	Population Level Biological Response IS Expected	In terms of reproduction, numbers, or distribution, initial implementation should occur at a level sufficient to expect a meaningful population response progressing to implementation at levels that result in improvements in the population. The range of actions within this level is not expected to achieve full success (i.e., Level 4).
Level 4: Ultimate Required Scale of Implementation		Implementation to the ultimate level required to remove as a limiting factor.

Management Plan Objectives

ERDC
Engineer Research and Development Center

Piping Plover Fundamental Objective: Avoid jeopardizing the continued existence of the piping plover due to USACE actions on the Missouri River.

- **Sub-Objective 1 (Distribution)**: Maintain a geographic distribution of piping plovers in the river and reservoirs in which they currently occur in both the Northern and Southern River Regions.
  - **Means Objective:** Meet sub-objectives 2, 3, and 4 in both the Northern and Southern Regions.
- **Sub-Objective 2 (Population)**: Maintain a population of Missouri River piping plovers with a modeled 95 percent probability that at least 50 individuals will persist for at least 50 years in both the Northern and Southern Regions.
  - **Means Objective (ESH)**: Provide sufficient ESH (in-channel riverine habitat) on the Missouri River to meet the persistence target.
  - **Metric**: Number of standardized and available ESH acres measured annually.
  - **Target**: Targets are shown in Table 1-1.
  - **Timeframe**: Median standardized ESH targets (450 acres in the Northern Region; 1,180 acres in the Southern Region) must be met for 3 out of 4 years. Median available acres must be met or exceeded for the specified percent of years over a running 12-year interval.

Management Plan Objectives

ERDC
Engineer Research and Development Center

- **Sub-Objective 3 (Population Dynamics)**: Maintain a stable or increasing long-term trend in population size in both regions.
  - **Metric**: Population growth rate (lambda; λ): the ratio of population size *N* between the current year and previous year (*Nt/Nt-1*); calculated annually.
  - **Target**: λ ≥ 1 (a growth rate greater than or equal to 1).
  - **Timeframe**: The growth rate target must be met as a 3-year running geometric mean calculated as the cube root of the product of the growth rates for each of the 3 years (i.e., (λ1* λ2* λ3)1/3).
- **Sub-Objective 4 (Reproduction)**: Maintain fledgling production by breeding pairs sufficient to meet the population growth rate objectives within both the Northern and Southern Regions on the Missouri River.
  - **Metric**: Fledge Ratio: Number of fledglings observed/(number of breeding adults/2), calculated annually.
  - **Target**: ≥ 1.14 chicks fledged per breeding pair.
  - **Timeframe**: The fledge ratio target met as a 3-year running arithmetic mean.

		Acres of Emergent Sandbar Habitat					
		Northern Region			Southern Region		
		2.5%ile	Median	97.5%ile	2.5%ile	Median	97.5%ile
Standardized ESH Acres		190	450	2160	330	1180	4720
Available ESH Acres Exceeded for Percentage of Years	75%	170	270	555	300	430	720
	50%	420	680	1295	500	740	1550
	25%	960	1920	2670	750	1410	3075
	10%	1965	3000	5165	1125	2240	4945

Pallid Sturgeon Objectives & Metrics

MRRP Goal: develop a suite of actions that meets ESA responsibilities for pallid sturgeon (PS), while continuing to operate the Missouri River System to meet its authorized purposes

FWS Fundamental Objective for Pallid Sturgeon: Avoid jeopardizing the continued existence of the pallid sturgeon from the USACE actions on the Missouri River.

Sub-objective 1: *Increase pallid sturgeon recruitment to age 1.*

- **Metric_1.1:** catch rates of naturally produced age 0 and age 1 PS
- **Metric_1.2:** model-based estimates of abundance of naturally produced age 0 and age 1 PS using data for age 0-4 fish
- **Metric_1.3:** model-based estimates of survival of naturally produced PS to age 1, using data for age 0-4 fish
- **Target:** measurable recruitment to age 1

Sub-objective 2: *Maintain or increase numbers of pallid sturgeon as an interim measure until sufficient and sustained natural recruitment occurs.*

- **Metric_2.1:** population estimates for PS by size class, age (particularly ages 2 to 3) and origin
- **Metric_2.2:** catch rates of all PS by size class and origin (to maintain legacy data)
- **Target:** TBD. Possible targets: 1) $\lambda > 1$ for PS age 2 and older; 2) survival rates of all size/age classes sufficient to provide stable population of PS age 2 and older; 3) acceptable probabilities of persistence and recovery (> 0.95) over 50 years (utilizing population models); and 4) > 5000 self-sustaining, genetically diverse PS in each adult population unit.

Management Actions & Alternatives

ERDC
Engineer Research and Development Center

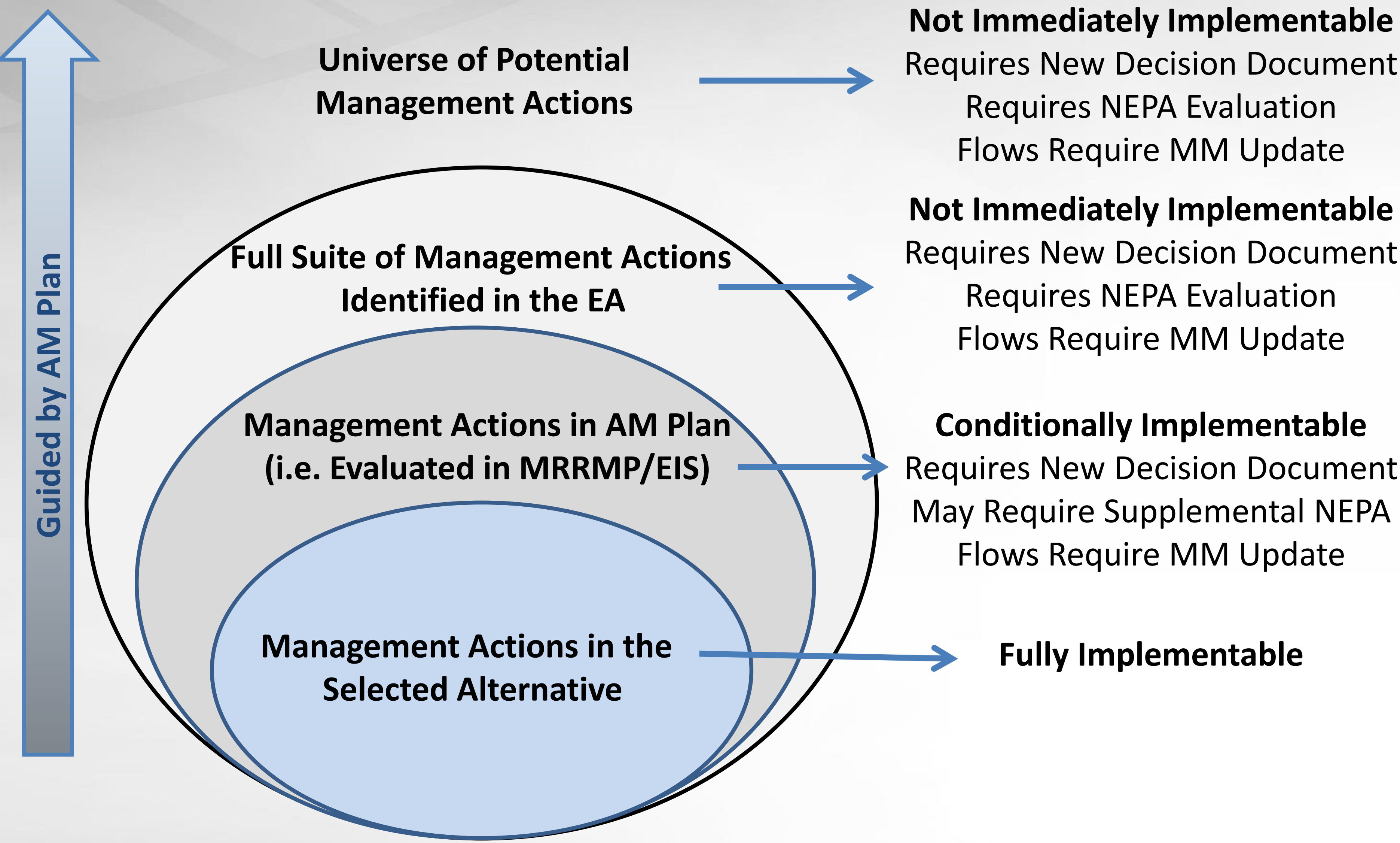
Management Actions	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Least Tern and Piping Plover						
Mechanical ESH Construction	X	X	X	X	X	X
Vegetation Management	X	X	X	X	X	X
Predator Management	X	X	X	X	X	X
Human Restriction Measures	X	X	X	X	X	X
Flow Management to Reduce Take	X	X	X	X	X	X
Spring Habitat-Creating Flow Release				X		
Fall Habitat-Creating Flow Release					X	
Monitoring and Research	X	X	X	X	X	X
Pallid Sturgeon (both Upper and Lower River)						
Propagation and Augmentation	X	X	X	X	X	X
Pallid Sturgeon Population Assessment Project	X	X	X	X	X	X
Level 1 and 2* Studies			X	X	X	X
Pallid Sturgeon: Upper River						
Monitoring and evaluation related to recruitment	X	X	X	X	X	X
Pallid Sturgeon: Lower River						
Spawning Habitat Construction			X	X	X	X
Early Life Stage Habitat Construction	X (SWH)	X (SWH)	X (IRC)	X (IRC)	X (IRC)	X (IRC)
Spawning Cue Release	X	X				X
Low Summer Flow		X				
Floodplain Connectivity		X				
Habitat Development and Land Management on MRRP Lands	X	X	X	X	X	X

Source: USFWS 2003

* Note that some Level 2 studies would require additional NEPA compliance beyond the scope of this EIS.

Scope of Actions in AM Plan relative to EIS & Preferred Alt

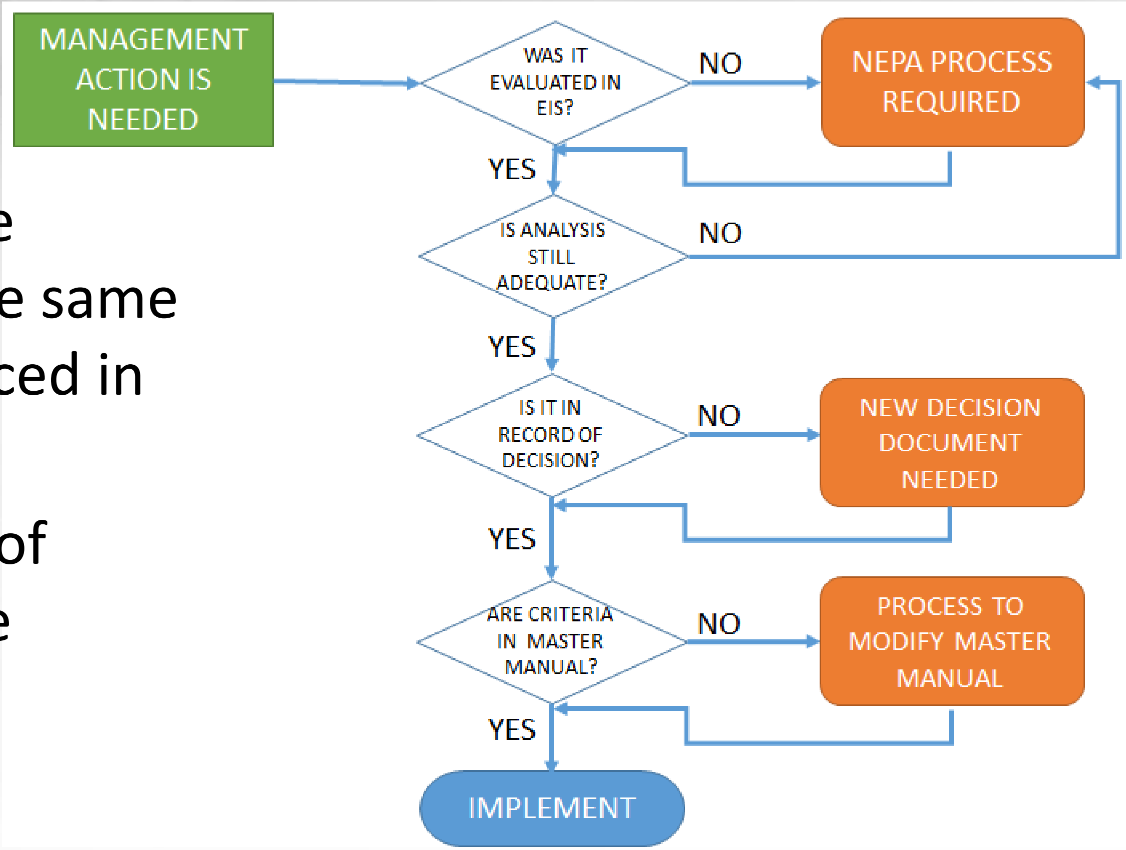
ERDC
Engineer Research and Development Center

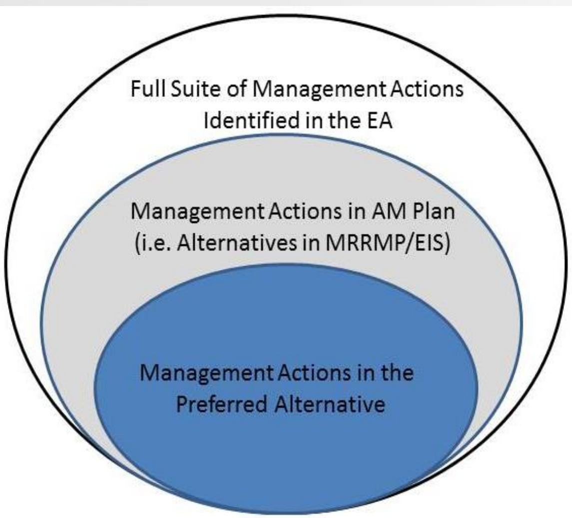


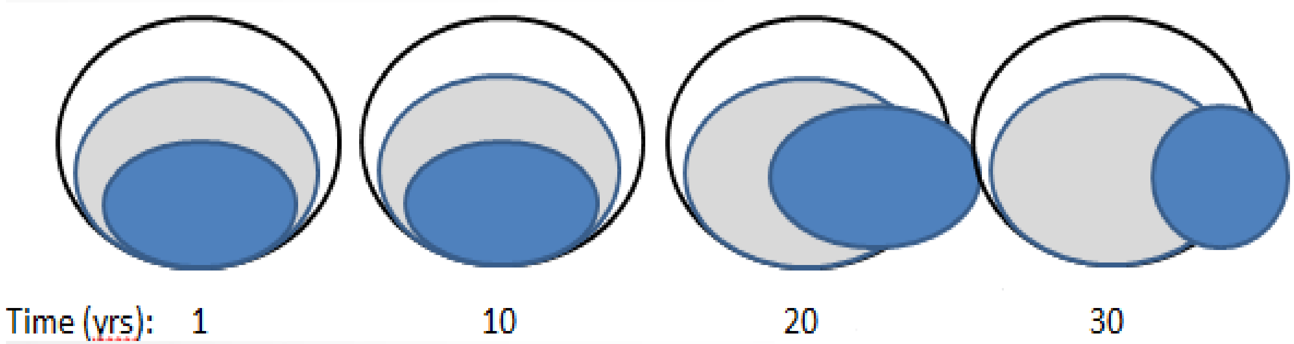
Requirements for Action Implementation

Issues:

- Scope of actions in the preferred alt aren't the same as the actions referenced in the AM Plan
- Under AM, the scope of actions COULD change







Missouri River Recovery Program

Independent Science Advisory Panel (ISAP)

Effects Analysis

Human Considerations

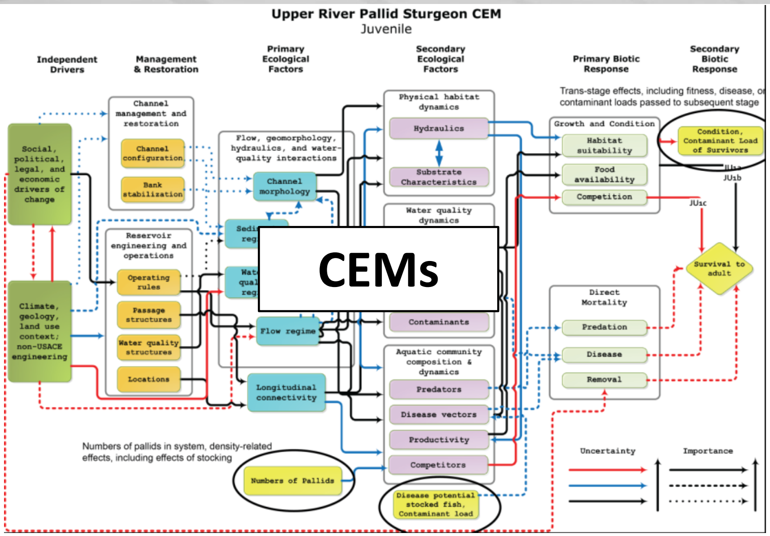
EIS Alternative Development

Adaptive Management Plan

Adaptive Management Plan

- Developed concurrently with MRRMP-EIS
- Four draft versions shared with stakeholders and/or ISAP
- Organization
  - Ch1 – Executive Summary
  - Ch2 – Governance
  - Ch3 – Birds
  - Ch4 – Fish
  - Ch5 – Human Considerations
  - Ch7 – Data & Communications
- Monitoring Plans in Appendices
- 540/680 pgs, respectively

Science Foundation



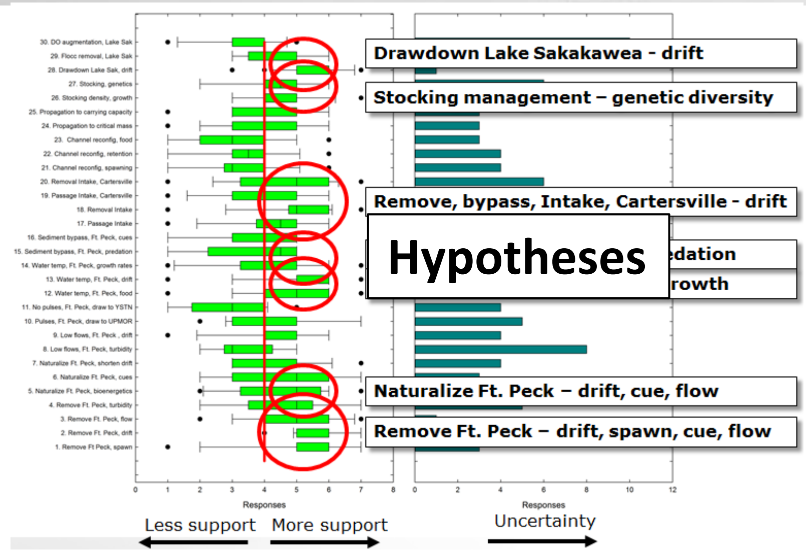


Table 4. Summary of time limits for level 3 implementation and scope of actions.

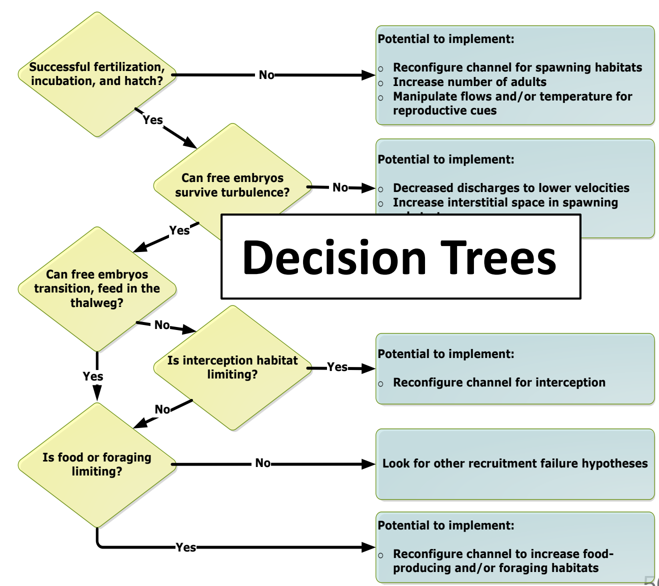
Action Category	Time Limit*	Minimum Scope	Maximum Scope
Population augmentation	Immediate	Current avg. stocking rate	Variable over time
IRC habitat development	2 years	Add 260K ac-d/yr	Add 500k ac-day/yr
Spawning habitat	2 years*	3 spawning sites	See decision tree**
Spawning cue flows			d to be 1 in 3 years num and maximum be developed and informed by population models and impact assessments***

Targets & Decision Criteria

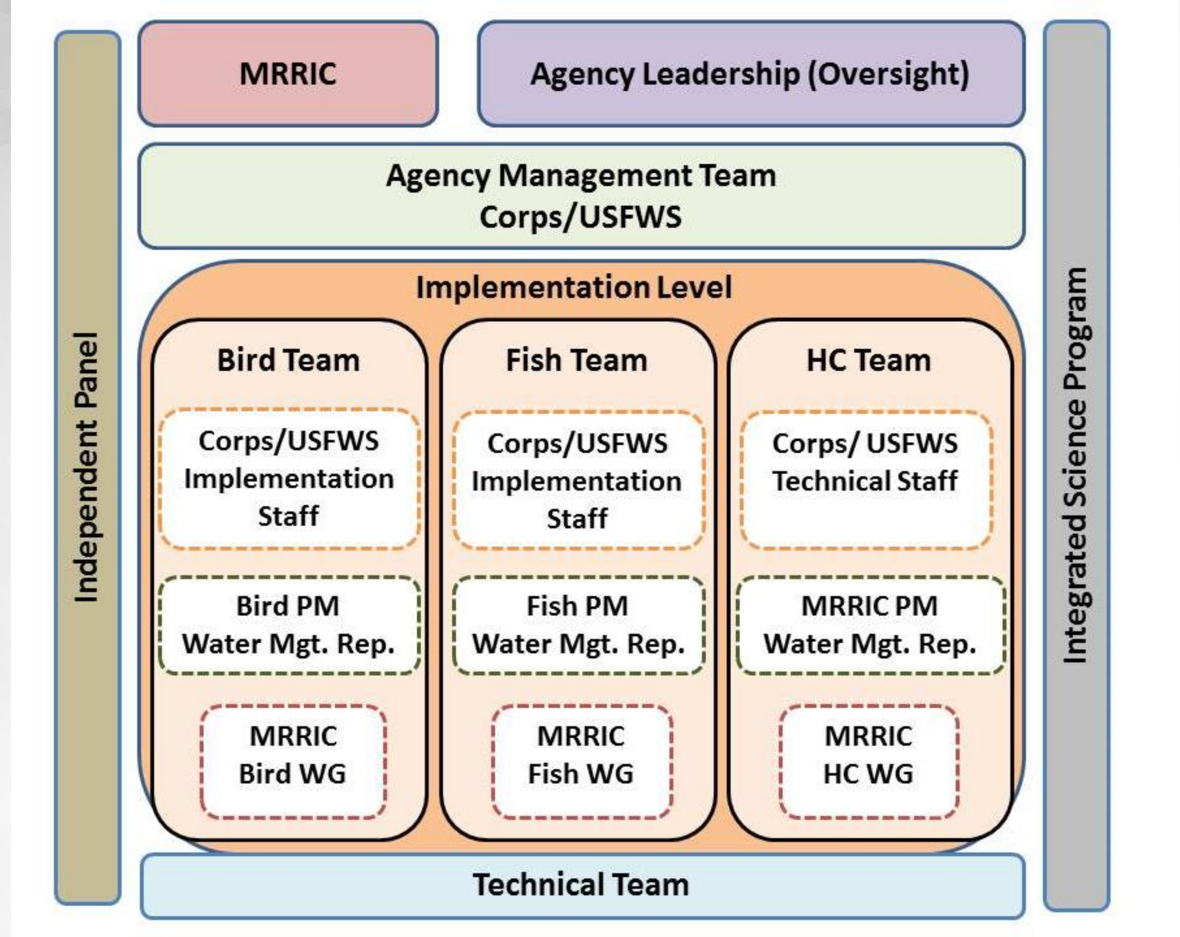
* Anticipated as Level 2 pilot projects focused on developing and evaluating high-quality spawning habitat.

** Spawning habitat implementation will be guided by the decision tree and associated decision criteria as described in the section below on spawning habitat.

*** Pallid population modeling will be used to set minimum spawning flow needs; bird impacts and status may inform decisions regarding spawning cue flows below Gavins Point Dam in any particular year.

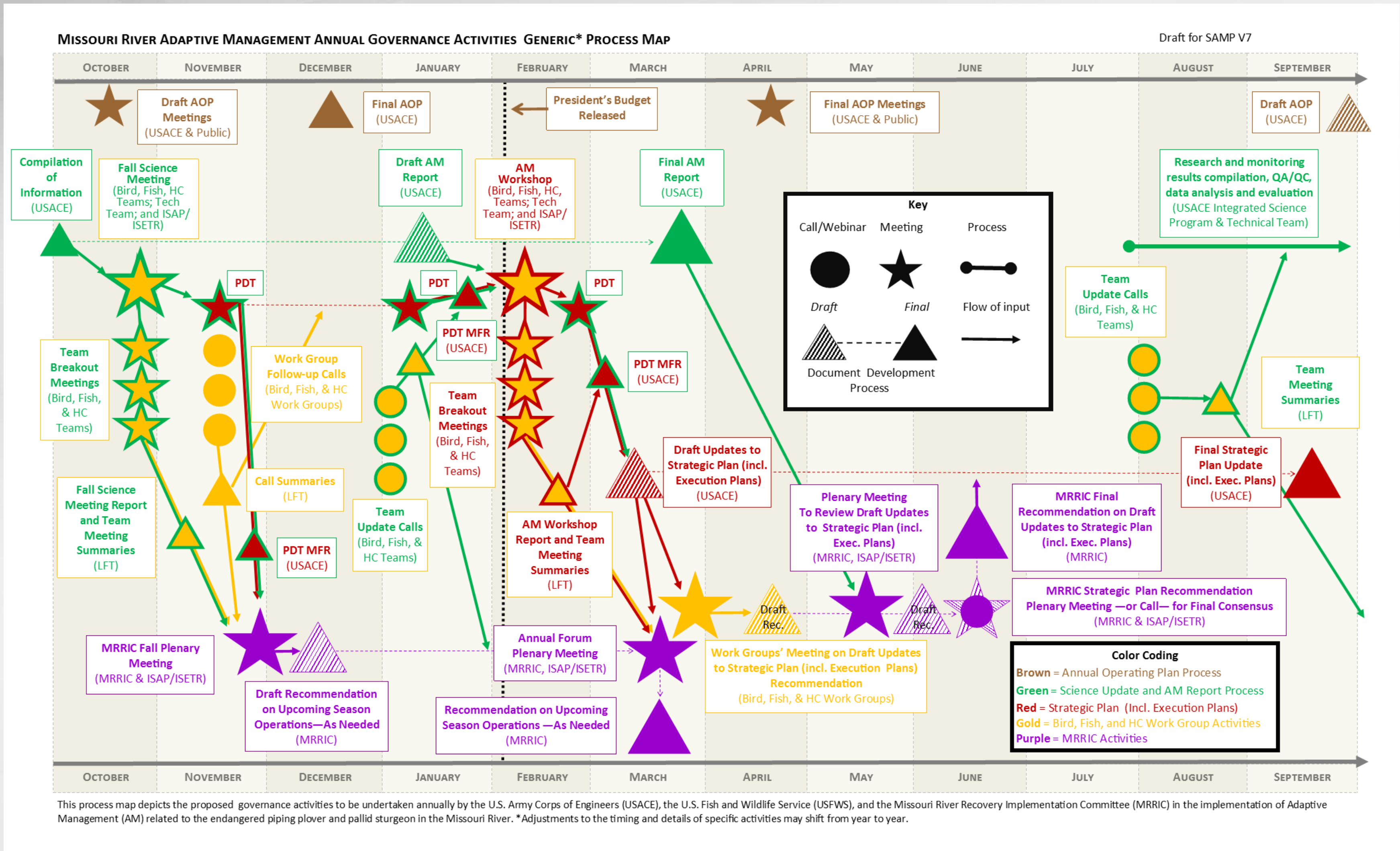


Governance Structure: Working Level

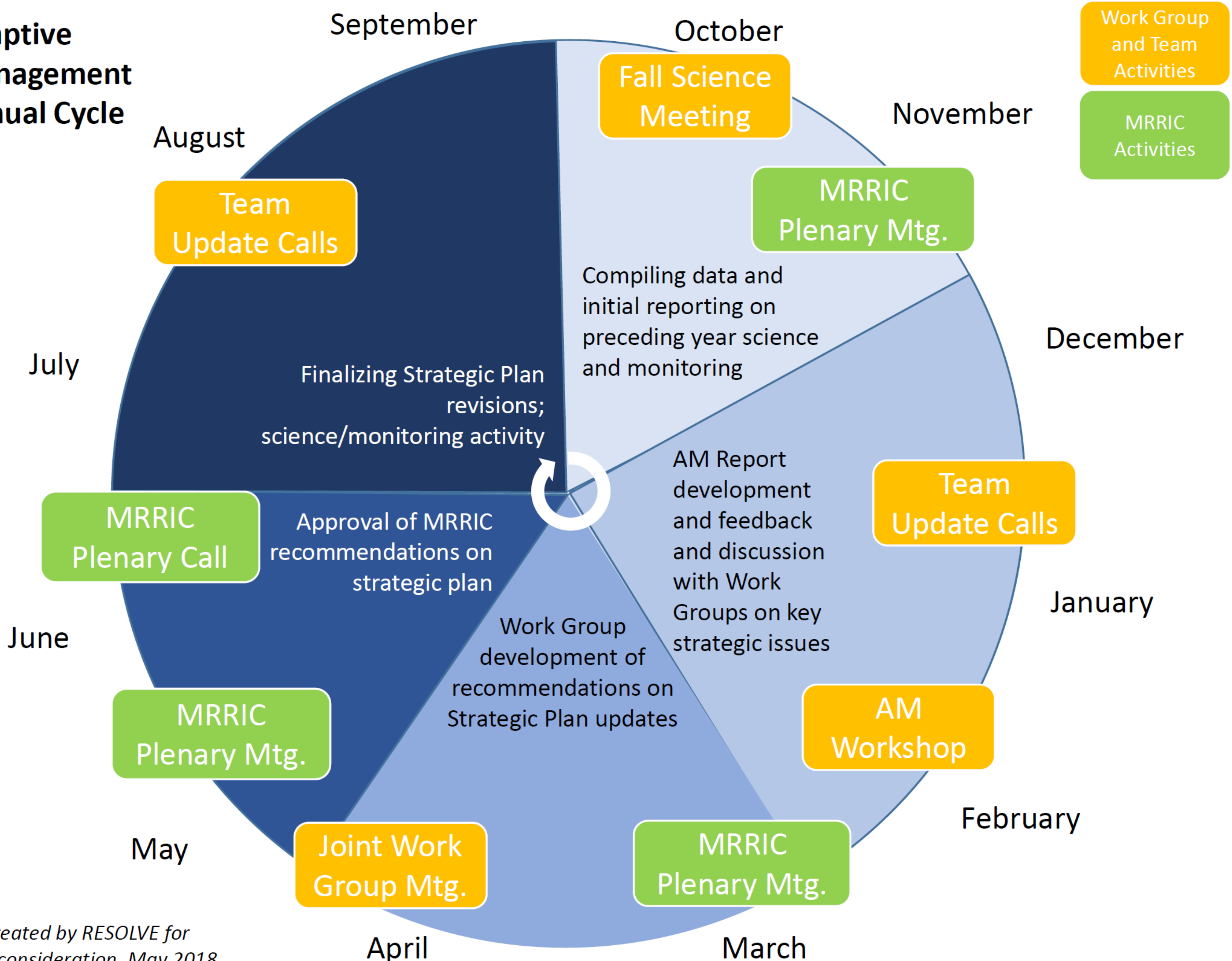


Communication and collaboration among scientists, managers and stakeholders

Engineer Research and Development Center



Adaptive Management Annual Cycle



Draft created by RESOLVE for MRRIC consideration, May 2018

Pallid sturgeon research, monitoring, and evaluation

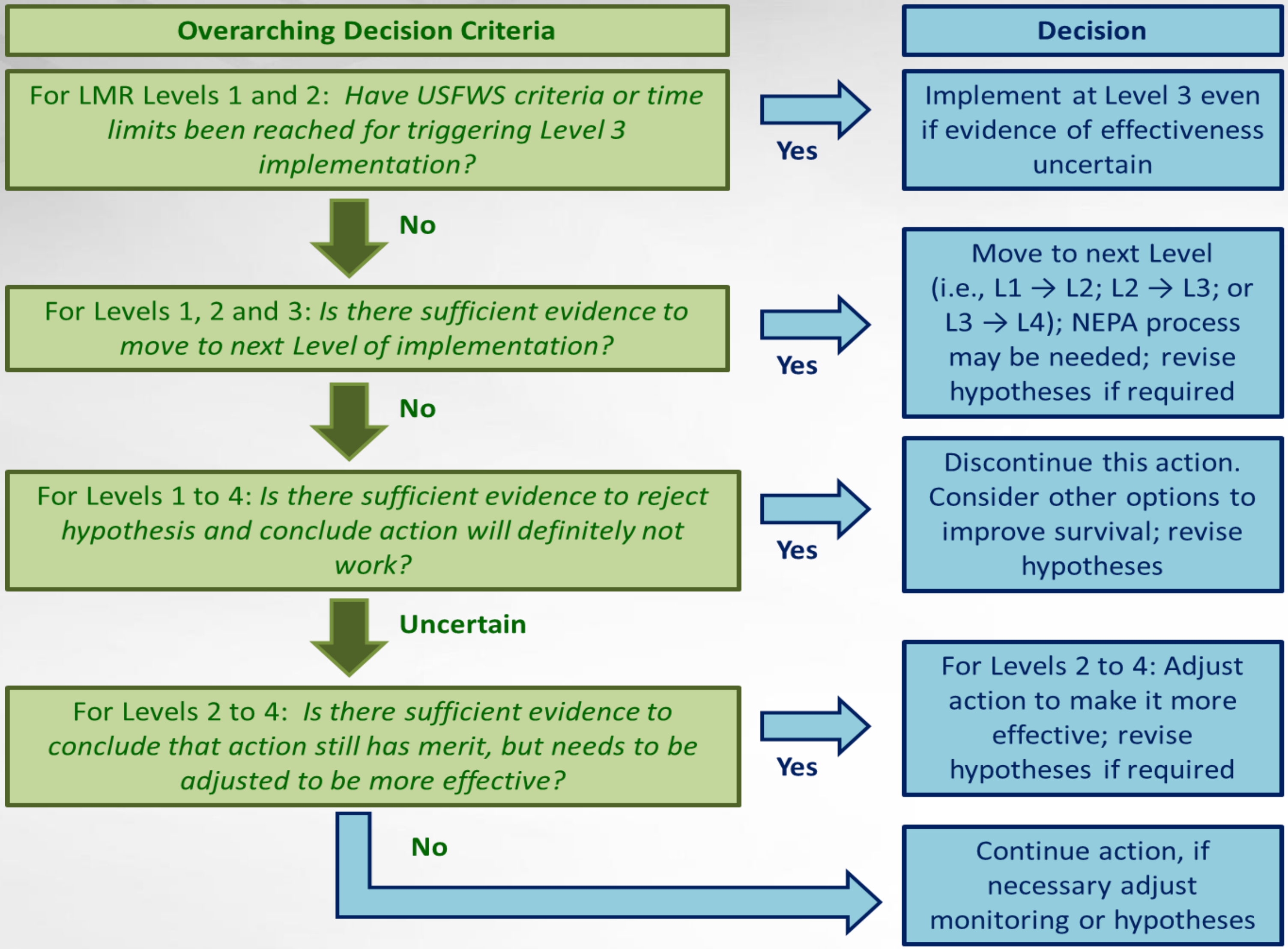
- **EA process yields 21 action hypotheses**
- **Recognize 4 levels of implementation:**
  - **Level 1**: foundational science
  - **Level 2**: field experimentation
  - **Level 3**: initial implementation -> population response
  - **Level 4**: full implementation
- **Science components address level 1 and level 2**
  - 74 components, 2016 – 2032
- **Levels 2-4: Hypothesis-driven monitoring (piloting updated concepts of channel reconfigurations:**
  - <u>Implementation</u> – action completed?
  - <u>Process, action effectiveness</u> – ecological response?
  - <u>Population</u> –growing, attaining the right size?

Pallid Sturgeon Decisions

Engineer Research and Development Center

- Find the right balance between science at Levels 1, 2 and 3 to improve understanding and actions at Levels 2, 3 and 4 to benefit sturgeon
- Guide the evaluation of multiple lines of evidence on priority hypotheses and the effectiveness of actions
- Guide decisions to move from L1 -> L2 -> L3 -> L4 in a logical sequence, or to adjust L3 / L4 actions
- Clarify trade-offs across multiple factors to make better decisions
- Provide a clear timetable for implementing L2 / L3 / L4 actions to help sturgeon, accelerate learning and motivate planning
- Evaluate progress towards meeting species sub-objectives and targets
- Reduce likelihood of adverse impacts to HC; facilitate rapid decisions

Overall decision tree

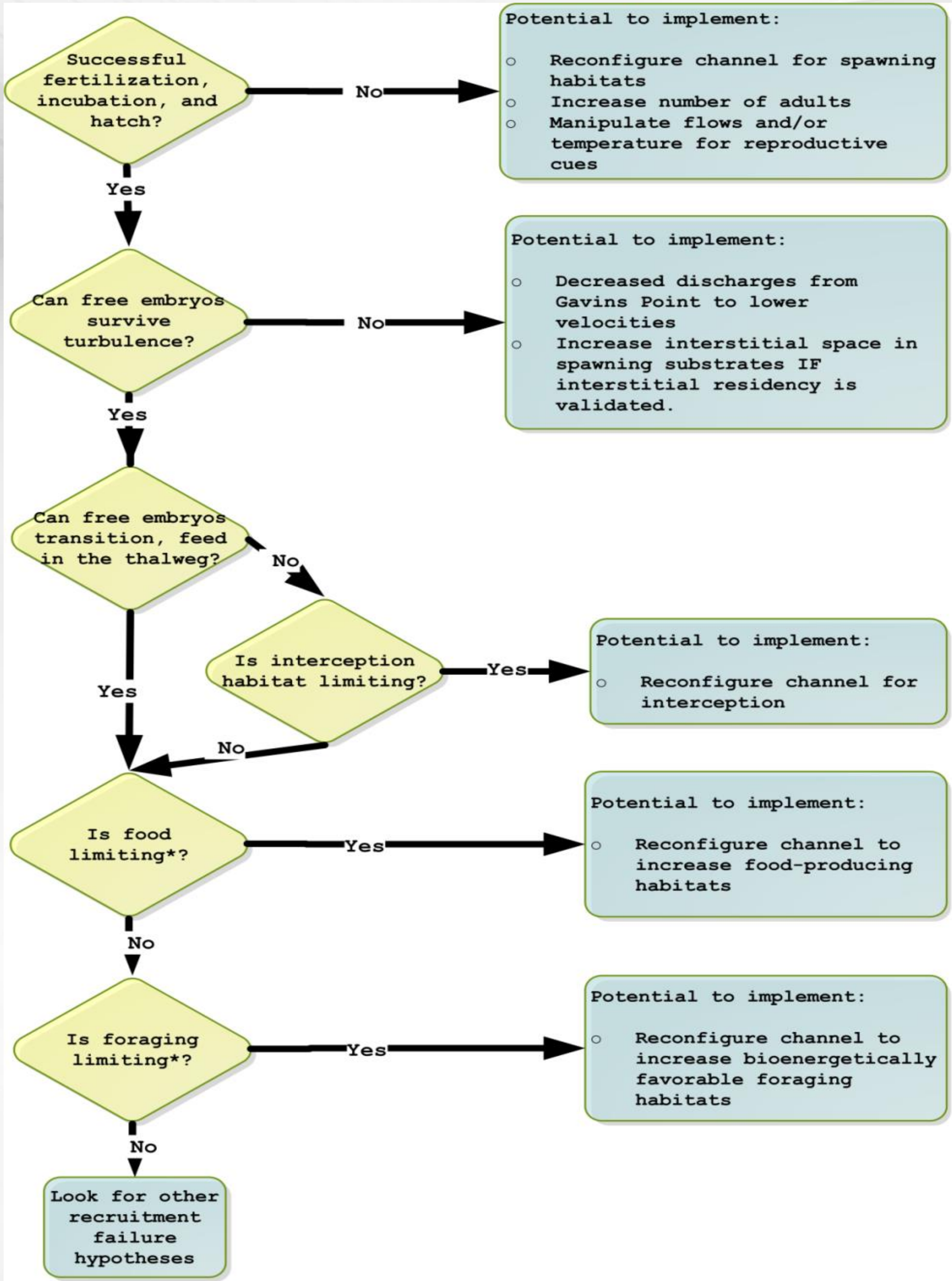


Decision Criteria for Moving from Level 2 to Level 3 (Table 22)

	Question	Y	U	N
1	Is this factor limiting pallid sturgeon reproductive and/or recruitment success?			
2	Are pallid sturgeon needs sufficiently understood with respect to this limiting factor?			
3	Do one or more management action(s) exist that could, in theory, address these needs?			
4	Has it been demonstrated that at least one kind of management action has a sufficient probability of satisfying the biological need?			
5	Have other biological, legal, and socioeconomic considerations been sufficiently addressed to determine whether or how to implement management actions to Level 3?			

Decision Criteria for Level 3 implementation
1 - A "Yes" to all five questions triggers Level 3 implementation
2 - A "Yes" to four of five, with an "Uncertain" for either #1 or #2 triggers a two-year clock to either reject the hypothesis or implement at Level 3

Simplified decision tree for Lower Missouri River



IRCs

esearch and
nt Center

Time Limits for L3 Actions Set by USFWS

ERDC
Engineer Research and Development Center

Action Category	Time Limit*	Minimum Scope	Maximum Scope
Population augmentation	Immediate	Current stocking rate as directed by USFWS Basin-wide Stocking and Augmentation Plan	Variable over time as directed by USFWS Basin-wide Stocking and Augmentation Plan
IRC habitat development	Stage 1: study phase (years 1-3 post-ROD)	Build 2 IRC sites per year (paired with control sites), adding 33,000 ac-d/yr of suitable habitat, using staircase design[1]. Assess potential for refurbishing existing SWH sites as IRCs	
	Stage 2 – continue study phase (years 4-6 post-ROD)	Build 2 IRC sites per year (paired with control sites), adding 33,000 ac-d/yr[1] of suitable habitat. Refurbish SWH sites in addition to study sites (rate TBD).	
	Stage 3 - Level 3 implementation (years 7-10 post-ROD)	Continue assessing IRC sites and refurbishing new SWH sites, adding at least 66,000 ac-d/yr[1] of suitable habitat. Determine required rate of Level 3 implementation based on stages 1 and 2.	
	Stage 4 – Level 4 implementation	Remove IRC habitat limitations to pallid sturgeon survival by implementation at Level 4.	
Spawning habitat[2]	2 years	1 spawning site	See decision tree in Figure 77
Spawning cue flows	9 years	Requirement for spawning cue flows (and appropriate scope) depends on the outcome of Level 1 and Level 2 monitoring and modeling studies during years 1-9. [3]	

Engineer Research and Development Center

Interception & Rearing Complex Timeline

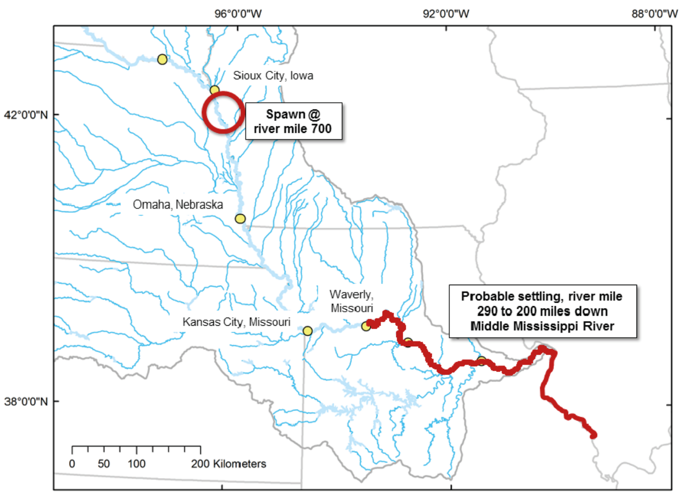


Figure 3. Geography of drift and dispersal. Presently available models indicate that a free embryo hatched at river mile 700 is likely to settle between river mile 290 on the Missouri River and 200 miles down the Middle Mississippi River.

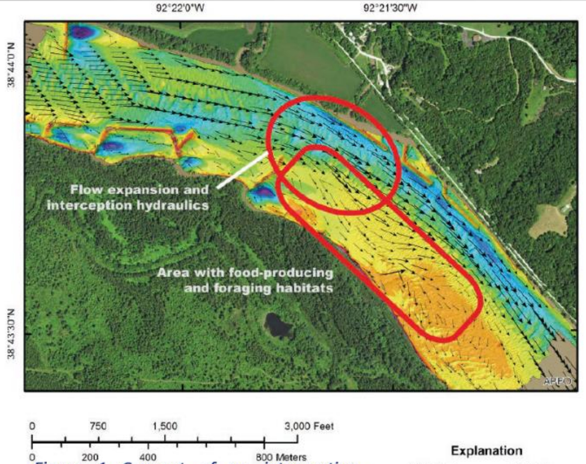
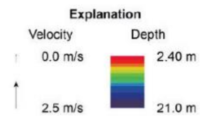


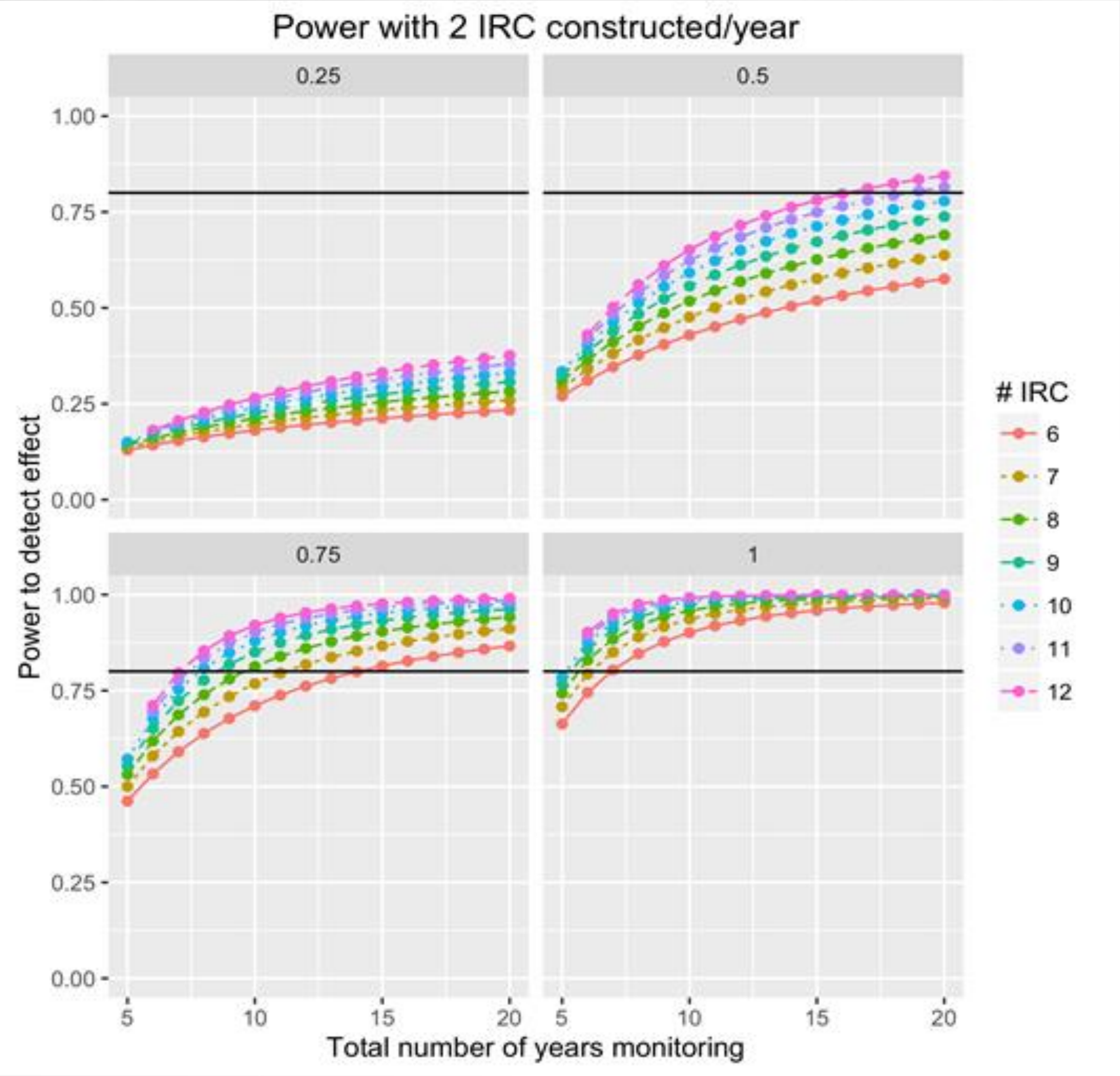
Figure 1 Concept of an interception-rearing complex near river mile 162. Flow expansion is shown by modeled current velocity and direction (arrows) angled away from the main channel towards the right descending bank.



Interception / Rearing Habitat	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Level 1																	
C1 Screening: limitations of food or forage habitats																	
C2 Tech. dev. For IRC sampling, modeling, measurement																	
C3 Field studies along gradients, food and forage habitats																	
C4 Mesocosm studies: quantitative habitat – survival	Contingent upon outcome of C3																
Level 2																	
C5 Design studies for IRC experiments	Design IRCs and SWH refurbishment; iteratively adjust designs																
C6 Field expts. with IRCs and SWH (stages 1 and 2)		Implement IRC staircase design & SWH refurbishment															
Level 3																	
Implement more IRCs if found to be successful (stage 3)																	

Power analysis evaluated ability to detect various increases in catch / effort (CPUE) over various time frames

<u>Bottom line</u>: *Can detect 75% increase in CPUE over 7-year period with 12 treatment-control pairs, building 2 sites per year.*



Staircase design for implementation of IRCs [2 paired sites / year over 7 years]

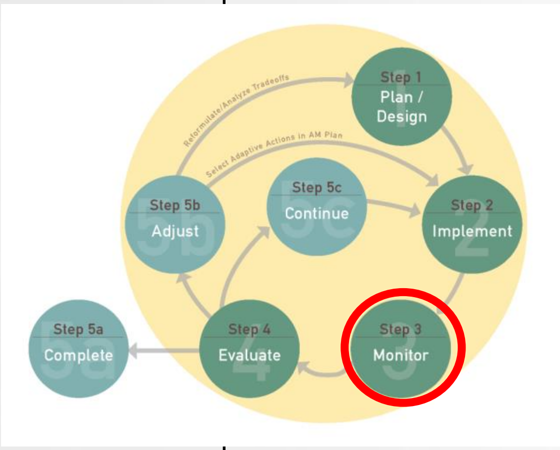
Site/Year	1	2	3	4	5	6	7	8
01	X	X	X	X	X	X	X	X
01 CT	X	X	X	X	X	X	X	X
02	X	X	X	X	X	X	X	X
02 CT	X	X	X	X	X	X	X	X
03		X	X	X	X	X	X	X
03 CT		X	X	X	X	X	X	X
04		X	X	X	X	X	X	X
04 CT		X	X	X	X	X	X	X
05			X	X	X	X	X	X
05 CT			X	X	X	X	X	X
06			X	X	X	X	X	X
06 CT			X	X	X	X	X	X
07				X	X	X	X	X
07 CT				X	X	X	X	X
08				X	X	X	X	X
08 CT				X	X	X	X	X
09					X	X	X	X
09 CT					X	X	X	X
10					X	X	X	X
10 CT					X	X	X	X
11						X	X	X
11 CT						X	X	X
12						X	X	X
12 CT						X	X	X

Initiation of Construction X

ERDC
Engineer Research and Development Center

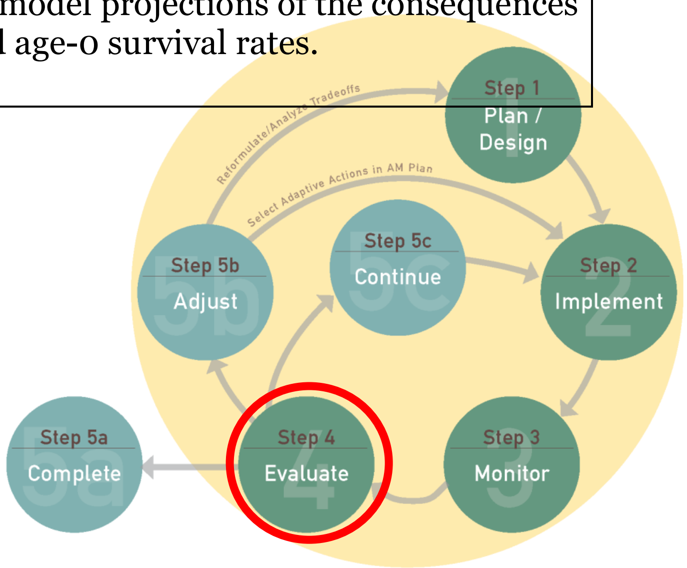
Monitoring IRCs

Level 2 / 3 Action	Implementation monitoring	Process monitoring	Population monitoring / modeling
IRC Habitat [H17, H18, H19] Metrics: sections 4.2.6.3.5 and 4.2.6.4.5	- “effective acreage” (acre-days of available IRC habitat/year)	- habitat metrics based on measures of depths, velocities, substrate, habitat complexity - trends in % SWH area with suitable habitat after refurbishment to IRCs - CPUE and Pr (apparent presence) at meso-habitat and project level; - production of food/area - fish condition (% empty/full stomachs; genetics; lipid content; length frequency distribution of age-0 fish) and bioenergetics modeling	- survival of hatchery-reared first-feeding pallid sturgeon larvae in IRCs, refurbished SWH, thalweg, and to age 1 - population size structure analysis (length-frequency distributions of age-1+ fish)



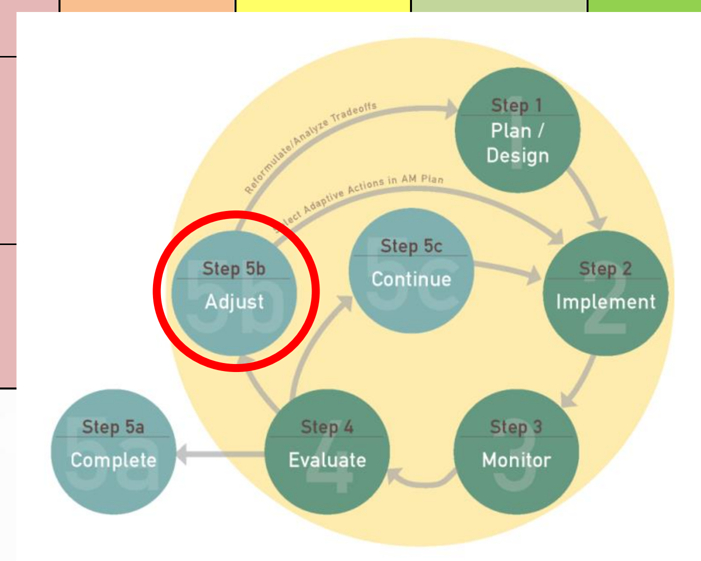
Evaluation Methods / Decision Criteria for IRCs

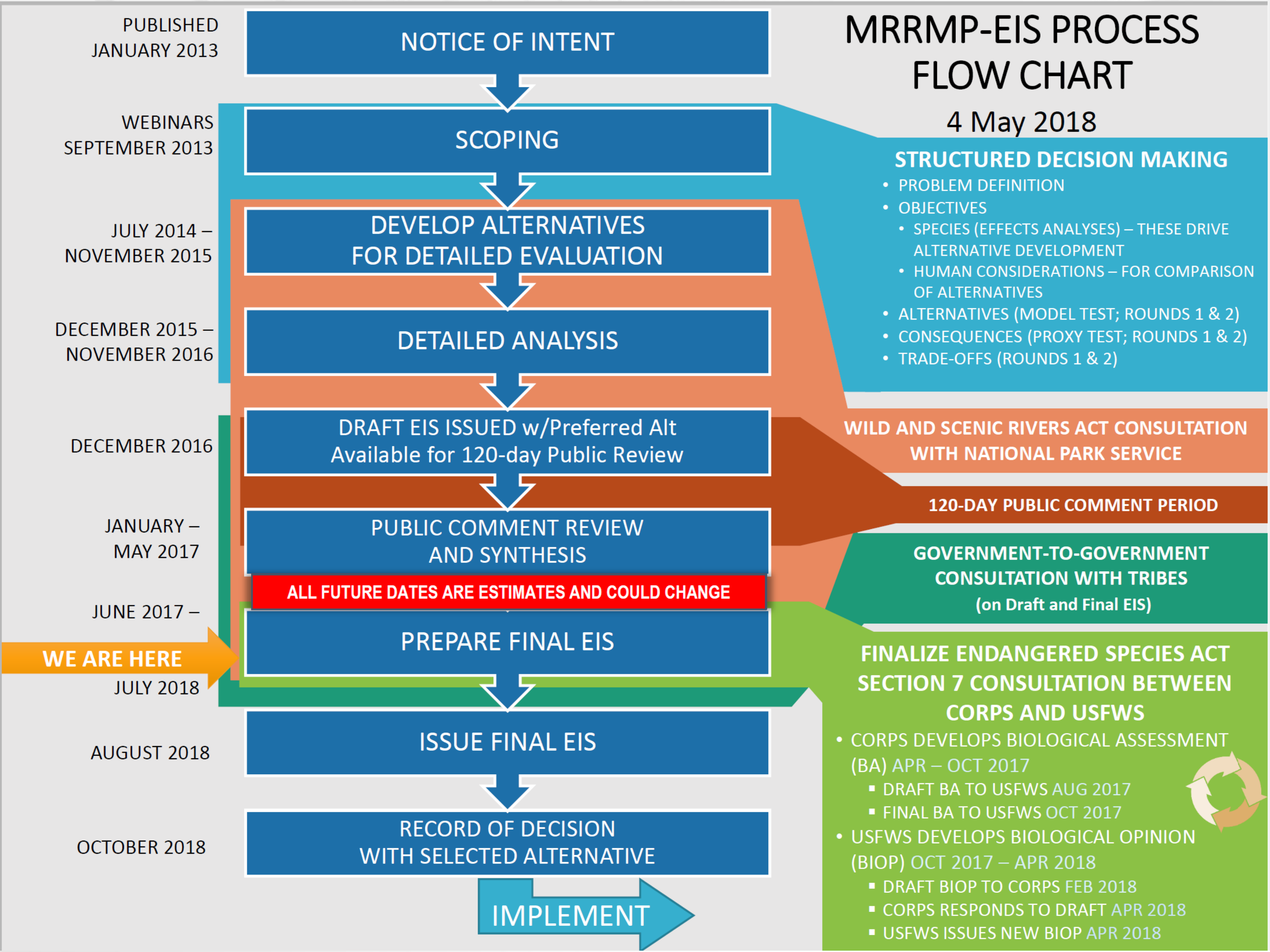
Action	Question [Level, Location]	Methods of evaluating action effectiveness
Interception and Rearing Complexes (IRCs) [H17, H18, H19]	Do free embryos and exogenously feeding larvae leave the thalweg and enter IRCs? [L3, Lower]	Predicted fate of free embryos from advection/ dispersion models. Testing of these predictions with field monitoring (see below).
	Is there sufficient food in IRCs for exogenously feeding larvae to grow better and maintain a healthier condition than reference areas and times? [L3, Lower] Do age-0 fish that occupy IRCs survive better than age-0 fish in reference areas and times? [L3, Lower]	Before-After (BA), Before-After-Control-Impact (BACI) or Staircase design comparisons of IRC habitat sites with reference areas and times, using the metrics listed in section 4.4 (e.g., CPUE, probability of apparent presence, food production/area, condition, growth and survival of age-0 fish), and applying covariates to help explain year to year variation (e.g., index of upstream spawning success).
	What's the population-level effect of improved survival of age-0 fish in IRCs? [L3, Lower]	Population model projections of the consequences of improved age-0 survival rates.



Decision Criteria at Level 3 for IRCs

Level 2 / 3 Action [Hypothesis]	Decision Criteria / Questions	Answers				
		Clearly NO.	Likely NO.	Incon-clusive	Likely YES.	Clearly YES.
Interception and Rearing Complexes (IRCs) [H17, H18, H19]	Do free embryos and exogenously feeding larvae leave the thalweg and enter IRCs? [L3, Lower]					
	Is there sufficient food in IRCs for exogenously feeding larvae to grow better and maintain a healthier condition than reference areas and times? [L3, Lower]					
	Do age-0 fish that occupy IRCs have a higher survival probability than age-0 fish in reference areas and times? [L3, Lower]					
	What's the population-level effect of improved survival of age-0 fish in IRCs? [L3, Lower]					




MRRMP-EIS PROCESS FLOW CHART
4 May 2018
PUBLISHED JANUARY 2013
NOTICE OF INTENT
WEBINARS SEPTEMBER 2013
SCOPING
JULY 2014 – NOVEMBER 2015
DEVELOP ALTERNATIVES FOR DETAILED EVALUATION
DECEMBER 2015 – NOVEMBER 2016
DETAILED ANALYSIS
DECEMBER 2016
DRAFT EIS ISSUED w/Preferred Alt Available for 120-day Public Review
JANUARY – MAY 2017
PUBLIC COMMENT REVIEW AND SYNTHESIS
ALL FUTURE DATES ARE ESTIMATES AND COULD CHANGE
JUNE 2017 – JULY 2018
WE ARE HERE
PREPARE FINAL EIS
AUGUST 2018
ISSUE FINAL EIS
OCTOBER 2018
RECORD OF DECISION WITH SELECTED ALTERNATIVE
IMPLEMENT
STRUCTURED DECISION MAKING
• PROBLEM DEFINITION
• OBJECTIVES
• SPECIES (EFFECTS ANALYSES) – THESE DRIVE ALTERNATIVE DEVELOPMENT
• HUMAN CONSIDERATIONS – FOR COMPARISON OF ALTERNATIVES
• ALTERNATIVES (MODEL TEST; ROUNDS 1 & 2)
• CONSEQUENCES (PROXY TEST; ROUNDS 1 & 2)
• TRADE-OFFS (ROUNDS 1 & 2)
WILD AND SCENIC RIVERS ACT CONSULTATION WITH NATIONAL PARK SERVICE
120-DAY PUBLIC COMMENT PERIOD
GOVERNMENT-TO-GOVERNMENT CONSULTATION WITH TRIBES (on Draft and Final EIS)
FINALIZE ENDANGERED SPECIES ACT SECTION 7 CONSULTATION BETWEEN CORPS AND USFWS
• CORPS DEVELOPS BIOLOGICAL ASSESSMENT (BA) APR – OCT 2017
▪ DRAFT BA TO USFWS AUG 2017
▪ FINAL BA TO USFWS OCT 2017
• USFWS DEVELOPS BIOLOGICAL OPINION (BIOP) OCT 2017 – APR 2018
▪ DRAFT BIOP TO CORPS FEB 2018
▪ CORPS RESPONDS TO DRAFT APR 2018
▪ USFWS ISSUES NEW BIOP APR 2018

Ten Enabling Characteristics for Effective Adaptive Management

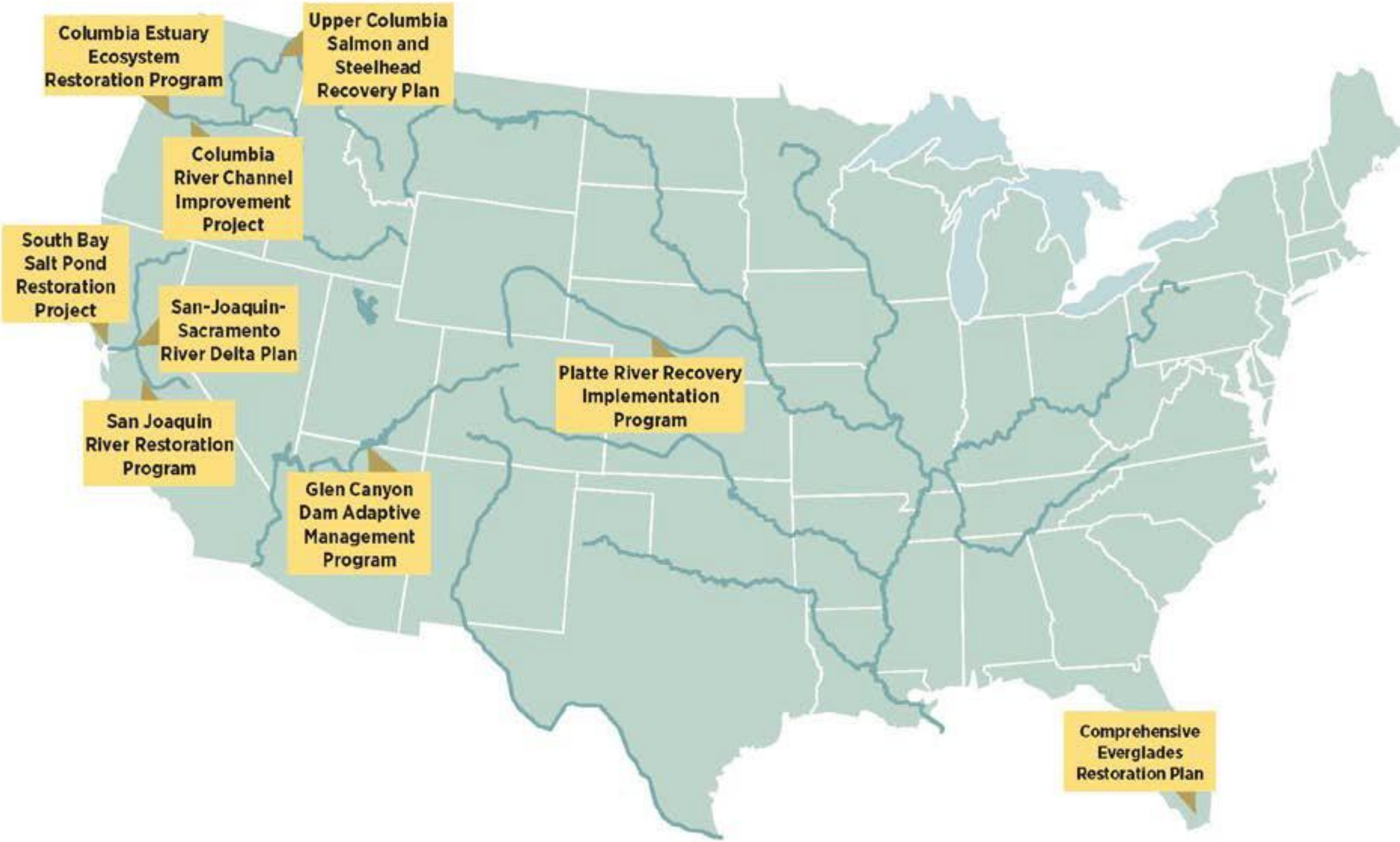
ERDC
Engineer Research and Development Center

1. Stakeholder engagement early and throughout
2. Clear articulation of objectives and program scope
3. Effects analysis to establish the best available science
4. Monitoring in an experimental framework
5. Identifying appropriate metrics and contingent decision criteria
6. Modeling to forecast outcomes from proposed management actions
7. Applying structured decision-making strategies to acknowledged trade-offs
8. Integrating human considerations into all aspects of risk assessment
9. Adaptive management governance structure and process
10. Independent scientific advice and review

Reserve Slides for Questions

- Following slides are not part of the presentation but are available to help address questions.

Lessons Learned Review



Key Take-Aways

ERDC
Engineer Research and Development Center

- **Role of AM –** The science and AM program must be integrated into how the overall recovery/restoration program does business in order to gain understanding and support, and effectively inform management decision-making. Learning must be a priority of the recovery/restoration program.
- **AM Approach −** Most restoration/recovery programs use a passive AM approach, with some active AM experiments to address critical uncertainties that limit achievement of program goals and objectives.
- **Stakeholder Involvement –** The definition of stakeholders differs from program to program, dependent upon funding sources and local and regional interests. The most important time for stakeholder engagement is during development of the AM Plan when the governance structure and collaborative processes are crafted; however, establishing ongoing opportunities for dialogue with stakeholders and including them in a shared decision-making process increases the probability of program success.

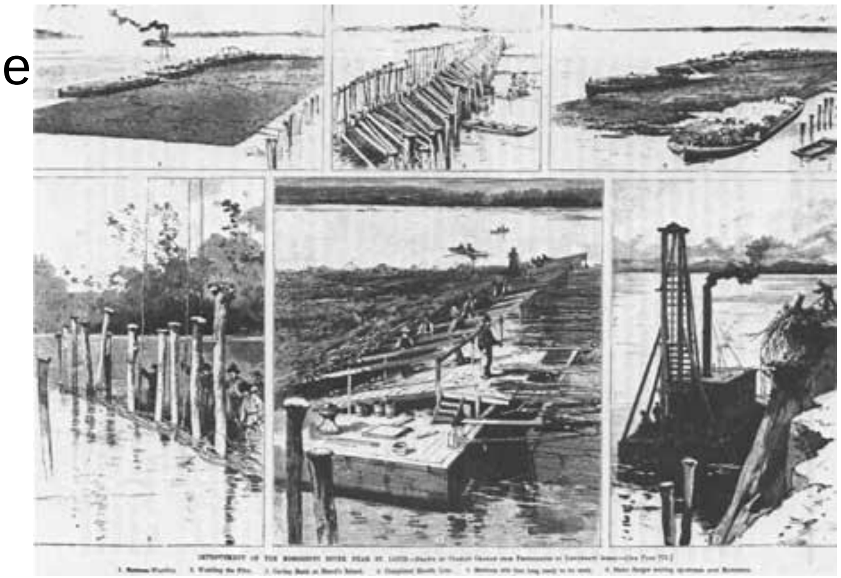
- **Governance Structure –** While governance can generally be grouped into two different models, (i.e., 1) collaborative governance entity created for AM implementation and 2) implementing agencies serve as decision makers), each AM program has a slightly different approach to decision-making based on its particular circumstances. Stakeholders sit on a decision-making body in several programs, but the federal agency(ies) often retain ultimate decision-making authority. In all cases the governance structure employs the basic tenants of AM to establish opportunities to learn and adjust management actions over time. Several programs have considered or implemented adjustments to their governance structures to better meet program and stakeholder needs. Regardless of the governance structure there is a need for open communication within and among agency/ stakeholder groups and extensive vetting leading up to decisions.
- **AM Champion –** Successful AM programs have an internal agency staff member assigned to facilitate and implement the AM Plan and a clear designation of roles and responsibilities, and long-term commitment of other involved parties.

- **Management Questions –** Identify the most important management questions and information needs up front, and using those questions to communicate program progress with managers, stakeholders, and other involved parties.
- **Linking Components of AM Plan –** Clearly identify and link the essential components of an AM Plan, including objectives, constraints, uncertainties, management questions, management actions, decision criteria, monitoring, and research. Continuously reinforce those connections, especially to decision makers, so they understand the applicability of monitoring and research.
- **Decision Criteria –** While the ultimate goal is to have decision criteria, few recovery/restoration programs have quantitative numeric decision criteria and/or triggers. Instead they rely on the best available science and professional judgment of subject matter experts to assess management action performance and determine whether adjustments to management actions need to be made. These AM programs are designed to provide information to define quantitative targets and triggers over time.

- **Ability to Translate Science into Management Recommendations – ** Several AM programs have protocols for taking assessment reports prepared by scientific technical experts and translating this information into recommendations for management actions that can be easily be understood by decision makers and stakeholders. Ensure that there are reasonable expectations for reports to be generated.
- **Decision Making –** Clearly define the decisions that need to be made, the processes for making them, timelines, and associated roles and responsibilities at the outset of the AM program. Ensure that the process is nimble enough to be responsive to new information and make necessary adjustments to management action implementation.

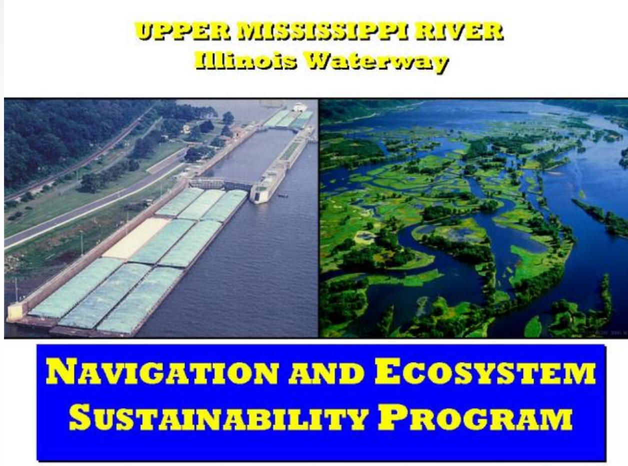
Corps History With AM

- Extensive practical experience with the general concept.
- Relatively little discussion of AM prior to ecosystem restoration authorities.
- Numerous institutional barriers and challenging factors.
- WRDA 2007
  - Sec. 2036
  - Sec. 2039
- AM Implementation Guidance
- Major ER Programs
  - CERP
  - UMRR
  - MRRP
  - LCA



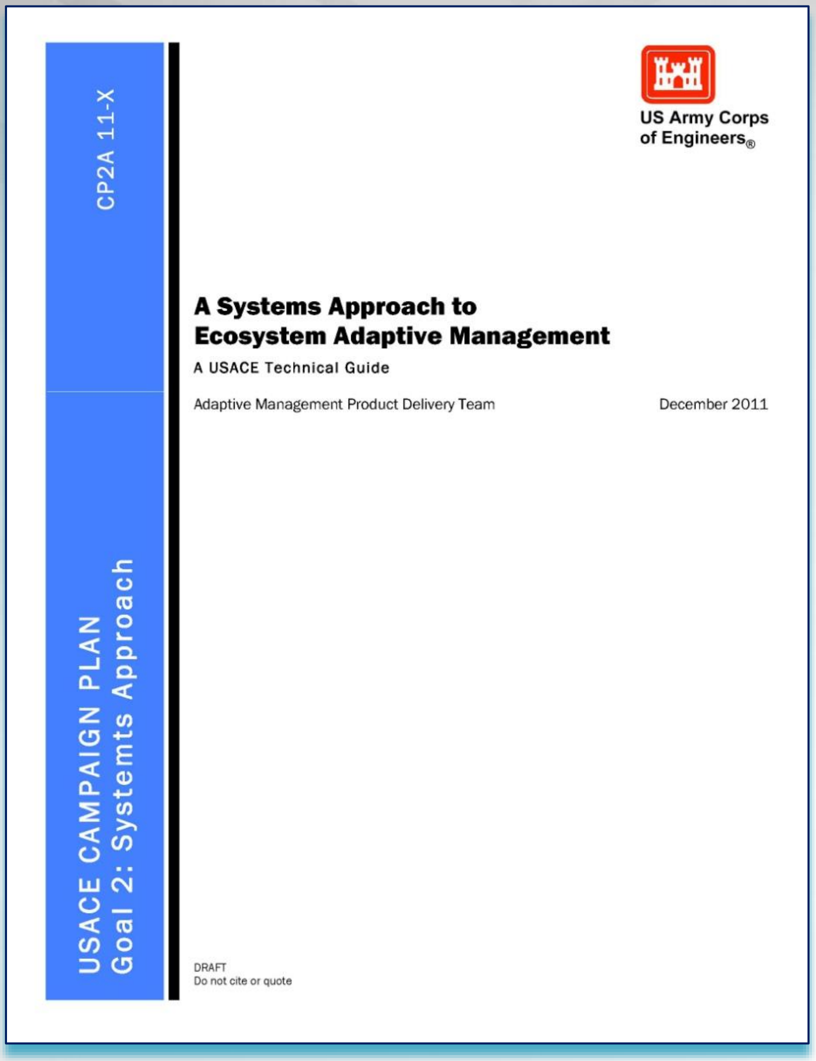
USACE Adaptive Management

Examples



ERDC
Engineer Research and Development Center

A Systems Approach to Ecosystem Adaptive Management: A USACE Technical Guide


USACE CAMPAIGN PLAN
Goal 2: Systemts Approach
CP2A 11-X

US Army Corps of Engineers®

A Systems Approach to Ecosystem Adaptive Management

A USACE Technical Guide

Adaptive Management Product Delivery Team

December 2011

DRAFT
Do not cite or quote

Role and Limitations of AM

- AM should be considered for all ER Projects
- Not all projects lend themselves to AM. Three elements must be present for AM to proceed:
  1. One or more critical uncertainty
  2. Ability to learn through monitoring
  3. Ability to make adjustments based on new knowledge
- Additionally, AM should afford a more cost-effective strategy than other alternatives (difficult to know *a priori*)
- Finally, institutional commitment is needed (see #3 above); this can be elusive for various reasons

Is Adaptive Management Needed?

ERDC
Engineer Research and Development Center

QUESTIONS

Is there sufficient flexibility within the project design and operations that permits adjustment of management alternatives?

If No, adaptive management is not possible
If Yes, continue with questions

Is the managed system well understood and are management outcomes readily predictable?

Do participants agree on the most effective design and operations to achieve goals and objectives?

Are the project/program goals and objectives understood and agreed upon?

ANSWERS

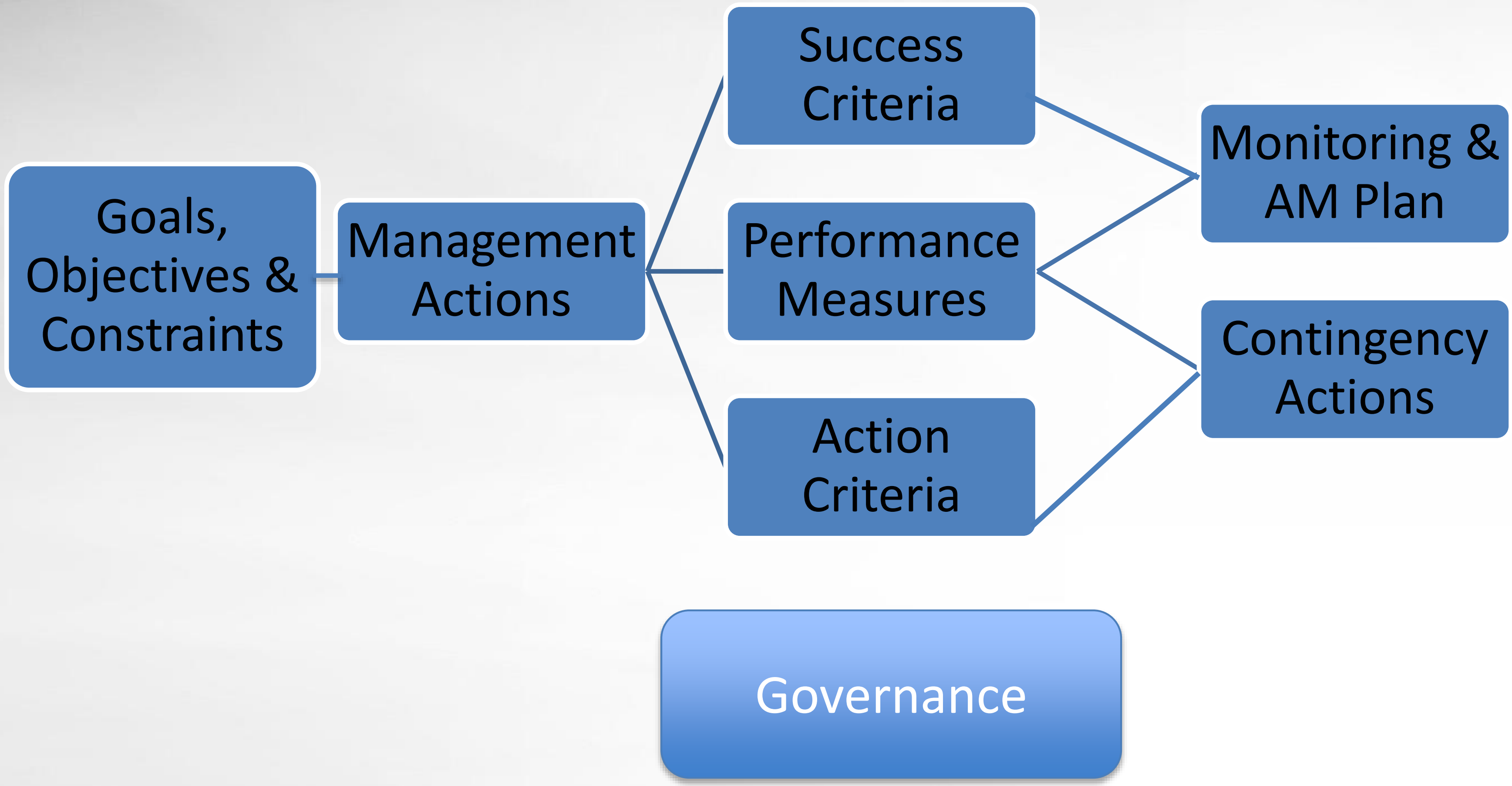
Yes to all → Adaptive Management is not needed

No to any → Adaptive Management can probably improve success

Options for Addressing Uncertainty

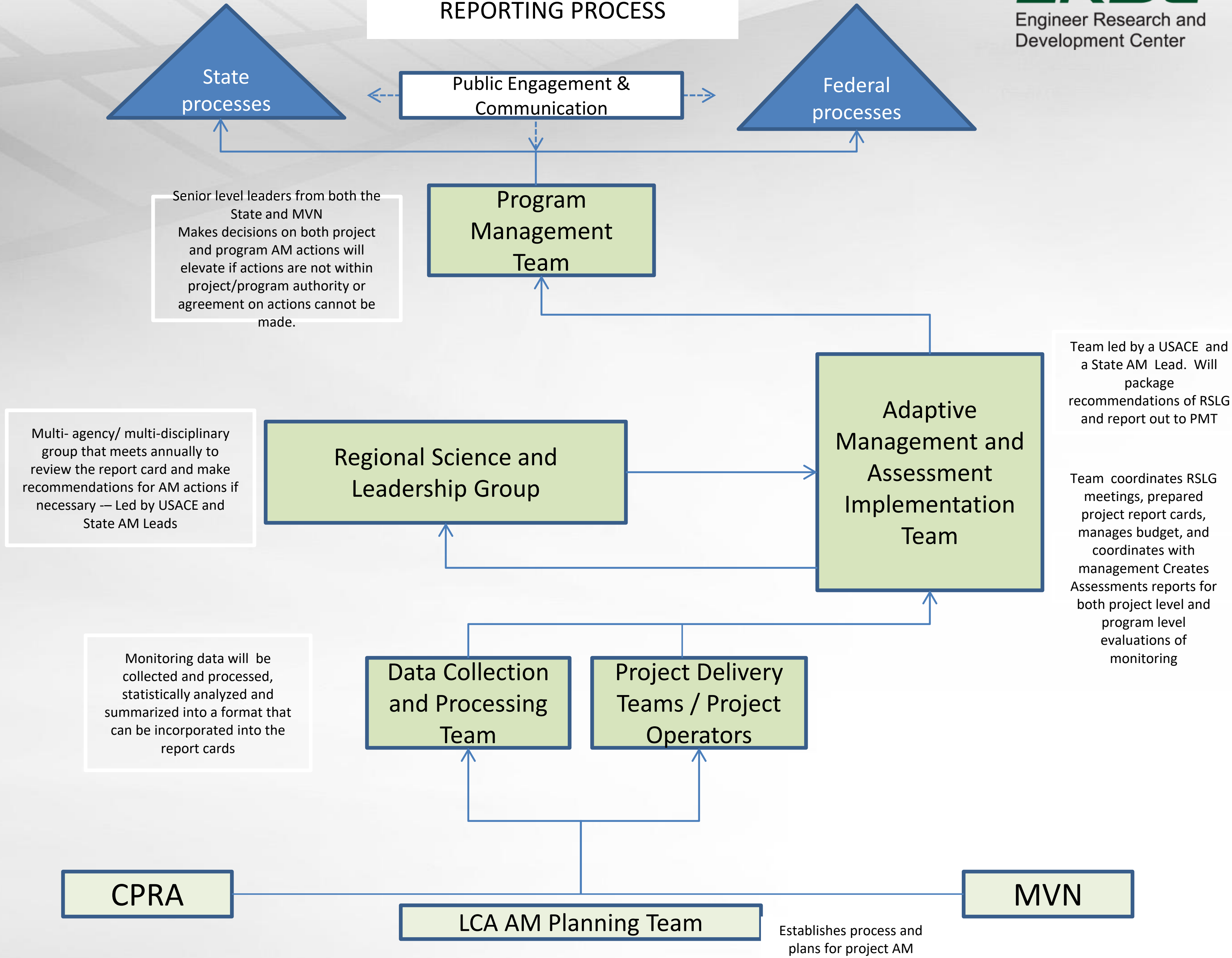
- Do nothing – wait until uncertainty is reduced to acceptable levels
- Scaled implementation using AM to refine scope and scale as knowledge improves
- Full implementation, factoring uncertainty into the scope and scale of actions

Linkages

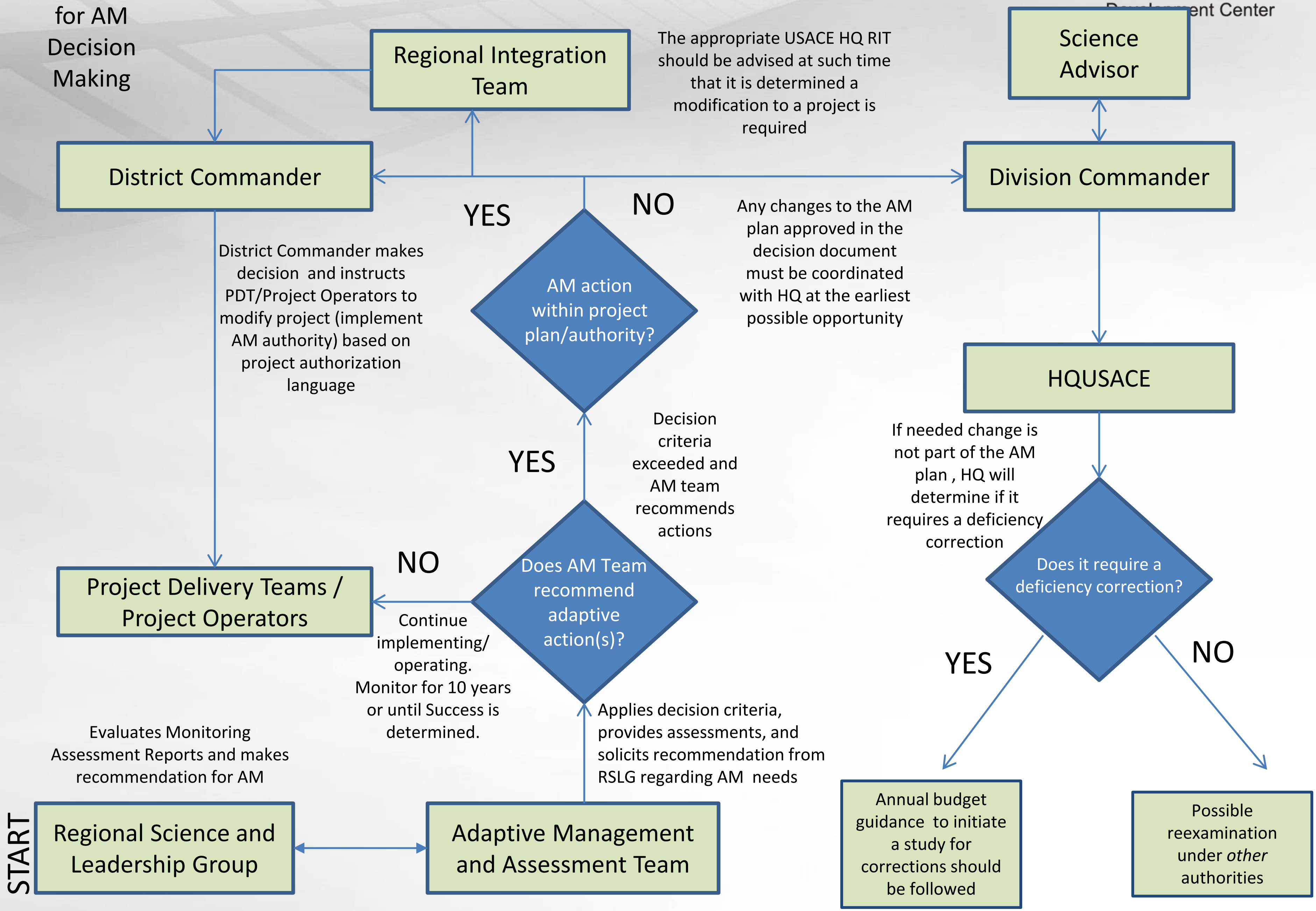

Goals, Objectives & Constraints
Management Actions
Success Criteria
Performance Measures
Action Criteria
Monitoring & AM Plan
Contingency Actions
Governance

LCA AM IMPLEMENTATION AND REPORTING PROCESS

Engineer Research and Development Center



Federal Processes for AM Decision Making



What are the benefits of AM?

Engineer Research and Development Center

- Provides a precautionary approach to act in the face of uncertainty
- Improved probability of project/program success
- Incorporates flexibility and robustness into project/ program design, implementation, and operations
- Process of developing an AM plan inevitably improves the plan formulation process & products
- Promotes collaboration and conflict resolution among agencies and stakeholders, scientists and managers while empowering all the above groups
- Moves the state of science and understanding of ecosystem restoration forward in a deliberate way
- Can improve cost effectiveness

Required Mindset for AM

- Be honest about uncertainties and tackle them head-on
- View choices/management actions** as ‘treatments’ to be tested
- Make a commitment to learning
- Mistakes are not all bad – they enhance learning
- Expect surprises and learn from them
- Encourage creativity and innovation
- Start small; build on successes

*** ….where actions can include various **management actions** related to allocation, restoration, levels and patterns of disturbance, as well as **policy-oriented measures** related to permitting, incentives, and financing, among others.*

Lessons from a Practitioner

ERDC
Engineer Research and Development Center

- AM has a critical planning component that requires careful consideration of uncertainties and outcomes; it is not strictly a post-construction consideration
- Development of an AM plan is as much about the *process* as it is the *product*
- Not all projects or programs lend themselves to AM
- Governance is crucial and may be difficult to assure for some projects and programs
- Cost estimates are complicated by uncertainties
- Refinement during PED is likely, and flexibility in implementation is probably needed
- Successful efforts typically have an AM “champion”

Lane Lefort

Site-Specific Project Implementation

EXAMPLE FOR ONE PROJECT
meanwhile, other projects are also being implemented

Engineer Research and Development Center

INITIATE
Year 1

- STRATEGIC PLAN → NEED
  - Quantity
  - Approx Location
  - Improvements

PLAN
Year 1 or 2

- SITE SELECTION PROCESS
- ENGINEERING & DESIGN
- SITE-SPECIFIC REGULATORY REQUIREMENTS
- PUBLIC COMMENT (& public meetings as appropriate)

EXECUTE
Year 2 or 3

- CONSTRUCTION

MONITOR
Years 3 +

- BIOLOGICAL
- PHYSICAL
- RESULTS → FALL SCIENCE MEETINGS

Fall Science Meeting

AM Workshop

AM Annual Report

MRRIC Recommendation

Strategic Plan

Next Cycle Starts: New Project

Focus of SP Update Process

CFY
- Minor adjustments based on appropriations

FY+1
- Minor adjustments based on new information and P-bud

FY+2
- Management actions , research and other studies or activities needed to meet objectives;
- Developed at level of detail for budgeting purposes

FY+3
- Adjustments to former FY+4 strategic plan based on current projections
- Updated risk management measures and priorities

FY+4
- New FY added to the strategic plan based on current projections
- Risk management measures and priorities

Science Update Process

ERDC
Engineer Research and Development Center

Fall Science Meeting

Species (and HC) Teams discuss initial results and findings

Researchers participate

Adaptive Management Workshop

Researchers present findings

Technical Team presents draft AM Report

ISAP(/ISETR) participation and initial evaluation of draft AM report

Species (and HC) Teams discuss monitoring and research results, including species and HC; develop initial recommendations for Annual Work Plan (informed by President's Budget)

Science Update Process

Annual Forum Webinar

Summarize AM Workshop and Final AM Report
Summarize ISAP review and Species (HC) Team recommendations

Draft Annual Work Plan Review Webinar

Management Team presents Annual Work Plan

MRRIC Annual Work Plan Recommendation Meeting

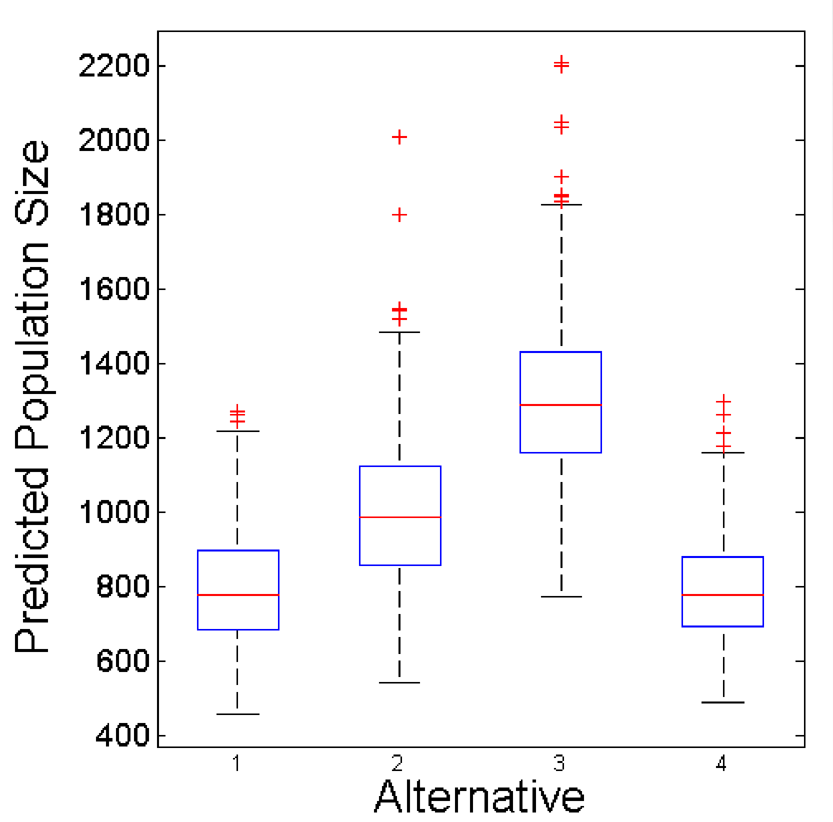
MRRIC plenary development of Annual Work Plan recommendations

MRRIC Meeting(s) (Topics Vary)

MRRIC plenary discussions of longer-term recommendations, HC, programmatic changes, etc.

Model applications

- Basic model behavior
- Model validation
- Effects of management actions
- Interactions of effects
- Comparison of management alternatives
- Effects of natural variability and extreme events



Quantitative decision criteria

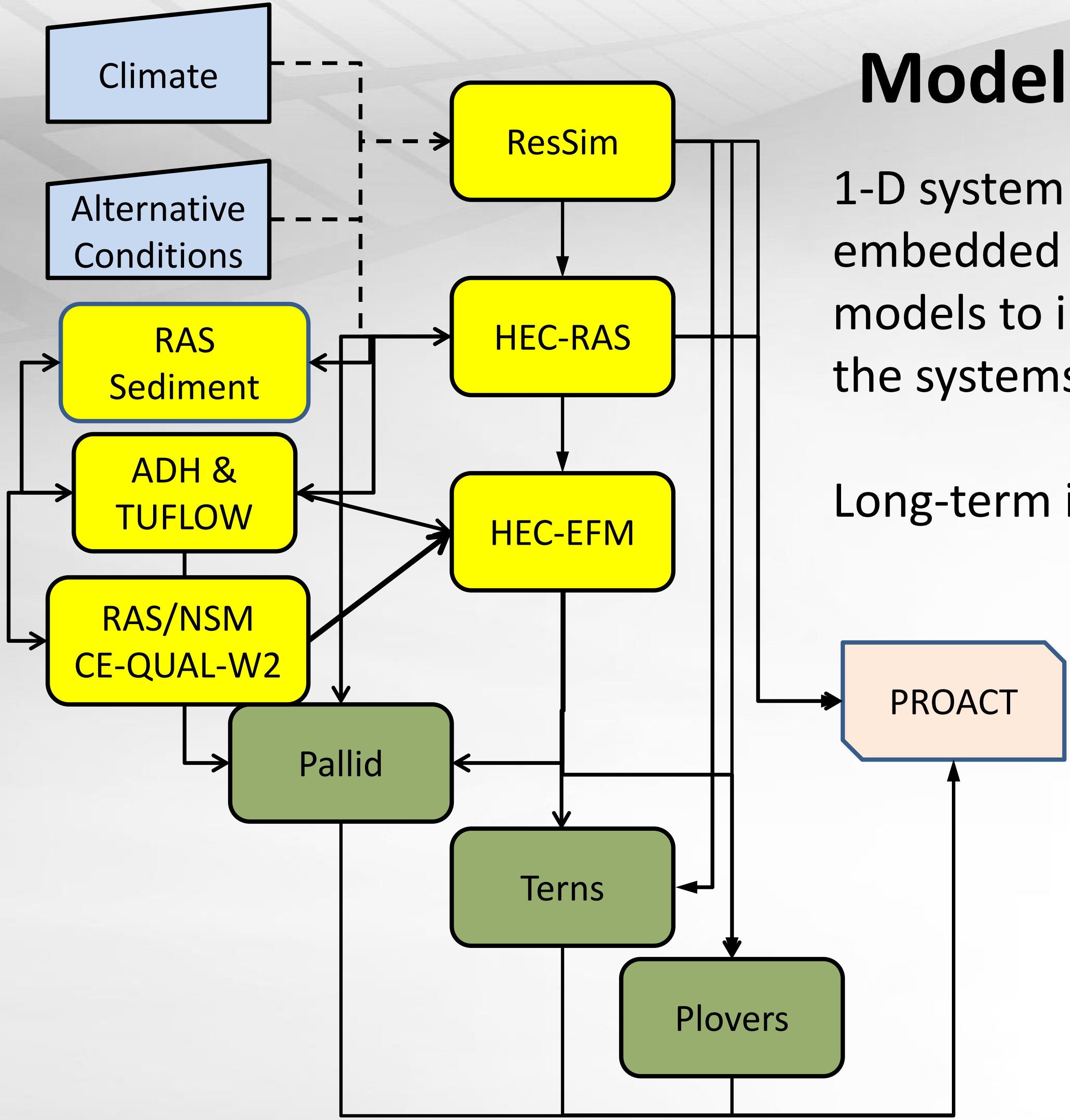
- **Increase likelihood of meeting targets under uncertainty**
- Reduce likelihood of adverse impacts
- Make trade-offs explicit
- **Make scientific findings actionable**
- Increase efficiency of resource use
- Facilitate decisions that must be made quickly
- Provide justification for actions
- **Account for multiple factors in single decisions**

Decision criteria examples

If combined releases plus tributary flows exceed flood thresholds **<(71kcfs at Omaha, 82kcfs at Nebraska City, or 126kcfs at Kansas City)>,** releases are decreased by **<5 kcfs>** increments until downstream flow criteria are met or the release falls below **<45 kcfs>**, at which point it is terminated.

If use of vegetation managed sandbars is less than **<50%>** and/or fledgling production less than **<80%>** that of new/unvegetated sandbars, use of methodologies should be reevaluated and discontinued if they cannot be improved to comparable levels.

Model Framework



1-D system model with embedded multi-dimensional models to inform/parameterize the systems models.

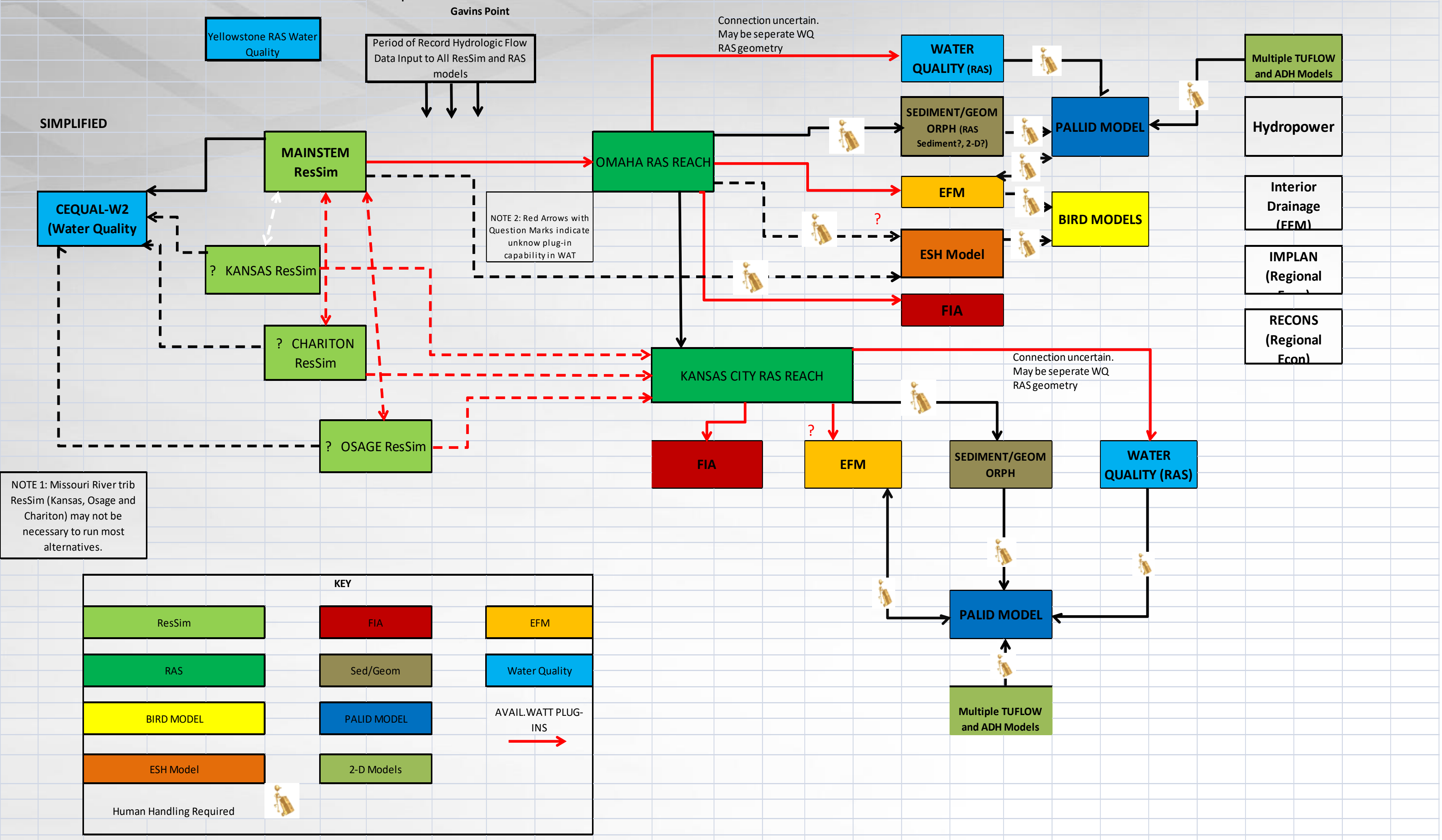
Long-term improvement strategy

ERDC Engineer Research and Development Center

Engineer Research and Development Center

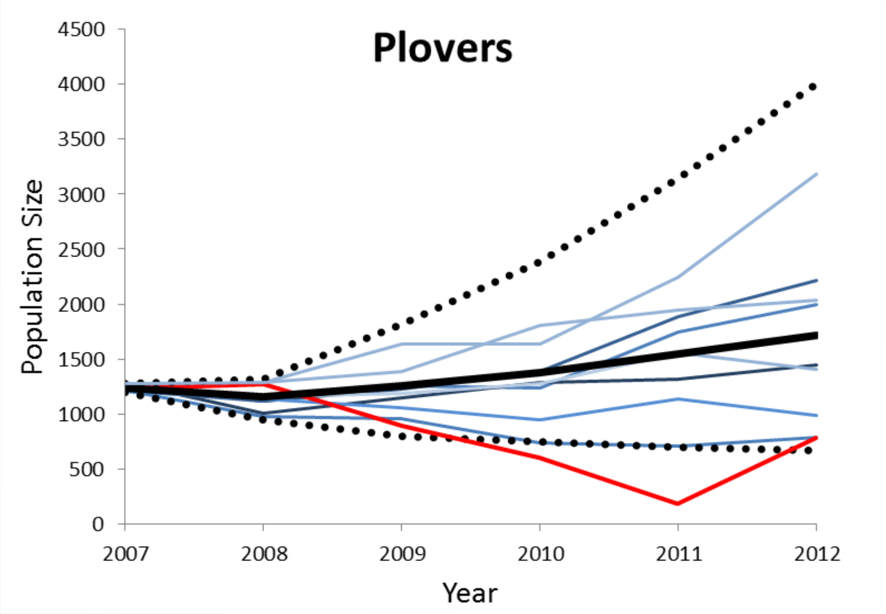
SIMPLIFIED MODEL INTEGRATION WORK FLOW

Example for flow alternative downstream of Gavins Point



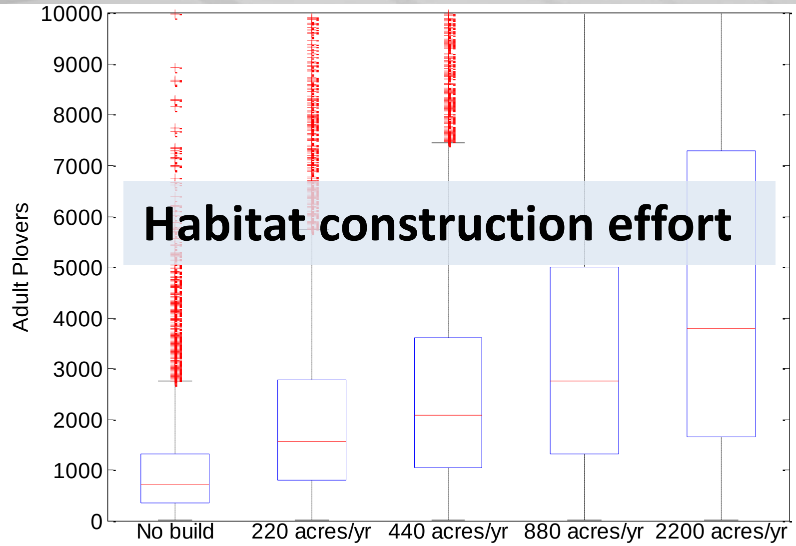
Terns and Plovers

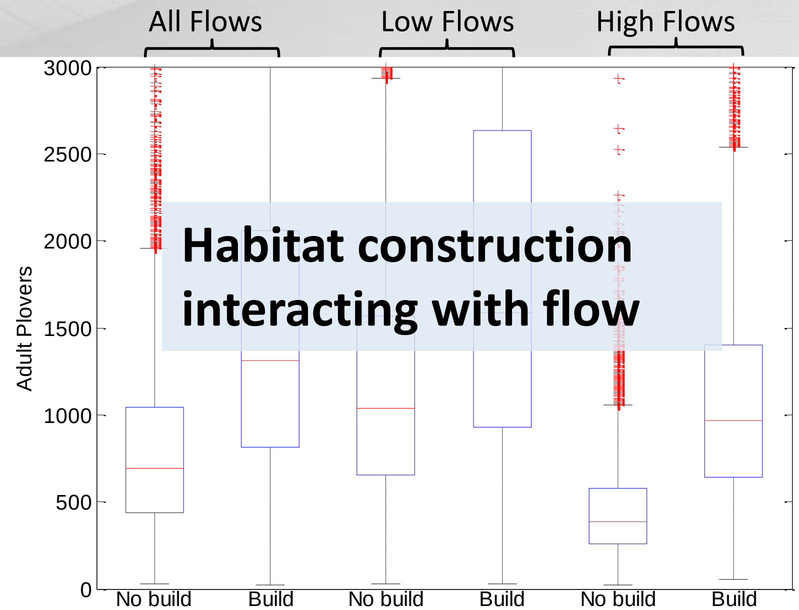
- Reasonably well-understood relationships between habitat and population response
- Other factors contribute to productivity
- Flows to create/sustain habitat remain a critical uncertainty

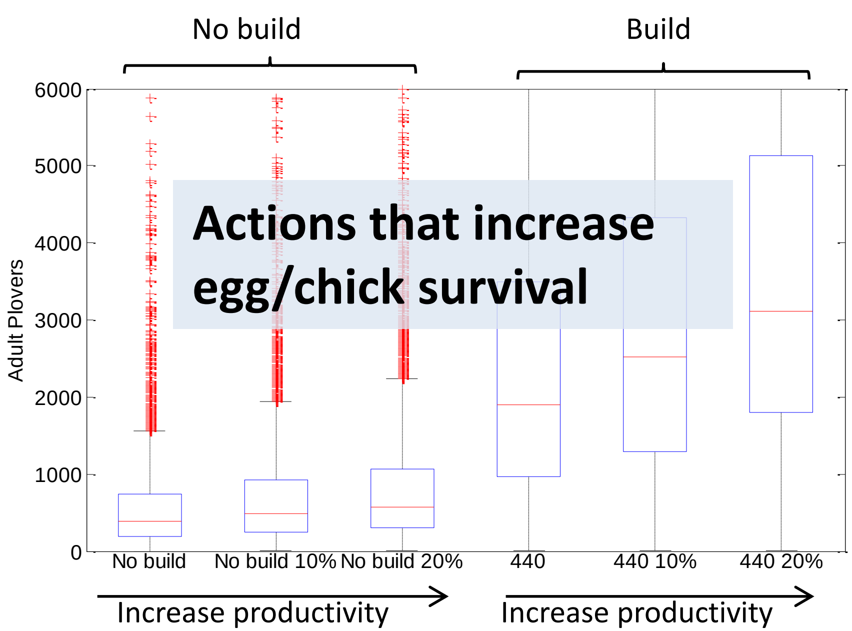


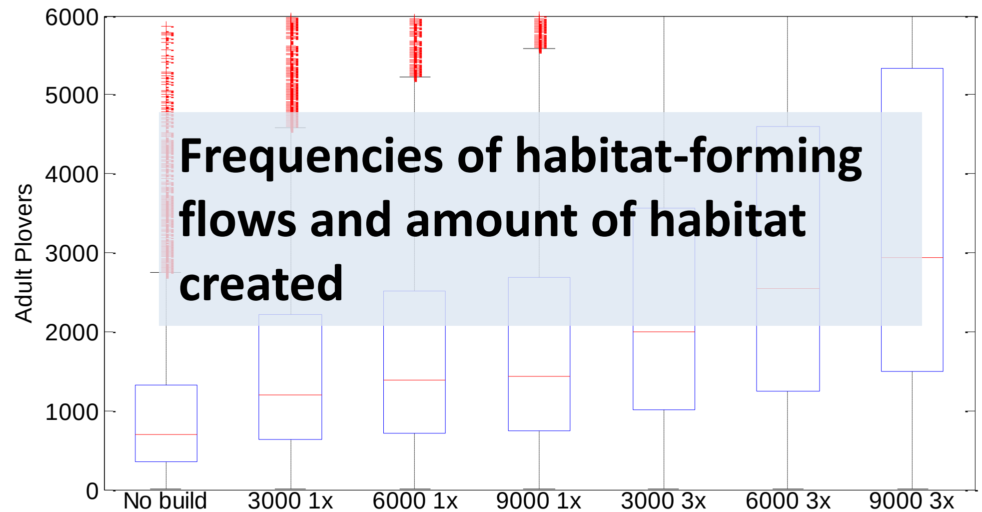
Examples of preliminary results

Engineer Research and Development Center









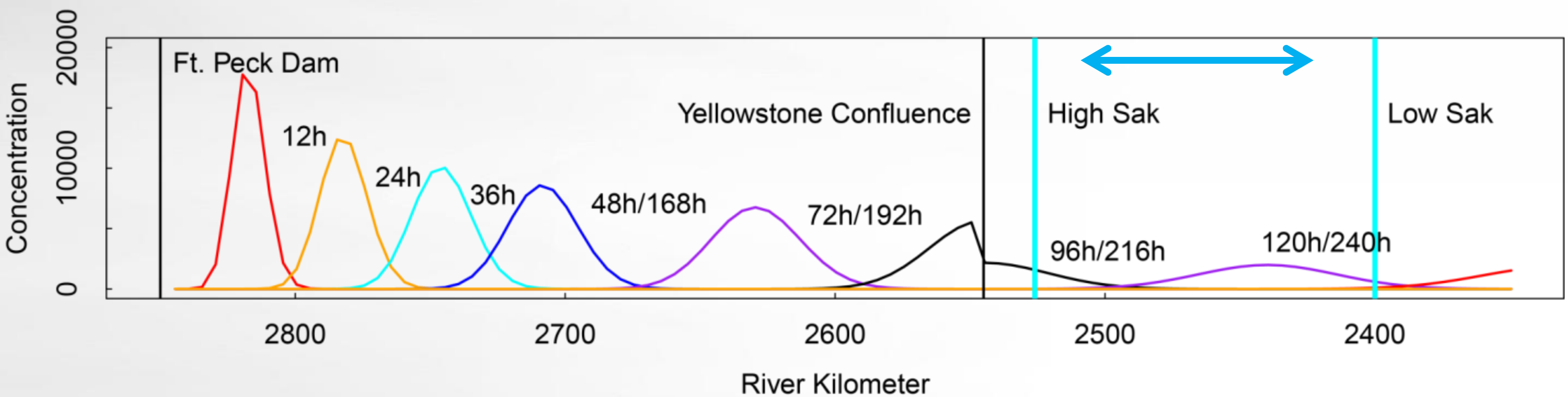
Advection/dispersion Model Free-embryo Drift

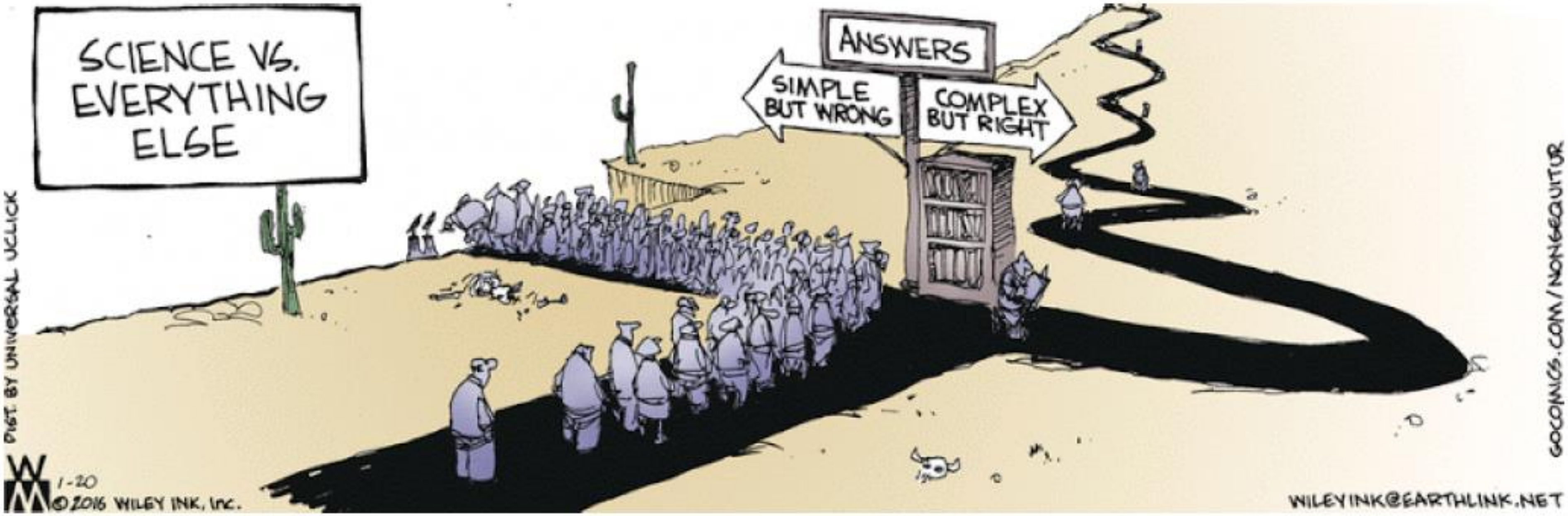
Destination = function of distance, drift velocity, (mostly f(water velocity, discharge), development (= f(temperature))

- At T_{50} = 18C, yolk plug expelled at 240 hours
  - 10 days immediate drift
  - <u>Or</u> 5 days drift with interstitial hiding
- AT T_{90}, yolk plug expelled at 216 hours
  - 9 days intermediate drift
  - <u>Or</u> 4 days drift with interstitial hiding

Drawdown + variation

Q_{50} Ft. Peck



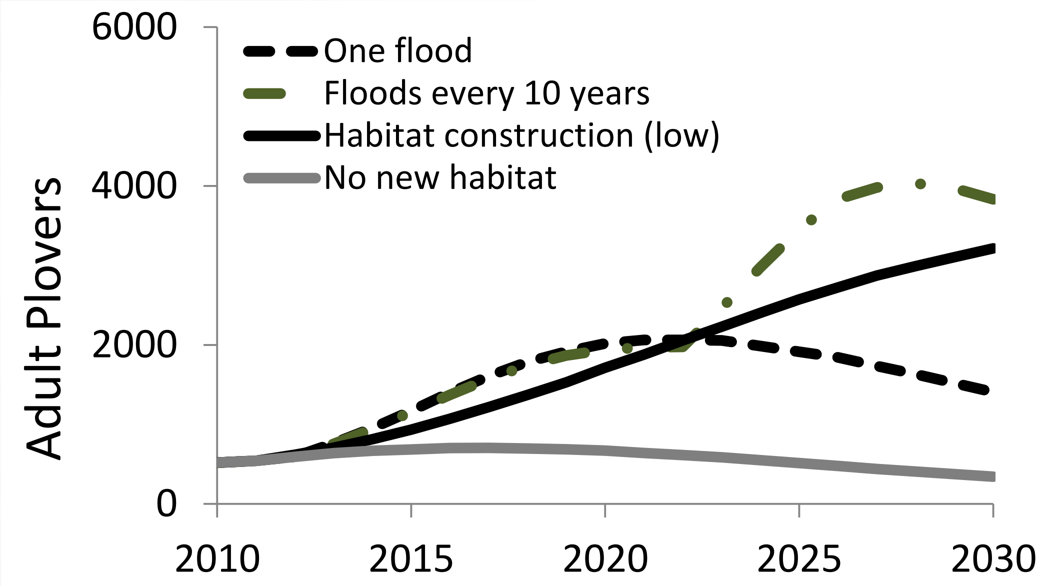


For every complex problem there is an answer that is clear, simple, and wrong.

- H. L. Mencken (1917)

Synthesis: Best Available Science Based on Lines of Evidence and Model Projections

- Evidence from:
  - Focused research
  - Past implementation of management actions
  - Natural flow events
  - Evidence from similar systems
- Model predictions
  - General effects
  - Results for defined cases

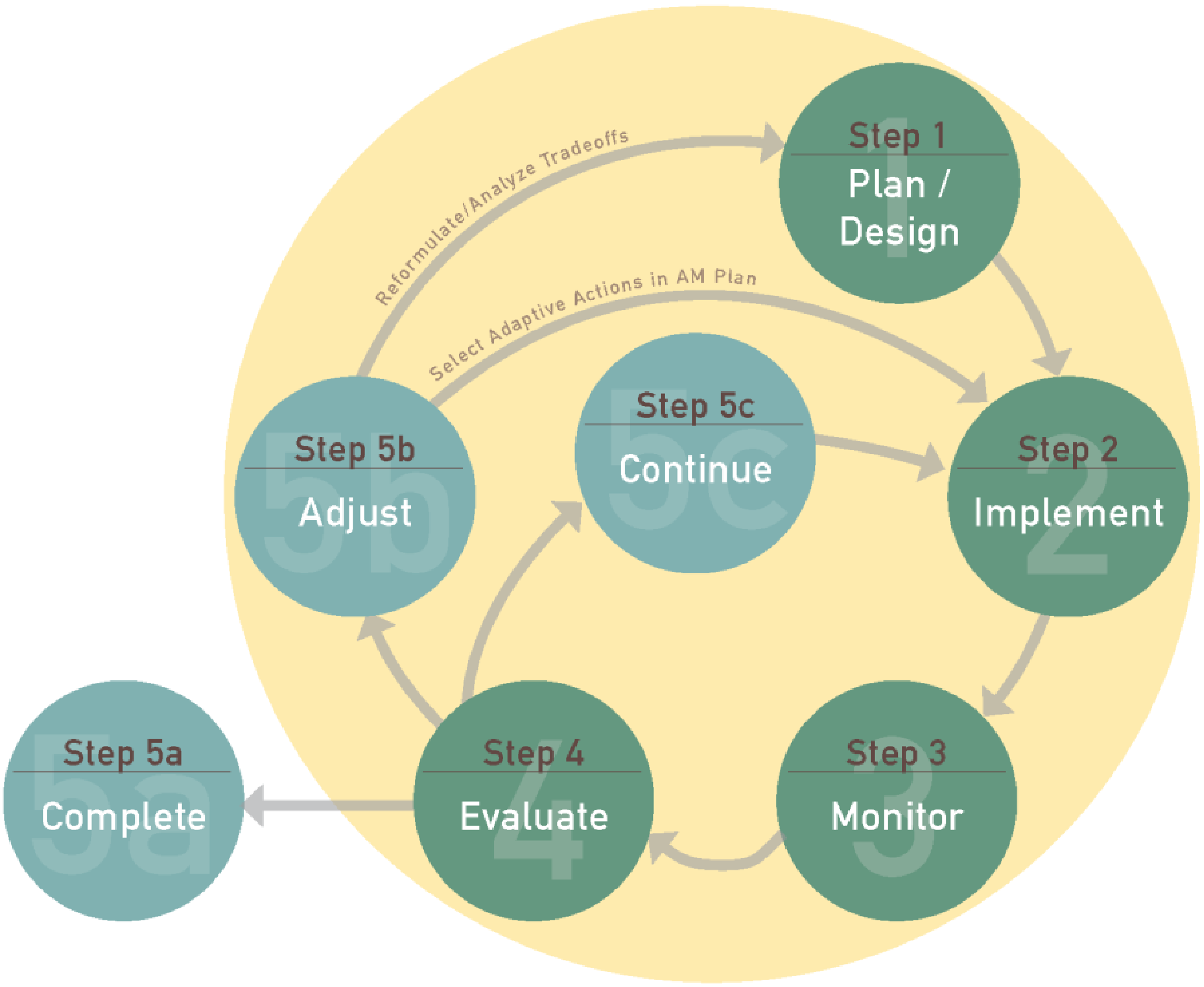


Criteria for advancing sturgeon actions

Engineer Research and Development Center

	Question	Y	U	N
1	Is this factor limiting pallid sturgeon reproductive and/or recruitment success?			
2	Are pallid sturgeon needs sufficiently understood with respect to this limiting factor?			
3	Do one or more management action(s) exist that could, in theory, address these needs?			
4	Has it been demonstrated that at least one kind of management action has a sufficient probability of satisfying the biological need?			
5	Have other biological, legal, and socioeconomic considerations been sufficiently addressed to determine whether or how to implement management actions to Level 3?			
	Criteria for Level 3 implementation			
	1 - A "Yes" to all five questions triggers Level 3 implementation			
	2 - A "Yes" to four of five, with an "Uncertain" for either #1 or #2 triggers a two-year clock to either reject the hypothesis or implement at Level 3			

Generic AM cycle

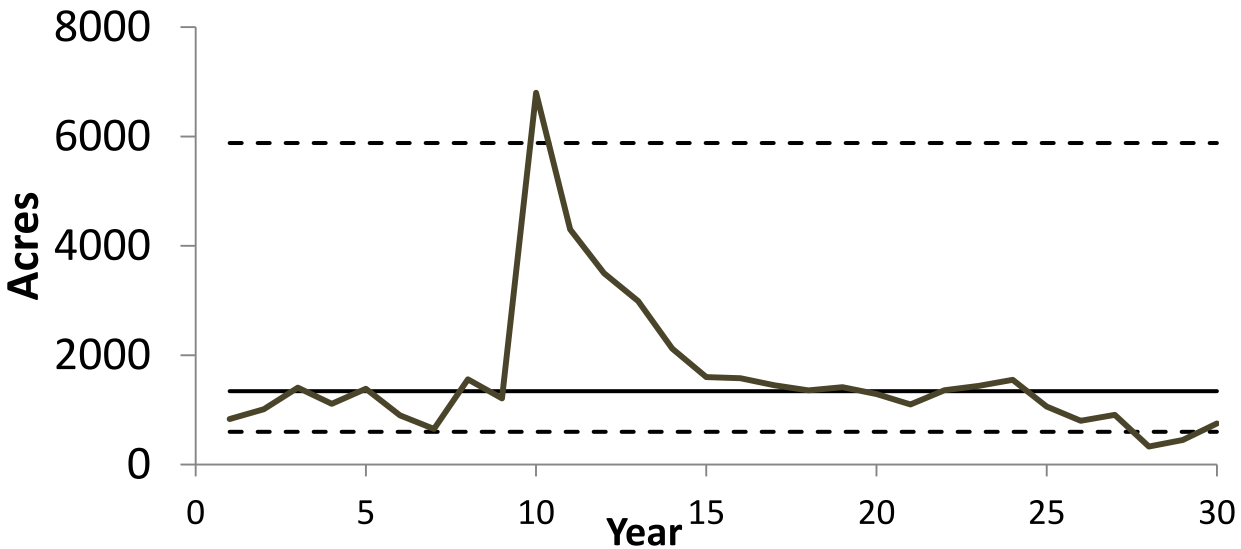


AM Cycle: Constructing Emergent Sandbar Habitat

- Deciding what to build and where
- Working within opportunities and constraints
- Implementation—contracting and construction
- Monitoring habitat and birds
- Research
- Assessment and evaluation of habitat and bird status and trends

Evaluation—current status and need to act

- How much ESH acres and birds are out there now?
  - Monitoring results
  - Model projections
  - Field observations
  - Anything unusual?
- Comparison to targets



Evaluation—using learning

- How much habitat is needed? Where?

  Learning: effects of flow on erosion, nesting success of birds, etc.

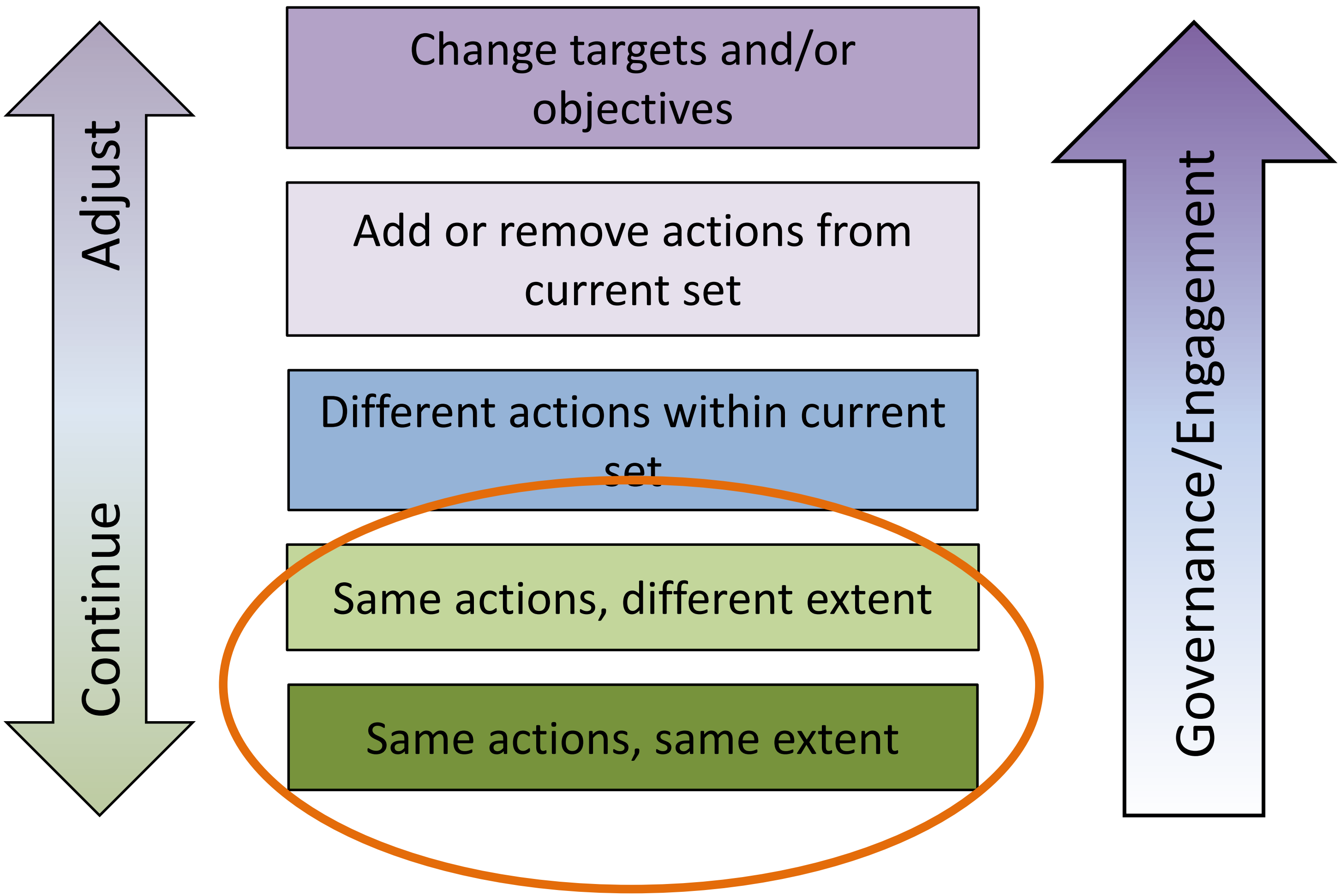
- What are the constraints? Are there enough resources?

  Learning: efficiency of construction, ways to improve habitat quality

- How do different management options compare?

  Learning: effects of construction methods, methods to improve quality and longevity of habitat, improved models to compare options

Types of Decisions



Decision examples

- Have enough budget to build everything needed: build 200 acres in Gavins Point Reach and 150 acres in Garrison
- Don’t have enough money: build 120 acres in Gavins
- Do nothing this year, but need to construct next year

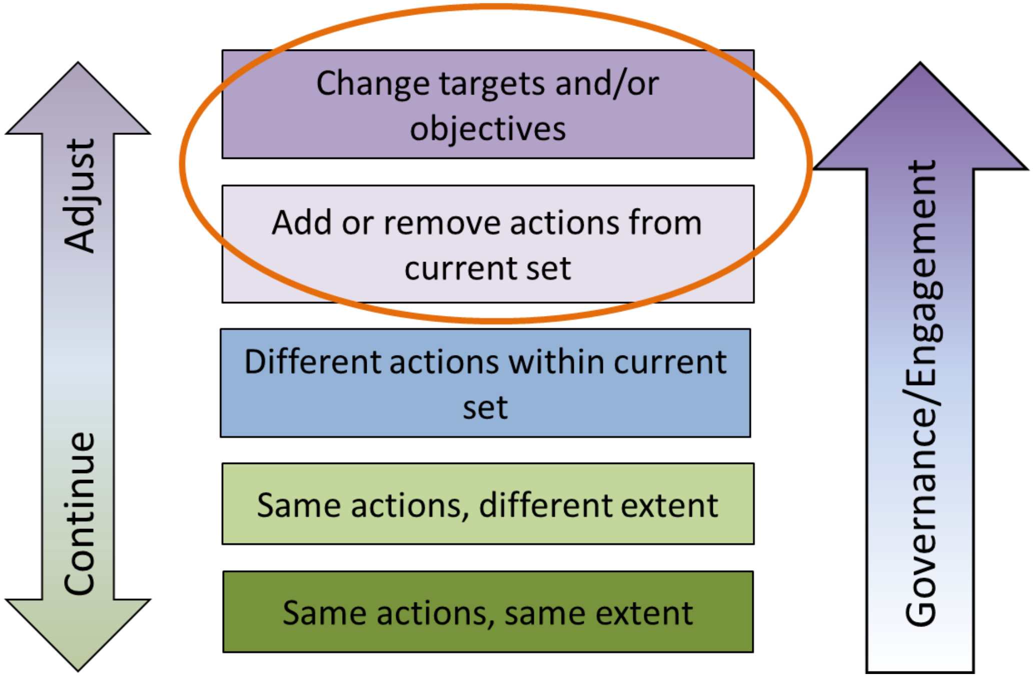
Implement and Monitor (and research)

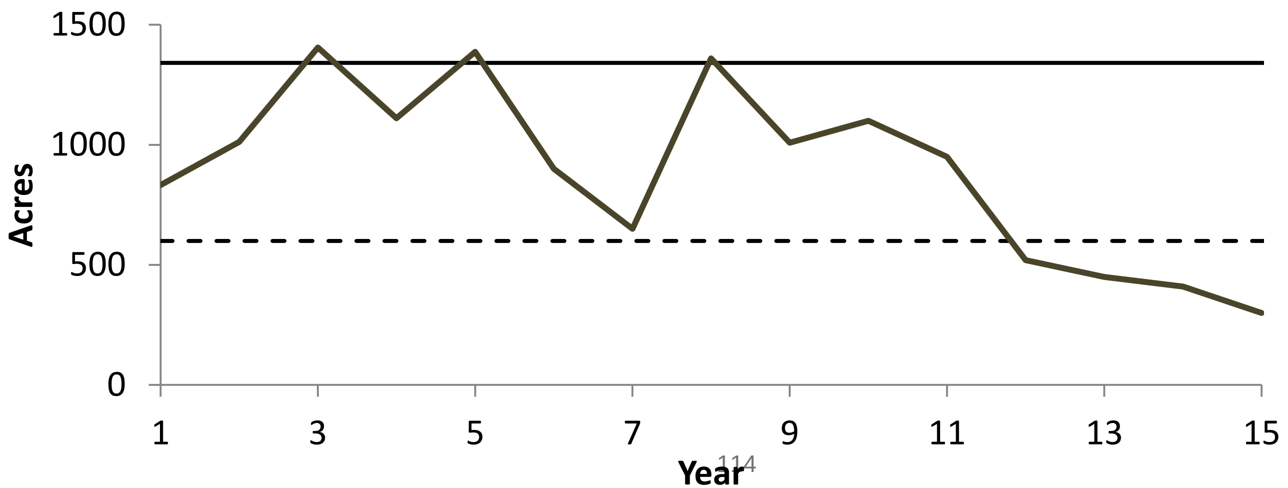
- Implementation:
  - contracts and construction

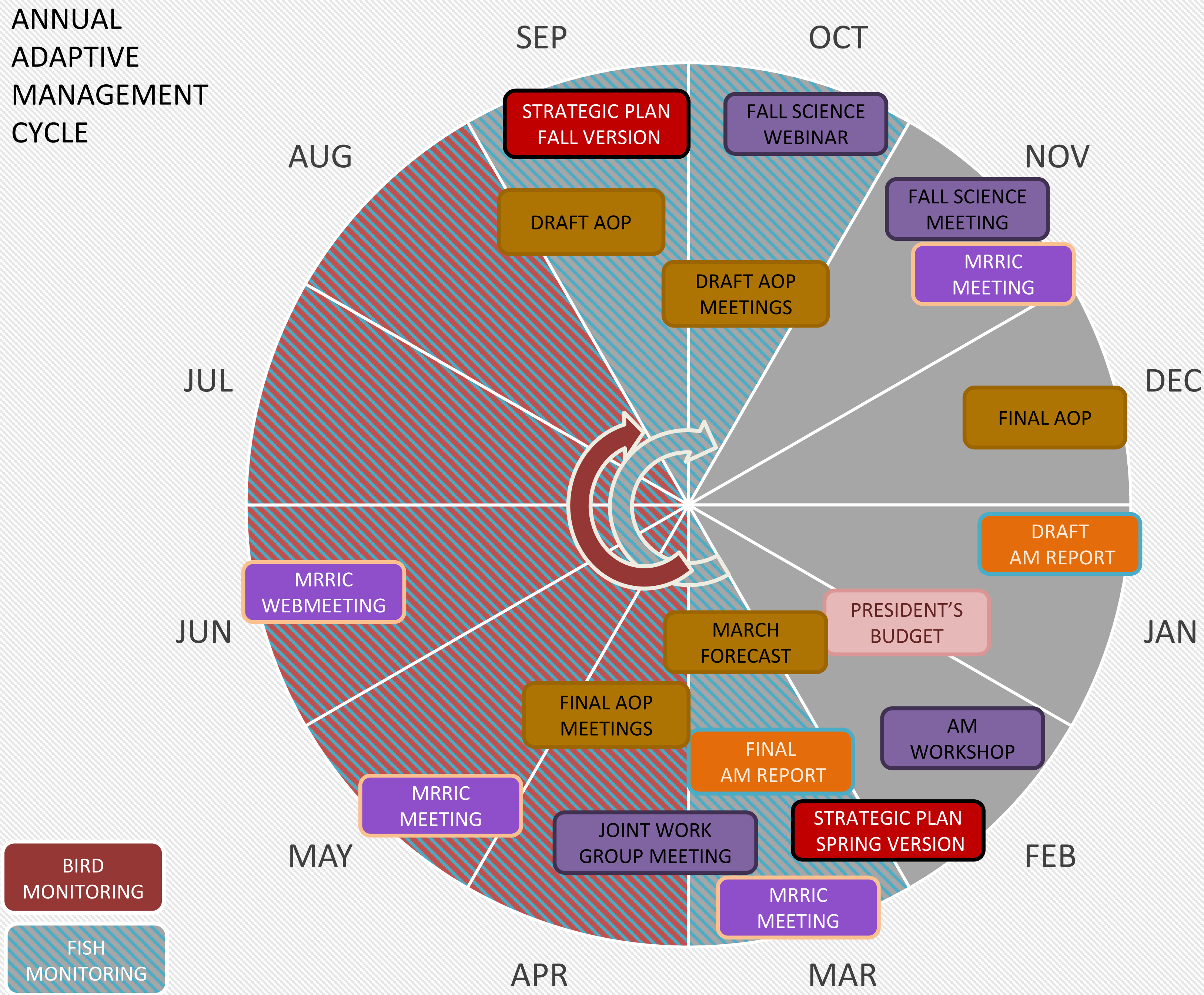
- Monitoring and research
  - Designed specifically to meet evaluation needs and address information gaps

Programmatic evaluation

- Revisiting actions, objectives, targets
- Triggered by learning over time that current management is not working as expected or constraints preclude success
- OR that management is working better than expected and can be adjusted







ANNUAL ADAPTIVE MANAGEMENT CYCLE
SEP
OCT
AUG
NOV
JUL
DEC
JUN
JAN
MAY
FEB
APR
MAR
STRATEGIC PLAN FALL VERSION
FALL SCIENCE WEBINAR
DRAFT AOP
DRAFT AOP MEETINGS
FALL SCIENCE MEETING
MRRIC MEETING
FINAL AOP
DRAFT AM REPORT
PRESIDENT'S BUDGET
MARCH FORECAST
MRRIC WEBMEETING
FINAL AOP MEETINGS
AM WORKSHOP
FINAL AM REPORT
STRATEGIC PLAN SPRING VERSION
MRRIC MEETING
JOINT WORK GROUP MEETING
MRRIC MEETING
BIRD MONITORING
FISH MONITORING

- **Problem Context**
- What is the problem that needed to addressed?
- Why does addressing the problem matter (to decision makers, scientists, and/or stakeholders)?
- What is the history of development for Adaptive Management / overview of the program (status, key issues, scientific uncertainties, key participants, etc.)?
- What is the regulatory context / drivers for AM development and ongoing management?
-
- **Solutions**
- How is the problem being addressed? What was done (related to developing objectives, funding, monitoring/assessment, triggers/thresholds, governance, transparency/inclusion, stakeholder engagement and buy-in)?
- How were Adaptive Management steps, AM tools, or AM principles used to address the challenge?
- What were some of the challenges that were encountered and how were they overcome?
-
- **Results**
- What were the outcomes from applying these solutions?
- What were some of the benefits / costs of applying AM?
- How has AM held up over time?
-
- **Lessons Learned**
- What are some transferable lessons for others (i.e., do’s and don’ts of applying AM)? Why?