PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM (PRRIP -or- Program)

Extension Science Plan – EXECUTIVE SUMMARY

November 28, 2021

Document Bookmarks:

I. PURPOSE

The purpose of the Science Plan is to describe a concise and practical roadmap to implementing Program science activities, analyzing and synthesizing multiple lines of data, and connecting useful scientific information to Governance Committee (GC) decision-making during the First Increment Extension (2020-2032). This Science Plan is organized around a set of priorities focused on GC questions related to the response of two target bird species (*Grus americana*, whooping crane; *Charadrius melodus*, piping plover) to Program water releases and other management actions. In addition, the Science Plan includes a bounded set of research activities directed at filling information gaps related to the life history ecology and habitat use of a Program target fish species (*Scaphirhynchus albus*; pallid sturgeon).

The Extension Science Plan is an update to the original PRRIP Adaptive Management Plan (AMP) that was incorporated into the Final Program Document and guided implementation of science activities during the First Increment from 2007-2019. While this Science Plan provides focus for Program science activities during the Extension from 2020-2032, the EDO will continue to collect monitoring data and evaluate new sources of information relative to First Increment Big Questions that have been answered conclusively throughout the remainder of the Extension. **Attachment 1** includes a table detailing Big Questions from the First Increment, their assessment status, and potential “red flags” or information that might necessitate the Program re-visiting these questions and their underlying hypotheses.

The Executive Summary of the Extension Science Plan will be presented to the GC for review and approval in March 2022. Subsequent changes to the Executive Summary, particularly the science priorities and Extension Big Questions identified below, will require review and approval by the GC during the course of the Extension. **Attachments 2-4** contain detailed information about Program hypotheses, monitoring protocols, implementation timelines, plans for data analysis/synthesis, and other important scientific and technical pieces of Program science. Changes to those technical pieces will occur through discussions with the Executive Director’s Office (EDO), Technical Advisory Committee (TAC), and Independent Scientific Advisory Committee (ISAC) but will not require GC approval and changes will be dictated by Program learning, methodology updates, and agreement within the technical arm of the Program based on the best available science.

II. OBJECTIVES & KEY QUESTIONS

The Platte River Recovery Implementation Program Extension Act, passed by Congress in 2019, and PRRIP Cooperative Agreement Amendment No. 1, signed by the Secretary of the Interior and the

Governors of Colorado, Wyoming, and Nebraska in 2019, extended the Program's First Increment through 2032. Incorporated by reference in the Cooperative Agreement Amendment, the Final Program Document Addendum (approved by the GC in 2017) set the following direction for Program science during this Extension:

A. Program <u>science objectives</u> for the Extension (negotiated by the GC during development of the Addendum):

1) *Scientific investigations* need to be completed to confirm the need for 130,000 acre-feet in annual reductions to target flow shortages.
2) The Program will invest the resources available to achieve at least 120,000 acre-feet in annual reductions to target flow shortages as quickly as possible during the Extension and will also *invest in the science* necessary to determine if the additional 10,000 acre-feet is justified.
3) The Program is committed to finding the additional resources necessary to achieve that additional 10,000 acre-feet *if justified by the science*.
4) Continued implementation of the *management actions* specified in the AMP related to SDHF, sediment augmentation, and least tern, piping plover, and whooping crane habitats.
5) Contribute to reach-scale *Phragmites and invasive species* control efforts.
6) Utilization of Program water assets to *implement and evaluate flow-related management actions* including SDHF and species-related target flows.
7) *Pallid sturgeon activities* in the Extension will be guided by the results of the incremental four-step process adopted by the GC at the September 2016 meeting (as updated by the 2020 Pallid Sturgeon Policy Frame).
8) The Program will continue to consider the emerging science related to climate change in management and decision making.

B. Program <u>management objectives</u> for the Extension (incorporated by reference in the Addendum from the original 2006 PRRIP Adaptive Management Plan):

1) Improve production of *piping plovers* from the central Platte River.
2) Contribute to the survival of *whooping cranes* during migration.
3) Avoid adverse impacts from Program actions on *pallid sturgeon* populations.
4) Within overall Management Objectives 1-3, provide benefits to *non-target listed species* and *non-listed species of concern* and reduce the likelihood of future listing.

In addition, the GC conducted a "mock negotiation" for the Second Increment in 2020 to look ahead to potential key policy considerations that will need addressed in building goals, objectives, and implementation priorities for the Second Increment. Those discussions resulted in a **set of key science questions** that relate to how science activities will be implemented during the Extension and to how science learning will be analyzed, synthesized, and communicated to the GC:

1) How should we identify and communicate target species outcomes as well as our ability to influence those outcomes?
2) In what specific ways will the continuation of Program management actions in a Second Increment contribute to Management Objective #4 (non-target species)?
3) How does current chokepoint capacity constrain ability to implement flow management actions and what are the incremental and relative benefits of increasing capacity?

4) What are the incremental and relative benefits and costs of using water versus mechanical/chemical means to create and/or maintain suitable in-channel species habitat?
5) What are the incremental and relative benefits to target species (or target species habitat) of other potential flow actions?
6) How much of the 19,000 acres of pre-1997 conservation land remains under conservation ownership and how many acres have been acquired (non-PRRIP) since 1997?
7) What proportion of existing non-PRRIP conservation lands benefit target species or species of concern as defined by the Program?
8) Are existing PRRIP and non-PRRIP conservation lands sufficient to meet the target species management objectives as detailed in the Extension Science Plan?

In short, these **objectives and questions** form the boundaries of Program science during the Extension and science learning will be directed at addressing these issues in a manner that informs GC decision-making throughout the Extension and during Second Increment negotiations that will occur near the end of the Extension.

III. EXTENSION SCIENCE PRIORITIES

During the Extension, Program science activities will center around two broad categories of learning as an organizing concept for relating scientific data and conclusions to the key objectives and questions noted above:

1) Active Learning – management action experiments

This Program science priority will focus on the design and implementation of specific Program management actions to learn how river form/function and the target bird species (primarily whooping cranes) respond. Science activities in this category of learning during the Extension will be supported by the application of rigorous adaptive management (AM) and clear efforts to test hypotheses related to predictions of river and target species responses to Program management actions. For the Extension, this science priority includes:

- The effectiveness of Program water management in creating and/or maintaining suitable whooping crane (WC) habitat through suppression of channel vegetation germination.
- The effectiveness of Program management actions (flow and mechanical tools) in controlling the spread of channel vegetation, particularly *Phragmites* (*Phragmites australis*), as means of creating and/or maintaining suitable WC habitat.
- The role of Program sediment augmentation in the south channel of the Platte River along Jeffrey Island in creating and/or maintaining suitable WC habitat.
- The relationship between WC use and flow and the seasonal effects of flow on WC use.
- The effect of Program flow management actions on pallid sturgeon use of the lower Platte River.

2) Maintenance Learning – improving and sustaining ongoing Program management actions

This Program science priority will focus on applying Program science to provide incremental refinements to ongoing Program management actions (primarily for piping plovers). Science activities in this category of learning during the Extension will be supported by the application of more traditional status/trends monitoring and the design of management treatments to identify variables that can be controlled or minimized through improvements in long-term management implementation. For the Extension, this science priority includes:

- Investigating the effects of predation (mammals, reptiles, birds) on piping plover productivity at Program-managed nesting sites.
- Complete research to provide a deeper understanding of the relationship between wet meadows and river stage.

IV. EXTENSION "BIG QUESTIONS"

The following set of "Big Questions", organized by science priority categories, are intended to serve as common organizing questions for addressing key areas of uncertainty for the Program and also to serve as a device for communicating with the GC on how science learning connects to decision-making as a helpful input. **Table 1** presents the Big Questions and the underlying hypotheses that will be tested and explored as means to answer each Big Question. New Big Questions or additional specific hypotheses may be added over time once questions are conclusively answered or if science learning points the Program in a different direction.

Table 1. PRRIP Extension Big Questions and priority hypotheses.

PRRIP Extension Big Questions (EBQ) & Priority Hypotheses (H)

Extension Science Priority – Active Learning

EBQ #1 – How effective is it to use Program water to maintain suitable whooping crane roosting habitat?

Management H: During drought periods, 30-day minimum germination suppression releases (2,000 cfs target between June 1-July 15) will slow vegetation expansion into the channel and increase the percent of AHR channel that remains highly suitable for whooping crane roosting.

Physical Process H: Vegetation germination and establishment is a function of percent of time bare sand substrate is inundated.

Alternative H: 30-day inundation (2000 cfs target) between June 1 – July 15 is insufficient.

EBQ #2 – How effective is Program management of Phragmites for maintaining suitable whooping crane roosting habitat?

Sub-questions**:**

- How effective have previous Program control efforts (flow, spraying, etc.) been?
- How much do growing season flows influence *Phragmites* expansion/control?

Management H: During drought periods, 30-day minimum channel inundating flow releases (2,000 cfs target between June 1-July 15) in combination with continued herbicide spraying will slow *Phragmites* rhizome/stolon expansion into the channel and increase the percent of AHR channel that remains highly suitable for whooping crane roosting.

Physical Process H: *Phragmites* expansion rates into the active river channel are a function of percent of time bare sand substrate is inundated.

Alternative H: 30-day inundation (2000 cfs target) between June 1 – July 15 is insufficient.

EBQ #3 – Is sediment augmentation necessary to create and/or maintain suitable whooping crane habitat?

Management H: Full scale sediment augmentation (60,000 – 80,000 tons annually in south channel below J2 Return) is necessary to offset the sediment deficit and halt narrowing and incision.

Alternative H: More or less sediment must be augmented to offset the south channel deficit.

EBQ #4 – Does flow influence WC decision to stop or fly over the AHR?

Management H: Probability of a whooping crane stopping and roosting within the AHR (vs. flying over) is a function of discharge.

Physical Process H: The probability of a WC stopover is a function of the relationship between wetted width and the percent of the channel that is of suitable depth for roosting (< 1 ft deep).

Alternative H: Time of day is the primary driver of WC stopovers with probability of use increasing with decreasing time until dark.

PRRIP Extension Big Questions (EBQ) & Priority Hypotheses (H)

EBQ #5 – Does flow influence WC stopover length within the AHR?

Management H: Length of WC stopover within the AHR is a function of discharge.

Physical Process H: WC stopover length is a function of the relationship between wetted width and the percent of the channel that is of suitable depth for roosting (< 1 ft deep).

Alternative H: Length of stay within the AHR has an inverse relationship with length of stay at the previous stopover and a direct relationship with distance traveled since last stopover.

EBQ #6 – Why is spring WC use of the AHR greater than fall WC use?

Management H: WC use of the AHR in the Spring vs. the Fall is a function of discharge, with higher use occurring in the Spring concurrently with higher discharge.

Physical Process H: WC use of the AHR is a function of the relationship between wetted width and the percent of the channel that is of suitable depth for roosting (<1 ft deep).

Alternative H: WC use of the AHR in the Spring is greater because WC do not stage in other areas prior to reaching the Platte, WC are further along in migration when they arrive, distance traveled since last stopover is longer, and stay length at previous stopovers is shorter when compared to Fall migration.

*EBQ #7 – What effect do Program flow management actions have on pallid sturgeon use of the lower Platte River?**

Pallid sturgeon genetics research

Learning Objective$_1$: Establish new genetic baselines for species identification and addressing hybridization.

Learning Objective$_2$: Identify spawning pallid sturgeon adults and age-0 pallid sturgeon collected on the lower Platte River and its confluence with the Missouri River to confirm successful spawning and recruitment.

Learning Objective$_3$: Reassess pallid sturgeon population dynamics and estimate effective population size.

Pallid sturgeon habitat and spawning research

Learning Objective$_1$: Assess pallid sturgeon use of the lower Platte River and its tributaries.

Learning Objective$_2$: Relate pallid sturgeon seasonal movements and spawning behavior to environmental patterns on the lower Platte River and its tributaries.

Learning Objective$_3$: Identify and describe pallid sturgeon spawning habitat on the lower Platte River and its tributaries.

Learning Objective$_4$: Verify successful pallid sturgeon spawning on the lower Platte River and its tributaries and recruitment from the lower Platte River to the Missouri River.

* A 3-step plan for addressing this Big Question is outlined in the PRRIP Pallid Sturgeon Agreement Framing Document approved by the GC in June, 2021. Summarized for EBQ#7 are the learning objectives for Step 1 of this plan. As research is further developed and information is obtained to generate more plausible hypotheses and predicted outcomes related to the agreed upon learning objectives, formal hypotheses for testing will be added to the Extension Science Plan. Results of formal tests of hypotheses will later feed into a Program Water Management Study and guidance for Program water operations through the remainder of the Extension and into the Second Increment.

Extension Science Priority – Maintenance Learning

EBQ #8 – How much of an effect does predation have on PP productivity?

<u>Learning Objective$_1$</u>: Quantify the impact of predation on PP productivity.

<u>Learning Objective$_2$</u>: Identify predator species responsible for losses.

<u>Learning Objective$_3$</u>: Determine when losses are incurred, at the nest or during brood rearing.

<u>Learning Objective$_4$</u>: Utilize population viability models to predict what effect decreases in fledge ratios due to predation may mean in terms of future PP breeding pairs on the central Platte River.

EBQ #9 – How effective is Program management at mitigating losses of PP productivity due to predation?

<u>Learning Objective$_1$</u>: Evaluate effectiveness of trapping, fencing, and/or predator deterrent lighting at reducing nest/brood failure due to predation.

<u>Learning Objective$_2$</u>: Develop predator management alternatives based upon learning through remote camera/video monitoring.

<u>Learning Objective$_3$</u>: Evaluate the necessity for additional predator management based upon PP response to predation over time.

EBQ #10 – Wet meadows research *(NOTE: this is a carryover task from the First Increment)*

<u>Learning Objective$_1$</u>: Understand relationships between hydrological and meteorological variables and groundwater levels at natural wet meadow sites.

<u>Learning Objective$_2$</u>: Understand what constitutes a functional hydrological regime for wet meadows along the central Platte River valley which can be used as a reference and applied to manage other sites.

<u>Learning Objective$_3$</u>: Develop a modeling tool that can be used by land managers in the central Platte River valley to inform management decisions.

Attachment 2 provides more detail on each of the priority hypotheses, including X-Y graphs, predicted findings to match against collected data over time, and connections to critical relationships as identified in updated Conceptual Ecological Models (CEMs) for the target species and for key river processes linked to Program management actions. **Attachment 3** details an approach to implementing management actions related to the science priorities and Big Questions, a timeline plotting out science priorities over the length of the Extension, a more detailed flow chart of management actions and science activities conducted through the Extension with decision points through time, and all monitoring and research protocols updated and revised as they stand in early 2022. **Attachment 4** details anticipated approaches to data analysis, graphs, figures, and other data communication tools; an explanation of how learning against the Big Questions and science priorities learning be summarized, subjected to independent science review, and communicated to the GC; and describes the anticipated use of decision-making tools like Structured Decision Making (SDM) to help the GC operationalize scientific and technical information as a useful input to decision-making. The Executive Director's Office (EDO) anticipates annually developing a State of the Platte Report and conducting an annual Science Plan Reporting Session as means to present the latest status/trends and conclusions related to collected data; to expose this information to the Technical Advisory Committee (TAC) and Independent Scientific Advisory Committee (ISAC) to ensure scientific rigor; and to communicate the latest findings to the GC.

V. EXTENSION SCIENCE UNCERTAINTY "PARKING LOT"

Table 2 describes a set of science uncertainties that could be addressed during the Extension if the Big Questions and hypotheses identified above are resolved, if they warrant focused investigation because their potential impacts on GC decision-making and Program management actions are apparent, and if there are available resources (staff time, funding, etc.) to conduct research, monitoring, or other necessary activities.

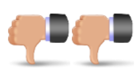
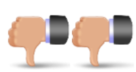
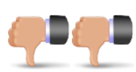
1 **Table 2.** PRRIP Extension science uncertainty "parking lot".

2

Uncertainty	Research, Monitoring, or Management?	Purpose (expected result)	How would this inform GC decision-making?
What is the AHR contribution to overall WC fitness?	Define WC fitness; research on fitness before, during, and after migration; monitoring of WC use of AHR during spring and fall migration	Insight into survival of WC post-migration as a result of AHR habitat use	Possible information to use in Program water management
What is the importance of the AHR to WC survival in the fall migration versus the spring migration?	Link to fitness research; monitoring of WC use of AHR during spring and fall migration	Insight into seasonal survival of WC post-migration as a result of AHR habitat use	Possible information to use in Program water management
What are the effects of J2 hydro-stepping on WC use of the AHR?	Research (table-top exercise with existing flow and WC data)	Possible guidance for J2 operations to reduce impacts	New hydrocycling agreement between Service, Central, and Program
What is the contribution of Program water management to wet meadow hydrology?	Expanded wet meadow hydrology research	Deeper insight into the relationship between river stage and wet meadows hydrology and health	Possible information to use in Program water management
How important is it to WC to use Program water to avoid fish kills?	WC foraging research; link to fitness research	Insight into summer flow requirements	Possible information to use in Program water management
How does the impact of predation on PP productivity change as nesting sites age?	Continued predation research and predator management; continued PP productivity monitoring during the summer nesting season	Long-term viability of Program PP nesting sites	Might inform management of current PP nesting sites and/or acquisition of new PP nesting sites
Are there enough forage resources at off-channel nesting sites to maintain PP productivity?	Research (expanded PP forage habits study)	Long-term viability of Program PP nesting sites	Might inform management of current PP nesting sites and/or acquisition of new PP nesting sites

3

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM (PRRIP -or- Program)
Extension Science Plan Attachment #1 – First Increment Big Question Status

PRRIP Big Question	2019 Assessment	Reassessment Triggers
Implementation – Program Management Actions and Habitat		
1. Will implementation of SDHF produce suitable tern and plover riverine nesting habitat on an annual or near-annual basis?		On-channel nesting on natural sandbar habitat following peak flow event(s)
2. Will implementation of SDHF produce and/or maintain suitable whooping crane riverine roosting habitat on an annual or near-annual basis?		Relationship between flow and whooping crane habitat is an Extension focus – will be addressed directly.
3. Is sediment augmentation necessary for the creation and/or maintenance of suitable riverine tern, plover, and whooping crane habitat?		Big Question carried forward into Extension – will be addressed directly.
4. Are mechanical channel alterations (channel widening and flow consolidation) necessary for the creation and/or maintenance of suitable riverine tern, plover, and whooping crane habitat?		Relationship between mechanical management actions and whooping crane habitat is an Extension focus – will be addressed directly.
Effectiveness – Habitat and Target Species Response		
5. Do whooping cranes select suitable riverine roosting habitat in proportions equal to its availability?		Whooping crane habitat selection analysis will be rerun on a five-year interval to identify changes in selection.
6. Does availability of suitable nesting habitat limit tern and plover use and reproductive success on the central Platte River?		Greater than ??% drop in piping plover breeding pairs per acre of suitable OCSW habitat over XX? years.
7. Are both suitable in-channel and off-channel nesting habitats required to maintain central Platte River tern and plover populations?		Increase in on-channel nesting with corresponding decrease in off-channel nesting.
8. Does forage availability limit tern and plover productivity on the central Platte River?		Observations of emaciated adults/chicks and/or drop in productivity that is not attributable to weather or predation.
9. Do Program flow management actions in the central Platte River avoid adverse impacts to pallid sturgeon in the lower Platte River?		Pallid sturgeon questions will be directly addressed during the Extension as part of genetics and habitat research projects.
10. Do Program management actions in the central Platte River cumulatively 1) produce detectable changes in the physical environment (i.e. habitat) and 2) result in a detectable increase in tern, plover, and whooping crane use of the Associated Habitats?	**LTPP Off-Channel** Habitat:  Species Response:  **WC On-Channel** Habitat:  Species Response: 	• LTPP Off-Channel: Greater than ??% drop in piping plover breeding pairs per acre of suitable OCSW habitat over XX? years. • WC On-Channel: Decreasing trend in proportion of the population using the AHR over XX? Years.

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM (PRRIP -or- Program)

Extension Science Plan Attachment #2 – CEMs & Priority Hypotheses

EVALUATION AND REFINEMENT OF CONCEPTUAL ECOLOGICAL MODELS (CEMs)

CEMs provide a visual framework or graphical representation for the Program's current or hypothesized understanding of the central and lower Platte River associated habitats relative to the target species. The conceptual models describe general functional relationships among essential components of the Platte River system, present an interpretation of how the Platte River system works, and reflect how Program management actions intend to alter key processes or attributes. CEMs are also used to identify areas of uncertainty relevant to Program decision-making to be evaluated and reduced through the application of adaptive management. During the Extension, the CEMs will be reviewed on a regular basis as new information becomes available and will be modified as warranted based on science learning from implementation of the Science Plan.

How were these CEMs developed?

The CEMs presented are revised versions of the CEMs included in the original AMP (Program, 2006a) that was negotiated as part of the Final Program Document (Program, 2006b). The revised CEMs were first developed by the Executive Director's Office (EDO) based on a large set of source material:

- Original CEM and priority hypotheses in the AMP.
- Synthesized learning from the First Increment as summarized in six (6) State of the Platte reports (2012, 2013, 2014, 2015, 2016, 2019).
- Peer-reviewed Program synthesis documents – [1]Tern and Plover Habitat Synthesis Chapters (EDO, 2015), Whooping Crane Habitat Synthesis Chapters (EDO, 2017).
- Program manuscripts published in refereed journals.
- CEMs developed for adaptive management programs on the Missouri River (Wildhaber et al., 2007; Buenau et al., 2016).
- Several publications on the subject of CEMs and their use in recovery, restoration, and adaptive management programs, including Ogden et al., 2005; Fischenich, 2008; and Nelitz et al., 2015.
- Review of publications recently provided from the U.S. Fish and Wildlife Service on the use of conceptual models in Structured Decision Making (SDM) numerical modeling exercises, including Martin et al., 2011; Stenton et al., 2011; and Webb et al., 2015.

The CEMs were discussed with and have been revised in conjunction with the Adaptive Management Working Group (AMWG) and the Independent Scientific Advisory Committee (ISAC) through a series of workshops and webinars in 2020-2021 as part of the development of this revised content for the Science Plan. The final CEM will be evaluated by the Technical Advisory Committee (TAC) and approved by the Governance Committee (GC) as part of approval of the revised Science Plan. Future updates to the CEM will be completed by the EDO, AMWG, and TAC with input from the ISAC and will be approved by the GC.

---

[1] The interior least tern was delisted in 2021 but is expected to remain a Program target species throughout the Extension. It has not been removed from the CEM but all hypotheses are specific to the piping plover.

General Structure of CEMs and Uncertainties

- **Drivers** are underlying factors that determine much of the dynamics of the Platte River system, but do not themselves determine physical riverine or target species responses. The drivers include social, political and economic factors in the basin that are the basis for the development and implementation of the Program and climate which is largely determinative of basin runoff.

- **Habitat management actions** represents management actions the Program or other entities may undertake during the Extension to improve quality or quantity of target species habitat.

- **Physical factors** include environmental conditions that drive Platte River structure and function and that link drivers to hydrological and geomorphological responses.

- **Habitat responses** describe the expected responses of target species habitat to Program management actions and physical factors.

- **Species management actions** describe additional Program management actions that, in combination with habitat management, are expected to result in a target species response.

- **Productivity factors** are a set of factors through which drivers, habitat management, and species management act to directly influence target species behavior and productivity.

- **Species performance indicators** describe and measure target species behavior and productivity in response to habitat management, physical factors, habitat responses, species management, and interactions with other species (predation). Species performance includes the indicators (metrics) used to evaluate the relationships identified in the conceptual ecological model and the responses of the target species to Program management actions.

- **Management objectives** are Program identified goals for providing benefits to target species.

- **Other factors** are larger-scale influences on species performance that are outside the control of the Program but that may have a large, if not determinative, effect on the species.

The CEMS were developed with enough detail to allow for continued evaluation of the depicted relationships and to identify and explore critical remaining uncertainties that can be related to Program management and decision-making.

Key to CEM Figures

- **High Focus During Extension (solid boxes)** – Based on Program learning, these components and relationships are anticipated to be effective at meeting Program management objectives during the Extension. As such, these will be the primary focus of research, monitoring, and associated data analysis and synthesis during the Extension.

- **Low Focus During Extension (partially transparent boxes)** – Based on Program learning, it is anticipated that these components and relationships will be ineffective at meeting Program management objectives during the Extension. As such, these will not be a focus of research, monitoring, and associated data analysis and synthesis during the Extension.
- **High Control – High Uncertainty (heavy red arrows)** – These relationships are the primary focus of adaptive management during the Extension. These represent areas of critical uncertainty that require reduction through research, monitoring, and associated data analysis and synthesis. Each heavy red arrow is accompanied by a red boxed number to identify the uncertainty. The red boxed numbers carry over to the tables that follow each CEM and provide more detail on the statement of the uncertainty as a Big Question, potential language for underlying hypotheses and competing hypotheses, potential management actions, key data to be collected, and the source of those data.

- **Low Control – High Uncertainty** (light red arrows) – These relationships indicate uncertainty but the lack of ability on the part of the Program to implement management actions to affect these relationships reduces the level of uncertainty to a second tier that likely will not be the subject of adaptive management focus during the Extension.

- **High Control – Low Uncertainty (heavy black arrows)** – These relationships can be affected by Program management actions but are not uncertain in terms of target species responses due to existing knowledge or the synthesis of Program learning from the First Increment.

- **Low Control – Low Uncertainty** (light black arrows) – These relationships are not uncertain in terms of target species responses but are also not able to be significantly affected by Program management actions.

Black boxes represent the grouping of similar components to minimize the number of connecting lines and reduce model complexity to improve readability and enhance focus on a smaller number of the most relevant uncertainties.

Whooping Crane Conceptual Ecological Model (CEM) and Sub-models

This section contains a brief description of the components of the CEM for whooping cranes (Table 1), the whooping crane CEM (Figure 1). The whooping crane CEM is followed by two sub-models that represent a deeper explanation of the relationships between hydrology, vegetation, and channel width (Figures 2 and 3). A script providing an explanation of the linkages between CEM and sub-model components and hyperlinked citations to key reference documents is provided in Tables 2 - 4.

Table 1. Description of the components of the CEM for whooping cranes as illustrated in Figure 1.

Component Category	Component	Description
Drivers	Social, Political, Legal, & Economic	Actions that affect the priorities of the Program, how it is implemented, and the bounds of GC decision-making.
	Climate	Basin and regional factors affecting water supply and hydrology, such as annual precipitation, temperature, and resulting weather patterns and their timing and magnitude over multiple years. Climate conditions affect the social, political, legal, and economic factors driving Program management.
Non-Program Habitat Management Actions	Baseflow for fish guilds	USFWS release of water to prevent fish kill, typically in late summer.
	Hydro-stepping	CNPPID operation that incrementally increases flow for more efficient power generation and returns it rapidly to baseflow levels in a repeating pattern during low flow periods typically occurring during Fall WC migration, but also possible depending on natural flows or flow releases during Spring WC migration.
Program Habitat Management Actions	Migration Flow Release	Flows released during the spring and fall whooping crane migration seasons for the purposes of potentially enhancing roosting/foraging conditions and increasing whooping crane use of the AHR. USFWS EA manager decision with input from Program.
	Fall High Flow Release	Late summer or early fall releases of 5,000-8,000 cfs of flow for 3-5 days as measured at Overton for the purposes of removing annual vegetation established within the channel.
	Channel Inundation Flow Releases	Flows maintained during the germination season for the purposes of reducing vegetation establishment within the channel and maintaining wide unobstructed channel widths for whooping cranes.
	Mechanical Channel Maintenance	Disking, herbicide application and mechanical channel-widening activities for creating and maintaining wide unobstructed view widths for whooping cranes and prepping the channel for future summer flow releases to reduce vegetation establishment and for the removal of annual vegetation through peak flow releases.
	Sediment Augmentation	Annual augmentation of sediment for the purposes of reducing the sediment deficit in the channel to reduce or prevent the downstream migration of channel degradation.
	Off-Channel Habitat Creation & Maintenance	The creation and maintenance of suitable off-channel palustrine wetlands and wet meadow habitat for whooping cranes
	Wetland Pumping	Augmentation of water via pumping into palustrine wetlands to increase the acres of suitable off-channel roosting area.
Physical Factors	Hydrology	The movement and quantification of river and ground water through the AHR.
	Channel Width	Width of channel that actively conveys flows at normal discharges.
	Vegetation	Established, dense vegetation ≥2-feet tall.
	Ice	Establishment of ice within the channel with the potential of scouring vegetation during the winter months.

Component Category	Component	Description
Habitat Responses	Acres of Suitable On-Channel Roosting Habitat	Acres of channel with ≥650-foot-wide unobstructed view widths and ≥1,100-foot-wide unforested corridor widths.
	Acres of Suitable On-Channel Foraging Habitat	Acres of channel with ≥650-foot-wide unobstructed view widths and ≥1,100-foot-wide unforested corridor widths.
	Acres of Off-Channel Roosting Habitat	Acres of palustrine wetlands within the AHR.
	Acres of Off-Channel Foraging Habitat	Acres of Program-defined wet meadow habitat and agricultural fields suitable for whooping crane foraging within the AHR.
Performance Indicators	Proportionate Use	Proportion of the annual population, as determined at Aransas National Wildlife Refuge, observed using the AHR through Program monitoring efforts.
	Distribution of Use	Distribution of whooping crane use locations within the AHR.
	Length of stay	Number of use days by a unique WC group within the AHR.
	On-Channel Roosting	Abundance of whooping cranes observed in the channel within the AHR during twilight, dusk, dawn, and overnight hours.
	On-Channel Foraging	Abundance of whooping cranes observed in the channel within the AHR during daylight hours.
	Off-Channel Roosting	Abundance of whooping cranes observed off-channel within the AHR during twilight, dusk, dawn, and overnight hours.
	Off-Channel Foraging	Abundance of whooping cranes observed off-channel within the AHR during daylight hours.
Management Objective	Contribute to Survival	Contribution to whooping crane migratory survival which results in population growth.
	Contribute to Reproduction	Contribution to whooping crane reproduction which results in population growth.
Other Factors	Migratory Habitat Conditions	Suitable roosting and foraging habitat within the migration corridor but outside the AHR.
	Natural Flows	Flows within the AHR not including EA released water or Program flow augmentation through groundwater recharge and other projects.
	Breeding Ground Conditions	Conditions on the breeding ground including nesting habitat availability and suitability, forage, weather, etc.
	Wintering Ground Conditions	Conditions on the wintering ground including forage availability, weather, etc.
	Spring vs. Fall	Migratory patterns vary depending on season.
	Stochastic Events	Factors such as disease outbreak, hurricane, etc. that influence the overall size or health of the population.

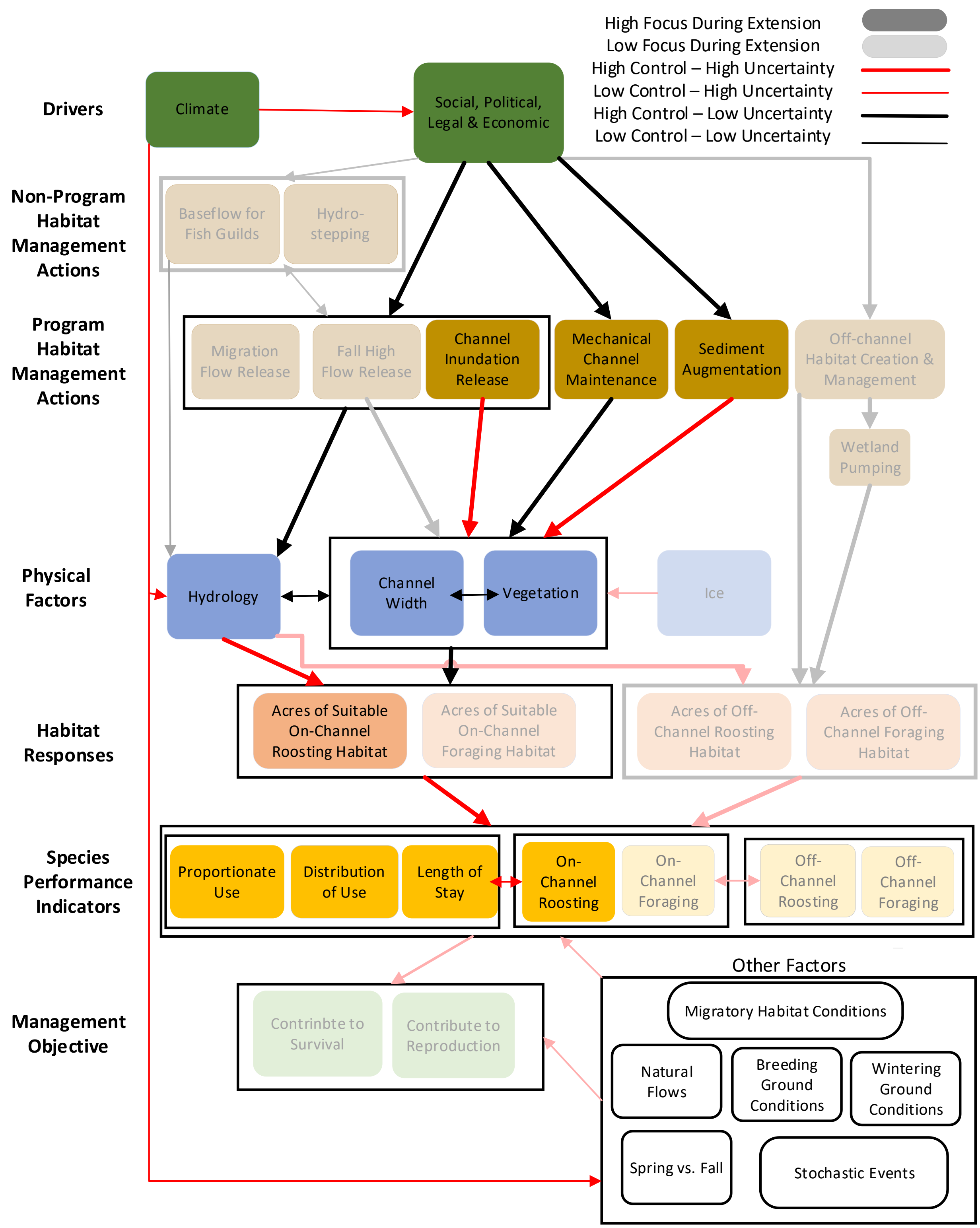


Figure 1. Whooping Crane Conceptual Ecological Model (CEM)

Table 2. Descriptions of hypothesized relationships between components in the whooping crane CEM (Figure 1) depicting level of uncertainty about and control over this relationship (arrow color & weight) with accompanying literature in support of these designations.

Starting Component(s)	Arrow Color & Weight	Ending Component(s)	Description	Data Sources & Citations
Climate		Social, Legal, Political, & Economic	Social, legal, political, & economic factors form the basis of the Program but the ability to implement the Program is influenced by climate, particularly related to water availability. The goals and objectives of the Program influence management decisions and their responses to climate.	Final Program Document; Extension Document; climate change input as part of operational model
Climate		Hydrology	Large amount of uncertainty relative to future impacts of climate on hydrology and the ability of the Program to model potential impacts and use those modeling results in Program planning and implementation. But the Program has no control over the effects of climate on water availability.	Water operations model using historic hydrology for wet and dry years
Climate		Migratory Habitat Conditions/Breeding Ground Conditions/Wintering Ground Conditions/Natural Flows/Spring vs. Fall/Stochastic Events	Large amount of uncertainty relative to future impacts of climate on habitat and other conditions outside the AHR. 2019 PVA Report for Species Metapopulation of Whooping cranes listed lower potential recruitment related to climate as one important factor that may reduce growth rates of the Aransas-Wood Buffalo population.	Gil-Weir et al. 2012; Traylor-Holzer 2019
Climate		Proportionate Use/Distribution of Use/Length of Stay/On- and Off-Channel Foraging or Roosting	Large amount of uncertainty relative to future impacts of climate on migratory season weather conditions, hydrology, and habitat availability within the AHR and along the wider migratory corridor. The Program has no control over the effects of climate on whooping crane use of the AHR. Uncertainty around the Program's ability to model potential impacts and use those modeling results in Program planning and implementation.	Water operations model using historic hydrology for wet and dry years. Gil-Weir et al. 2012; Traylor-Holzer 2019
Social, Legal, Political, & Economic		Baseflow for Fish Guilds/Hydro-stepping	Program has limited control over these water uses that effect the amount of water available for management actions and in turn the ability of the Program to manage and control water actions in the AHR.	USFWS Target Flow Releases; CNPPID water operations guidelines.
Social, Legal, Political, & Economic		Migration Flow Release/Fall High Flow Release /Channel Inundation Release	Little uncertainty about the bounds of the Program, resources, water law, etc. that effect the amount of water available for management actions and in turn the ability of the Program to manage and control water actions in the AHR.	Final Program Document; Extension Document; AMP Versions 1.0 and 2.0
Social, Legal, Political, & Economic		Mechanical Channel Maintenance	Little uncertainty about the bounds of the Program, resources that effect the amount of land available for management actions and in turn the ability of the Program to apply mechanical actions in the AHR.	Final Program Document; Extension Document; AMP Versions 1.0 and 2.0
Social, Legal, Political, & Economic		Sediment Augmentation	Little uncertainty about the bounds of the Program, resources that effect the amount sediment augmentation activities and in turn the ability of the Program to augment sand in the AHR.	Final Program Document; Extension Document; AMP Versions 1.0 and 2.0

Starting Component(s)	Arrow Color & Weight	Ending Component(s)	Description	Data Sources & Citations
Social, Legal, Political, & Economic		Off-Channel Habitat Creation & Maintenance	Little uncertainty about the bounds of the Program, resources that effect the amount of land available for management actions and in turn the ability of the Program to create and maintain off-channel habitat in the AHR. Lack of suitable off-channel palustrine wetland sites led the GC to focus management toward on-channel habitat for whooping cranes.	Final Program Document; Extension Document; AMP Versions 1.0 and 2.0
Baseflow for Fish Guilds/Hydro-stepping		Migration Flow Release/Fall High Flow Release/Channel Inundation Release	Trade-offs between water usage within and outside Program control. Little uncertainty about how these water uses reduce water availability for Program water management, but Program does not have unilateral control over these flow releases.	Water operations modeling
Baseflow for Fish Guilds/Hydro-stepping		Hydrology	Little uncertainty about how these water management activities impact river hydrology, but Program does not have unilateral control over these flow releases.	Gaging station data
Migration Flow Release/Fall High Flow Release/Channel Inundation Release		Hydrology	Little uncertainty about the relationship between Program flow management and river hydrology but the Program cannot control other important factors such as natural peak flow events.	PRRIP 2017; Tetra Tech 2017; Water operations modeling and gaging station data
Fall High Flow Release		Channel Width/Vegetation	Program learning that indicates a spring SDHF as envisioned in AMP Version 1.0 will not result in intended effects on whooping crane habitat. Fall high flow release given lower priority for learning in favor of spring channel inundation flow releases to suppress germination.	PRRIP 2017; Tetra Tech 2017; Farnsworth et al. 2018; Geomorphology and In-channel Vegetation Monitoring data
Channel Inundation Release		Channel Width/Vegetation	Important uncertainty to explore - ability of Program to manage available water to impede vegetation germination and *Phragmites* expansion and thus maintain or expand unvegetated channel width.	Hosner 1958; Karlinger et al. 1981; Currier 1982; Carter-Johnson 1994; Currier 1997; Knezevic et al. 2008; Rapp 2012; PRRIP 2019; Marks & Atia 2020; Geomorphology and In-channel Vegetation Monitoring modeling; Water operations modeling; Gaging station data
Mechanical Channel Maintenance		Channel Width/Vegetation	Strong relationship between mechanical channel maintenance and channel width and vegetation. Effectiveness of herbicide on controlling *Phragmites* has not been quantified, but important for building a long-term strategy for maintaining and expanding unvegetated channel width.	Tetra Tech 2017; Farnsworth et al. 2018; Geomorphology and In-channel Vegetation Monitoring data. Annual Aerial Herbicide application (*Phragmites* spraying) data

Starting Component(s)	Arrow Color & Weight	Ending Component(s)	Description	Data Sources & Citations
Sediment Augmentation		Channel Width/Vegetation	Important uncertainty to evaluate. Sediment augmentation necessary to prevent incision and subsequent narrowing (due to sediment deficit from J-2 Return) from moving downstream past the Overton Bridge.	Tetra Tech 2017; The Flatwater Group 2014; PRRIP 2018; Geomorphology and In-channel Vegetation Monitoring data
Off-Channel Habitat Creation & Maintenance		Acres of Suitable Off-Channel Roosting/Foraging Habitat	Little uncertainty about the ability of the Program to create and maintain off-channel habitat in the AHR. WC do use off-channel habitat mainly for diurnal foraging largely in agricultural fields. Use of wet meadows has been limited and use of Program-managed palustrine wetlands has not been observed. There is only so much of that habitat that can be acquired/developed/managed by the Program.	Baasch et al. 2017; Howlin and Nasman 2017; PRRIP 2018; Baasch et al. 2019; PRRIP 2021
Wetland Pumping		Acres of Suitable Off-Channel Roosting/Foraging Habitat	Wetland pumping can be used to fill wetlands created for WC use, but WC use of these palustrine wetlands has been low within the AHR.	Baasch et al. 2017; PRRIP 2018; PRRIP 2021
Hydrology		Channel Width/Vegetation	Interactive effects of hydrology, channel width, and vegetation. Influence of vegetation ratchet effect.	Farnsworth et al. 2018; Baasch et al. 2017; Bankhead et al. 2017
Channel Width		Vegetation	Interactive effects of hydrology, channel width, and vegetation. Influence of vegetation ratchet effect.	Pollen-Bankhead et al. 2014; Baasch et al. 2017; Farnsworth et al. 2018
Ice		Channel Width/Vegetation	Likely an important relationship to explore and understand but very difficult for the Program to control, experiment, or monitor to learn.	PRRIP 2019
Hydrology		Acres of Suitable On-Channel Habitat	Important uncertainty. Connection between Program flow management activities, acres of suitable on-channel habitat, and whooping crane use.	Baasch et al. 2017; Farnsworth et al. 2018; Baasch et al. 2019; Gaging station data; Geomorphology and In-channel Vegetation Monitoring data
Hydrology		Acres of Suitable Off-Channel Habitat	Uncertainty remaining about the connection between Program flow management activities and wet meadow hydrology. Existing literature suggests saturation, inundation, and/or shallow groundwater during the months of April - June are driving factors behind wet meadow vegetation persistence. The relative contribution of river flow and precipitation to shallow groundwater levels remains to be determined. WC use of these off-channel wetland has been limited in the AHR.	Wesche et al. 1994; Henszey et al. 2004; Chen 2007; Chavez Ramirez and Weir 2011; Baasch et al. 2019; EDO 2021

1

Starting Component(s)	Arrow Color & Weight	Ending Component(s)	Description	Data Sources & Citations
Channel Width/Vegetation		Acres of Suitable On-Channel Habitat	Program learning supports WC use of wide unvegetated channels and banks cleared of riparian forest. Program mechanical management and large natural high flow events can have a large impact on this.	Baasch et al. 2017; Howlin and Nasman 2017; Pearse et al. 2017; Baasch et al. 2019; Baasch et al. 2019
Acres of Suitable On-Channel Habitat		Proportionate Use/Distribution of Use/Length of Stay/On-Channel Foraging or Roosting	Important uncertainty to explore during the Extension. High uncertainty about the relationship between flow management during migration and whooping crane use. Learning to date on a use site scale suggests the link between flow and WC use may be tentative. Program learning supports unvegetated widths and distance to nearby forest as being more important for WC use.	Pearse et al. 2017; Baasch et al. 2017; Howlin and Nasman 2017; Baasch et al. 2019; Baasch et al. 2019
Acres of Suitable Off-Channel Habitat		Proportionate Use/Distribution of Use/Length of Stay/Off-Channel Foraging or Roosting	WC do use off-channel habitat mainly for diurnal foraging largely in agricultural fields. Use of wet meadows has been limited and use of Program-managed palustrine wetlands has not been observed.	Baasch et al. 2017; Howlin and Nasman 2017; Pearse et al. 2017; Baasch et al. 2019; EDO 2021
On-Channel Roosting/Foraging		Off-Channel Roosting/Foraging	Likely an important behavioral relationship. Diurnal use sites both on and off-channel are selected in closer proximity to the previous night's roosting site.	Howlin and Nasman 2017
On-Channel Roosting		Proportionate Use/Distribution of Use/Length of Stay	Important relationship to explore. WC behavioral patterns likely important for proportionate use, distribution of use, and length of stay. Performance indicators highly interdependent.	Baasch et al. 2017; Howlin and Nasman 2017; Pearse et al. 2017; Baasch et al. 2019; Baasch et al. 2019; Pearse et al. 2020
Proportionate Use/Distribution of Use/Length of Stay/On- and Off-Channel Roosting and Foraging		Contribute to Survival/Reproduction	Stopovers along migratory corridor provide essential roosting habitat and energetic resources for successful migration. However, the migratory nature of WC, brief stopover use of AHR along, low numbers and bias with telemetry birds, and natural low variability in adult survival and reproduction parameters make determining this relationship difficult. Collaboration with research partners may help us obtain data for survival and reproduction.	Gil-Weir et al. 2012; Wilson et al. 2016; Pearse et al. 2019; Pearse et al. 2020; Final Program Document
Migratory Habitat Conditions/ Natural Flows/Breeding Ground Conditions/ Wintering Ground Conditions/ Spring vs Fall Use Patterns/Stochastic Events		Proportionate Use/Distribution of Use/Length of Stay/On- and Off-Channel Roosting and Foraging	These factors likely have significant impacts on whooping crane use of the AHR but are outside the control of the Program.	Moore et al. 2005, Pearse et al. 2018, Pearse et al. 2020
Migratory Habitat Conditions/ Natural Flows/Breeding Ground Conditions/ Wintering Ground Conditions/ Spring vs Fall Use Patterns/Stochastic Events		Contribute to Survival/Reproduction	These factors likely have significant impacts on the whooping crane population but are outside the control of the Program.	Gil-Weir et al. 2012; Wilson et al. 2016; Pearse et al. 2019; Traylor-Holzer 2019; Pearse et al. 2020; Final Program Document

Annual and Perennial Vegetation Establishment Sub-model (Figure 2)

This sub-model relates the potential channel inundation flow release, fall high flow release, herbicide and disking to vegetation suppression and vegetation scour. A script providing an explanation of the linkages between sub-model components and hyperlinked citations to key reference documents is provided in Table 3.

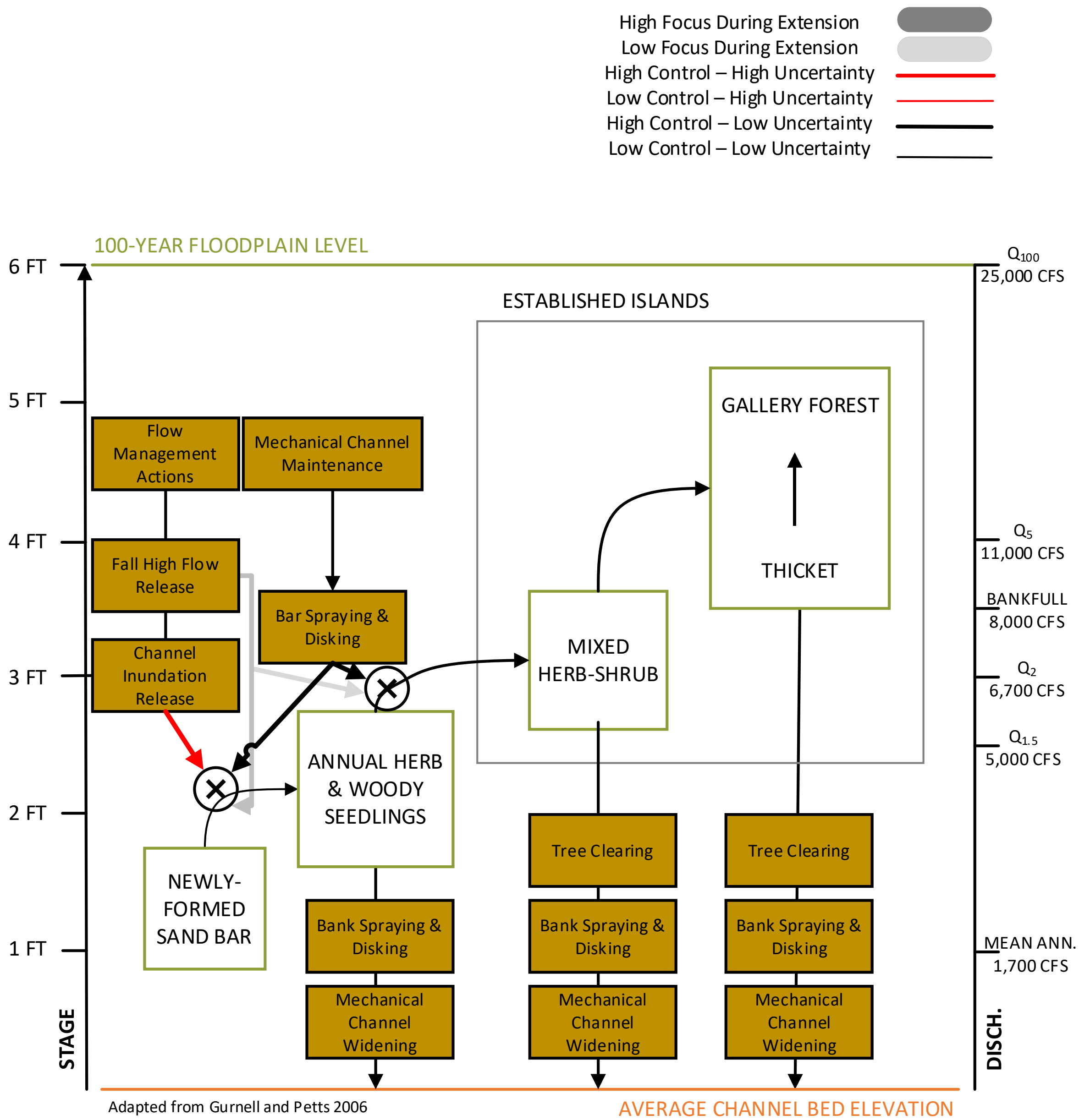


Figure 2. Annual and perennial vegetation establishment sub-model.

1 **Table 3.** Descriptions of hypothesized relationships between components in the annual and perennial vegetation sub-model (Figure 2) depicting level of
2 uncertainty about and control over this relationship (arrow color & weight) with accompanying literature in support of these designations.

Starting Component(s)	Arrow Color & Weight	Ending Component(s)	Description	Data Sources & Citations
Fall High Flow Release		Newly Formed Sandbars/Annual Herb and Woody Seedlings	Important uncertainty to explore related to GC policy decision to implement a release 5,000 – 8,000 cfs for three days in September during the Extension and Program learning that indicates a spring SDHF as envisioned in AMP Version 1.0 will not result in intended effects on whooping crane habitat. Fall high flow release given lower priority for learning in favor of spring channel inundation flow releases to suppress germination.	Johnson 1994; Currier 1997; Johnson 1997; Simons and Associates 2000; Murphy et al. 2004; Tetra Tech 2017; Geomorphology and In-channel Vegetation Monitoring data
Channel Inundation Flow Releases		Newly Formed Sandbars	Important uncertainty to explore - ability of Program to manage available water to impede vegetation germination, thus maintain or expand unvegetated channel width.	Hosner 1958; Karlinger et al. 1981; Currier 1982; Johnson 1994; Currier 1997; Johnson 1997, Simons and Associates 2000; Murphy et al. 2004; Tetra Tech 2017; PRRIP 2019; Marks & Atia 2020; Geomorphology and In-channel Vegetation Monitoring modeling; Water operations modeling; Gaging station data
Bar Spraying/Disking		Newly Formed Sandbars/Annual Herb and Woody Seedlings	Strong relationship between mechanical channel maintenance and channel width and vegetation. These management activities take the channel back to a stage-zero riverbed.	Farnsworth et al. 2018
Annual Herb and Woody Seedlings		Bank Spraying and Disking/Mechanical Channel Widening	Strong relationship between mechanical channel maintenance and channel width and vegetation. These management activities take the channel back to a stage-zero riverbed.	Farnsworth et al. 2018
Mixed Herb-Shrub		Tree Clearing/Bank Spraying and Disking/Mechanical Channel Widening	Strong relationship between mechanical channel maintenance and channel width and vegetation. These management activities take the channel back to a stage-zero riverbed.	Farnsworth et al. 2018
Gallery Forest/Thicket		Tree Clearing/Bank Spraying and Disking/Mechanical Channel Widening	Strong relationship between mechanical maintenance and channel width and vegetation. These management activities take the channel back to a stage-zero riverbed.	Farnsworth et al. 2018

3

Phragmites Sub-Model (Figure 3)

This sub-model relates the potential channel inundation flow release and annual herbicide application to the prevention of *Phragmites* germination and expansion. A script providing an explanation of the linkages between sub-model components and hyperlinked citations to key reference documents is provided in Table 4.

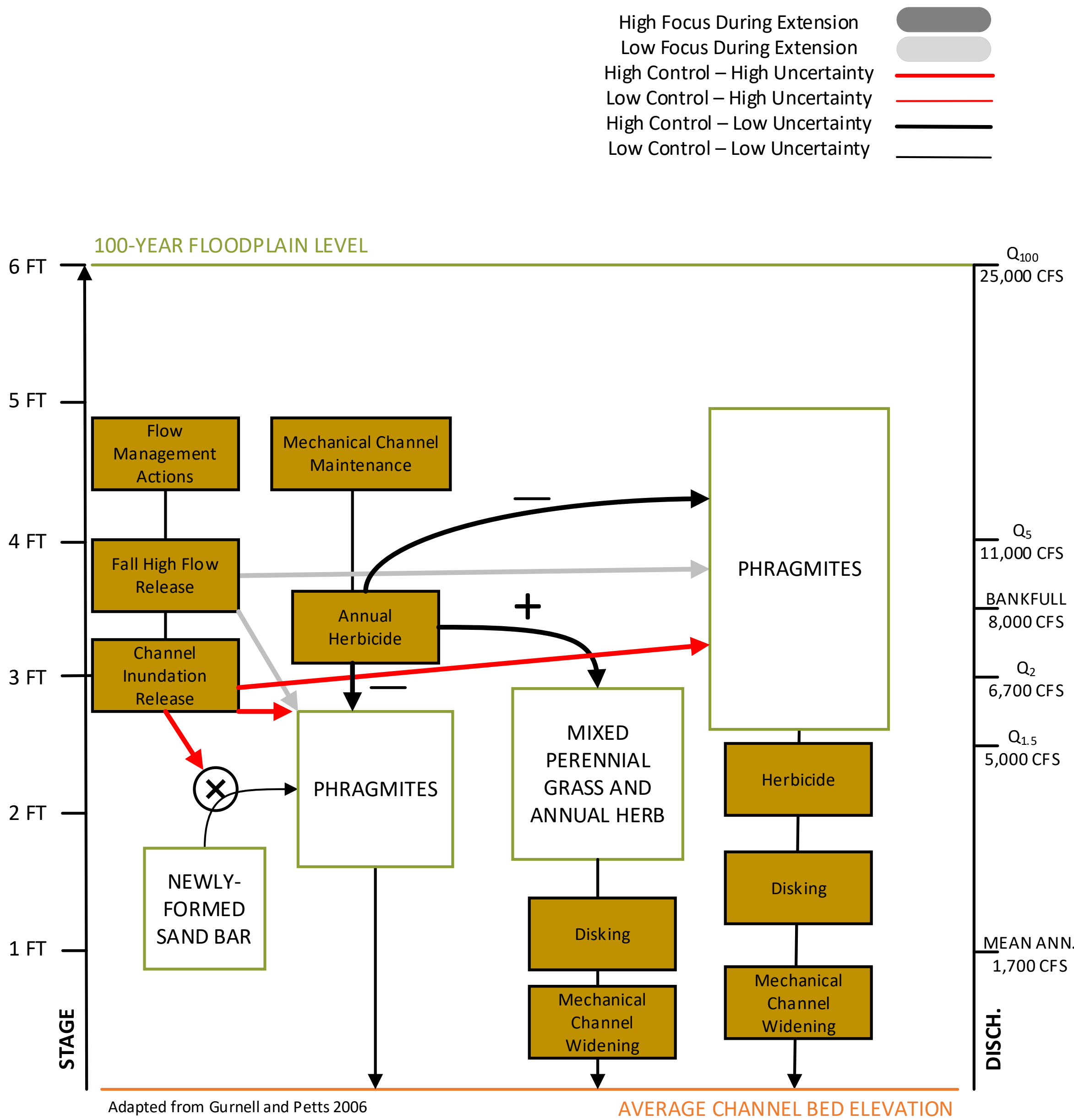


Figure 3. *Phragmites* sub-model.

Table 4. Descriptions of hypothesized relationships between components in the *Phragmites* sub-model (Figure 3) depicting level of uncertainty about and control over this relationship (arrow color & weight) with accompanying literature in support of these designations.

Starting Component(s)	Arrow Color & Weight	Ending Component(s)	Description	Data Sources & Citations
Fall High Flow Release		*Phragmites*	Important uncertainty to explore related to GC policy decision to implement a release 5,000 – 8,000 cfs for three days in September during the Extension and Program learning that indicates a spring SDHF as envisioned in AMP Version 1.0 will not result in intended effects on whooping crane habitat. Fall high flow release given lower priority for learning in favor of spring channel inundation flow releases to suppress germination.	Johnson 1994; Johnson 1997, Currier 1997; Simons and Associates 2000; Murphy et al. 2004; Tetra Tech 2017; Geomorphology and In-channel Vegetation Monitoring data
Channel Inundation Flow Releases		Newly Formed Sandbars/*Phragmites*	Important uncertainty to explore - ability of Program to manage available water to impede *Phragmites* germination and/or expansion and thus maintain or expand unvegetated channel width and improve flow conveyance.	Knezevic et al. 2008; Rapp 2012; PRRIP 2019; Marks & Atia 2020; Geomorphology and In-channel Vegetation Monitoring modeling; Water operations modeling; Gaging station data
Annual Herbicide		Mixed Perennial Grass and Annual Herbs	Herbicide has been shown to be effective for controlling *Phragmites*, though effect size has not been quantified at the scale of the AHR. Herbicide is important for building a long-term strategy for maintaining and expanding unvegetated channel width and flow conveyance.	Knezevic et al. 2008; Rapp 2012; Farnsworth et al. 2018
No Annual Herbicide		*Phragmites*	Herbicide has been shown to be effective for controlling *Phragmites*, though effect size has not been quantified at the scale of the AHR. Herbicide is important for building a long-term strategy for maintaining and expanding unvegetated channel width and flow conveyance.	Knezevic et al. 2008; Rapp 2012;
Mixed Perennial Grass and Annual Herbs		Disking/Mechanical Channel Widening	Strong relationship between mechanical channel maintenance and channel width and vegetation. These management activities take the channel back to a stage-zero riverbed.	Farnsworth et al. 2018
Phragmites		Herbicide/ Disking/Mechanical Channel Widening	Strong relationship between herbicide, disking, mechanical maintenance and channel width and vegetation. These management activities take the channel back to a stage-zero riverbed.	Knezevic et al. 2008; Rapp 2012; Farnsworth et al. 2018

Pallid Sturgeon Conceptual Ecological Model (CEM)

This section contains a brief description of the components of the CEM for pallid sturgeon (Table 5) and the CEM (Figure 4). A script providing an explanation of the linkages between components and hyperlinked citations to key reference documents is provided in Table 6.

Table 5. Description of the components of the CEM for pallid sturgeon as illustrated in Figure 4.

Component Category	Component	Description
Drivers	Social, Political, Legal, & Economic	Actions that affect the priorities of the Program, how it is implemented, and the bounds of GC decision-making.
	Climate	Basin and regional factors affecting water supply and hydrology, such as annual precipitation, temperature, and resulting weather patterns and their timing and magnitude over multiple years. Climate conditions affect the social, political, legal, and economic factors driving Program management.
Habitat Management Actions	Flow Releases	Flow management actions implemented by the Program to benefit target species in the AHR.
	Sediment Augmentation	Annual augmentation of sediment for the purposes of reducing the sediment deficit in the channel to reduce or prevent the downstream migration of channel degradation.
Physical Factors	Hydrology	The movement and quantification of river and ground water through the central and lower Platte River.
	Channel Width/Depth	Width and depth of channel that actively conveys flows at normal discharges.
	Channel Morphology & Structure	Three-dimensional form and composition of the river channel, including bank form, riverbed topography, riverbed substrate, and vegetational structure.
Habitat Responses	Channel Connectivity	Connectivity of the channel suitable for adult pallid sturgeon migration between deeper pools of water.
	Spawning and Incubation Habitat	Areas within the lower Platte River suitable for successful pallid sturgeon spawning and incubation of free-embryos.
	Larval Drift Habitat	Areas within the lower Platte River suitable for drift and development of pallid sturgeon larvae.
	Foraging Habitat	Areas within the lower Platte River suitable for successful pallid sturgeon foraging.
Productivity Factors	Distance from Missouri River	Distance from documented pallid sturgeon use of the lower Platte River to the confluence of the lower Platte with the Missouri River.
	Water Velocity and Depth	Velocity and depth of the water at pallid use locations and associated with pallid spawning, free-embyo/larvae capture.
	Water Temperature	Diurnal temperature of the water at pallid use locations and associated with pallid spawning, free-embryo/larvae capture.
	Dispersal	Turbidity of the water at pallid use locations and associated with pallid spawning, free-embryo/larvae capture.
	Forage availability	Abundance of prey species suitable for pallid sturgeon consumption.
	Predation	The act of predators consuming pallid sturgeon free-embryos, larvae, juveniles and/or adults.

Component Category	Component	Description
Species Performance Indicators	Lower Platte River Use	Abundance, spatial-temporal distribution, and movement of pallid sturgeon using the lower Platte River.
	Lower Platte River Spawning	Abundance of pallid sturgeon using the lower Platte River that demonstrate spawning behavior, successfully release and deposit eggs/sperm to result in fertile pallid sturgeon eggs.
	Free-embryos	Successful hatching of pallid sturgeon
	Larvae Dispersal	The process of pallid sturgeon larvae being distributed via drift.
	Recruitment	The result of successful reproduction and survival of juvenile pallid sturgeon until sexual maturity.
Management Objective	Provide Benefits and/or Avoid/Minimize Impacts	Manage Program water use in a way that contributes to and/or avoids or minimizes negative impacts on pallid sturgeon habitat and reproduction.
Other Factors	Missouri/Other River Conditions	Flows, pallid sturgeon habitat suitability and availability, etc. in rivers outside the lower Platte River.
	Stocking Rates	Rate of pallid sturgeon stocking within the lower Platte River and other river segments including the Missouri River, Yellowstone River, Mississippi River, etc.
	Natural Flows	Flows within the central and lower Platte River excluding EA released water or Program flow augmentation through groundwater recharge and other projects.
	Stochastic Events	Factors such as disease outbreak, drought, etc. that influence the overall size or health of the population.

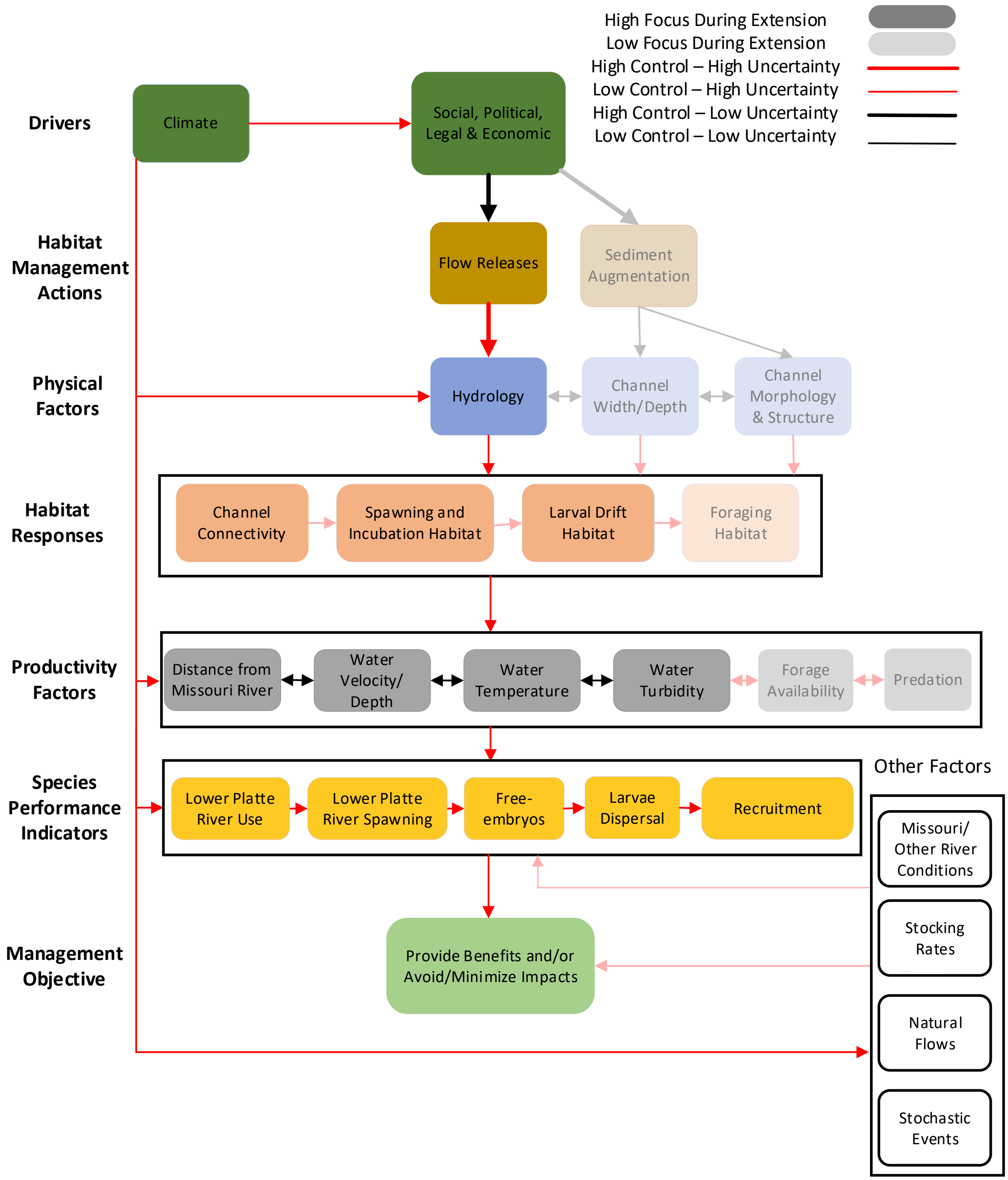


Figure 4. Pallid Sturgeon Conceptual Ecological Model (CEM). *Pallid sturgeon CEM will be updated with information gained from genetic, habitat, and spawning research.*

Table 6. Descriptions of hypothesized relationships between components in the pallid sturgeon CEM (Figure 4) depicting level of uncertainty about and control over this relationship (arrow color & weight) with accompanying literature in support of these designations. *Pallid sturgeon CEM will be updated with information gained from genetic, habitat, and spawning research.*

Starting Component(s)	Arrow Color & Weight	Ending Component(s)	Description	Data Sources & Citations
Climate		Social, Legal, Political, & Economic	Social, legal, political, & economic factors form the basis of the Program but the ability to implement the Program is influenced by climate, particularly related to water availability. Two-way arrow, the goals and objectives of the Program influence management decisions and their responses to climate.	Final Program Document; Extension Document; climate change input as part of operational model
Climate		Hydrology	Large amount of uncertainty relative to future impacts of climate on hydrology and the ability of the Program to model potential impacts and use those modeling results in Program planning and implementation. But the Program has no control over the effects of climate on water availability.	Water operations model using historic hydrology for wet and dry years
Climate		Water Velocity/ Depth/Temperature/ Turbidity/ Forage Availability/ Predation	Large amount of uncertainty relative to future impacts of climate on water velocity, depth, temperature, and turbidity. Uncertainty about the future impacts of climate on pallid forage availability and predation levels. Uncertainty regarding the ability of the Program to model potential impacts and use those modeling results in Program planning and implementation. But the Program has no control over the effects of climate on these variables.	
Climate		Lower Platte River Use/Spawning/Free-embryos/Larvae Dispersal/Recruitment	Large amount of uncertainty relative to future impacts of climate on pallid use of the lower Platte River for spawning, production of viable free-embryos, larval dispersal, recruitment and the ability of the Program to model potential impacts and use those modeling results in Program planning and implementation. But the Program has no control over the effects of climate on these indicators.	
Climate		Missouri/Other River Conditions/Stocking Rates/Natural Flows/Stochastic Events	Large amount of uncertainty relative to future impacts of climate on Missouri River conditions, natural flows, and other stochastic events like disease and the ability of the Program to model potential impacts and use those modeling results in Program planning and implementation. But the Program has no control over the effects of climate on these variables.	
Social, Legal, Political, & Economic		Flow Releases	Little uncertainty about the bounds of the Program, resources, water law, etc. that effect the amount of water available to benefit target species in the AHR.	Final Program Document; Extension Document; AMP Versions 1.0 and 2.0

Starting Component(s)	Arrow Color & Weight	Ending Component(s)	Description	Data Sources & Citations
Social, Legal, Political, & Economic		Sediment Augmentation	Little uncertainty about the bounds of the Program, resources that effect the amount sediment augmentation activities and in turn the ability of the Program to augment sand in the AHR.	Final Program Document; Extension Document; AMP Versions 1.0 and 2.0
Sediment Augmentation		Channel Width/Depth/Morphology & Structure	Sediment augmentation by the Program at J-2 Return is expected to have little to no measurable effect on lower Platte channel width, depth, morphology, or structure.	Tetra Tech 2017
Flow Releases		Hydrology	Little uncertainty about the relationship between Program flow management and river hydrology. Stage change study indicates there is an inability to detect Program flow management actions in the lower Platte but remaining uncertainty about this on the part of some Program parties makes this an area of high uncertainty during the Extension.	Stage change study
Hydrology		Channel Width/Depth/ Morphology/Structure	Program water management has little impact on or control over lower Platte River hydrology to affect channel morphology.	Stage change study
Channel Width/Depth/ Morphology/Structure		Channel Connectivity/Spawning & Incubation Habitat/Larval Drift Habitat/Foraging Habitat	Important area of uncertainty to investigate, but Program has little control over lower Platte River morphology to affect pallid sturgeon habitat.	Peters & Parham 2008; Jacobsen et al. 2014; Jacobsen et al. 2015; DeLonay et al. 2016;
Hydrology		Channel Connectivity/Spawning & Incubation Habitat/Larval Drift Habitat/Foraging Habitat	Part of the large amount of uncertainty regarding pallid sturgeon use, occurrence, spawning, and recruitment in the lower Platte River; the types and use of pallid sturgeon habitat in the lower Platte River and the relationship between these habitat types and hydrology.	Peters & Parham 2008; Hamel et al. 2014; Jacobsen et al. 2014; Jacobsen et al. 2015; DeLonay et al. 2016
Channel Connectivity		Spawning & Incubation Habitat/Larval Drift Habitat/Foraging Habitat	Important area of uncertainty to investigate, but Program has little control over lower Platte River hydrology and geomorphology to connect and potentially expand pallid sturgeon habitat.	Peters & Parham 2008; Jacobsen et al. 2014; Jacobsen et al. 2015; DeLonay et al. 2016;;
Channel Connectivity/Spawning & Incubation Habitat/Larval Drift Habitat/Foraging Habitat		Distance from Missouri River/ Water Velocity/Depth/ Temperature/Turbidity/ Forage Availability/Predation	Part of the large amount of uncertainty regarding pallid sturgeon use, occurrence, spawning, and recruitment in the lower Platte River is centered around identifying and characterizing the various types of pallid sturgeon habitat utilized at different life history stages. The abiotic and biotic factors listed here not only help define habitat, but have also been linked to pallid sturgeon spawning and recruitment.	Peters & Parham 2008; Jacobsen et al. 2014; Jacobsen et al. 2015; DeLonay et al. 2016;

1

Starting Component(s)	Arrow Color & Weight	Ending Component(s)	Description	Data Sources & Citations
Distance from Missouri River		Water Velocity/Depth/ Temperature/Turbidity/ Forage Availability/Predation	As pallid sturgeon move upstream from the Missouri River confluence into the lower Platte River, they encounter changes in the abiotic and biotic factors that influence spawning and successful reproduction, but these factors are out of Program control.	Peters & Parham 2008; Hamel et al. 2014; EDO Pallid Sturgeon Memo
Water Velocity/Depth/ Temperature/Turbidity		Forage Availability/Predation	Little is known about how forage availability and predation changes in response to water velocity, depth, temperature, and turbidity; also outside of Program control.	Jacobsen et al. 2014; Jacobsen et al. 2015
Distance from Missouri River/ Water Velocity/Depth/ Temperature/Turbidity/ Forage Availability/Predation		Lower Platte River Use/Lower Platte River Spawning/Free-embryos/Larvae Dispersal/Recruitment	Part of the large amount of uncertainty regarding pallid sturgeon use, occurrence, spawning, and recruitment in the lower Platte River are abiotic factors used as cues by pallid sturgeon for entering and patterns of movement within the lower Platte River, and for successful spawning and recruitment. Biotic pressures, such as forage availability and predation, that may limit successful pallid reproduction in the lower Platter River and their response to hydrology, channel morphology, and structure remain largely unknown	Peters & Parham 2008; Hamel et al. 2014; EDO Pallid Sturgeon Memo
Lower Platte River Use		Lower Platte River Spawning/Free-embryos/Larvae Dispersal	Important uncertainty for investigation. Direct relationship, outside the control of the Program.	Peters & Parham 2008; Hamel et al. 2014; EDO Pallid Sturgeon Memo
Lower Platte River Spawning/Free-embryos/Larvae Dispersal		Recruitment	Important uncertainty for investigation. Direct relationship, outside the control of the Program	
Missouri/Other River Conditions/Stocking Rates/Natural Flows/Stochastic Events		Lower Platte River Use/Lower Platte River Spawning/Free-embryos/Larvae Dispersal/Recruitment	These factors likely have significant impacts on pallid sturgeon use and spawning in the lower Platte River but are outside the control of the Program.	Peters & Parham 2008
Missouri/Other River Conditions/Stocking Rates/Natural Flows/Stochastic Events		Provide Benefits and/or Avoid/Minimize Impacts	These factors likely have significant impacts on the ability of the Program to provide benefits and/or avoid or minimize negative impacts on pallid sturgeon but are outside the control of the Program.	Final Program Document
Lower Platte River Use/Lower Platte River Spawning/Free-embryos/Larvae Dispersal/Recruitment		Provide Benefits and/or Avoid/Minimize Impacts	Direct relationship with high uncertainty. The ability of the Program to provide benefits and/or avoid or minimize negative impacts on pallid sturgeon will depend upon documented use and spawning within the lower Platte River.	Final Program Document

1

Tern and Plover Conceptual Ecological Model (CEM)

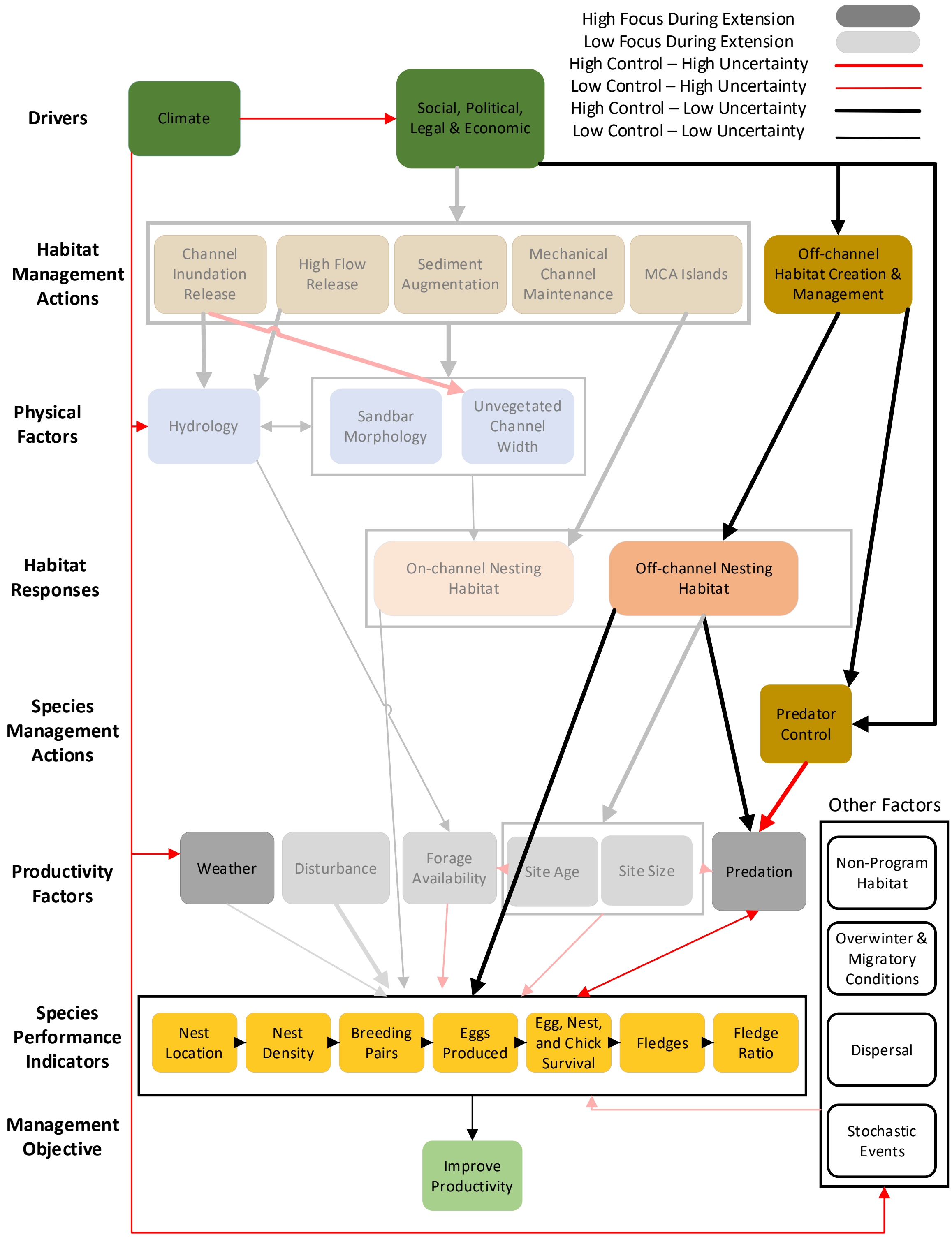
This section contains a brief description of the components of the CEM for least terns and piping plovers (Table 7) and the CEM (Figure 5). A script providing an explanation of the linkages between components and hyperlinked citations to key reference documents is provided in Table 8.

Table 7. Description of the components of the CEM for least terns and piping plovers as illustrated in Figure 5.

Component Category	Component	Description
Drivers	Social, Political, Legal, & Economic	Actions that affect the priorities of the Program, how it is implemented, and the bounds of GC decision-making.
	Climate	Basin and regional factors affecting water supply and hydrology, such as annual precipitation, temperature, and resulting weather patterns and their timing and magnitude over multiple years. Climate conditions affect the social, political, legal, and economic factors driving Program management.
Habitat Management Actions	Channel Inundation Release	Flows maintained during the germination season for the purposes of reducing vegetation establishment within the channel and maintaining wide channels for the potential establishment of suitable in-channel nesting islands following natural high-flow events.
	High Flow Release	Flows of 5,000-8,000 cfs for 3-5 days during the fall to remove annual vegetation following the germination season for the potential establishment of suitable in-channel nesting islands following natural high-flow events.
	Sediment Augmentation	Annual augmentation of sediment for the purposes of reducing the sediment deficit in the channel to reduce or prevent the downstream migration of channel degradation.
	Mechanical Channel Maintenance	Channel disking, herbicide application, and mechanical channel-widening activities for future channel inundation releases to reduce vegetation establishment and remove vegetation through high flow releases for the potential establishment of suitable in-channel nesting islands following natural high-flow events.
	MCA Islands	Established vegetated islands cleared and maintained free of vegetation for the purposes of in-channel nesting islands for terns and plovers and eventual channel widening through lateral erosion for whooping cranes.
	Off-Channel Habitat Creation & Maintenance	Creation and maintenance of off-channel sand and water nesting habitat for terns and plovers.
Physical Factors	Hydrology	The movement and quantification of river and ground water through the Associated Habitat Reach (AHR).
	Sandbar Morphology	The creation and evolution of sandbars and the factors that drive these processes. Visible result of braided river processes whereby sediment continuously erodes and deposits in the downstream direction with respect to stage and sandbars are the visible waves in which energy is dissipated.
	Unvegetated Channel Width	Width of open channel area maintained free of vegetation to encourage on-channel tern and plover nesting within the AHR
Habitat Responses	On-Channel Nesting Habitat	Suitable nesting habitat, as defined by the Program's minimum habitat criteria, created and/or maintained for the purposes of on-channel nesting by terns and plovers.
	Off-Channel Nesting Habitat	Suitable off-channel sand and water nesting habitat, as defined by the Program's minimum habitat criteria, maintained for the purposes of off-channel nesting by terns and plovers.
Species Management Actions	Predator Control	Trapping, fencing, and other activities implemented to reduce predation on tern and plover nests, chicks, and adults.
Productivity Factors	Weather	The state of the atmosphere at a place and time including heat, humidity, solar intensity, wind, rain, etc.
	Disturbance	Any human activity that reduces the occurrence of and productivity on suitable nesting and foraging habitat.
	Forage Availability	Availability of tern (small-bodied fish) and plover (invertebrates) forage.
	Site Age	The age of a nesting site since first established as suitable nesting habitat.
	Site Size	The size of a nesting site in acres
	Predation	The act of predators consuming tern and plover nests, chicks, or adults.

Component Category	Component	Description
Species Performance Indicators	Nest Location	The physical location of individual tern and plover nests.
	Nest Density	Number of tern and plover nests per acre of suitable nesting habitat as defined by the Program's minimum habitat criteria.
	Breeding Pairs	An estimate of the number of unique male/female pairs nesting at a specified location during a specified period of time based upon nest and brood counts and taking renesting into account (Baasch *et al*. 2015). The Program typically reports breeding pairs at their peak, when numbers of breeding pairs observed during a single observation period within the entire Program AHR first peaked.
	Eggs Produced	Highest number of eggs observed over the nesting period within a single unique nest.
	Egg, Nest & Chick Survival	The survival of tern and plover eggs, nests and chicks through hatching and fledging, respectively. *Not currently measured.*
	Fledges	Number of plover chicks attributed to a unique nest that survive to 28 days of age. Number of tern chicks attributed to a unique nest that survive to 21 days of age.
	Fledge Ratio	Number of tern and plover fledglings produced per breeding pair within a site or the AHR.
Management Objective	Improve Productivity	Increase in reproductive productivity in response to Program management actions.
Other Factors	Non-Program Habitat	Nesting and foraging habitat outside the AHR (i.e., McConaughey, lower Platte River, Missouri River, etc.).
	Overwinter & Migratory Conditions	Other factors that reduce or enhance the survival of tern and plover fledglings and adults and ultimately influence recruitment.
	Dispersal	The process of terns and plovers distributing throughout their breeding range which include immigration and emigration.
	Stochastic Events	Factors such as disease outbreaks, etc. that reduce the overall size or health of the population.

1



2
3
4 **Figure 5.** Tern and Plover Conceptual Ecological Model (CEM).

Table 8. Descriptions of hypothesized relationships between components in the least tern and plover CEM (Figure 5) depicting level of uncertainty about and control over this relationship (arrow color & weight) with accompanying literature in support of these designations.

Starting Component(s)	Arrow Color & Weight	Ending Component(s)	Description	Data Sources & Citations
Social, Legal, Political, & Economic		Climate	Social, legal, political, & economic factors form the basis of the Program but the ability to implement the Program is influenced by climate, particularly related to water availability. Goals and objectives of the Program influence management decisions and their responses to climate.	Final Program Document; Extension Document; climate change input as part of operational model.
Climate		Hydrology	Large amount of uncertainty relative to future impacts of climate on hydrology and the ability of the Program to model potential impacts and use those modeling results in Program planning and implementation. But the Program has no control over the effects of climate on water availability.	Using historic hydrologic conditions to inform water operations modeling to make predictions under varying climate change scenarios.
Climate		Weather	Uncertainty about the impacts of climate change on local weather patterns and events which can have a significant impact on tern/plover productivity, but again the Program can do little to account for this impact other than to provide nesting dispersal opportunities as a backstop against the effects of localized weather events (heavy rain, hailstorms, etc.).	Climate change input as part of operational model; maybe some expected productivity loss due to more frequent/intense weather events included in operational model and/or models used by the GC in SDM as part of decision-making.
Climate		Non-Program Habitat/Overwinter & Migratory Conditions/Dispersal/Stochastic Events	Uncertainty about the impacts of climate change on weather patterns and events which can have a significant impact on tern/plover survival and recruitment.	
Social, Legal, Political, & Economic		Channel Inundation Release/High Flow Release/Sediment Augmentation/Mechanical Channel Maintenance/MCA Islands	Little uncertainty about the bounds of the Program, resources, water law, etc. that effect the amount of water and land available for management actions and in turn the ability of the Program to manage and control water, augment sand, and apply mechanical actions in the AHR.	Final Program Document; Extension Document; AMP Versions 1.0 and 2.0
Social, Legal, Political, & Economic		Off-channel Habitat Creation and Maintenance	Little uncertainty about the bounds of the Program, resources, water law, etc. that effect the amount of water and land available for management actions and in turn the ability of the Program to create and maintain off-channel habitat in the AHR.	Final Program Document; Extension Document; AMP Versions 1.0 and 2.0
Social, Legal, Political, & Economic		Predator Control	Little uncertainty about the bounds of the Program to manage and control predators in the AHR other than the Services' willingness to allow avian trapping at off-channel nesting sites.	Final Program Document; Extension Document; AMP Versions 1.0 and 2.0
Channel Inundation Release		Hydrology	Little uncertainty about the relationship between Program flow management in the summer and river hydrology but the Program cannot control other important factors such as irrigation return flows, hydrocycling, USFWS target flow releases, drought, and runoff	Gaging station data

Starting Component(s)	Arrow Color & Weight	Ending Component(s)	Description	Data Sources & Citations
High Flow Release		Hydrology	Little uncertainty about the relationship between peak flows and river hydrology but peak flows are currently driven by natural events over which the Program has no control. Program peak flow management is limited by the Good Neighbor Policy and conveyance constraints at the North Platte choke point.	Farnsworth et al. 2017; Farnsworth et al. 2018; Gauging station data
Channel Inundation Release/High Flow Release/Sediment Augmentation/Mechanical Channel Maintenance/MCA Islands		Sandbar Morphology/Unvegetated Channel Width	The mix of these Program management activities does have an impact on channel morphology and width, but the largest factor now is peak flows driven by natural events outside the control of the Program, except to inform GC and determine if the peak flows may be protected.	PRRIP 2015; Farnsworth et al. 2017; Farnsworth et al. 2018
Channel Inundation Release		Unvegetated Channel Width	Important uncertainty to explore - ability of Program to manage available water to impede vegetation germination and *Phragmites* expansion and thus maintain or expand unvegetated channel width.	Hosner 1958; Karlinger et al. 1981; Currier 1982; Carter-Johnson 1994; Currier 1997; Knezevic et al. 2008; Rapp 2012; PRRIP 2019; Marks & Atia 2020; Geomorphology and In-channel Vegetation Monitoring modeling; Water operations modeling; Gaging station data
MCA Islands		On-Channel Nesting Habitat	The Program can build and manage this habitat to specification, but on-channel habitat is dynamic, changing in size and location over time	Tern and Plover Final SDM Report
Off-Channel Habitat Creation & Maintenance		Off-Channel Nesting Habitat	The Program can build and manage this habitat to specification.	Baasch et al. 2017; Farrell et al. 2018; PRRIP Tern and Plover Monitoring and Research Reports
Off-Channel Habitat Creation & Maintenance		Predator Control	The Program can build and manage this habitat to specification. Predator control efforts include predator peninsula design with surrounding moat, USDA/APHIS trapping, predator exclusion fencing, and predator deterrent lighting.	PRRIP Tern and Plover Monitoring and Research Reports
Hydrology		Sandbar Morphology/Unvegetated Channel Width	High correlation but low ability on the part of the Program to control natural peak flow events.	PRRIP 2015; Farnsworth et al. 2017; Farnsworth et al. 2018
Hydrology		Forage Availability	Primarily an issue of forage fish for terns. Data from First Increment do not link flow to forage availability or productivity.	Baasch et al. 2017; Sherfy et al. 2012
Sandbar Morphology/Unvegetated Channel Width		On-Channel Nesting Habitat	Creation of on-channel nesting habitat is driven more by natural peak flow events over which the Program has no control. Tern and plover nesting occurs prior to late spring floods within the AHR, reducing the potential for successful nesting.	PRRIP 2015; Farnsworth et al. 2017; Farnsworth et al. 2018; Farnsworth et al. 2018

Starting Component(s)	Arrow Color & Weight	Ending Component(s)	Description	Data Sources & Citations
On-Channel Nesting Habitat		Nest Location/Nest Density	Though external science from the Missouri River and the Atlantic Coast demonstrates large increases in nesting incidence by plovers in response to the creation of on-channel and shoreline habitat, few nests resulted from the creation of in-channel nesting islands by the Program from 2013 – 2016. Nesting prior to cessation of spring flooding further reduced successful nesting. The paucity of on-channel nesting has precluded attempts to characterize preferred on-channel nesting locations or examine nest density limitations for terns and plovers.	Catlin 2009; PRRIP 2015; Farnsworth et al. 2017; Farnsworth et al. 2018; Farnsworth et al. 2018; Robinson et al. 2019; PRRIP Tern and Plover Monitoring and Research Reports
On-Channel Nesting Habitat		Breeding pairs/Eggs Produced/Egg, Nest and Chick Survival/Fledges/Fledge Ratio	Few nests resulted from the creation of in-channel nesting islands by the Program from 2013 – 2016. Nesting prior to spring flooding reduced nest and chick survival and provided little opportunity for renesting. Without on-channel habitat creation, no on-channel nesting has been documented since 2016 for either terns or plovers.	PRRIP 2015; Farnsworth et al. 2017; Farnsworth et al. 2018; Farnsworth et al. 2018; PRRIP Tern and Plover Monitoring and Research Reports
Off-Channel Nesting Habitat		Nest Location/Nest Density	Alternatively, tern and plover nest counts have increased significantly in response to the creation of off-channel nesting habitat. Nest site selection characteristics have been described for both terns and plovers for off-channel nesting within the AHR.	Baasch et al. 2017; PRRIP Tern and Plover Monitoring and Research Reports
Off-Channel Nesting Habitat		Breeding pairs/Eggs Produced/Egg, Nest and Chick Survival/Fledges/Fledge Ratio	Program can directly impact through habitat creation and management. Significant positive relationship between acres of off-channel nesting habitat and breeding pairs, leading to increased productivity.	PRRIP Tern and Plover Monitoring and Research Reports
Off-Channel Nesting Habitat		Site Age/Site Size	Program can directly impact through habitat creation. Site age is determined at time of habitat creation. Creation of new off-channel habitat is expected to be limited to the restoration of acres already purchased.	PRRIP Tern and Plover Monitoring and Research Reports
Off-Channel Nesting Habitat		Predation	As predictable sources of tern and plover nesting, predators may learn to target off-channel sites as stable food sources. Important relationship with productivity.	PRRIP Tern and Plover Monitoring and Research Reports
Predator Control		Predation	Important area for Program research directly linked to tern and plover productivity. Need to develop a toolbox for predator control options with information on effectiveness over time.	Catlin 2009; Catlin et al. 2011; Beaulieu 2012; Saunders et al. 2017; PRRIP Tern and Plover Monitoring and Research Reports
Weather		Nest Location/Nest Density	Nest site selection based on elevation and distance to water may be in response to potential for inundation during spring rains. Program cannot control weather but can manage habitat to make less of it subject to flooding.	Baasch et al. 2017

Starting Component(s)	Arrow Color & Weight	Ending Component(s)	Description	Data Sources & Citations
Weather		Breeding pairs/Eggs Produced/Egg, Nest and Chick Survival/Fledges/Fledge Ratio	Weather is significant impact but cannot control weather events.	Farrell et al. 2018
Disturbance		Nest Location/Nest Density	Negative impact on nesting, but Program can control at managed sites.	Nest maps in relation to active mining and high traffic areas.
Disturbance		Breeding pairs/Eggs Produced/Egg, Nest and Chick Survival/Fledges/Fledge Ratio	Literature on colonial nesting birds demonstrates a negative impact of disturbance on productivity. Program can control disturbance at managed sites. Program research, similar to that on the Missouri River demonstrates no apparent reduction in productivity associated with inside monitoring	Carney and Sydeman 1999; Blackmer et al. 2004; Carey 2009; Roche et al. 2014; Farrell & Baasch 2020 PRRIP Tern and Plover Monitoring and Research Reports
Forage Availability		Nest Location/Nest Density	Nest site forage availability may be important for plovers that rely more heavily on site-specific resources, whereas this link has not been supported for terns. Single study on invertebrate forage availability at off-channel sites demonstrated comparable invertebrate abundance to that of riverine sandbars.	Baasch et al. 2017; Sherfy et al. 2012
Forage Availability		Breeding pairs/Eggs Produced/Egg, Nest and Chick Survival/Fledges/Fledge Ratio	Nest site forage availability may be important for plovers that rely more heavily on site-specific resources, whereas this link has not been supported for terns. Though plover foraging may temporarily reduce insect abundance, there is no evidence of declining body condition over the nesting season that would suggest reduced forage availability limits productivity in plovers nesting at OCSW sites. Data from First Increment does not indicate limits on forage fish availability to support tern productivity.	Baasch et al. 2017; Sherfy et al. 2012
Site Age/Site Size		Forage Availability	As off-channel nesting sites age and/or amount of forageable shoreline decreases, invertebrate forage resources may decline, reducing plover productivity. There is no evidence of declining body condition over the nesting season that would suggest insufficient forage availability limits productivity in plovers nesting at OCSW sites.	Sherfy et al. 2012
Site Age/Site Size		Predation	Possibly some relationship between older sites and predation. Predators may learn to rely on predictable off-channel sites as stable sources of prey, but there is only so much habitat that can be purchased and/or developed/managed in the AHR. Predator presence/predation has not been systematically quantified using comparable methods over multiple years. Annual losses to predation show high variability across sites and across years.	Program long-term dataset on tern and plover productivity and losses due to predation.

Starting Component(s)	Arrow Color & Weight	Ending Component(s)	Description	Data Sources & Citations
Site Age/Site Size		Nest Location/Nest Density	Identified area of uncertainty with regard to nest site selection based upon site age and site size. Appears to be at least a year lag in site creation and site use by terns and plovers.	Program long-term dataset on tern and plover nesting.
Site Age/Site Size		Breeding pairs/Eggs Produced/Egg, Nest and Chick Survival/Fledges/Fledge Ratio	May be relationship between site age/site size and productivity over time but there are only so many sites the Program can acquire and/or develop/manage due to limitations in acres, budget, etc.	Program long-term dataset on tern and plover productivity.
Predation		Nest Location/Nest Density	Distance from predator perch important criteria for nest site selection. Predation reduces current and potential future nesting densities (reduces renesting probability).	Baasch et al. 2017; Swift et al. 2020
Predation		Breeding pairs/Eggs Produced/Egg, Nest and Chick Survival/Fledges/Fledge Ratio	Documented losses to predation were high in 2018 – 2019. Important area for Program research: determine the impact of predation, types of predators responsible, possible control methods, and the effectiveness of control methods.	Catlin 2009; Catlin et al. 2011; Beaulieu 2012; Saunders et al. 2017; PRRIP Tern and Plover Monitoring and Research Reports
Nest Location		Nest Density	Direct relationship. Plover territoriality makes density more important for plover productivity. Program may be able to increase plover densities by modifying site shape (lobular designs separate nesting territories and add linear feet of shoreline for foraging).	Baasch et al. 2017; PRRIP Tern and Plover Monitoring and Research Reports
Nest Location/Nest Density		Breeding pairs/Eggs Produced/Egg, Nest and Chick Survival/Fledges/Fledge Ratio	Direct relationship. Plover territoriality makes density more important for plover nesting. Program may be able to increase plover densities by modifying site shape (lobular designs separate nesting territories and add linear feet of shoreline for foraging). No significant relationship between nest density and nest success.	Baasch et al. 2017; Farrell et al. 2018; PRRIP Tern and Plover Monitoring and Research Reports; PRRIP Tern and Plover Final SDM Report
Breeding Pairs		Eggs Produced	Direct relationship. May be outside of Program control.	
Breeding Pairs		Egg, Nest, and Chick Survival/Fledges/Fledge Ratio	Direct relationship. Program can manage for improved reproductive success through habitat management and predator control.	Baasch et al. 2015; PRRIP Tern and Plover Monitoring and Research Reports
Egg, Nest, and Chick Survival		Fledges/Fledge Ratio	Direct relationship. Program can manage for improved reproductive success through habitat management and predator control.	PRRIP Tern and Plover Monitoring and Research Reports
Nest Location/Nest Density		Predation	Predators may be attracted to the presence of breeding adults and active nests, with higher densities attracting more predators. Nests at the periphery of nesting sites, closer to predator perches, may be subject to higher predation rates.	Catlin 2009; Baasch et al. 2017; Farrell et al. 2018
Breeding pairs/Eggs Produced/Egg, Nest and Chick Survival/Fledges/Fledge Ratio		Predation	Predators may be attracted to the presence of breeding adults, active nests, mobile chicks and fledglings, with higher densities attracting more predators.	Catlin 2009

Starting Component(s)	Arrow Color & Weight	Ending Component(s)	Description	Data Sources & Citations
Non-Program Habitat/Overwinter & Migratory Conditions/Dispersal		Nest Location/Nest Density	These factors likely have significant impacts on tern/plover use and occurrence in the AHR but are outside the control of the Program.	Swift et al. 2021
Non-Program Habitat/Overwinter & Migratory Conditions/Dispersal		Breeding pairs/Eggs Produced/Egg, Nest and Chick Survival/Fledges/Fledge Ratio	These factors likely have significant impacts on tern/plover productivity in the AHR but are outside the control of the Program.	Swift et al. 2021
Nest Location/Nest Density/Breeding pairs/Eggs Produced/Egg, Nest and Chick Survival/Fledges/Fledge Ratio		Improve Productivity	Each of these performance indicators has an impact on target species productivity. First Increment Extension will continue to monitor these indicators of productivity to evaluate progress toward the Program's Management Objective of improving tern and plover productivity on the central Platte River.	Final Program Document; PRRIP Tern and Plover Monitoring and Research Reports

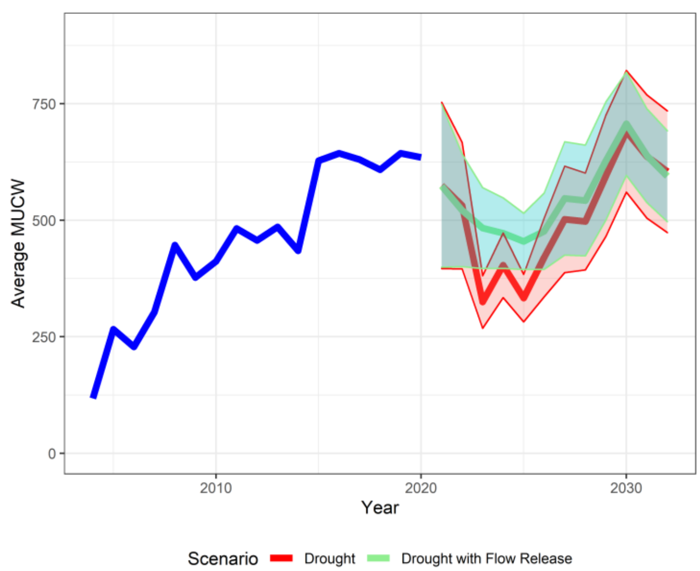
1

Active Learning – Management Action Experiments

Extension Big Question #1: How effective is it to use Program water to maintain suitable* whooping crane roosting habitat?
**Channels with ≥ 650 ft maximum width unobstructed by dense vegetation (MUCW) are highly suitable for whooping crane roosting.*

Management Hypothesis: During drought periods, 30-day minimum germination suppression releases (2,000 cfs target between June 1-July 15) will slow vegetation expansion into the channel and increase the percent of AHR channel that remains highly suitable for whooping crane roosting.
Assumes ongoing Phragmites spraying. Program science strongly indicates that natural peak flow events exceeding 13,000 cfs or mechanical vegetation clearing are necessary to remove vegetation and increase MUCW. Germination suppression releases are only hypothesized to maintain unvegetated width.

X-Y Graph



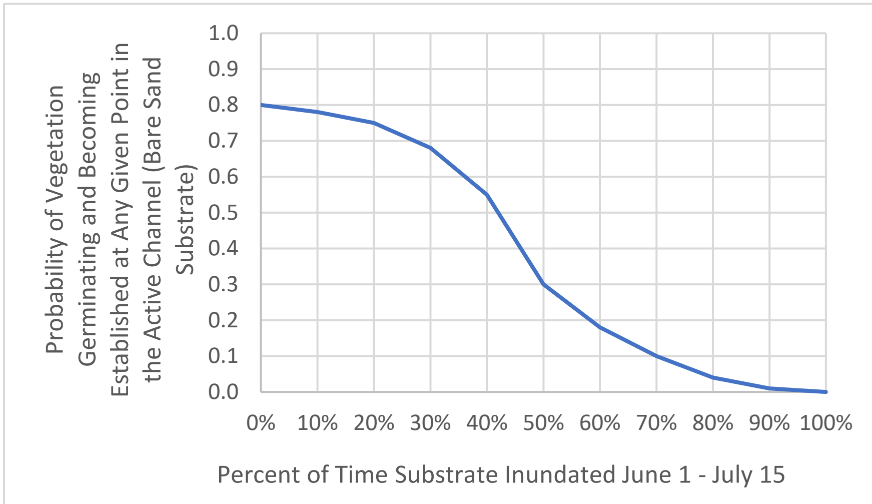
Based upon the Program's machine learning model, it is hypothesized that channel-inundating flow releases for at least 30 days (June 1-July 15; target 2,000 cfs) will suppress seed germination and slow loss of MUCW during drought periods absent natural peak flows of sufficient magnitude (>13,000 cfs) to naturally maintain and/or increase MUCW.

Alternative Hypotheses:

- 30-day inundation between June 1 – July 15 is insufficient – must maintain release throughout growing season
- The 2,000 cfs target is too much or too little to maintain suitable MUCWs.
- Hydrocycling increases/decreases effectiveness of germination suppression release
- Insufficient water and/or conveyance capacity to implement release.
- Ongoing *Phragmites* spraying (herbicide application) is primarily responsible for channel width maintenance by controlling rate of vegetation establishment. Herbicide kills vegetation and flow subsequently removes islands/dead standing biomass via lateral erosion.
- Mechanical vegetation clearing is necessary to maintain suitable MUCWs.
- Fall SDHF will scour < 1 year old seedlings and maintain suitable MUCWs.

Underlying Physical Process Hypothesis: Vegetation germination and establishment is a function of percent of time bare sand substrate is inundated (30-day period between June 1 – July 15).

X-Y Graph



Probability of seed germination at any given point in the active channel decreases with increasing percent of time bare sand substrate is inundated by > 0.1 ft during the period of June 1 – July 15. Preventing seed germination eliminates colonization by species such as cottonwoods, willows and reed canarygrass that become visual obstructions and initiate transition from unvegetated sandbar to vegetated island.

Alternative Hypotheses:

- 30-day inundation (2,000 cfs target) between June 1 – July 15 is insufficient. Seedlings that germinate during July – September sufficient to initiate the transition to vegetated island.
- Seedlings germinate in May. June inundation insufficient to kill newly established seedlings and prevent transition to vegetated island.
- Vegetation establishment not important – herbicide application prevents transition to vegetated islands.
- Vegetation establishment not important - mechanical vegetation removal prevents transition to vegetated islands.
- Spring to summer vegetation establishment not important – fall SDHF prevents transition to vegetated island.

Implementation Notes:

Implement germination suppression flow release annually for 2 – 5 years and monitor to determine effectiveness. Effectiveness will be assessed via annual geomorphology and in-channel vegetation monitoring to determine relationship between inundation and vegetation establishment as well as by comparison of observed and predicted MUCW changes from machine learning model. During this period, portions of Program habitat complexes may be “reset” by spraying and mechanical removal of newly vegetated islands.

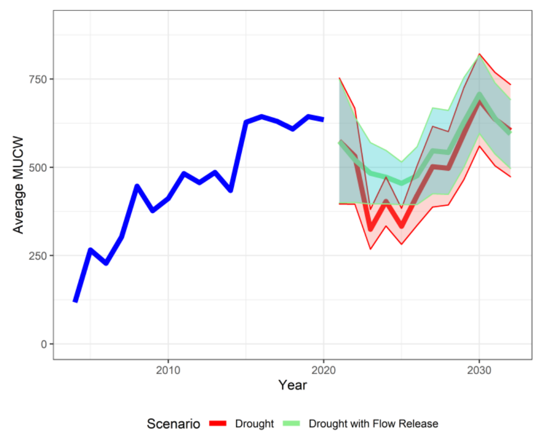
Extension Big Question #2: How effective is Program management of Phragmites for maintaining suitable* whooping crane roosting habitat?

**Channels with ≥ 650 ft maximum width unobstructed by dense vegetation (MUCW) are highly suitable for whooping crane roosting.*

Management Hypothesis: During drought periods, 30-day minimum channel inundating flow releases (2,000 cfs target between June 1-July 15) in combination with continued herbicide spraying and channel disking will slow *Phragmites* rhizome/stolon expansion into the channel and increase the percent of AHR channel that remains highly suitable for whooping crane roosting.

Assumes ongoing Phragmites spraying. Program science strongly indicates that natural peak flow events exceeding 13,000 cfs or mechanical vegetation clearing are necessary to remove vegetation and increase MUCW. Channel-inundating flow releases are only hypothesized to maintain unvegetated width.

X-Y Graph



Based upon the Program's machine learning model, it is hypothesized that channel-inundating flow releases for at least 30 days (June 1-July 15; target 2,000 cfs) will slow *Phragmites* expansion into the river channel during the period of inundation, slowing the loss of MUCW during drought periods absent natural peak flows of sufficient magnitude (>13,000 cfs) to naturally maintain and/or increase MUCW, thus providing incremental benefits in controlling *Phragmites* above those provided by herbicide application alone.

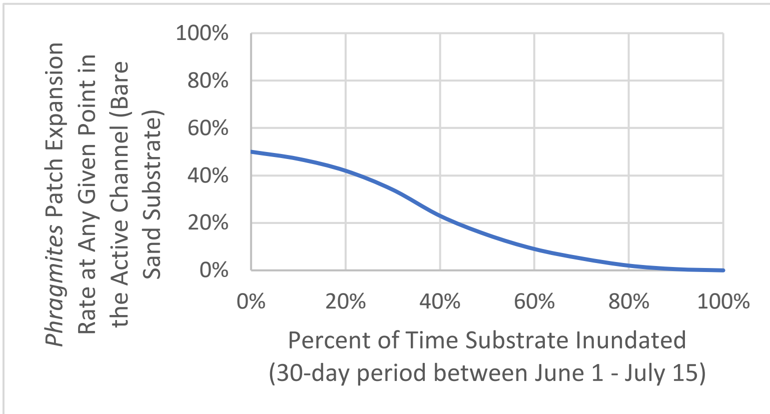
Alternative Hypotheses:

- 30-day inundation between June 1 – July 15 is insufficient – must maintain release throughout growing season
- The 2,000 cfs target is too much or too little to control *Phragmites* expansion and maintain suitable MUCWs.
- Hydrocycling increases/decreases effectiveness of inundating flow release
- Insufficient water and/or conveyance capacity to implement release.
- Ongoing *Phragmites* spraying (herbicide application) is primarily responsible for channel width maintenance by controlling rate of vegetation expansion. Herbicide kills vegetation and flow subsequently removes islands/dead standing biomass via lateral erosion.
- Mechanical vegetation clearing is necessary to control *Phragmites* expansion and maintain suitable MUCWs.
- Fall SDHF will scour *Phragmites* from in-channel sandbars and channel banks and maintain suitable MUCWs.

1

Underlying Physical Process Hypothesis: *Phragmites* expansion rates into the active river channel are a function of percent of time bare sand substrate is inundated.

X-Y Graph



Phragmites patch expansion rate at any given point in the active channel decreases with increasing percent of time bare sand substrate is inundated by > 0.1 ft during the 30-day period between June 1 – July 15. Slowing rhizome/stolon expansion into the active channel reduces subsequent in-channel sediment trapping, stem development, and patch expansions that become visual obstructions and initiate transition from unvegetated sandbar to vegetated island.

Alternative Hypotheses:

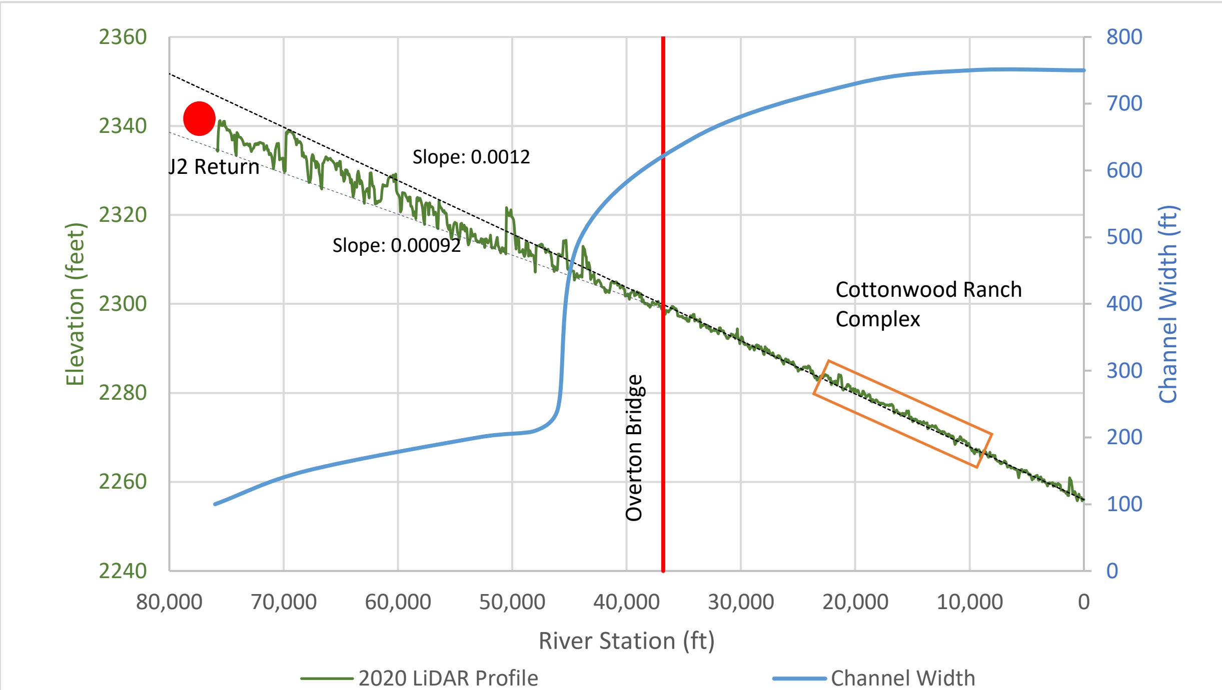
- 30-day duration insufficient to slow rhizome/stolon expansion. Longer periods of inundation required.
- Timing of June inundation is incorrect to slow rhizome/stolon expansion. *Phragmites* vegetative expansion during April – May or July – September is sufficient to initiate the transition to vegetated island.
- Expansion into the channel is driven by seedling germination. Seeds germinate in April, becoming established in May. June inundation insufficient to kill newly established seedlings and prevent transition to vegetated island.
- Vegetative *Phragmites* expansion not important – herbicide application prevents transition to vegetated islands.
- Vegetative *Phragmites* expansion not important - mechanical vegetation removal prevents transition to vegetated islands.
- Spring to summer *Phragmites* expansion not important – fall SDHF prevents transition to vegetated island.

Implementation Notes:

Implement inundation flow release annually for 2 – 5 years and monitor *Phragmites* patch expansion rates and MUCW to determine any incremental benefit of these flow releases beyond what is achieved with annual herbicide applications. Effectiveness will be assessed via annual geomorphology and in-channel vegetation monitoring as well as by comparison of observed and predicted MUCW changes from machine learning model. During this period, portions of Program habitat complexes may be "reset" by spraying and mechanical removal of newly vegetated islands.

A desktop exercise using past data collected by the Program to evaluate the effects of high and low flows with and without herbicide application is also expected to provide information on the effectiveness of herbicide application and potential incremental benefits water may provide to effectively control *Phragmites* expansion and maintain channel width.

Extension Big Question #3: Is sediment augmentation necessary to create and/or maintain suitable whooping crane habitat?
Management Hypothesis: Sediment augmentation is necessary to halt narrowing and incision in the south channel downstream of the J2 Return.
X-Y Graph



Full scale sediment augmentation (60,000 – 80,000 tons annually in south channel below J2 Return) is necessary to offset the sediment deficit and halt narrowing and incision that has caused the upper portion of the south channel to transition to a narrow meandering planform, which is much less suitable for WC roosting. If incision is not halted, the affected reach will continue to expand downstream past the Overton bridge, reducing habitat suitability at the Cottonwood Ranch complex.

Alternative Hypotheses:

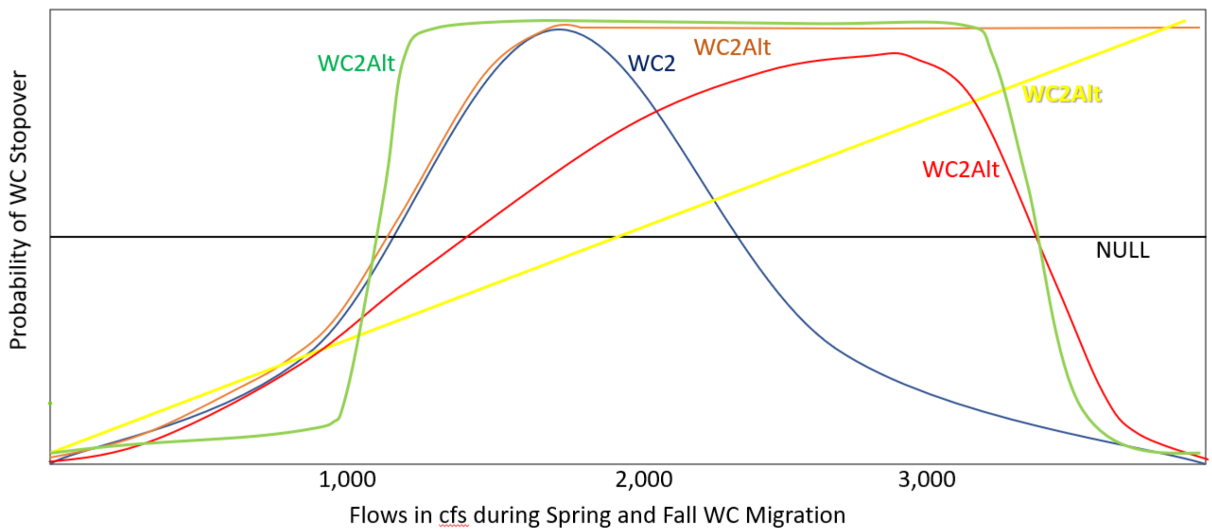
- More or less sediment must be augmented to offset the south channel deficit.
- Full scale augmentation is not feasible over the long term – not enough supply.
- Incision and narrowing progresses downstream so slowly that augmentation is not necessary.

Implementation Notes:
The Program has implemented full-scale sediment augmentation since 2017. Following augmentation in 2021, the EDO will evaluate the performance of sediment augmentation during that period. At the conclusion of that investigation, the GC will determine if augmentation should continue as well as whether or not additional research is needed.

Extension Big Question #4: Does flow influence WC decision to stop or fly over the AHR?

Management Hypothesis: Probability of WC stopping within the AHR is related to flow.

X-Y Graph



Probability of a whooping crane stopping and roosting within the AHR (vs. flying over) is a function of discharge. The relationship could take a number of forms.

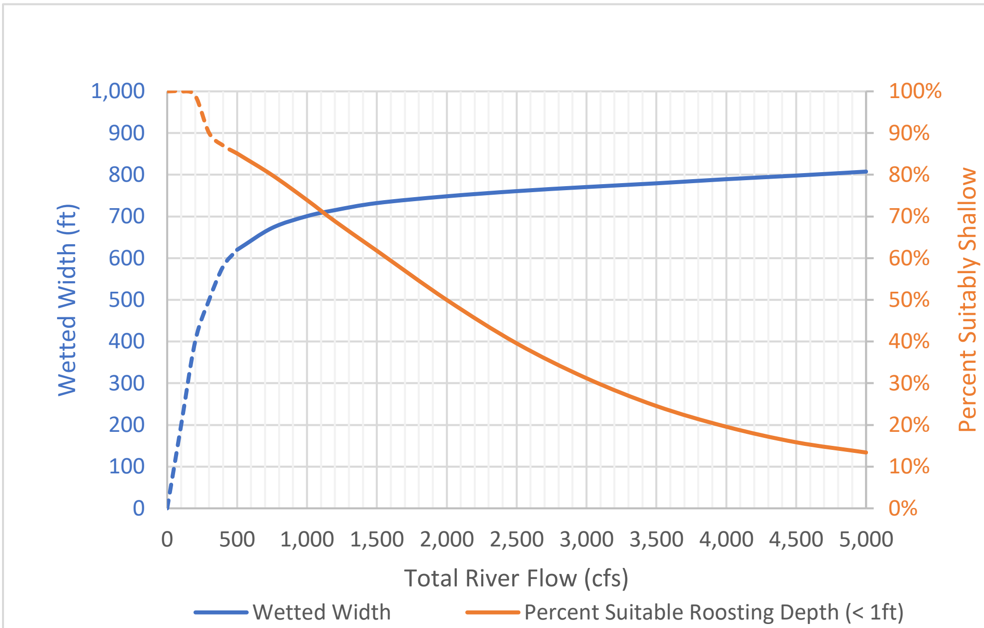
Alternative Hypotheses:

- Time of day is the primary driver of WC stopovers with probability of use increasing with decreasing time until dark.
- The probability of WC stopping over is primarily a function of MUCW and unforested corridor width.
- The probability of WC stopping over is primarily a function of land cover or habitat suitability within a 16 km radius of flyover location.
- Weather (wind speed and direction, precipitation, temperature) encountered since the last stopover is an important predictor of WC stopovers with the probability of use of the AHR increasing as weather conditions become less favorable for flight.
- Length of stay at previous stopover (inverse relationship) and distance traveled since last stopover (direct relationship) are important predictors of WC stopovers.
- Point in migration (proportion of migration completed) is an important predictor of WC stopovers with the probability of use of the AHR demonstrating a quadratic relationship with proportion of migration completed.

1

Underlying Physical Processes Hypothesis – The probability of a WC stopover is a function of the relationship between wetted width and the percent of the channel that is of suitable depth for roosting (< 1 ft deep).

X-Y Graph



Probability of WC stopover increases with increasing discharge to approximately 1,000 cfs (channel mostly inundated) and decreases above 3,000 cfs due to loss of suitable shallow roosting area. Less than 30% of the main channel remains at a depth of < 1 ft with those areas predominantly located adjacent to vegetated banks or bars.

Alternative Hypothesis:

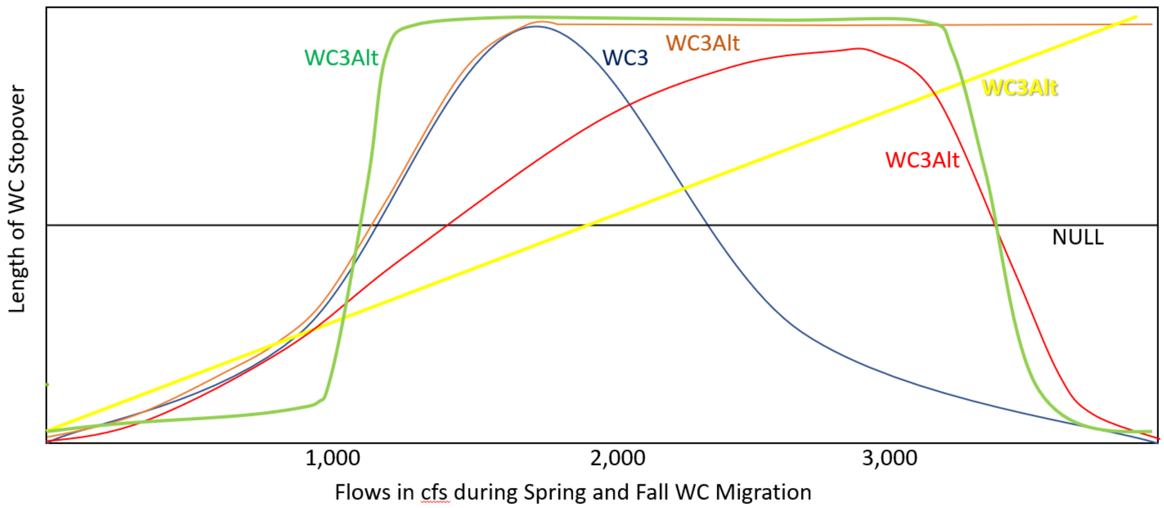
- The probability of a WC stopover increases with wetted area, regardless of depth, thus stopovers increase with flow.

Implementation Notes:

As a general hypothesis this will be investigated as a desktop exercise utilizing cellular telemetry data to further explore the effects of instantaneous flow on the decision to stopover as WC encounter the AHR. It may be beneficial to examine this question over the larger migratory corridor to gain a more general understanding of how flow affects this decision at other locations. If desktop analyses demonstrate flow to be important for WC stopover decisions, the Program can move toward a management hypothesis and perform flow experiments on the ground as water is available to test WC decision to stopover based upon flows during WC migration, starting by filling data gaps for WC tolerance to low flows.

Extension Big Question #5: Does flow influence WC stopover length within the AHR?
Management Hypothesis: Length of WC stopover within the AHR is a function of discharge.

X-Y Graph



Length of WC stopover within the AHR is a function of discharge. The relationship could take a number of forms.

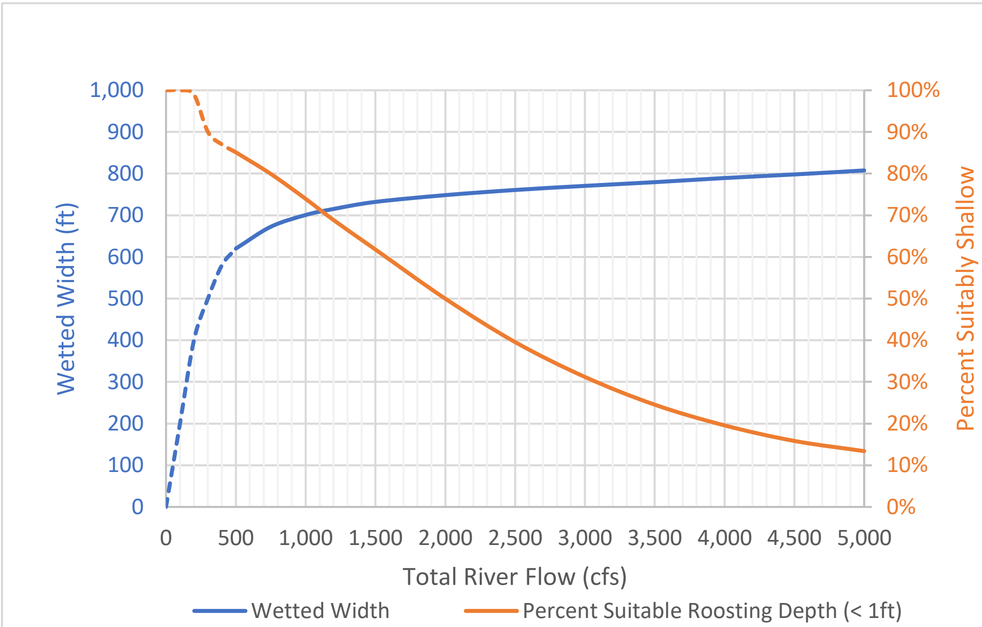
Alternative Hypotheses:

- Length of stay within the AHR has an inverse relationship with length of stay at the previous stopover and a direct relationship with distance traveled since last stopover.
- WC stopover length is inversely related to daily variability in flow.
- WC stopover length is primarily a function of MUCW and unforested corridor width.
- WC stopover length is primarily a function of land cover or habitat suitability within a 16 km radius of use location.
- Weather (wind speed and direction, precipitation, temperature) is an important predictor of WC stopover length with the length of stay within the AHR increasing as weather conditions become less favorable for flight.
- The length of a WC stopover within the AHR is longer during the Fall migration. Stopover length within the AHR recapitulates the overall migratory pattern with longer Fall stopovers than Spring stopovers.
- Point in migration (proportion of migration completed) is an important predictor of WC stopover length with stopover length demonstrating a quadratic relationship with proportion of migration completed.
- WC group size, composition (adults, sub-adults, juveniles), and whether or not they are associated with sandhill cranes are important predictors of WC stopover length.

1

Underlying Physical Processes Hypothesis – WC stopover length is a function of the relationship between wetted width and the percent of the channel that is of suitable depth for roosting (< 1 ft deep).

X-Y Graph



WC stopover length increases with increasing discharge to approximately 1,000 cfs (channel mostly inundated) and decreases above 3,000 cfs due to loss of suitable shallow roosting area. Less than 30% of the main channel remains at a depth of < 1 ft with those areas predominantly located adjacent to vegetated banks or bars.

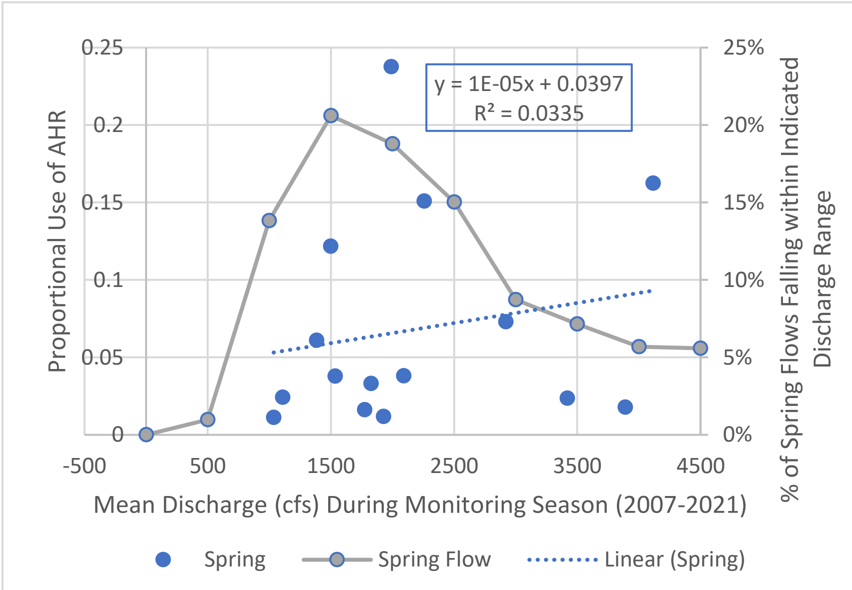
Alternative Hypothesis:

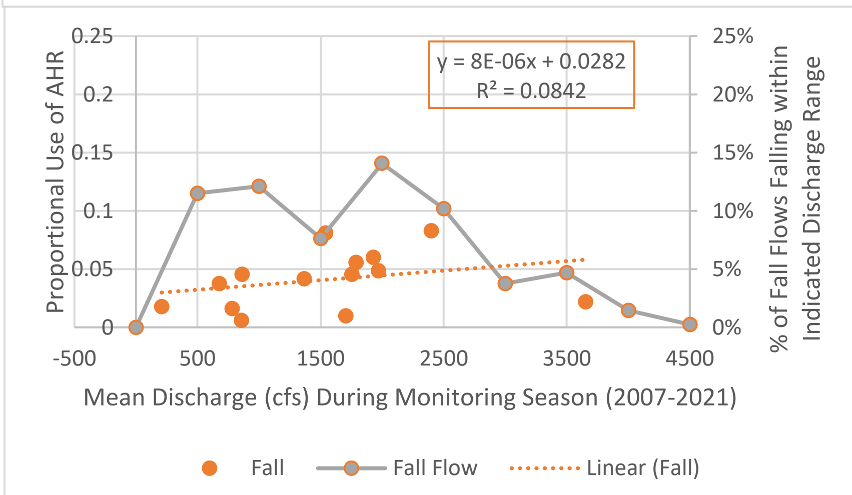
- Length of WC stopover increases with wetted area, regardless of depth, thus stopover lengths increase with flow.

Implementation Notes:

As a general hypothesis this will be investigated as a desktop exercise utilizing PRRIP monitoring data and telemetry data to further explore the effects of flow on WC stopover lengths within the AHR, including periods of drought (2015) and high flows (2019). The amount of daily variability in flow experienced by WC that stop within the AHR will also be examined both spatially and temporally to determine whether hydro-stepping has an effect on WC stopover lengths within the AHR. It may be beneficial to examine this question over the larger migratory corridor utilizing cellular telemetry data to gain a more general understanding of how flow affects stopover lengths at other locations. If desktop analyses demonstrate flow to be important for WC stay lengths, the Program can move toward a management hypothesis and perform flow experiments on the ground as water is available to test WC stopover lengths in response to flows during WC migration, starting by filling data gaps for WC tolerance to low flows.

Extension Big Question #6: Why is Spring WC use of the AHR greater than Fall use?
Management Hypothesis: WC use of the AHR in the Spring is greater than during the Fall due to higher flows during this period.
X-Y Graph





WC use of the AHR in the Spring vs. the Fall is a function of discharge, with higher use occurring in the Spring concurrently with higher discharge.

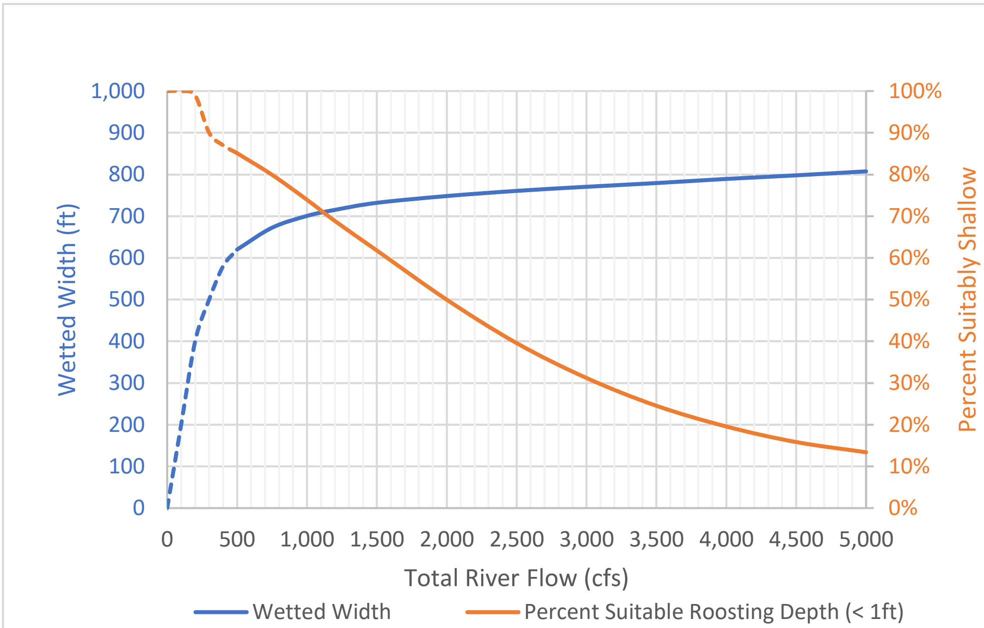
1

Alternative Hypotheses:

- WC use of the AHR in the Spring is greater because WC do not stage in other areas prior to reaching the Platte, WC are further along in migration when they arrive, distance traveled since last stopover is longer, and stay length at previous stopovers is shorter when compared to Fall migration.
- WC stay longer in the AHR during Spring migration because daily variability in flow is lower.
- WC use of the AHR in the Spring is greater because proportional wetland landcover is greater.
- WC use of the AHR in the Spring is greater due to more expansive unobstructed views (wider MUCW, reduced vegetation cover, lower vegetation heights, trees without leaves) that together increase perceived area of both on and off-channel suitable habitat during this period when compared with the Fall
- WC use of the AHR in the Spring is greater because they encounter the AHR later in the day during this migratory season than they do during the Fall migratory season, increasing the probability of a stopover.
- WC use of the AHR in the Spring is greater because weather (wind speed and direction, precipitation, temperature) conditions are less favorable for flight (heading into colder conditions, not away from them).
- WC use of the AHR in the Spring is greater because group sizes are larger, more numerous and longer stopovers by juveniles and subadults (non-reproductive), and because of the presence of sandhill cranes (more abundant with longer stopovers within the AHR in the Spring).

Underlying Physical Processes Hypothesis – WC use of the AHR is a function of the relationship between wetted width and the percent of the channel that is of suitable depth for roosting (<1 ft deep).

X-Y Graph



The proportion of the AWB WC population that uses the AHR increases with increasing discharge to approximately 1,000 cfs (channel mostly inundated) and decreases above 3,000 cfs due to loss of suitable shallow roosting area. Less than 30% of the main channel remains at a depth < 1 ft with those areas predominantly located adjacent to vegetated banks and bars.

Alternative Hypothesis:

- WC use of the AHR increases with wetted area, regardless of depth, thus use increases with flow.

Implementation Notes:

As a general hypothesis this will be investigated as a desktop exercise utilizing PRRIP monitoring data and telemetry data to further explore the effects of flow on WC use of the AHR in the Spring vs. Fall. The amount of daily variability in flow experienced by WC that stop within the AHR will also be examined both spatially and temporally to determine whether hydro-stepping in conjunction with low flows has a greater effect on WC use of the AHR in the Fall than in the Spring. It may be beneficial to examine this question over the larger migratory corridor utilizing cellular telemetry data to gain a more general understanding of how Spring vs. Fall use patterns differ at other locations. If desktop analyses demonstrate flow to be important for explaining differences in WC use of the AHR, the Program can move toward a management hypothesis and perform flow experiments on the ground as water is available to test WC response to Spring vs. Fall flows, starting by filling data gaps for WC tolerance to low flows.

Extension Big Question #7: What effect do Program flow management actions have on pallid sturgeon use of the lower Platte River?

Pallid sturgeon genetics research

Learning Objective$_1$: Establish new genetic baselines for species identification and addressing hybridization.

Learning Objective$_2$: Identify spawning pallid sturgeon adults and age-0 pallid sturgeon collected on the lower Platte River and its confluence with the Missouri River to confirm successful spawning and recruitment.

Learning Objective$_3$: Reassess pallid sturgeon population dynamics and estimate effective population size.

Pallid sturgeon habitat and spawning research

Learning Objective$_1$: Assess pallid sturgeon use of the lower Platte River and its tributaries.

Learning Objective$_2$: Relate pallid sturgeon seasonal movements and spawning behavior to environmental patterns on the lower Platte River and its tributaries.

Learning Objective$_3$: Identify and describe pallid sturgeon spawning habitat on the lower Platte River and its tributaries.

Learning Objective$_4$: Verify successful pallid sturgeon spawning in the lower Platte River and its tributaries and recruitment from the lower Platte River to the Missouri River.

Implementation Notes:

A 3-step plan for addressing this Big Question is outlined in the PRRIP Pallid Sturgeon Agreement Framing Document approved by the GC in June, 2021. Summarized for EBQ#7 are the learning objectives for Step 1 of this plan. As research is further developed and information is obtained to generate more plausible hypotheses and predicted outcomes related to the agreed upon learning objectives, formal hypotheses for testing will be added to the Extension Science Plan.

Step 1 is a collaborative research effort by the University of Nebraska Lincoln, Nebraska Game and Parks Commission, Southern Illinois University, and the Program. Spawning adults, non-reproductive adults, and juveniles will be captured, tagged, and monitored both through active and passive telemetry to document pallid sturgeon location, movement, timing, extent of use, and describe pallid spawning behavior on the lower Platte and its tributaries. Free embryo/larvae sampling downstream of identified spawning events as well as at the Platte confluence with the Missouri river followed by genetic analyses of collected free embryos/larvae will determine successful spawning and recruitment of pallid sturgeon. USGS gages for flow, turbidity, temperature will provide data to examine potential explanatory variables.

Results of formal tests of hypotheses will later feed into a Program Water Management Study and guidance for Program water operations through the remainder of the Extension and into the Second Increment.

Maintenance Learning – Improving and Sustaining Ongoing Program Management Actions

EBQ #8 – How much of an effect does predation have on PP productivity?

Learning Objective$_1$: Quantify the impact of predation on PP productivity.

Learning Objective$_2$: Identify predator species responsible for losses.

Learning Objective$_3$: Determine when losses are incurred, at the nest or during brood rearing.

Learning Objective$_4$: Utilize population viability models to predict what effect decreases in fledge ratios due to predation may mean in terms of future PP breeding pairs on the central Platte River.

EBQ #9 – How effective is Program management at mitigating losses of PP productivity due to predation?

Learning Objective$_1$: Evaluate effectiveness of trapping, fencing, and/or predator deterrent lighting at reducing nest/brood failure due to predation.

Learning Objective$_2$: Develop predator management alternatives based upon learning through remote camera/video monitoring.

Learning Objective$_3$: Evaluate the necessity for additional predator management based upon PP response to predation over time.

Implementation Notes:

In connection with outside monitoring of plover habitat use and productivity, track surveys around nesting peninsulas and deployment of site- and nest-level trail and video cameras will provide documentation of predator presence, plover losses due to predation, and overall productivity at a site and system level. Losses of plover nests and chicks to predation and overall productivity at OCSW sites where baseline predator control includes trapping and fencing at land entrances to nesting peninsulas will be examined over the long term and compared to responses following implementation of additional predator management including predator exclosure fencing around entire nesting peninsulas and implementation of predator deterrent lighting. Information gathered will be used to develop novel and targeted strategies for mitigating losses due to predation. A Crystal Ball population model will help determine when losses to predation (number of losses over how many years) present greater risk to local population growth, warranting implementation of additional predator management.

EBQ #10 – Wet meadows research *(NOTE: this is a carryover task from the First Increment)*
Learning Objective$_1$: Understand relationships between hydrological and meteorological variables and groundwater levels at natural wet meadow sites. **Learning Objective$_2$:** Understand what constitutes a functional hydrological regime for wet meadows along the central Platte River valley which can be used as a reference and applied to manage other sites. **Learning Objective$_3$:** Develop a modeling tool that can be used by land managers in the central Platte River valley to inform management decisions.

Implementation Notes:
Utilization of hydrological and climatological monitoring data collected since 2013 to develop analytical and numerical groundwater models to assess hydrologic drivers in natural and restored wet meadows at the Fort Kearny and Shoemaker Island habitat complexes.

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM (PRRIP -or- Program)

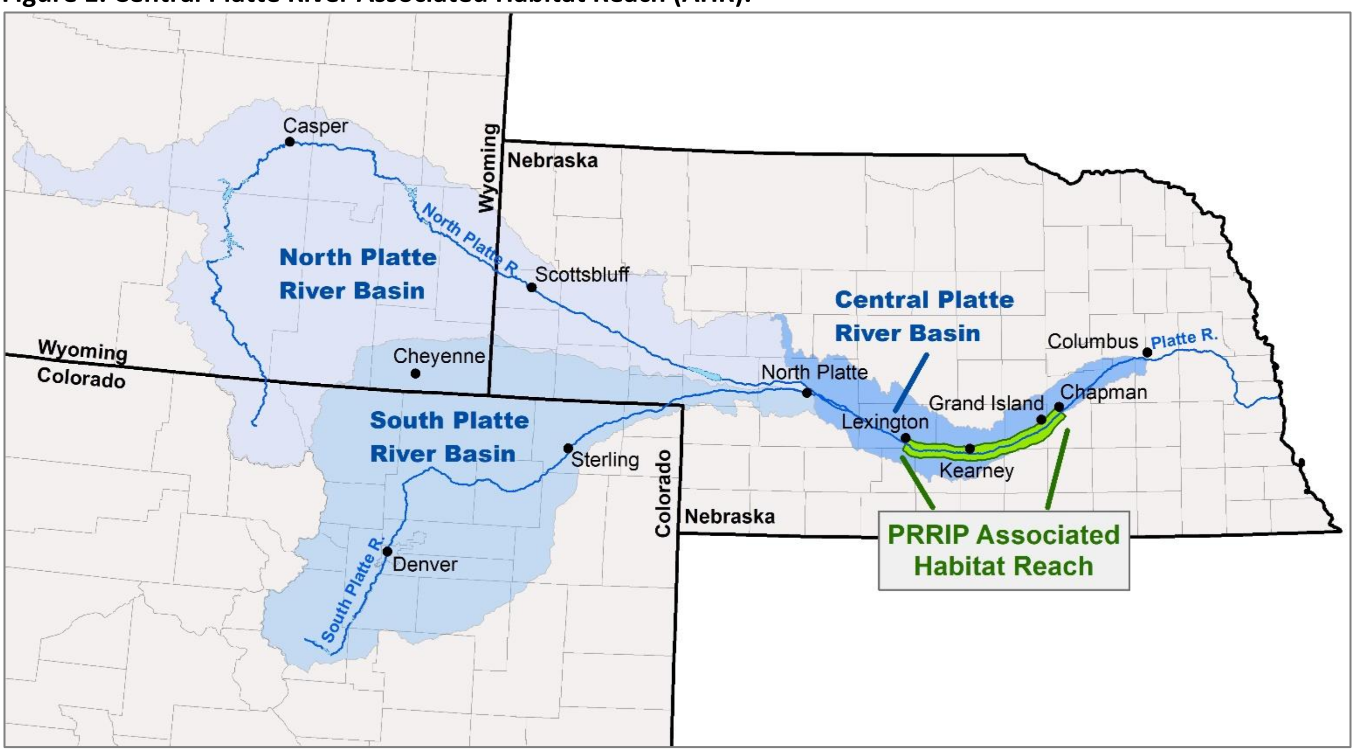
Extension Science Plan Attachment #3 – Implementation Activities & Timeline

This Implementation Guide is focused on identifying and organizing the research, monitoring and management activities that will be undertaken during the Extension to address the Big Questions and inform Second Increment negotiations.

Extent and Scale of Science Plan Implementation

Science Plan activities will primarily occur in the segment of the Platte River region extending from Lexington to Chapman, which is referred to as the associated habitats reach (AHR) for the Program's three target bird species. Pallid sturgeon research will be conducted on the segment of the lower Platte River extending from the Loup River confluence to the Missouri River confluence. Since all Program management actions and most research and monitoring will occur in the Central Platte AHR, this section of the implementation plan will focus on the extent and scale of actions in this ninety-mile reach of the river (Figure 1).

Figure 1. Central Platte River Associated Habitat Reach (AHR).



System-Level Activities and Actions

System-Level Monitoring and Research Activities

Physical process (geomorphology and vegetation) and target species use/productivity monitoring and research are conducted at a system-scale. Target species monitoring is based on regular reconnaissance surveys (airplane and airboat) followed up with more intensive monitoring at use locations. Use occurs on a mix of PRRIP, conservation and private properties. When use occurs on private and/or conservation properties, we request access and monitor if granted.

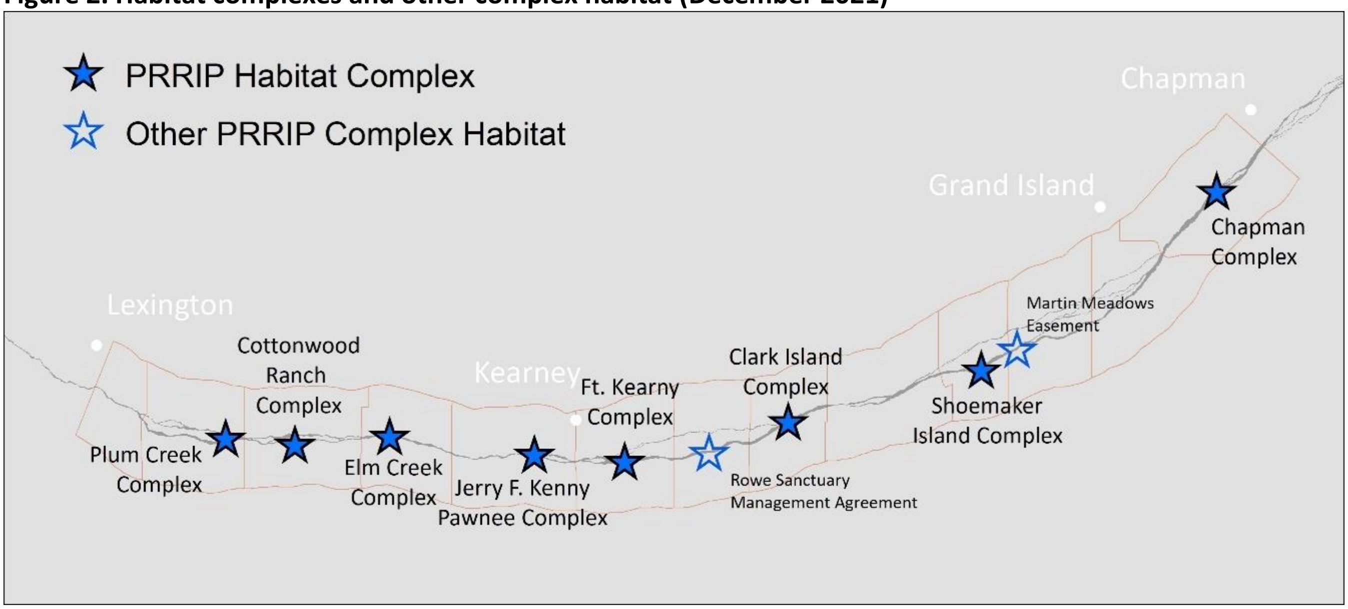
During the First Increment, geomorphology and vegetation monitoring was field-based and required access permission from over 100 landowners. In 2017 the Program shifted to a remote sensing protocol (aerial imagery and LiDAR) that eliminated access permission and spatial coverage issues. Remote sensing data is collected in June and in November. Training and validation data is collected by the Executive Director's Office (EDO) on Program properties, which are distributed throughout the AHR.

System-Level Management Actions

Program management actions that affect the AHR at a system-level include sediment phragmites spraying, sediment augmentation and vegetation management flow releases.[1] Phragmites spraying occurs annually throughout the AHR. Flow and sediment introduced by the Program are conveyed downstream through the entire reach, affecting the entirety of the channel within the AHR. Habitat Complexes and Non-Complex Habitat.

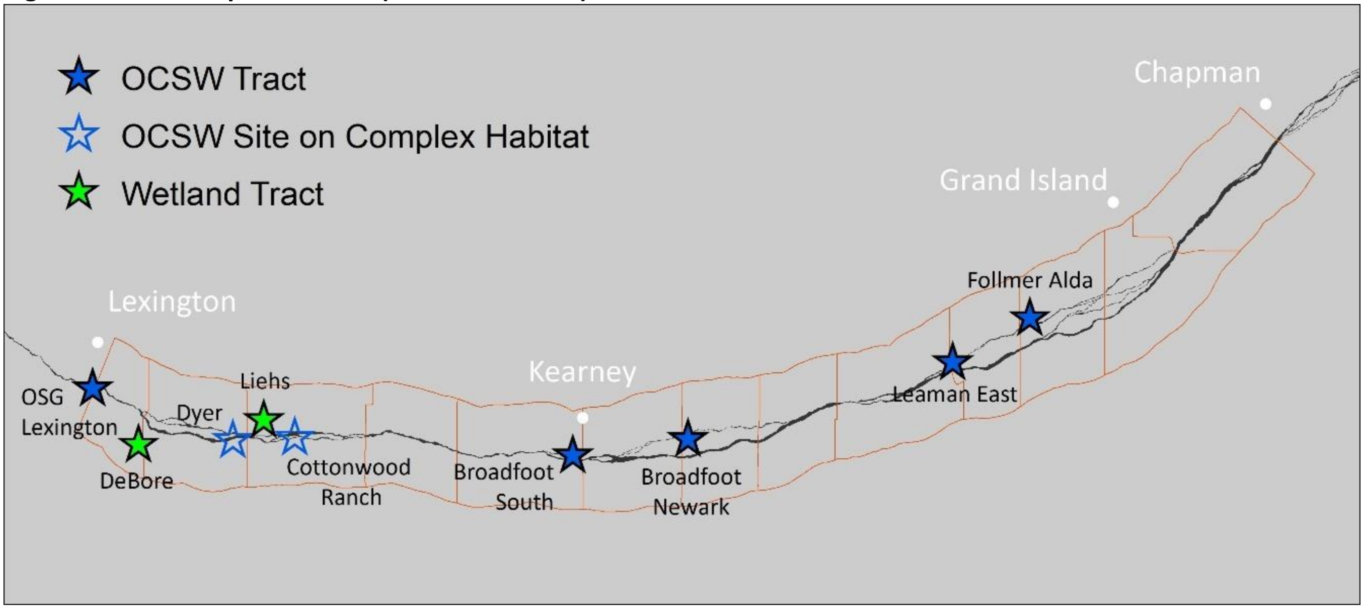
As of December 2021, the Program has secured an interest in approximately 12,000 acres of habitat land and has executed agreements to implement management on an additional 1,500 acres. Of this total, approximately 13,000 acres are classified as complex habitat organized into eight habitat complexes consisting of channel areas, wet meadow and buffer (Figure 2). The remaining land is classified as non-complex habitat (Figure 3) and is comprised of approximately 600 acres of OCSW tern and plover nesting habitat and 250 acres of palustrine wetland for whooping crane roosting.

Figure 2. Habitat complexes and other complex habitat (December 2021)



[1] The USFWS may also release water from the Environmental Account for other purposes.

Figure 3. Non-complex habitat (December 2021)



Activities and Actions on Non-Program Lands

The Program can also increase the extent of monitoring, research and management actions by partnering with existing conservation and utility landowners that already own and manage target species habitat. In some cases, the Program may be able to conduct species use and selection research on habitat that is currently being managed to provide benefits to the target species. In other cases, the Program may enter into management agreements with the landowner that allow the Program to implement management experiments on non-Program lands. These types of agreements are opportunistic in nature and will be pursued as long as the Program maintains adequate resources to fulfill restoration and maintenance obligations on Program lands.

Science Plan Activity Diagrams

This section of the Implementation Guide consists of activity diagrams that outline major activities and decision points culminating in Second Increment negotiations. Diagrams generally follow the order of Big Questions – management action implementation followed by target species response and general learning. Research and monitoring protocols and other relevant guidance documents are generally included as attachments to the Extension Science Plan.

Overview of Activity Diagrams

Figure 4 presents a legend for activity diagrams. A brief description of each activity follows:

- Problem Assessment Investigation or Research: High-level assessment of monitoring and research data to inform potential future activities. This includes development of modeling tools for a structured decision-making process to inform Second Increment negotiations.
- Management Experiment Implementation Design: Design of flow or habitat management experiments to be tested during the Extension.
- Management Experiment Implementation Actions and Monitoring: Implementation and monitoring of management actions like flow releases, predator management, etc. intended to provide target species benefits.
- System-Level Monitoring and Data Synthesis: Monitoring of system-level physical processes and/or target species response to management actions.
- Performance Evaluation: Integration and synthesis of system- and experiment-scale data to evaluate the performance of management actions to benefit target species.
- Decision: Action adjustment point – continue, adjust or terminate actions.
- Action Terminator: Terminate management action.

Figure 4. Action diagram legend.

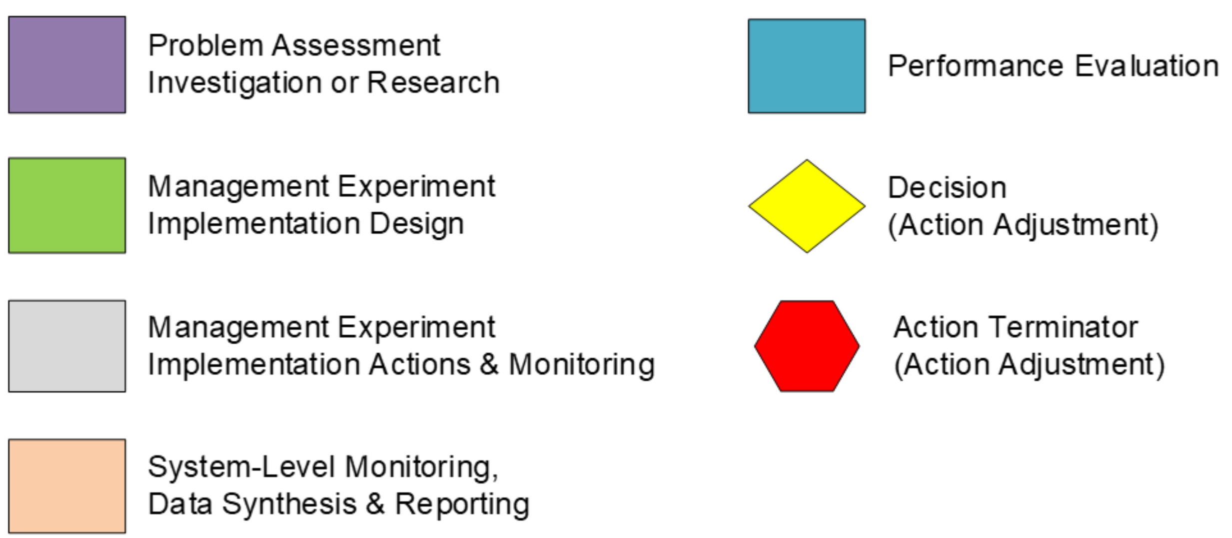
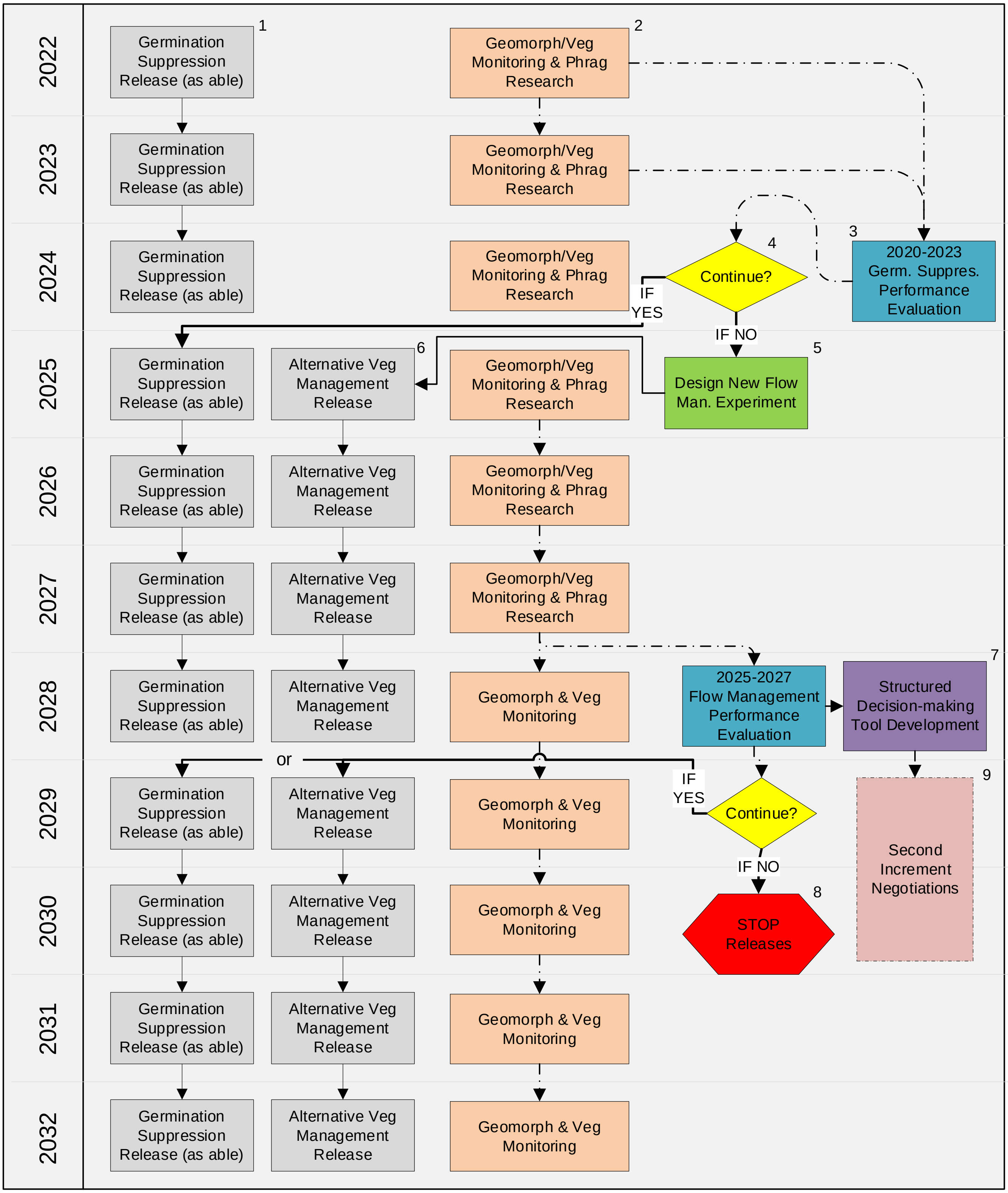


Figure 5. Vegetation Management (WC Habitat) Flow Release Activity Diagram



Vegetation Management (WC habitat) flow release activity diagram notes

1. Implementation of germination suppression or other flow management actions to create and/or maintain suitable WC roosting habitat.

2. System-scale geomorphology and vegetation monitoring including collection of high-resolution imagery in June and November and bathymetric LiDAR in November. Implementation of phragmites research (field and remote sensing) to assess growth/spread and response to spraying.

3. Analysis of system-scale geomorphology and vegetation monitoring and phragmites research evaluate the performance of germination suppression flows (or alternative vegetation management release) in creating and/or maintaining suitably-wide unobstructed channel widths for WC roosting.

4. Continue germination suppression flow releases because 1) action is effective in maintaining suitably-wide unobstructed channel widths or 2) more data is needed to assess performance.

5. If germination suppression release is not effective, design new flow management action to be tested.

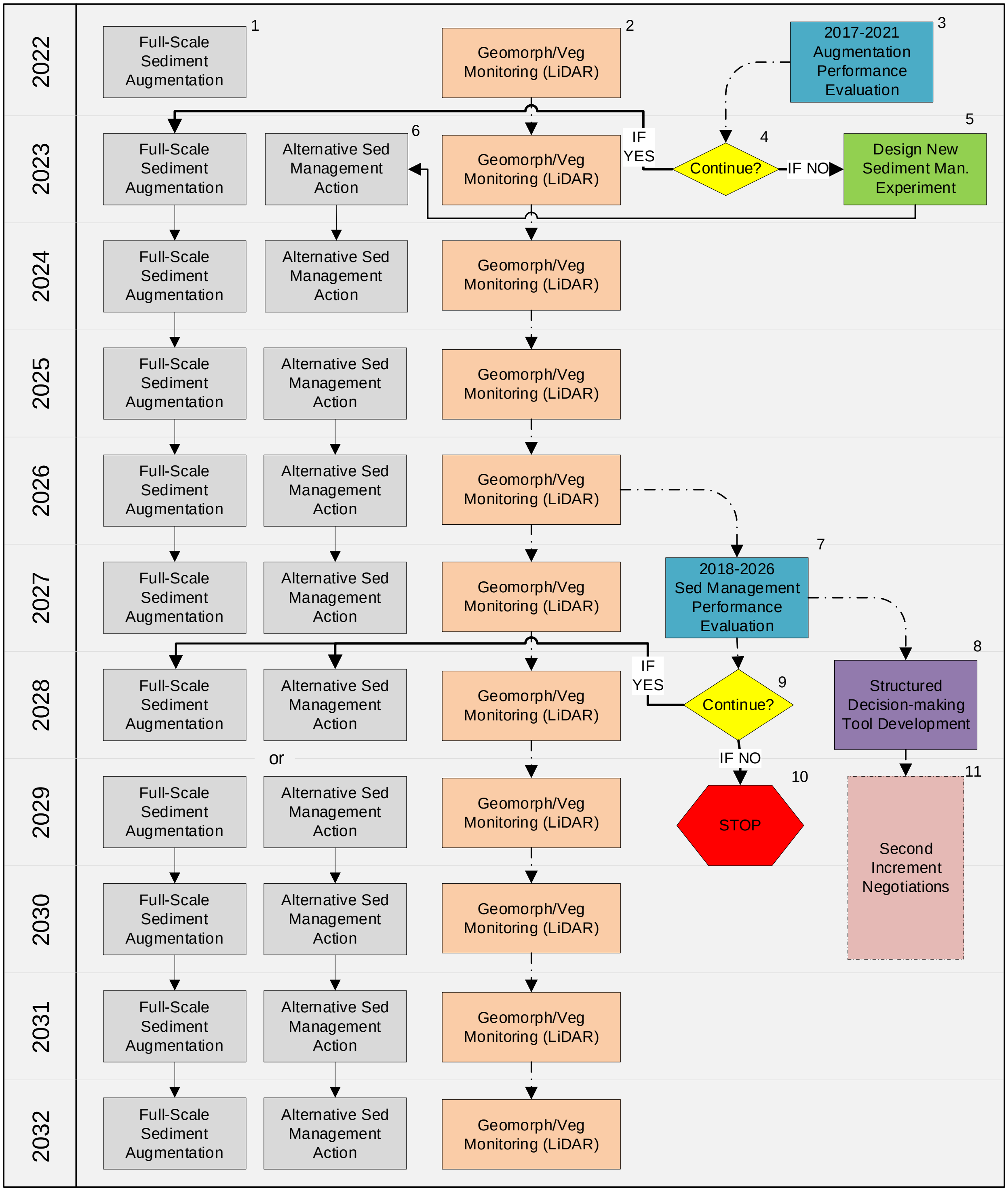
6. Implementation of new flow management action to create and/or maintain suitably-wide unobstructed channel widths for WC roosting.

7. Development of structured decision-making tools/models using results of geomorphology and vegetation monitoring and phragmites research. Tools/models will be used as part of a structured decision-making (SDM) process to quantify the performance of Second Increment flow management alternatives in creating/ maintaining suitable WC roosting habitat.

8. If alternative flow release is ineffective and/or no other flow management actions are identified, terminate vegetation management flow releases.

9. Negotiation of Second Increment utilizing a SDM framework.

1 **Figure 6. Sediment Augmentation Activity Diagram**



2

Sediment augmentation action diagram explanatory notes.

1. Implementation of full-scale sediment augmentation (60,000 – 80,000 tons) below the J-2 Return in the South Channel of the Platte upstream of Overton.

2. System-scale geomorphology and vegetation monitoring including collection of high-resolution imagery in June and November and bathymetric LiDAR in November.

3. Evaluation of channel morphology in the South Channel of the Platte downstream of the J-2 Return to assess the effectiveness of sediment augmentation in halting the downstream progression of channel degradation and narrowing.

4. Continue full-scale sediment augmentation because 1) it appears to be effective in offsetting degradation and narrowing or 2) addition data is needed to assess performance.

5. If evaluation indicates sediment augmentation is not effective, design new sediment management experiment.

6. Implementation of alternative sediment management experiment.

7. Evaluation to assess the effectiveness of alternative sediment management action in halting the downstream progression of channel degradation and narrowing.

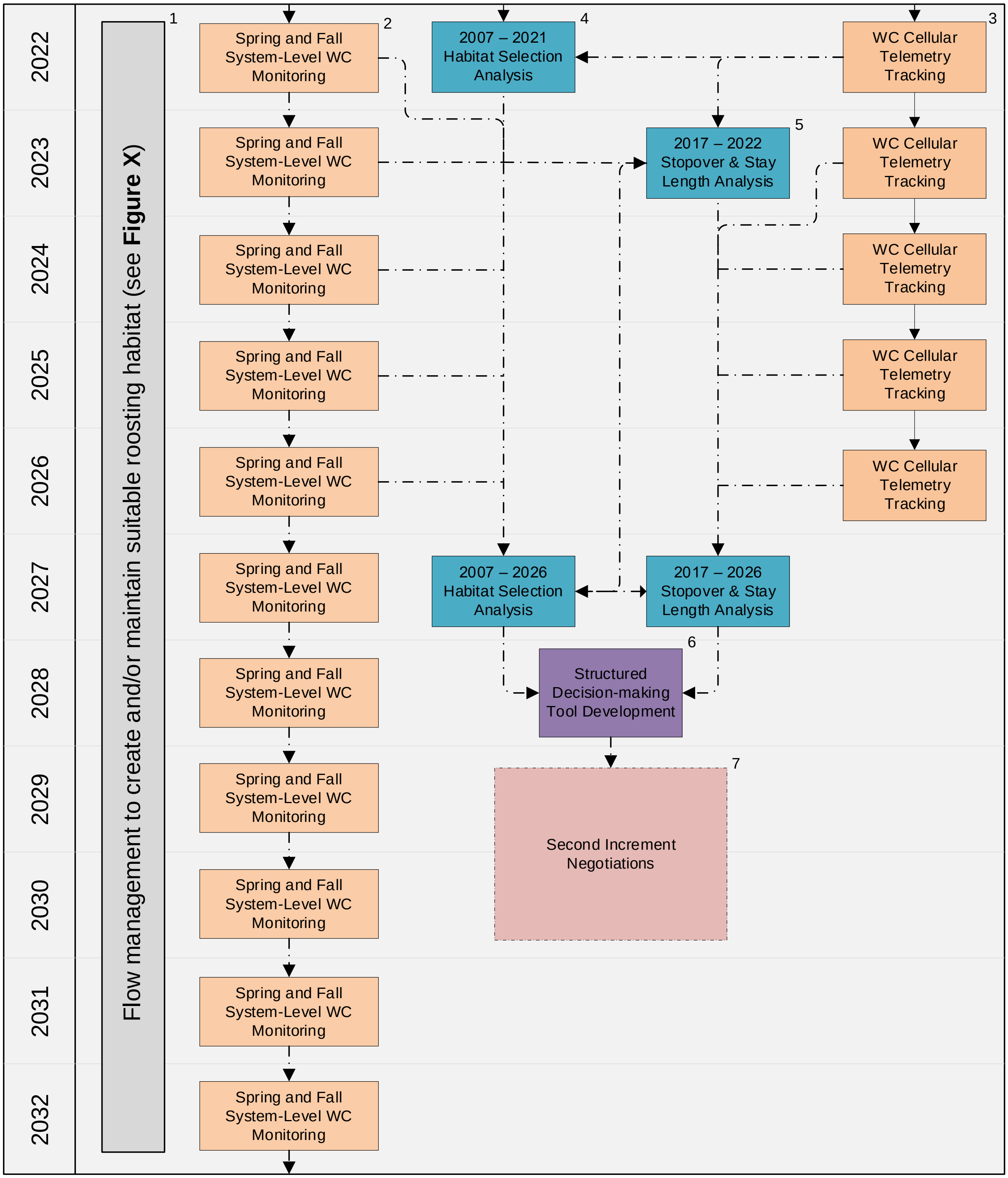
8. Development of structured decision-making tools/models using results of augmentation evaluation. Tools/models will be used to quantify the costs/benefits of sediment augmentation in the Second Increment as part of a structured decision-making process (SDM).

9. Continue full-scale sediment augmentation or alternative sediment management action because 1) it appears to be effective in offsetting degradation and narrowing or 2) addition data is needed to assess performance.

10. Stop augmentation/sediment management actions.

11. Negotiation of Second Increment utilizing a SDM framework.

Figure 7. Whooping Crane Activity Diagram.



Whooping crane explanatory notes.

1. Implementation of germination suppression or other flow management actions along with mechanical management (vegetation clearing and herbicide application) to create and/or maintain suitable whooping crane roosting habitat.

2. Annual system-level whooping crane monitoring to detect WC stopovers in the Associated Habitat Reach, identify roost locations, and document physical characteristics at roost sties. Protocol is implemented during the spring and fall migration and is based on daily aerial surveys and opportunistic locates. Data is synthesized into spring and fall monitoring reports.

3. Cellular telemetry study (initiated by others) to gain a better understanding of WC stopover areas, habitat use patterns, and factors influencing habitat use at different spatial and temporal scales. Data used to evaluate whether or not flow influences whether cranes stopover on AHR, length of stay, and differences between spring and fall use.

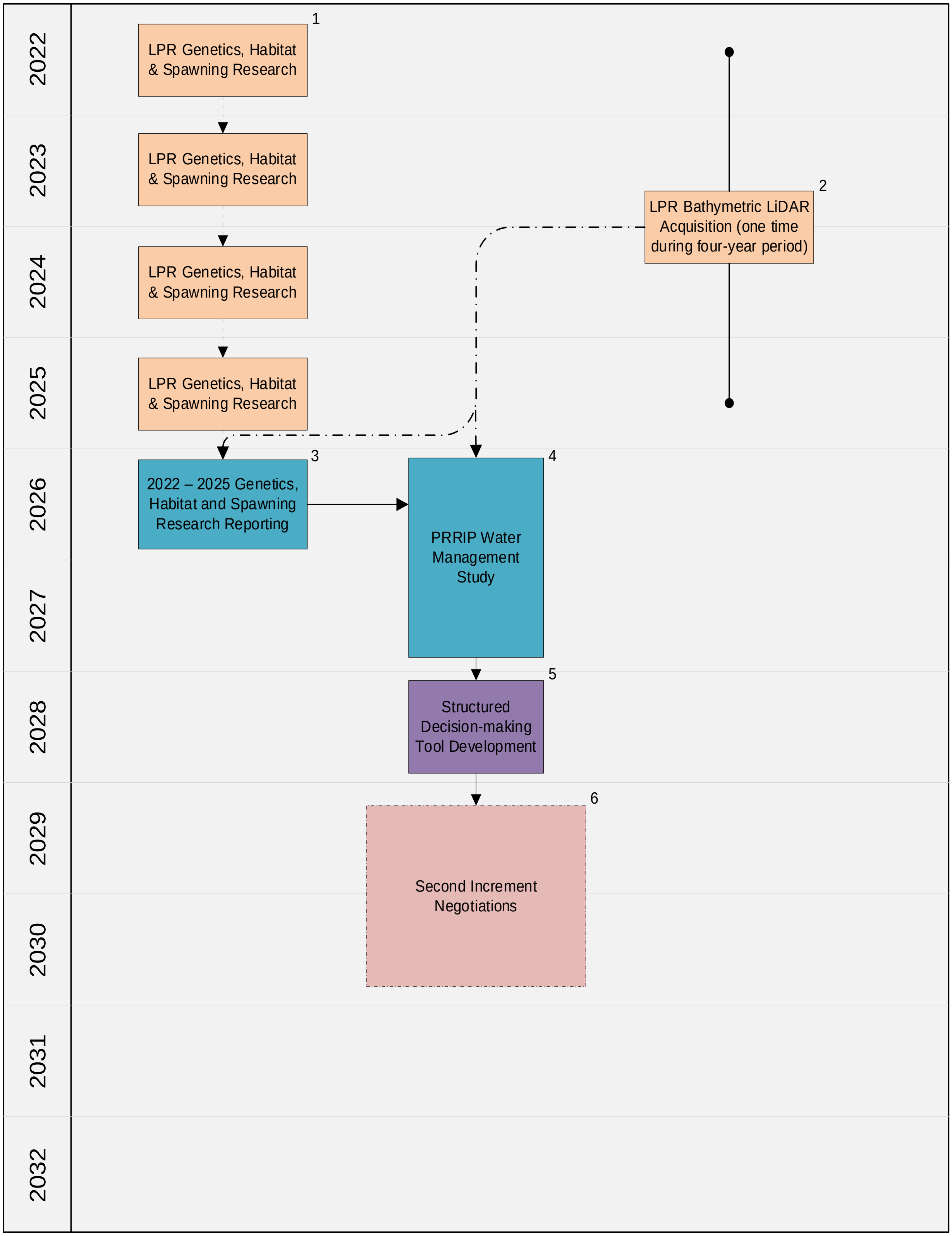
4. Analysis of system-level whooping crane use data and cellular telemetry data to identify physical habitat metrics that are good predictors of WC roost locations and update PRRIP habitat criteria.

5. Analysis of cellular telemetry and system-level whooping crane use data to evaluate factors influencing WC stopovers and stay length including flow, time of day, weather, physical habitat characteristics, etc.

6. Development of structured decision-making tools/models using results of habitat selection and stopover/ stay length analyses. Tools/models will be used to quantify WC effects of Second Increment management alternatives as part of a structured decision-making process (SDM).

7. Negotiation of Second Increment utilizing a SDM framework.

1 **Figure 8. Pallid Sturgeon Activity Diagram**



2

Pallid sturgeon activity diagram explanatory notes.

1. Lower Platte River (LPS) pallid sturgeon (PS) habitat research comprising of capture and tagging of PS to facilitate tracking of PS movement via a passive telemetry network and active tracking of tagged fish via airboat. Researchers will attempt to identify spawning habitat, confirm spawning and collect PS larvae. Genetics samples from PS captures and larvae will be analyzed (along with banked samples) to identify PS, PS/shovelnose hybrids and shovelnose sturgeon.

2. Bathymetric LiDAR acquisition in the segment of the LPR from the Loup River Confluence to the Missouri River Confluence. Data will be used to inform LPR habitat research and PRRIP water management study.

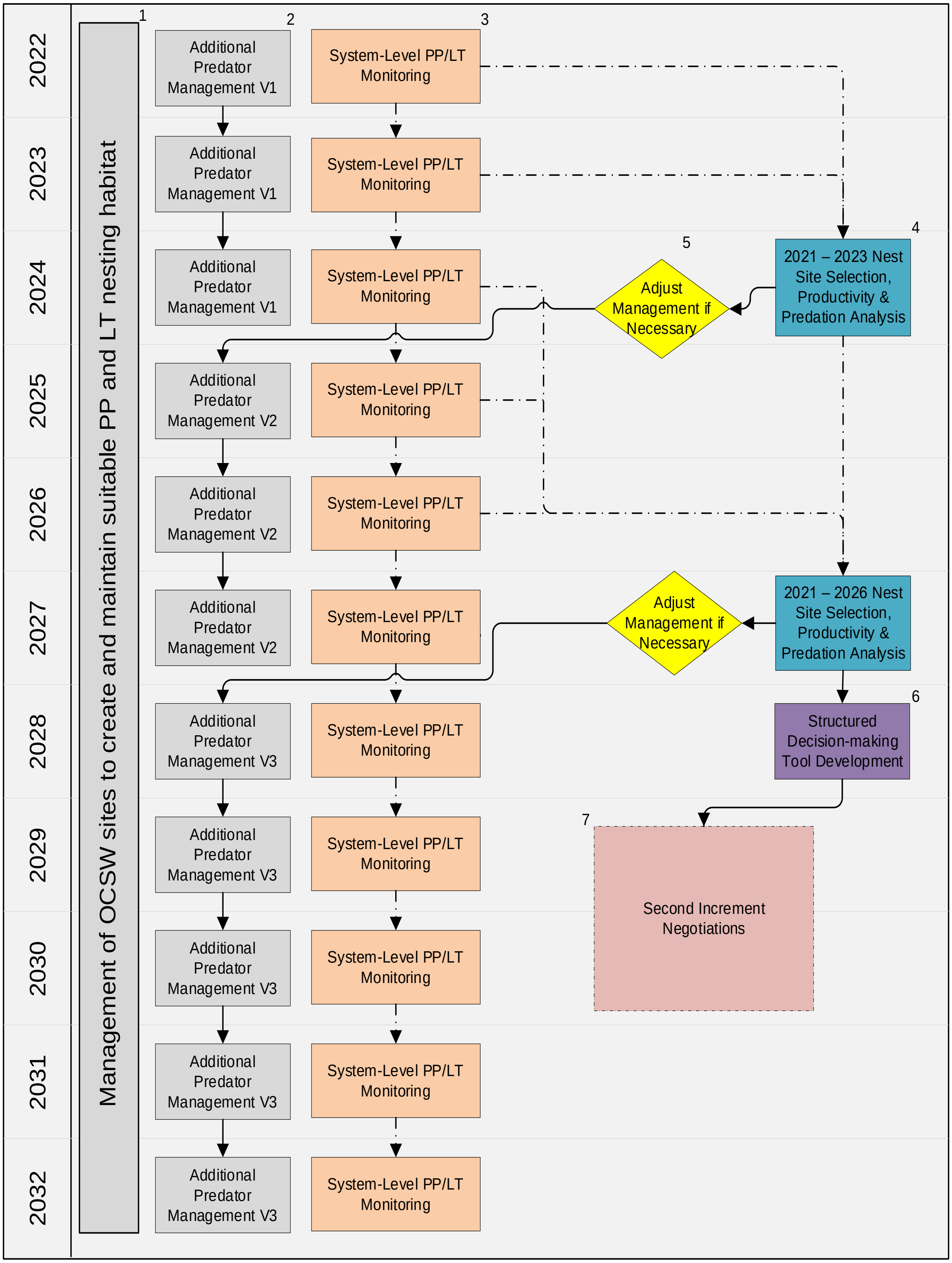
3. Analysis of genetics and LPR habitat data to assess hybridization, reassess population structure, and estimate effective population size. Analysis of LPR PS habitat research to assess PS use, spawning habitat, and spawning success in the LPR as well as the contributions of the LPR to PS population.

4. PRRIP water management study to identify benefits and potential impacts of Program water management on PS in the LPR and develop rules to guide Program water operations in a way that continues to provide identified benefits and avoids/minimizes impacts on PS.

5. Development of structured decision-making tools/models using results from PS research and water management study. Tools/models will be used to quantify PS effects of Second Increment management alternatives as part of a structured decision-making process (SDM).

6. Negotiation of Second Increment utilizing a SDM framework.

Figure 1. Piping Plover and Least Tern Action Diagram.



Piping plover and least tern action diagram explanatory notes.

1. Implementation of habitat management and baseline predator control at OCSW sites. This includes vegetation control, installation and maintenance of fencing at peninsula land entrance, and trapping.

2. Implementation of additional predator management actions including site-level fencing and lighting.

3. System-level monitoring of PP and LT habitat use and productivity. Monitoring includes bi-monthly river and OCSW surveys with more intensive site-level outside monitoring once nesting is observed. Site-level and nest-level camera (trail and video) is also conducted to identify frequency and cause of losses on OCSW habitat.

4. Analysis of system-level PP/LT monitoring to identify physical habitat ecological metrics that are good predictors of OCSW nest locations, quantify species productivity, and quantify impacts of predation.

5. If necessary, adjust predator control activities to improve productivity. This likely includes implementation of some form of avian predator control (based on 2020-2021 data).

6. Development of structured decision-making tools/models using results from site selection, productivity and predation analysis. Tools/models will be used to quantify PP effects of Second Increment management alternatives as part of a structured decision-making process (SDM).

7. Negotiation of Second Increment utilizing a SDM framework.

Wet Meadows

The final Extension Big Question relates to wet meadows – specifically completion of a First Increment wet meadows study that focused on assessing the hydrologic drivers in natural and restored wet meadows at the Fort Kearny and Shoemaker Island habitat complexes. We anticipate that this study will be completed by the end of 2022 and work products will include a report and tools that can be used to assess the potential for wet meadow creation/restoration at locations within the AHR based on topography, channel morphology and other physical site conditions. We do not anticipate continuing wet meadow research and monitoring after the completion of this study. As such we did not include an activity diagram.

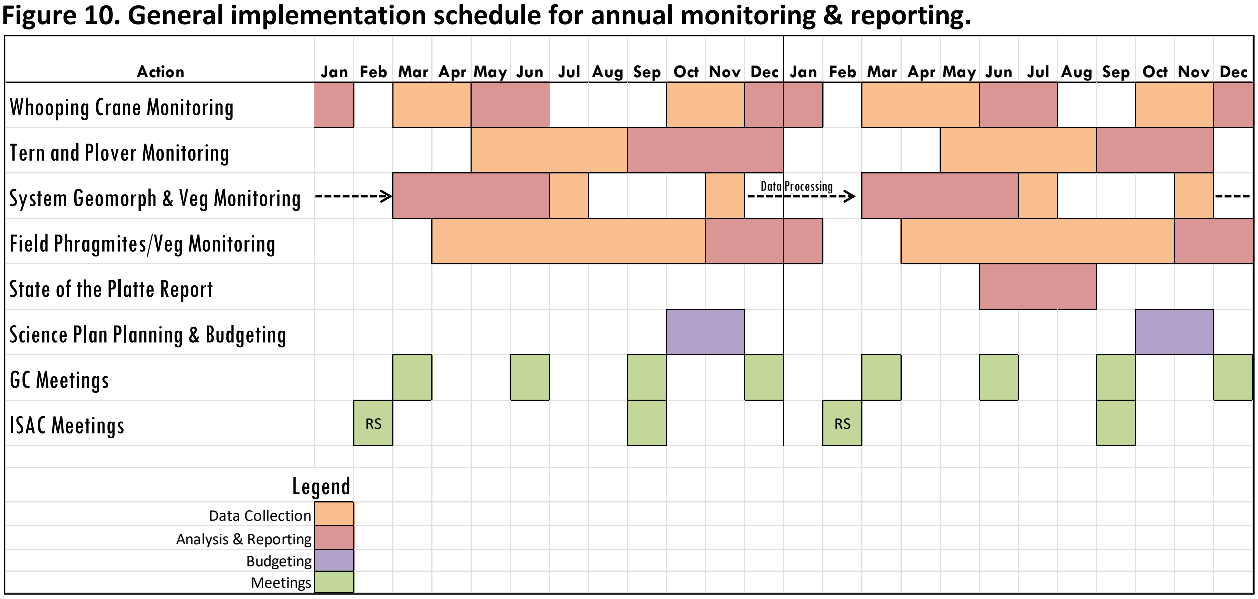
Synthesis, Analysis, & Reporting

For Science Plan implementation to inform decision-making, synthesis and analysis of annual monitoring efforts (geomorphology and vegetation, WC, PP/LT,) must occur soon enough to be relevant for annual work planning and budgeting. At the same time, larger analyses of management activity performance and associated target species response require multiple years of data to generate meaningful results. This section of the Guide presents both an annual monitoring analysis and science communication schedule as well as a timeline for broader analyses of management activity performance and species response.

Annual Monitoring Implementation & Analysis Schedule

A schedule of annual monitoring, analysis is presented in Figure 10. The schedule is generally designed to facilitate synthesis and analysis of annual WC and PP/LT monitoring data prior to a February Independent Science Advisory Committee (ISAC) meeting (Science Plan Reporting Session). System-scale geomorphology/vegetation data analysis will not be completed prior to the February ISAC meeting due to remote sensing contractor data processing time. Those results will be presented at a September ISAC meeting.

Figure 10. General implementation schedule for annual monitoring & reporting.

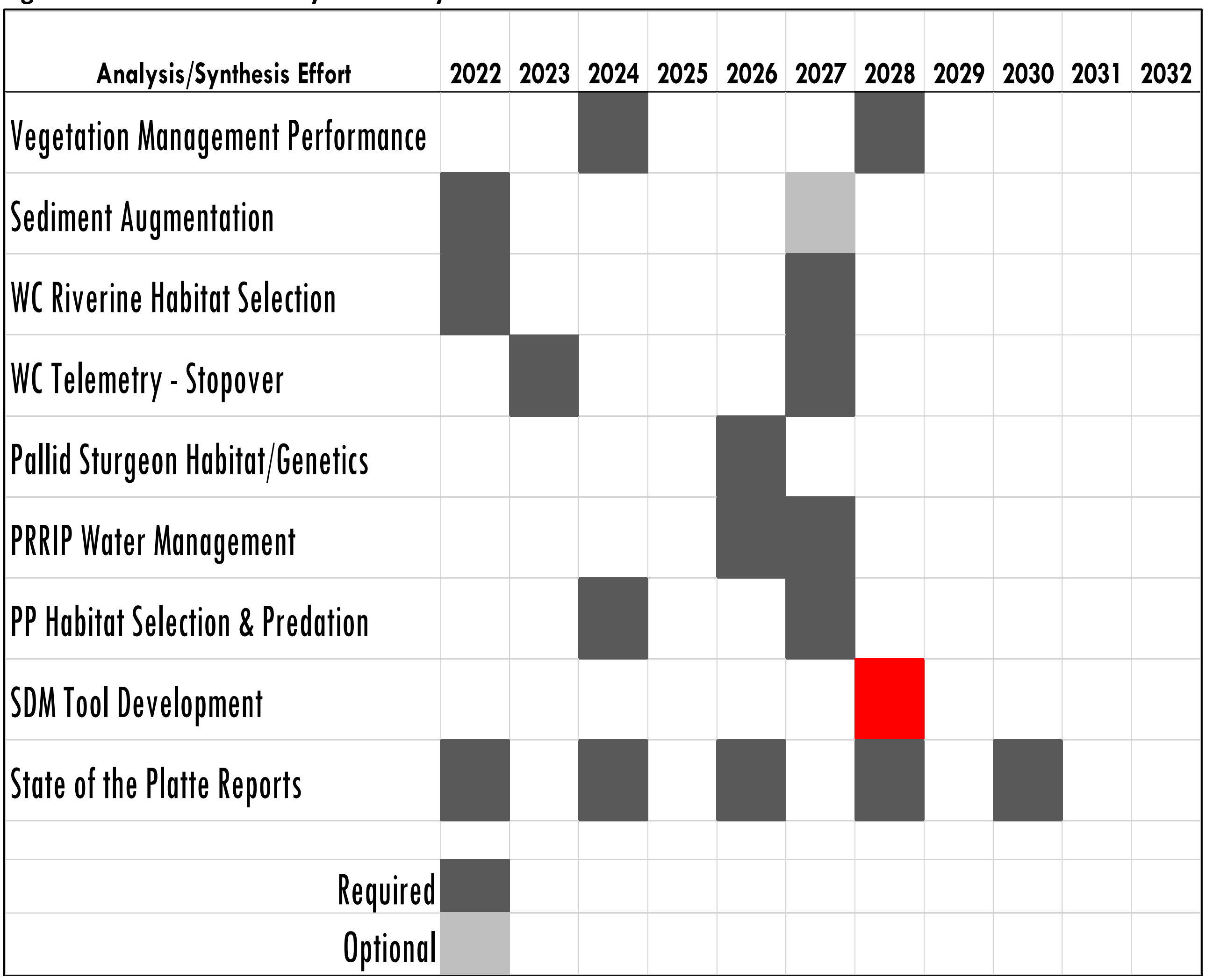


*Annual Science Plan Reporting Session denoted by letters "RS"

Multi-Year Synthesis Timeline

A general timeline for large-scale multi-year data synthesis efforts is presented in Figure 11. The timeline generally accommodates two rounds for each effort, one during 2022-2024 and one in 2027 in preparation for SDM tool development. We anticipate that the methods and models used in the first round of syntheses will be carried forward to the second round in 2027. Use of existing analyses frameworks will accommodate a higher analysis workload in 2027 than could be accomplished if all syntheses were to be developed from scratch. Once 2027 syntheses are completed, the results will be used to develop SDM tools – models that will be used to quantify system/species response to management alternatives.

Figure 2. Timeline of multi-year data synthesis efforts.



PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM (PRRIP -or- Program)

Extension Science Plan Attachment #4 – Analysis, Synthesis, & Decision-Making

Materials for Attachment #4 will be developed through November, 2021 – February, 2022.