REQUEST FOR PROPOSALS (RFP)

RESPONSE OF INVASIVE *PHRAGMITES* PATCHES TO CHANNEL INUNDATION AND HERBICIDE TREATMENTS ALONG THE CENTRAL PLATTE RIVER 2024 - 2027

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM
Office of the Executive Director
4111 4th Avenue, Suite 6
Kearney, Nebraska 68845

January 26, 2024

Contents

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM (PRRIP -or- PROGRAM)
REQUEST FOR PROPOSALS (RFP)

SUBJECT:	*Phragmites australis* Monitoring Services
REQUEST DATE:	January 26, 2024
PRE-PROPOSAL MEETING:	February 8, 2024
CLOSING DATE:	February 19, 2024
POINT OF CONTACT:	Jason Bruggeman Headwaters Corporation Office: (308) 237-5728; Cell: (308) 293-5605 bruggemanj@headwaterscorp.com

OVERVIEW

The Platte River Recovery Implementation Program (Program or PRRIP) initiated on January 1, 2007 between the states of Nebraska, Wyoming, and Colorado and the Department of the Interior to address endangered species issues in the central and lower Platte River basin. Program "target species" include the whooping crane, piping plover, interior least tern (now de-listed), and pallid sturgeon. The Program has been charged with management of land and water along the central Platte River to achieve management objectives for these target species.

A Governance Committee (GC) has been established that reviews, directs, and provides oversight for activities undertaken during the Program. The GC is comprised of one representative from each of the three states, three water user representatives, two representatives from environmental groups, and two members representing federal agencies. Headwaters Corporation provides the Executive Director and staff for the Program, collectively known as the Executive Director's Office (EDO). Program staff are located in Nebraska and Colorado and are responsible for assisting in carrying out various Program-related activities.

In the early 2000s, portions of the central Platte River channel in Nebraska narrowed as a result of an intensive *Phragmites australis (*hereafter *Phragmites)* infestation and drought conditions. This narrowing of the Platte River channel reduced habitat suitability for the endangered whooping crane that stop along the central Platte during their spring and fall migrations. In addition, *Phragmites* expansion limited water conveyance, reducing the ability to deliver water throughout the reach. One of PRRIP's current science objectives is to contribute to reach-scale *Phragmites* control efforts with a focus on understanding the effectiveness of Program water management actions to control the spread of *Phragmites* to create and maintain suitable whooping crane roosting habitat (Extension Big Question #2, PRRIP 2022, pg. 47). In addition to mechanical and chemical control, the Program has an interest in understanding how river flow may be used to slow *Phragmites* rhizome and stolon expansion into the river channel because *Phragmites* expansion has occurred during periods of drought. Previous work on *Phragmites* by PRRIP and future directions are summarized below.

PRRIP initiated monitoring of *Phragmites* in 2022 with a pilot scale project to determine the feasibility of monthly data collection following proposed sampling protocol, evaluate and adjust methods as necessary to address priority hypotheses, and provide information on variability in explanatory variables and patch response.

The project was expanded and refined in 2023. The revised study design focused more on bankline patches that directly interact with river flow. Additional data were collected to quantify growth patterns for individual patches, stolon/rhizome networks, and individual stolons, with measurements specifically taken to allow for the quantification of growth into and across the active river channel.

Ultimately the intent is to gather the information necessary to describe and quantify *Phragmites* growth and expansion patterns prior to, during, and following Program-managed flow releases and twice annual system-scale herbicide applications. The current study design allows for learning about the conditions under which river flow can be an effective tool for *Phragmites* growth management and the conditions under which chemical and/or mechanical management may be more suitable. The project will gather information on how much water may be required, when, and where, to be effective; but also, information about the conditions under which water is ineffective and the scale over which chemical and/or mechanical intervention will be required.

The GC submits this Request for Proposals (RFP) to solicit proposals from Consultants to provide ***three years of Phragmites monitoring and associated data analysis***. Two years of data have already been collected by the Program establishing the scope of the project and methods for data collection (detailed in Scope of Work and **Exhibit A**). Methods for performing data analyses have been outlined in **Exhibit A** but may be collaboratively revised by the EDO and the Consultant after selection and prior to analysis.

The term Consultant shall be used throughout this document to describe both potential <u>RFP Respondents</u> submitting a proposal and the <u>successful Respondent</u> performing the work upon award of the project.

SCOPE OF WORK

The selected Consultant will provide *Phragmites* patch growth and expansion monitoring services that will be used in conjunction with river flow and water coverage data from PRRIP and herbicide application data from the Platte Valley Weed Management Area to document, quantify, and describe *Phragmites* response to flow and herbicide over time and across the Program's Associated Habitat Reach along the central Platte River from Lexington to Chapman, Nebraska.

The Program's objective is to collect data on the spatial extent of *Phragmites* patches and individual stolons/rhizomes over the course of the growing season in response to river flow and herbicide treatment. The Program has collected two years of data to address this question. To allow for analysis of *Phragmites* response over multiple growing seasons, the Consultant will follow the monitoring protocol developed by the Program for data collection in the field (**Exhibit A**). Briefly summarized, the Consultant will survey approximately 156 *Phragmites* patches distributed over three study sites monthly from May through October each year, over the next three years (2024–2026). The study sites are located on Program-owned land and are near the towns of Overton, Kearney, and Grand Island, Nebraska. The Consultant will use an RTK GPS unit to delineate patch, stolon, bank line, and edge of water boundaries in relation to one another. The Consultant will also individually mark and measure five or more stolons for each patch to be found and measured repeatedly throughout the growing season. Maximum patch height, patch stem density, life stage, condition, presence of visible stolons or rhizomes, and proportion of other plant cover will be recorded. If visible evidence of herbicide application exists, the Consultant will map the affected area using the RTK GPS as well. Photos of each patch are taken for later reference.

Two river stage gages at each of the three study sites are to be installed, maintained, and monitored during the course of the growing season beginning in May, with monthly data downloads through October. Stage gages are to be removed following completion of each year's data collection to prevent damage by ice. In addition, data from the nearest USGS river stage gages on the Platte River at Overton, Kearney, and Grand Island as well as discharge data from the Johnson Hydropower Return (J2 Return) will be used to estimate river flow over time at individual *Phragmites* patches.

The Consultant will be responsible for data entry, processing, database management, and error checking in a manner compatible with previous Program efforts. The Consultant will map patch expansion by creating polygons in GIS representing patch area, stolon reach, bank line, and edge of water surfaces from RTK point location data collected in the field. Daily, monthly, and annual growth rates and directionality of growth of patches and stolons will be calculated as response variables.

The Consultant will utilize results from an annual 2-D hydraulic model developed by the Program that utilizes annual topobathymetric LiDAR and USGS stream gage data to estimate area of water coverage, depth, velocity, sheer stress, and other spatially explicit hydraulic metrics at various flow levels on the central Platte River for the purpose of quantifying the spatial and temporal extent of patch inundation under varying flows. Time and extent of inundation, along with water depth, velocity, and sheer stress are of interest as explanatory variables.

An initial data analysis plan, including hypotheses to be tested, explanatory variables, response variables, comparisons to be made between modeled patch inundation and measured patch inundation, and alternative analytical approaches, can be found in **Exhibit A**. The data analysis plan will be collaboratively revised by the EDO together with the Consultant upon selection and following Consultant familiarity with the dataset.

The specific steps to onboard the selected Consultant will be determined following selection, but a general description of the anticipated progression of the study is provided below. Once selected, the Consultant and EDO will work collaboratively to:

- Visit study sites and introduce field methods.
- Perform an initial review of field data collection methods and the field data collected in 2022 and 2023.
- Perform an initial review of available hydrologic and hydraulic data.
- Determine additional data needs.
- Propose alternative explanatory and/or response variables.
- Determine the best methodology to integrate previous data collection with future data collection.
- Propose alternative analytical frameworks for hypothesis testing.
- Modify existing field methodology and data analysis plan to reflect decisions made for moving forward.
- Present modifications in study design and/or analysis to the Program's Technical Advisory Committee for review.
- Provide written and oral progress reports annually to Program Advisory and Governance Committees.

The Consultant will engage in regular formal and informal communication and coordination with the Program's Technical Point of Contact, EDO, and Program committees to keep them informed of progress toward and potential impediments to achieving Program objectives. The Consultant will provide the EDO with all project data and a written report describing methods, data collected, analyses performed, results, and interpretations relative to Program objectives to be presented at the Program's annual Science Plan Reporting Session in February of 2025 and 2026. A final data transfer and cumulative synthesis report following 2026 data collection will be due by April 1, 2027. Annual reports will be reviewed by the EDO, working together with the Consultant to finalize, prior to being sent to Program Advisory Committees and Governance Committee for review and approval. The Consultant will be responsive to Program EDO and Committee feedback. The Consultant will participate in the Program's annual Science Plan Reporting Sessions.

The following areas of expertise may be necessary to complete the full scope of work:

- *Phragmites australis* identification and ability to differentiate this species from other riparian species.
- Navigation to and from field sites and previously surveyed *Phragmites* patches.
- Collection of positional and elevation data using an RTK GPS unit.
- River stage gage installation, maintenance, and data download.
- Data collection, processing, error checking, and database management.
- Integration of river stage gage data and 2-D hydrodynamic model water surfaces to quantify patch inundation at various flows over time.
- Geospatial analysis/water surface elevation data processing.
- Multi-factor statistical analysis and development of models in program R to predict *Phragmites* expansion under different management scenarios.

PROJECT BUDGET

An estimated project budget with justification of costs should be submitted in the proposal. Cost will be one of the factors considered in selection.

CONTRACT TERMS

The selected Consultant will be retained by:

Nebraska Community Foundation
PO Box 83107
Lincoln, NE 68501

Proposals should indicate whether the Consultant agrees to the contract terms as outlined in the attached Program's Professional Services Contract (**Exhibit B**) or provide a clear description of any exceptions to the terms and conditions.

The initial term of the contract is expected to be for a three-year period beginning at the date of final signing of the contract (late March, 2024 through mid-2027). The actual contract schedule will be developed with the Consultant and incorporated into the contract. Contracted services will be performed on a time and materials not to exceed basis. Under the final contract, a written Notice to

Proceed from the EDO will be required before work begins. All work will be contingent on availability of Program funding.

The selected Consultant may be requested to negotiate additional services, with the option to extend, re-compete, or cancel at the discretion of the GC.

SUBMISSION REQUIREMENTS

All interested parties having experience providing the services listed in this RFP are requested to submit a proposal.

Instructions for Submitting Proposals

One (1) electronic (PDF) copy of your proposal must be submitted to Jason Bruggeman by email at bruggemanj@headwaterscorp.com *no later than 5:00 PM Central Standard Time on Monday, February 19, 2024.* The maximum allowable proposal PDF size is 15MB, and proposals are to be limited to a total of 50 pages or less. A proposal is late if received any time after 5:00 PM Central Standard Time and will not be eligible for consideration.

Questions regarding the information contained in this RFP should be submitted to Jason Bruggeman at bruggemanj@headwaterscorp.com. A list of compiled Consultant questions and responses will be maintained on the Program web site (www.PlatteRiverProgram.org) in the same location as this RFP solicitation. The last day to accept questions is February 14, 2024.

RFP Schedule

The EDO expects to complete the selection process and award the work by March 29, 2024. The following table represents the RFP schedule:

Description	Date	Time (CST)
Issue RFP	By Jan 26, 2024	n/a
Pre-proposal virtual meeting	Feb 8, 2024	12:00 PM
Last day for respondents to submit questions regarding the RFP	February 14, 2024	5:00 PM
Proposals due from Consultants	February 19, 2024	5:00 PM
Evaluation of Proposals	February 26 through March 11, 2024	
Interviews	Week of March 18, 2024	
Award of Work	On or before March 29, 2024	
Start of Work	Early April, 2024	
Completion of Work	Approximately late March, 2027	

Virtual Pre-Proposal Meeting

A **mandatory** virtual pre-proposal meeting of interested parties will be held on February 8, 2024 from 12:00-1:00 PM Central Standard Time via Microsoft Teams for the purpose of familiarizing potential Consultants with the Scope of Work and requirements included herein before submitting a response to this RFP. To register, please email Jason Bruggeman (bruggemanj@headwaterscorp.com) with names and email addresses for the people from your firm and/or team expected to join the virtual pre-proposal meeting by 12:00 PM Central Standard Time on February 6, 2024. A meeting invite with the Microsoft Teams link will be forwarded to expected participants.

The meeting will include a brief overview by the EDO regarding the objectives of the project, the scope of services, and the timeline. It is the Consultant's responsibility, during the pre-proposal meeting, to ask questions necessary to understand the RFP so the Consultant can submit a proposal that is complete according to the RFP requirements. No minutes will be distributed by the EDO regarding the meeting. Any proposals submitted by Consultants who did not register for and participate in the mandatory virtual pre-proposal meeting will be rejected.

<u>*Proposal Content*</u>

Proposals should respond to the following general topics:

1) **Project understanding:** Discussion that demonstrates the Consultant's understanding of key objectives, goals and constraints.
2) **Project approach:** Discussion of the Consultant's approach to data collection and data analysis including critical issues, tasks, or considerations that may have shaped your approach. This section should not be a reiteration of the general scope of work presented in Section II of this RFP or the protocol included as **Exhibit A**. That scope was provided as general guidance and original thinking and/or discussion of improvements to that approach are welcome and encouraged. Specific items that should be addressed in the approach include:
    a. Additional metrics that may be particularly useful for understanding *Phragmites* response to river flow.
    b. Alternative explanatory variables to be explored that may provide more information on how much water, when, and for how long, may be required to limit *Phragmites* expansion into the active river channel.
    c. A plan for quantifying patch inundation over time under sub-daily changes in flow conditions as reflected in multiple sources of data contributing to this metric.
    d. Alternatives for data analysis that may be appropriate and a stepwise process for testing and selecting an approach.
3) **Qualifications and project experience:** Provide project team organization, resumes/qualifications, and responsibilities. Identify relevant project experience, particularly within the past five years, including the name, location, and brief description of the projects; name, address, email, and phone number for the primary client contact; and the involvement/role of the proposed team members in those projects.
4) **Project Budget including Rate Schedule:** Proposed budget to complete the scope of work in this RFP as well as a schedule of 2024 standard hourly and reimbursable cost rates by labor category.
5) **Additional Documentation Required**: **Certificate of Good Standing and Certificate of Insurance** – <u>include both with proposal</u>. The Program's Professional Services Contract (**Exhibit B**) describes requirements for a Certificate of Good Standing (*Exhibit B, Section 8.G.)* and Insurance (*Exhibit B, Section 8.S.*). Proof of a Certificate of Good Standing and all Insurance types and coverage levels will be required before a contract is issued and both will be included in the contract.
6) **Attestation: Certification Regarding Lobbying** – proposal must indicate Contractor's ability to sign the PRRIP Certification Regarding Lobbying during the contracting phase. The certification is included in **Exhibit B**.

7) **Attestation: Conflict of Interest** – proposal must include a statement noting no potential conflict of interest exists between this project and other past or on-going projects, including any projects currently being conducted for the Program.
8) **Attestation: Debarment and Suspension** – proposal must include a statement certifying Contractor is not on the federal suspended and disbarred list. A DUNS[1] and SAM[2] number are required to assist in verification.
9) **Attestation: Acceptance of Terms and Conditions** – proposal must include a statement noting Consultant can abide by all terms and conditions as outlined in **Exhibit B** or provide a clear description of any exceptions to the terms and conditions.

Criteria for Evaluating Proposals

The GC appointed a Proposal Selection Panel that will evaluate all proposals and select a Consultant based on the following principal considerations:

1. The Consultant's understanding of the overall project goals, constraints, elements, and their approach to successfully implementing the project scope.

2. Qualifications and the relevant experience of the proposed project team members and firm, which may include:
    a. Ability to work under typical field conditions experienced in central Nebraska from May through October (exposure to high water, low/high temperatures, rain, sun, stinging insects, and pollen).
    b. Familiarity with *Phragmites* and riparian vegetation typical of the central Platte River.
    c. Familiarity with central Platte River water operations, flow dynamics, and geomorphology.
    d. Familiarity with the project study sites.
    e. Experience leveraging data from multiple sources and gages to increase predictive accuracy and reliability.
    f. Experience working with multi-factor statistical analyses of ecologically complex processes.

3. Estimated budget to complete the scope of work. *This is a qualifications-based selection. Budget will be one but not the deciding factor in Contractor Selection.*

Interviews may be held if necessary, as determined by the Proposal Selection Panel.

Award Notice

After completing the evaluation of all proposals and, if deemed necessary, interviews, the Proposal Selection Panel will select a Consultant. That firm will negotiate with the EDO to establish a fair and equitable contract. If an agreement cannot be reached, a second firm will be invited to negotiate and so on. If the Program is unable to negotiate a mutually satisfactory contract with a Consultant, it may, at its sole discretion, cancel and reissue a new RFP.

[1] https://www.dnb.com/duns-number.html
[2] https://federalcontractorregistry.com/

Program Perspective

The GC has the sole discretion and reserves the right to reject any and all proposals received in response to this RFP and to cancel this solicitation if it is deemed in the best interest of the Program to do so. Issuance of this RFP in no way constitutes a commitment by the Program to award a contract, or to pay Consultant's costs incurred either in the preparation of a response to his RFP or during negotiations, if any, of a contract for services. The Program also reserves the right to make amendments to this RFP by giving written notice to Consultants, and to request clarification, supplements, and additions to the information provided by a Consultant.

By submitting a proposal in response to this solicitation, Consultants understand and agree that any selection of a Consultant or any decision to reject any or all responses or to establish no contracts shall be at the sole discretion of the Program. To the extent authorized by law, the Consultant shall indemnify, save, and hold harmless the Nebraska Community Foundation, the states of Colorado, Wyoming, and Nebraska, the Department of the Interior, members of the Governance Committee, and the Executive Director's Office, their employees, employers, and agents, against any and all claims, damages, liability, and court awards including costs, expenses, and attorney fees incurred as a result of any act or omission by the Consultant or its employees, agents, sub-Consultants, or assignees pursuant to the terms of this project. Additionally, by submitting a proposal, Consultants agree that they waive any claim for the recovery of any costs or expenses incurred in preparing and submitting a proposal.

Exhibit A

RESPONSES OF INVASIVE *PHRAGMITES* PATCHES TO CHANNEL INUNDATION AND HERBICIDE TREATMENTS ALONG THE CENTRAL PLATTE RIVER

Field Methodology and Data Analysis Plan

Prepared by:
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November 28, 2023

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I. INTRODUCTION

Non-native *Phragmites* (*Phragmites australis subsp. Australis*; hereafter *Phragmites*) is an invasive weed species associated with wetlands that spreads rapidly and outcompetes many native plants due to its high primary productivity, large above- and below-ground biomass, and clonal propagation (Amsberry et al. 2000). Once established, *Phragmites* alters wetland hydrology, narrows stream channels, and modifies wildlife habitat (Tulbure et al. 2007, Knezevic et al. 2008). In particular, avian species are especially affected by *Phragmites* infestations due to impacts on wetlands and streams that may affect waterfowl and shorebirds, and loss of native, short-grass habitats important to breeding grassland specialist species (Kessler et al. 2011, Robichaud and Rooney 2022, Dinehart et al. 2023).

In the early 2000s, portions of the central Platte River channel in Nebraska narrowed as a result of an intensive *Phragmites* infestation and drought conditions (Galatowitsch et al. 2016). This narrowing of the Platte River channel reduced habitat suitability for waterfowl and migratory waders, most notably the endangered whooping crane (*Grus americana*). Individuals from the migratory Aransas-Wood Buffalo whooping crane population use the Platte River as stopover habitat during their spring and fall migrations to and from their breeding area in Canada. Whooping crane roost sites along the Platte River have been associated with wider unobstructed channel widths (Baasch et al. 2019) because channels that are narrow and have visibility obstructed by tall vegetation reduce the likelihood of detecting predators and increase predation risk. Therefore, management actions to widen channels through reduction of tall vegetation is one key to maintaining highly suitable whooping crane stopover habitat.

The Platte River Recovery Implementation Program (PRRIP or Program) has applied management actions to improve whooping crane stopover habitat since 2007 (Farnsworth et al. 2018, PRRIP 2022). These efforts have included short duration high flow water releases, tree removal, disking, and herbicide treatments to *Phragmites* patches along the banks of the Platte River and its side channels (Knezevic et al. 2013, Farnsworth et al. 2018, PRRIP 2022). Herbicide applications, in particular, have reduced the extent of in-channel *Phragmites* infestations and widened the channel (Johnson 2012, Rapp 2012). However, herbicide treatments alone may not be effective at controlling spread of *Phragmites* and repeated applications in both spring and fall may be necessary (Rapp et al. 2012). One of PRRIP's current science objectives is to contribute to reach-scale *Phragmites* control efforts with a focus on understanding the effectiveness of Program water management actions to control the spread of *Phragmites* to create and maintain suitable whooping crane roosting habitat (PRRIP 2022). In addition to mechanical and chemical control, the Program has an interest in understanding how river flow may be used to slow *Phragmites* rhizome and stolon expansion into the river channel (PRRIP 2022) because periods of low flow associated with drought have been associated with *Phragmites* expansion (Galatowitsch et al. 2016).

The Program's management hypothesis pertaining to flow and *Phragmites* expansion is as follows:

> Releases to achieve a 30-day minimum flow target of 1500 cubic feet per second (cfs) 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 the Associated Habitat Reach channel that remains highly suitable for whooping crane roosting (PRRIP 2022).

This prediction is related to a hypothesized physical process in which *Phragmites* expansion rates into the active river channel are inversely related to the percent of time bare sand substrate is inundated during a 30-day period between June 1–July 15 (PRRIP 2022). To test these hypotheses, we designed a field study to survey *Phragmites* patches along the central Platte River each month of the growing season from May through October to examine: (1) areal growth rates of entire *Phragmites* patches; (2) areal growth rates of stolon reaches and changes in maximum distance of stolon expansion into the river channel; and (3) changes in the lengths of individual stolons. Herein, we describe field methodology used to collect data to address the effectiveness of flow releases to inhibit *Phragmites* patch expansion into the river channel. We also detail our methods for analyses of *Phragmites* patch and stolon reach data collected during 2022 and 2023.

II. METHODS

A. Study Areas

The Program's Associated Habitat Reach (AHR) of the central Platte River extends from Lexington to Chapman, Nebraska (Figure 1). Our study areas consisted of three complexes of PRRIP-owned lands spanning the AHR from west to east along the central Platte River (Figure 1). The Plum Creek study area was comprised of the Cook and Dyer properties south of Overton (Figure 2). The Fort Kearney study area consisted of the Wyoming and Sherrerd properties south of Kearney (Figure 3). The Chapman study area included the Bergen and Robinson properties east of Grand Island (Figure 4).

We established study areas with two adjacent PRRIP-owned or managed lands in an effort to designate one property to have *Phragmites* patches sprayed with herbicide during spring and/or fall and the other property to have no *Phragmites* patches sprayed with herbicide. In the Plum Creek study area, we designated the western Cook property as a no-spray zone and the eastern Dyer property as a spray zone scheduled for herbicide treatments in September. At Fort Kearney, we designated the western Wyoming property as a no-spray zone and the eastern Sherrerd property as a spray zone scheduled for herbicide treatments in June and September. At Chapman, we separated the Robinson property into west and east halves and designated the western half as a spray zone scheduled for herbicide treatments in June and September and the eastern half as a no-spray zone. The Bergren property fell entirely within the spray zone. Both the Robinson and Bergren properties underwent large scale tree removal in the fall of 2021. In addition, in-channel disking took vegetated sandbars back to bare sand in October of 2021. Therefore, in-channel islands and shorelines were in early successional stages at the onset of our study.

B. Sampling Design

a. 2022 Pilot Study Selection of Phragmites Patch Sample

We used a simple random sampling design to select *Phragmites* patches to survey during the 2022 pilot study. We classified patches that were >10 ft from the bankline of a main or secondary river channel as an inland patch. We classified patches that were in or along the bankline of a main or secondary river channel as a bankline patch. We also used a PRRIP water surface elevation (WSE) model to predict the spatial extent of river coverage at a discharge of 1500 cfs in ArcGIS Pro 3.1.1 (ESRI 2022) and classified any patch that intersected the 1500 cfs WSE polygon as a bankline patch. If we observed patches inundated by water during our July 2022 surveys, then we also classified those as bankline patches. In total, the 2022 sample consisted of 68 bankline and 87 inland patches. We provide a description of field methodology and data collected during the 2022 pilot study in the Appendix and a comparison of data collected during 2022 and 2023 in Table A1.

b. 2023 Phragmites Patch Sample Reallocation

Due to the large number of inland patches in our sample during 2022 that were not subject to inundation as a result of our 1500 cfs flow release, we used data collected during the 2022 pilot study and field visits to the study areas in March 2023 to identify additional bankline patches that could be added to the sample to better test the effects of our management action. We also used data from 2022 to identify small inland patches with low *Phragmites* stem density or bankline patches in backwater slough channels or along inland ponds that could be removed from the sample such that field effort could be better allocated to surveying bankline patches along the main river channels. We added 45 new bankline patches to our sample in 2023 and removed 42 inland and backwater patches from the sample that were surveyed during 2022. Therefore, our 2023 sample of bankline patches included 55 patches previously surveyed during 2022 and the 45 new bankline patches that had not been surveyed. Overall, our 2023 sample included 156 patches, of which 100 were classified as bankline patches (Table 1). We retained 56 inland patches that were surveyed in 2022 in our 2023 sample to allow for evaluation of *Phragmites* growth patterns outside the active river channel at 1500 cfs. We surveyed 45 patches in the Chapman study area, 59 in the Fort Kearney study area, and 52 in the Plum Creek study area during 2023 (Table 1; Figures 2, 3, 4).

C. Field Data Collection

a. Phragmites Patch Measurements

We made monthly delineations of all 156 *Phragmites* patches in the sample and recorded patch attributes during May through October 2023. Therefore, for each patch, we had a time series of six consecutive months of patch delineations and attribute data. We separated each month into three 10-day periods and generally surveyed each study area during the same period for each month. In 2023, we generally conducted surveys in the: Plum Creek study area during the first 10 days of the month (i.e., June 1–10); Fort Kearney study area during the second 10 days (i.e., June 11–20); and Chapman study area during the final 10 days (i.e., June 21–30). This ensured consecutive patch measurements were consistently separated by an average of 30 days.

We navigated to *Phragmites* inland and bankline patches included in the sample using the ArcGIS Field Maps (ESRI 2023) application on a mobile phone. We used previously delineated patch boundaries from July 2022 for navigation and patch assessment in May 2023. For surveys conducted after May 2023, we used the patch boundaries delineated during May 2023 surveys. We used a Trimble TSC3 controller and RTK unit (Trimble, Inc., Westminster, Colorado) to delineate *Phragmites* patch boundaries and other patch related attributes, and record elevation. We also recorded data on patch attributes through visual assessments and other measurements. Although some data collected were the same for inland and bankline patches, we made additional RTK and patch attribute measurements for bankline patches (Tables 2, 3).

i. RTK Job Creation

For each day that we delineated patch boundaries, we created a new job in the Trimble TSC3 coded with the name of the study area and the date. For example, for a survey of the Plum Creek study area on July 3, 2023, we coded the job as "PlumCreek07032023." We specified job properties as follows: "Nebraska 2600 (United States/ Plane 1983)" for the coordinate system; "US survey feet" for units; "Ground" for Cogo settings; and "Previous point" for Media file. We extended the receiver pole to 6.562 ft (2 m). Once the job was created, we selected the "Measure" option to begin taking patch delineation measurements. We selected the "Rapid point" option and entered the height to the base of the antenna mount as 6.562 ft. We began each patch boundary delineation by entering the patch number followed by a ".1" in the point name field and "p" for patch boundary in the measurements code field. For example, for patch no. 184, we began the survey by entering "184.1" in the point name field. This ensured consecutive points delineated with the RTK within patch 184 would be labeled as 184.1, 184.2, 184.3, etc…

ii. Inland Patches

We selected a start point for our patch delineation as one *Phragmites* stem located on the outer boundary of the patch. We placed a surveyor's flag at this point for reference when completing the patch delineation to ensure we fully encircled the patch. We placed the RTK receiver pole at the start point, leveled the pole, and hit "Enter" to record the first point location as "PatchNo.1." We then moved in a counterclockwise direction to the next *Phragmites* stem, or cluster of stems, on the outer boundary of the patch, placed the receiver pole at the point, leveled the pole, and hit "Enter" to record the second point location as "PatchNo.2." We continued this procedure in a counterclockwise direction until we had encircled the patch, fully delineated the outer patch boundary, and returned to the surveyor's flag at the starting point. Maintaining a counterclockwise direction ensured that we kept the *Phragmites* patch on our left-hand side at all times when conducting the delineation. We provide an example of an inland patch boundary that was delineated in 2023 in Figure 5.

If the patch had been sprayed with herbicide during June or September and the effects of the herbicide on the *Phragmites* were visible, then we also used the RTK to delineate a spray zone for the patch. Similar to our patch boundary delineation, we placed a surveyor's flag at the start point of the spray zone. We changed the code in the TSC3 measurements window from "p" to "z" for zone. However, we continued the consecutive point numbering for the patch from the number we left off at the last patch boundary measurement. We delineated the spray zone in a counterclockwise direction and placed the RTK receiver pole at as many points along the outer edge of the spray zone as necessary to map the extent the *Phragmites* patch was sprayed.

After completion of the patch boundary delineation, we recorded additional patch attribute data in pencil on a paper datasheet (Tables 2, 4). We estimated the height of the tallest green, living, and growing *Phragmites* stem to the nearest one-half foot. We used a visual assessment of *Phragmites* stem density and classified it as low (≤33% stem density); medium (33% to 66%); and high (>66%). Because patches often consisted of uneven spatial distribution of stem density, we recorded the average stem density for the entire patch based on our visual assessment. We recorded the life stage of the *Phragmites* plants as vegetative (V); flowers (F); or seeds (S). We recorded the condition of the *Phragmites* plants as alive/green (A); having partial dieback (P); or brown, dormant, or dead (D). We recorded the percent cover of other non-*Phragmites* vegetation within the *Phragmites* patch boundary as none (N); low (≤33%); medium (33% to 66%); or high (>66%). We recorded whether any stolons were present as a yes/no categorical variable. We also took photograph(s) of the patch to document change over time.

iii. Bankline Patches

As with inland patches, we selected a start point for our patch delineation as one *Phragmites* stem located on the outer boundary of the patch and placed a surveyor's flag at this point. We also identified the upstream and downstream extent of the patch along the channel and placed surveyor's flags at each point. These flags were generally placed on the bankline to provide reference points for the additional stolon boundary, bankline, and edge of water RTK measurements taken for bankline patches (Tables 3, 5). We used the same techniques for mapping the patch boundary of bankline patches as we did for inland patches described in (ii) above. We did not include stolons (horizontal growths into or along channel) or rhizomes protruding from eroded banks in the patch boundary map for bankline patches due to the separate measurements made of a stolon boundary. Therefore, we restricted our patch boundary delineation to the area of *Phragmites* vertical shoot growth for bankline patches.

After completing the patch boundary delineation, we mapped the stolon boundary. Stolons are horizontal *Phragmites* shoots and growths that extend into the channel and/or along the channel (Figure 6). We changed the code in the TSC3 measurements window from "p" to "s" for stolon and continued the consecutive point numbering for the patch from the number we left off at the last patch boundary measurement. We began stolon boundary measurements at the flag placed at the upstream extent of the patch and took RTK measurements at the outermost extent of all *Phragmites* stolons associated with the patch until we ended at the flag placed at the downstream extent of the patch (Figure 6). Therefore, the stolon boundary consisted of a line instead of an enclosed polygon that could be combined with the patch boundary in ArcGIS to calculate the total patch area. If there were no stolons along a portion of the patch, then the outermost extent of the stolon boundary was the same as the patch boundary along the channel.

We then mapped the stream bankline from the upstream to downstream extent of the patch (Figure 7). We defined the bankline for most patches to be the top of the stream bank that designated the channel boundary where the majority of normal discharge occurred. We changed the code in the TSC3 measurements window from "s" to "b" for "bankline" and continued the consecutive point numbering for the patch from the number we left off at the last stolon boundary measurement. We began bankline measurements at the point on the bank closest to the upstream flag. We took RTK measurements along the stream bank until we ended at the point on the bank closest to the downstream flag. Therefore, the bankline measurement consisted of a line that spanned the *Phragmites* patch from upstream to downstream (Figure 7).

Next, we mapped the edge of water and water surface elevation from the upstream to downstream extent of the *Phragmites* patch between the two flags. We changed the code in the TSC3 measurements window from "b" to "eow" for "edge of water" and continued consecutively numbering points for the patch. For each edge of water measurement, we ensured that the bottom of the RTK receiver pole was placed at the surface of the water to record an accurate water surface elevation. We also recorded the time that we began taking edge of water measurements. We encountered five different scenarios when making edge of water measurements.

1. The edge of the water corresponded to the flowing river that intersected the *Phragmites* patch (Figures 8, 9). We made one set of edge of water measurements from the upstream to downstream extent of the patch resulting in a series of dots that could be connected to estimate the proportion of the patch inundated by water.

2. The edge of the water corresponded to the flowing river that did not intersect any of the *Phragmites* patch (Figures 10, 11). We made one set of edge of water measurements from the upstream to downstream extent of the patch resulting in a series of dots that could be connected to estimate the distance from the patch to the nearest water.

3. The entire patch was inundated by the flowing river (Figures 12, 13). We made one water surface elevation measurement to estimate the depth of the patch under water and document the water surface elevation during the patch measurement.

4. The river channel was mostly dry near the patch, but a remnant pool of water existed in the channel at or near the edge of the patch (Figures 14, 15). We made two or more edge of water measurements. First, we delineated the boundaries of the remnant pool(s). Second, we marked the edge of the flowing river at the edge of water locations closest to the patch and from the upstream to downstream extent of the patch. We coded edge of water measurements for each measurement as "eow1," "eow2," "eow3," etc.

5. The *Phragmites* patch was located on an island, the river channel was dry near one or both sides of the island, and remnant pools of water and the flowing river needed to be mapped (Figures 16, 17, 18, 19). We made three or more edge of water measurements. First, we delineated the boundaries of the remnant pool(s) on both sides of the island if present. Second, we marked the edge of the flowing river at the edge of water locations closest to the patch and from the upstream to downstream extent of the patch on both sides of the island. We coded edge of water measurements for each measurement as "eow1," "eow2," "eow3," etc.

If the patch had been sprayed with herbicide during June or September and the effects of the herbicide on the *Phragmites* were visible, then we also used the RTK to delineate a spray zone for the patch in a similar manner to that described in II.C.a.ii for inland patches.

After completing the patch boundary, stolon boundary, bankline, edge of water, and spray zone (if necessary) delineations, we recorded additional patch attribute data in pencil on a paper datasheet (Tables 3, 5). We recorded the same data as we did for inland patches. We estimated the height of the tallest green, living, and growing *Phragmites* stem to the nearest one-half foot. We used a visual assessment of average *Phragmites* stem density and classified it as low (≤33% stem density); medium (33% to 66%); and high (>66%). We recorded the life stage of the *Phragmites* plants as vegetative (V); flowers (F); or seeds (S). We recorded the condition of the *Phragmites* plants as alive/green (A); having partial dieback (P); or brown, dormant, or dead (D). We recorded the percent cover of other non-*Phragmites* vegetation within the *Phragmites* patch boundary as none (N); low (≤33%); medium (33% to 66%); or high (>66%). We recorded several additional attributes for bankline patches. We recorded whether any stolons were present as a yes/no categorical variable and entered whether or not a stolon boundary was delineated with the RTK. We entered whether or not bankline and edge of water measurements were delineated with the RTK. We recorded the time we began the edge of water measurement. We estimated the percentages of the *Phragmites* patch boundary and stolon boundary inundated by water as a categorical variable as: 0 (0%); 1 (1–25%); 2 (26–50%); 3 (51–75%); 4 (76–99%); and 5 (100%). Finally, we took photograph(s) of the patch to document change over time.

b. Stolon Length Measurements

For bankline patches, we also marked, measured, and recorded the length of randomly selected stolons (Table 6). For each bankline patch, we selected five stolons at random, tied pink flagging to each stolon, measured the stolon length from its base where it emerged from the sand or mud to its tip at the end of the growth, and recorded the length in feet and inches in pencil on a paper datasheet (Table 6, Figure 20). We wrote the stolon number in black permanent marker on each pink flagging corresponding to the number of the stolon being measured on the datasheet. We initially marked up to five stolons (numbered 1, 2, 3, 4, 5), or vertical shoots in the channel that could turn into potential stolons, during May patch visits, searched for the five marked stolons during all subsequent monthly visits, and measured the length of each marked stolon when found. Due to difficulty finding marked stolons during higher water and flow conditions during June, we marked up to five more stolons in each bankline patch and numbered them 6, 7, 8, 9, and 10. Therefore, we had up to 10 stolons to find and measure during patch surveys conducted

July through October. We removed stolons from the sample that broke during measurements or had flagging fall off between months.

c. Platte River Elevation and Discharge Measurements

During April and May 2023, we deployed a total of six In-Situ Troll Series data loggers (In-Situ, Inc., Fort Collins, CO) across the three study areas to provide measurements of water surface elevation at 15 min intervals throughout our May through October *Phragmites* surveys (Figure 21). We deployed two data loggers per study area at different locations in the main river channel or side channels. When possible, we placed data loggers close to *Phragmites* patches included in our sample. To minimize the chance the loggers would be damaged during periods of high river flow, we fastened loggers within a PVC tube bolted to a u-post that we secured into the river bottom. We attached the instrument cable leading from the logger to a t-post on the riverbank (Figure 21) and downloaded logger data during subsequent monthly field visits to the study area.

We also downloaded Platte River discharge and stage measurements from U.S. Geological Survey (USGS) stage gages that were located close to our study areas. We used data from the: Overton, NE gage (USGS 2023a) combined with discharge data from the Johnson Hydropower Return for our Plum Creek study area; Kearney, NE gage (USGS 2023b) for our Fort Kearney study area; and Grand Island, NE gage (USGS 2023c) for our Chapman study area. We used the following process to evaluate discharge at the Plum Creek study area. First, we used discharge recorded every 15 min from the USGS Overton gage divided by the average daily discharge from the Overton gage to provide a relative measure of how the 15-min discharge was related to average daily discharge. Second, we multiplied that proportion by the average daily discharge from the Johnson Hydropower Return to estimate a 15-min discharge at the Johnson Hydropower Return.

III. STATISTICAL ANALYSES AND HYPOTHESES

A. Factors Related to Patch Area Changes Over Time in 2023

We examined factors related to the areal changes of the 156 *Phragmites* patches during May through October 2023 at approximately monthly intervals. We defined a patch boundary in GIS by connecting consecutive RTK points coded with a "p" and creating a polygon for each patch for each month of surveys. We then calculated the patch area for each month. For bankline patches that had a stolon boundary measurement, we connected consecutive RTK points coded with a "s" and created a stolon boundary polygon for each bankline patch for each month of surveys. We then calculated the stolon reach area for each month. We calculated the total patch area for each patch for each month by adding the patch area to the stolon reach area.

a. Response Variable

We defined a response variable for each patch, p, as the daily areal growth rate ($r_{p,t}$; ft^2/day). We calculated the daily areal growth rate by subtracting the total patch area for month t from the total patch area for month t+1 and dividing by the number of days between consecutive patch measurements. Therefore, for each patch measured during May through October on a monthly basis, we calculated five areal growth rates.

b. Covariates and Hypotheses

We defined a total of 38 covariates in four suites quantifying *Phragmites* patch attributes, water and flow metrics, herbicide treatments, and statistical variables. We used these covariates in both *a priori* and exploratory analyses to examine their impact on overall *Phragmites* patch growth.

i. *Phragmites* Patch Attributes

We defined seven covariates describing attributes of *Phragmites* patches and other potential explanatory variables. We defined these covariates to assess their role in affecting *Phragmites* growth, which was not necessarily related to our management hypothesis regarding flow and herbicide.

1. *Total patch perimeter*. Total perimeter of the *Phragmites* patch (ft). We hypothesized daily areal growth rates would be positively correlated with total patch perimeter because larger patches would have more established rhizomes that would facilitate patch expansion faster than smaller patches.

2. *Maximum height.* The maximum height of a vertical *Phragmites* stem in the patch (ft). We predicted daily areal growth rates would be positively correlated with maximum height because patches with taller *Phragmites* stems would be indicative of a healthier patch capable of faster expansion.

3. *Stem density.* A categorical variable denoting the average stem density of *Phragmites* in the patch classified as: low (≤33%); medium (33–66%); and high (>66%). We expected patches with high and low stem density would have the highest and lowest daily areal growth rates, respectively, because patches with higher stem densities would be indicative of a healthier patch with less interspecific competition that was capable of faster expansion.

4. *Life stage*. A categorical variable denoting the life stage of the majority of *Phragmites* stems in the patch classified as: vegetative; flowering; or seeds. We predicted daily areal growth rates would be greatest during the vegetative life stage and lowest during the seed production stage due to how the *Phragmites* stems were allocating resources during the different stages of growth.

5. *Proportion of stolon reach area.* The proportion of the total patch area that was comprised of the stolon reach area. We hypothesized daily areal growth rates would be positively correlated with the proportion of stolon reach area because of the aggressive growth of stolons and rapid expansion of patches that may occur due to stolons.

6. *Distance to river during germination suppression flow release*. The nearest distance from the centroid of the patch to the edge of the river channel as defined by edge of water data from field observations collected during May 30–June 12, 2023, when river discharge was at or near 1500 cfs. We predicted

patches closer to the river channel would have higher daily growth rates compared to patches farther from the river due to proximity to surface water.

7. *Aspect*. A categorical variable denoting the predominant aspect of the patch as north, east, south, west, or flat (i.e., no aspect). We expected south-facing patches to have the highest daily growth rates and north-facing patches to have the lowest daily growth rates due to greater exposure to direct sunlight for south-facing patches.

ii. Empirical Water and Flow Metrics

We defined 12 covariates describing weather, water, flow, and patch inundation variables as determined from empirical data collected during field measurements, or from flow gages or weather stations. Covariates that we specifically defined to evaluate our management hypothesis regarding flow at 1500 cfs are denoted with an asterisk (*).

*1. *Proportion of patch inundated by water during June germination suppression flow release.* The proportion of the total patch area that was inundated by water during the target 1500 cfs flow release during the first two weeks of June. We made empirical measurements of the edge of water relative to patch boundaries for all bankline patches during May 30–June 12, 2023, at all three study areas when river discharge was at or near 1500 cfs. We hypothesized daily areal growth rates would be negatively correlated with the proportion of the patch inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water during June.

*2. *Total accumulated time of river discharge ≥1500 cfs*. The total time between consecutive patch area measurements that discharge of the Platte River was ≥1500 cfs based on discharge data at the USGS gage closest to the study area combined with water surface elevation data from our stage gages deployed in each study area. For the Plum Creek study area, we used a combination of flow data from the USGS Overton gage and the Johnson Hydropower Return to quantify discharge. We used data from the USGS Kearney gage for patches in the Fort Kearney study area and data from the Grand Island gage for patches in the Chapman study area. We predicted daily growth rates would be negatively correlated with the total accumulated time ≥1500 cfs due to inhibition of *Phragmites* expansion into the river channel by flowing water at greater discharge. This covariate is also designed to be used as an interaction with covariates 3 and 4 defined below.

3. *Proportion of patch area in river channel.* The proportion of the total patch area that was within the river channel (wet or dry) as defined by the bankline delineation. We hypothesized daily areal growth rates would be positively correlated with the proportion of the total patch area within the river channel due to proximity to water and an increased likelihood that patches with a higher proportion of area in the channel would be in contact with water for longer periods during the growing season. We predicted that daily growth rates would be negatively correlated with a total accumulated time ≥1500 cfs*proportion of patch area in river channel interaction due to inhibition of *Phragmites* expansion into the river channel by flowing water at greater discharge. Daily growth rates of patches with more *Phragmites* in the channel

would be affected more by the total time at higher discharge than patches with a low proportion of *Phragmites* in the channel.

4. *Proportion of patch perimeter in contact with river channel along bankline.* The proportion of the total patch perimeter that was within the river channel as defined by the bankline delineation. We predicted daily growth rates would be positively correlated with the proportion of total patch perimeter within the river channel due to similar rationale as for the proportion of patch area in the river channel. Similarly, we expected daily growth rates to be negatively correlated with a total accumulated time ≥1500 cfs*proportion of patch perimeter in river channel interaction.

5. *Average minimum daily river discharge.* The average minimum daily value of Platte River discharge between consecutive patch area measurements based on discharge data at the USGS gage closest to the study area. This covariate is designed to be used in interactions with covariates 3 and 4 to distinguish between effects on bankline and inland patches. We predicted daily growth rates would be negatively correlated with an average minimum daily discharge*proportion of patch area in river channel interaction and an average minimum daily discharge*proportion of patch perimeter in river channel interaction due to inhibition of *Phragmites* expansion into the river channel by flowing water at higher discharge.

6. *Average maximum daily river discharge.* The average maximum daily value of Platte River discharge between consecutive patch area measurements based on discharge data at the USGS gage closest to the study area. This covariate is designed to be used in interactions with covariates 3 and 4 to distinguish between effects on bankline and inland patches. We predicted daily growth rates would be negatively correlated with an average maximum daily discharge*proportion of patch area in river channel interaction and an average maximum daily discharge*proportion of patch perimeter in river channel interaction due to inhibition of *Phragmites* expansion into the river channel by flowing water at higher discharge.

7. *Total accumulated time >25% of patch was inundated*. The total accumulated time between consecutive patch area measurements that >25% of the *Phragmites* patch was inundated with water. We used our empirical patch boundary, stolon reach boundary, and edge of water delineations made with the RTK to relate the percent of patch inundation with discharge data from the nearest stage gage and USGS gage. We predicted daily growth rates would be negatively related to the total time >25% of the patch was inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water.

8. *Total accumulated time >50% of patch was inundated*. The total accumulated time between consecutive patch area measurements that >50% of the *Phragmites* patch was inundated with water. We used our empirical patch boundary, stolon reach boundary, and edge of water delineations made with the RTK to relate the percent of patch inundation with discharge data from the nearest stage gage and USGS gage. We predicted daily growth rates would be negatively related to the total time >50% of the patch was inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water.

9. *Total accumulated time >75% of patch was inundated*. The total accumulated time between consecutive patch area measurements that >75% of the *Phragmites* patch was inundated with water. We

used our empirical patch boundary, stolon reach boundary, and edge of water delineations made with the RTK to relate the percent of patch inundation with discharge data from the nearest stage gage and USGS gage. We predicted daily growth rates would be negatively related to the total time >75% of the patch was inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water. We expected the total accumulated time >75% of the patch was inundated to be a better predictor of daily growth rates than the >50% or >25% metrics.

10. *Average proportion of patch inundated by water over previous month*. The average proportion of the entire patch boundary that was inundated by water between consecutive patch area measurements. We predicted daily growth rates would be negatively related to the average proportion of the patch inundated due to inhibition of *Phragmites* expansion into the river channel by flowing water.

*11. *Difference between average patch elevation and water surface elevation at 1500 cfs.* The water surface elevation recorded during flow at or near 1500 cfs subtracted from the average patch elevation based on RTK measurements of the patch and stolon reach boundaries. We made empirical measurements of the edge of water relative to patch boundaries for all bankline patches during May 30–June 12, 2023, at all three study areas when river discharge was at or near 1500 cfs. For bankline patches, we estimated the water surface elevation at the edge of the water corresponding to the intersection between the water surface and patch boundary. For inland patches, we estimated the water surface elevation at the nearest edge of water location to the edge of the inland patch. This covariate is designed to be used with the *distance to river* covariate defined in the previous section to distinguish bankline from inland patches. We predicted daily growth rates to increase as distance to river increased and elevation difference decreased because inland patches with elevations closer to groundwater would grow more rapidly than inland patches with elevations farther above groundwater. Likewise, we predicted daily growth rates to decrease as distance to river decreased and elevation difference decreased because growth of bankline patches inundated by water at 1500 cfs flows would be inhibited into the channel.

12. *Total accumulated monthly precipitation*. The total accumulated precipitation for the month prior to the patch area measurements as recorded at the climate station closest to each of the three study areas (National Weather Service–National Oceanic and Atmospheric Administration 2023). We hypothesized daily areal growth rates would be positively related to the total accumulated precipitation for the month because greater precipitation would promote patch growth and expansion.

iii. Modeled Water and Flow Metrics

We defined 10 covariates describing water, flow, and patch inundation variables as determined from the 2-D hydrodynamic model. Covariates that we specifically defined to evaluate our management hypothesis regarding flow at 1500 cfs are denoted with an asterisk (*).

*1. *Proportion of patch predicted to be inundated by water at 1500 cfs.* The proportion of the total patch area based on June patch delineations predicted to be inundated by water based on a 1500 cfs flow model. We hypothesized daily areal growth rates would be negatively correlated with the proportion of the patch inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water during June.

2. *Total accumulated time >25% of patch was inundated*. The total accumulated time between consecutive patch area measurements that >25% of the *Phragmites* patch was inundated with water based on predicted water surface elevation. We used the 2-D hydrodynamic model to generate predicted water surface elevations corresponding to the range of discharge measurements that occurred during the previous month, which was then used to estimate percent of patch inundation and total time of patch inundation. We predicted daily growth rates would be negatively related to the total time >25% of the patch was inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water.

3. *Total accumulated time >50% of patch was inundated*. The total accumulated time between consecutive patch area measurements that >50% of the *Phragmites* patch was inundated with water based on predicted water surface elevation. We used the 2-D hydrodynamic model to generate predicted water surface elevations corresponding to the range of discharge measurements that occurred during the previous month, which was then used to estimate percent of patch inundation and total time of patch inundation. We predicted daily growth rates would be negatively related to the total time >50% of the patch was inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water.

4. *Total accumulated time >75% of patch was inundated*. The total accumulated time between consecutive patch area measurements that >75% of the *Phragmites* patch was inundated with water based on predicted water surface elevation. We used the 2-D hydrodynamic model to generate predicted water surface elevations corresponding to the range of discharge measurements that occurred during the previous month, which was then used to estimate percent of patch inundation and total time of patch inundation. We predicted daily growth rates would be negatively related to the total time >75% of the patch was inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water. As with the empirical data, we expected the total accumulated time >75% of the patch was inundated to be a better predictor of daily growth rates than the >50% or >25% metrics.

5. *Average proportion of patch inundated by water over previous month*. The average proportion of the entire patch boundary that was inundated by water between consecutive patch area measurements as predicted by the 2-D model. We predicted daily growth rates would be negatively related to the average proportion of the patch inundated due to inhibition of *Phragmites* expansion into the river channel by flowing water.

*6. *Difference between average patch elevation and predicted water surface elevation at 1500 cfs.* The predicted water surface elevation at 1500 cfs subtracted from the average patch elevation based on RTK measurements of the patch and stolon reach boundaries. For bankline patches, we estimated the water surface elevation at the edge of the water corresponding to the intersection between the water surface and patch boundary. For inland patches, we estimated the water surface elevation at the nearest edge of water location to the edge of the inland patch. This covariate is designed to be used with the *distance to river* covariate defined in the previous section to distinguish bankline from inland patches. We predicted daily growth rates to increase as distance to river increased and elevation difference decreased because inland patches with elevations closer to groundwater would grow more rapidly than inland patches with elevations farther above groundwater. Likewise, we predicted daily growth rates to decrease as distance to river decreased and elevation difference decreased because growth of bankline patches inundated by water at 1500 cfs flows would be inhibited into the channel.

7. *Average daily water surface elevation*. The mean daily water surface elevation between consecutive patch area measurements as predicted by the 2-D model. For bankline patches that were at least partially inundated, we estimated the water surface elevation at the edge of the water corresponding to the intersection between the water surface and patch boundary. For bankline patches that were not inundated, we estimated the water surface elevation at the edge of the water located nearest to the patch edge. For inland patches, we estimated the water surface elevation at the nearest edge of water location to the edge of the inland patch. We expected daily growth rates of bankline patches to be negatively related to the average daily water surface elevation because higher water surface elevations would be indicative of greater river discharge, which would inhibit patch expansion into the channel. However, for inland patches we expected daily growth rates to be positively related to average daily water surface elevation because of the potential decrease in distance between inland patches and ground water.

8. *Monthly minimum water surface elevation*. The minimum water surface elevation between consecutive patch area measurements as predicted by the 2-D model. We estimated water surface elevations for bankline and inland patches as described in (7) and made similar predictions for bankline and inland patches.

9. *Monthly maximum water surface elevation*. The maximum water surface elevation between consecutive patch area measurements as predicted by the 2-D model. We estimated water surface elevations for bankline and inland patches as described in (7) and made similar predictions for bankline and inland patches.

10. *Average maximum daily shear stress at patch edge.* The maximum daily shear stress due to flow along the patch edge averaged over the period between consecutive patch measurements. We used the 2-D hydrodynamic model to generate predicted shear stress values where the patch edge intersects the edge of water at various flow conditions experienced during the month and estimate the maximum value of shear stress for each day. We averaged the maximum value of shear stress for each day over the period between consecutive patch measurements to derive an average shear stress value for each patch for each month. We predicted daily growth rates would be negatively correlated with average maximum daily shear stress for bankline patches because more shear stress at the patch edge would inhibit stolon expansion into the channel and restrict patch growth to along the bankline.

iv. Herbicide Treatments

We defined six covariates describing herbicide treatments on *Phragmites* patches. Covariates that we specifically defined to evaluate our management hypothesis regarding herbicide are denoted with an asterisk (*).

*1. *Proportion of patch sprayed with herbicide in June 2023.* The proportion of the *Phragmites* patch that was sprayed with herbicide during the June 2023 treatment as determined from the overlap between our patch boundary map and the July and/or August spray zone maps. We hypothesized daily growth rates during July, August, and September would be negatively related to the proportion of the patch sprayed in June.

*2. *Proportion of patch sprayed with herbicide in September 2023.* The proportion of the *Phragmites* patch that was sprayed with herbicide during the September 2023 treatment as determined from the overlap between our patch boundary map and the October spray zone map. We hypothesized daily growth rates between September and October would be negatively related to the proportion of the patch sprayed in September.

*3. *June 2023 spray.* An indicator variable denoting the patch was sprayed with herbicide during the June 2023 treatment. We expected daily growth rates during July, August, and September would be lower in patches sprayed during the June treatment.

*4. *September 2023 spray.* An indicator variable denoting the patch was sprayed with herbicide during the September 2023 treatment. We expected daily growth rates between September and October would be lower in patches sprayed during the September treatment.

*5. *June 2022 spray*. An indicator variable denoting the patch was sprayed with herbicide during June 2022 based on visual inspection of the patch during 2023 and spray zone polygons from June 2022. We predicted daily growth rates in 2023 would be lower in patches sprayed during 2022.

*6. *September 2022 spray*. An indicator variable denoting the patch was sprayed with herbicide during September 2022 based on visual inspection of the patch during 2023 and spray zone polygons from September 2022. We predicted daily growth rates in 2023 would be lower in patches sprayed during 2022.

v. Statistical Variables

We defined three covariates as variables to account for the statistical design of our study. These variables were included in our models to account for repeated measurements over time or unexplained variability in our data.

1. *Patch Number.* A unique identifying number for each patch to be included in mixed-effects models as a random effect.

2. *Month.* A continuous variable denoting the month of data collection to be used in mixed-effects models as a random effect to account for temporal correlation between consecutive patch area measurements. We assigned the number 1, 2, 3, 4, 5, and 6 for the months of May, June, July, August, September, and October, respectively.

3. *Study area.* A categorical variable denoting the study area in which the patch was located (Chapman; Fort Kearney; Plum Creek) to be used as a fixed effect blocking factor. Use of study area as a blocking factor may help reduce unexplained variability and better assess the influence of other covariates. We expected patches in the Chapman study area to have the highest rates of growth because of the braided nature of the Platte River through this study area makes for less incised banks, a broader flood plain, and closer proximity of vegetation to ground water. In contrast, we predicted patches in the Plum Creek study area would have the lowest rates of growth because the river bankline is generally steep, incised, and *Phragmites* patches at top of banks and inland are farther from ground water.

c. Modeling Approach

We used a stepwise approach to examine covariates for inclusion in our final analysis. First, we developed univariate models and models consisting of two covariates and an interaction when use of an interaction was appropriate using covariates from suites (i) *Phragmites* patch attributes, (ii) empirical water and flow metrics, and (iv) herbicide treatments. We used mixed-effects regression techniques (Pinheiro and Bates 2000, Zuur et al. 2009) in R (R Core Team 2022, Pinheiro et al. 2023) to fit models with *Patch Number* as a random effect to account for repeated area measurements in the same patch over time. We also included *Month* nested within *Patch Number* to account for temporal correlation in area measurements between and across months. We determined the strength of relationships by assessing whether 95% confidence intervals (CIs) of coefficient estimates include 0 and whether they are centered on 0 (sensu Arnold 2010). We included covariates with 95% CIs that did not include 0 or had a small extent of overlap with 0 in the next step of our analyses.

Second, we developed multiple competing hypotheses expressed as mixed-effects regression models consisting of additive combinations of main effects and interactions of covariates carried forward from our step one analyses. We assessed multicollinearity among covariates included in each candidate model by calculating variance inflation factors (VIFs; Neter et al 1996) and excluding models containing covariate combinations with VIFs > 5. We calculated an AICc value and Akaike model weight (*w*) for each model, and ranked and selected the best-approximating models based on models with ΔAICc < 2 (Burnham and Anderson 2002).

Third, we systematically added and substituted covariates from suite (iii) (modeled water and flow metrics) for those from suite (ii) for all models in our candidate model list developed in step two to determine whether modeled covariates provide a better fit to the data than empirically derived covariates. We calculated an AICc value and Akaike model weight (*w*) for each model, and ranked and selected the best-approximating models based on models with ΔAICc < 2 (Burnham and Anderson 2002).

We compared AIC values for models from step two to those from step three and selected the models with the lowest AIC values for further interpretation.

Finally, in exploratory work, we examined the data to determine if nonlinear relationships were present between the response variable and continuous covariates. We conducted exploratory analyses using non-linear mixed models or generalized additive mixed models (GAMM; Zuur et al. 2009) to assess whether inclusion of nonlinear covariate terms improved model fit.

B. Factors Related to Stolon Reach Areal Growth Rates and Patch and Stolon Expansion into the Channel Over Time

We examined factors related to the areal changes and expansion of stolon reaches into the river channel of 100 bankline *Phragmites* patches during May through October 2023 at approximately monthly intervals. To accomplish this, we used stolon reach boundaries defined for our analyses in III.A to calculate the stolon reach area and maximum stolon reach distance into the channel for each month of patch measurements. We also examined factors related to the areal changes of the entire patch into the river channel of the 100 bankline patches during May through October 2023 at approximately monthly intervals. For this effort, we determined the portion of the total patch boundary that was contained within the channel for each month of measurements.

a. Response Variables

We defined one response variable for each stolon reach from each bankline patch, *p*, as the daily stolon areal growth rate ($s_{p,t}$; ft^2/day). We calculated the daily areal growth rate by subtracting the stolon reach area for month *t* from the stolon reach area for month *t*+1 and dividing by the number of days between consecutive patch measurements. Therefore, for each bankline patch measured during May through October on a monthly basis, we calculated five stolon areal growth rates.

We defined a second response variable for each stolon reach from each bankline patch as the maximum distance of stolon expansion into the river channel (ft). We used a combination of the bankline and stolon reach boundaries for each bankline patch to determine the maximum distance from the bankline to the outer edge of the stolon reach boundary for each patch for each month.

We defined a third response variable for each bankline patch as the daily areal growth rate within the active channel ($c_{p,t}$; ft^2/day). We calculated the daily areal growth rate by subtracting the portion of the total patch area within the active channel for month *t* from the portion of the total patch area within the active channel for month *t*+1 and dividing by the number of days between consecutive patch measurements.

b. Covariates and Hypotheses

We used many of the same covariates that we defined to examine total patch area growth rates for our daily stolon areal growth rate, stolon expansion, and daily areal growth rate within the active channel analyses. However, because our stolon growth rate and expansion analyses did not use data from inland patches, we restricted our covariates only to those applicable to bankline patches. In addition to those previously defined, we defined new covariates specific to the stolon reach and active channel that are listed below. Covariates unique to these analyses are denoted with an †. Covariates that we specifically defined to evaluate our management hypothesis regarding flow at 1500 cfs are denoted with an asterisk (*).

i. <u>*Phragmites* Patch Attributes</u>

We defined four covariates describing attributes of *Phragmites* patches.

1. *Total patch perimeter*. Defined above. We hypothesized daily areal stolon reach growth rates and daily areal total patch growth rates in the active channel would be positively correlated with total patch perimeter because larger patches would have more established rhizomes that would facilitate patch and stolon reach expansion faster than smaller patches. We also expected the maximum distance of stolon expansion into the river channel would be positively correlated with total patch perimeter.

2. *Stem density.* Defined above. We expected patches with high stem density would have the highest daily areal stolon reach growth rates and daily areal total patch growth rates in the active channel, and greatest maximum distance of stolon expansion because patches with higher stem density would be indicative of a healthier patch capable of faster expansion through rhizomes and above ground stolons.

3. *Aspect*. Defined above. We expected south-facing patches to have the highest daily areal stolon reach growth rates and daily areal total patch growth rates in the active channel, and maximum distance of stolon expansion due to greater exposure to direct sunlight for south-facing patches, which would promote patch and stolon growth.

4. †*Maximum angle of bankline curvature.* The maximum angle of the bankline extending through the patch relative to the primary direction of flow. We defined the angle of patches on the inside of river channel bends to be negative and the angle of patches on the outside of river bends to be positive for a comparison of the effects of flow on patches located inside and outside of bends in the channel. We predicted daily areal stolon reach growth rates, daily areal total patch growth rates in the active channel, and maximum distance of stolon expansion would be negatively related to maximum angles of curvature due to increased velocity and shear stress that *Phragmites* stolons and vertical shoots would experience during the germination suppression flow release and at discharge >1500 cfs.

ii. <u>Empirical Water and Flow Metrics</u>

We defined 11 covariates describing empirically derived water, flow, and stolon reach inundation variables.

1. **Total accumulated time of river discharge ≥1500 cfs*. Defined above. We predicted daily areal stolon growth rates, daily areal total patch growth rates in the active channel, and maximum distance of stolon

expansion would be negatively correlated with the total accumulated time ≥1500 cfs due to inhibition of *Phragmites* expansion into the river channel by flowing water at greater discharge.

2. *Average minimum daily river discharge.* Defined above. We predicted daily areal stolon growth rates, daily areal total patch growth rates in the active channel, and maximum distance of stolon expansion would be negatively correlated with average minimum daily discharge due to inhibition of *Phragmites* expansion into the river channel by flowing water at higher discharge.

3. *Average maximum daily river discharge.* Defined above. We predicted daily areal stolon growth rates, daily areal total patch growth rates in the active channel, and maximum distance of stolon expansion would be negatively correlated with average maximum daily discharge due to inhibition of *Phragmites* expansion into the river channel by flowing water at higher discharge.

4. †*Total accumulated time >25% of stolon reach was inundated*. The total accumulated time between consecutive patch area measurements that >25% of the stolon reach area was inundated with water. We used our empirical stolon reach boundaries and edge of water delineations made with the RTK to relate the percent of stolon reach area inundation with discharge data from the nearest USGS gage and water surface elevation data from the nearest stage gage. We predicted daily stolon reach area growth rates, daily areal total patch growth rates in the active channel, and the maximum distance of stolon expansion would be negatively related to the total time >25% of the stolon reach was inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water.

5. †*Total accumulated time >50% of stolon reach was inundated*. The total accumulated time between consecutive patch area measurements that >50% of the stolon reach area was inundated with water. We used our empirical stolon reach boundaries and edge of water delineations made with the RTK to relate the percent of stolon reach area inundation with discharge data from the nearest USGS gage and water surface elevation data from the nearest stage gage. We predicted daily stolon reach area growth rates, daily areal total patch growth rates in the active channel, and the maximum distance of stolon expansion would be negatively related to the total time >50% of the stolon reach was inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water.

6. †*Total accumulated time >75% of stolon reach was inundated*. The total accumulated time between consecutive patch area measurements that >75% of the stolon reach area was inundated with water. We used our empirical stolon reach boundaries and edge of water delineations made with the RTK to relate the percent of stolon reach area inundation with discharge data from the nearest USGS gage and water surface elevation data from the nearest stage gage. We predicted daily stolon reach area growth rates, daily areal total patch growth rates in the active channel, and the maximum distance of stolon expansion would be negatively related to the total time >75% of the stolon reach was inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water.

7. *†*Proportion of patch within active channel inundated by water during June germination suppression flow release.* The proportion of the entire patch within the active channel that was inundated by water

during the target 1500 cfs flow release during the first two weeks of June. We made empirical measurements of the edge of water relative to patch boundaries for all bankline patches during May 30–June 12, 2023, at all three study areas when river discharge was at or near 1500 cfs. We hypothesized daily areal total patch growth rates in the active channel would be negatively correlated with the proportion of the patch within the active channel inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water during June.

8. †*Average proportion of patch within active channel inundated by water over previous month*. The average proportion of the entire patch boundary contained within the active channel that was inundated by water between consecutive patch area measurements. We predicted daily areal total patch growth rates in the active channel would be negatively related to the average proportion of the patch inundated due to inhibition of *Phragmites* expansion into the river channel by flowing water.

9. *†*Proportion of stolon reach area inundated by water during June germination suppression flow release.* The proportion of the stolon reach area that was inundated by water during the target 1500 cfs flow release during the first two weeks of June. We hypothesized daily stolon reach area growth rates and maximum distance of stolon expansion would be negatively correlated with the proportion of the stolon reach area inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water during June.

10. †*Average proportion of stolon reach area inundated by water over previous month*. The average proportion of the stolon reach boundary that was inundated by water between consecutive patch area measurements. We predicted daily stolon reach area growth rates and maximum distance of stolon expansion would be negatively related to the average proportion of the patch inundated due to inhibition of *Phragmites* expansion into the river channel by flowing water.

11. *Total accumulated monthly precipitation*. Defined above. We hypothesized daily areal stolon growth rates, daily areal total patch growth rates in the active channel, and maximum distance of expansion would be positively related to the total accumulated precipitation for the month because greater precipitation would promote patch growth and expansion through both rhizomes and above ground stolons.

iii. Modeled Water and Flow Metrics

We defined nine covariates describing modeled water, flow, and stolon reach inundation variables.

1. *†*Proportion of stolon reach predicted to be inundated by water at 1500 cfs.* The proportion of the stolon reach boundary area based on June patch delineations predicted to be inundated by water based on a 1500 cfs flow model. We predicted daily stolon reach area growth rates, daily areal total patch growth rates in the active channel, and the maximum distance of stolon expansion would be negatively correlated with the proportion of the stolon reach inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water during June.

2. †*Total accumulated time >25% of stolon reach was inundated*. The total accumulated time between consecutive patch area measurements that >25% of the stolon reach area was inundated with water based on predicted water surface elevation. We used the 2-D hydrodynamic model to generate predicted water surface elevations corresponding to the range of discharge measurements that occurred during the previous month, which we then used to estimate percent of stolon reach inundation and total time of stolon reach inundation. We predicted daily stolon reach area growth rates, daily areal total patch growth rates in the active channel, and the maximum distance of stolon expansion would be negatively related to the total time >25% of the stolon reach was inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water.

3. †*Total accumulated time >50% of stolon reach was inundated*. The total accumulated time between consecutive patch area measurements that >50% of the stolon reach area was inundated with water based on predicted water surface elevation. We used the 2-D hydrodynamic model to generate predicted water surface elevations corresponding to the range of discharge measurements that occurred during the previous month, which we then used to estimate percent of stolon reach inundation and total time of stolon reach inundation. We predicted daily stolon reach area growth rates, daily areal total patch growth rates in the active channel, and the maximum distance of stolon expansion would be negatively related to the total time >50% of the stolon reach was inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water.

4. †*Total accumulated time >75% of stolon reach was inundated*. The total accumulated time between consecutive patch area measurements that >75% of the stolon reach area was inundated with water based on predicted water surface elevation. We used the 2-D hydrodynamic model to generate predicted water surface elevations corresponding to the range of discharge measurements that occurred during the previous month, which we then used to estimate percent of stolon reach inundation and total time of stolon reach inundation. We predicted daily stolon reach area growth rates, daily areal total patch growth rates in the active channel, and the maximum distance of stolon expansion would be negatively related to the total time >75% of the stolon reach was inundated by water due to inhibition of *Phragmites* expansion into the river channel by flowing water.

5. †*Average proportion of stolon reach inundated by water over previous month*. The average proportion of the stolon reach boundary that was inundated by water between consecutive patch area measurements as predicted by the 2-D model. We predicted daily stolon reach growth rates and maximum distance of stolon expansion would be negatively related to the average proportion of the stolon reach inundated due to inhibition of *Phragmites* stolon expansion into the river channel by flowing water.

6. †*Average maximum daily shear stress at stolon edge.* The maximum daily shear stress due to flow along the edge of the stolon boundary averaged over the period between consecutive patch measurements. We used the 2-D hydrodynamic model to generate predicted shear stress values where the stolon boundary edge intersects the edge of water at various flow conditions experienced during the

month and estimate the maximum value of shear stress for each day. We averaged the maximum value of shear stress for each day over the period between consecutive patch measurements to derive an average shear stress value for each patch for each month. We predicted daily stolon reach area growth rates, daily areal total patch growth rates in the active channel, and the maximum distance of stolon expansion would be negatively correlated with average maximum daily shear stress because more shear stress on stolons would inhibit stolon expansion into the channel and restrict their growth to along the bankline.

7. *Average daily water surface elevation*. Defined above. We predicted daily stolon reach area growth rates, daily areal total patch growth rates in the active channel, and the maximum distance of stolon expansion would be negatively related to the average daily water surface elevation because higher water surface elevations would be indicative of greater river discharge, which would inhibit patch expansion into the channel.

8. *Monthly minimum water surface elevation*. Defined above. We made similar hypotheses about our response variables and monthly minimum water surface elevation as in (7).

9. *Monthly maximum water surface elevation*. Defined above. We made similar hypotheses about our response variables and monthly maximum water surface elevation as in (7).

iv. <u>Herbicide Treatments</u>

We defined six covariates describing herbicide treatments on *Phragmites* patches. Covariates that we specifically defined to evaluate our management hypothesis regarding herbicide are denoted with an asterisk (*).

*1. *Proportion of patch sprayed with herbicide in June 2023.* Defined above. We hypothesized daily areal stolon growth rates and daily areal total patch growth rates in the active channel during July, August, and September would be negatively related to the proportion of the patch sprayed in June. Likewise, we predicted maximum distance of stolon expansion would be negatively related to the proportion of patch sprayed.

*2. *Proportion of patch sprayed with herbicide in September 2023.* Defined above. We hypothesized daily areal stolon growth rates, daily areal total patch growth rates in the active channel, and maximum distance of stolon expansion between September and October would be negatively related to the proportion of the patch sprayed in September.

*3. *June 2023 spray.* Defined above. We expected daily areal stolon growth rates and daily areal total patch growth rates in the active channel during July, August, and September 2023 would be lower in patches sprayed during the June treatment.

*4. *September 2023 spray.* Defined above. We expected daily areal stolon growth rates and daily areal total patch growth rates in the active channel between September and October would be lower in patches sprayed during the September 2023 treatment.

*5. *June 2022 spray*. Defined above. We predicted daily areal stolon growth rates, daily areal total patch growth rates in the active channel, and maximum distance of stolon expansion in 2023 would be lower in patches sprayed during June 2022.

*6. *September 2022 spray*. Defined above. We predicted daily areal stolon growth rates, daily areal total patch growth rates in the active channel, and maximum distance of stolon expansion in 2023 would be lower in patches sprayed during September 2022.

v. Statistical Variables

We defined three covariates as variables to account for the statistical design of our study.

1. *Patch Number.* Defined above.

2. *Month.* Defined above.

3. *Study area.* Defined above.

c. Modeling Approach

We used the same stepwise approach and model selection techniques described in III.A.c for our analyses of stolon reach area growth rates and maximum distance of stolon expansion into the river channel. For each response variable, we used mixed-effects regression techniques (Pinheiro and Bates 2000, Zuur et al. 2009) in R (R Core Team 2022, Pinheiro et al. 2023) to fit models with *Patch Number* as a random effect to account for repeated measurements in the same patch over time. We also included *Month* nested within *Patch Number* to account for temporal correlation in measurements between and across months. For each analysis, we separately ranked and selected the best-approximating models based on models with ΔAICc < 2 (Burnham and Anderson 2002).

We conducted exploratory analyses determine if nonlinear relationships were present between the response variable and continuous covariates using non-linear mixed models or GAMM (Zuur et al. 2009) to assess whether inclusion of nonlinear covariate terms improved model fit.

C. Factors Related to Changes in Length of Individual Stolons

We used data from length measurements of individually marked stolons to examine changes in stolon lengths over time. We used measurements from stolons marked in May, June, and/or July, and found and measured in at least one subsequent month of surveys during June through October. We also used data from stolon length measurements for which the stolon was initially marked and measured, but never relocated for subsequent measurements such that we had one length measurement of the stolon for the entire growing season.

a. Response Variable

We defined a response variable as the individual stolon length, $length_{p,i,t}$, in ft, where *p* denoted the *Phragmites* patch identifying number; *i* denoted the number of the stolon marked in the patch (i.e., 1, 2, 3, …8, 9, 10); and *t* denoted the month of the measurement (i.e., 1 (May), 2 (June), …, 5 (September), 6 (October)).

b. Covariates and Hypotheses

We used many of the same covariates for our individual stolon length analysis as we did for our daily stolon areal growth rate analysis as defined in section III.B.b (Table 7). We did not use several covariates from III.B.b because we were interested in factors related to individual stolon lengths and growth, and not expansion into the river channel. Some of our hypotheses regarding covariate relationships with individual stolon lengths were also different than our predictions for daily stolon areal growth rates and maximum distance of expansion into the channel (Table 7). In particular, we expected increased duration and extent of stolon inundation with water would promote individual stolon growth because of the presence of water. Our field observations noted that stolons continued growing rapidly when inundated in flows with higher discharges. However, instead of growing and expanding into the river channel, the stolons grew along and parallel to the bankline. We also defined two new temporal covariates to be used in the analysis that are listed below.

1. *Day*. Day of the survey season with May 1 equal to *day* = 1 and October 31 equal to *day* = 184. We expected individual stolon lengths to be positively related to *day* with lengths increasing the fastest during the first 90 days of the survey season when *Phragmites* resources were devoted to horizontal and vertical growth and expansion. We expected individual stolon lengths to continue increasing during the final 90 days of the survey season, but at a lesser rate than during the first 90 days because *Phragmites* resources switch to flowering and seed production, and vertical growth begins from rooted stolons.

2. *Week*. Week of the survey season with May 1–7 equal to *week* = 1 and October 23–29 equal to *week* = 26. We expected individual stolon lengths to be positively related to *week* with lengths increasing the fastest during the first 13 weeks of the survey season due to the same rationale as described above for the *day* covariate.

c. Modeling Approach

We used the same stepwise approach and model selection techniques described in III.A.c for our individual stolon length analysis. We used mixed-effects regression techniques (Pinheiro and Bates 2000, Zuur et al. 2009) in R (R Core Team 2022, Pinheiro et al. 2023) to fit models with *p,i* as a random effect to account for repeated measurements of the same stolon in the same patch over time. We also included *t* nested within *p,i* to account for temporal correlation in measurements between and across months. We ranked and selected the best-approximating models based on models with ΔAICc < 2 (Burnham and Anderson 2002).

We conducted exploratory analyses determine if nonlinear relationships were present between the response variable and continuous covariates using non-linear mixed models or GAMM (Zuur et al. 2009) to assess whether inclusion of nonlinear covariate terms improved model fit.

D. Comparisons Between Empirical and Modeled Estimates of *Phragmites* Inundation

We examined the relationship between empirically collected measurements of *Phragmites* patch inundation using data from 2023 to those predicted from the 2-D hydrodynamic flow model. Although empirical data may provide more accurate estimates of inundation at the time and day of the measurement, the data are time consuming to collect across 100 bankline patches and may only be obtained once or twice a month. In contrast, model-derived estimates can give daily estimates of water surface elevations, velocity, and shear stress, and may potentially have more utility in understanding water-*Phragmites* patch relationships in a multiple regression modeling framework. Therefore, understanding the utility and limitations of empirical data relative to model-based predictors was of paramount importance before continuing extensive empirical data collection in the field.

We used ArcGIS to calculate the proportion of each *Phragmites* patch that was inundated with water on the day and at the time of sampling using our monthly empirical RTK measurements of total patch boundary (i.e., stolon reach and *Phragmites* vertical growth) and edge of water. Overall, we had six empirical estimates of the proportion of patch inundation for each patch on the day and at the time of sampling from May through October 2023. We used the date and time of the patch's edge of water measurements to determine Platte River discharge (cfs) to the nearest 15 min at the U.S. Geological Survey stage gage closest to the study area. We used data from the: Overton, NE gage (USGS 2023a) combined with discharge data from the Johnson Hydropower Return for our Plum Creek study area; Kearney, NE gage (USGS 2023b) for our Fort Kearney study area; and Grand Island, NE gage (USGS 2023c) for our Chapman study area.

We used this Platte River discharge measurement for the date and time of patch sampling to parameterize our 2-D hydrodynamic flow model to estimate the WSE at each sampled patch at the corresponding discharge to the nearest 500 cfs. We used ArcGIS to calculate the proportion of each *Phragmites* patch that was inundated with water using the intersection between our monthly empirical RTK measurements of total patch boundary and the WSE polygon at the corresponding discharge. Overall, we had six modeled estimates of the proportion of patch inundation for each patch on the day and at the time of sampling from May through October 2023.

We compared empirical and modeled estimates of the proportion of the *Phragmites* patch inundated with water for each patch from May through October 2023. We used generalized linear mixed-effects models (Zuur et al. 2009) with a binomial distribution with the empirical estimate of the proportion of patch inundation as the response variable and the modeled estimate of the proportion of patch inundation as the independent variable. We included *Patch Number* as a random effect to account for repeated measurements in the same patch over time, and *Month* nested within *Patch Number* to account for temporal correlation in measurements between and across months. We estimated the regression coefficient and its standard error to determine the relationship between modeled and empirical proportion of inundation estimates. We also calculated pseudo-R^2 values for the mixed effects model, which is represented by the conditional and marginal coefficients of determination (Zuur et al. 2009) using package *MuMIn* in R (R Core Team 2022, Bartoń 2023). The marginal coefficient of determination represents the variance explained by fixed effects in the model, whereas the conditional coefficient of determination provides a measure of the variance explained by the entire model consisting of both fixed and random effects.

E. Factors Related to Total Patch Area Changes During 2022 and 2023

Data collected during 2022 using the Trimble TSC3 controller and RTK included the boundary of the entire *Phragmites* patch with no separate delineations for the stolon reach boundary and *Phragmites* patch boundary consisting of vertical growth. Additionally, no bankline or edge of water measurements were taken with the RTK, and no lengths of individual stolons were measured during 2022. Therefore, we could not conduct the analyses described in III.A, III.B, and III.C using data from 2022 and 2023 combined. We used a modified version of the analyses described in III.A to examine factors related to growth rates of total *Phragmites* patch areas during 2022 and 2023, which are described below.

a. Response Variables

For 2023 data, we used our estimates of total patch area that were calculated as described in III.A. For 2022, we used the entire delineated patch boundary to calculate the total patch area in ArcGIS for each patch for each month. We defined a response variable for each patch, *p*, as the daily areal growth rate ($r_{p,t,y}$; ft^2/day) for year *y* (2022; 2023). We calculated the daily areal growth rate by subtracting the total patch area for month *t* from the total patch area for month *t*+1 and dividing by the number of days between consecutive patch measurements. Therefore, for each patch measured during May through October on a monthly basis, we calculated five areal growth rates. Patches surveyed in both 2022 and 2023 had at most a total of 10 areal growth rates whereas patches surveyed in only 2022 or only 2023 had at most five growth rates.

We defined a second response variable as the growing season areal patch growth rate ($g_{p,y}$; ft^2/day) for each patch for each year. We calculated $g_{p,y}$ for each year by subtracting the total patch area delineated during May surveys from the total patch area determined during October surveys and dividing by the number of days between May and October patch measurements. Patches surveyed in both 2022 and 2023 had two growing season areal growth rates whereas patches surveyed in only 2022 or 2023 had one growth rate.

b. Covariates and Hypotheses

We used many of the same covariates for our analyses of combined 2022 and 2023 *Phragmites* daily areal growth rates as we used for our analyses using only 2023 data (see section III.A.b; Table 8). Because we did not collect empirical edge of water measurements at patches or deploy stage gages during 2022, we used the nearest USGS gage to provide an index of duration of flow ≥1500 cfs and average minimum and maximum daily river discharge when combining data from both 2022 and 2023 (Table 8). In addition, we defined *year* as a categorical variable denoting the year the patch measurements were taken (2022; 2023). We expected areal growth rates to be higher in 2023 compared to 2022 due to above average precipitation during summer 2023 and drought conditions during 2022.

We defined suites of new covariates for our analyses of growing season areal patch growth rates to account for patch attribute, water, and flow conditions across the entire May through October growing season. Hypotheses for the comparable monthly versions of previously defined covariates are provided in section III.A.b.

i. *Phragmites* Patch Attributes

1. *Maximum growing season height.* The maximum height of a vertical *Phragmites* stem in the patch (ft) across the entire growing season.

2. *Maximum growing season stem density.* Categorical variable (low; medium; high) denoting the maximum recorded stem density in the patch during the entire growing season.

3. *Distance to river during germination suppression flow release*. Defined in section III.A.b.i.

4. *Aspect*. Defined in section III.A.b.i.

ii. Empirical Water and Flow Metrics

1. *Total accumulated time of river discharge ≥1500 cfs across the entire growing season*. The total time between May 1–October 31 that river discharge at the USGS gage closest to the *Phragmites* patch was ≥1500 cfs.

2. *Maximum proportion of patch area in river channel*. The maximum proportion of the total patch area that was contained in the active river channel based on the monthly patch delineations from 2022 and 2023, and bankline measurements from 2023.

3. *Maximum proportion of patch perimeter in contact with river channel along bankline*. The maximum proportion of the total patch perimeter that was contained in the active river channel based on the monthly patch delineations from 2022 and 2023, and bankline measurements from 2023.

4. *Average minimum daily river discharge across entire growing season*. The average of daily minimum river discharge measurements May 1–October 31 at the USGS gage closest to the *Phragmites* patch.

5. *Average maximum daily river discharge across entire growing season*. The average of daily maximum river discharge measurements May 1–October 31 at the USGS gage closest to the *Phragmites* patch.

6. *Total accumulated precipitation during growing season*. The sum of monthly precipitation measurements between May 1–October 31 as recorded at the climate station closest to each of the three study areas (National Weather Service–National Oceanic and Atmospheric Administration 2023).

iii. <u>Modeled Water and Flow Metrics</u>

1. *Proportion of June patch boundary predicted to be inundated by water at 1500 cfs*. Defined in section III.A.b.iii.

2. *Average proportion of patch inundated by water over growing season.* The average proportion of the entire patch boundary that was inundated by water based on daily predictions from the 2-D hydrodynamic model and monthly patch boundaries.

3. *Total accumulated time >25% of patch was inundated across growing season*. The total time between May 1–October 31 that >25% of the patch was predicted to be inundated by water based on daily predictions from the 2-D hydrodynamic model and monthly patch boundaries.

4. *Total accumulated time >25% of patch was inundated across growing season*. The total time between May 1–October 31 that >50% of the patch was predicted to be inundated by water based on daily predictions from the 2-D flow model and monthly patch boundaries.

5. *Total accumulated time >25% of patch was inundated across growing season*. The total time between May 1–October 31 that >75% of the patch was predicted to be inundated by water based on daily predictions from the 2-D hydrodynamic model and monthly patch boundaries.

6. *Difference between average patch elevation during June and predicted water surface elevation at 1500 cfs*. Defined in section III.A.b.iii.

7. *Average maximum daily shear stress at patch edge during growing season*. The average of the maximum daily shear stress at the patch edge across the May 1–October 31 growing season as predicted by the 2-D flow model.

8. *Mean daily average water surface elevation during growing season*. The mean daily average water surface elevation during May 1–October 31 as predicted by the 2-D flow model at the patch edge. To be used as an interaction term with the *maximum proportion of patch area in river channel* or *maximum proportion of patch perimeter in contact with river channel along bankline* covariates to distinguish inland from bankline patches.

9. *Mean daily minimum water surface elevation during growing season*. The mean daily minimum water surface elevation during May 1–October 31 as predicted by the 2-D flow model at the patch edge. To be used as an interaction term with the *maximum proportion of patch area in river channel* or *maximum*

proportion of patch perimeter in contact with river channel along bankline covariates to distinguish inland from bankline patches.

10. *Mean daily maximum water surface elevation during growing season*. The mean daily maximum water surface elevation during May 1–October 31 as predicted by the 2-D flow model at the patch edge. To be used as an interaction term with the *maximum proportion of patch area in river channel* or *maximum proportion of patch perimeter in contact with river channel along bankline* covariates to distinguish inland from bankline patches.

11. *Standard deviation of water surface elevation during growing season*. The standard deviation of daily water surface elevation during May 1–October 31 as predicted by the 2-D flow model at the patch edge. To be used as an interaction term with the *maximum proportion of patch area in river channel* or *maximum proportion of patch perimeter in contact with river channel along bankline* covariates to distinguish inland from bankline patches.

12. *Coefficient of variation of water surface elevation during growing season*. The coefficient of variation of daily water surface elevation during May 1–October 31 as predicted by the 2-D flow model at the patch edge. To be used as an interaction term with the *maximum proportion of patch area in river channel* or *maximum proportion of patch perimeter in contact with river channel along bankline* covariates to distinguish inland from bankline patches.

iv. Herbicide Treatments

1. *June 2023 spray.* Defined in section III.A.b.iv.
2. *September 2023 spray.* Defined in section III.A.b.iv.
3. *June 2022 spray*. Defined in section III.A.b.iv.
4. *September 2022 spray*. Defined in section III.A.b.iv.

v. Temporal Variables

1. *Year.* Defined above.

vi. Statistical Variables

1. *Patch number.* Defined in section III.A.b.v.
2. *Study area.* Defined in section III.A.b.v.

c. Modeling Approach

For our analyses of daily areal total patch growth rates, we used a similar stepwise approach and model selection technique as described in section III.A.c. However, because we did not have empirical data on edge of water and patch inundation from 2022, we were not able to include covariates that used these data in our model step. Likewise, we were not able to directly substitute modeled water and flow covariates for their empirically derived counterparts. We used mixed-effects regression techniques (Pinheiro and Bates 2000, Zuur et al. 2009) in R (R Core Team 2022, Pinheiro et al. 2023) to fit models with *Patch Number* as a random effect to account for repeated measurements in the same patch over time. We also included *Month* nested within *Patch Number* to account for temporal correlation in measurements between and across months. We ranked and selected the best-approximating models based on models with ΔAICc < 2 (Burnham and Anderson 2002) for the final steps of the analyses.

We also used a stepwise approach and model selection technique similar to that described above and in section III.A.c for our analyses of growing season areal patch growth rates. Because we did not have repeated measurements of the same patch across months, we used mixed-effects regression techniques (Pinheiro and Bates 2000, Zuur et al. 2009) in R (R Core Team 2022, Pinheiro et al. 2023) to fit models with only *Patch Number* as a random effect to account for repeated measurements in the same patch over the two years. We ranked and selected the best-approximating models based on models with ΔAICc < 2 (Burnham and Anderson 2002) for the final steps of the analyses.

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V. TABLES

Table 1. Summary of the sample of bankline and inland *Phragmites* patches surveyed by study area during May through October 2023 along the central Platte River, Nebraska.

Study area	No. of bankline	No. of inland	Total no. patches
Chapman	30	15	45
Fort Kearney	39	20	59
Plum Creek	31	21	52
Total	100	56	156

Table 2. Sample of a data sheet used for data collection on inland *Phragmites* patches during May through October 2023 along the central Platte River, Nebraska.

INLAND PATCHES **SITE:** ____________ **OBSERVER(S):** ____________ **DATE:** ____________

Patch ID	Patch bndry map? (p)	Max phrag height (ft, in)	Phrag stem density	Phrag life stage	Phrag condition	Stolon/ rhizome present?	Other plant cover	Spray zone map? (z)	Photo times/IDs	Notes / additional photos

Phrag stem density: L (≤33%); M (33-66%); H (>66%)

Phrag life stage: V (vegetative); F (flowers); S (seeds)

Phrag condition: A (alive/green); P (partial dieback); D (brown/dormant/dead)

Other plant cover: N (none); L (≤33%); M (33-66%); H (>66%)

Table 3. Sample of a data sheet used for data collection on bankline *Phragmites* patches during May through October 2023 along the central Platte River, Nebraska.

BANKLINE PATCHES **SITE:** ____________ **OBSERVER(S):** ____________ **DATE:** ________

Patch ID	Patch bndry map? (p)	Max phrag height (ft, in)	Phrag stem density	Phrag life stage	Phrag condition	Stolon / rhizome present?	Stolon reach map? (s)	Other plant cover	Bank line map? (b)	Edge of water map? (eow)	Time of EOW msmt	% veg in water	% stolon in water	Spray zone map? (z)	Photo times or IDs	Notes / additional photos

Phrag stem density: L (≤33%); M (33-66%); H (>66%)

Phrag life stage: V (vegetative); F (flowers); S (seeds)

Phrag condition: A (alive/green); P (partial dieback); D (brown/dormant/dead)

Other plant cover: N (none); L (≤33%); M (33-66%); H (>66%)

% veg in water: 0 (0%); 1 (1-25%); 2 (26-50%); 3 (51-75%); 4 (76-99%); 5 (100%)

% stolon in water: 0 (0%); 1 (1-25%); 2 (26-50%); 3 (51-75%); 4 (76-99%); 5 (100%)

Table 4. Definitions of data entry fields for data collection on inland *Phragmites* patches during May through October 2023 along the central Platte River, Nebraska. Data entry fields correspond to the sample datasheet provided in Table 2.

Datasheet entry field	Description
Patch ID	Patch identification number corresponding to the patch number in ArcGIS field maps and hard copy maps
Patch bndry map? (p)	**Y/N:** was the patch boundary mapped? Code patch boundary in RTK as "p"
Max phrag height (ft)	Measurement of the tallest *Phragmites* stem in the patch to the nearest one-half foot (in feet, inches)
Phrag stem density	Stem density of *Phragmites* in the patch categorized as: **L (≤33%); M (33-66%); H (>66%)**
Phrag life stage	Life stage of *Phragmites* categorized as: **V (vegetative); F (flowers); S (seeds)**
Phrag condition	Above ground *Phragmites* condition categorized as: **A (alive/green); P (partial dieback); D (brown/dormant/dead)**
Stolon / rhizome present?	**Y/N:** are stolons or visible rhizomes present?
Other plant cover	Average cover of non-*Phragmites* plant species in patch categorized as: **N (none); L (≤33%); M (33-66%); H (>66%)**
Spray zone map? (z)	**Y/N:** was the spray boundary mapped if the patch was previously sprayed in spring or fall? Code spray zone in RTK as "z"
Photo times or ID	Record the time or camera IDs for any photos of the patch that are taken
Notes / additional photos	Description and IDs/times of additional photos; make notes on back of sheet if more space needed

Table 5. Definitions of data entry fields for data collection on bankline *Phragmites* patches during May through October 2023 along the central Platte River, Nebraska. Data entry fields correspond to the sample datasheet provided in Table 3.

Datasheet entry field	Description
Patch ID	Patch identification number corresponding to the patch number in ArcGIS field maps and hard copy maps
Patch bndry map? (p)	**Y/N:** was the patch boundary mapped? Code patch boundary in RTK as "p"
Max phrag height (ft)	Measurement of the tallest *Phragmites* stem in the patch to the nearest one-half foot (in feet, inches)
Phrag stem density	Stem density of *Phragmites* in the patch categorized as: **L (≤33%); M (33-66%); H (>66%)**
Phrag life stage	Life stage of *Phragmites* categorized as: **V (vegetative); F (flowers); S (seeds)**
Phrag condition	Above ground *Phragmites* condition categorized as: **A (alive/green); P (partial dieback); D (brown/dormant/dead)**
Stolon / rhizome present?	**Y/N:** are stolons or visible rhizomes present?
Stolon reach map? (s)	**Y/N:** was the stolon reach boundary mapped? Code stolon boundary in RTK as "s"
Other plant cover	Average cover of non-*Phragmites* plant species in patch categorized as: **N (none); L (≤33%); M (33-66%); H (>66%)**
Bank line map? (b)	**Y/N:** if present, was the bank line boundary mapped? Code bankline in RTK as "b"
Edge of water map? (eow)	**Y/N:** was edge of the nearest water surface in the channel mapped? Code edge of water in RTK as "eow"
Time of EOW msmt	The time the edge of water mapping began
% veg in water	Estimated % of patch (vertical vegetative growth) covered by water: **0 (0%); 1 (1-25%); 2 (26-50%); 3 (51-75%); 4 (76-99%); 5 (100%)**
% stolon in water	Estimated % of stolons / emergent rhizomes covered by water: **0 (0%); 1 (1-25%); 2 (26-50%); 3 (51-75%); 4 (76-99%); 5 (100%)**
Spray zone map? (z)	**Y/N:** was the spray boundary mapped if that patch was previously sprayed? Code spray zone in RTK as "z"
Photo times or ID	Record the time(s) or camera IDs for any photos of the patch that are taken
Notes / additional photos	Description and IDs/times of additional photos; make notes on back of sheet if more space needed

Table 6. Sample of a data sheet used for data collection on stolon lengths during May through October 2023 along the central Platte River, Nebraska.

BANKLINE - STOLON LENGTH

SITE: ____________ **OBSERVER(S):** ____________ **DATE:** ________

Patch ID	Stolon length 1 (ft, in)	Stolon length 2 (ft, in)	Stolon length 3 (ft, in)	Stolon length 4 (ft, in)	Stolon length 5 (ft, in)	Notes

Table 7. Covariates used in the analysis examining factors related to changes in the lengths of individual stolons from *Phragmites* patches surveyed during May through October 2023 along the central Platte River, Nebraska. For each covariate, the definition and hypothesized direction of correlation with the response variable are provided. If applicable, the section in which covariates were previously defined in the main text is provided.

Covariate	Definition	Hypothesis
	Phragmites Patch Attributes	
Total patch perimeter	Section III.B.b.i	$\beta > 0$
Stem density	Section III.B.b.i	$\beta > 0$
Aspect	Section III.B.b.i	$\beta > 0$ for *Aspect* = south; $\beta < 0$ for *Aspect* = north
	Empirical Water and Flow Metrics	
Average minimum daily river discharge	Section III.B.b.ii	$\beta > 0$
Average maximum daily river discharge	Section III.B.b.ii	$\beta > 0$
Total accumulated time >25% of stolon reach was inundated	Section III.B.b.ii	$\beta > 0$
Total accumulated time >50% of stolon reach was inundated	Section III.B.b.ii	$\beta > 0$
Total accumulated time >75% of stolon reach was inundated	Section III.B.b.ii	$\beta > 0$
Total accumulated monthly precipitation	Section III.B.b.ii	$\beta > 0$
Average proportion of stolon reach area inundated by water over previous month	Section III.B.b.ii	$\beta > 0$
	Modeled Water and Flow Metrics	
Total accumulated time >25% of stolon reach was inundated	Section III.B.b.iii	$\beta > 0$
Total accumulated time >50% of stolon reach was inundated	Section III.B.b.iii	$\beta > 0$
Total accumulated time >75% of stolon reach was inundated	Section III.B.b.iii	$\beta > 0$
Average proportion of stolon reach area inundated by water over previous month	Section III.B.b.iii	$\beta > 0$
Average daily water surface elevation	Section III.B.b.iii	$\beta > 0$
Monthly minimum water surface elevation	Section III.B.b.iii	$\beta > 0$
Monthly maximum water surface elevation	Section III.B.b.iii	$\beta > 0$
	Herbicide Treatments	
June spray	Section III.A.b.iv	$\beta < 0$
September spray	Section III.A.b.iv	$\beta < 0$
Sprayed in June 2022	Section III.A.b.iv	$\beta < 0$
Sprayed in September 2022	Section III.A.b.iv	$\beta < 0$

	Temporal Variables	
Day	Section III.C.b	*β* > 0
Week	Section III.C.b	*β* > 0
	Statistical Variables	
Patch number (p)	Section III.A.b.v	Random effect
Stolon number (i)	Unique identifying number for each stolon marked in the patch	Random effect
Month (t)	Section III.A.b.v	Random effect
Study area	Section III.A.b.v	Random effect

Table 8. Covariates used in the analysis examining factors related to daily areal growth rates of *Phragmites* patches during 2022 and 2023 along the central Platte River, Nebraska. For each covariate, the definition and hypothesized direction of correlation with the response variable are provided. If applicable, the section in which covariates were previously defined in the main text is provided.

Covariate	Definition	Hypothesis
	Phragmites Patch Attributes	
Total patch perimeter	Section III.A.b.i	$\beta > 0$
Maximum height	Section III.A.b.i	$\beta > 0$
Stem density	Section III.A.b.i	Patches with high and low stem density would have the highest and lowest growth rates, respectively
Life stage	Section III.A.b.i	Growth rates would be greatest during the vegetative life stage and lowest during the seed production stage
Proportion of stolon reach area	Section III.A.b.i	$\beta > 0$
Distance to river	Section III.A.b.i	$\beta < 0$
Aspect	Section III.A.b.i	$\beta > 0$ for *Aspect* = south; $\beta < 0$ for *Aspect* = north
	Empirical Water and Flow Metrics	
Total accumulated time of river discharge ≥1500 cfs	Section III.A.b.ii. We will not have empirical edge of water data from our patches for 2022 and will have to use data from the nearest gage as an index	$\beta < 0$
Proportion of patch area in river channel	Section III.A.b.ii	$\beta > 0$. Growth rates would be negatively correlated with a total accumulated time ≥1500 cfs*proportion of patch area in river channel interaction
Proportion of patch perimeter in contact with river channel along bankline	Section III.A.b.ii	$\beta > 0$. Growth rates would be negatively correlated with a total accumulated time ≥1500 cfs*proportion of patch perimeter in river channel interaction
Average minimum daily river discharge	Section III.A.b.ii	Growth rates would be negatively correlated with an average minimum daily discharge*proportion of patch area in river channel interaction
Average maximum daily river	Section III.A.b.ii	Growth rates would be negatively

discharge		correlated with an average maximum daily discharge*proportion of patch area in river channel interaction
Total accumulated monthly precipitation	Section III.A.b.ii	$\beta > 0$
	Modeled Water and Flow Metrics	
Proportion of patch predicted to be inundated by water at 1500 cfs.	Section III.A.b.iii	$\beta < 0$
Total accumulated time >25% of patch was inundated	Section III.A.b.iii	$\beta < 0$
Total accumulated time >50% of patch was inundated	Section III.A.b.iii	$\beta < 0$
Total accumulated time >75% of patch was inundated	Section III.A.b.iii	$\beta < 0$
Average proportion of patch inundated by water over previous month	Section III.A.b.iii	$\beta < 0$
Difference between average patch elevation and predicted water surface elevation at 1500 cfs	Section III.A.b.iii	To be used in interaction with *distance to river* covariate. We predicted daily growth rates would increase as distance to river increased and elevation difference decreased. We predicted daily growth rates would decrease as distance to river decreased and elevation difference decreased.
Average daily water surface elevation	Section III.A.b.iii	$\beta < 0$ for bankline patches $\beta > 0$ for inland patches
Monthly minimum water surface elevation	Section III.A.b.iii	$\beta < 0$ for bankline patches $\beta > 0$ for inland patches
Monthly maximum water surface elevation	Section III.A.b.iii	$\beta < 0$ for bankline patches $\beta > 0$ for inland patches
Average maximum daily shear stress at patch edge	Section III.A.b.iii	$\beta < 0$
	Herbicide Treatments	
June 2022 spray	Section III.A.b.iv	$\beta < 0$
September 2022 spray	Section III.A.b.iv	$\beta < 0$
June 2023 spray	Section III.A.b.iv	$\beta < 0$
September 2023 spray	Section III.A.b.iv	$\beta < 0$
	Temporal Variables	

Year	Categorical variable denoting the year (2022; 2023)	*β* > 0 for *year* = 2023
	Statistical Variables	
Patch number (p)	Section III.A.b.v	Random effect
Year (y)	Categorical variable denoting the year (2022; 2023)	Random effect
Month (t)	Section III.A.b.v	Random effect
Study area	Section III.A.b.v	Random effect

VI. FIGURES

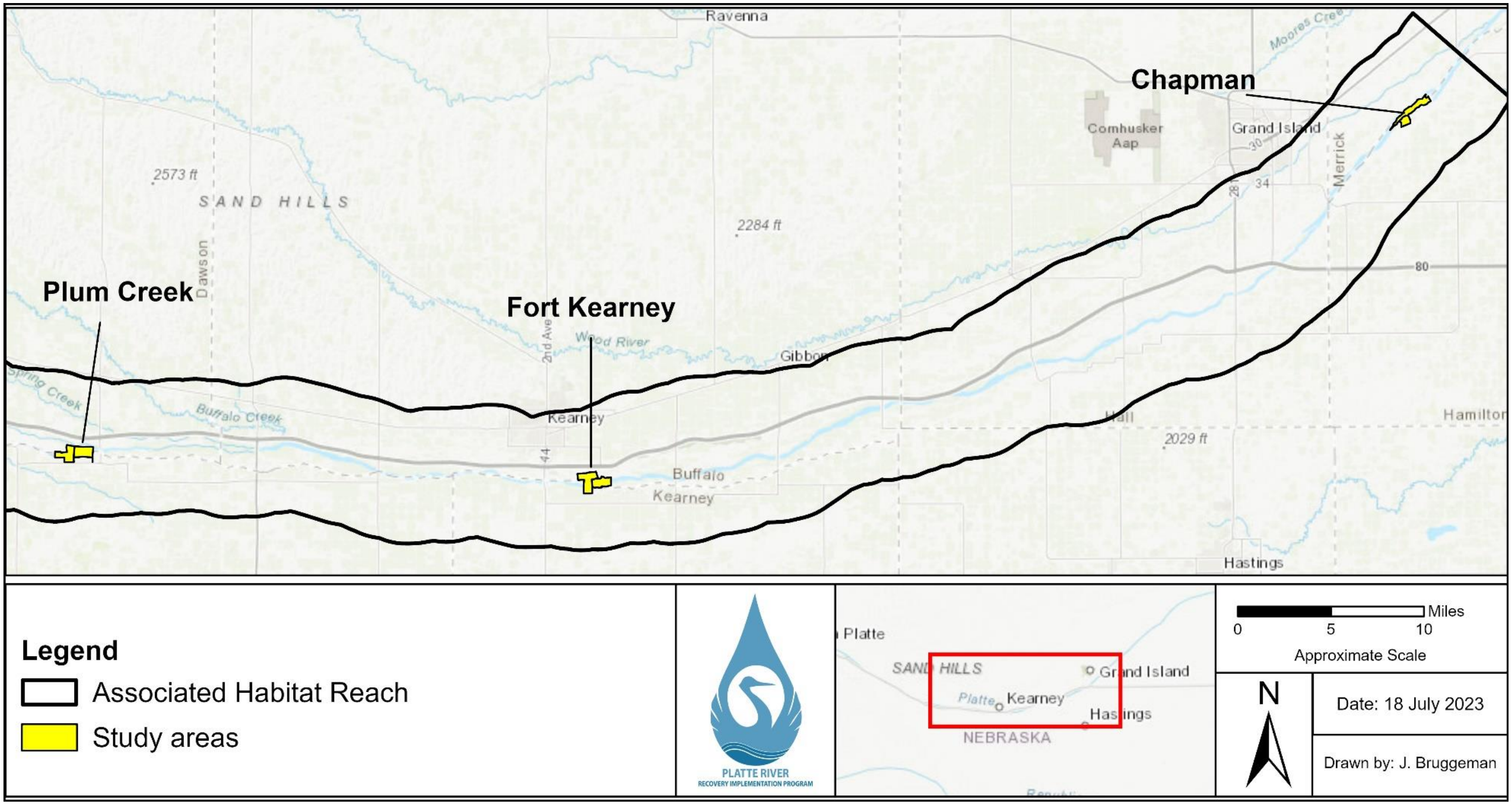

Figure 1. Locations of three study areas in the Associated Habitat Reach along the central Platte River, Nebraska in which *Phragmites* patches were surveyed during 2022 and 2023.

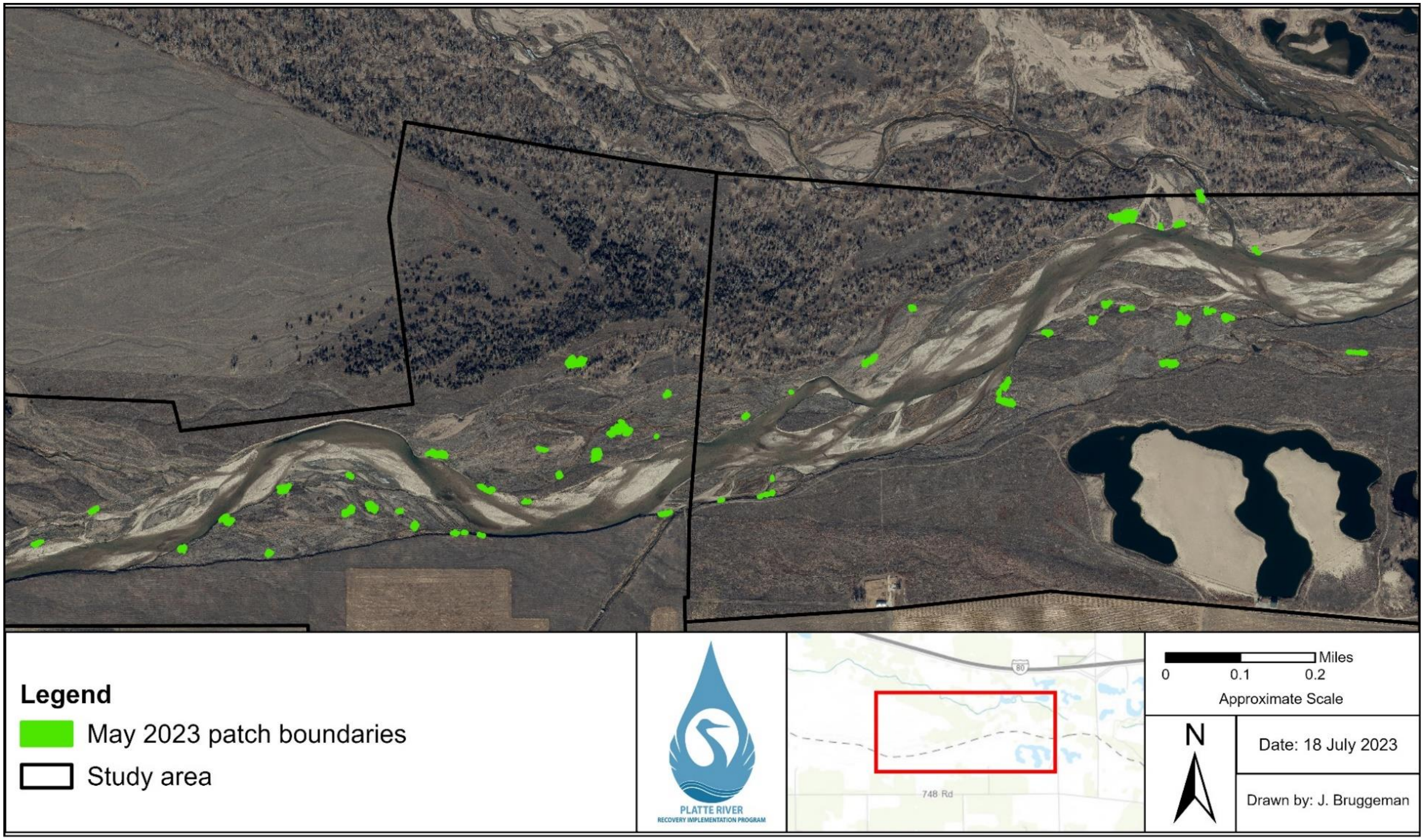

Figure 2. Distribution of *Phragmites* patches in the Plum Creek, Nebraska study area that were surveyed during May through October 2023. *Phragmites* patch boundaries delineated during May 2023 surveys are depicted. The Plum Creek study area consists of the Cook tract (located in the west polygon; non-herbicide zone) and Dyer tract (east polygon; herbicide spray zone).

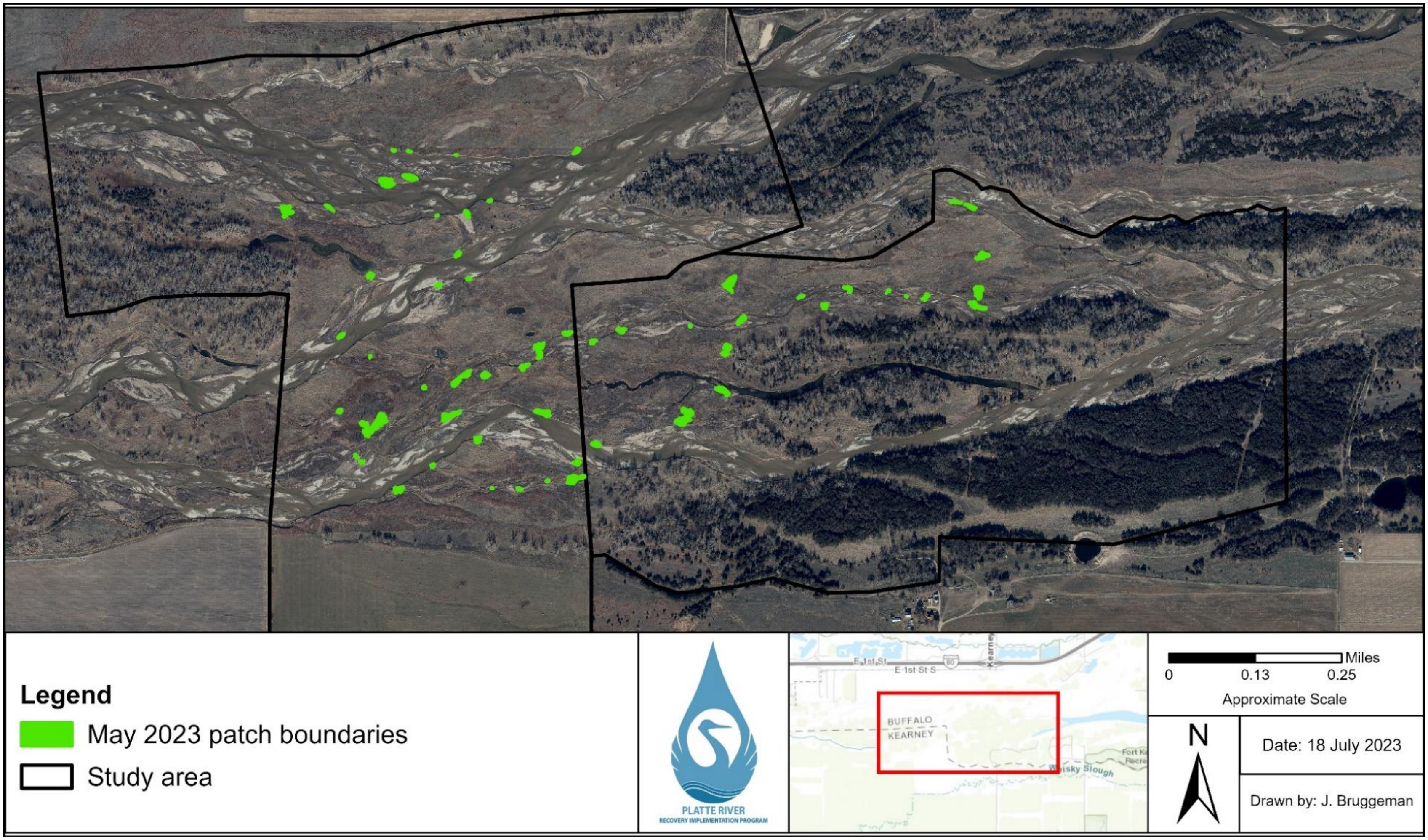

Figure 3. Distribution of *Phragmites* patches in the Fort Kearney, Nebraska study area that were surveyed during May through October 2023. *Phragmites* patch boundaries delineated during May 2023 surveys are depicted. The Fort Kearney study area consists of the Wyoming tract (west polygon; non-herbicide zone) and Sherrerd tract (east polygon; herbicide spray zone).

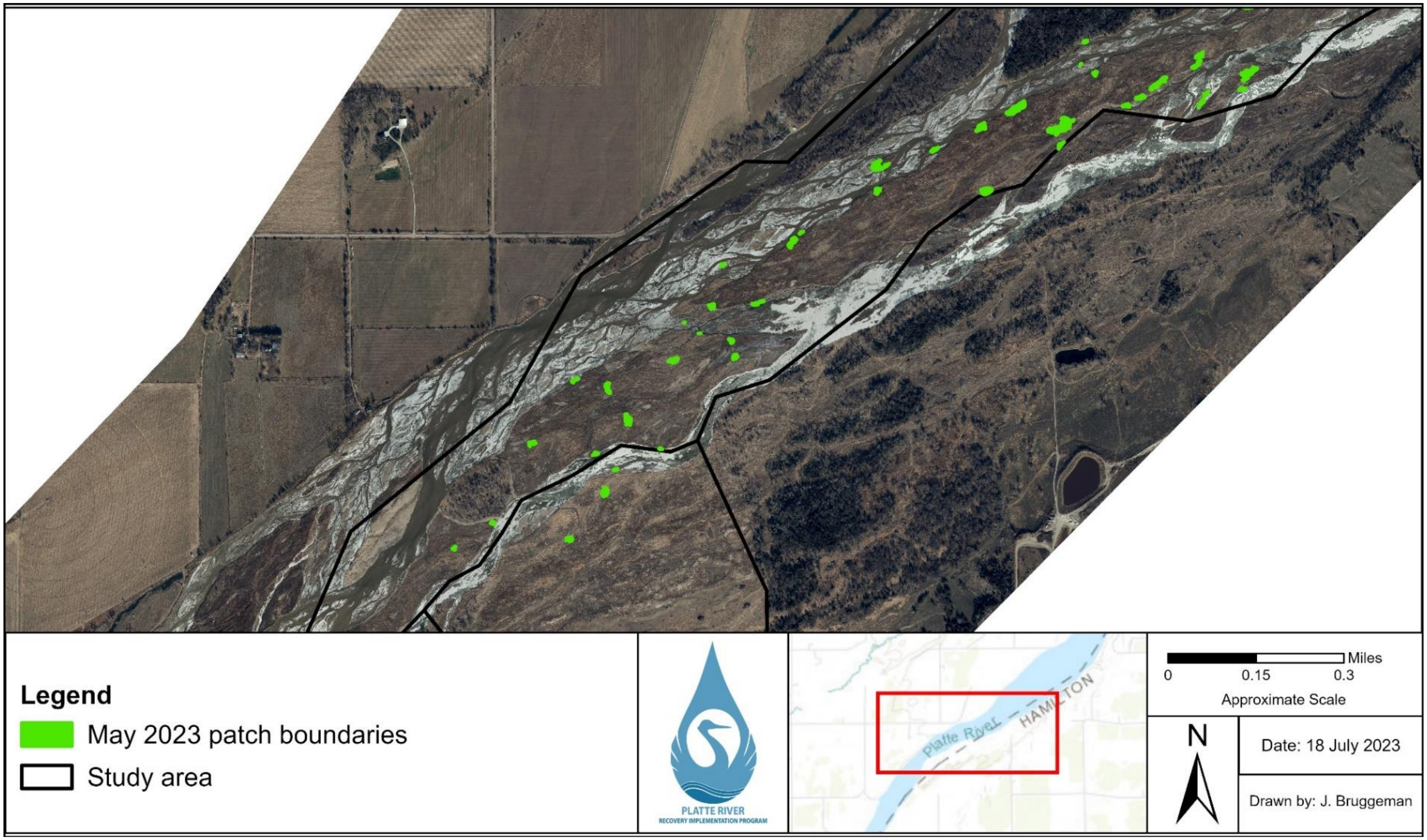

Figure 4. Distribution of *Phragmites* patches in the Chapman, Nebraska study area that were surveyed during May through October 2023. *Phragmites* patch boundaries delineated during May 2023 surveys are depicted. The Chapman study area consists of the Bergen tract (southwest polygon) and Robinson tract (north large polygon). The herbicide spray zone consisted of the western half of the entire study area and the non-herbicide zone consisted of the eastern half of the Robinson tract.

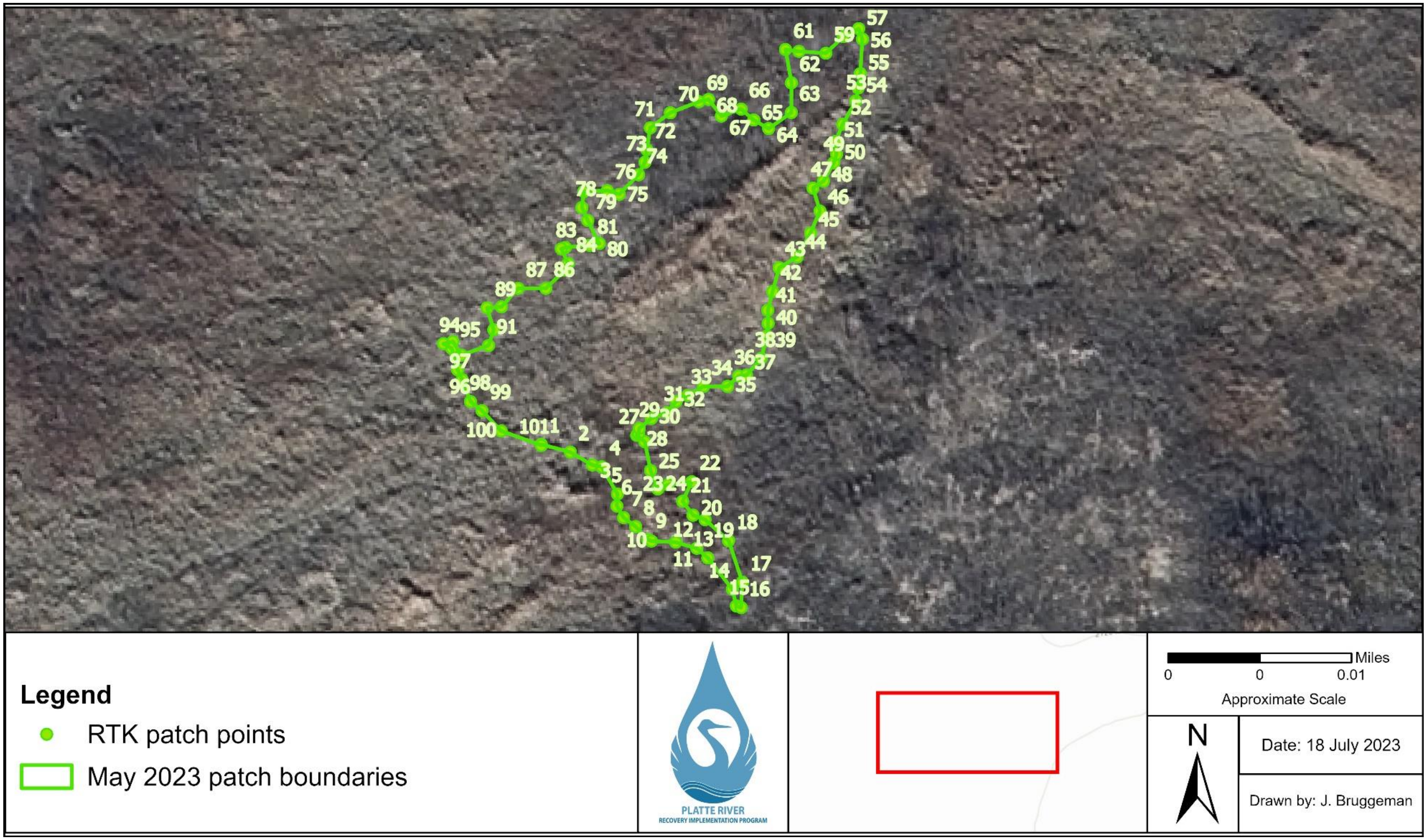

Figure 5. Example of a delineated boundary of an inland *Phragmites* patch that was surveyed during May 2023. The RTK points used to define the patch boundary are depicted along with the point number that ranged from 1 to 101.

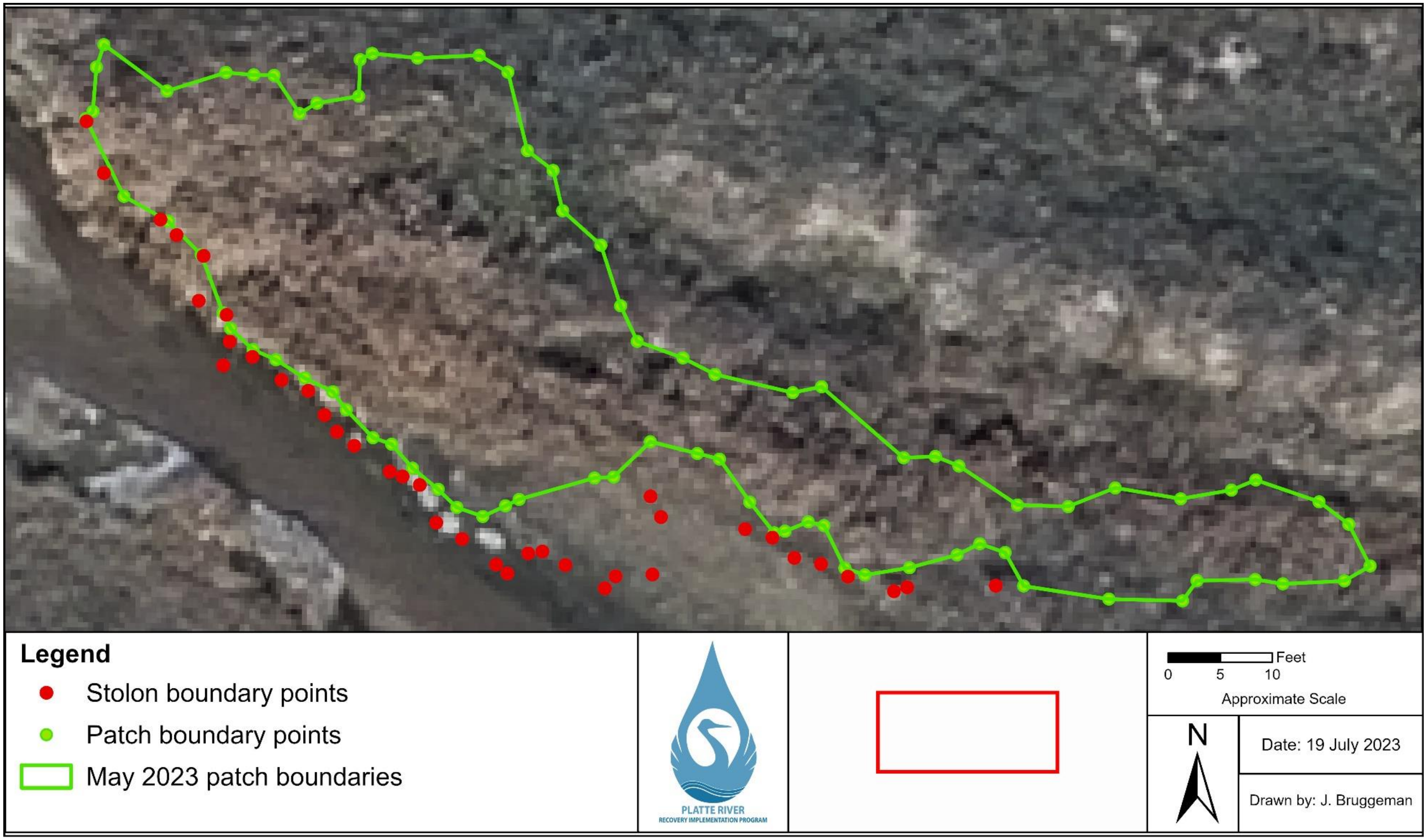

Figure 6. Example of delineated boundaries of a bankline *Phragmites* patch (green circles and line) and corresponding stolon reach (red circles) surveyed during May 2023. Circles depict individual RTK points taken to define the boundaries.

Figure 7. Example of delineated boundaries of a bankline *Phragmites* patch (green circles and line), stolon reach (red circles), and river channel bankline (light green circles) surveyed during May 2023. Circles depict RTK points taken to define the boundaries. Satellite imagery shown is from fall 2022 and does not depict water conditions during the time of the May survey.

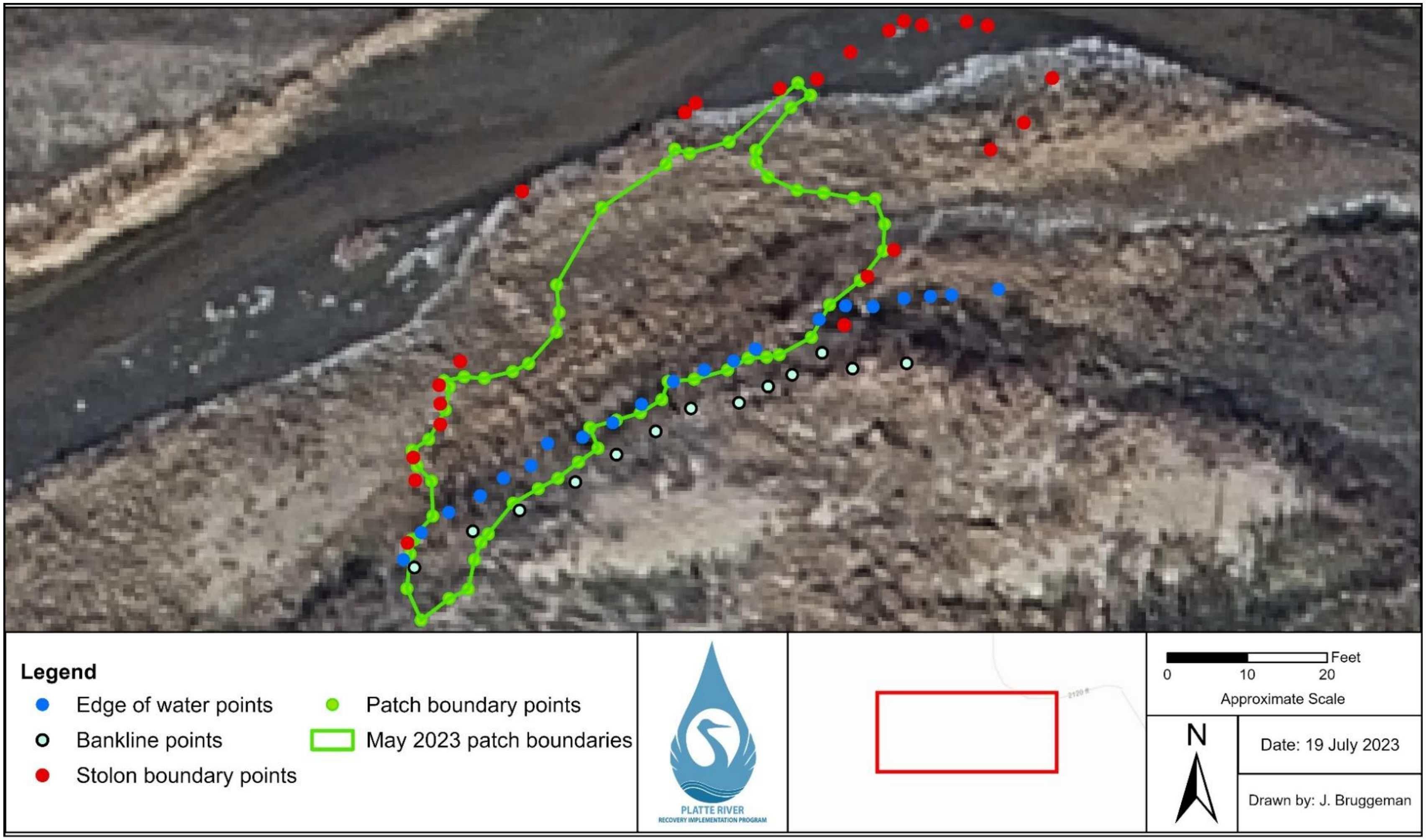

Figure 8. Example of delineated boundaries of a bankline *Phragmites* patch (green circles and line), stolon reach (red circles), river channel bankline (light green circles), and edge of water (blue circles) surveyed during May 2023. Circles depict RTK points. Satellite imagery shown is from fall 2022 and does not depict water conditions during the time of the May 2023 survey.

Figure 9. Photo of the bankline patch (in foreground) corresponding to the patch depicted in Figure 8. This photo was taken on the southeast corner of the patch and facing to the northwest.

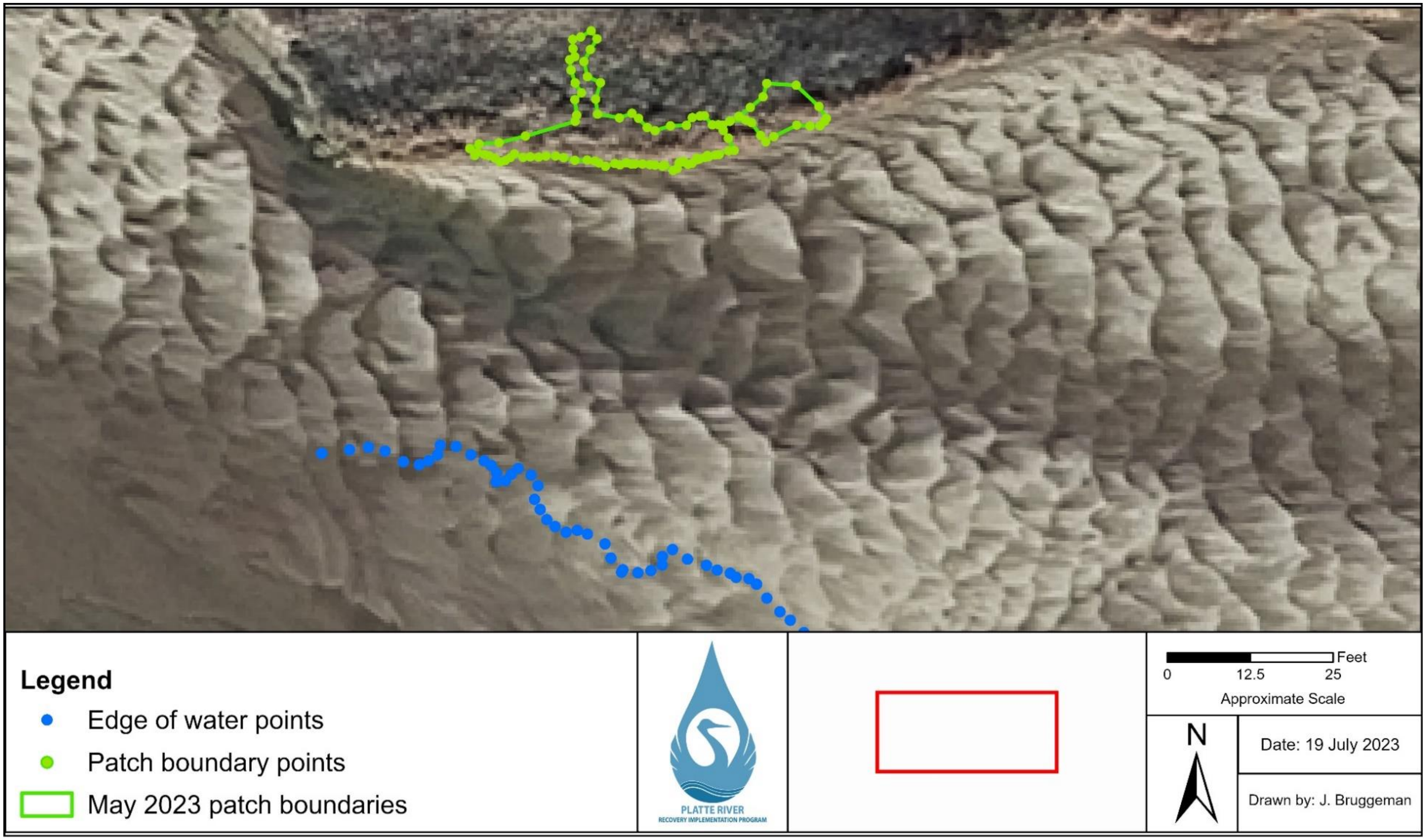

Figure 10. Example of delineated boundaries of a bankline *Phragmites* patch (green circles and line) and edge of water (blue circles) surveyed during May 2023. Circles depict RTK points. Satellite imagery shown is from fall 2022 and does not depict water conditions during the time of the May 2023 survey.

Figure 11. Photo of the bankline patch corresponding to the patch depicted in Figure 10.

Figure 12. Example of delineated boundaries of a bankline *Phragmites* patch (green circles and line) surveyed during June 2023 and corresponding water surface elevation measurement (blue circle). Circles depict RTK points. Satellite imagery shown is from fall 2022 and does not depict water conditions during the time of the May 2023 survey.

Figure 13. Photo of the bankline patch corresponding to the patch depicted in Figure 12 that was completely inundated by flowing water in the river channel.

Figure 14. Example of delineated boundaries of a bankline *Phragmites* patch (green circles and line), stolon reach (red circles), and two edges of water (blue circles) surveyed during May 2023. Circles depict RTK points. Satellite imagery shown is from fall 2022 and does not depict water conditions during the time of the May 2023 survey.

Figure 15. Photo of the bankline patch corresponding to the patch depicted in Figure 14.

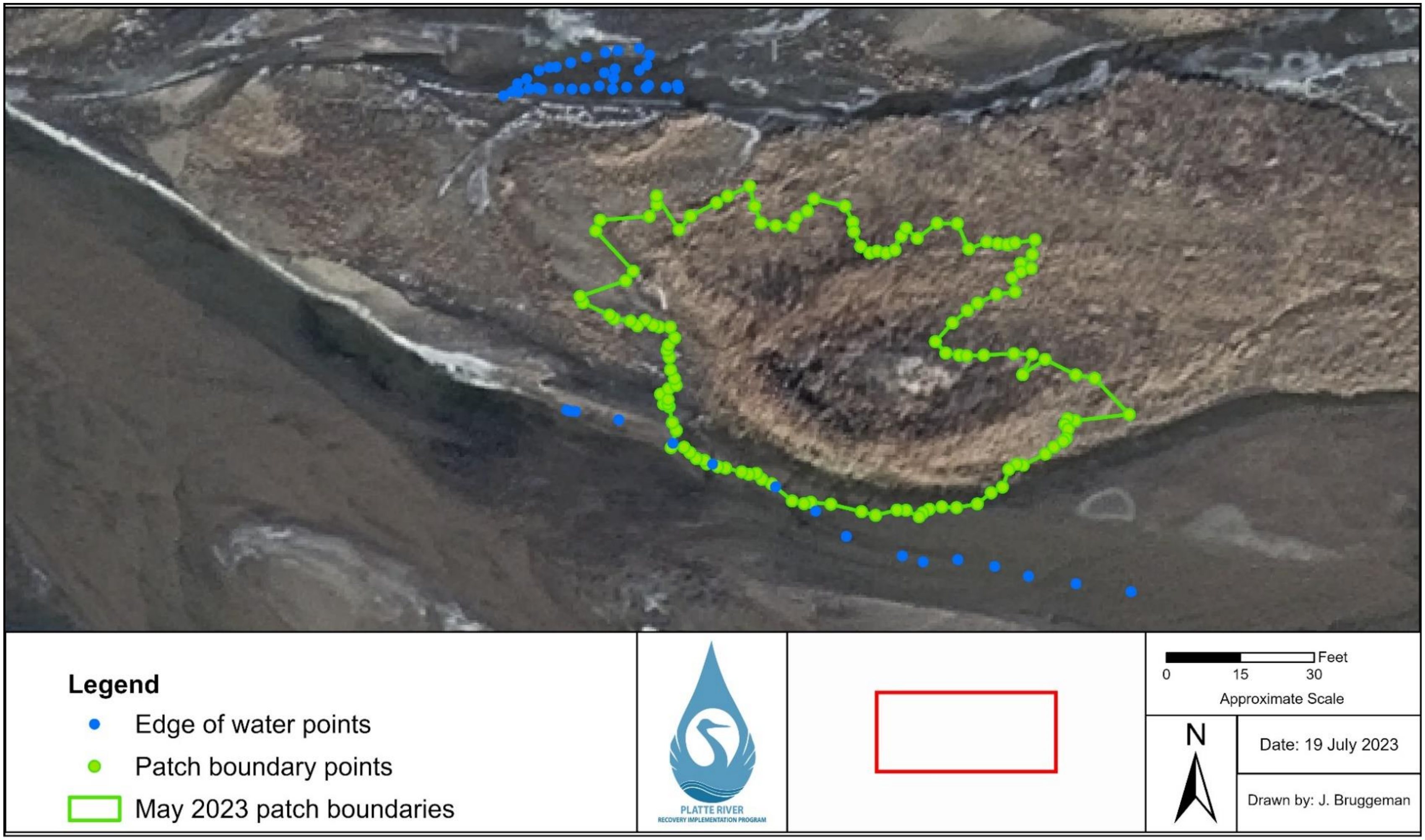

Figure 16. Example of delineated boundaries of an island bankline *Phragmites* patch (green circles and line) and two edges of water (blue circles) surveyed during May 2023. Circles depict RTK points. Satellite imagery shown is from fall 2022 and does not depict water conditions during the time of the May 2023 survey.

Figure 17. Photo of the island bankline patch corresponding to the patch depicted in Figure 16.

Figure 18. Example of delineated boundaries of an island bankline *Phragmites* patch (green circles and line) and two edges of water (blue circles) surveyed during May 2023. Circles depict RTK points. Satellite imagery shown is from fall 2022 and does not depict water conditions during the time of the May 2023 survey.

Figure 19. Photo of the island bankline patch corresponding to the patch depicted in Figure 18.

Figure 20. Example of a stolon that was flagged and measured as part of the study on changes in individual stolon length over time.

Figure 21. A stage gage assembly that was deployed in the Platte River at the Fort Kearney study area during May 2023.

VII. APPENDIX.

A. Description of Field Methodology Used During the 2022 Pilot Study

During the 2022 pilot study, we made RTK measurements to delineate the entire *Phragmites* patch boundary consisting of both the area of vertical shoot growth and the horizontal stolon reach. We did not conduct separate delineations to distinguish area of vertical shoot growth from horizontal stolon reach, and we did not define the edge of water relative to the patch or the bankline. Similar to 2023, we selected a start point for our patch delineation as one *Phragmites* stem located on the outer boundary of the patch. We placed the RTK receiver pole at the start point, leveled the pole, and hit “Enter” to record the first point location as “Patch.1.” We then moved in a counterclockwise direction to the next *Phragmites* stem, or cluster of stems, on the outer boundary of the patch, placed the receiver pole at the point, leveled the pole, and hit “Enter” to record the second point location as “Patch.2.” We continued this procedure in a counterclockwise direction until we had encircled the patch, fully delineated the outer patch boundary including the stolon reach (if present), and returned to the starting point. Maintaining a counterclockwise direction ensured that we kept the *Phragmites* patch on our left-hand side at all times when conducting the delineation.

During 2022 we recorded additional patch attribute data on a paper datasheet similar to what we recorded in 2023; however, we did not record the percent of patch and stolon reach inundation for bankline patches as we did in 2023 (Table A1). We estimated the height of the tallest green, living, and growing *Phragmites* stem to the nearest one-half foot. We used a visual assessment of *Phragmites* stem density and classified it as low (≤33% stem density); medium (33% to 66%); and high (>66%). We recorded the life stage of the *Phragmites* plants as vegetative (V); flowers (F); or seeds (S). We recorded the condition of the *Phragmites* plants as alive/green (A); having partial dieback (P); or brown, dormant, or dead (D). We recorded the percent cover of other non-*Phragmites* vegetation within the *Phragmites* patch boundary as none (N); low (≤33%); medium (33% to 66%); or high (>66%). We identified and listed the other species contained within the patch for heterogenous patches.

Table A1. Comparisons of *Phragmites* patch attribute, boundary, and RTK measurement data collected during 2022 to that from 2023 for inland and bankline patches along the Central Platte River, Nebraska.

Measurement	Collected in 2022	Collected in 2023
Inland and Bankline Patch Attributes		
Maximum stem height	Yes	Yes
Stem density	Yes	Yes
Life stage	Yes	Yes
Condition	Yes	Yes
Percent cover of other (non-*Phragmites*) vegetation	Yes	Yes
Stolons present? (yes/no)	Yes	Yes
Identification of other plant species in patch	Yes	No
Bankline Patch Attributes		
Percent of patch inundated by water	No	Yes
Percent of stolon reach inundated by water	No	Yes
Time of edge of water measurements and percent inundation assessment	No	Yes
RTK Measurements of Inland Patches		
Vertical growth boundary	Yes	Yes
Herbicide spray zone	No	Yes
RTK Measurements of Bankline Patches		
Combined vertical growth and stolon reach boundary	Yes	Yes
Vertical growth boundary	No	Yes
Stolon reach boundary	No	Yes
Bankline	No	Yes
Edge of water / water surface elevation	No	Yes
Herbicide spray zone	No	Yes

Exhibit B

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM
PROFESSIONAL SERVICES CONTRACT

1. **Parties.** This Professional Services Contract is made and entered into by and between Nebraska Community Foundation ("NCF"), representing all signatories to the Platte River Recovery Implementation Program (the "Program"), and ____________________ ("Consultant").

2. **Purpose of Contract.** The purpose of this Contract is to allow NCF, acting as the fiscal agent for the Governance Committee (GC) of the Program, to retain the services of the Consultant to render certain technical or professional services hereinafter described in connection with an undertaking to be financed by the Program, and to delegate the Executive Director's Office ("ED Office") through its Executive Director or designee the authority to administer this Contract.

3. **Term of Contract and Required Approvals.** *The term of this Contract is generally from DATE through DATE.* All services shall be completed during this term. The services to be performed under this Contract will commence upon receipt of authorization to proceed. If the Consultant has been delayed and as a result will be unable, in the opinion of the Program, to complete performance fully and satisfactorily within this Contract period, the Consultant may be granted an extension of time, upon submission of evidence of the causes of delay satisfactory to the Program. An extension of the contract term must be in writing, signed by both Parties in order for it to be valid.

4. **Payment for Services.**

A. **Billing Amount.** The Program agrees to pay the Consultant a fixed price of **$XXX,XXX** based on the approved Scope of Work as detailed in **Exhibit A – Project Scope of Work**. The total budget for the Scope of Work in Exhibit A is $XXX,XXX.

B. **Billing Rates.** Consultant shall not exceed the costs and rates for each task included in **Exhibit A** unless authorized in writing by the Program. The contract total amount is controlling and is a ceiling price that Consultant exceeds at its own risk. Payment shall be made directly to the Consultant. The Consultant shall maintain hourly records of time worked by its personnel to support any audits the Program may require. Invoices shall be submitted no more often than monthly for activities and costs accrued since the last invoice.

C. **Billing Procedures.** The Consultant shall send invoices for services performed for the various tasks outlined in **Exhibit A** to the ED Office. Invoices shall include all services and costs accrued by Contractor and Subconsultants since the last billing report. The Program's Executive Director, upon receiving the invoice, will review and advance the invoice to the Bureau of Reclamation who will advise NCF of approval. NCF will make payment of these funds directly to the Consultant within 30 days of receiving notice of approval. Payments are due within 60 days of the billing date.

D. **Withholding of Payment.**

(i) When the Program has reasonable grounds for believing that the Consultant will be unable to perform this Contract fully and satisfactorily within the time fixed for performance, then the Program may withhold payment of such portion of any amount otherwise due and payable to the Consultant reasonably deemed appropriate to protect the Program against such loss. These amounts may be withheld until the cause for the withholding is cured to the Program's satisfaction or this Contract is terminated pursuant to Section 8.T. Any amount so withheld may be retained by the Program for such period as it may be deemed advisable to protect the Program against any loss. This provision is intended solely for the benefit of the Program and no person shall have any right against the Program or NCF by reason of the Program's failure or refusal to withhold monies. No interest shall be payable by the Program or NCF on any amounts withheld under this provision. This provision is not intended to limit or in any way prejudice any other right of the Program or NCF.

(ii) If a work element has not been completed by the dates established in **Exhibit A**, the Program may withhold all payments beginning with the month following that date until such deficiency has been corrected.

E. Final Completion and Payment. The final payment shall be made upon acceptance of the final report, receipt of the final billing, and if applicable, execution of the final contract amendment documenting the final contract amount.

5. Responsibilities of Consultant.

A. Scope of Services. The Consultant shall perform the specific services required under this Contract in a satisfactory and proper manner as outlined in **Exhibit A**. If there is any conflict between this Contract and the provisions of the specific requirements of **Exhibit A**, the specific requirements shall prevail.

B. Personnel. All of the services required hereunder will be performed by the Consultant or under its supervision, and all personnel engaged in the work shall be fully qualified and shall be authorized, licensed, or permitted under state law to perform such services, if state law requires such authorization, license, or permit.

C. Subcontracts.

(i) Approval Required for Subcontracts. Any subcontractors required by the Consultant in connection with the services or work performed or rendered under this Contract will be limited to such individuals or firms as were specifically identified in the proposal and agreed to during negotiations or are specifically authorized in writing by the Program during the performance of this Contract. The Consultant shall include a list of the proposed subcontractors; the scope and extent of each subcontract; and the estimated dollar amount of each subcontract prior to Contract execution to the Program for approval that will be incorporated by reference in **Exhibit A**. During the performance of the Contract, substitutions in or additions to such subcontracts will be subject to the prior written approval of the Program. Program approval of subcontractors will not relieve the Consultant from any responsibilities outlined in this Contract. The Consultant shall be responsible for the actions of any subcontractors.

(ii) Billings for Subcontractors. Billings for subcontractor services will not include any mark up. Subcontract costs will be billed to the Program at the actual costs as billed to the Consultant.

Subcontract costs will be documented by attaching the subcontractor's invoice to the Consultant's invoice.

(iii) **Copies of Subcontracts.** The Consultant shall provide to the Program copies of each subcontract immediately following execution with the subcontractor. All subcontracts between the Consultant and a subcontractor shall refer to and conform to the terms of this Contract. However, nothing in this Contract shall be construed as making NCF or the Program a party to any subcontract entered between the Consultant and a subcontractor.

(iv) **Contracts for Subcontractors.** All subcontracts that Consultant enters into shall include any applicable provisions and certifications required by 2 CFR Part 200, including Appendix II thereto, and any other federal, state, or local laws or regulations.

(v) **Debarment and Suspension.** Consultant shall not enter into subcontracts with any entity or individual that is suspended, debarred, or otherwise excluded from participation in the transaction covered by this Contract.

D. **Requests from the Program.** The Consultant shall be responsible and responsive to the Program and the ED Office in their requests and requirements related to this Contract.

E. **Reports, Maps, Plans, Models and Documents.** Consultant shall furnish to the Program one (1) copy of maps, plans, worksheets, logs, field notes, or other documents prepared under this Contract, and one (1) copy of each unpublished report prepared under this Contract.

F. **Inspection and Acceptance.** All deliverables furnished by the Consultant shall be subject to rigorous review by the ED Office prior to acceptance.

6. **<u>Responsibilities of the Program.</u>**

A. **Designated Representative.** The Executive Director shall act as the Program's administrative representative with respect to the Consultant's service to be performed under this Contract and shall have complete authority to transmit instructions, receive information, and interpret and define the Program's policies and decisions with respect to services rendered under this Contract.

B. **Data to be Furnished to the Consultant.** All information, data, reports, and maps as are available to the Program and necessary for the carrying out of the Scope of Services set forth herein shall be furnished to the Consultant without charge, and the ED Office shall cooperate with the Consultant in every way possible in the carrying out of the project.

C. **Review Reports.** The ED Office shall examine all studies, reports, sketches, opinions of construction costs, and other documents presented by the Consultant to the Program and shall promptly render in writing the Program's decisions pertaining thereto within the time periods specified in **Exhibit A**.

D. **Provide Criteria.** The ED Office shall provide all criteria and full information regarding its requirements for the project.

7. Special Provisions.

A. No Finder's Fees. No finder's fee, employment agency fee, or other such fee related to the procurement of this Contract shall be paid by either party.

B. Publication. It is understood that the results of this work may be available to the Consultant for publication and use in connection with related work. Use of this work for publication and related work by the Consultant must be conducted with full disclosure to and coordination with the ED Office.

C. Publicity. Any publicity or media contact associated with the Consultant's services and the result of those services provided under this Contract shall be the sole responsibility of the Program. Media requests of the Consultant should be directed to the ED Office.

D. Monitor Activities. The Program shall have the right to monitor all Contract-related activities of the Consultant and all subcontractors.

E. Kickbacks. The Consultant certifies and warrants that no gratuities, kickbacks, or contingency fees were paid in connection with this Contract, nor were any fees, commissions, gifts, or other considerations made contingent upon the award of this Contract. If the Consultant breaches or violates this warranty, the Program may, at its discretion, terminate this Contract without liability to the Program, or deduct from the Contract price or consideration, or otherwise recover, the full amount of any commission, percentage, brokerage, or contingency fee.

F. Debarment and Suspension. Consultant certifies by signing this Contract that neither Consultant nor its principals are presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded by any federal department or agency from participation in the transaction covered by this Contract.

G. Anti-Lobbying. Consultant makes the representations set forth in **Exhibit B – Certification Regarding Lobbying**, incorporated by reference as part of this Contract. The Consultant shall execute such Certification at the time of executing this Contract.

H. Office Space, Equipment, and Supplies. The Consultant will supply its own office space, equipment, and supplies.

8. General Provisions.

A. Amendments. Any changes, modifications, revisions, or amendments to this Contract that are mutually agreed upon by the parties to this Contract shall be incorporated by written instrument and signed by the parties to this Contract.

B. Applicable Law; Venue. The construction, interpretation, and enforcement of this Contract shall be governed by the laws of the State of Nebraska. The Courts of the State of Nebraska shall have jurisdiction over this Contract and the parties.

C. Assignment; Contract Not Used as Collateral. Neither party shall assign or otherwise transfer any of the rights or delegate any of the duties set forth in this Contract without the prior written consent of the other party. The Consultant shall not use this Contract, or any portion thereof, as collateral for any financial obligation, without the prior written permission of the Program.

D. Audit; Access to Records. The Program, NCF, and any of their representatives shall have access to any books, documents, papers, and records of the Consultant that are pertinent to this Contract. The Consultant shall, immediately upon receiving written instruction from the Program or NCF, provide to NCF, the Program, or any governmental entity, independent auditor, accountant, or accounting firm, all books, documents, papers, and records of the Consultant which are pertinent to this Contract. The Consultant shall cooperate fully with NCF or any such governmental entity, independent auditor, accountant, or accounting firm, during the entire course of any audit authorized by or required of the Program.

E. Availability of Funds. Each payment obligation of the Program is conditioned upon the availability of funds and continuation of the Platte River Recovery Implementation Program. If funds are not allocated and available for the continuance of the services performed by the Consultant, the contract may be terminated by the Program at the end of the period for which the funds are available. The Program shall notify the Consultant at the earliest possible time of the services which will or may be affected by a shortage of funds. No penalty shall accrue to the Program in the event this provision is exercised, and the Program shall not be obligated or liable for any future payments due or for any damages as a result of termination under this section. This provision shall not be construed to permit the Program to terminate this Contract to acquire similar services from another party.

F. Award of Related Contracts. The Program may undertake or award supplemental or successor contracts for work related to this Contract. The Consultant shall cooperate fully with other consultants and the Program in all such cases.

G. Certificate of Good Standing. The Consultant shall provide a Certificate of Good Standing from the relevant Secretary of State office prior to performing work under this Contract, to be incorporated by reference into this Contract as **Exhibit C – Consultant Certificate of Good Standing**.

H. Compliance with Law. The Consultant shall keep informed of and comply with all applicable federal, state, and local laws and regulations in the performance of this Contract.

I. Confidentiality of Information. All documents, data compilations, reports, computer programs, photographs, and any other work provided to or produced by the Consultant in the performance of this Contract shall be kept confidential by the Consultant unless written permission is granted by the Program for its release.

J. Conflicts of Interest

(i) Consultant shall not engage in providing consultation to or representation of clients, agencies, or firms that may constitute a conflict of interest giving rise to a disadvantage to the Program or a disclosure which would adversely affect the interests of the Program. Consultant shall notify the Program of any potential or actual conflicts of interest arising during the course of the Consultant's performance under this Contract. This Contract may be terminated in the event a conflict of interest arises. Termination of the Contract will be subject to a mutual settlement of accounts. In the event the contract is terminated under this provision, the Consultant shall take steps to ensure that the file, evidence, evaluation, and data are provided to the Program or its designee. This does not prohibit or affect the Consultant's ability to engage in consultations, evaluations, or representation under agreement with other agencies, firms, facilities, or attorneys so long as no conflict exists.

(ii) A conflict of interest warranting termination of the Contract includes, but is not necessarily limited to, representing a client in an adversarial proceeding against the Program, its signatories, boards, commissions, or the NCF, or initiating suits in equity.

K. Entirety of Contract. This Contract represents the entire and integrated Contract between the parties and supersedes all prior negotiations, representations, and agreements, whether written or oral.

L. Force Majeure. Neither party shall be liable for failure to perform under this Contract if such failure to perform arises out of causes beyond the control and without the fault or negligence of the nonperforming party. Such causes may include, but are not limited to, acts of God or the public enemy, fires, floods, epidemics, pandemics, quarantine restrictions, freight embargoes, and unusually severe weather. This provision shall become effective only if the party failing to perform immediately notifies the other party of the extent and nature of the problem, limits delay in performance to that required by the event and takes all reasonable steps to minimize delays. This provision shall not be effective unless the failure to perform is beyond the control and without the fault or negligence of the nonperforming party.

M. Indemnification. The Consultant shall indemnify and hold harmless NCF, the Program, the ED Office, and their officers, agents, employees, successors and assignees from any and all claims, lawsuits, losses, and liability arising out of Consultant's failure to perform any of Consultant's duties and obligations hereunder or in connection with the negligent performance of Consultant's duties or obligations, including but not limited to any claims, lawsuits, losses, or liability arising out of Consultant's malpractice. The obligations of this paragraph shall survive termination of this Contract.

N. Independent Consultant. The Consultant shall function as an independent contractor for the purposes of this Contract and shall not be considered an employee of the Program, NCF, or ED Office for any purpose. The Consultant shall assume sole responsibility for any debts or liabilities that may be incurred by the Consultant in fulfilling the terms of this Contract and shall be solely responsible for the payment of all federal, state, and local taxes that may accrue because of this Contract. Nothing in this Contract shall be interpreted as authorizing the Consultant or its agents and/or employees to act as an agent or representative for or on behalf of NCF or the Program, or to incur any obligation of any kind on the behalf of NCF or the Program. The Consultant agrees that no health/hospitalization benefits, workers' compensation and/or similar benefits available to NCF, Program, or ED Office employees will inure to the benefit of the Consultant or the Consultant's agents and/or employees as a result of this Contract.

O. Notices. All notices arising out of, or from, the provisions of this contract shall be in writing and given to the parties at the address provided under this Contract, either by regular mail, facsimile, e-mail, or delivery in person. Notice is effective upon delivery.

P. Notice and Approval of Proposed Sale or Transfer of the Consultant. The Consultant shall provide the Program with the earliest possible advance notice of any proposed sale or transfer or any proposed merger or consolidation of the assets of the Consultant. Such notice shall be provided in accordance with the notice provision of this Contract.

Q. Ownership of Documents, Work Product, Materials. All documents, reports, records, field notes, data, samples, specimens, and materials of any kind resulting from performance of this Contract are at all times the property of the Program.

R. Patent or Copyright Protection. The Consultant recognizes that certain proprietary matters or techniques may be subject to patent, trademark, copyright, license or other similar restrictions, and warrants that no work performed by the Consultant or its subcontractors will violate any such restriction.

S. Insurance Coverage. The Consultant's relevant Certificate of Insurance shall be provided to the Program and incorporated by reference into this Contract as **Exhibit D – Consultant Certificate of Insurance**. The Consultant shall not commence work under this Contract until the Consultant has obtained the following insurance coverages and provided the corresponding certificate noting such coverages:

(i) Commercial General Liability Insurance. Consultant shall provide coverage during the entire term of the Contract against claims arising out of bodily injury, death, damage to or destruction of the property of others, including loss of use thereof, and including products and completed operations in an amount not less than Two Million Dollars ($2,000,000.00) aggregate and One Million Dollars ($1,000,000.00) per occurrence. These minimum limits can be met by primary and umbrella liability policies. Coverage shall include Premises-Operations, Products/Completed Operations, Contractual, Broad Form Property Damage, and Personal Injury.

(ii) Business Automobile Liability Insurance. Consultant shall maintain, during the entire term of the Contract, automobile liability insurance in an amount not less than One Million Dollars ($1,000,000.00) per occurrence. Coverage will include bodily injury and property damage covering all vehicles, including hired vehicles, owned and non-owned vehicles.

(iii) Workers' Compensation and Employers' Liability Insurance. The Consultant shall provide proof of workers' compensation coverage. Consultant's insurance shall include "Stop Gap" coverage in an amount not less than Five Hundred Thousand Dollars ($500,000.00) per employee for each accident and disease.

(iv) Professional Liability Insurance. The Consultant shall provide proof of professional liability insurance covering damages arising out of negligent acts, errors, or omissions committed by Consultant in the performance of this Agreement, with a liability limit of not less than One

Million Dollars ($1,000,000) per claim. The Consultant shall maintain this policy for a minimum of two (2) years after completion of the work or shall arrange for a two-year extended discovery (tail) provision if the policy is not renewed. The intent of this policy is to provide coverage for claims arising out of the performance of professional services under this Contract and caused by any error, omission, breach, or negligent act, including infringement of intellectual property (except patent or trade secret) of the Consultant.

T. Taxes. The Consultant shall pay all taxes and other such amounts required by federal, state and local law, including but not limited to federal and state income taxes, social security taxes, workers' compensation, unemployment insurance, and sales taxes.

U. Termination of Contract. This Contract may be terminated, without cause, by the Program upon fifteen (15) days' advance written notice. This Contract may be terminated immediately for cause if the Consultant fails to cure its performance in accordance with the terms of this Contract within seven (7) days after receiving notice from the Program. In the event of a termination, the Program shall pay Consultant for all reasonable work performed up to the effective date of the termination. In the event the contract is terminated under this provision, the Consultant shall take steps to ensure that the file, evidence, evaluation, and data are provided to the Program or its designee.

V. Third Party Beneficiary Rights. The parties do not intend to create in any other individual or entity the status of third-party beneficiary, and this Contract shall not be construed so as to create such status. The rights, duties, and obligations contained in this Contract shall operate only between the parties to this Contract and shall inure solely to the benefit of the parties to this Contract. The provisions of this Contract are intended only to assist the parties in determining and performing their obligations under this Contract.

W. Time is of the Essence. Time is of the essence in all provisions of the Contract.

X. Titles Not Controlling. Titles of paragraphs are for reference only and shall not be used to construe the language in this Contract.

Y. Waiver. The waiver of any breach of any term or condition in this Contract shall not be deemed a waiver of any prior or subsequent breach.

Z. Survival. The parties' obligations under sections 8.D. (Audit/Access to Records), 8.R. (Insurance Coverage), and 8.T. (Termination of Contract) will survive the termination of this Contract.

9. Contacts.

For the Foundation:
Jason D. Kennedy, Chief Financial & Administrative Officer
Nebraska Community Foundation
PO Box 83107
Lincoln, Nebraska 68501-3107
Phone: (402) 323-7330
Email: jkennedy@nebcommfound.org
FEIN: 47-0769903

For the Consultant:
CONTACT NAME
TITLE
CONSULTANT NAME
ADDRESS 1
ADDRESS 2
ADDRESS 3
PHONE:
EMAIL:
FEIN:
DUNS:
SAM Unique Entity ID:

For the ED Office:
NAME
TITLE
4111 4th Avenue
Kearney, NE 68845
Phone:
Email:

10. <u>Signatures</u>.
By signing this Contract, the undersigned certify that they have read and understood it, that they have the authority to sign it, and that their respective Party agrees to be bound by the terms of the Contract.

NEBRASKA COMMUNITY FOUNDATION:

____ ________________
Jason D. Kennedy Date
Chief Financial and Administrative Officer

CONSULTANT:

____ ________________
NAME Date
TITLE

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM ACKNOWLEDGEMENT
I hereby certify that the Governance Committee of the Platte River Recovery Implementation Program (Program) has authorized the Nebraska Community Foundation, acting as contracting agent of the Governance Committee of the Program, to enter into this Agreement.

____ ________________
Jason M. Farnsworth Date
Executive Director

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM (PRRIP -or- Program)
EXHIBIT A – Project Scope of Work

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM (PRRIP -or- Program)
EXHIBIT B – Certification Regarding Lobbying

The undersigned certifies, on behalf of the Consultant, that to the best of his or her knowledge and belief:

1. No federal appropriated funds have been paid or will be paid, by or on behalf of the Consultant, to any person for influencing or attempting to influence an officer or employee of any federal agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any federal grant, the making of any federal loan, the entering into of any cooperative agreement, or the extension, continuation, renewal, amendment, or modification of any federal contract, grant, loan, or cooperative agreement.

2. No registrant under the Lobbying Disclosure Act of 1995 has made any lobbying contacts on behalf of the Consultant with respect to the federal grant or cooperative agreement under which the Consultant is receiving monies.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who makes an expenditure prohibited by Section 1 above or who fails to file or amend the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

FOR THE CONSULTANT:

____ __________________

NAME Date

TITLE

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM (PRRIP -or- Program)
EXHIBIT C – Consultant Certificate of Good Standing

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM (PRRIP -or- Program)
EXHIBIT D – Consultant Certificate of Insurance