BUREAU OF RECLAMATION

Improving Predictions of Scour in the Vicinity of Vegetation in Habitat Rehabilitation Areas

Science and Technology Program
Research and Development Office
Final Report No. ST-2023-19290-01

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14. ABSTRACT

A modeling suite has been developed for simulating vegetation lifecycle and the effects on hydraulics and sediment transport in the riparian environment. The models are based upon the SRH-2D package (Lai, 2010), which contains a two-dimensional flow and mobile bed sediment transport model. With combined support from Reclamation’s Science & Technology Program and the Albuquerque Area Office, the cumulative stress lifecycle model was applied to analyze revegetation alternative actions associated with a channel realignment project along a subreach of the Rio Grande in New Mexico. We analyzed the response of four species to three annual hydrographs that represent wet, average, and dry conditions. Relationships between hydrology, hydraulics, groundwater, and vegetation are complex, and the modeling provides useful insights by parameterizing variables and linking important physical processes. As originally scoped, the focus of the proposed study was to improve ability to predict scour in and around vegetated areas, utilizing the realignment project as a numerical case study. Updates to the vegetation model will be necessary in order to include the capabilities within a public-facing distribution of the SRH-2D modeling suite. We project these updates to be conducted under the umbrella of facilitated adoption and plan to propose support through Reclamation’s Research Office during fiscal year 2024

15. SUBJECT TERMS
SRH-2D, riparian vegetation, hydraulic modeling, sediment transport

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Improving Predictions of Scour in the Vicinity of Vegetation in Habitat Rehabilitation Areas

Final Report No. ST-2023-19290-01

prepared by

Technical Service Center
Daniel Dombroski, Hydraulic Engineer

Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Disclaimer

Acknowledgements

The Science and Technology Program, Bureau of Reclamation, sponsored this research.

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Executive Summary

River restoration projects are often motivated by a need to promote biological, geomorphic, and hydraulic processes that are important to the local and regional ecosystem. Increasing population numbers of a single (or several) species is often a primary driver for restoration projects, although the path to achieving end goals is often complicated by the constraints imposed by managed systems and heavily allocated resources. Due to the challenges and costs associated with such projects, stakeholders and administrators are increasingly expecting quantitative analysis be performed to project the value and effectiveness of restoration alternatives relative to existing conditions. Multidimensional hydraulic, sediment, and habitat modeling are now routinely requested by project offices in order to meet these demands, however the complexity of ecohydraulic processes requires improvements in ability to predict interactions that effect localized patterns. For example, predicting the effects of riparian vegetation on hydraulics and sediment transport within managed riverine systems is a growing need due to the increasing priority of maintaining ecosystem function while sustaining water conveyance. Development of riparian modeling tools are motivated by a need to quantitatively address questions such as the following:

Conveyance: How will re-vegetation actions within restoration projects affect flood risks?

Sediment: How do varying riparian vegetation characteristics associated with restoration actions influence sediment transport dynamics within the system?

Habitat: How will restoration actions impact quality, quantity, and distribution of habitat?

Management: How do reservoir operations affect vegetation recruitment and survival in the downstream riparian corridor?

These questions are particularly relevant to regions of the Western U.S. where multi-benefit water projects (e.g., projects that enhance flood safety, irrigation, wildlife habitat, and public recreation) are legally mandated components of regional and state-wide planning and funding efforts. These multi-benefit projects can be critically dependent on modeling of riparian vegetation and the effects on hydraulic conveyance and sediment transport.

To address these needs, a modeling suite has been developed for simulating vegetation lifecycle and the effects on hydraulics and sediment transport in the riparian environment. The models are based upon the SRH-2D package (Lai, 2010), which contains a two-dimensional flow and mobile bed sediment transport model. The capabilities of the modeling suite are comprised of two distinct components:

A vegetation-hydraulic solver that uses measured vegetation parameters and calculated hydraulic variables to estimate a spatially-distributed, dynamic roughness coefficient that is coupled to the simulated hydrodynamics and sediment transport calculations through the bed shear stress.

A cumulative stress lifecycle algorithm that predicts the establishment, growth, and removal of riparian vegetation based on measured parameters and calculated hydraulic variables.

The components of the riparian vegetation modeling suite have been developed and enhanced through a series of individually funded projects, the utility of which have been demonstrated at the project level: Platte River Recovery Implementation Program (Murphy, Fotherby, Randle, & Simons, 2006), San Joaquin River Restoration Project (Dombroski D. E., 2017; Chaulagain, et al., 2022; Dombroski D. E., 2014), Trinity River Restoration Program (Dombroski D. E., 2016), Rio Grande Bosque Del Apache Realignment Project (Dombroski & Holste, 2023). The model development has leveraged in-kind support through mutually-beneficial collaborations with other agencies and institutions, including the U.S. Army Corps of Engineers, Massachusetts Institute of Technology, and University of New Mexico.

With combined support from Reclamation's Science & Technology Program and the Albuquerque Area Office, the cumulative stress lifecycle model was applied to analyze revegetation alternative actions associated with a channel realignment project along a subreach of the Rio Grande in New Mexico. Construction of the Bosque del Apache (BDA) Pilot Realignment Project was completed in Spring 2021. The project realigned 2.5 miles of the Rio Grande channel from a perched condition near the spoil levee to the lower elevation eastern floodplain. The project purpose is to promote long-term effective conveyance of water and sediment through the reach while minimizing the potential for spoil levee failure. Additionally, channel realignment seeks to promote sustainability and resiliency of the reach by considering channel dynamics and habitat. Prior to project construction, a primary uncertainty was the vegetative response of the newly cleared channel and surrounding riparian areas to the newly imposed hydrologic regime. We used the SRH-2D hydraulic model coupled to the vegetive lifecycle model to address questions regarding how the riparian landscape may evolve under different conditions. We analyzed the response of four species to three annual hydrographs that represent wet, average, and dry conditions. Relationships between hydrology, hydraulics, groundwater, and vegetation are complex, and the modeling provides useful insights by parameterizing variables and linking important physical processes. Model results can be used to inform monitoring and adaptive management as the project evolves over time. For complete reporting on the BDA realignment, application of the lifecycle model, and analysis of results from the study, see the full report included in the appendix.

As originally scoped, the focus of the proposed study was to improve ability to predict scour in and around vegetated areas, utilizing the BDA realignment project as a numerical case study. Prediction of scour that will affect vegetation recruitment and removal, to the benefit or detriment of habitat rehabilitation projects, is important to guide designers to ensure long-term success of restoration projects. It is expected that removal of vegetation is most critical in the early stages of germination before root systems have established. In this case, scour will be tightly coupled to the mobility of the substrate. The current model utilizes a velocity-based predictor of scour, which is a carryover from the one-dimensional implementation that lacked the detailed hydraulic information necessary to make more robust shear stress-based predictions. Updating the lifecycle model to incorporate shear-based predictors of scour is anticipated to improve modeling of complex interactions between flow, sediment, and vegetation, especially in applications where scour may be of significant concern. The current publicly-facing version of

SRH-2D utilizes an approach that partitions the shear stress into components attributed to the grain roughness and form drag. The grain roughness is primarily responsible for computing sediment mobilization, and the form drag can be further decomposed into components arising from bed forms and vegetation. Each component of the shear stress partition is written as a function of the hydraulic variables (depth and velocity) and a roughness contribution. The total roughness is then taken as the square root of the sum of the squared products. Details on the implementation of shear partitioning in SRH-2D are found in the user manual (Lai & Gaeuman, 2020).

The riparian vegetation modeling capabilities were developed before the shear stress partitioning methodology was implemented in SRH-2D, and coding updates are required to modify the way roughness is handled within the vegetation model. Specifically, we will need to account for the different roughness components that feed the SRH-2D hydraulic solver, and tie that back into an updated algorithm for predicting processes such as scour. The required updates have larger-scale implications to user adoption of the vegetation model, as it is not currently available in the public distribution. Thus, conducting the updates to the vegetation model will be necessary in order to include the capabilities within a public-facing distribution of the SRH-2D modeling suite. We project these updates to be conducted under the umbrella of facilitated adoption and plan to propose support through Reclamation’s Research Office during fiscal year 2024.

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Appendix A

Two-Dimensional Vegetation Modeling of Bosque del Apache Pilot Realignment

Technical Report No. ENV-2023-065

Two-Dimensional Vegetation Modeling of Bosque del Apache Pilot Realignment

Middle Rio Grande Project, New Mexico
Upper Colorado Basin Region

U.S. Department of the Interior **April 2023**

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Cover Photo – Looking downstream at realignment project, May 2021 (Reclamation/James Fluke).

Technical Report No. ENV-2023-065

Two-Dimensional Vegetation Modeling of Bosque del Apache Pilot Realignment

Middle Rio Grande Project, New Mexico
Upper Colorado Basin Region

Prepared by:

Bureau of Reclamation
Technical Service Center
Denver, Colorado

U.S. Department of the Interior **April 2023**

Technical Report No. ENV-2023-065

Two-Dimensional Vegetation Modeling of Bosque del Apache Pilot Realignment

Middle Rio Grande Project, New Mexico
Upper Colorado Basin Region

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Peer Review Certification

This report has been reviewed by Blair Greimann, P.E., Ph.D., former Technical Specialist for the Sedimentation and River Hydraulics Group. The report is believed to be in accordance with the service agreement and standards of the profession.

Acronyms and Abbreviations

1D	one-dimensional
2D	two-dimensional
404MA	404 Permit Mitigation Area
AAO	Albuquerque Area Office
ac	acre
ac-ft	acre-feet
ave	average
BDA	Bosque del Apache
cfs	cubic feet per second
LFCC	Low Flow Conveyance Channel
LiDAR	Light Detection and Ranging
MRG	Middle Rio Grande
SRH	Sedimentation and River Hydraulics
SWFL	Southwestern Willow Flycatcher
YBCU	Yellow-billed Cuckoo

Acknowledgments

The Albuquerque Area Office (AAO) has provided funding for work on the Pilot Realignment Project, in addition to overall project management. The contributions of the entire AAO project team have been invaluable for bringing this project from concept to construction. Cameron Herrington (AAO Hydraulic Engineer and Project Manager), Robert Padilla (AAO Supervisory Hydraulic Engineer), Brian Hobbs (former AAO Project Manager – Biologist), Jonathan AuBuchon (former AAO Hydraulic Engineer), and Aubrey Harris (former AAO Hydraulic Engineer) have provided helpful suggestions throughout the process. Brian Hobbs, Jonathan AuBuchon, and Christopher Grosso (AAO Biologist) were instrumental in developing the scope and obtaining data for the vegetation modeling study. These contributions are gratefully appreciated.

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Executive Summary

Construction of the Bosque del Apache (BDA) Pilot Realignment Project was completed in Spring 2021. The project realigned 2.5 miles of the Rio Grande channel from a perched condition near the spoil levee to the lower elevation eastern floodplain. Before project implementation, the main channel filled with sediment three times between 2008 and 2019. This phenomenon is known as a sediment plug and is caused by a sediment transport discontinuity during high magnitude, long duration runoff events. Sediment plugs cause channel capacity and levee stability concerns during extended periods of overbanking flow. Therefore, the channel was mechanically realigned to simulate a natural avulsion process and reduce the risk of future sediment plugs and associated impacts to water delivery and infrastructure. The project purpose is to promote long-term effective conveyance of water and sediment through the reach while minimizing the potential for spoil levee failure. Additionally, channel realignment seeks to promote sustainability and resiliency of the reach by considering channel dynamics and habitat.

Vegetation clearing along the realignment corridor was one of the most significant construction activities. The response of the cleared area, and the effects of the project on nearby existing vegetation, was difficult to predict during planning and design. To address these questions, a two-dimensional (2D) vegetation model study analyzed the expected vegetation lifecycle and dynamics in response to the BDA Pilot Realignment Project. A vegetation module within the SRH-2D hydrodynamic model simulates changes to the vegetation distribution in the project area through germination, establishment, and mortality. We analyzed the response of four species to three annual hydrographs that represent wet, average, and dry conditions. Relationships between hydrology, hydraulics, groundwater, and vegetation are complex, and the modeling provides useful insights by parameterizing variables and linking important physical processes. Model results can be used to inform monitoring and adaptive management as the project evolves over time.

The results generally indicate that the germination success or failure, and subsequent distribution of seedlings, is a much more complex process than would be indicated by volume of water for each hydrograph. The wet hydrograph resulted in the largest germination area for Coyote Willow and Salt Cedar, while the average hydrograph resulted in the largest germination area for Cottonwood and Tree Willow. The spatial distribution is strongly dependent on the hydrograph type; dry years with a low spring runoff tend to have most germination concentrated near the channel margins. Susceptibility of newly-germinated vegetation to natural stressors is not only a function of the species-specific biological attributes, but also the spatio-temporal conditions of the riparian landscape and hydraulic conditions under which the vegetation is establishing. We compared vegetated and non-vegetated initial conditions and found that existing vegetation mitigates the effect of varying water year types on changes to the overall population. Germination on bare surfaces depends on the hydrograph magnitude and timing relative to the germination period, whereas surfaces with existing vegetation are unlikely to be colonized by new vegetation. The modeling results are consistent with observations along the Rio Grande where bare surfaces are quickly vegetated after a spring runoff event. Unvegetated bars within the channel are highly susceptible to colonization during periods of low flow.

1 Introduction

The Bosque del Apache (BDA) Pilot Realignment Project is the result of several years of planning, analysis, design, and construction. A 2.5-mile channel segment was realigned from a perched condition near the spoil levee to the lower elevation eastern floodplain (Figure 1). Vegetation clearing began in Spring 2018 and final construction was completed in Spring 2021. The project is termed a "pilot" because planning and design are ongoing for a second realignment phase immediately to the north.

This reach of the Middle Rio Grande (MRG) has been prone to sediment plugs where the main channel fills with sediment during any long duration, high magnitude, spring runoff event (Tetra Tech 2010, Park 2013, Julien and Rainwater 2014). Sediment plugs occurred during 2008, 2017, and 2019 within the BDA National Wildlife Refuge and 1991, 1995, and 2005 further downstream near Tiffany Junction. Sediment plugs cause channel capacity and levee stability concerns during extended periods of overbanking flow. Historically, when the river became perched above the floodplain or plugged with sediment, the channel would avulse to a new location. A combination of lower peak flow events, a densely vegetated floodplain, and infrastructure constraints have prevented avulsions in recent years. Therefore, the channel was mechanically realigned to simulate a natural avulsion process and reduce the risk of future sediment plugs and associated impacts to water delivery and infrastructure. The project purpose is to promote long-term effective conveyance of water and sediment through the reach while minimizing the potential for spoil levee failure. Additionally, channel realignment seeks to promote sustainability and resiliency of the reach by considering channel dynamics and habitat.

Holste (2021) provides a complete description of the design and analysis of the BDA Pilot Realignment Project. The primary goals are to improve water delivery and protect infrastructure. Promoting a more dynamic river channel is also a project goal and an associated objective is to increase habitat for the Southwestern Willow Flycatcher (SWFL) and Yellow-billed Cuckoo (YBCU). Existing vegetation within the realignment area was classified as unsuitable habitat for the SWFL and YBCU prior to construction (Siegle and Ahlers 2017). Removing invasive vegetation and providing for a more dynamic channel is expected to allow a mosaic of native vegetation to become established that will be more favorable for avian species.

SWFL habitat tends to consist of young age classes of willow species, while YBCU habitat is often composed of a mature cottonwood and willow overstory that may or may not include an understory layer (Siegle and Moore 2020). Optimal SWFL habitat has dense vegetation near surface water or saturated soil. The establishment of dense willow-dominated vegetation is often the result of recent sediment deposition. YBCU habitat is less sensitive to the water table because plants in mature stands have a deeper root system. YBCU territories in the project area have increased in recent years, possibly due to the maturation of vegetation that was established during the 2005 and 2008 spring runoff events.

Conceptually, channel realignment is expected to improve SWFL and YBCU habitat within the eastern floodplain while potentially having a negative effect on riparian vegetation near the existing channel. Moving the channel to the east should decrease depth to groundwater in the realignment area while increasing depth to groundwater near the existing channel. Effects on groundwater to the west of the existing channel will likely be mitigated by water levels in the Low Flow Conveyance Channel (LFCC). Realigning the channel to the eastern floodplain should promote scour and deposition of sediment to provide new opportunities for germination and establishment of vegetation.

Vegetation is also important for water delivery, channel morphology, and maintenance costs. Transpiration from vegetation during the growing season uses a significant amount of water that is then not available for downstream delivery (Jasechko et al. 2013, Reclamation 1952). Vegetation interacts with the channel by narrowing the active width, providing cohesion to the banks, and promoting sediment deposition by reducing velocity. Channel narrowing through vegetation encroachment is the dominant geomorphic trend on the MRG during the last several decades (Greimann and Holste 2018). Undesirable vegetation growth, especially for non-native species, often requires chemical and mechanical treatment to manage, which increases maintenance.

In this report, we use two-dimensional (2D) modeling to examine the expected vegetation lifecycle and dynamics in response to the BDA Pilot Realignment Project. A vegetation module within the SRH-2D hydrodynamic model simulates changes to the vegetation distribution in the project area through germination, establishment, and mortality. The SRH-2D vegetation module is based on studies that simulated vegetation characteristics using the SRH-1D model applied to the Sacramento River, San Joaquin River, and the Rio Grande (Greimann et al. 2011, Wang et al. 2018, Zhang et al. 2019). The study estimates the response of four species (cottonwood, coyote willow, Goodding's black willow – known as tree willow, and salt cedar) to three different hydrographs (Wet – 2008, Dry – 2011, Average – 2015). Our goal is not to use the model to make absolute or definitive predictions, but to develop hypotheses that inform monitoring and adaptive management. Relationships between hydrology, hydraulics, groundwater, and vegetation are complex, and the modeling provides useful insights by parameterizing variables and linking important physical processes.

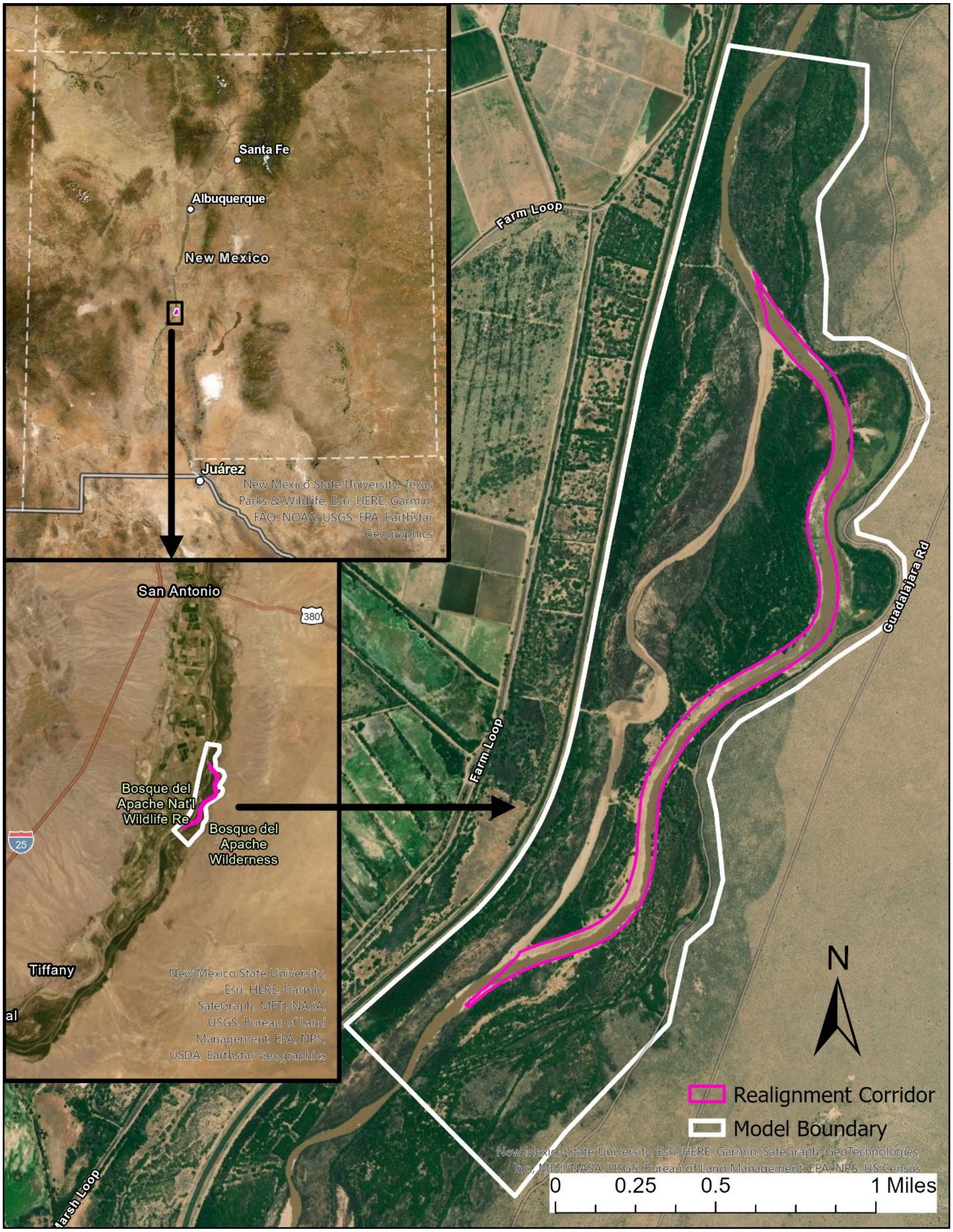

Figure 1—Location map for BDA Pilot Realignment Project and model boundary. Aerial imagery from ESRI Basemap, Maxar Vivid, June 2021.

2 Model Development

2.1 Elevation Data

Light Detection and Ranging (LiDAR) for the project area was acquired during a flight on October 1, 2016 (Atlantic, 2017) when the river was nearly dry. Table 1 documents the coordinate reference system. The Albuquerque Area Office (AAO) modified the LiDAR terrain using AutoCAD Civil 3D to create the design surface for channel realignment. Holste (2021) describes the full details of the design. Model simulations for this study were completed in 2019 and 2020 during construction of the realignment project, so the model input uses the design surface rather than the as-built surface.

Table 1—Coordinate reference system for project LiDAR (Atlantic, 2017)

Attribute	Description
Coordinate System	State Plane New Mexico Central (FIPS 3002)
Horizontal Datum	North American Datum of 1983 (2011)
Vertical Datum	North American Vertical Datum of 1988
Units of Reference	U.S. Survey Feet
Geoid Model	Geoid12B

2.2 Roughness

Hydraulic roughness for the model simulations used the Manning's n-values from Holste (2019), which were adapted from prior work by Harris (2017). Harris (2017) assigned roughness to polygons that were based on 2016 vegetation mapping (Siegle and Ahlers 2017) and field reconnaissance. Table 2 lists the vegetation types and corresponding roughness, while Figure 2 illustrates the spatial distribution within the model domain. Holste (2021) discusses the sensitivity of roughness values in this reach to flow regime and channel bedforms while analyzing the effects on sediment transport. Roughness varies temporally as a function of flow and channel morphology. However, the vegetation dynamics model applied constant roughness values at all flows to provide consistency when comparing scenarios and because of computational limits.

Table 2—Manning's roughness values used in model simulations

Dominant Vegetation Type	Polygon Code	Roughness (n-value)
River channel	Channel	0.02*
Bare soil (vegetation removal areas)	-	0.02*
Open water	OP	0.035
Saltcedar and willows in shrub-sized stands	SC 5	0.05
Saltcedar: dense, young, low growth	SC 6d	0.06
Cottonwood with little or no understory	C 4	0.08
Saltcedar in dense shrub-sized stands or cottonwood in dense stands, intermediate sized, with little to no understory	SC or C 4d-5d	0.1
Coyote willows and others, dense with well-developed understory	CW 3d	0.175**

*roughness value applied for upper regime flow because water surface elevation is most sensitive to roughness at high flow (roughness would be larger at low flows with bedforms, but a constant value is used for modeling hydrographs)

**assumes significant debris, undergrowth, and other woody material on or near ground level

Figure 2—Distribution of roughness zones within delineated model boundary.

This vegetation study modeled seasonal hydrographs including flows that ranged from very low, near zero cubic feet per second (cfs), to high, near 5000 cfs. To further understand the interaction between vegetation and hydraulics, we selected several steady-state flows and dynamic roughness algorithms to compare to the assumed roughness values. Dombroski (2014) developed a routine within SRH-2D to dynamically calculate roughness as a function of vegetation conditions and hydraulic variables. Therefore, the calculated roughness varies according to simulated discharge through the reach. Hydraulic roughness modeling algorithms are dependent primarily on estimates of vegetation height and density, which can be derived from remotely-sensed LiDAR point returns. Figure 3, Figure 4, and Figure 5 present 2D distributions of

computed roughness for steady flows of 500 cfs, 2500 cfs, and 4600 cfs using the Baptist (2007) algorithm. Figure 6 and Figure 7 present computed roughness for a steady flow of 4600 cfs using the Jarvela (2004) and Kouwen (2000) algorithms, respectively. Collectively, the images provide a qualitative comparison of how predicted roughness may vary with hydraulic conditions and method of computation. The roughness generally increases with flow depth and velocity because there is more interaction between the vegetative structure and the water column, assuming the vegetation is not overtopped. Dry cells of the computational mesh default to a user-specified value. For a discharge of 500 cfs (Figure 3), the flow remains predominantly in-channel and the default roughness is assigned for most of the distribution. Therefore, calculation of roughness for high, out-of-bank flow conditions provides more informative results (Figure 5 through Figure 7). The algorithms are highly parameterized and generally developed for a specific functional type of vegetation. In comparison with the design roughness (Figure 2), the calculated roughness using the Kouwen (2000) algorithm (Figure 7) provides a qualitatively reasonable agreement.

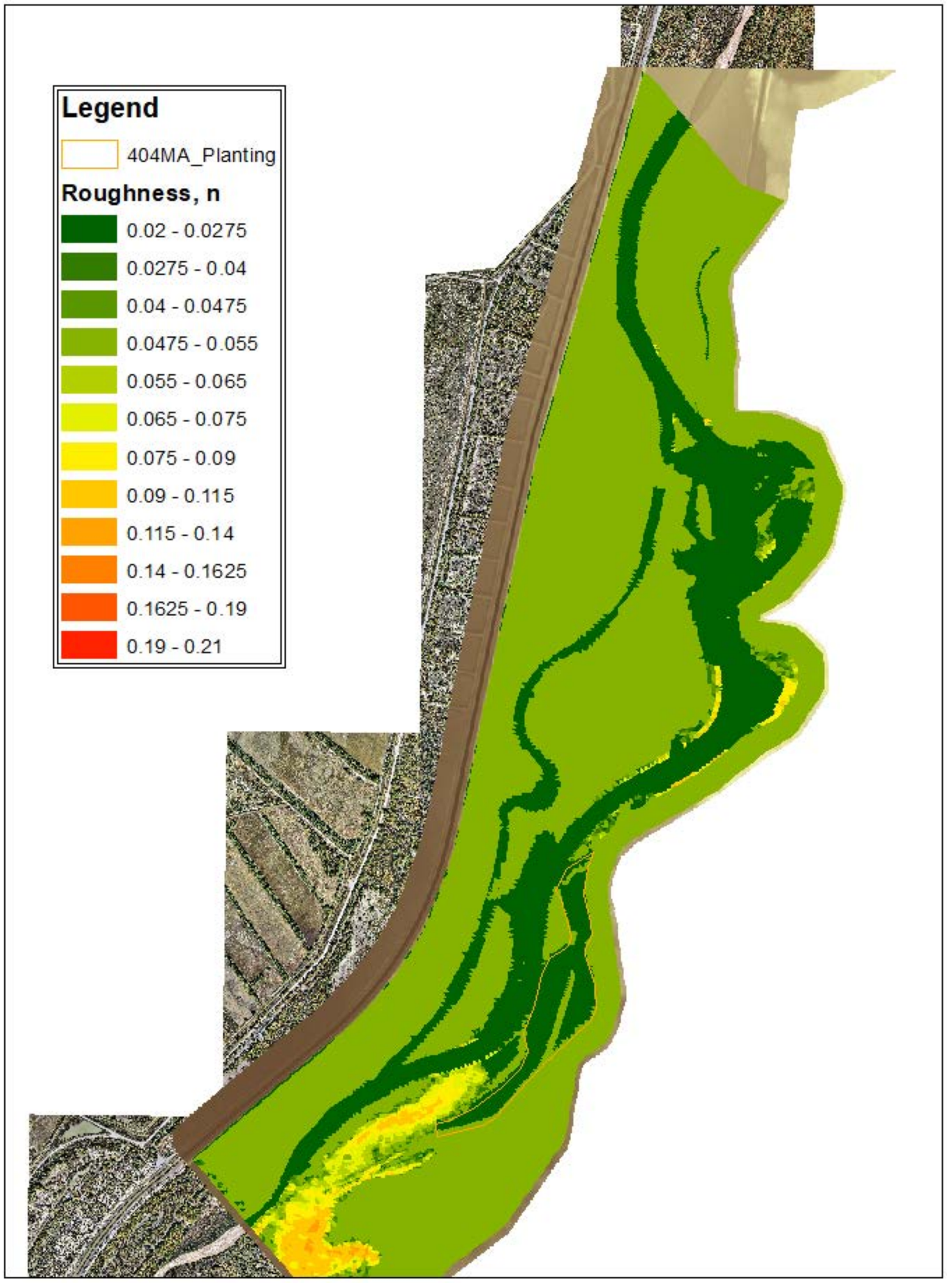

Figure 3—Calculated roughness at 500 cfs using the Baptist (2007) algorithm.

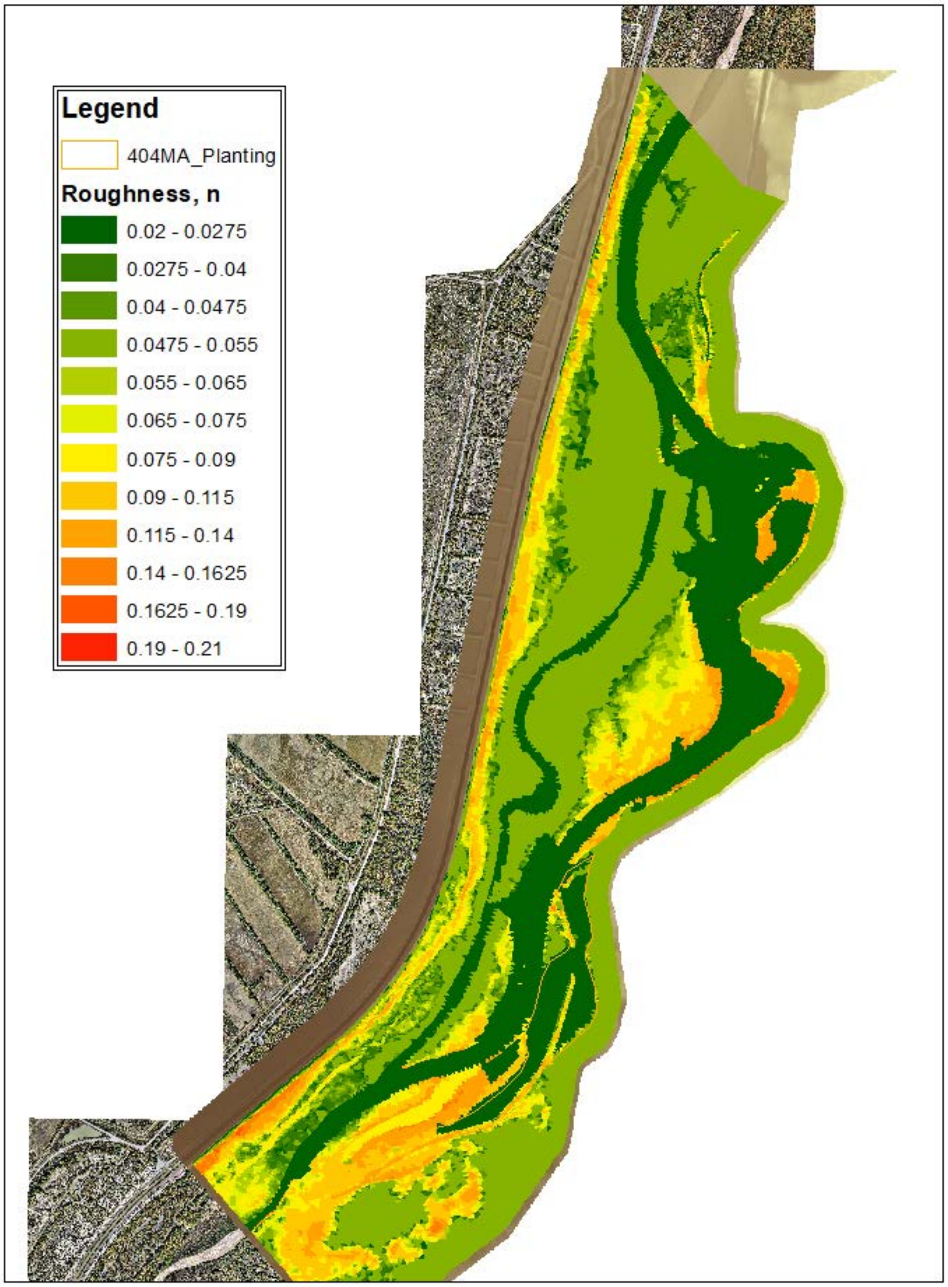

Figure 4—Calculated roughness at 2500 cfs using the Baptist (2007) algorithm.

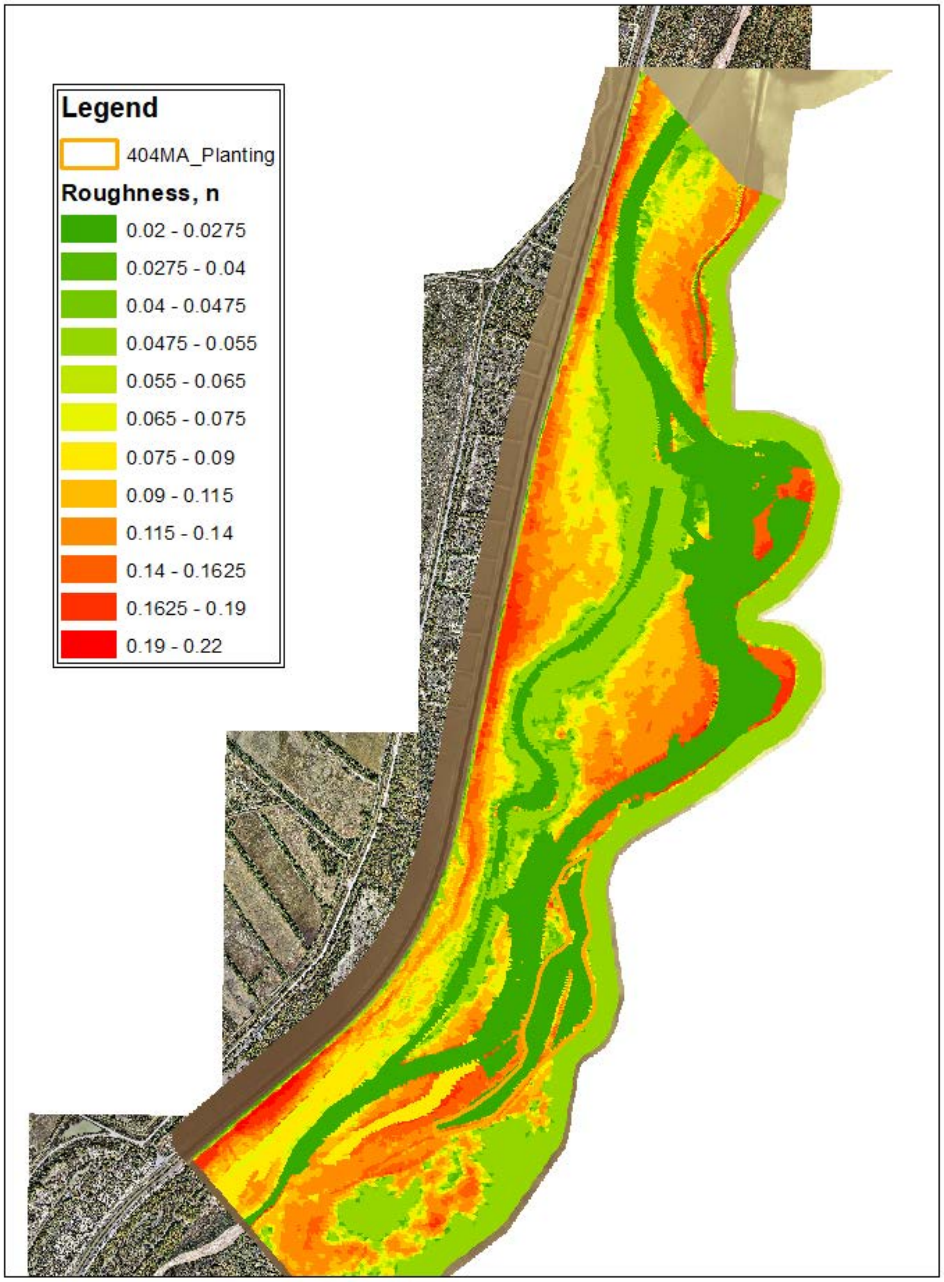

Figure 5—Calculated roughness at 4600 cfs using the Baptist (2007) algorithm.

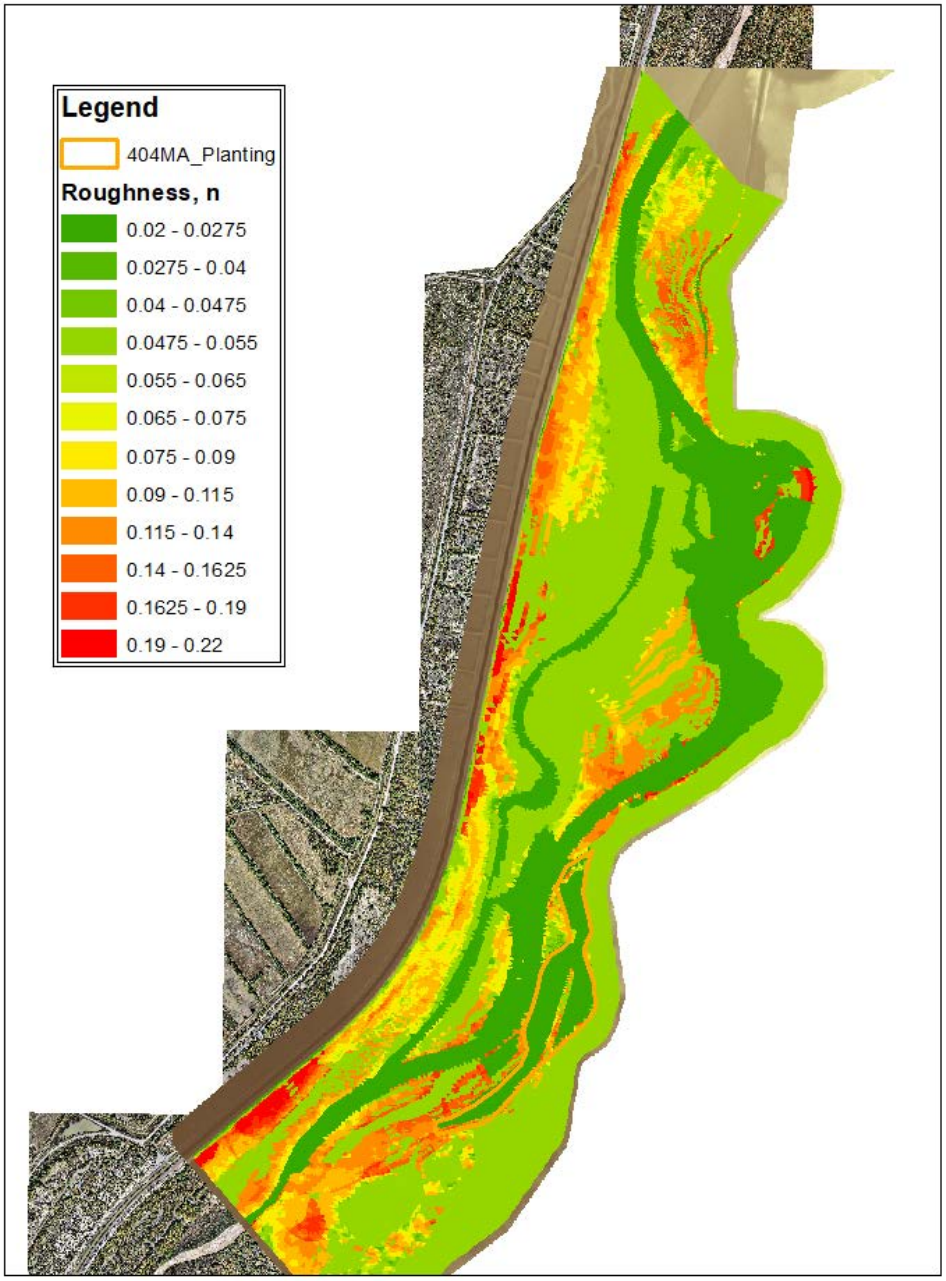

Figure 6—Calculated roughness at 4600 cfs using the Jarvela (2004) algorithm.

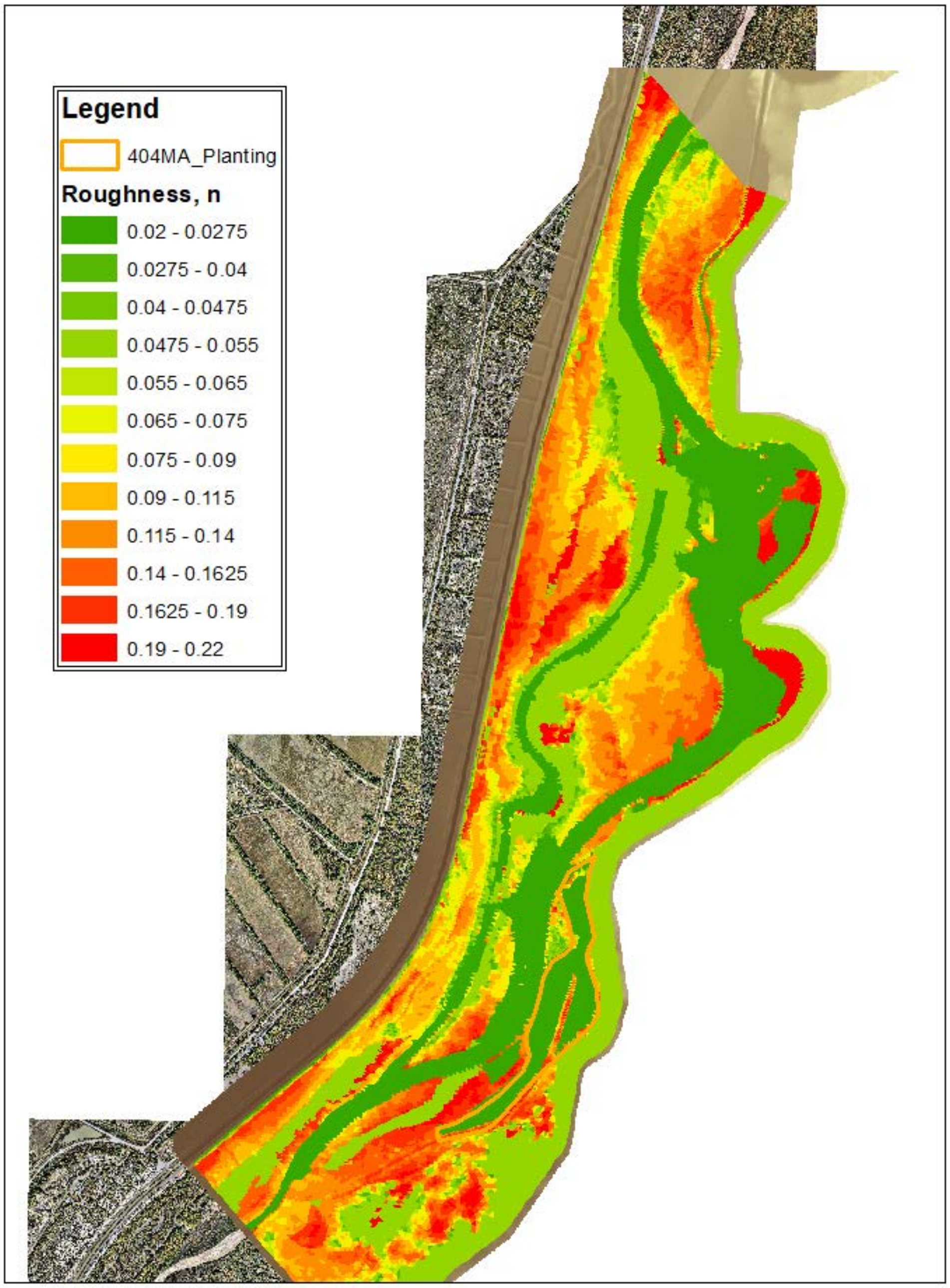

Figure 7—Calculated roughness at 4600 cfs using the Kouwen (2000) algorithm.

2.3 Boundary Conditions

The downstream boundary condition for the model was specified as a rating curve (water surface elevation as a function of discharge). Figure 8 presents the rating curve, which was developed from one-dimensional (1D) numerical modeling by extracting results at a cross section located in the same position as the 2D model boundary (Holste 2021). The 1D model extended several

miles upstream and downstream to eliminate sensitivity to the boundary condition. Figure 9 shows the upstream boundary condition, which was specified as a hydrograph (discharge as a function of time). The model was run for three different hydrographs to test the effect of varying water year types on the hydraulics and vegetation dynamics. The hydrographs were based on data representing "wet" (calendar year 2008), "dry" (calendar year 2011), and "average" (ave) conditions (calendar year 2015). The term "average" does not refer to a numerical average, but simply indicates that 2015 was a relatively typical hydrologic year for the period when gage records near the project are available (September 30, 2005, to present). Each simulation was run for a full calendar year, with the first day corresponding to January 1st (Figure 10). Mean daily flow at the project area was determined using the methodology described by Holste (2019) to subtract 50 cfs from the upstream Highway 380 Gage (USGS 08355490) to account for losses over the 7 miles between the gage and the project.

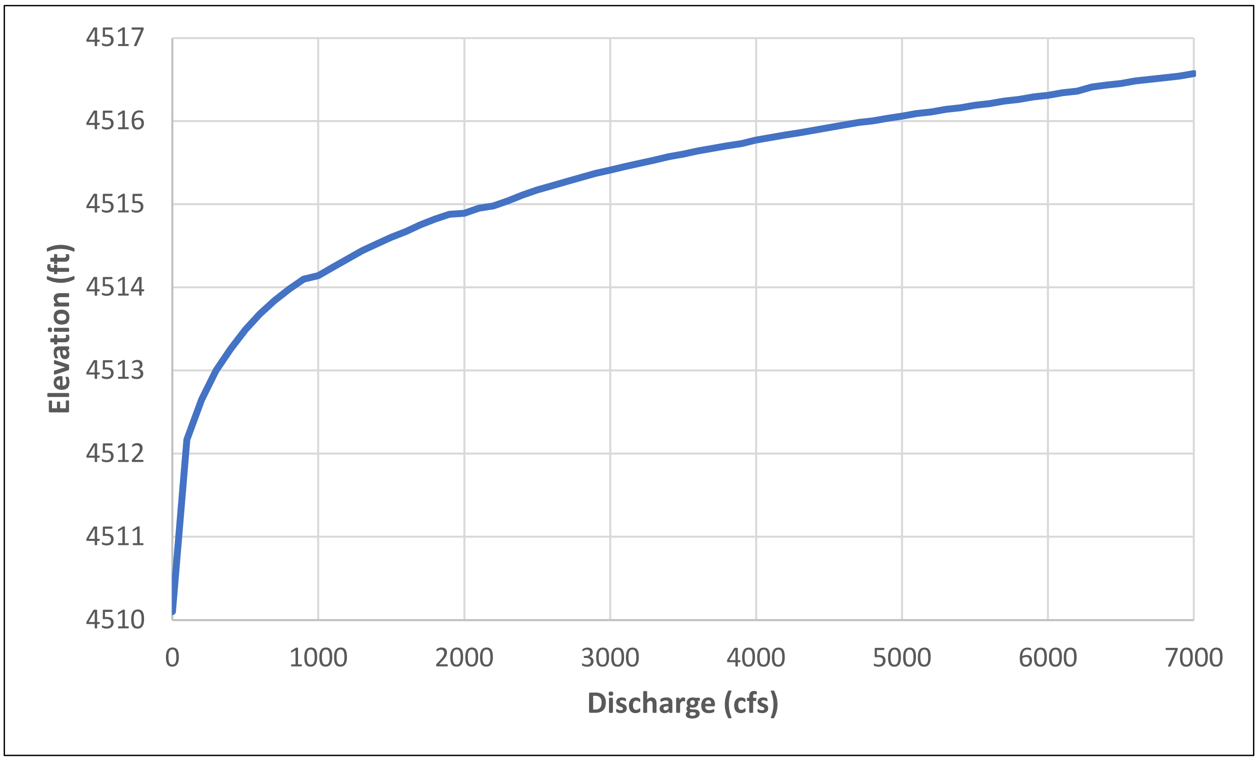

Figure 8—Water surface elevation rating curve applied at downstream boundary of SRH-2D model

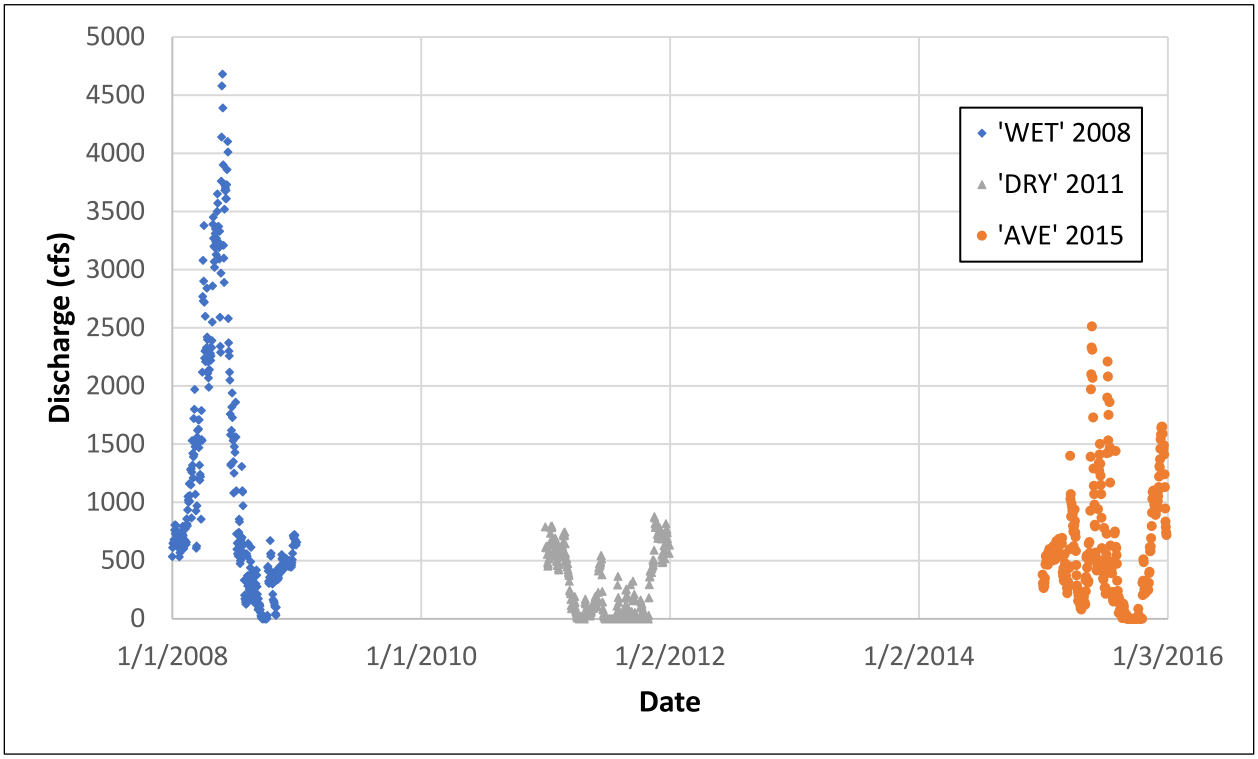

Figure 9—Hydrographs and representative water year types used in the simulations.

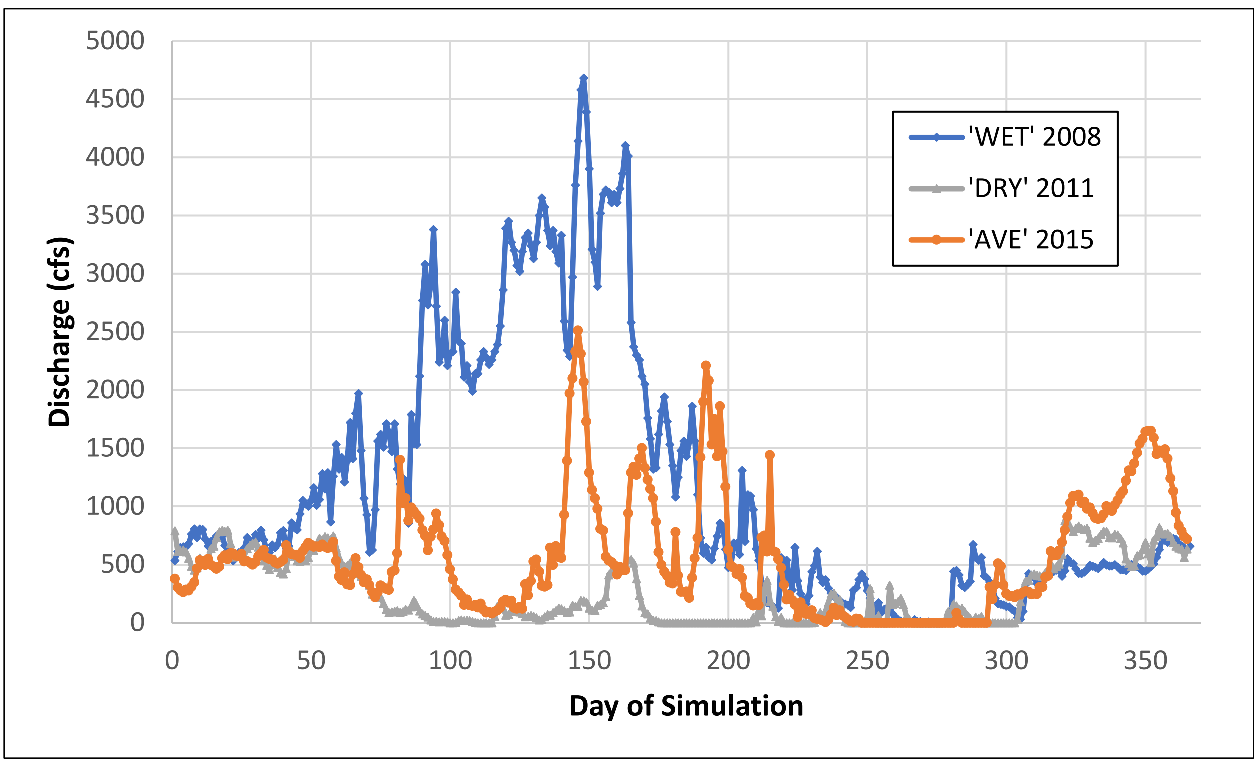

Figure 10—Hydrographs and water year type plotted as a function of simulation day number.

2.4 Vegetation

Vegetation characteristics are an important model input including the spatial distribution, species type, age, and density. The selected species to model include Cottonwood, Coyote Willow, Tree Willow, and Salt Cedar. The database of germination, growth, and stressor sensitivity parameters to inform the model were taken from a compendium based on prior vegetation modeling work (Fotherby, 2013) and are attached in the appendix of this report. In the model, vegetation communities within any region are fractionally composed of individual species. To establish a as-built distribution of vegetation communities, we began with a polygon shapefile (Figure 11) that was developed in 2016 to map vegetation communities according to the Hink and Ohmart classification system (Siegle and Ahlers, 2017). We then modified the pre-project classification to account for realignment project construction, including vegetation clearing and planting (Figure 12). The following steps summarize modifications to the 2016 polygons:

- Clip by model boundary
- Remove unneeded fields in attribute table and combine like polygons
- Overlay 300-foot-wide channel corridor and delete vegetation within this area
- Include coyote willow planting zones
- Overlay planned vegetation removal areas beyond the channel and delete vegetation

The vegetation lifecycle model was run with two initial conditions for each simulated hydrograph: a vegetated initial condition (developed from steps above) and a completely non-vegetated initial condition. The purpose of the two initial conditions was to analyze sensitivity of germination to existing vegetation. A non-vegetated initial condition implies that existing vegetation at the beginning of a model run does not affect the potential for new germination. This provides insight about where new vegetation would be likely to grow if the landscape were completely barren. The vegetated initial condition, accounting for project implementation as described above, analyzes if new vegetation would be able to outcompete existing vegetation. In both cases, seed distribution was assumed to cover the full model domain; the actual germination is governed by species-specific parameters that control behavioral rules within the model's lifecycle algorithms. Germination is limited by the following factors:

- Germination temporal window
- Seed elevation relative to water surface
- Time ground has been dry
- Co-location of pre-existing species

Conceptually, the rule-based limitations on germination are designed to prevent the model from predicting establishment in space or time that is biologically or physically unrealistic.

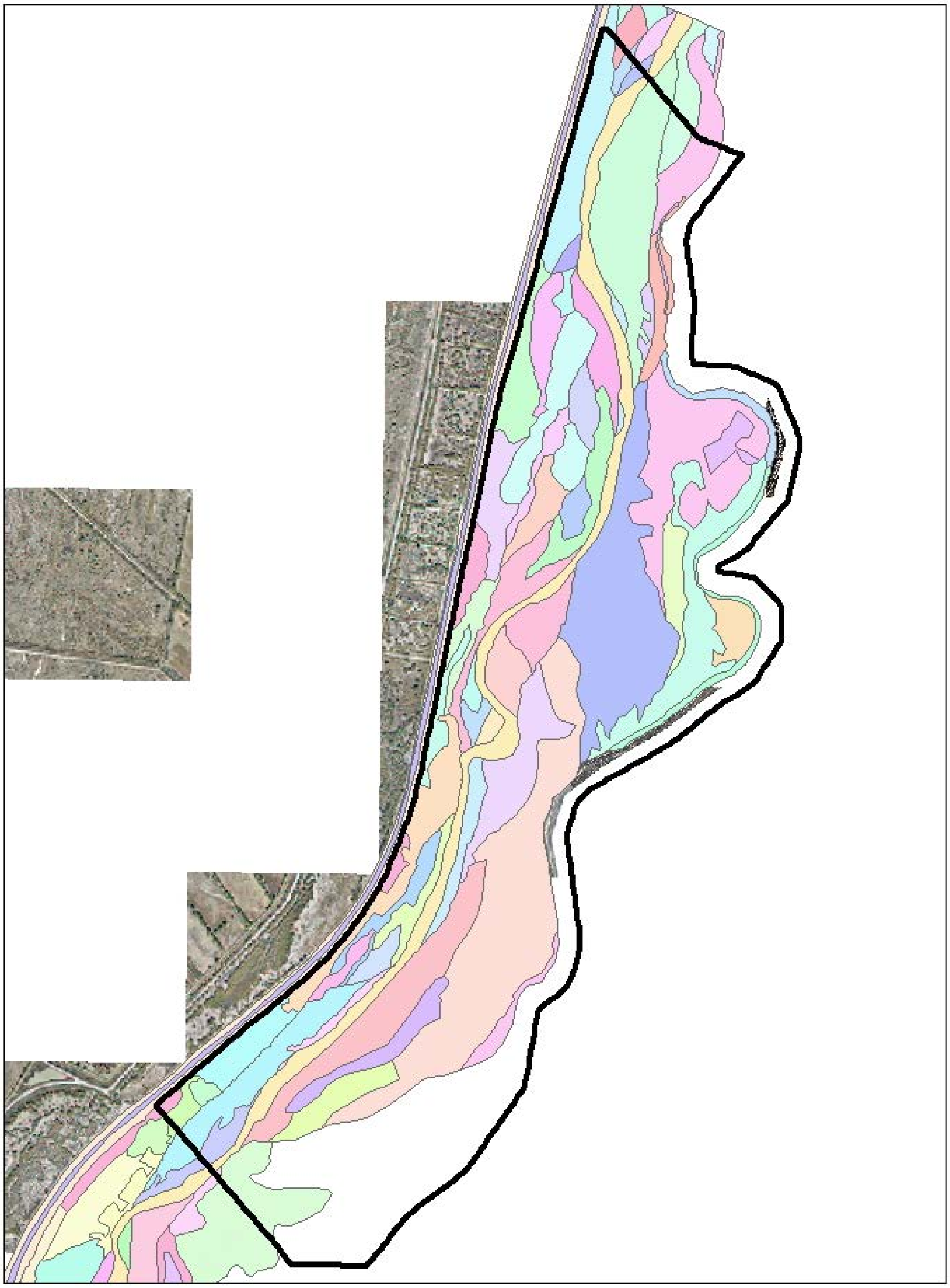

Figure 11— Pre-project polygon shapefile that was developed in 2016 to map existing vegetation communities according to the Hink and Ohmart classification system (Siegle and Ahlers, 2017). Over 60 different vegetation communities (colored polygons) were identified within the confines of the model domain (thick black line), although the species composition was dominated by Cottonwood, Coyote Willow, Salt Cedar, and Russian Olive.

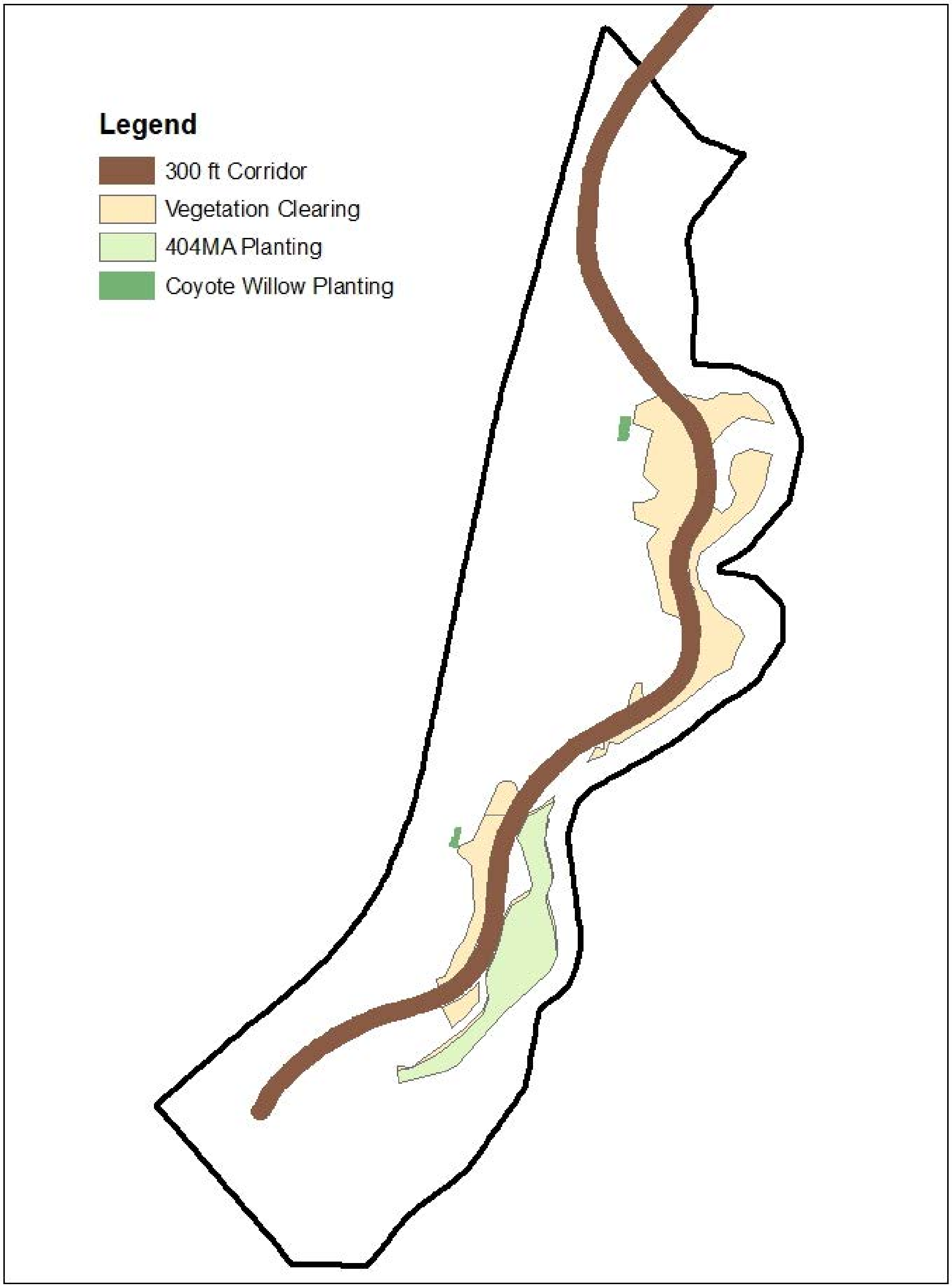

Figure 12—Delineation of project design elements that were used to modify the pre-project vegetation distribution in Figure 11. Shown are areas where existing vegetation was removed for the new channel and floodplain as well as planned replanting areas.

3 Results and Discussion

The non-vegetated initial condition is analyzed first to compare the tendencies of seed germination for different species and different hydrographs. Table 3 and Figure 13 show the total area in acres (ac) of newly established vegetation within the modeled reach and include the annual water volume in acre-feet (ac-ft) for reference. The vegetated area is calculated by summing the individual areas of all computational mesh cells in which the species is classified as alive at the end of the one-year simulation period. This result ignores the existing vegetation distribution and assumes a bare ground condition at the start of the simulation. Table 4 and Figure 14 present similar results for a vegetated initial condition in which the new seedlings must compete with existing vegetation. Results consider the distribution of vegetation at the beginning of the simulation and report how the total area changes for each species and hydrograph type.

Table 3—Total area of species establishment within model domain for each hydrograph using *non-vegetated* initial condition

Water Year Type	Water Volume (ac-ft)	Cottonwood (ac)	Coyote Willow (ac)	Tree Willow (ac)	Salt Cedar (ac)
Dry	193,450	595	650	542	434
Ave	403,900	880	1026	897	770
Wet	845,190	729	1134	514	893

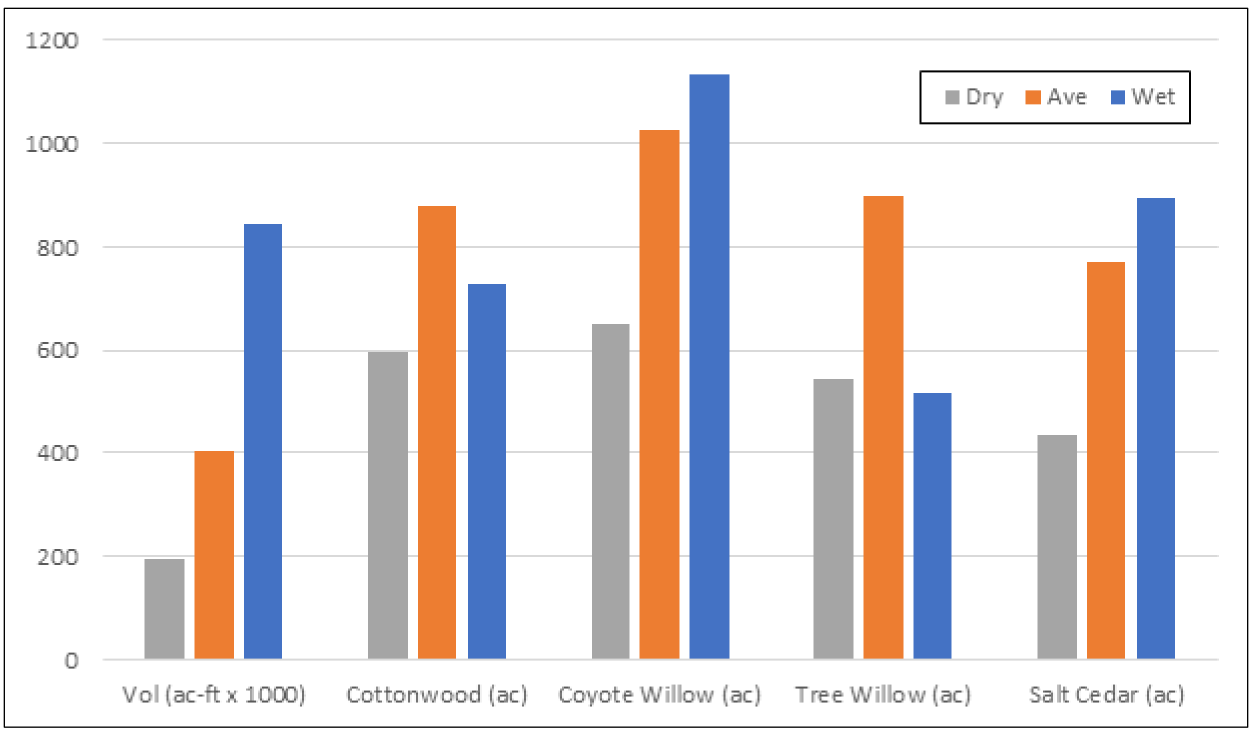

Figure 13—Total area of species establishment within model domain for each hydrograph using *non-vegetated* initial condition (data from Table 3).

Table 4—Total area of species establishment within model domain for each hydrograph using *vegetated* initial condition

Water Year Type	Water Volume (ac-ft)	Cottonwood (ac)	Coyote Willow (ac)	Tree Willow (ac)	Salt Cedar (ac)
Initial	-	979	384	379	750
Dry	193,450	1147	665	552	803
Ave	403,900	1123	756	561	815
Wet	845,190	1076	824	448	782

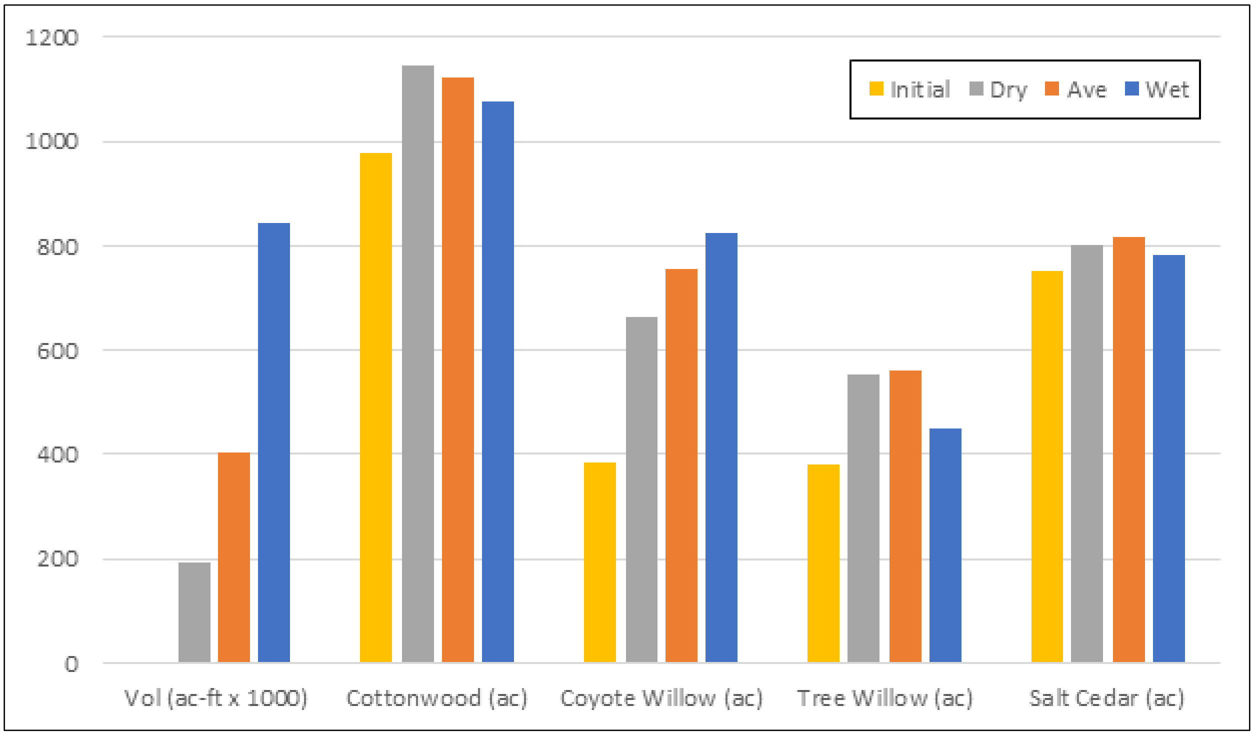

Figure 14—Total area of species establishment within model domain for each hydrograph using *vegetated* initial condition (data from Table 4).

Results for the non-vegetated initial condition (Table 3 and Figure 13) demonstrate that successful establishment of vegetation does not necessarily correspond simply to the volume of water flowing through the system. Each of the water year types represented a two-fold increase in water volume (i.e., ‘Ave’ is approximately twice the volume of ‘Dry’; ‘Wet’ is approximately twice the volume of ‘Ave’); however, the vegetation establishment area did not directly correlate. For example, Tree Willow establishment area was lowest for the ‘Wet’ hydrograph simulation. Coyote Willow and Salt Cedar showed the greatest extent of establishment for the ‘Wet’ hydrograph simulation, but not in direct proportion to the increasing volume of water. The establishment of vegetation is a function of how the water is distributed in relation to the germination window.

Results for the vegetated initial condition (Table 4 and Figure 14) demonstrate that existing vegetation distributions may have a significant effect on the establishment of seedlings. Alternatively, the results demonstrate that an existing vegetation distribution mitigates the effect of varying water year type on changes to the overall population. The simulations initiated with an existing vegetation distribution (Figure 14) show that final established area at completion of simulation is less dependent on water year type than simulations initiated with non-vegetated conditions (Figure 13). Established vegetation shows greater resistance to drowning, desiccation, and scour than seedlings; therefore, the inclusion of an initial distribution modulates the effect of varying water year types.

Figure 15 through Figure 17 compare total area of each species that have succumbed to mortality mechanisms of drowning, desiccation, and scour, respectively, for simulations initiated with a bare (non-vegetated) versus vegetated initial condition. Results are presented for each of the three water year types assumed for the simulations. Very little Coyote Willow and Gooddings Willow were susceptible to drowning for any of the water year type conditions (Figure 15). The parameters specify up to a year or more of inundation timescale before adult trees will die due to inundation. Conversely, Cottonwood and Salt Cedar were both shown to be susceptible, but with opposite trends; more Cottonwood drowning was observed for the non-vegetated initial condition while more Salt Cedar drowning was observed for the vegetated initial condition. Area of mortality caused by drowning was almost negligible for the ‘Wet’ hydrograph simulation, suggesting that germination has occurred during a period of sufficiently high flow and elevation so that it doesn’t subsequently become drowned out. Perhaps surprising is the relatively large area of mortality by inundation during the ‘Dry’ water year type hydrograph. Like removal by scour, establishment can fail when germination occurs too close in elevation to a main flow channel, such as may occur in low-flow seasons.

For mortality caused by desiccation (Figure 16), the results indicate significantly greater susceptibility on an aerial basis when initiated with the non-vegetated condition, across all species types investigated. However, comparing across species, Salt Cedar is predicted to be more susceptible to desiccation, regardless of initial condition, relative to other types (Fotherby, 2013). Perhaps intuitively, the ‘Dry’ water year type hydrograph resulted in simulations predicting a relatively large area of desiccation. The ‘Dry’ water year type hydrograph limits all vegetation survival due to the periods of no flow conditions.

Figure 17 shows that removal of vegetation by scour is predicted to occur over a similar area extent for both the vegetated and non-vegetated conditions across all species types. For all but Salt Cedar, removal by scour is likely more prevalent for the ‘Dry’ and ‘Ave’ water year types because more germination takes place in lower elevation terrain regions closer to the channel that are more likely subject to subsequent high velocity flows. It should be noted that the scour mechanism in the model is based purely on a velocity threshold and will be subject to further examination and refinement in a paired study funded by the Reclamation Research Office Science & Technology Program.

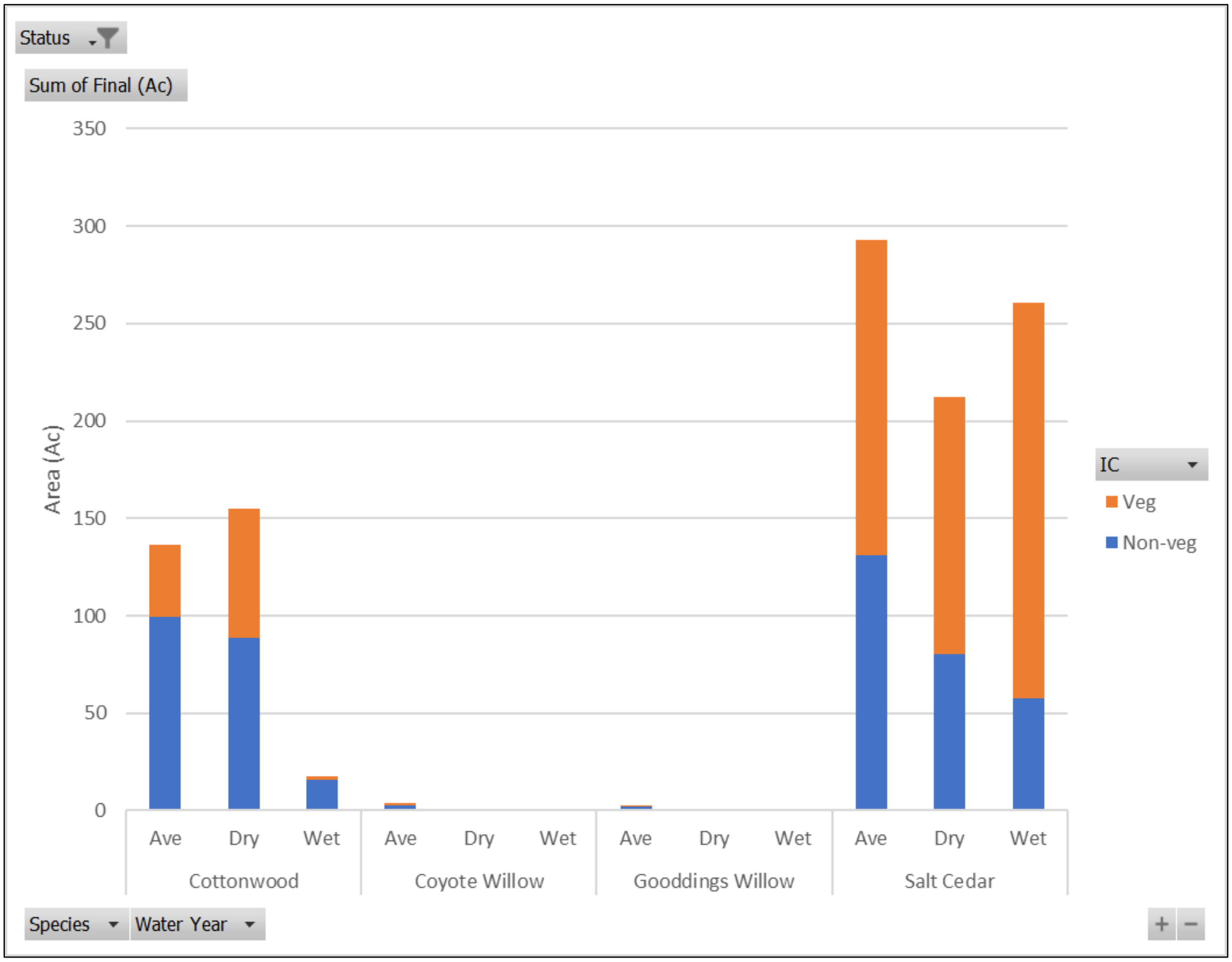

Figure 15—Total area of each species that have succumbed to mortality mechanisms of drowning for simulations initiated with a bare (non-vegetated) versus vegetated initial condition. The bars are stacked to show comparative size.

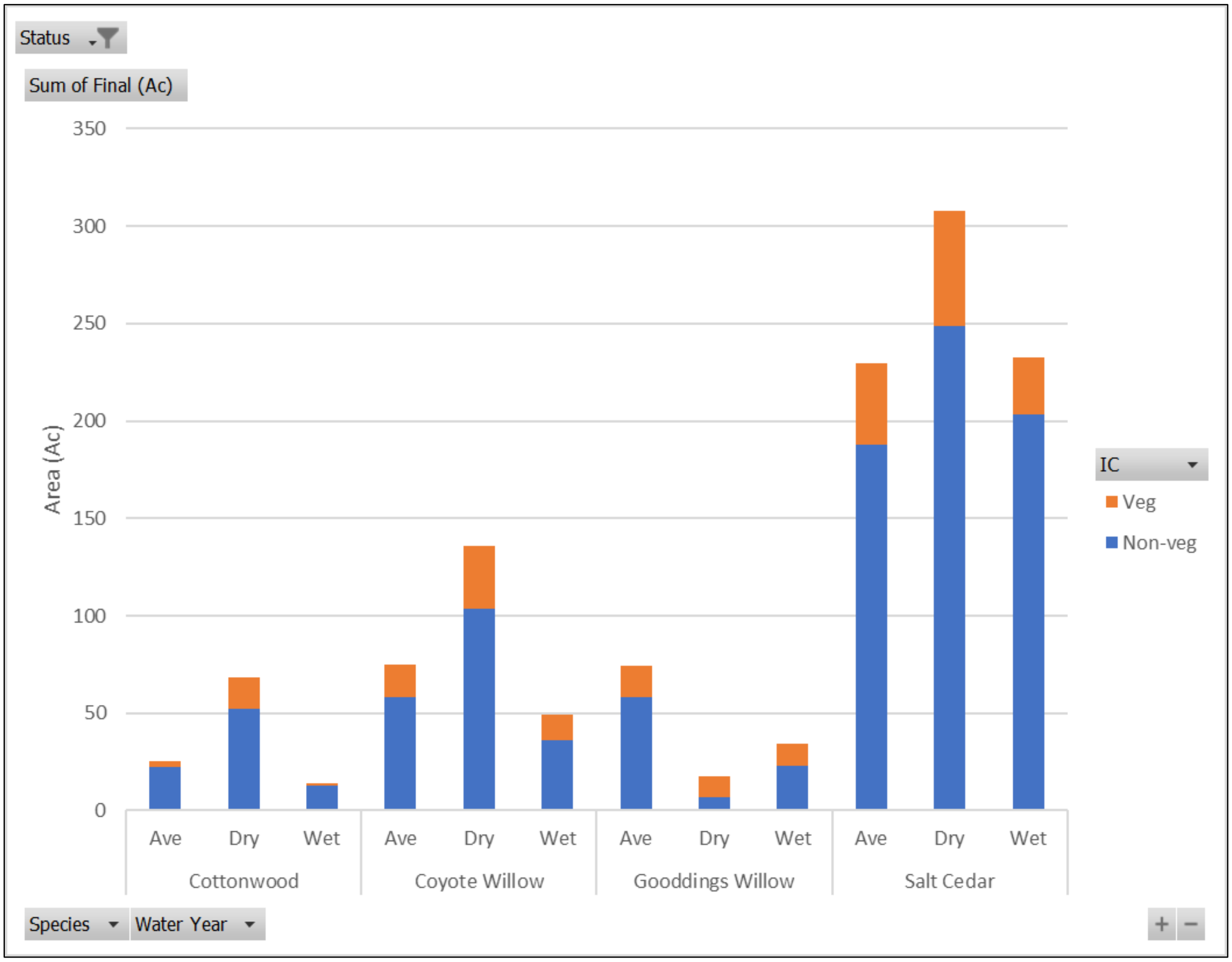

Figure 16—Total area of each species that have succumbed to mortality mechanisms of desiccation for simulations initiated with a bare (non-vegetated) versus vegetated initial condition.

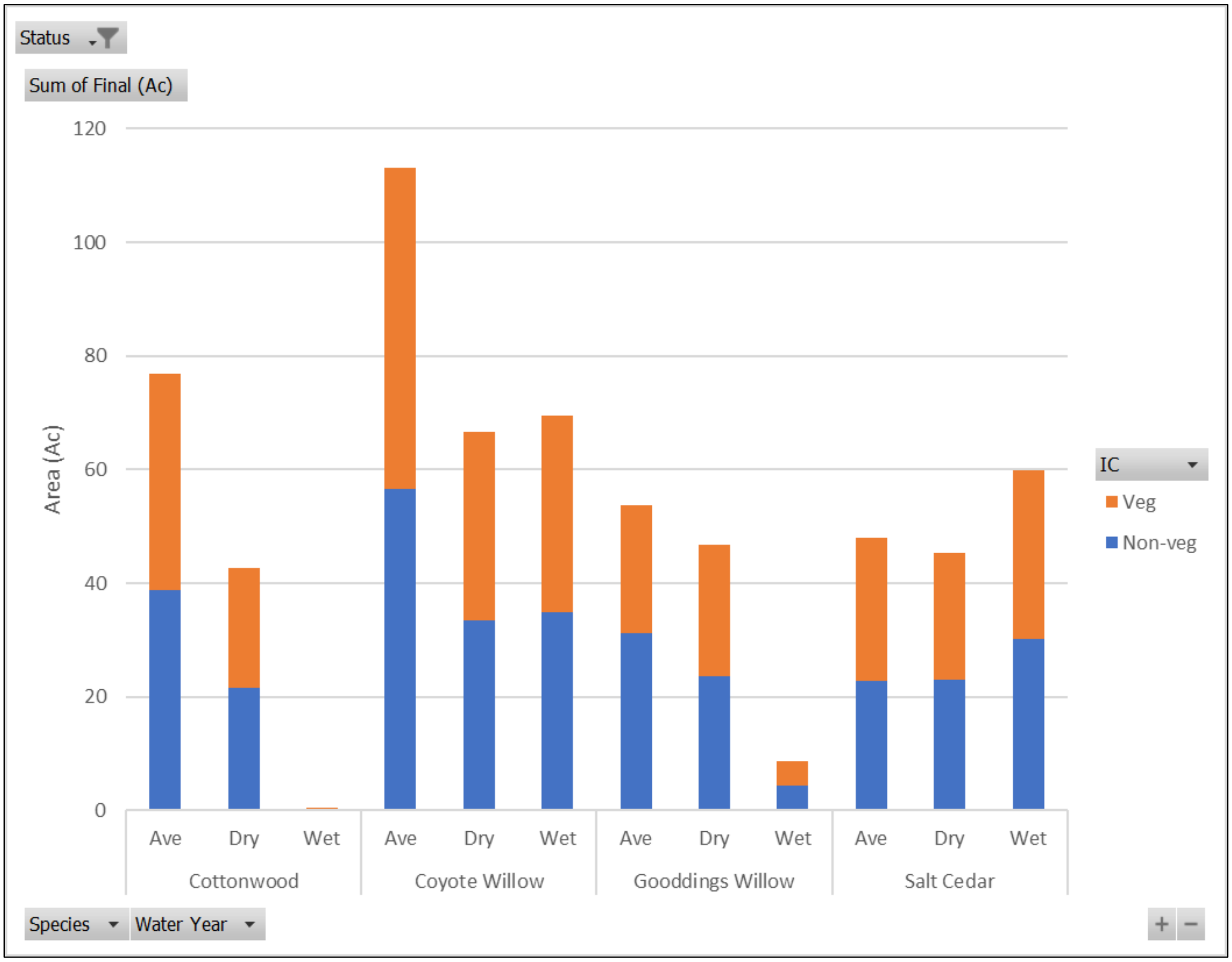

Figure 17—Total area of each species that have succumbed to mortality mechanisms of scour for simulations initiated with a bare (non-vegetated) versus vegetated initial condition.

Another difference in the results between the simulations using a non-vegetated versus vegetated initial condition is the age distribution of the communities. Figure 18 and Figure 19 illustrate dynamic differences for cottonwood between simulations initiated with the non-vegetated and vegetated conditions, respectively. In each figure, the top panel shows a time series of the total area alive with the area of vegetation killed from each mortality mode (scoured, drowned, desiccated, competed). The middle panel shows the wet hydrograph, and the bottom panel shows species age (min, mean, and max). In the non-vegetated initial condition case (Figure 18), total area alive begins at zero and does not increase until the temporal beginning of the germination window. In the vegetated initial condition case (Figure 19), total area alive begins at about 1000 acres and increases through the germination period. In the non-vegetated initial condition case, mortality by drowning is much more significant because of the location of seed germination along water's edge and the susceptibility of seedlings to inundation. The age distribution is entirely comprised of newly-germinated plants in the non-vegetated initial condition case, whereas the age distribution is dominated by established plants in the vegetated initial condition case.

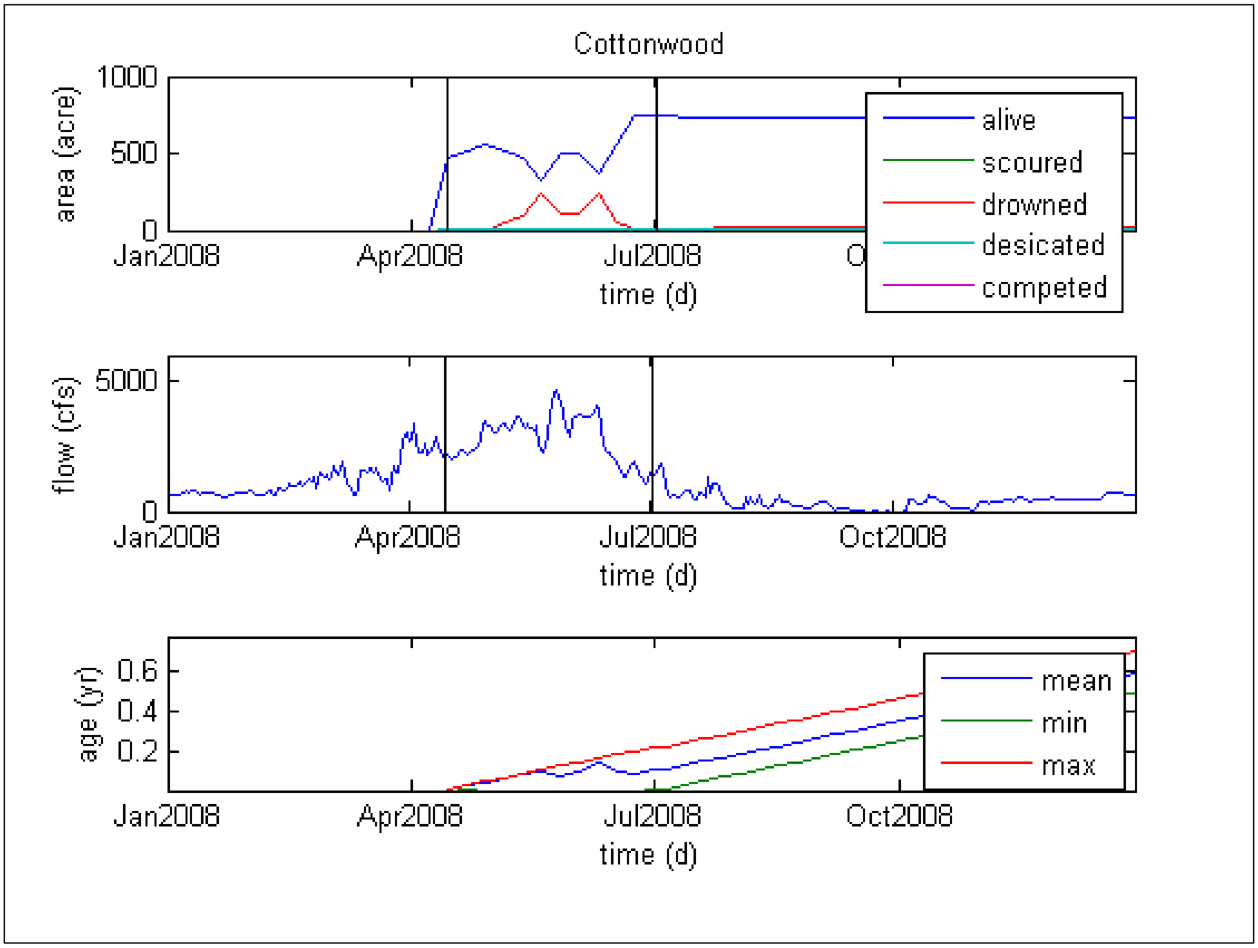

Figure 18—Cottonwood results for *non-vegetated* initial condition and wet hydrograph scenario. Top panel shows time series of total area for established seedlings (alive) and dead seedlings (scoured, drowned, desiccated, competed). Middle panel shows wet hydrograph (2008), and bottom panel shows species age for newly established vegetation (mean, min, max). Vertical lines represent start and end of germination period.

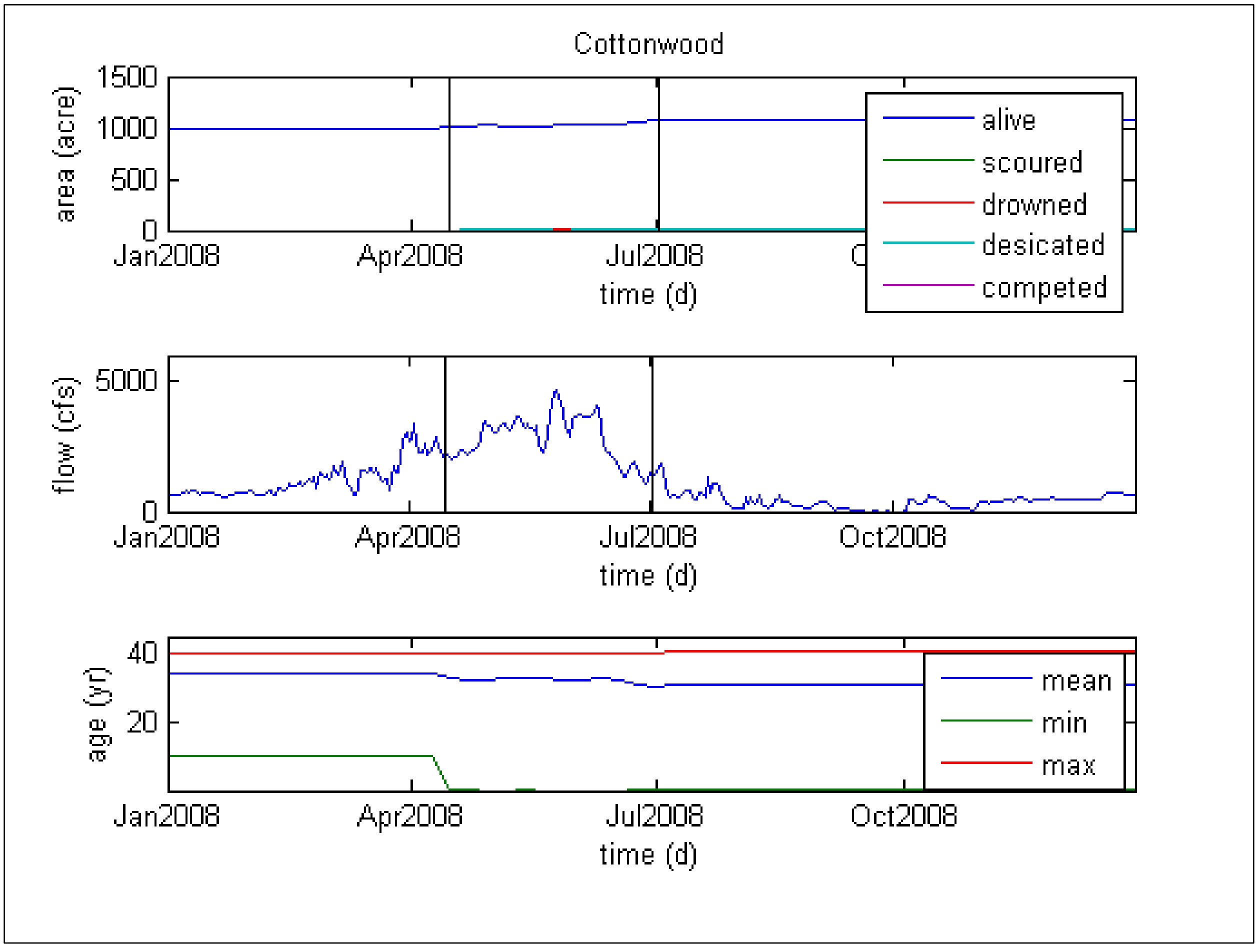

Figure 19—Cottonwood results for *vegetated* initial condition and wet hydrograph scenario. Top panel shows time series of total area for established vegetation (alive) and dead vegetation (scoured, drowned, desiccated, competed). Middle panel shows wet hydrograph (2008), and bottom panel shows species age for established vegetation (mean, min, max). Vertical lines represent start and end of germination period.

Figure 20 and Figure 21 illustrate dynamic differences for Salt Cedar between the non-vegetated and vegetated initial condition simulations, respectively. In each figure, the top panel shows a time series of the total area alive with the area of vegetation killed from each mortality mode (scoured, drowned, desiccated, competed). The middle panel shows the wet hydrograph, and the bottom panel shows species age (min, mean, and max). The figures demonstrate the role mortality mechanisms may play when there are different age distributions of plants. Figure 20 shows that desiccation can be a significant mortality mechanism in the receding limb of a hydrograph, even during a wet water year. Conversely, Figure 21 shows that for an established community of vegetation, susceptibility to drowning can be significant for the same high flow event. Drowning may be especially relevant to channel realignment projects where riparian populations may experience very different hydraulic conditions than pre-project conditions.

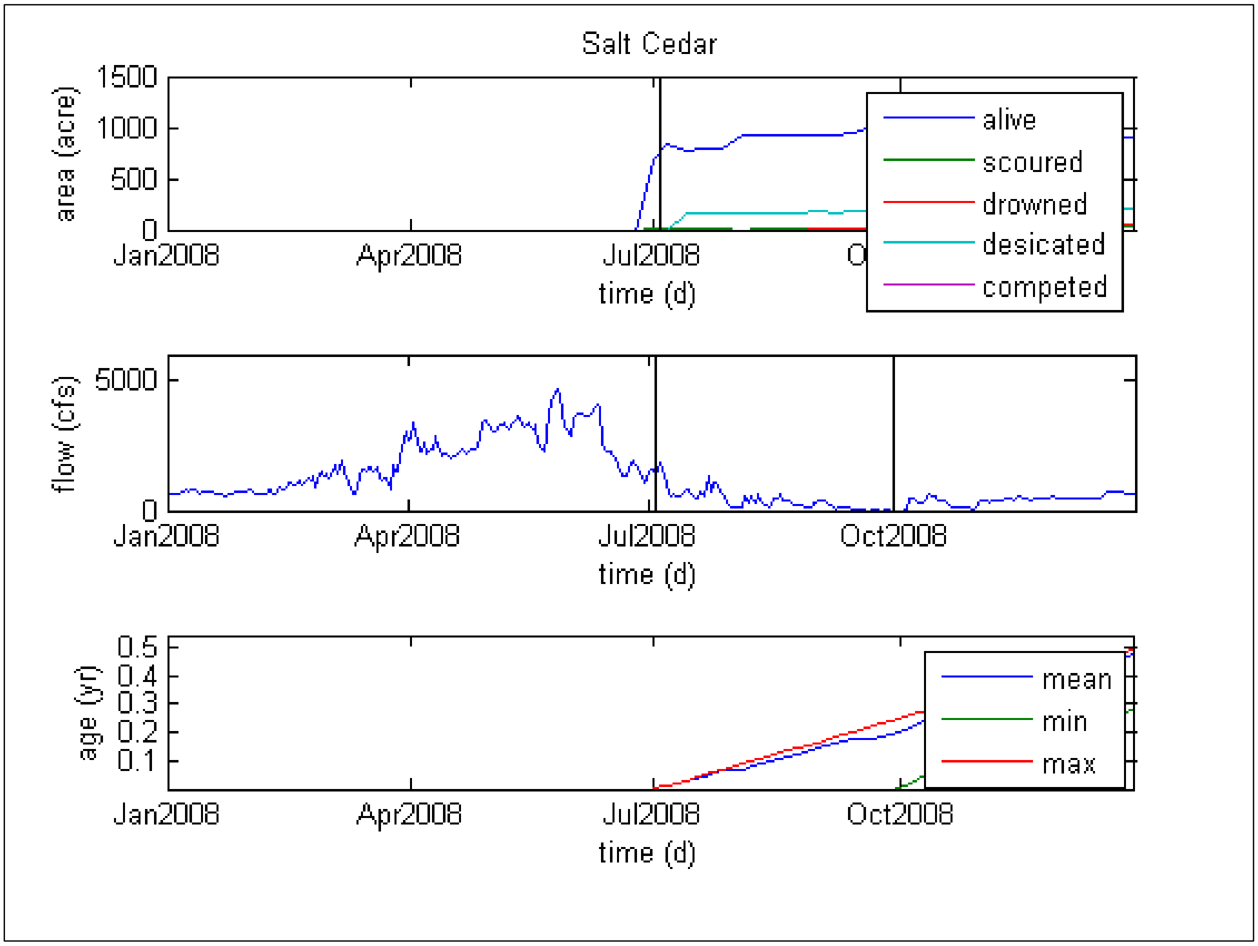

Figure 20—Salt Cedar results for *non-vegetated* initial condition and wet hydrograph scenario. Top panel shows time series of total area for established seedlings (alive) and dead seedlings (scoured, drowned, desiccated, competed). Middle panel shows wet hydrograph (2008), and bottom panel shows species age for newly established vegetation (mean, min, max). Vertical lines represent start and end of germination period.

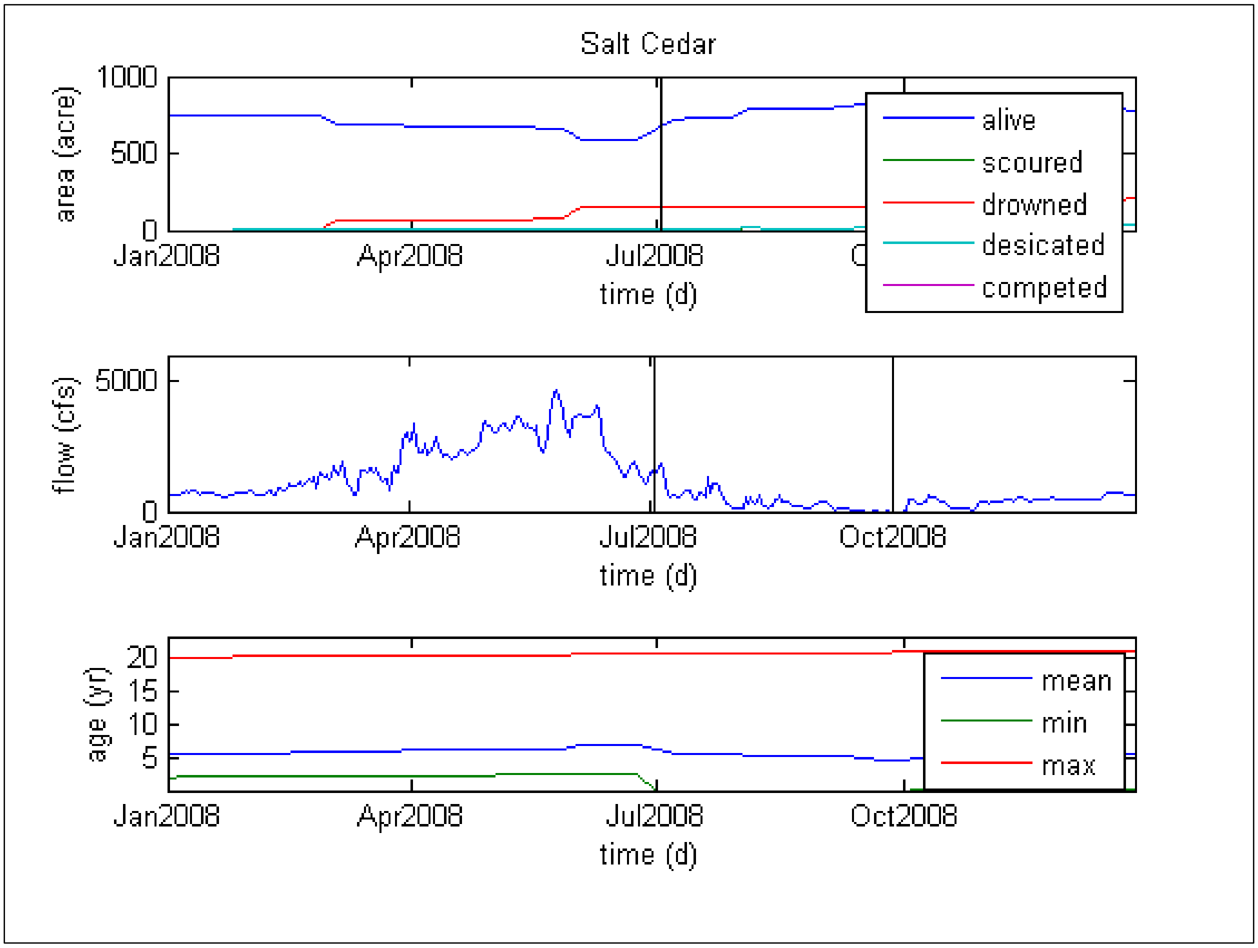

Figure 21—Salt Cedar results for *vegetated* initial condition and wet hydrograph scenario. Top panel shows time series of total area for established vegetation (alive) and dead vegetation (scoured, drowned, desiccated, competed). Middle panel shows wet hydrograph (2008), and bottom panel shows species age for established vegetation (mean, min, max). Vertical lines represent start and end of germination period.

Figure 22 through Figure 29 provide spatial distributions of predicted germination within the modeled reach for the non-vegetated initial condition. Removal and mortality identifiers are included as well as the planned 404 Permit Mitigation Area (404MA) Planting. In all figures, the inundation map (right panel) represents the maximum flow for the hydrograph around the timing of the germination window, which controls the establishment extent. Although these figures are a more qualitative presentation of establishment than Table 3, the maps provide comprehensive spatial information about how the vegetation is predicted to distribute as a function of the varying hydrographs. Further differences in establishment between the species are due to differences in the species-specific germination window, sensitivity to wetting conditions, and parameterizations for processes causing mortality and removal.

Comparing Cottonwood establishment in Figure 22 for the ‘Wet’ water year type to Figure 23 for the ‘Dry’ water year type illustrates that the spatial distribution can be very different even if the total areal coverage is similar. The predicted distribution of Cottonwood was highly sensitive

to the water year type, however the total area coverage of species survival at simulation completion was similar. Cottonwood has the earliest seasonal germination window out of the species simulated, which closely coincided with the peak of the hydrograph for the ‘wet’ water year type simulation. This resulted in germination predominantly located in the higher ground elevation areas for the ‘wet’ water year type simulation; the results of the ‘dry’ water year type simulations show a nearly opposite distribution through the modeled reach.

Coyote Willow was predicted to have a much larger total establishment area for the ‘Wet’ water year type than the ‘Dry’, and the comparison of Figure 24 to Figure 25 demonstrates the spatial difference. Coyote Willow has a resistance to drowning at young age that is approximately twice that of Cottonwood. Therefore, Coyote Willow seedlings show greater ability to survive inundation during the high flow portion of the seasonal hydrographs. Conversely, Coyote Willow has greater susceptibility to desiccation than cottonwood because Coyote Willow requires seedlings to maintain closer proximity to groundwater. For the wet hydrograph, there is approximately 50% more establishment of Coyote Willow than Cottonwood (non-vegetated initial condition). This is likely due to both the extended germination window of Coyote Willow and the resistance of Coyote Willow to mortality by inundation. Coyote Willow is likely to fair better in wet years while Cottonwood is likely to fair better in drier years.

Gooddings Black Willow (Figure 26 and Figure 27) exhibits a similar result as Cottonwood, in that the difference in hydrographs results in establishment in different regions of the modeled reach. Goodding’s Black Willow has similarly low resistance to desiccation as Coyote Willow and therefore suffers correspondingly from losses. Goodding’s Black Willow has a very short germination window which further reduces the potential success of the plant. As a result, relatively low numbers of established plants are observed in the simulations. The model predicts slightly greater establishment of Goodding’s Black Willow for the ‘dry’ hydrograph than the ‘wet’; likely, this is a result of germination occurring in locations that are subsequently desiccated after the fall of the peak of the ‘wet’ hydrograph. In comparison, the difference between peak and baseflow conditions is not as large for the ‘dry’ hydrograph. This is particularly true because the germination window is limited to a low flow portion of the ‘dry’ hydrograph. Goodding’s Black Willow has strong resistance to mortality by inundation, so seedlings can establish in areas with low base flow and survive flooding events. The predicted distribution of establishment is very different between the ‘dry’ and ‘wet’ hydrograph water years, where in the ‘dry’ case, establishment preferentially occurs in lower-lying elevation regions.

Figure 28 and Figure 29 demonstrate the sensitivity of the invasive Salt Cedar to the hydrographs, where the ‘Wet’ conditions resulted in nearly complete coverage over the model domain. Salt Cedar is the single invasive species simulated through the modeling exercise. The predicted distribution of salt cedar is extensive for the ‘wet’ water year hydrograph. A significant factor contributing to the predicted germination is a temporal window that that is aligned with the falling limb of the high-flow hydrograph, providing opportunity for germination over a range of ground elevations. Although desiccation also results, the proximity to ground water elevation is sufficient to maintain large survival rates over the simulation period.

The extent of predicted germination is very different for the ‘dry’ hydrograph, which greatly limits access to ground water. Desiccation is also high due to several short flow peaks occurring during the germination temporal window followed by immediate return to baseflow conditions. For the case of Salt Cedar, the coincidence of the germination window with the falling limb of the hydrograph resulted in a predicted explosion of the invasive species through the modeled reach. If the peak of the hydrograph hypothetically coincided with the germination window (i.e., a seasonally later high flow period), it is predicted that germination distribution of salt cedar would be more limited because much of the modeled reach would be inundated.

Overall, the results indicate that both the establishment and removal of vegetation via various mortality mechanisms is much more complicated than can by predicated simply by the volume of flow delivered by a seasonal hydrograph. The specifics of species-based parameterizations along with timing of germination relative to rising and declining limbs of seasonal hydrographs all need to be explored to understand predicted survival.

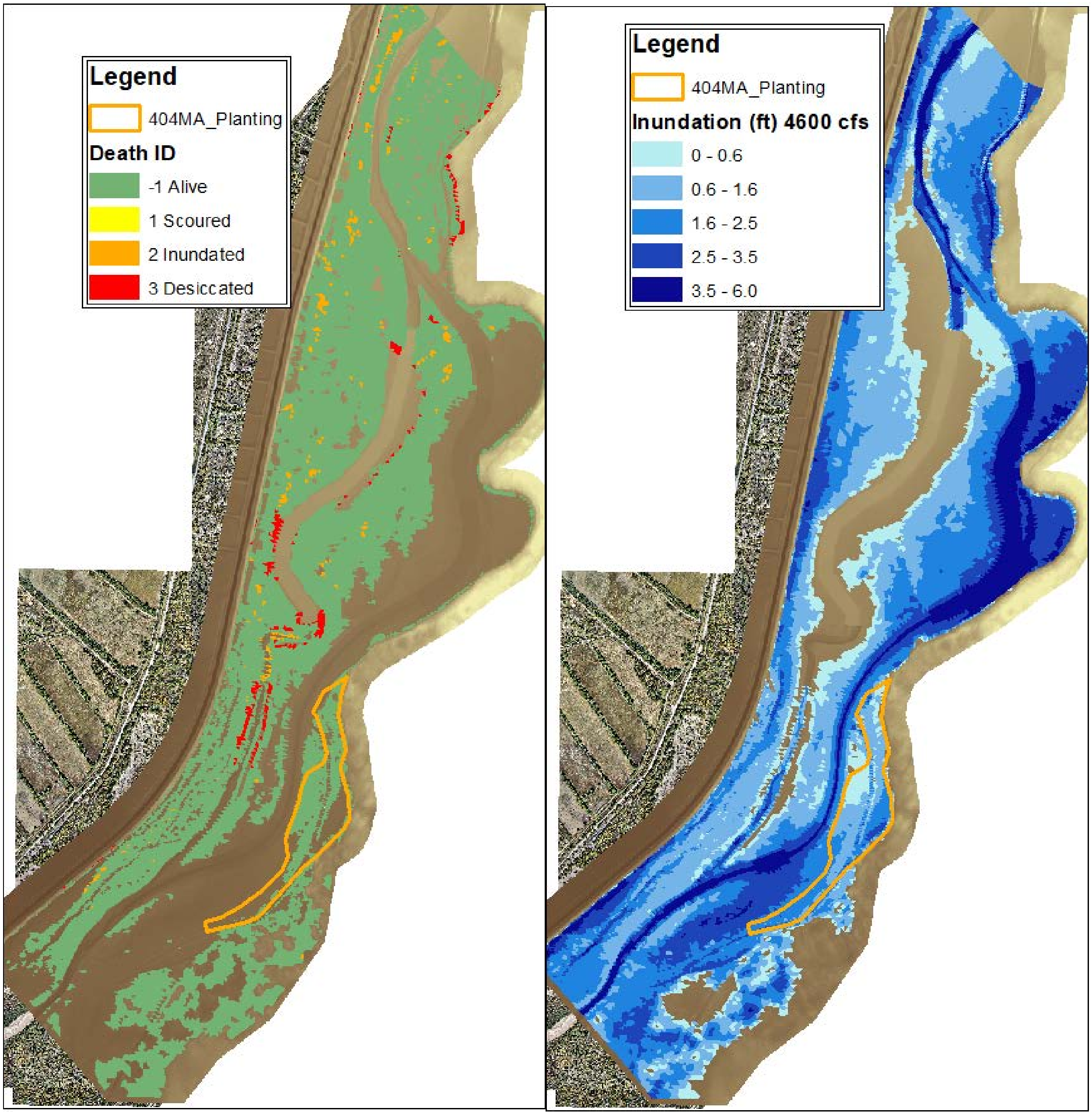

Figure 22—Cottonwood germination distribution and mortality identifiers (left panel) for *non-vegetated* initial condition and *wet* hydrograph scenario. Removal of vegetation by scour (yellow) was near zero. Right panel shows inundation at 4600 cfs, the peak mean daily discharge during 2008 spring runoff.

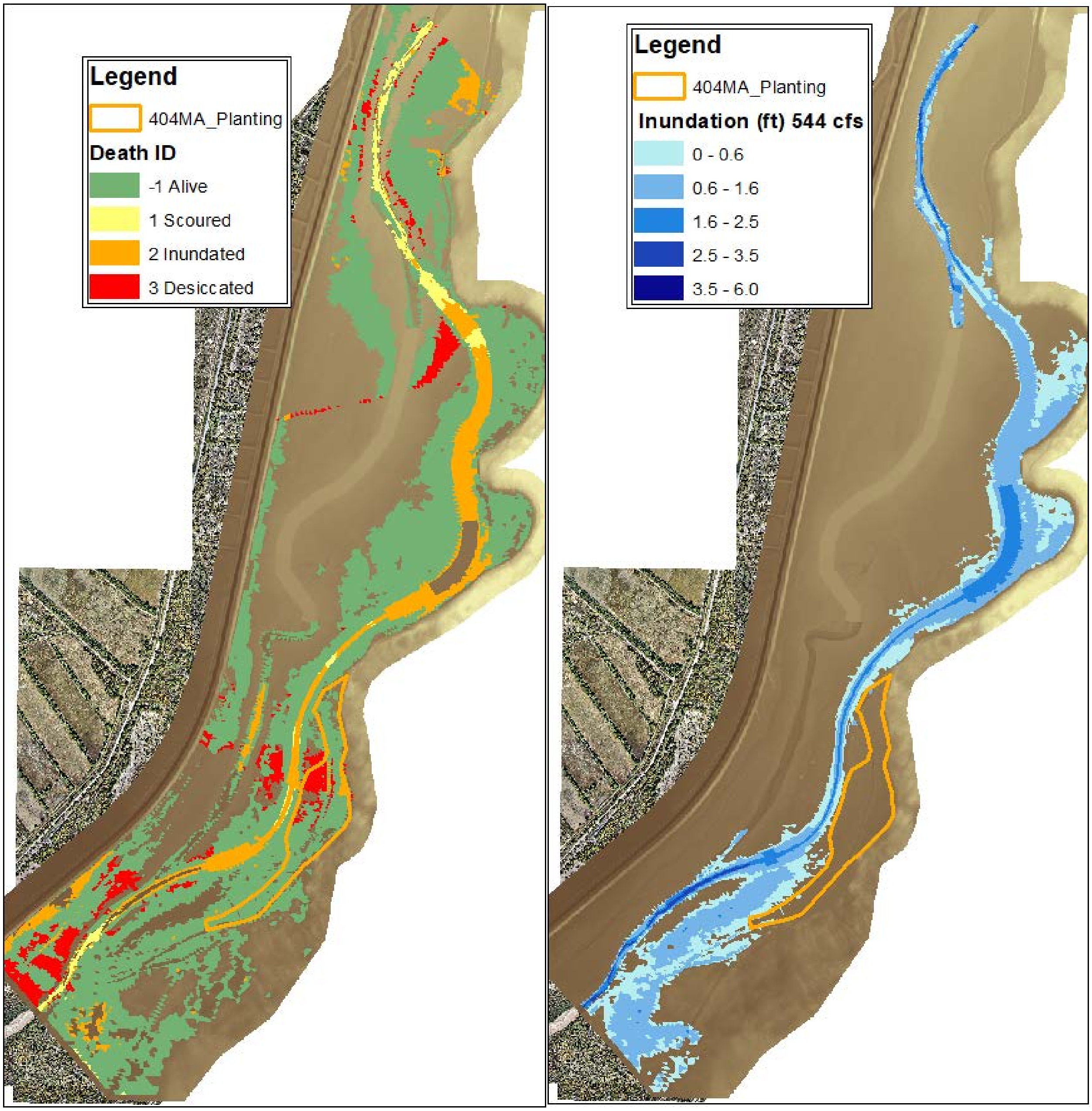

Figure 23—Cottonwood germination distribution and mortality identifiers (left panel) for *non-vegetated* initial condition and *dry* hydrograph scenario. Right panel shows inundation at 544 cfs, the peak mean daily discharge during 2011 spring runoff.

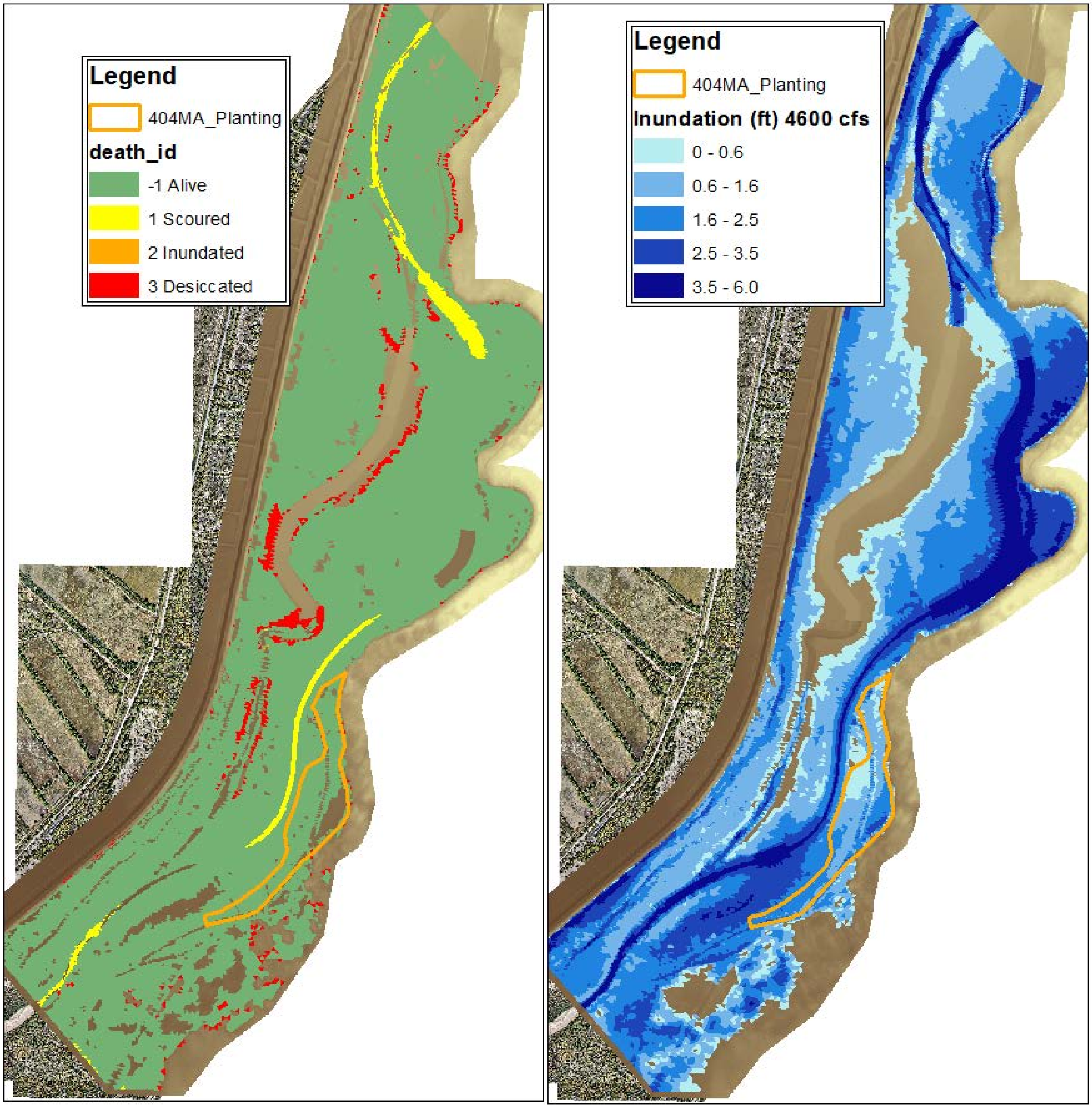

Figure 24—Coyote Willow germination distribution and mortality identifiers (left panel) for *non-vegetated* initial condition and *wet* hydrograph scenario. Mortality of vegetation by inundation (orange) was near zero. Right panel shows inundation at 4600 cfs, the peak mean daily discharge during 2008 spring runoff.

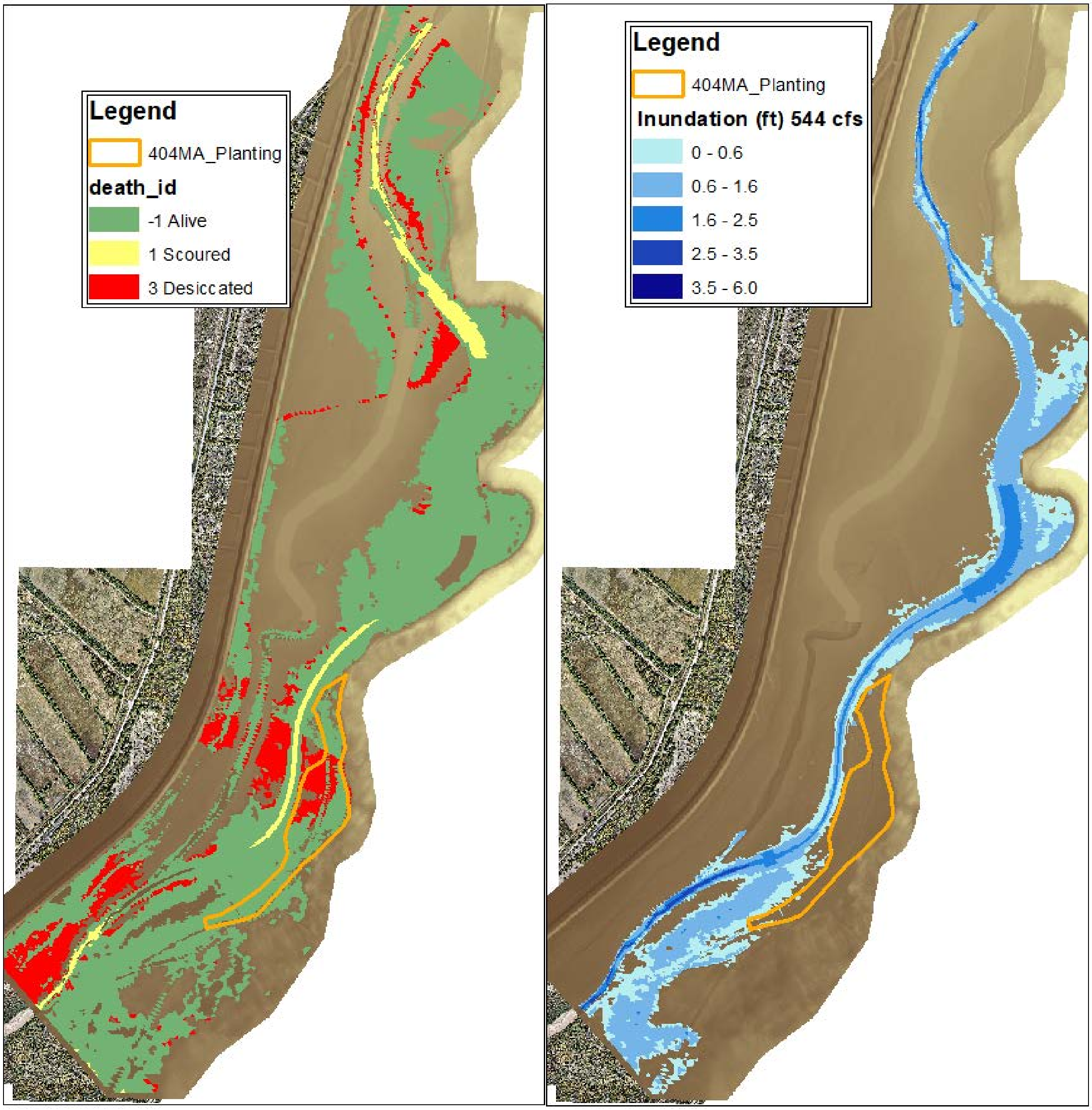

Figure 25—Coyote Willow germination distribution and mortality identifiers (left panel) for *non-vegetated* initial condition and *dry* hydrograph scenario. There was no inundation-related mortality of vegetation. Right panel shows inundation at 544 cfs, the peak mean daily discharge during 2011 spring runoff.

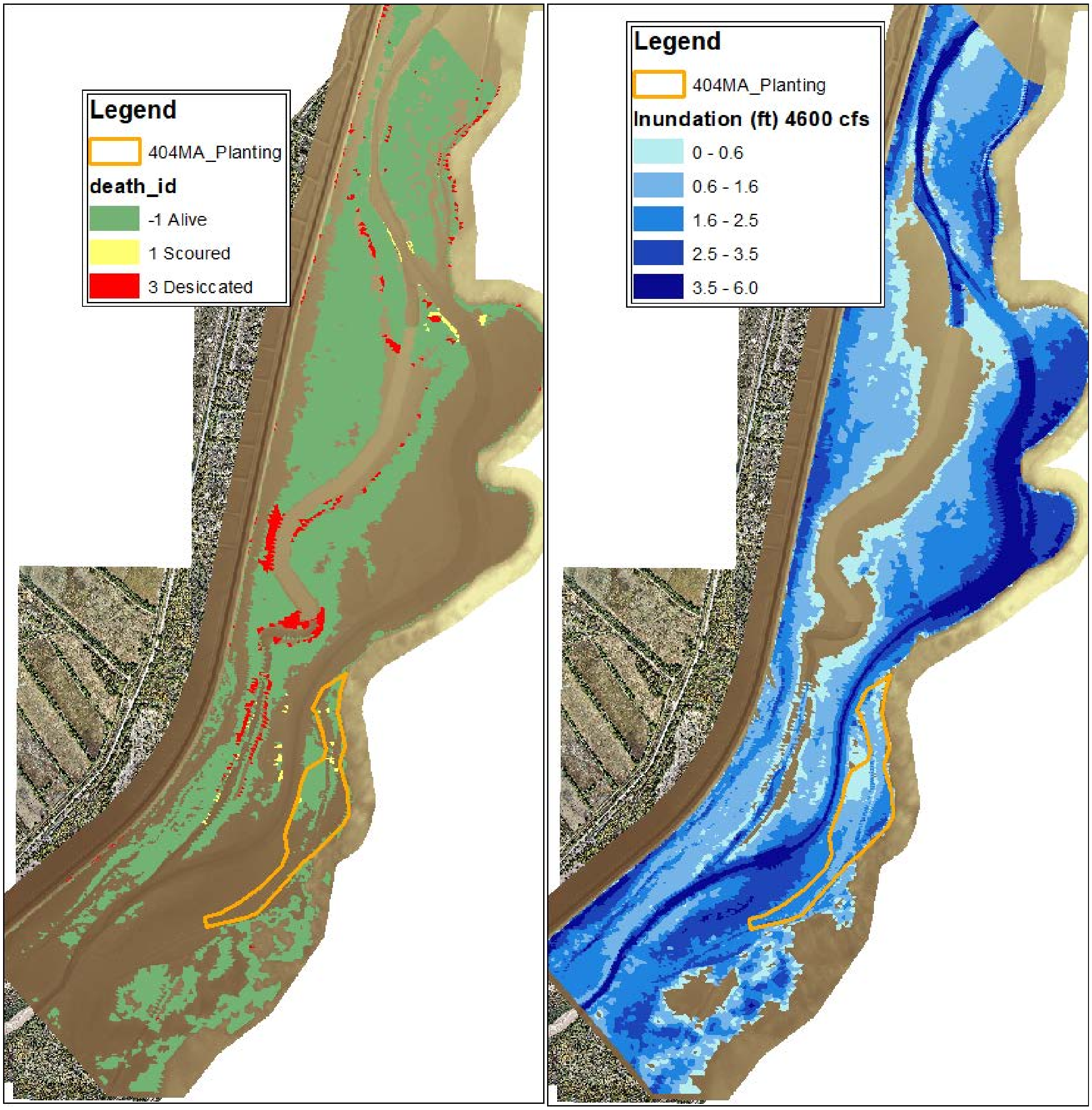

Figure 26—Tree Willow germination distribution and mortality identifiers (left panel) for *non-vegetated* initial condition and *wet* hydrograph scenario. There was no inundation-related mortality of vegetation. Right panel shows inundation at 4600 cfs, the peak mean daily discharge during 2008 spring runoff.

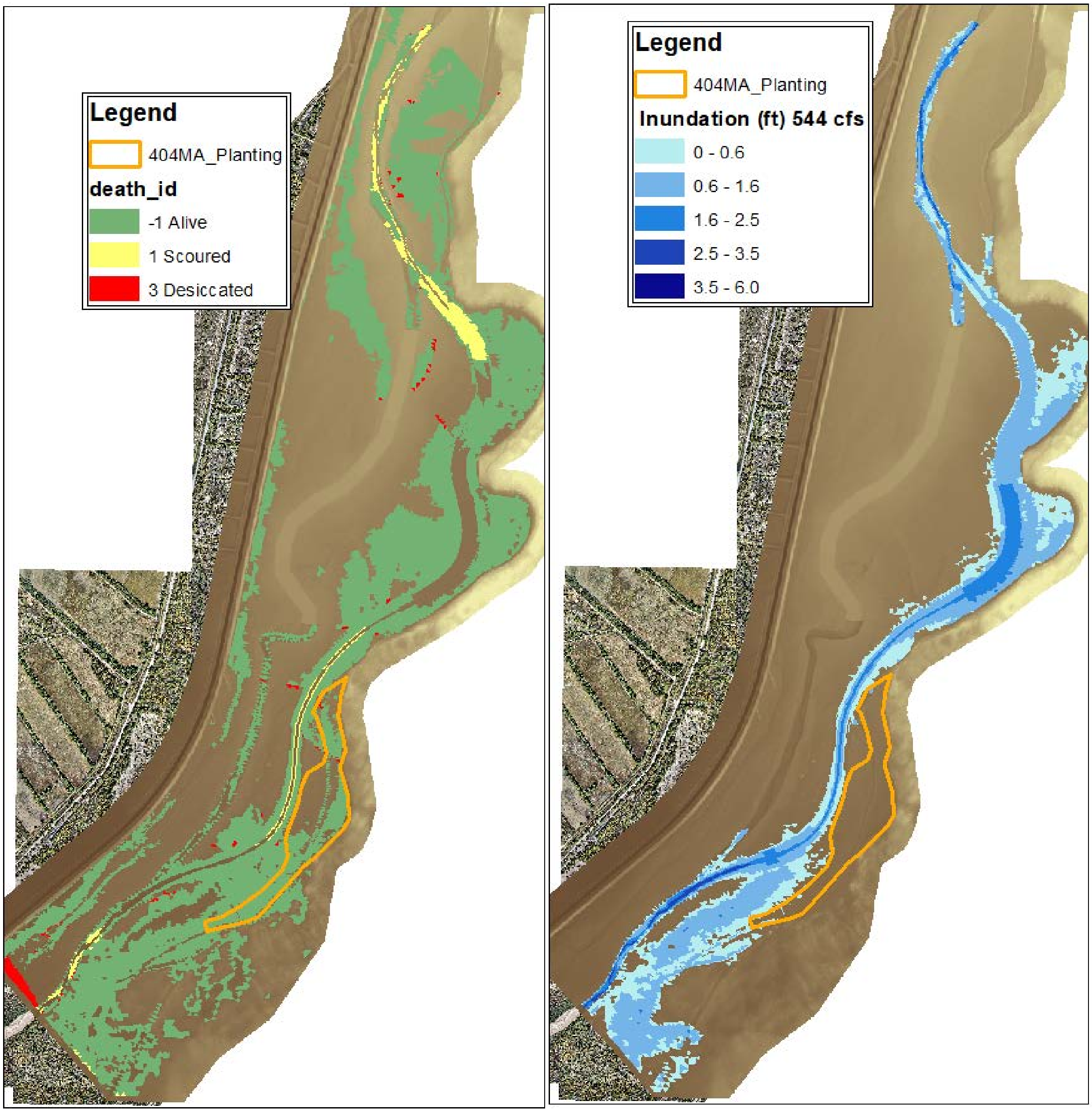

Figure 27—Tree Willow germination distribution and mortality identifiers (left panel) for *non-vegetated* initial condition and *dry* hydrograph scenario. There was no inundation-related mortality of vegetation. Right panel shows inundation at 544 cfs, the peak mean daily discharge during 2011 spring runoff.

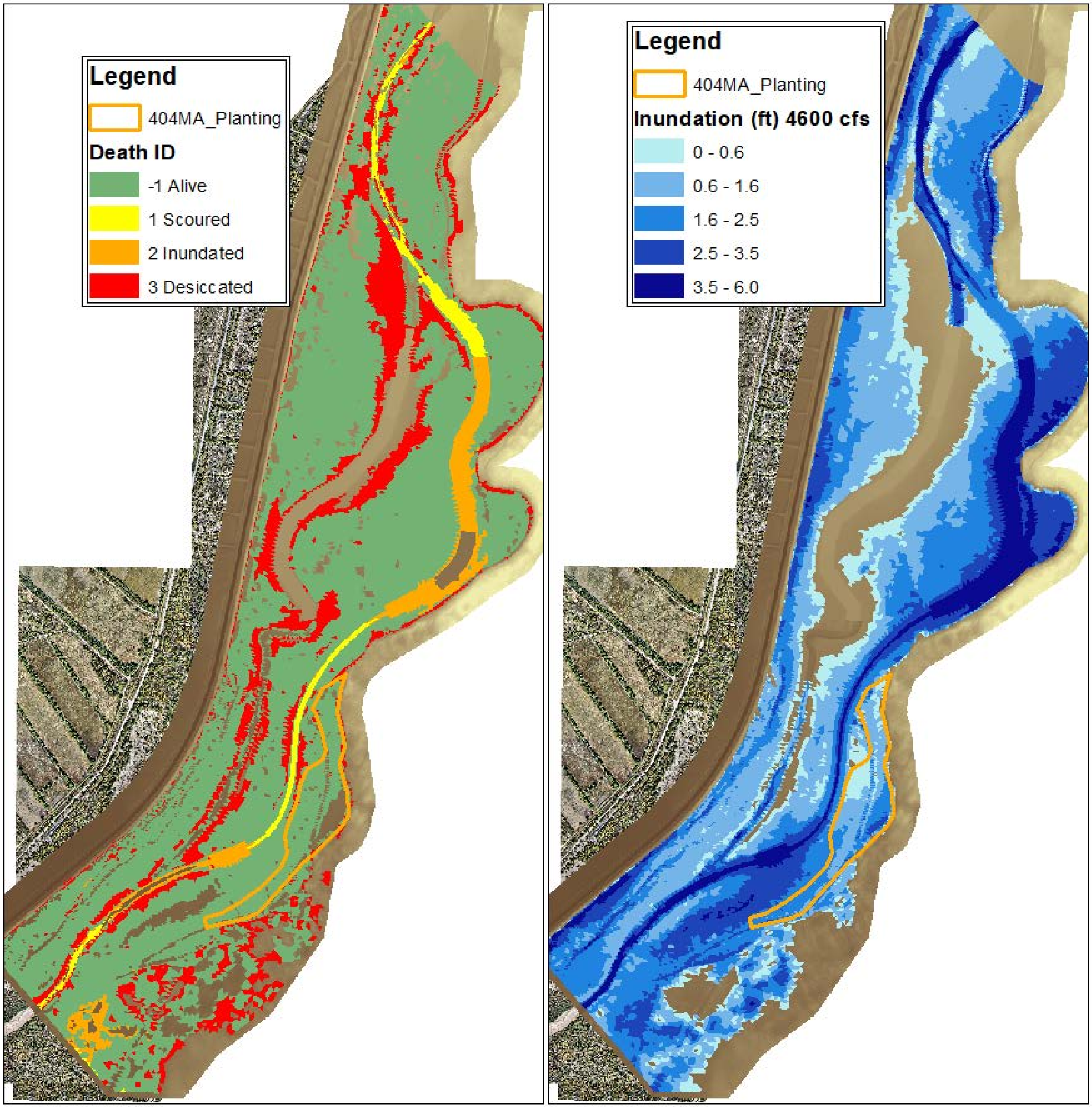

Figure 28—Salt Cedar germination distribution and mortality identifiers (left panel) for *non-vegetated* initial condition and *wet* hydrograph scenario. Right panel shows inundation at 4600 cfs, the peak mean daily discharge during 2008 spring runoff.

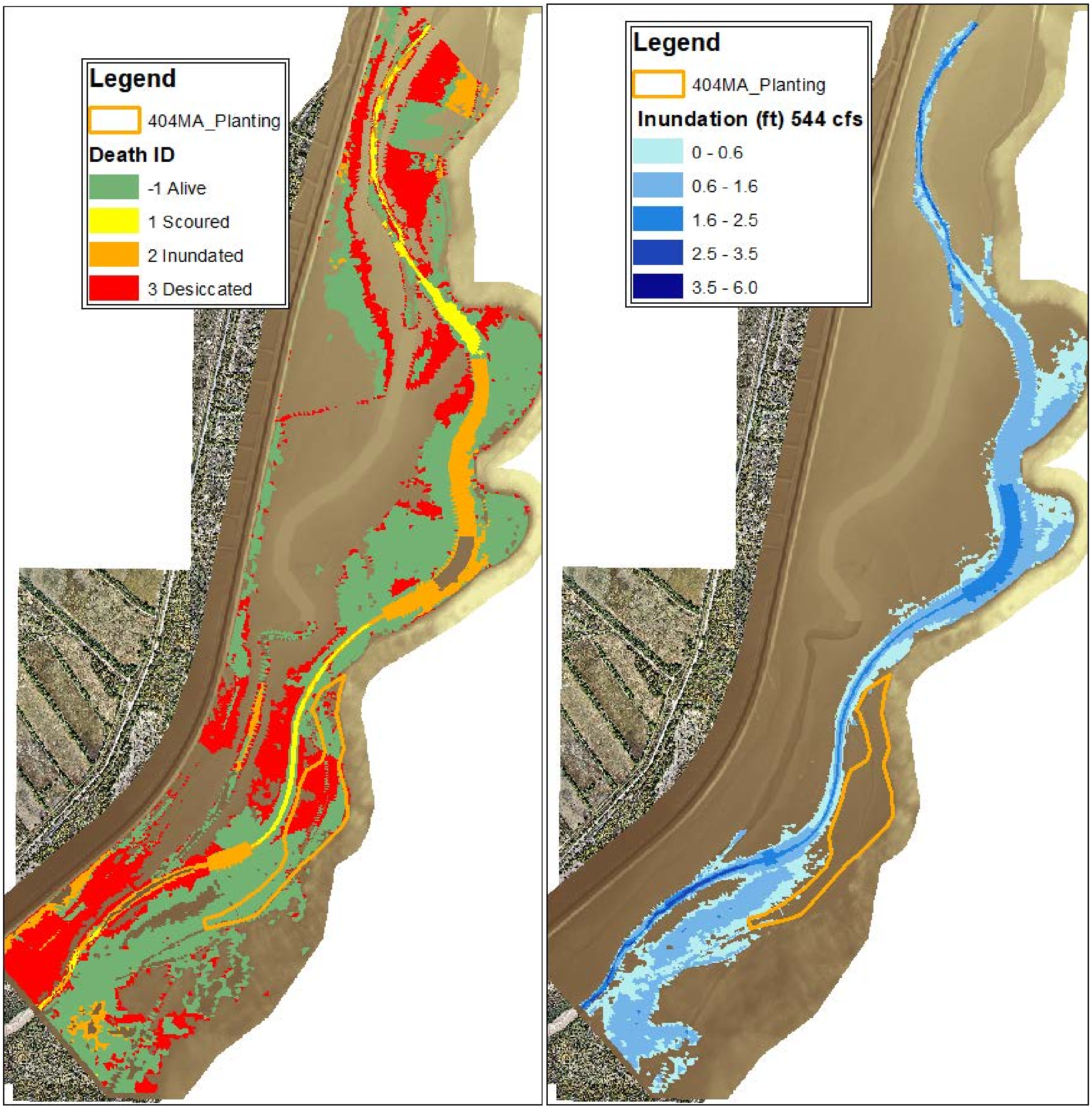

Figure 29—Salt Cedar germination distribution and mortality identifiers (left panel) for *non-vegetated* initial condition and *dry* hydrograph scenario. Right panel shows inundation at 544 cfs, the peak mean daily discharge during 2011 spring runoff.

4 Conclusions

A 2D hydraulic and riparian vegetation model was applied to examine the expected vegetation lifecycle and dynamics in response to the BDA Pilot Realignment Project. A vegetation module within the SRH-2D hydrodynamic model simulates changes to the vegetation distribution in the project area through germination, establishment, and mortality. The study estimated the response of four species to three different hydrographs (Wet – 2008, Dry – 2011, Average – 2015). The vegetation modeling case study was designed to illustrate the utility in simulating riparian response processes to designed channel realignment conditions, while testing hypotheses that inform monitoring and adaptive management. Cottonwood, Gooddings Black Willow (Tree Willow), Coyote Willow, and the invasive Salt Cedar were each incorporated within the model via species-specific parameterizations governing the germination, establishment, and removal as a function of historically observed water year type hydrographs. The results generally indicate that the germination success or failure, and subsequent distribution of seedlings, is a much more complex process than would be indicated by volume of water under each hydrograph alone. The wet hydrograph resulted in the largest germination area for Coyote Willow and Salt Cedar, while the average hydrograph resulted in the largest germination area for Cottonwood and Tree Willow. The spatial distribution is strongly dependent on the hydrograph type; dry years with low spring runoffs tend to have most germination concentrated near the channel margins. Although the model could not possibly consider all the biotic and abiotic factors effecting germination, establishment, and removal, specific concluding remarks from the study include the following observations:

- Vegetation roughness can generally be predicted numerically based on measured or projected biological conditions of the species present and utilized to predict hydraulic conditions, including distributions of depth and velocity.
- Germination and establishment of vegetation in the riparian landscape shows a complex dependency on the dynamics of the hydrologic season convolved with the natural germination timescale.
- Susceptibility of newly-germinated vegetation to natural stressors is not only a function of the species-specific biological attributes, but also the spatio-temporal conditions of the riparian landscape and hydraulic conditions under which the vegetation is establishing.
- An existing riparian landscape may have a very different response to new hydrologic events and natural stressors than a barren landscape initially devoid of vegetation.

The comparison of establishment patterns as a function of differential initial conditions (vegetated vs bare) illustrates the susceptibility of newly germinated seedlings to natural stressors. Depending on project objectives, the results of the modeling effort and comparisons drawn may motivate the need for active revegetation actions to be incorporated within river restoration and channel grading projects. Active planting may provide greater control over evolution of the riparian landscape post-construction, whereas the project outcome may otherwise be in part left to chance due to variability in water availability and distribution. Conversely, results from such a comparison may demonstrate that a passive approach to

vegetation establishment is warranted, mitigating the costs associated with active clearing and revegetation. Ultimately, the efficacy of a strategy to support riparian vegetation is likely application dependent and a function of the species composition, hydrologic regime, and inherent stressors within the system.

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Appendix A

Input Parameters for Vegetation Model

```
VPM              1.000        7.00                     !     vegetation time step (days) and output time step (days)
***     year              month       day       hour      Rio Grande BDA Realignment
VTM               1980            1         3        0              !     run dates    1/3/1980    1/3/1981
***     number of veg typenumber of soil types               !     Veg verification     File Rev.10/23/2012
VNM                  8            1
***     initialization shapefile, also uses csv based on same shp file name
VIN     VegPoly2016_ModelBoundary_simp6.shp
VIT     ABBREV                     ! Title of vegetation field
***     Model Veg Types
***     Veg 1             Cottonwood  C        Plains vs Fremont vs Deltoides, Probably not important
***     Veg 2             Coyote WilloCW
***     Veg 3             Goodding's WTW
***     Veg 4             Salt Cedar  SC
***     Veg 5             Other RipariRPNT     Not simulated
***     Veg 6             Other RipariRPNS     Not simulated
***     Veg 7             Other InvasiINV      Not simulated
***     Veg 8             Other No GroNOG      Not simulated
```

***	HO_2016	1 C	Density	2 CW	Density	3 TW	Density	4 SC	Density	5 RPNT	Density	6 RPNS	Density	7 INV	Density	8 NOG	Density			
VIV	ATX6D	0	1	0	1	0	1	0	1	99	0.75	0	1	0	1	0	1	!	Very young and low growth	1
VIV	C-CW-B5d	10	0.33	10	0.33	0	1	0	1	0	1	99	0.33	0	1	0	1	!	Shrub-sized stands	56
VIV	C-RO_CW-B-SC3d	40	0.5	10	0.33	0	1	20	0.33	0	1	99	0.33	99	0.5	0	1	!	Intermediate-sized trees with well-developed u	2
VIV	C-RO_CW3d	40	0.5	10	0.75	0	1	0	1	0	1	0	1	99	0.5	0	1	!	Intermediate-sized trees with well-developed u	57
VIV	C-RO_SC-B3d	40	0.5	0	1	0	1	20	0.5	0	1	99	0.5	99	0.5	0	1	!	Intermediate-sized trees with well-developed u	3
VIV	C-RO_SC-CW3d	40	0.5	10	0.5	0	1	20	0.5	0	1	0	1	99	0.5	0	1	!	Intermediate-sized trees with well-developed u	4
VIV	C-SC-CW-B5	10	0.1	10	0.1	0	1	2	0.1	0	1	99	0.1	0	1	0	1	!	Shrub-sized stands	58
VIV	C-SC_CW-B3d	40	0.5	10	0.5	0	1	20	0.5	0	1	99	0.5	0	1	0	1	!	Intermediate-sized trees with well-developed u	5
VIV	C-SC_SC-TW3d	40	0.5	0	1	10	0.5	2	0.5	0	1	0	1	99	0.5	0	1	!	Intermediate-sized trees with well-developed u	6
VIV	C-SC_TW-C3d	10	0.5	0	1	10	0.5	20	0.5	99	0.5	0	1	0	1	0	1	!	Intermediate-sized trees with well-developed u	7
VIV	C-SC4d	40	0.5	0	1	0	1	20	0.5	0	1	0	1	0	1	0	1	!	Intermediate-sized trees with little or no und	8
VIV	C-TW_SC-NMO-B3d	40	0.5	0	1	40	0.5	2	0.33	0	1	99	0.66	0	1	0	1	!	Intermediate-sized trees with well-developed u	9
VIV	C-TW_SC3d	40	0.5	0	1	40	0.5	2	0.75	0	1	0	1	0	1	0	1	!	Intermediate-sized trees with well-developed u	10
VIV	C-TW4	40	0.25	0	1	40	0.25	0	1	0	1	0	1	0	1	0	1	!	Intermediate-sized trees with little or no und	11
VIV	C_B-SC-CW3d	40	0.75	10	0.33	0	1	2	0.33	0	1	99	0.33	0	1	0	1	!	Intermediate-sized trees with well-developed u	12
VIV	C_CW-B-SC3d	40	0.75	10	0.33	0	1	2	0.33	0	1	99	0.33	0	1	0	1	!	Intermediate-sized trees with well-developed u	13
VIV	C_CW-B3d	40	0.75	10	0.5	0	1	0	1	0	1	99	0.5	0	1	0	1	!	Intermediate-sized trees with well-developed u	14
VIV	C_CW-C3	10	0.25	10	0.25	0	1	0	1	99	0.25	0	1	0	1	0	1	!	Intermediate-sized trees with well-developed u	15
VIV	C_CW-CAT3d	40	0.75	10	0.5	0	1	0	1	0	1	99	0.5	0	1	0	1	!	Intermediate-sized trees with well-developed u	16
VIV	C_CW3d	40	0.75	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	!	Intermediate-sized trees with well-developed u	17
VIV	C_SC-B-CW3d	40	0.75	10	0.33	0	1	2	0.33	0	1	99	0.33	0	1	0	1	!	Intermediate-sized trees with well-developed u	18
VIV	C_SC-B3	40	0.25	0	1	0	1	2	0.2	0	1	99	0.2	0	1	0	1	!	Intermediate-sized trees with well-developed u	59
VIV	C_SC-B3d	40	0.75	0	1	0	1	2	0.5	0	1	99	0.5	0	1	0	1	!	Intermediate-sized trees with well-developed u	19
VIV	C_SC-C3d	10	0.5	0	1	0	1	2	0.5	99	0.5	0	1	0	1	0	1	!	Intermediate-sized trees with well-developed u	20
VIV	C_SC-CW3d	40	0.75	10	0.5	0	1	2	0.5	0	1	0	1	0	1	0	1	!	Intermediate-sized trees with well-developed u	21
VIV	C_SC-RO-B3d	40	0.75	0	1	0	1	2	0.33	0	1	99	0.33	99	0.33	0	1	!	Intermediate-sized trees with well-developed u	22
VIV	C_SC-RO3d	40	0.75	0	1	0	1	2	0.5	0	1	0	1	99	0.5	0	1	!	Intermediate-sized trees with well-developed u	23
VIV	C_SC1	40	0.25	0	1	0	1	2	0.25	0	1	0	1	0	1	0	1	!	Tall/mature trees with well-developed understory	60
VIV	C_SC1d	40	0.75	0	1	0	1	2	0.75	0	1	0	1	0	1	0	1	!	Tall/mature trees with well-developed understory	24
VIV	C_SC3d	40	0.75	0	1	0	1	2	0.75	0	1	0	1	0	1	0	1	!	Intermediate-sized trees with well-developed u	25
VIV	C4	40	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	!	Intermediate-sized trees with little or no und	26
VIV	C4d	40	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	!	Intermediate-sized trees with little or no und	27
VIV	CW-B5d	0	1	10	0.5	0	1	0	1	0	1	99	0.5	0	1	0	1	!	Shrub-sized stands	61
VIV	CW-C-TW5d	10	0.33	10	0.33	10	0.33	0	1	0	1	0	1	0	1	0	1	!	Shrub-sized stands	62
VIV	CW-SC-B-C5	10	0.1	10	0.1	0	1	2	0.1	0	1	99	0.1	0	1	0	1	!	Shrub-sized stands	28
VIV	CW-SC-B5	0	1	10	0.1	0	1	2	0.1	0	1	99	0.1	0	1	0	1	!	Shrub-sized stands	29
VIV	CW-SC-B5d	0	1	10	0.25	0	1	2	0.25	0	1	99	0.25	0	1	0	1	!	Shrub-sized stands	30
VIV	CW-SC-C5d	10	0.25	10	0.25	0	1	2	0.25	0	1	0	1	0	1	0	1	!	Shrub-sized stands	31
VIV	CW-SC5d	10	0.5	0	1	0	1	2	0.5	0	1	0	1	0	1	0	1	!	Shrub-sized stands	32
VIV	CW5d	0	1	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	!	Shrub-sized stands	33
VIV	CW6	0	1	2	0.25	0	1	0	1	0	1	0	1	0	1	0	1	!	Very young and low growth	34
VIV	LFCC	0	1	0	1	0	1	0	1	0	1	0	1	0	1	99	1	!	Low Flow Conveyance Channel	35
VIV	MH	0	1	0	1	0	1	0	1	0	1	99	1	0	1	0	1	!	Wet meadow / Marsh	36
VIV	OP	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	!	Open Area	37
VIV	OW	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	!	Open Water	38
VIV	RO-C_CW-SC3d	40	0.5	10	0.5	0	1	2	0.5	0	1	0	1	99	0.5	0	1	!	Intermediate-sized trees with well-developed u	39
VIV	RO-SC-C_TW-B3d	40	0.33	0	1	10	0.5	20	0.33	0	1	99	0.5	99	0.33	0	1	!	Intermediate-sized trees with well-developed u	40
VIV	RO_CW-B-SC3d	0	1	10	0.33	0	1	2	0.33	0	1	99	0.33	99	0.75	0	1	!	Intermediate-sized trees with well-developed u	41
VIV	Road	0	1	0	1	0	1	0	1	0	1	0	1	0	1	99	1	!	Road	42
VIV	SBM-ATX6	0	1	0	1	0	1	0	1	99	0.2	99	0.2	0	1	0	1	!	Very young and low growth	63
VIV	SC-B-C-CW5	10	0.1	10	0.1	0	1	2	0.1	0	1	99	0.1	0	1	0	1	!	Shrub-sized stands	43
VIV	SC-B-CW5	0	1	10	0.1	0	1	2	0.1	0	1	99	0.1	0	1	0	1	!	Shrub-sized stands	44
VIV	SC-B5	0	1	0	1	0	1	2	0.2	0	1	99	0.2	0	1	0	1	!	Shrub-sized stands	45
VIV	SC-B5d	0	1	0	1	0	1	2	0.5	0	1	99	0.5	0	1	0	1	!	Shrub-sized stands	46
VIV	SC-C-RO_SC3d	40	0.33	0	1	0	1	2	0.75	0	1	0	1	99	0.66	0	1	!	Intermediate-sized trees with well-developed u	47
VIV	SC-C_SC-CW3d	40	0.5	10	0.5	0	1	2	0.5	0	1	0	1	99	0.5	0	1	!	Intermediate-sized trees with well-developed u	48
VIV	SC-C5d	10	0.5	0	1	0	1	2	0.5	0	1	0	1	0	1	0	1	!	Shrub-sized stands	49
VIV	SC-CW-B5d	0	1	10	0.33	0	1	2	0.33	0	1	99	0.33	0	1	0	1	!	Shrub-sized stands	50
VIV	SC-CW5	0	1	10	0.2	0	1	2	0.2	0	1	0	1	0	1	0	1	!	Shrub-sized stands	51
VIV	SC_CW-B3d	0	1	10	0.5	0	1	20	0.75	0	1	99	0.5	0	1	0	1	!	Intermediate-sized trees with well-developed u	52
VIV	SC4d	0	1	0	1	0	1	20	0.75	0	1	0	1	0	1	0	1	!	Intermediate-sized trees with little or no und	53
VIV	SC5	0	1	0	1	0	1	2	0.25	0	1	0	1	0	1	0	1	!	Shrub-sized stands	64
VIV	SC5d	0	1	0	1	0	1	2	0.75	0	1	0	1	0	1	0	1	!	Shrub-sized stands	54
VIV	SC6d	0	1	0	1	0	1	2	0.5	0	1	0	1	0	1	0	1	!	Very young and low growth	55

```
***
**********************************************************************
***     Begin Veg Type 1     Freemont Cottonwood
**********************************************************************
***     VNAME
VVN     Fc
***     MTYPE
MMT                  1            ! Simulation Method (0 = none, 1 = air, 2 = water)
***     MSTART           MEND
MDY                105         182
***     MDAYS            MMAX      MHEIGHT  MBELOW
MPR                0.5           2     1.00     0.10
***     max height of establish (above?) of low water
MEL                 25
**********************************************************************
***     GTYPE
GMT                  1                       ! Simulation Method (0 if none performed, 1 = stalk, canopy, root)
***     max stalk growth rate (ft/day) for each month (ONLY USED FOR DISPLAY PURPOSES)
***     age               Jan         Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
GST                  0           0        0    0.012    0.012    0.012    0.012    0.012    0.012    0.012    0.012    0.012        0
GST                  3           0        0    0.006    0.006    0.006    0.006    0.006    0.006    0.006    0.006    0.006        0
***     max height        ONLY USED FOR DISPLAY PURPOSES
GSM                 10
***     GCP_ RATE max shaded canopy spread rate (ft/day) for each month          2.16
***     GCP_AGE           Jan         Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
GCP                  0           0        0    0.002    0.002    0.002    0.002    0.002    0.002    0.002    0.002    0.002        0
GCP                  2           0        0    0.005    0.005    0.005    0.005    0.005    0.005    0.005    0.005    0.005        0
GCP                 15           0        0    0.008    0.008    0.008    0.008    0.008    0.008    0.008    0.008    0.008        0
GCP                 45           0        0    0.002    0.002    0.002    0.002    0.002    0.002    0.002    0.002    0.002        0
***     GCP_MAX
GCM                 20
***     GRT_RATE max root growth rate (ft/day) for each m(2.5 cm/day)            2.5  0.082021
***     GRT_AGE           Jan         Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
GRT                  0           0        0   0.0656   0.0656   0.0656   0.0656   0.0656   0.0656   0.0656   0.0656   0.0656        0
GRT                  6           0        0    0.011    0.011    0.011    0.011    0.011    0.011    0.011    0.011    0.011        0
***     GRT               GRT_DEPTH
GRS                0.1          24
**********************************************************************
***     RTYPE
RMT                  0                       ! Simulation Method (0 if none performed)
***     ***               age-roughness table
***     ***               age          Roughness
***     RAM                          0     0.04
***     RAM                          5     0.06
***     RAM                         30     0.08
***     death types
**********************************************************************
***     CTYPE
CMT                  1                       ! Simulation Method (0 if none performed)
CID                  6                       ! Death id
***     age that species Y has to be to kill species 1CW at age  (-1 any age of Y plant will kill--doesn't work LF)
***         KILL_AGE          1 C      2 CW      3 TW 4 SC      5 RPNT    6 RPNS       7 INV     8 NOG
***     CAGE
CMP                0.1          99        3        99        2         2      0.25         2      0.01
CMP                  2          99       99        99       99        99        99         3      0.01
CMP                  3          99       99        99       99        99        99        99      0.01
***     SHADE_AGE age of species at which it is shade tolerant
CSH                 99
**********************************************************************
***     STYPE
SMT                  1                       ! Simulation Method (0 if none performed)
SID                  1                               ! Death id
***     SAGE              SVEL_CRIT
SVC                  0           2
SVC                  1         2.5
SVC                  2           3
SVC                  3           4
SVC                  4           5
SVC                  5           6
**********************************************************************
***     BTYPE
BMT                  0                               ! Simulation Method (0 if none performed)
```

```
***     BID                         ?                  ! Death id
***     BDP                         2                  ! Burying depth
********************************************************************
***     DTYPE
DMT                  1                                 ! Simulation Method (0 if none performed)
DID                  2                                 ! Death id
***     DAGE             DTIME (d)   DDEPTH (ft)
DTM                  0          16          1
DTM                0.5          28          1
DTM                  5         240          1
DTM                 20         730          1
********************************************************************                                   70 to 100 ave to max mahoony & rood 1998
***     YTYPE                                                                                                 70 cm            27.6 in
YMT                  1                                 ! Simulation Method (0 if none performed)
YID                  3                                 ! Death id
***     YAGE             YTIME (d)   YHEIGHT (ft)      height above capillary fringe required for descication (ft?)  Try 0 for gravel and 1 ft for sand.
YTM                  0           2      0.5
YTM                  1           7      0.5
YTM                  2          14      0.5
YTM                  3          28      0.5
YTM                 20         180      0.5
***     Months drying is allowed      (0 can not kill plants with desic, 1 can kill plants by desic LF)Changed from 0 and 1 to False and True
***     Jan              Feb         Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
YMN     F                F           F        T        T        T        T        T        T        T        F        F
********************************************************************
***     ITYPE
IMT                  0                       ! 1 = on, 0 = off
********************************************************************
***     ATYPE
AMT                  0                       ! Simulation Method (0 if none performed)
***     AID                         5                  ! Death id
***     ATM                        75                  ! Age of death
********************************************************************
***     Begin Veg Type 2     Coyote Willow (Narrow Leaf Willow) Salix exigua
********************************************************************
***     VNAME
VVN     sbw
***     MTYPE
MMT                  1             ! Simulation Method (0 = none, 1 = air, 2 = water)
***     MSTART           MEND
MDY                129         273
***     MDAYS            MMAX        MHEIGHT  MBELOW
MPR                1.5           2      1.00     0.20
***     max lateral spread rate (ft/day) for each month
***     age              Jan         Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
MLT                  0           0     0.07     0.07     0.07     0.07     0.07     0.07     0.07     0.07     0.07     0.07        0
MLT                  1           0     0.11     0.11     0.11     0.11     0.11     0.11     0.11     0.11     0.11     0.11        0
***     max height of establish (above?) of low water
MEL                 25
********************************************************************
***     GTYPE
GMT                  1                       ! Simulation Method (0 if none performed, 1 = stalk, canopy, root)
***     max stalk growth rate (ft/day) for each month   ONLY USED FOR DISPLAY PURPOSES
***     age              Jan         Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
GST                  0           0        0    0.008    0.008    0.008    0.008    0.008    0.008    0.008    0.008    0.008        0
***     max height       ONLY USED FOR DISPLAY PURPOSES
GSM                  6
***     GCP_RATE max shaded canopy spread rate (ft/day) for each month     (was 0.008)
***     GCP_AGE          Jan         Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
GCP                  0           0        0        0    0.002    0.002    0.002    0.002    0.002    0.002    0.002        0        0
GCP                  2           0        0        0    0.004    0.004    0.004    0.004    0.004    0.004    0.004        0        0
***     GCP_MAX
GCM                  4
***     GRT_RATE max root growth rate (ft/day) for each 1.5 cm/day              1.5 0.049213
***     GRT_AGE          Jan         Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
GRT                  0           0        0    0.065    0.065    0.065    0.065    0.065    0.065    0.065    0.065    0.065        0
***     GRT              GRT_DEPTH
GRS                0.2           8
********************************************************************
***     RTYPE
RMT                  0                       ! Simulation Method (0 if none performed)
***     ***              age-roughness table
***     ***              age         Roughness
***     RAM                         0     0.04
***     RAM                         5     0.07
***     RAM                        30     0.01
***     death types
********************************************************************
***     CTYPE            Competition
CMT                  1                       ! Simulation Method (0 if none performed)
CID                  6                       ! Death id
***     ***              age that species Y has to be to kill species 1NW at age  (-1 any age of Y plant will kill)
***         KILL_AGE             1 C      2 CW     3 TW 4 SC      5 RPNT    6 RPNS       7 INV     8 NOG
***     CAGE
CMP                0.1          99       99       99        2        2      0.25        2      0.01
CMP                  2          99       99       99       99       99        99        3      0.01
CMP                  5          99       99       99       99       99        99       99      0.01
***     SHADE_AGE        age of species at which it is shade tolerant
CSH                  2
********************************************************************
***     STYPE
SMT                  1                       ! Simulation Method (0 if none performed)
SID                  1                                         ! Death id
***     SAGE             SVEL_CRIT
SVC                  0           2
SVC                  1           3
SVC                  2           4
SVC                  3           5
SVC                  4           8
********************************************************************
***     BTYPE
BMT                  0                                 ! Simulation Method (0 if none performed)
***     BID                         ?                  ! Death id
***     BDP                         2                  ! Burying depth
********************************************************************
***     DTYPE
DMT                  1                                 ! Simulation Method (0 if none performed)
DID                  2                                 ! Death id
***     DAGE             DTIME (d)   DDEPTH (ft)
DTM                  0          35          1
DTM                  5        1460          1
DTM                 20        1700          1
********************************************************************
***     YTYPE
YMT                  1                                 ! Simulation Method (0 if none performed)
YID                  3                                 ! Death id
***     YAGE             YTIME (d)   YHEIGHT (ft)      height above capillary fringe required for descication
YTM                  0           2      0.1
YTM                  1           7      0.1
YTM                  2          11      0.1
YTM                  3          25      0.1
YTM                  4          25      0.1
YTM                  5          25      0.1
YTM                 29          50      0.1
***     Months drying is allowed                       Changed from 0 and 1 to False and True
***     Jan              Feb         Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
YMN     F                T           T        T        T        T        T        T        T        T        T        F
********************************************************************
***     ITYPE
IMT                  0                       ! 1 = on, 0 = off
********************************************************************
***     ATYPE
AMT                  0                       ! Simulation Method (0 if none performed)
***     AID                         5                  ! Death id
***     ATM                        99                  ! Age of death
********************************************************************
***     Begin Veg Type 3     Goodings Black Willow
********************************************************************
***     VNAME
VVN     Gbw
***     MTYPE
MMT                  1             ! Simulation Method (0 = none, 1 = air, 2 = water)
***     MSTART           MEND
MDY                130         148
***     MDAYS            MMAX        MHEIGHT  MBELOW
MPR                0.5           2      1.00     0.20
***     max height of establish (above?) of low water
MEL                 25
********************************************************************
***     GTYPE
GMT                  1                       ! Simulation Method (0 if none performed, 1 = stalk, canopy, root)
***     max stalk growth rate (ft/day) for each month   ONLY USED FOR DISPLAY PURPOSES
***     age              Jan         Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
GST                  0           0        0     0.01     0.01     0.01     0.01     0.01     0.01     0.01     0.01  0.00328        0
```

```
GST                  3          0        0    0.005    0.005    0.005    0.005    0.005    0.005    0.005    0.005  0.00656        0
***     max height        ONLY USED FOR DISPLAY PURPOSES
GSM                  8
***     GCP_RATE max shaded canopy spread rate (ft/day) for each month          0.27
***     GCP_AGE           Jan         Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
GCP                  0          0        0    0.002    0.002    0.002    0.002    0.002    0.002    0.002    0.002    0.002        0
GCP                  2          0        0    0.005    0.005    0.005    0.005    0.005    0.005    0.005    0.005    0.005        0
GCP                 15          0        0    0.008    0.008    0.008    0.008    0.008    0.008    0.008    0.008    0.008        0
GCP                 45          0        0    0.002    0.002    0.002    0.002    0.002    0.002    0.002    0.002    0.002        0
***     GCP_MAX
GCM                 20
***     GRT_RATE max root growth rate (ft/day) for each  2 cm/day                  2 0.065617
***     GRT_AGE           Jan         Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
GRT                  0          0        0   0.0656   0.0656   0.0656   0.0656   0.0656   0.0656   0.0656   0.0656   0.0656        0
GRT                  6          0        0     0.01     0.01     0.01     0.01     0.01     0.01     0.01     0.01     0.01        0
***     GRT               GRT_DEPTH
GRS                0.2         22
**********************************************************************
***     RTYPE
RMT                  0                      ! Simulation Method (0 if none performed)
***     ***               age-roughness table
***     ***               age         Roughness
***     RAM                         0      0.04
***     RAM                         5      0.06
***     RAM                        30      0.08
***     death types
**********************************************************************
***     CTYPE             Competition
CMT                  1                      ! Simulation Method (0 if none performed)
CID                  6                      ! Death id
***     age that species Y has to be to kill species 1BW at age  (-1 any age of Y plant will kill)
***         KILL_AGE            1 C     2 CW     3 TW 4 SC     5 RPNT   6 RPNS      7 INV    8 NOG
***     CAGE
CMP                0.1         99        3       99        2        2     0.25        2     0.01
CMP                  2         99       99       99       99       99       99        3     0.01
CMP                  3         99       99       99       99       99       99       99     0.01
***     SHADE_AGE         age of species at which it is ;(was 8)
CSH                 99
**********************************************************************
***     STYPE
SMT                  1                      ! Simulation Method (0 if none performed)
SID                  1                                        ! Death id
***     SAGE              SVEL_CRIT
SVC                  0          2
SVC                  1          3
SVC                  2          4
SVC                  3          5
SVC                  4          8
**********************************************************************
***     BTYPE
BMT                  0                                ! Simulation Method (0 if none performed)
***     BID                         ?                 ! Death id
***     BDP                         2                 ! Burying depth
**********************************************************************
***     DTYPE
DMT                  1                                ! Simulation Method (0 if none performed)
DID                  2                                ! Death id
***     DAGE              DTIME (d)   DDEPTH (ft)
DTM                  0         35        1
DTM                  5       1460        1
DTM                 20       1700        1
**********************************************************************
***     YTYPE
YMT                  1                                ! Simulation Method (0 if none performed)
YID                  3                                ! Death id
***     YAGE              YTIME (d)   YHEIGHT (ft)      height above capillary fringe required for descication
YTM                  0          2      0.1            !
YTM                  1          5      0.1            !
YTM                  2         11      0.1            !
YTM                  3         25      0.1            !
YTM                  6         50      0.1
***     Months drying is allowed               (0 can not kill plants with desic, 1 can kill plants by desic LF)
***     Jan               Feb         Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
YMN     F                 F           F        T        T        T        T        T        T        T        F        F
**********************************************************************
***     ITYPE
IMT                  0                      ! 1 = on, 0 = off
**********************************************************************
***     ATYPE
AMT                  0                      ! Simulation Method (0 if none performed)
***     AID                         5                 ! Death id
***     ATM                        50                 ! Age of death
**********************************************************************
***     Begin Veg Type 4     Salt Cedar
**********************************************************************
***     VNAME
VVN     tam
***     MTYPE
MMT                  1             ! Simulation Method (0 = none, 1 = air, 2 = water)
***     MSTART            MEND
MDY                183        274
***     MDAYS             MMAX        MHEIGHT  MBELOW
MPR                  1          2      1.00     0.20
***     max lateral spread rate (ft/day) for each month
***     age               Jan         Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
MLT                  0          0        0        0    0.009    0.009    0.009    0.009    0.009    0.009    0.009        0        0
MLT                  1          0        0        0     0.02     0.02     0.02     0.02     0.02     0.02     0.02        0        0
***     max height of establish (above?) of low water
MEL                 15
**********************************************************************
***     GTYPE
GMT                  1                      ! Simulation Method (0 if none performed, 1 = stalk, canopy, root)
***     max stalk growth rate (ft/day) for each month            ONLY USED FOR DISPLAY PURPOSES
***     age               Jan         Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
GST                  0          0        0     0.09     0.09     0.09     0.09     0.09     0.09     0.09     0.09     0.09        0
***     max height        ONLY USED FOR DISPLAY PURPOSES
GSM                  6
***     GCP_RATE max shaded canopy spread rate (ft/day) for each month
***     GCP_AGE           Jan         Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
GCP                  0          0        0        0    0.004    0.004    0.004    0.004    0.004    0.004    0.004        0        0
***     GCP_MAX
GCM                  4
***     GRT_RATE max root growth rate (ft/day) for each  5 cm/day                  5 0.164042
***     GRT_AGE           Jan         Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
GRT                  0          0        0        0    0.009    0.009    0.009    0.009    0.009    0.009    0.009        0        0
GRT                  1          0        0        0     0.02     0.02     0.02     0.02     0.02     0.02     0.02        0        0
***     GRT               GRT_DEPTH
GRS                  1         40
**********************************************************************
***     RTYPE
RMT                  0                      ! Simulation Method (0 if none performed)
***     ***               age-roughness table
***     ***               age         Roughness
***     RAM                         0      0.04
***     RAM                         5      0.07
***     RAM                        30       0.1
***     death types
**********************************************************************
***     CTYPE             Competition
CMT                  1                      ! Simulation Method (0 if none performed)
CID                  6                      ! Death id
***     age that species Y has to be to kill species 5AR at age  (-1 any age of Y plant will kill)
***         KILL_AGE            1 C     2 CW     3 TW 4 SC     5 RPNT   6 RPNS      7 INV    8 NOG
***     CAGE
CMP                0.1          1        1        1       99        1        1       99     0.01
CMP                  2         99       99       99       99       99       99       99     0.01
***     SHADE_AGE         age of species at which it is shade tolerant
CSH                 99
**********************************************************************
***     STYPE
SMT                  1                      ! Simulation Method (0 if none performed)
SID                  1                                        ! Death id
***     SAGE              SVEL_CRIT
SVC                  0          2
SVC                  1          5
SVC                  2          6
SVC                  3          7
**********************************************************************
***     BTYPE
BMT                  0                                ! Simulation Method (0 if none performed)
***     BID                         ?                 ! Death id
***     BDP                         2                 ! Burying depth
**********************************************************************
***     DTYPE
```

```
DMT                     1                               ! Simulation Method (0 if none performed)
DID                     2                               ! Death id         same as black willow time
***     DAGE              DTIME (d)   DDEPTH (ft)
DTM                     0          28        1
DTM                     4          90        1
DTM                    10         480        1
************************************************************************
***     YTYPE
YMT                     1                               ! Simulation Method (0 if none performed)
YID                     3                               ! Death id
***     YAGE              YTIME (d)   YHEIGHT (ft)      height above capillary fringe required for descication  was .25
YTM                     0           4      0.1
YTM                     1           9      0.1
YTM                     3          35      0.1
***     Months drying is allowed
***     Jan               Feb         Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
YMN     T                 T           T        T        T        T        T        T        T        T        T        T
************************************************************************
***     ITYPE
IMT                     0                     ! 1 = on, 0 = off
************************************************************************
***     ATYPE
AMT                     0                     ! Simulation Method (0 if none performed)
***     AID                         5                   ! Death id
***     ATM                        99                   ! Age of death
************************************************************************
***     Begin Veg Type 5     Other Riparian Trees
************************************************************************
***     VNAME
VVN     RPNT
***     MTYPE
MMT                     0            ! Simulation Method (0 = none, 1 = air, 2 = water)
************************************************************************
***     GTYPE
GMT                     0                     ! Simulation Method (0 if none performed, 1 = stalk, canopy, root)
************************************************************************
***     RTYPE
RMT                     0                     ! Simulation Method (0 if none performed)
***     death types
************************************************************************
***     CTYPE
CMT                     0                     ! Simulation Method (0 if none performed)
************************************************************************
***     STYPE
SMT                     0                     ! Simulation Method (0 if none performed)
************************************************************************
***     BTYPE
BMT                     0                               ! Simulation Method (0 if none performed)
************************************************************************
***     DTYPE
DMT                     0                               ! Simulation Method (0 if none performed)
************************************************************************
***     YTYPE
YMT                     0                               ! Simulation Method (0 if none performed)
************************************************************************
***     ITYPE
IMT                     0                     ! 1 = on, 0 = off
************************************************************************
***     ATYPE
AMT                     0                     ! Simulation Method (0 if none performed)
************************************************************************
***     Begin Veg Type 6     Other Riparian Shrubs
************************************************************************
***     VNAME
VVN     RPNS
***     MTYPE
MMT                     0            ! Simulation Method (0 = none, 1 = air, 2 = water)
************************************************************************
***     GTYPE
GMT                     0                     ! Simulation Method (0 if none performed, 1 = stalk, canopy, root)
************************************************************************
***     RTYPE
RMT                     0                     ! Simulation Method (0 if none performed)
***     death types
************************************************************************
***     CTYPE
CMT                     0                     ! Simulation Method (0 if none performed)
************************************************************************
***     STYPE
SMT                     0                     ! Simulation Method (0 if none performed)
************************************************************************
***     BTYPE
BMT                     0                               ! Simulation Method (0 if none performed)
************************************************************************
***     DTYPE
DMT                     0                               ! Simulation Method (0 if none performed)
************************************************************************
***     YTYPE
YMT                     0                               ! Simulation Method (0 if none performed)
************************************************************************
***     ITYPE
IMT                     0                     ! 1 = on, 0 = off
************************************************************************
***     ATYPE
AMT                     0                     ! Simulation Method (0 if none performed)
************************************************************************
***     Begin Veg Type 7     Other Invasives
************************************************************************
***     VNAME
VVN     INV
***     MTYPE
MMT                     0            ! Simulation Method (0 = none, 1 = air, 2 = water)
************************************************************************
***     GTYPE
GMT                     0                     ! Simulation Method (0 if none performed, 1 = stalk, canopy, root)
************************************************************************
***     RTYPE
RMT                     0                     ! Simulation Method (0 if none performed)
***     death types
************************************************************************
***     CTYPE
CMT                     0                     ! Simulation Method (0 if none performed)
************************************************************************
***     STYPE
SMT                     0                     ! Simulation Method (0 if none performed)
************************************************************************
***     BTYPE
BMT                     0                               ! Simulation Method (0 if none performed)
************************************************************************
***     DTYPE
DMT                     0                               ! Simulation Method (0 if none performed)
************************************************************************
***     YTYPE
YMT                     0                               ! Simulation Method (0 if none performed)
************************************************************************
***     ITYPE
IMT                     0                     ! 1 = on, 0 = off
************************************************************************
***     ATYPE
AMT                     0                     ! Simulation Method (0 if none performed)
************************************************************************
***     Begin Veg Type 8     Other No Grow
************************************************************************
***     VNAME
VVN     NOG
***     MTYPE
MMT                     0            ! Simulation Method (0 = none, 1 = air, 2 = water)
************************************************************************
***     GTYPE
GMT                     0                     ! Simulation Method (0 if none performed, 1 = stalk, canopy, root)
************************************************************************
***     RTYPE
RMT                     0                     ! Simulation Method (0 if none performed)
***     death types
************************************************************************
***     CTYPE
CMT                     0                     ! Simulation Method (0 if none performed)
************************************************************************
***     STYPE
SMT                     0                     ! Simulation Method (0 if none performed)
************************************************************************
***     BTYPE
BMT                     0                               ! Simulation Method (0 if none performed)
************************************************************************
```

```
***     DTYPE
DMT                     0                               ! Simulation Method (0 if none performed)
********************************************************************
***     YTYPE
YMT                     0                               ! Simulation Method (0 if none performed)
********************************************************************
***     ITYPE
IMT                     0                      ! 1 = on, 0 = off
********************************************************************
***     ATYPE
AMT                     0                      ! Simulation Method (0 if none performed)
********************************************************************
END
```