RECLAMATION
Managing Water in the West

Technical Report No. SRH-2013-09

Vegetation Modeling with SRH-1DV

Predicting the Interactions between Flow, Sediment, and Riparian Vegetation Research and Development

U.S. Department of the Interior
Bureau of Reclamation

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Cover Photo: Basin Creek, Durango, Colorado, May 2011 (Reclamation)

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EXECUTIVE SUMMARY

Predicting the impacts of flow management actions on the environment can be challenging. There are conceptual models for qualitative predictions of ecological response, and monitoring approaches to study vegetation and habitat response after implementation; however, there are few tools to predict the outcome of particular actions or to predict the difference between different management alternatives. SRH-1DV (Sedimentation and River Hydraulics-One Dimensional Vegetation model), a numerical modeling tool, was developed from a one-dimensional flow and sediment transport model (SRH-1D). This tool can help with both improving our understanding of complex ecological responses, and help with general predictions prior to implementation of management actions.

Geomorphic conditions of flow, sediment, riparian vegetation, and groundwater are linked in the SRH-1DV simulation. Hydraulics, sediment transport and groundwater conditions are defined by physical laws of nature, and the ecological factor, vegetation growth, is described by known plant response to the geomorphic factors. The establishment, growth, and mortality of vegetation is tracked on a daily basis in response to dynamic physical conditions, and is tracked as individual plants located on every point and at every cross section in the model. Up to twelve vegetation types, normally plant species, have been selected to represent the riparian vegetation in a flood plain. Initial vegetation conditions are assigned from vegetation maps, but the distribution of plants can shift with changes in flow, sediment, and groundwater conditions.

The numerical model is a representation of the vegetation continuum concept with no two species occupying the same niche. Distribution of vegetation types (species) is determined by species' response to environmental conditions, and each species has a unique array of responses to changes in the environment. Assuming each plant species responds somewhat differently, no two species occupy an identical environmental niche in the historical context. A numerical model is used to represent the subtle distinctions between the vegetation processes of each species, to produce simple or overlapping vegetation cover areas. Variation in conditions and variation in plant coping mechanisms produce a spatially and temporally varied environment.

Parameters are used to describe germination, growth, and mortality aspects of the plant lifecycle. Plant propagation can occur through air-borne seeds or lateral root spread. Growth of the stem, canopy, and roots of each plant on a point are tracked by the model. Plants can be removed through desiccation, inundation, shading, competition, scour, burial and senescence. The assessment of each factor is described and tables of parameters from five previous SRH-1DV studies are compiled in this report.

A desiccation field study and a desiccation laboratory study of cottonwood seedlings, and an inundation laboratory study of cottonwood seedlings, have been the source of many cottonwood parameters. Results from the cottonwood laboratory desiccation study were also used to develop a stress model for cottonwood desiccation mortality. Alternative sources for parameters are journal articles and government developed plant databases and plant indexes. Parameters selected for model use are investigated through sensitivity studies and calibration studies. Notes, references and resources to aid parameter selection for 21 vegetation types (mainly species) are included.

Two limitations of this model are the one-dimensional (1D) structure that does not allow detailed study of localized conditions, and the reliance on representative parameter selection. Despite these limitations, experiences from four previous studies (Rio Grande study is not yet complete) indicate SRH-1DV has been an effective tool for analyzing vegetation coverage and response to changed conditions from alternative flow management scenarios. The 1D vegetation model is well suited to large river floodplains up to 100 miles in length and long temporal studies of up to eight decades. Despite the advances this tool offers, a general recommendation is to continue to apply numerical model assessments in comparative studies where the differences between results are more relevant than the absolute values. Recommendations for future SRH-1DV model applications are also included with suggested vegetation elements to be transferred to a 2D vegetation model.

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1. INTRODUCTION

SRH-1D is a one-dimensional (1D) flow and sediment transport model developed by the Sedimentation and River Hydraulics (SRH) Group at the Bureau of Reclamation (Reclamation) to study river flow and sediment transport processes. Details of the numerical solution of the SRH-1D flow computations, sediment transport algorithms, and channel representation can be found in Huang and Greimann (2007, 2010). In 2006, Reclamation's Technical Service Center (TSC) began expanding SRH-1D by adding vegetation, a third aspect of geomorphic processes, to river studies. Both SRH-1D and SRH-1DV are cross section based models that compute steady or unsteady water surface profiles and compute sediment transport capacity in multiple sediment sizes to report resulting vertical changes in the channel bed. However, SRH-1DV differs from SRH-1D by estimating groundwater and providing information on the establishment, growth, and mortality of riparian vegetation in the flood plain in response to the modeled flow and sediment transport scenarios.

SRH-1DV was developed by TSC for Reclamation's Mid Pacific Region and the cottonwood studies of the Sacramento River NODOS Project. Development of the numerical model SRH-1DV by TSC continues with each successive project application. It has been applied twice for Sacramento River studies (Reclamation, 2011; Fotherby and Greimann, 2012), and twice for San Joaquin River projects (Greimann and Fotherby, 2009; Holburn-Gordan, 2011). A Rio Grande SRH-1DV model and study are currently underway. In addition, Reclamation applied a predecessor of SRH-1DV, the 1D flow, sediment and vegetation model, SedVeg (Murphy et al., 2006), to Platte River studies from 1999 to 2006. Conference papers (Fotherby and Randle, 2007; Greimann and Fotherby, 2012) also detail the progress and improvements in numerical vegetation modeling.

Figure 1-1. The physical world is represented mathematically in a numerical model (Reclamation).

Required input for execution of the SRH-1DV program is geometry, flow, sediment, groundwater, and vegetation input files. In this compendium, we focus on the vegetation module, vegetation growth mechanics, vegetation input file, vegetation parameters, and resources for understanding the vegetation cycle of each plant. The information has been collected to document the current approach and understanding of 1D vegetation modeling (figure 1-1).

One-dimensional models expand our knowledge of systems and can be used to assess general trends in large regions and over multi-decadal periods of time. The proven utility of this tool has encouraged the Sedimentation and River Hydraulics Group and the Reclamation Science and Technology Program, to move forward on a two-dimensional (2D) vegetation model. A proposed 2D version will be suited to questions specific to localized site conditions and the 1D and 2D tools are intended to serve complementary needs. A 1D model provides vegetation trend information for the entire study area in response to changes in water management, and 2D results from a specific reach can inform on details, including changes in channel resistance from the loss or gain in vegetation at a site. We would like to aid future 1D and 2D vegetation studies, by documenting previous advances with the SRH-1DV models. Included are:

- descriptions of required vegetation input;
- documentation of vegetation parameters from previous studies;
- documentation of notes and resources for selecting vegetation input; and
- conclusions from studies summarizing the approaches and information most useful to future 1D and 2D numerical vegetation modeling.

2. NUMERICAL VEGETATION MODELLING

The vegetation model SRH-1DV was an expansion of SRH-1D with the addition of a groundwater module and a vegetation module for the Sacramento NODOS study. Vegetation life cycle mechanisms were expanded in successive projects.

Groundwater, a critical aspect of riparian vegetation growth, is estimated based on the river water surface, soil conductivity, and groundwater boundary conditions at the boundary of the cross section geometry. The model tracks the water table for each cross section and assumes that groundwater at one cross section is not significantly affected by groundwater at another cross section. The vegetation module allows representation of multiple vegetation types or land uses and tracks the growth of the different plants with respect to the surface flow and groundwater table at each point and at every cross section in the model (figure 2-1).

The simulated vegetation types are building blocks representing the riparian communities at the project site. Freemont cottonwood, Gooding's black willow, narrow leaf/sandbar willow, and upland grass have been included in most of the SRH-1DV models, in addition to a no-grow or cultivated land designation that is used to exclude developed areas in the flood plain.

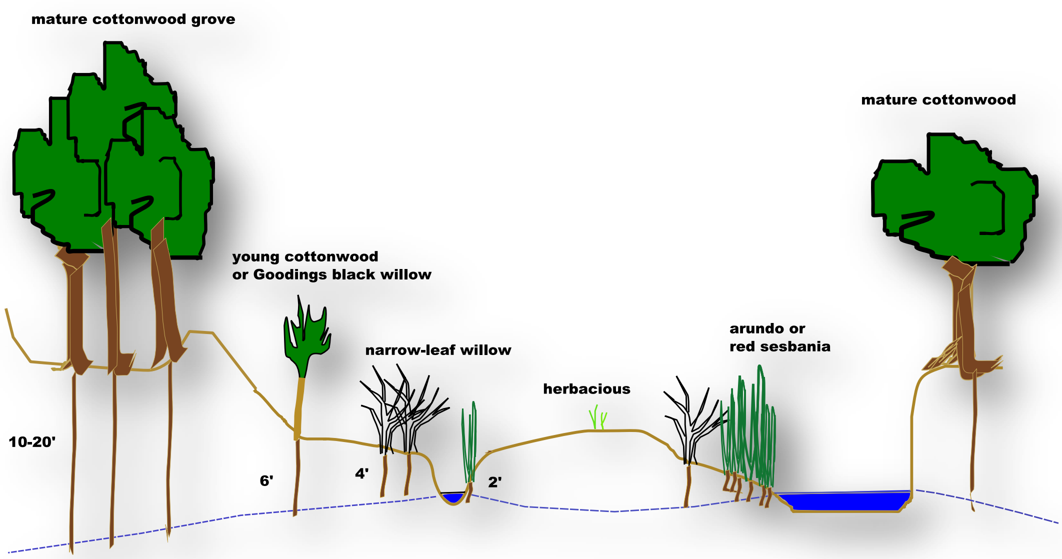


Figure 2-1. Sketch of model cross section relating river flow, groundwater, terrain elevation, vegetation location, and root depth

The model can track the establishment, growth, and mortality of vegetation on several hundred cross sections with several hundred points per cross section, and multiple vegetation types at each point. After establishment of the plant, the growth of roots, stems, and canopies are simulated, and the rules for plant survival through competition between plant types can also be defined. Modes of plant mortality can include desiccation, inundation (drowning), scour, competition, and shading. Mortality by burial or senescence (age) was also used briefly. Vegetation establishment, growth, and mortality are computed in response to daily inputs of flow, and the computed hydraulics, groundwater surface, and sediment transport.

River flow, sediment transport, and groundwater computations in SRH-1DV are based on physical laws including the momentum and mass conservation equations. The ecological processes of plant growth cannot be fully described by physical laws, but instead rely on parameters that describe each aspect of plant growth. Parameters describe root, stem and canopy growth for the plants at every stage of development, and parameters describe the response of plants to stress and mortality factors activated by geomorphic change (surface flow, groundwater, sediment transport) and environmental factors such as air temperature. Multiple parameters are required to describe plant establishment, growth, and mortality, so parameter selection is evaluated during modeling through sensitivity and calibration studies (figures 2-2a and 2-2b). SRH-1DV performs the complex tracking of vegetation response to geomorphic conditions, and produces the quantified predictions that aid assessment of river systems and floodplain management actions. Due to the large number of parameters involved, this tool is best used as a comparative predictor of scenarios instead of an absolute predictor of outcome.

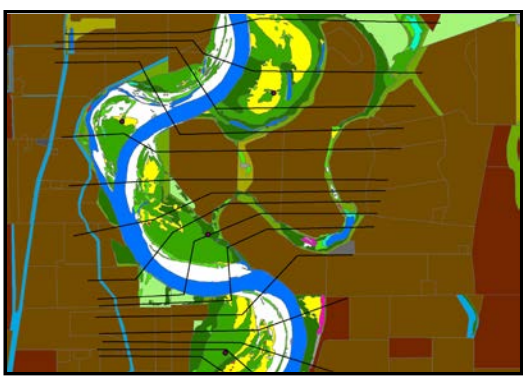
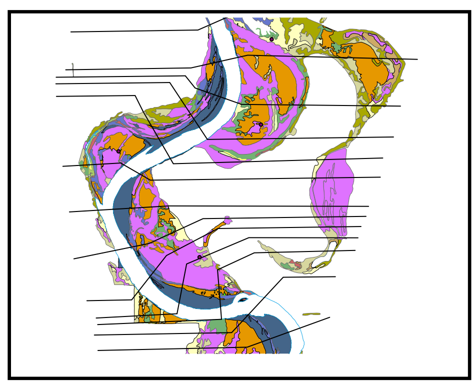



Figure 2-2a and 2-2b. Validation of simulated values for the Sacramento River using differences in 1999 and 2007 vegetation mapping.

Limitations

SRH-1DV is a computationally powerful tool but there are also limitations to keep in mind:

- The model is limited to a study of riparian vegetation where river water and not rainfall, is the predominant source of soil moisture.
- Lateral river shifts and associated changes in vegetation coverage cannot be represented in a 1D model.

- 1D models are dependent on a cross section structure to represent ground topography. Consistent representation of varying shapes of mapped polygans and detailed information on local conditions is difficult to obtain with a cross section representation. Also surface representation with cross sections can be problematic at contorted or compressed meander bends.
- Vegetation coverage between cross sections and between cross section points is represented by the conditions at the nearest point. An appropriate number of cross sections and good point coverage are needed at river banks where the physical terrain changes rapidly, and locations where flow conditions vary.
- Only identified factors of vegetation growth and survival are represented in the model.
- Many parameters are required to perform simulations of vegetation growth.
- Parameters are assigned from the known range of real world values but these values can vary based on regional and local climate patterns making sensitivity and calibration studies useful.

Benefits

Some of the benefits of this tool are:

- Simulations of linked geomorphic processes and riparian vegetation growth provide predictive and deterministic outcomes based on the assumed flow scenarios.
- Large project areas (100 miles) and long periods of time (70 years) can be evaluated.
- Multiple scenarios can be generated easily to bracket the range of response.
- Small distinctions between flow operations or other management actions can be more readily detected and understood with these quantitative results in comparison to general qualitative assessments.
- The complex response of vegetation can be more readily identified and understood.
- This tool is well suited to comparative assessments between alternatives.
- Many alternatives can be investigated in a cost effective manner, prior to the more costly approach of field implementation.

Groundwater Parameters

The location of groundwater is a major factor in the survival of riparian plants. An estimate of groundwater elevation is used in the model to determine the distance to the root tip of the plant (the lowest point of the plant), and for computing desiccation and inundation mortalities. Groundwater levels are a function of the river water elevation and a soil permeability coefficient. The module solves for the groundwater levels, and assumes no groundwater interaction between cross sections. Therefore, the groundwater solutions obtained from SRH-1DV will only be applicable near the river, i.e., generally within the alluvial soils of the floodplain. The user can enter separate saturated hydraulic conductivities for the left and right overbanks. It is also possible to enter a known flux or fixed water surface boundary condition at the ends of the cross section.

Groundwater parameters are assigned by cross section, similar to sediment inputs. The model assumes that each cross section is independent of the other cross sections. As an example, the saturated hydraulic conductivity that was calibrated based upon well data from the California Department of Water Resources (CDWR, 2005) is given in table 2-1.

Table 2-1. Example Groundwater Parameters for Simulation (Reclamation, 2011)

	Sacramento Calibrations (Reclamation 2011)	San Joaquin EIS (Greimann & Fotherby 2009)	Sacramento EIS (Fotherby & Greimann, 2011)	San Joaquin Restoration (Holburn-Gordon, 2011)	Rio Grande Habitat
Left and right hydraulic conductivity, ft/day (K)	100,000	100,000	100,000	100,000	100,000
Height of capillary fringe Ft *(Sand 0.8, Gravel 0.11)*	0.8 or 1.1	2	0.8 or 1.1	0.8	0.8
Maximum drop velocity ft/day *	0.5	0.5	0.5	0.5	0.5
Groundwater minimum height, ft (h_{min})**	20	50	20	50	20
Groundwater maximum height, ft (h_{max})***	1	-1	1	1	1

** Maximum value for groundwater decline is assigned if the channel goes dry for long periods.*
*** The groundwater surface elevation should not be h_{min} lower than the minimum water surface elevation in the cross section.*
**** If the bed is dry, the groundwater should not be more h_{max} higher than the bed elevation.*

Soil Conditions

The height of the capillary fringe is necessary to define the distance above the water table plants are able to extract water. The localized soil conditions are one of the most significant factors in vegetation establishment (Auchincloss et al., 2012). Finer soils retain moisture from precipitation and drops in the water surface more effectively. This translates to a shorter duration of drought for plants and less need for plant root growth or alternative coping mechanisms. Simulations with coarser soils will have smaller numbers of new plants surviving the first three years.

In rivers with some sediment load there can be a wide variation in sediment conditions from site to site. Even a single bedform feature can have abrupt transitions from coarse sediment to fine sediment within a few feet so a common question is what soil type should be selected. One-dimensional models are often used to represent the average conditions for an entire project area. The soil type in this instance might be selected for each cross section based on predominate soil types in the most active area of plant establishment, i.e banks, bars and/or active overbank areas. If the soil type is varied frequently within the main model, the soil type could be held constant in one simulation to look at the sensitivity of this factor and to aid understanding of extent of influence. A second approach is run two simulations with distinct conditions, one sand and one gravel, to identify the range of response, and a third approach is to use all sand in efforts to detect change when there are only small differences in the flow management plan.

In contrast to a 1D model, a 2D model is often more focused on local conditions and a detailed assignment of soil types should be considered. Future 2D models should include a means of assigning soil conditions to points or areas of the model surface to reflect the variation in soils that can be noted for example in backwater areas, across large sandbars, or on opposite banks with conditions alternating between meander bends.

Levees and Other Boundary Conditions

During dry periods with no flow in the channel, the minimum groundwater elevation (h_{min}) can be influenced by groundwater flow conditions outside the boundaries of the model. These conditions are generalized by assigning a lower limit (h_{min}) to groundwater elevation for lands within the model. A second limit, h_{max}, is assigned to the water surface on lands behind levees. Unless the levee is breached, surface water depth behind a levee is influenced more by drainage patterns of adjacent lands than by the surface water of the river. The three dimensional (3D) drainage patterns cannot be adequately described within the boundaries of the model, so a general maximum depth of flooding behind levees is assigned. Both h_{min} and h_{max} are values in feet with respect to the ground elevation.

Selecting Vegetation Types

Five sets of vegetation input files have been assembled for the development of the SRH-1DV model and four projects. Within the vegetation files are the parameters for each vegetation type and to date there has been as many as 13 vegetation types used in a single simulation. Initial conditions of mapped vegetation alliances are represented by the vegetation types selected for the model. The model can readily accommodate up to 20 vegetation types but the model code should have the capability of physically distinguishing the growth and survival methods of each vegetation type. There is also the practical interest in keeping the number of vegetation types to a manageable size for data analysis and reduction, while balancing the need to represent all main plants in the study area.

Type versus Alliance

The vegetation categories in the study area are described as vegetation types instead of ‘species’, ‘alliances’, or ‘designations’. A vegetation type is often a species, but can also be an alliance or designation. The first input file for Sacramento studies and development of the model contained only 3 vegetation types (table 2-2): Fremont cottonwood, grass and “no grow”. Fremont cottonwood is a species, no grow is a designation, and grass is a generic grouping or alliance of herbaceous and drought resistant upland grasses that provide ground cover. Each vegetation type is selected for a model because it may be a species of interest, a predominant plant in the study area, is needed to represent essential characteristics of a mapped alliance, or is geomorphically significant. Invasive plants like tamarisk or red sesbania can be geomorphically significant by strengthening banks and confining flows, causing increased flow velocities and sediment transport. Vegetation types from previous studies are included in table 2-2.

A no grow designation has been used in all studies including the initial development period (Sacramento River Cottonwood Calibration). The vegetation types herbaceous, herbaceous bank herbs and upland grasses are all a grass alliance used to define areas that cannot be colonized by plants like cottonwood, and to define areas that become available when the grass is scoured by high flows. With the exception of the vegetation type, grass, alliances have generally been less useful than representative species. Mixed forest and invasives are two alliances employed as vegetation types in the Sacramento studies. Mixed forest was a mapped vegetation designation that was matched in the model to aid the calibration study. A generic invasive was also selected to represent arundo, pepperweed and other invasive species. But a large drawback to using alliances is that the grouped plants can have widely varying parameters for germination, growth and mortality, and tradeoffs on accurate representation have to be made. Parameters for mixed forest, including germination season, soon evolved to average values, and parameters for the vegetation type- invasives became focused on the single most prevalent invasive plant, arundo. A grass alliance has worked because it is primarily a mechanical device for simulating germination, and generic parameters that support rapid colonization can be selected. Excluding the no grow and agricultural land no grow categories, and counting only one grass alliance, a total of 21 vegetation types have been used for SRH-1DV modeling. Excluding the mixed forest and invasive species alliances, 19 species have been distinctly represented in SRH-1DV.

Table 2-2. Vegetation types used in previous studies

Modeled Vegetation Type	Latin Name	Abbreviation
Sacramento River Cottonwood Calibration		
Freemont cottonwood	*Populus fremontii*	Fc
Grass	*NA*	grass
no grow	*NA*	nogr
San Joaquin River EIS Alternatives Analysis		
Freemont cottonwood	*Populus fremontii*	Fc
sandbar/narrow leaf/coyote willow	*Salix exigua*	sbw
Herbaceous	*NA*	grass
arundo*	*Arundo donax*	arun

Modeled Vegetation Type	Latin Name	Abbreviation
red sesbania/scarlette wisteria*	*Sesbania punicea*	rs
no grow	*NA*	nogr
Sacramento River EIS Alternatives Analysis		
Freemont cottonwood	*Populus fremontii*	Fc
mixed forest	*NA*	mxf
Gooding's black willow	*Salix gooddingii*	Gbw
sandbar/narrow leaf/coyote willow	*Salix exigua*	sbw
Herbaceous	*NA*	grass
invasive (mainly arundo)*	mainly *arundo donax*	inv
agricultural no grow	*NA*	ag
no grow	*NA*	nogr
San Joaquin River Restoration		
Freemont cottonwood	*Populus fremontii*	Fc
Oregon ash	*Fraxinus latifolia*	Oash
Gooding's black willow	*Salix gooddingii*	Gbw
sandbar/narrow leaf/coyote willow	*Salix exigua*	sbw
Elderberry	*Sambuscus*	eld
California wildrose	*Rosa californica*	rose
salt grass	*Distichlis spicata*	salt
bearded (creeping) rye grass	*Leymus triticoides*	crye
California mugwort/California sagebrush	*Artemisia californica*	mug
California bulrush	*Schoenoplectus californicus*	Cbr
buttonbush willow	*Cephalanthus occidentalis*	bbw
riparian bank herbs	NA	rbh
no grow	NA	nogr
Rio Grande Habitat		
Freemont cottonwood	*Populus fremontii*	Fc
Gooding's black willow	*Salix gooddingii*	Gbw
sandbar/narrow leaf/coyote willow	*Salix exigua*	sbw
seep willow/mulefat	*Baccharis salicifolia*	mule
honey mesquite	*Prosopis glandulosa*	hmq
four-wing saltbush	*Atriplex canescens*	fwsb
broad-leaved cattail	*Typha latifolia*	catt
Russian olive*	*Elaeagnus angustifolia*	Rolv
tamarisk/salt cedar*	*Tamarix sp.*	tam
upland grass	*NA*	grass
no grow	NA	nogr
**Invasive species*		

Initial Conditions

At the start of a model simulation there are no established plants on the framework of cross sections that represent the river geometry. SRH-1DV was developed with a feature to assign existing plants from vegetation mapping (figure 2-3), to cross sections prior to the model simulation. Cross section points are assigned vegetation types based on the mapped vegetation polygons that overlay the point location. A chart in the vegetation input file translates vegetation communities or alliances into representative vegetation types, ages and point densities for the start of the simulation. If vegetation mapping is not available, vegetation can also be grown in a warm-up period of 20 years or more prior to the main simulation to bring woody species to maturity.

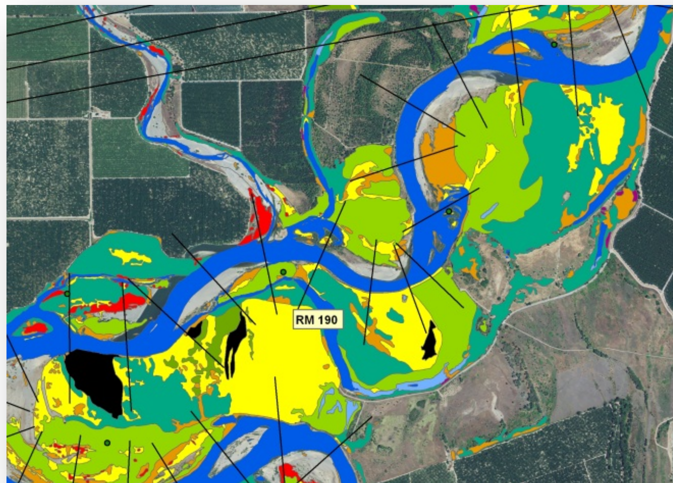


Figure 2-3. Vegetation mapping overlain on Sacramento River cross sections at River Mile (RM) 190 in SRH-1DV.

3. VEGETATION INPUT FILES

Similar to the vegetation observed in the field, the vegetation simulated in SRH-1DV will colonize sites and compete for survival using adaptive techniques and growth rates specific to each plant, and in response to changed conditions at each point location (flow, sediment transport, groundwater elevation, and air temperature for determining germination periods or icing). Different aspects of plant growth can be switched on or off or adjusted through the vegetation input file to match the characteristics of each vegetation type. These descriptors differentiate the plants and improve the simulation of plant life. Methods to describe and distinguish plant development have advanced with each project application.

Vegetation parameters in the input file are divided into two sections:

- general model parameters and a table to translate mapped initial conditions into the vegetation types simulated by the model; and
- germination, growth, and mortality parameters grouped by vegetation type.

Listed in tables 3-1 to 3-3 are descriptors of the computer field code used in the SRH-1DV vegetation input files (Greimann et al., 2011). The records and fields for general parameters and initial vegetation conditions are outlined in table 3-1; germination, growth and roughness parameters are outlined in table 3-2; and mortality parameters are outlined in table 3-3.

Table 3-1. General Vegetation Input Records and Vegetation Initial Condition Records for SRH-1DV (Reclamation et al., 2011).

Record	Fields		Field Descriptions
VNM	NVEG		Number of vegetation types
	NSOIL		Number of soil types
VPM	VDT		Vegetation time step
	VDTPLT		Vegetation output time step
VTM	SYR		Start year
	SMN		Start month
	SDY		Start day
	SHR		Start hour
VIN	GIS_NAME		Name of ARC-GIS shape file that will be read to determine initial vegetation coverage
VIT	VEG_ID		Name of field in shape file that will be read to identify the vegetation type
VIV	FIELD_NAME		Vegetation code correspond to names in shape file GIS_NAME field name VEG_ID
	1 to NVEG	AGE_INIT	Initial age of vegetation
		DENS_INIT	Initial aerial density of vegetation, if less than one then a fraction of points are assigned to that vegetation type

Table 3-2. Germination and Growth Input Parameters for SRH-1DV. Parameters are repeated for each vegetation type. Length is in feet, time is counted in days, and calendar days are assigned by Julian date (Reclamation, 2011).

Record	Fields	Field Descriptions
VVN	VNAME	Name of vegetation type, used for output descriptions
	GERMINATION	
MMT	MTYPE	Simulation method for germination: 1 = Seed dispersal by air, 2 = Seed dispersal by water
If MTYPE= 1		
MDY	MSTART	Start day for germination (Julian date)
	MEND	End day for germination (Julian date)
MPR	MDAYS	Days from time seeds fall on ground until growth starts during germination period.
	MMAX	Maximum number of days between germination and time when water table was within MHEIGHT of ground surface
	MHEIGHT	Height above groundwater table considered moist enough for germination
	MBELOW	Depth below groundwater table germination can still occur

Lateral Root Spread			
MLT	1 to N	MLT_AGE	Age specified for lateral root spread rates
		MLT_RATE (1 to 12)	Root growth rate each month
MEL	Maximum height of plant establishment above low water		
GROWTH			
GMT	GTYPE		Simulation method for growth (1 is only option)
GST	1 to N	GST_AGE	Age at which stalk growth rates are given
		GST_RATE (1 to 12)	Stalk growth rate at each month
GSM	GST_MAX		Maximum height of stalk
GCP	1 to N	GCP_AGE	Age at which canopy spread rates are given
		GCP_RATE (1 to 12)	Canopy spread rates at each month
GCM	GCP_MAX		Maximum width of canopy
GRT	1 to N	GRT_AGE	Age at which root growth rates are given
		GRT_RATE (1 to 12)	Root growth rate at given month
GRS	GRT		Depth below groundwater table at which growth of root stops
	GRT_DEPTH		Maximum depth of root growth
ROUGHNESS			
RMT	RTYPE		Simulation method of vegetation roughness computation (0 if input roughness is not altered, 1 if based on plant age)
RAM	1 to N	RAM_AGE	Average age of plants in cell
		RAM_ ROUGHNESS	Roughness value for average age of plants

Table 3-3. Mortality Input Parameters for SRH-1DV. Parameters are repeated for each vegetation type. Length is in feet, time is counted in days, and calendar days are assigned by Julian date (Reclamation, 2011).

MORTALITIES			
Competition			
CMT	CTYPE		Type of competition simulation performed (0 if none, 1 if age comparison)
If CTYPE= 1			
CID	CDEATH_ID		Identification number of competition death
CMP	1 to NVEG	CAGE	Age of species that could be killed
		KILL_AGE 1 to NVEG	Age of other species which could outcompete the species at given age
Shading			
CSH	SHADE_AGE		Age at which species become shade tolerant
Scour			
SMT	STYPE		Type of scour simulation performed (0 if none, 1 if critical velocity method)
IfSTYPE = 1			
SID	SDEATH_ID		Identification number of scour death
SVC	SAGE		Age at which critical velocity is given
	SVEL_CRIT		Critical velocity above which plant is killed due to scour
Burial			
BMT	BTYPE		Type of burying simulation performed (0 if none, 1 if local depth above top of plant is used as criteria)
IfBTYPE = 1			
BID	BDEATH_ID		Identification number of burying death
BDP	BDEPTH		Depth of burial above top of plant required to kill plant.
Inundation			
DMT	DTYPE		Type of drowning simulation performed (0 if none, 1 if depth below water surface method)
IfDTYPE= 1			

Record	Fields		Field Descriptions
DID	DDEATH_ID		Identification number of drowning death
DTM	DAGE		Age at which time and depth of drowning is given
	DTIME		Number of days the root crown must be below DDEPTH for drowning
	DDEPTH		Depth below water surface the root crown must be for drowning to take place
Desiccation			
YMT	YTYPE		Type of desiccation simulation performed (0 if none, 1 if number of days above capillary fringe method, 2 is water stress method)
If YTYPE = 1or2			
YID	YDEATH_ID		Identification number of desiccation death
If YTYPE = 1			
YTM	YAGE		Age at which time and height above capillary fringe is given
	YTIME		Number of days the root elevation must be YHEIGHT above the capillary fringe
	YHEIGHT		Height above capillary fringe the roots must be for death by desiccation
If YTYPE = 2			
YWT	1 to N	YWT_RATE	Rate of water table decline
		DESC_RATE (1toNSOIL)	A desiccation rate is entered for each soil type (NSOIL).
If YTYPE = 1or2			
YMN	YMN(1to12)		Indicates if desiccation can or cannot occur in a given month (1 or 0, respectively)
Ice Scour			
IMT	ITYPE		Type of ice scour simulation performed (0 if none, only current option
Senescence			
AMT	ATYPE		Type of age death simulation performed (0 if none, only current option)
If ATYPE = 1			
AID	ADEATH ID		Identification number of age death
ATM	AMAX		Age at which death occurs
END			

General Parameters and Initial Conditions

VIN, VIT and VIV records are used when GIS vegetation mapping is available to assign existing vegetation conditions to model cross sections at the start of the simulation. A VIN record identifies a file with a table of mapped polygons (csv file) constructed from a GIS file of polygons (shp file). The shp file contains labels, areas, and other information associated with each vegetation polygon. The VIT record identifies the list containing names of vegetation communities in the csv file. The VIV file matches GIS mapped communities to the initial age and density of the associated model vegetation types. For example, the GIS shape file may contain 30 mapped categories of land use, which are translated into 8 modeled vegetation types using the VIV records. Due to the size of the tables, the initial conditions tables with values from previous SRH-1DV studies are presented in the Appendix.

Plant Density

Density is input to the initial conditions tables as a decimal representing the percent of points in the mapped polygon. For a density of 0.1 or 10 percent, the associated age and type of vegetation is assigned to 1 point out of every 10 points in the mapped polygon. A vegetation type excluded from a mapped community is assigned an age of 0. For example an area described as “Riparian Scrub” may have sparsely located grasses, occasional shrubs, and a rare tree. All riparian scrub polygons would be assigned points:

- 1-year grass at 6 out of 10 points
- 3-year willow at 3 out of 10 points
- 10-year cottonwood at 1 out of 10 points

All other vegetation types in the riparian scrub VIV record would be assigned an age of 0.

Descriptions of the mapped communities and aerial photos were used to match communities with vegetation types in the existing conditions table, and to assign average densities and representative ages. After initialization, the model tracks growth of the assigned plants, in addition to computing new vegetation (germination) when conditions are suitable. GIS mapping has been used to assign vegetation to all SRH-1DV models, and assigning density to initial conditions began with the later SRH-1DV models: Sacramento River Alternatives Analysis; San Joaquin River Restoration Analysis; and the Rio Grande Habitat Study.

Parameters Input by Vegetation Type

Theriot (1993, p. 2) relates the historical development of vegetation continuum that is synonymously descriptive of the methodology for representing multiple vegetation types in a numerical model:

> "Gleason (1917) proposed a hypothesis relating to the individualistic occurrence of plants. His hypothesis has developed into the continuum concept, which indicates that plant species distribution is determined by the species' response to its environment. Whittaker (1967) and McIntosh (1980) later developed Gleason's ideas, expanding on the continuum concept. They maintain that since plant species adapt differently, no two occupy the same zone. This concept results in a continuum of overlapping species associations, each responding to subtly different environmental factors… groups of species have fairly similar tolerances that tend to group them on these gradients (Mitsch and Gosselink 1986). Gleason's individualistic hypothesis can be supported by several studies (Curtis and McIntosh 1951, Brown and Curtis 1952, Bray 1956, Whittaker 1956, Curtis 1959, Whittaker and Niering 1965, and Mohler 1979). These studies show that although species have different ecological amplitudes and do not occupy the same niche, they organize as units based on similar ecological conditions. Moreover, intergrades caused by interspecific competition occur between defined types of plant associations...attributed to continuous environmental variability in time or space or to environmental modification."

The simulation of plant establishment, growth and mortality and the zones that they occupy, i.e. the individual occurrence of plants, is dependent on representing the tolerance of each vegetation type to conditions and seasons. Not all conditions and the full range of plant responses can be included in the numerical model. The intent is to represent conditions for the most significant vegetation factors and plant responses, and select parameters that define and distinguish the tolerance of the plant (vegetation type) to the represented conditions.

Figure 3-1. Gooding's black willow seeds (Reclamation)

Each vegetation type in the numerical model is identified by the

VVN record, followed by the parameters associated with that type. For eight vegetation types, there would be eight sets of parameters. Parameters are often entered in tables by age of the plant type. Parameters are interpolated by the model when the plant age falls between the values listed in the table. If the age is smaller than the first age listed in the table, the parameter of the first age is used. If the age is larger than the last age listed in the table, the parameter of the last age is used. Germination, growth, and mortality parameters are described in the next sections, and the parameters from previous SRH-1DV models for each vegetation type are similarly organized and presented by plant life stages.

Figure 3-2. Red sesbania seed pods floating on the water (Reclamation)

Germination Parameters

Vegetation can spread in the simulation through seed germination and/or lateral root growth. The main assumption for air dispersed seed germination is an unlimited supply of seed available during the seed dispersal period (figure 3-1) and seed can be distributed throughout the study area. The seed dispersal method has also been used to represent the spread of seed consumed and spread by birds or animals. This dispersal may be more restricted but at this time there is no germination technique to represent a more restricted dispersal.

An approach for water dispersed seeds and propagules was tested in the San Joaquin River Alternatives Analysis and in the Sacramento River Alternatives Analysis, but still requires further development. A water germination option would enhance modeling for native and invasive riparian species (Groves et al., 2009; Watterson and Jones, 2006) but is not used at this time (figure 3-2).

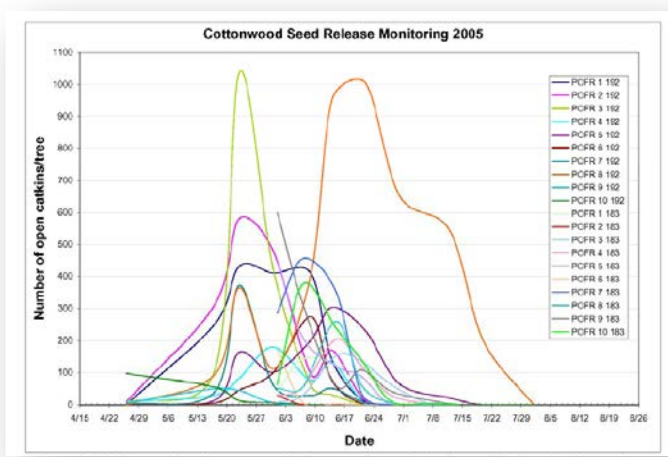


Figure 3-3. Cottonwood seed release characteristics at CDWR study sites RM183 and RM 192.5 on the Sacramento River. Catkins are a strand of tiny, inconspicuous and short lived flowers on cottonwoods (figure from CDWR, 2005).

MDY, Begin and End Date of Dispersal Season. Seed dispersal dates reported by the California Department of Water Resources (CDWR) from 2005 field studies were used in Sacramento River studies (figure 3-3). Seed dispersal dates can also be found in journal articles and the Fire Effects series by the USFS. The dates of germination seasons can vary with the region and climate, supporting the premise the germination season is better tied to air temperature than established by calendar dates (Morgan, 2005; Stillwater Sciences 2006, Stella et al., 2006). There is an option in the model to assign the seed dispersal period by temperature. Daily air temperatures for each year of simulation are entered on a separate sheet of the input file. This option has not been used although the function for germination of cottonwood, Gooding's black willow and sandbar willow are available from the San Joaquin River.

An option is available to add a second air-dispersed germination period. Some species may have two germination periods (honey mesquite) or the germination period may be split by the calendar year in warmer climates. For example the first period of upland grass propagation may include the winter Julian Days for October to December and the second period may extend from January to March.

MDY- MSTART- Start of seed dispersal period in Julian Days
MDY- MEND- End of seed dispersal period in Julian Days

MPR, Germination Parameters for Air Dispersed Seeds. A new plant can germinate and begin to grow every day of the assigned germination period with good moisture conditions and if shade or competition rules (including bare ground requirements) do not immediately eliminate the young plant. Four parameters describe germination: the length of the germination period, MDAYS, a grace period from desiccation immediately following germination, MMAX, the height of the capillary zone above the water table (fringe height), MHEIGHT, and the distance below groundwater a seed can still germinate, MBELOW. MMAX, the grace period after germination, includes two assumptions: 1. roots begin to grow from the surface, and 2. sufficient moisture remains in the seed pod, new plant or drying soils following germination, to survive a short period if the capillary zone drops below the surface of the ground. MMAX is the maximum number of days allowed after germination, for the new roots of the plant to be separated from the capillary zone of the soil. Capillary fringe height, MHEIGHT, depends on the soils but is often assigned a value of 1 foot. Similar to soils, MHEIGHT can vary within the study reach but is assigned only one value per vegetation type in the simulation.

MPR- MDAYS. Days for germination to occur. With good moisture conditions, a plant can emerge MDAYS after the first day of the germination period, and seeds can continue to emerge until MDAYS after the end of the germination period.
MPR- MMAX. Maximum number of days after germination, when desiccation will not remove plants. This applies when the capillary fringe height (MHEIGHT) is below the ground surface where the seed is located.
MPR- MHEIGHT. Capilary zone or distance above groundwater that soil remains moist.

MPR- MBELOW. Distance below the groundwater that germination can still occur. Plants with no ability to germinate under water are assigned values of 0.01 ft and plants with more tolerance (California bulrush or broad leaf cattail) can have values of 0.2 to 0.5 ft.

Plant characteristics data fields from the USDA NRCS plant database that are helpful in determining germination parameters for the SRH-1DV vegetation input file are:

Fruit/Seed Abundance: What is the amount of seed produced by the plant compared to other species with the same growth habit?

- None, Low, Medium, High

Fruit/Seed Period Begin: Season in which the earliest fruit or seed of the fruit/seed period is visually obvious.

- Spring, Summer, Fall, Winter, Year-round

Fruit/Seed Period End: Season in which the latest fruit or seed of the fruit/seed period is visually obvious.

- Spring, Summer, Fall, Winter, Year-round

Fruit/Seed Persistence: Are the fruit or seed generally recognized as being persistent on the plant?

- Yes, No

Propagated By Bare Root: Is it practical to propagate this plant as a bare root product?

- Yes, No

Propagated By Seed: Is it practical to propagate this plant by seed?

- Yes, No

Cold Stratification Required: Will cold stratification significantly increase the seed germination percentage of this plant?

- Yes, No

Propagated By Sprigs: Is it practical to propagate this plant by sprigs?

- Yes, No

Propagated By Tubers: Is it practical to propagate this plant by tubers?

- Yes, No

Seed Spread Rate: What is the capability of the plant to spread through its seed production compared to other species with the same growth habit?

- None, Slow, Moderate, Rapid

Seedling Vigor: What is the expected seedling survival percentage of the plant compared to other species with the same growth habit?

- Low, Medium, High

Vegetative Spread Rate: At what rate can this plant can spread compared to other species with the same growth habit?

- None, Slow, Moderate, Rapid

Germination parameters for air-spread seeds from previous SRH-1DV models are listed in table 3-4. Water spread germination is under development.

Table 3-4. Air-Spread Seed Germination Parameters from SRH-1DV Models. Season is in Julian Days (JD).

Type	MDY Seed dispersal season 1 (JD)	MDY Seed dispersal season 2 (JD)	MDAYS Days to germinate[1]	MMAX Max. days seed can endure dry conditions[2]	MHEIGHT Capillary (ft)[3]	MBELOW Depth below g.w. germination can still occur (ft)[4]
Sacramento River Alternatives Analysis						
Fc	120-180		0.5	2	1	0.1
mxf	135-160		1	2	0.5	0.01
Gbw	144-162		0.5	2	1	0.2
sbw	129-273		1.5	2	1	0.2
hb	0-150		1	45	200	0.01
inv	90-210		1	6	1	0.2
San Joaquin River Restoration						
Fc	120-180		0.5	2	1	0.1
Oash	90-152		1	2	1	0.01
Gbw	144-162		0.5	2	1	0.2
sbw	129-273		1.5	2	1	0.2
eld	91-151		1.5	2	10	0.01
rose	91-152		1.5	7	10	0.01
salt	121-243		1	2	1	0.1
Crye	150-195		1	2	1	0.01
mug		*None- mainly fire spread so germination must be initiated in select years*				
Cbr	198-260		1	2	0.75	0.2
bbt	152-273		1	2	1	0.2
rip	182-273		1	2	1	0.2
Rio Grande Habitat Study						
Fc	105-182		0.5	2	1	0.10
Gbw	130-148		0.5	2	1	0.20
sbw	129-273		1.5	2	1	0.20
mule	90-240		1.5	2	1	0.01
hmq	99-151	211-271	0.3	2	1	0.01
fwsb	74-120		14	2	40	0.00
catt	198-260		3	2	0.75	0.5
Rolv	90-240		3	2	1	0.10
tam	183-274		1	2	1	0.20
grass	80-150		1	2	200	0.01

Germination/Growth Parameter - Lateral Root Spread Rate

Figure 3-4. The stolon (similar to rhizome) of a phragmites plant spreading 25 feet across a sand bar, Platte River, Nebraska (Reclamation)

A lateral root spread feature was added to represent plants that expand coverage area through root growth. It is both a growth parameter and a germination parameter but is located in the vegetation input file with germination parameters. Lateral root growth tracking can be activated in combination with germination through seed dispersal. Sandbar willow, arundo and red sesbania are examples of plants that spread by both seed and lateral root growth.

Lateral root growth can also be used as a mechanism to represent the spread of plants through rhizomes or stolon (figure 3-4). Once the root or rhizome extends half the distance to the next lateral cross section point, or points on the next cross section upstream or downstream, the adjacent point is colonized by a similar plant.

MLT Age. Age at which lateral root spread rates are given.
MLT Rate (12) – Lateral root spread rate. There are 12 root spread values to assign, one for each month.

MEL – Maximum height of plant establishment above low water. This value limits lateral root spread to a maximum elevation roots can move water to. Red sesbania and arundo are both present on the San Joaquin River but red sesbania (allelopath) can out compete arundo except at higher locations above the river where red sesbania cannot colonize (possibly shorter roots). The MEL for arundo should be assigned a larger value than the red sesbania MEL to represent the higher elevations that arundo can colonize. Lateral spread rate parameters that have been used in previous SRH-1DV models are listed in table 3-6.

The plant characteristics data fields from the USDA/NRCS plant database that are helpful in determining lateral root growth parameters for the SRH-1DV vegetation input file are:

Growth Form: What is the primary growth form on the landscape in relation to soil stabilization on slopes and streamsides? Each plant species is assigned the single growth form that most enhances its ability to stabilize soil.

- **Bunch:** Plant development by intravaginal tillering at or near the soil surface without production of rhizomes or stolons.

- **Colonizing:** A plant that is likely to behave as a colonizer when planted to enhance soil stabilization.
- **Multiple Stems:** Plant development by producing two or more stems. Examples: roundleaf dogwood (*Cornus rugosa*) and red huckleberry (*Vaccinium parvifolium*).
- ***Rhizomatous:*** *Plant development by the production of rhizomes which give rise to vegetative spread.*
- **Single Crown:** A herbaceous plant that develops one persistent base.
- **Single Stem:** Plant development by the production of one stem. Examples: corn (*Zea mays*) and American beech (*Fagus grandifolia*).
- ***Stoloniferous:*** *Plant development by the production of stolons which give rise to vegetative spread.*
- **Thicket Forming:** A plant that is likely to develop thickets when planted to stabilize soil.

Table 3-6. Lateral Spread Rate Parameters (MLT and MEL) from SRH-1DV Models

Veg Type	MEL.	Age*	Jan**	Feb**	Mar**	Apr**	May**	Jun**	Jul**	Aug**	Sep**	Oct**	Nov**	Dec**
San Joaquin River Alternatives Analysis														
ar	12	0	0	0	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0
rs	3	0	0	0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0
Sacramento River Alternatives Analysis														
sbw	200	0	0	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0
		1	0	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0
San Joaquin River Restoration														
sbw	25	0	0	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0
		1	0	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0
eld	100	0	0	0	0	0.04	0.04	0.04	0.04	0.04	0.04	0	0	0
		1	0	0	0	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0
rose	100	0	0	0	0	0.065	0.065	0.065	0.065	0.065	0.065	0	0	0
salt	10	0	0	0	0	0	0.03	0.03	0.03	0.03	0.03	0	0	0
crye	50	0	0	0	0	0	0.42	0.42	0.42	0.42	0.42	0	0	0
Cbr	50	0	0	0	0	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0
rbh	75	0	0	0	0	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0
Rio Grande Habitat Study														
sbw	25	0	0	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0
		1	0	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0
catt	25	0	0	0	0	0.033	0.033	0.033	0.033	0.033	0.033	0	0	0
tam	15	0	0	0	0	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0	0
		1	0	0	0	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0	0

**MLT_Age in years*
***MLT_Rate, monthly spread rate, in ft/day*

Growth Parameters

Stalk Growth Rate, GST, Maximum Height of the Stalk, GSM. The stalk growth rate defines growth by plant age for each month of the year and maximum height of the stalk halts growth when the maximum plant height is reached. Stalk growth rate and maximum height are not relevant to other computations in the model, but do control the appearance of the stalk in the cross-section window during the simulation. Quality control and understanding of processes are both enhanced by observing cross sections during the simulation. Since the values were assigned to differentiate the vegetation type on screen, and were inconsequential to the results from previous SRH-1DV studies, these values are not presented.

Plant height was used in the Platte River studies to compute the sight distance for Whooping Crane where tall vegetation was undesirable, and height can be used to determine channel roughness, especially in a 2D model. Age can be used as a surrogate for plant stature since the growth rate is a direct function of age, but does not represent differences in monthly growth rates. Plant height as an indicator would also become more valuable if the growth of plants was advanced to become a function of plant age, monthly growth rate, AND water stress (less growth with less moisture).

GCP, Shaded Canopy Spread Rate. The growth of the canopy is tracked radially out from the point and the spread rate can be assigned by month. This value is presently used to compute shading mortality. When the canopy extends over shade susceptible plants on an adjacent point, the plant covered by canopy/shade is removed. The canopy growth rate is often calculated from the reported average canopy radius, divided by the age of the plant at maturity.

*GCM, Maximum Canopy Width (Radius).*This value limits the canopy spread to a maximum specified radius. This parameter is normally assigned an average value for the species.
Maximum canopy radius and shaded canopy spread rates for each month of the year are listed in table 3-7.

Table 3-7. Canopy Spread Rate (ft/day) for Each Month (GCP) and Maximum Canopy Radius (GCM), ft, from SRH-1DV Models

GCM veg type/max radius (ft)	**GCP Age**	**GCP Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sacramento R. Alternatives Analysis													
Fc/10, mxf/15 Gbw/10	0	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0
	2	0	0	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0
	15	0	0	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0
	45	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0
Sbw/0.1 herb/0.1 inv / 0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
San Joaquin R. Alternatives Analysis (EIS)													
arun/3	0	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0
red/3	0	0	0	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0
San Joaquin R. Restoration Analysis													
Fc/10 Oash/15 Gbw/10	0	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0
	2	0	0	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0
	15	0	0	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0
	45	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0
Sbw/0.1 rose/0.2 crye/0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
eld/0.5	0	0	0	0	0.004	0.004	0.004	0.004	0.004	0.004	0	0	0
mug/3	0	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0.01	0.01
Cbr/0.4	0	0	0	0	0.004	0.004	0.004	0.004	0.004	0.004	0	0	0
bbw/6	0	0	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0	0	0
rbh/2	0	0	0	0	0.003	0.003	0.003	0.003	0.003	0.003	0	0	0
Not Used													
salt/0.1 ppw/0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
arun/3	0	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0
tamx/ 0.4	0	0	0	0	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0	0
red/0.4	0	0	0	0	0.004	0.004	0.004	0.004	0.004	0.004	0	0	0

Rio Grande Habitat Study													
GCM. veg type /max radius (ft)	**GCP. age**	**GCP. Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Fc/10 Gbw/10	0	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0
	2	0	0	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0
	15	0	0	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0
	45	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0
sbw/0.1 upgrass/0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
mule/4	0	0	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0	0
	2	0	0	0	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0	0
hmq/0.1	0	0	0	0	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0	0
	1	0	0	0	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0	0
	2	0	0	0	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0	0
	4	0	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0	0
Fwsb/3.5	0	0	0	0	0.005	0.005	0.005	0.005	0.005	0.005	0	0	0
catt/0.4	0	0	0	0	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0	0	0
Ro/15	0	0	0	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0	0
	3	0	0	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0	0
Tamx/2	0	0	0	0	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0	0

GRT (GRT_Age, GRT_Rate), Root Growth Rate. Values for root growth rate are assigned by plant age (GRT_Age) for each month of the year (GRT_Rate). If root growth can be sustained at the same rate as the drop in water table elevation, the roots can continue to supply the plant with moisture from groundwater (figure 3-5). The root growth parameter is best thought of as a "no stress" root growth value.

GRS (GRT), Maximum Depth of Root Below the Water Table Before Growth Stops. Root growth is often limited by the proximity of the groundwater table and the tolerance of the root to wet soils. The National Wetlands Indicator that is available from USDA NRCS Plant Characteristics Information online can help in determining an appropriate GRT parameter. Many of the riparian plants simulated in the model do not grow underwater but wetland plants like cattail and bulrush have anaerobic tolerance and other coping mechanisms that allow gas exchange when the roots (and sometimes the root cap) are submerged. This parameter is another useful means of distinguishing plant characteristics.

GRS (GRT_Depth), Maximum Depth of Root Growth. Maximum root depth is one of the most sensitive parameters in the model for defining survival between different vegetation types. Maximum root depth is a function of the maximum depth the plant species can move moisture and nutrients from (physiology); soil moisture availability and the rate and depth of groundwater drop during new plant development; the proximity of the groundwater surface (anaerobic tolerance-roots require oxygen to transpire) can restrain growth; and soil and geological conditions. Densely compacted soils or rock can restrict the extension of roots and aeration, but in the simulation we assume maximum depths can be attained in the alluvial soils. Aeration is addressed with inundation tracking described under plant mortality and with the value for GRS (GRT) *Maximum Depth of Root Below the Water Table Before Growth Stops*.

Figure 3-5. Two sandbar willow from the same germination period. The right plant died earlier from desiccation and has less root and stem development (Reclamation).

The GRT_Depth parameter is normally the maximum depth that the plant physiology can reach and represents the tap root, not the lateral spread of roots. The growth of a taproot appears to be most prominent in young plants up to about 6 years. Riparian plants are often phreatophytes, and at least initially are dependent on rapid vertical root growth for soil moisture from groundwater. SRH-1DV does not directly account for precipitation in the analysis of plant survival. Lateral root growth development (occurring with tap root development for woody species) may reduce plant reliance on the groundwater table. Lateral root growth is represented as a plant colonizing mechanism under model germination, but is not tracked as a source for soil moisture in mortality computations. Plant stress in the simulation is based on proximity to groundwater and does not credit for precipitation, so in semi-arid and arid climates, root depths and growth rates used in the model should be the more rapid and of deep values reported in the literature. Resources for maximum root growth include Zimmerman (1969), honey mesquite papers (see honey mesquite resources in Chapter 4) and the fire effects series of papers available online from the U.S. Forest Service (see all species resources in Chapter 4).

Table 3-8. Root growth parameters GRT (ft), GRT_Depth (ft), GRT_Age (yrs), and GRT_Rates (ft/day) from previous studies

Type	max depth below		Age	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	water table	Ground													
Sacramento River Alternatives Analysis															
Fc	0.1	24	0	0	0	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0
			6	0	0	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0
Mxf	0.01	20	0	0	0	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0
			6	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
Gbw	0.1	22	0	0	0	0.0656	0.0656	0.0656	0.0656	0.0656	0.0656	0.0656	0.0656	0.0656	0
			6	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
Sbw	0.2	8	0	0	0	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0
Herb	0.01	0.5	0	0.0042	0.0042	0.0042	0.0042	0	0	0	0	0.0042	0.0042	0.0042	0.0042
Inv	0.2	5	0	0	0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0
San Joaquin River Alternatives Analysis (EIS)															
Arun	0.2	3.5	0	0	0	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0
Red	1	2.5	0	0	0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0
San Joaquin River Restoration Analysis															
Fc	0.1	24	0	0	0	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0
			6	0	0	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0
Oash	0.1	20	0	0	0	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0
			6	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
Gbw	0.1	22	0	0	0	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0
			6	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
Sbw	0.2	8	0	0	0	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0
Eld	0.01	6	0	0	0	0	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0
Rose	0.01	4	0	0	0	0	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0	0
Salt	0.2	1	0	0	0	0	0.02	0.02	0.02	0.02	0.02	0.02	0	0	0
Crye	0.2	10	0	0	0	0	0	0.04	0.04	0.04	0.04	0.04	0	0	0
Mug	0.01	2	0	0.004	0.004	0.004	0.004	0	0	0	0	0	0	0.004	0.004
Cbr	2	3	0	0	0	0	0.004	0.004	0.004	0.004	0.004	0.004	0	0	0
Bbt	0.2	6	0	0	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0
Rbh	0.2	4	0	0	0	0	0.006	0.006	0.006	0.006	0.006	0.006	0	0	0
Not Used															
Ppw	0.1	10	0.1	0	0	0.04	0.04	0.04	0.04	0.04	0	0	0	0	0
Arun	0.2	3.5	0	0	0	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0
Tamx	1	40	0	0	0	0	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0	0
			1	0	0	0	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0	0
red	1	2.5	0	0	0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0

Rio Grande Habitat Study															
Fc	0.1	24	0	0	0	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0
			6	0	0	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0
Gbw	0.1	22	0	0	0	0.0656	0.0656	0.0656	0.0656	0.0656	0.0656	0.0656	0.0656	0.0656	0
			6	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
sbw	0.2	8	0	0	0	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0
mule	0.01	7	0	0	0	0	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0
hmq	0.2	100	0	0	0	0	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0	0
			1	0	0	0	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0	0
			2	0	0	0	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0	0
			4	0	0	0	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0	0
fwsb	-5	30	0	0	0	0.0133	0.0133	0.0133	0.0133	0.0133	0.0133	0.0133	0	0	0
catt	2	3	0	0	0	0	0.033	0.033	0.033	0.033	0.033	0.033	0	0	0
Ro	0.1	40	0	0	0	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.03	0
			3	0	0	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0
tamx	1	40	0	0	0	0	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0	0
			1	0	0	0	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0	0
upgrass	0.01	0.5	0	0.0042	0.0042	0.0042	0.0042	0	0	0	0	0.0042	0.0042	0.0042	0.0042

Plant characteristics data fields listed below are available online from the USDA NRCS plant database and can be helpful in determining growth parameters for the vegetation input file. Root growth parameters for previous SRH-1DV models are presented in table 3-8.

Growth Rate: What is the growth rate after successful establishment relative to other species with the same growth habit?

- Slow, Moderate, Rapid

Height at Base Age, Maximum: Maximum height (in feet) of a tree, shrub or sub-shrub, under ideal conditions, at a base age. The base age is 20 years for trees in temperate areas (>30 degrees north latitude), 10 years for trees in tropical areas (≤30 degrees north latitude), and 10 years for all shrubs and sub-shrubs. Ideal conditions are defined as soil pH = 5.0-7.8; soil salinity ≤ 4 mmhos/cm; soil depth ≥ 40 inches; effective average annual precipitation ≥ 30 inches; soil texture class = medium [silts]; no ponding; rare or no annual flooding; and high water table depth ≥ 1 foot during plant active growth period. Plants other than trees, shrubs, and sub-shrubs are left blank here.

Height at Maturity: Expected height (in feet) of plant at maturity. This is an estimate of the median mature height of all plants of a species or cultivar. Within a species mature height is quite variable, so this estimate is provided only to give a rough idea for planning purposes.

Frost Free Days, Minimum: The minimum average number of frost-free days within the plant's known geographical range. For cultivars, the geographical range is defined as the area to which the cultivar is well adapted rather than marginally adapted.

Root Depth, Minimum: The minimum depth of soil (in inches) required for good growth. Plants that do not have roots such as rootless aquatic plants (floating or submerged) and epiphytes are assigned a minimum root depth value of zero.

Roughness

The user can define the relationship between roughness coefficients and vegetation age in the SRH-1DV model. An initial set of roughness values for the main channel and left and right overbanks is taken from the geometry input of the model. During the simulation, the roughness can be modified point by point based upon the type and age of the vegetation species that is present. The average roughness is then computed in the main channel and left and right overbanks. The total hydraulic roughness of the cross section is the conveyance weighted composite of the main channel and left and right overbanks. Roughness values from previous studies are listed in table 3-9.

The relationship between roughness and vegetation age has not been extensively tested in the previous simulations. Future field data and sensitivity analysis will help to incorporate more reliable mechanisms to link vegetation growth and roughness. This might slightly change the water surface elevation, and thus impact the estimates of erosion and deposition, and may have some influence on vegetation mortality associated with scour or inundation. A sensitivity analysis was conducted on the in-channel Manning's roughness coefficient for a levee setback alternative on the San Joaquin is given in Appendix A.

Table 3-9. Roughness parameters (Manning's n) used in previous studies.

Sacramento River Alternatives Analysis

Fc		Mxf		Gbw		sbw		herb		inv	
age	n	Age	n	age	n	age	n	age	n	age	n
0	0.04	0	0.04	0	0.04	0	0.04	0	0.04	0	0.04
5	0.06	5	0.06	5	0.06	5	0.07	5	0.045	5	0.07
30	0.08	30	0.08	30	0.08	30	0.01	30	0.045	30	0.1

Rio Grande Habitat Study

Fc		Gbw		sbw		mule		hmq	
age	n	Age	n	age	n	age	n	age	n
0	0.04	0	0.04	0	0.04	0	0.04	0	0.04
5	0.06	5	0.06	5	0.07	5	0.07	5	0.07
30	0.08	30	0.08	30	0.1	30	0.1	30	0.1

fwsb		catt		Ro		tam		upgras s	
age	n	Age	n	age	n	age	n	age	n
0	0.04	0	0.04	0	0.04	0	0.04	0	0.04
5	0.06	3	0.08	5	0.06	5	0.07	5	0.045
30	0.08			30	0.08	30	0.1	30	0.045

San Joaquin River Alternatives Analysis and Restoration Study

Roughness is shut off for all vegetation, i.e. channel and overbank roughness do not change with the growth of vegetation.

Mortality Parameters - Desiccation

Resilience to drought varies widely with species. Fremont cottonwood and Gooding's black willow have drought-coping mechanisms as adult plants that increase the plants resilience. Horton et al. (2001) report on the canopy dieback mechanism that allows plants to reduce water consumption through branch sacrifice during dry periods. A coping mechanism for cottonwood seedlings is illustrated in figure 3-6 with a laboratory study by Stockholm Environment Institute at UC Davis for development of the Riparian Habitat Establishment Model, RHEM (Reclamation, 2011). In the figure, the pod of cottonwood seedlings subjected to dryer conditions (no irrigation and a water table decline of 1cm/day) has less canopy development. As described by the RHEM model (Reclamation 2011), energy is transferred from stem and canopy growth to root growth when water resources are limited. There are increasing numbers of plant loss as a water shortage continues and the coping mechanisms of the plants no longer conserve a sufficient amount of moisture.

Drought mortality for seedlings is also a function of the soils. Shown in figures 3-7a and 3-7b are seedling survival field measures in both sandy and gravel soils. Field data on cottonwood seedlings was collected from two bars on the Sacramento River in 2006. Sandy soils support cottonwood seedlings over a wider elevation band (1.3 ft vs. 1 ft). Finer soils are more successful at retaining moisture and the relationship between river water surface and the minimum elevation of seedling establishment in sandy soil can be less direct. Field measurements were used to calibrate the effects of soil type and the desiccation of cottonwood seedlings simulated with SRH-1DV.

Desiccation mortality, YMT, can be simulated two different ways in the SRH-1DV model, a root depth method, YTM, and a cumulative water stress method, YWT. At this time the water stress method of simulating plant mortality applies specifically to young cottonwood plants less than one year, and has not been developed for other vegetation types or ages.

Figure 3-6. Two pods of Fremont cottonwood seedlings in laboratory study after 62 days of growth. Left Photo. Seedlings have been irrigated twice daily with free drainage i.e. there is no water shortage and the soil is moist, equivalent to the capillary zone above a groundwater table. Right Photo. Cottonwood seedlings are not irrigated and the water table was held at 5 cm below the surface from Day 1 to Day 10. Beginning on Day 11, the water table was lowered 1 cm/day (Charles Young, Stockholm Environment Institute).

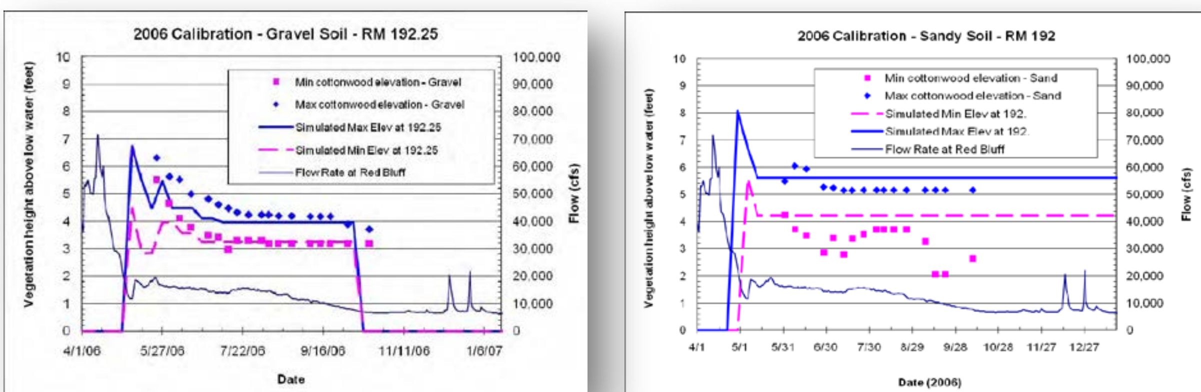
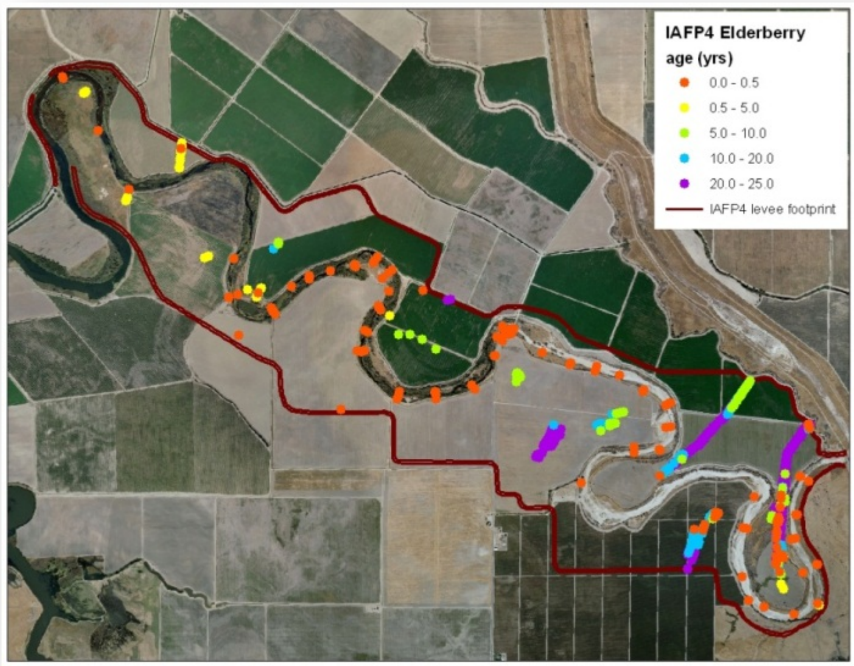


Figure 3-7a and 3-7b. Simulated elevation above low water (6,000 cfs) of cottonwood recruitment, compared to measured elevations of recruitment in 2006. Figure 3-7a represents a point bar with gravel soils at RM 192.25 and the sand bar at RM 192 (figure 2-3b) has sandy soil. Measured and simulated values are compared to daily flow at the Red Bluff CDWR gage (Reclamation, 2011).

Figure 12. Seedlings before July 28th (left) were very healthy. The right photo, taken on August 23rd at RM 183, shows dehydrating seedlings following a recession exceeding root growth capabilities.

Figure 3-8. Illustration of cottonwood desiccation mortality from a field study at a Sacramento River sand and gravel bar (RM 183) (CDWR, 2005).

YTM, Desiccation by Root Depth. The root depth method depends on separation between the root tip and the capillary zone of the water table for a specified number of days to determine when desiccation will occur. Horton et al. (2001) report on canopy dieback and mortality during dry periods for Freemont cottonwood, Gooding's black willow and tamarisk based on the depth to groundwater. Seedlings are more susceptible to desiccation due to limited energy reserves to focus on root growth (RHEM model from Greimann et al., 2011). Managed rivers with rapid water surface decline during seed germination periods limit establishment of new cottonwoods and other riparian plants (Johnson, 1994; Scott et al., 1996; Rood and Mahoney, 1990). In fluvial systems where the groundwater decline is responsive to surface water decline, the root growth rate of the seedling has to keep pace with the drop in groundwater to supply the necessary soil moisture (figure 3-8). The recruitment box model (Mahoney and Rood, 1993, 1998; Roberts et al., 2002, Stella et al., 2004) describing the relationship between rapid water surface drawdown, root growth rate and desiccation mortality is a conceptual tool benefiting both ecologists and water managers. The model helps define the maximum water surface drop that will support cottonwood seedling regeneration. Desiccation by root depth mortality in SRH-1DV is a similar, but automated approach to estimating desiccation impacts from changes in the water surface. The root depth method is used for most vegetation types with the exception of cottonwood plants in the Sacramento River Calibration and Alternatives Analysis studies and the San Joaquin River Restoration study. An application of SRH-1DV in the San Joaquin Restoration study (Holburn-Gordon, 2011) compared plant survival with and without irrigation (figure 3-9).



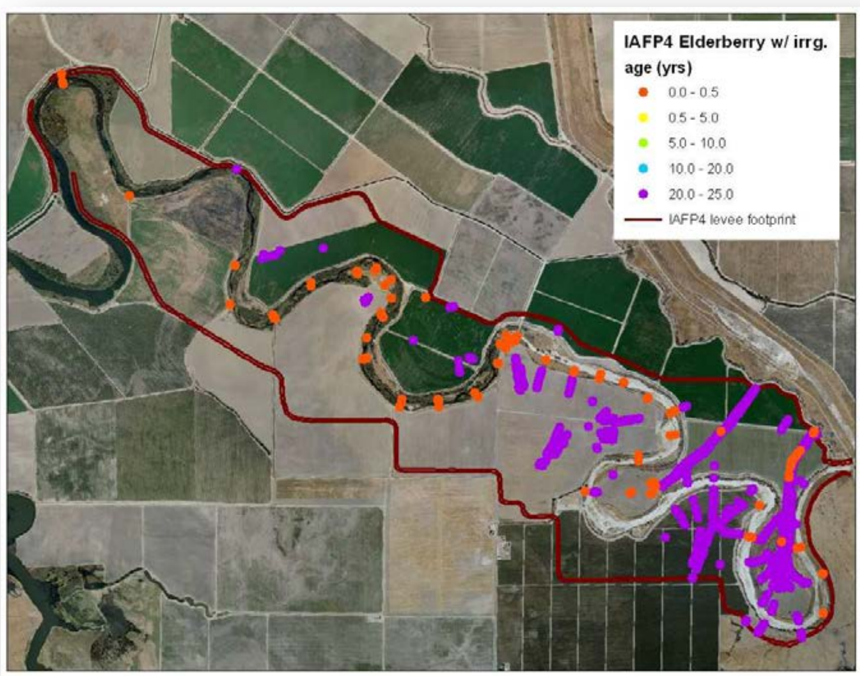


Figure 3-9. Elderberry distribution at the end of 23 year simulation period for the reach, IAFP4, with all mortality options (top) and with irrigation i.e. no desiccation (bottom), in years 1-5 (Holburn-Gordon, 2011).

The desiccation by root depth method, YTM, requires three parameters, YAGE, YTIME, and YHEIGHT.

YTM, YAGE. Age of plant (years) when drought resistance is defined by YTIME and YHEIGHT.
YTM, YTIME. Number of days the root tip (lowest elevation of plant) must be above the capillary fringe a distance YHEIGHT, before mortality occurs.
YTM, YHEIGHT. A root tip (lowest elevation of the plant) must be a specified height (feet) above the capillary fringe, before the countdown (YTIME) begins to desiccation.
YMN, Months Desiccation is Allowed. This record can be used to assign dormant months when desiccation will not harm the plant.

Parameters for desiccation by root depth from previous studies are listed in table 3-10, and the months when desiccation is permitted are listed in table 3-11.

Table 3-10. Desiccation parameters for desiccation by root depth method, YTM

Trees

age	days	height
Fremont Cottonwood		
SacAA		
0	2	0.5
1	7	0.5
2	14	0.5
3	28	0.5
20	180	0.5
SacAA, SJRRest, RioHab		
Method 2 (table 3-x)		
Gooding's black willow		
SacAA, RioHab		
0	2	0.1
1	5	0.1
2	11	0.1
3	25	0.1
6	50	0.1
SJRRest		
0	3	0.1
1	7	0.1
3	28	0.1
20	60	0.1
mixed forest		
SacAA		
0	3	0.1
1	7	0.1
2	14	0.1
3	28	0.1
6	60	0.1
Oregon ash		
SJRRest		
0	2	0.1
1	5	0.1
3	21	0.1
20	45	0.1
Russian olive		
RioHab		
0	3	0.1
6	60	0.1
honey mesquite		
RioHab		
0	5	0.2
10	90	0.2

Shrubs

age	days	height
sand bar willow		
SacAA, RioHab		
0	2	0.1
1	5	0.1
2	11	0.1
3	25	0.1
4	25	0.1
5	25	0.1
29	50	0.1
SJRRest		
0	3	0.1
1	7	0.1
3	28	0.1
20	60	0.1
button brush willow		
SJRRest		
0	3	0.1
1	7	0.1
3	28	0.1
20	60	0.1
mulefat		
RioHab		
0	2	0.1
3	21	0.1
elderberry		
SJRRest		
0	5	0.1
1	11	0.1
3	42	0.1
20	90	0.1
California wildrose		
SJRRest		
0	4	0.1
1	9	0.1
3	37	0.1
20	80	0.1
four-wing salt bush		
RioHab		
0	5	0.2
10	90	0.2
mugwort		
SJRRest		
desiccation is turned off		

Invasives

age	days	height
invasives		
SacCal, SacAA		
0	5	0.5
1	10	0.5
2	20	0.5
3	50	0.5
arundo		
SJRAA		
0	2	0.01
1	7	0.01
2	14	0.01
3	28	0.01
SJRRest*		
0	2	0.01
1	7	0.01
2	14	0.01
3	28	0.01
tamerix		
RioHab, SJRRest*		
0	4	0.1
1	9	0.1
3	35	0.1
red sesbania		
SJRAA		
0	2	0.01
1	7	0.01
2	14	0.01
3	28	0.01
SJRRest*		
0	3	0.1
1	7	0.1
3	28	0.1
20	60	0.1
pepper weed		
SJRRest*		
0.1	5	0.5
3	90	0.5

**SJRRest invasives were not used: tamerix, pepperweed, red sesbania and arundo*

Grass and Wetlands

age	days	height
herbaceous/upland grass		
SacCal&AA, SJRAA, RioHab		
desiccation is turned off		
riparian bank herbs		
SJRRest		
0	2	0.1
3	21	0.1
salt grass		
SJRRest		
0	3	0.1
1	7	0.1
bearded (creeping) rye		
SJRRest		
0	4	0.1
1	10	0.1
California bulrush		
SJRRest		
0	2	0.1
3	21	0.1
broad leaf cattail		
RioHab		
0	2	0.1
2	100	0.1

SacAA = Sacramento River Alternatives Analysis
SJRAA = San Joaquin River Alternatives Analysis
SJRRest = San Joaquin River Restoration Study
RioHab = Rio Grande Habitat Study

Table 3-11. Months plants are not dormant and can be removed by desiccation

Vegetation Type	abbrev	SacAA	SJRAA	SJRest	RioHab
Fremont cottonwood	Fcwd	Apr-Oct	Feb-Nov	Apr-Oct	Apr-Oct
Gooding's black willow	Gbw	Apr-Oct	Feb-Nov	Apr-Oct	Apr-Oct
Oregon ash	Oash			Apr-Oct	
Russian olive	Ro				Apr-Oct
honey mesquite	hmq				Feb-Nov
mixed forest	mxf	Apr-Oct			
sandbar willow	sbw	Feb-Nov	Feb-Nov	Feb-Nov	Feb-Nov
seep willow/mulefat	mule				Mar-Oct
buttonbush willow	bbw			Mar-Nov	
elderberry	eld			Mar-Nov	
California wildrose	rose			Mar-Nov	
California mugwort	mug*			NA	
four-wing saltbush	fwsb				Feb-Nov
California bulrush	Cbr			Mar-Nov	
broad-leaf cattail	catt				Mar-Nov
salt grass	salt			year round	
bearded (creeping) rye grass	crye			year round	
herbaceous	herb	Apr-Oct	Apr-Oct		
riparian bank herbs	rbh			Mar-Nov	
upland grass	upgrass				Apr-Oct
red sesbania	red		Feb-Nov		
arundo	arun		Feb-Nov		
invasive	inv	Mar-Nov			
tamarisk	tam				year round

*Desiccation is not simulated for mugwort

SacAA = Sacramento River Alternatives Analysis
SJRAA = San Joaquin River Alternatives Analysis
SJRRest = San Joaquin River Restoration Study
RioHab = Rio Grande Habitat Study

YWT, Desiccation by Cumulative Water Stress. The second method, based on water stress of young plants, was added following laboratory desiccation studies of cottonwood plants conducted by SEI (WRIME, Inc. 2009). Cumulative stress imposed on the young plant (measured as a desiccation/Recovery rate) is tracked until a user-specified water stress is reached and the plant is removed. Desiccation rates for the water stress method are provided for two soil types. These values were developed based on the RHEM studies (WRIME, Inc. et al., 2009; Greimann et al., 2011).

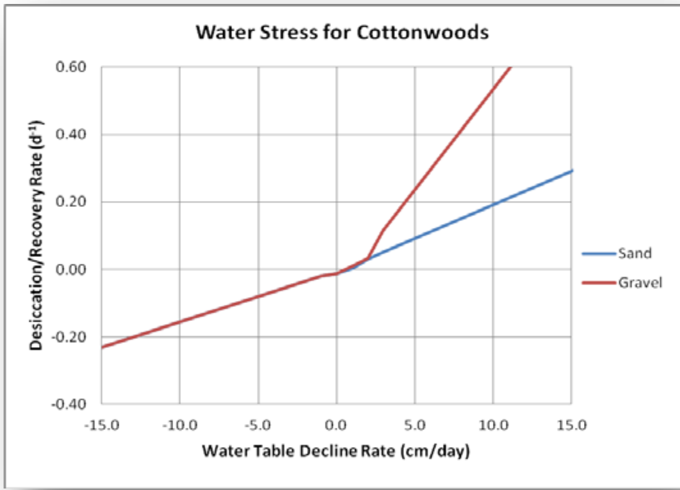


Figure 3-10. Water stress values from laboratory study of cottonwood desiccation as the water table declined (WRIME, Inc. et al., 2009).

Desiccation/Recovery rate values for cottonwoods in sand and gravel soil types are shown in figure 3-10 and table 3-12. Plants are assumed to die from desiccation when the stress parameter exceeds a user specified value. In the study conducted by SEI, cottonwoods generally perished when the water stress parameter exceeded 0.6. If this desiccation mortality is selected, cottonwood plants older than 1 year will not die from desiccation. . The water stress method was used for Fremont cottonwood simulated in the Sacramento River Alternatives Analysis, the San Joaquin River Restoration Study and the Rio Grande Habitat Study.

Table 3-12. Desiccation Method 2 for cottonwoods with water stress rates for sand and gravel soils

WT decline (ft/d)	Desiccation Rate (d-1)	
	Sand	Gravel
-3.280	-1.510	-1.510
-0.0328	-0.018	-0.021
0.000	-0.012	-0.013
0.0328	0.005	0.009
0.0656	0.030	0.032
0.0984	0.051	0.115
3.280	1.990	5.900

Mortality Parameter – Inundation

Inundation mortality is simulated in SRH-1DV when the root crown of a plant is submerged by a specified depth and for an extended period of time. The threshold time of inundation and the depth of inundation above the root crown can be entered as a function of age. Similar to desiccation, seedling mortality by inundation can be readily studied in the laboratory. Parameters for inundated cottonwood seedlings of 1 year or less are available from a laboratory study by WRIME, Inc. et al. (2009), and Auchencloss et al. (2012).

<u>Duration</u>

The selection of parameters for mature plants is often based on reported values from field studies where flooding has occurred. There is a wealth of information on species in the Midwest and southeast presumably due to frequent Missouri and Mississippi floods, and from reservoir construction and maintenance studies by the Corps of Engineers. There are more opportunities to study flooded trees in the Midwest and East, then in the semi-arid west. Both detailed information for common species and relative ratings for the less studied species in the west have been used to assign inundation parameters. A summary of data by Whitlow and Harris (1979) includes plant studies from the west in the South Pacific Division. Additional sources for western species include Stromberg, et al. (1993) and Merritt and Cooper (2000).

<u>Inundation Tolerance Ratings</u>

Several flood tolerance ratings are available including the National Wetlands Index (Reed, 1988), the Corps of Engineers (COE), Flood Tolerance Index (FTI) for the southeast (Theriot, 1993), a water logging tolerance rating (WLT) by Hook (1984) for the south and the US Forest Service resource packet (online) for the northeast area, Flood Effects on Trees. Some summaries on studies from the twentieth century are available. The Minnesota Pollution Control Agency offers a guide for Midwest species including grasses and shrubs (Shaw and Schmidt, 2003) in addition to woody species.

COE's qualitative FTI ranking uses four categories to describe the inundation tolerance of each plant species:

- Tolerant: most individuals survived more than 150 days of flooding during the growing season.
- Somewhat Tolerant: some individuals killed by less than 90 days of flooding and some individuals survived greater than 150 days of flooding.
- Slightly Tolerant: most individuals survived more than 50 days but less than 100 days of flooding.
- Intolerant: severe effects with less than 50 days of flooding.

The USFS NA region ranking is based on tolerance to inundation of 15 days per year, 7 days per year, and less. The USDA NRCS Plant Characteristics lists

Anaerobic Tolerance (what is the relative tolerance to anaerobic soil conditions?). The four categories are: None, Low, Medium, High.

The National Wetland Indicator, originally defined by the USFWS, is being revised by the USDA NRCS as of June 2012. New definitions are couched in terms of a hydrophyte, a plant growing only in water or in very wet earth (i.e. a plant with a high tolerance of inundation). Both the new and original definitions, with estimated probability of occurrence, are included in table 3-13.

Table 3-13. National Wetland Indicators including original definition (USFWS) and the revised definition (USDA NRSC).

Indicator Code	Wetland Type	1988 Comment / 2012 Comment
OBL	Obligate Wetland	Occurs almost always (estimated probability 99%) under natural conditions in wetlands. / ***Almost always is a hydrophyte, rarely in uplands***.
FACW	Facultative Wetland	Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands. ***/ Usually is a hydrophyte but occasionally found in uplands.***
FAC	Facultative	Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%). ***/ Commonly occurs as either a hydrophyte or non-hydrophyte.***
FACU	Facultative Upland	Usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33***%). / Occasionally is a hydrophyte but usually occurs in uplands.***
UPL	Obligate Upland	Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified. If a species does not occur in wetlands in any region, it is not on the National List***.*** ***/ Rarely is a hydrophyte, almost always in uplands.***

<u>Submergence Depth</u>

In addition to age and duration of flooding, the inundation mortality in SRH-1DV is dependent on the depth of water submerging a plant. Wetland plants and riparian species often have coping mechanisms including metabolic adaptions, oxygen transport and rhizospheric oxidation, aerenchyma tissue, and adventitious roots (Shaw and Schmidt, 2003; Koch et al., 1990) that help sustain the plant when the root cap is submerged. Coping mechanisms can allow species to survive multi-years of inundation (Harris and Marshall, 1963; Van der Valk, 1992), but it is not always clear what threshold depth of submergence is required to harm the plant. Instances of flooding are normally associated with a gradually drawdown in the water surface over time. An investigation focused on critical submergence depth is recommended and could benefit from a larger literature search and/or from laboratory studies.

Selection of minimum water depth values for vegetation types in the previous SRH-1DV models has been based on available references and/or a variation of the cottonwood inundation values. The level of stress from water depth is a function of plant height and the amount of canopy that is submerged, in addition to the variation between species. More attention was given to varying the flow depth with respect to plant age and structure/height (categories of herbaceous, shrub, or woody), than varying the flow depth for different plant species. More depth is required to prevent aeration and submerge the root cap of a mature tree with protruding roots, in comparison to depth needed to reduce oxygen exchange in grass or in new shoots of young plants where the entire canopy can be easily submerged. Values from previous studies for age, time and submerged depth are presented in table 3-14.

<u>Additional Factors</u>
In addition to the three factors in the SRH-1DV model, plant age, inundation time, and water depth over the root cap; inundation mortality can also be a function of stress, water temperature, flow and the season of submergence. A second or third flood event in a single season will increase the stress on the plant and reduce the flood duration a plant can withstand. The survival time of plants can also be affected by the water temperature, with warmer water having a more detrimental effect (Auchincloss et al., 2012). Li, et al. (2005) reports standing water is more damaging than moving water and inundation in the dormant season causes more stress than flooding during the growing season (Walters et al., 1980). Stress, water temperature, flow and season have not been included as inundation factors in SRH-1DV, due to increased complexity for an unknown level of impact. However the three represented inundation factors (age, duration, depth of submergence) do appear significant and are valuable means of distinguishing vegetation types and characteristics within the modeled simulation.

DTM, DAGE. Age of plant when it is susceptible.
DTM, *DTIME*. Length of time plant is submerged before it can no longer recover.
DTM, DDEPTH. Minimum depth of water over the root crown to eradicate the plant.

Table 3-14.Mortality parameters for inundation. DAGE, DTIME and DDEPTH define the age, submergence time and depth of flow over root cap when a vegetation type is subject to mortality by inundation.

Trees

age	time (d)	depth
Fremont Cottonwood		
SacAA, SJRRest		
0	15	0.5
1	30	1
2	30	2
3	60	2
4	120	2
5	150	2
RioHab		
0	16	1
0.5	28	1
5	240	1
20	730	1
Gooding's black willow		
SacAA, SJRRest		
0	18	0.5
1	35	1
2	35	2
3	70	2
4	150	2
5	180	2
RioHab		
0	35	1
5	1460	1
20	1700	1
mixed forest		
SacAA		
0	12	0.25
1	25	1
2	25	2
3	50	2
4	90	2
5	120	2
Oregon ash		
SJRRest		
0	18	0.25
1	35	1
2	35	2
3	70	2
5	160	2
Russian olive		
RioHab		
0	7	1
5	21	1

Shrubs

age	time (d)	depth
sand bar willow		
SacAA, SJRRest		
0	18	0.5
1	35	1
2	35	2
3	70	2
4	150	2
5	180	2
RioHab		
0	35	1
5	1460	1
20	1700	1
buttonbrush willow		
SJRRest		
0	25	0.5
1	45	1
mulefat		
RioHab		
0	10	1
5	60	1
elderberry		
SJRRest		
0	3	0.5
5	10	0.5
California wildrose		
SJRRest		
0	3	0.5
5	10	0.5
four-wing saltbush		
RioHab		
0	2	0.1
3	3	-6
mugwort		
SJRRest		
0	5	0.1
1	12	0.1
honey mesquite		
RioHab		
0	4	0.5
5	21	0.5

Invasives

age	time (d)	depth
red sesbania		
SJRAA		
0	30	0.25
1	60	0.25
2	120	0.25
3	180	0.25
4	360	0.25
SJRRest		
0	18	0.5
3	120	0.5
arundo		
SJRAA, SJRRest		
0	20	0.25
1	35	0.25
2	70	0.25
3	100	0.25
4	200	0.25
invasives		
SacAA		
0	18	0.5
1	35	1
2	35	2
3	70	2
4	150	2
5	180	2
tamerix		
SJRRest		
0	28	0.5
3	90	1
5	180	1
RioHab		
0	28	1
4	90	1
10	480	1
pepperweed		
SJRRest		
0.1	5	0.5
3	90	0.5

Grasses and Wetlands

age	time (d)	depth
herbaceous/upland grass		
SacAA, RioHab		
0	5	0.1
1	12	0.1
salt grass		
SJRRest		
0	25	0.5
1	45	1
bearded creeping rye		
SJRRest		
0	7	0.1
1	21	0.1
California bulrush		
SJRRest		
0	2	0.1
3	21	0.1
broad leaf cattail		
RioHab		
0	30	0.5
1	60	1.5
2	90	2.75
3	720	1.5

SacAA = Sacramento River Alternatives Analysis
SJRAA = San Joaquin River Alternatives Analysis
SJRRest = San Joaquin River Restoration Study
RioHab = Rio Grande Habitat Study

Mortality Parameter - Shading

A single parameter, *CSH*, is needed to define the shading mortality. The user enters the age at which a plant becomes tolerant of shading. A value of 99 was used for plants that are never tolerant of shading. However a larger value should be chosen if the sum of the oldest plant in years, and the length of the simulation (years) exceeds 59 years. Plants have to be located directly below a canopy to be impacted. Some plants are identified as susceptible to shade only as seedlings. Presumably they can outgrow this mortality due to the coping mechanism of a fuller canopy (the shaded plant can accelerate canopy growth on sunny aspects). The use of this mortality parameter has evolved in each project with the conjunctive use of the competition table. A mortality count in the code totals plant kills from both competition and shading. In a dissertation by Faust (2006), shade tolerance was found to be the dominant mechanism structuring riparian communities in northern Missouri floodplain forests. Shade tolerance for conifers and hardwoods is rated in the U.S. Forest Service Silvics handbook (Burns and Honkala, 1990).

CSH, Shade_Age. Age when the plant/vegetation type is tolerant of shading (table 3-15).

Table 3-15. Shade Tolerance, SHADE_AGE. Age of vegetation when it is shade tolerant. Values are listed by vegetation type included in previous study.

	Fc	Gbw	mxf	Oash	Ro	hmq	Sbw	bbw	mule	Fwsb	eld	rose	mug
SacAA	1	1	0.1	-	-	-	1	-	-	-	-	-	-
SJRAA	5	5	-	-	-	-	99	-	-	-	-	-	-
SJRRest	1	1	-	0	-	-	99	-	-	-	99	0	99
RioHab	99	99	-	-	0	99	2	-	99	0	-	-	-

	Herb	Up grass	crye	salt	inv	arun	Red	tam	ppw	catt	Cbr
SacAA	99	-	-	-	3	-	-	-	-	-	-
SJRAA	99	-	-	-	99	99	99	-	-	-	-
SJRRest	-	-	99	99	-	3	0	99	99	-	99
RioHab	-	99	-	-	-	-	-	-	-	99	-

" – " Indicates the vegetation type was not used in the simulations for that project.

SacAA = Sacramento River Alternatives Analysis
SJRAA = San Joaquin River Alternatives Analysis
SJRRest = San Joaquin River Restoration Study
RioHab = Rio Grande Habitat Study

Mortality Parameter - Competition

The competition table was initially used to identify plants that required bare ground to germinate, and also used as a more specific method of defining shade susceptibility. Now the table is also used to identify alleopaths (plants that can change soil chemistry and prevent the growth of different vegetation types), to identify salt or hedge intolerant plants, and to identify dominant plants when the form of dominance is not well defined. Age of the Y plants indicate when they are old enough to eliminate plant X at the specified age (tables 3-16a and 3-16b). A value of 99 indicates that species Y will not be able to remove species X at its specified age (if initial age plus the years of the simulation are less than 99). No grow and agricultural lands were always assigned 0.01 to immediately remove any attempted plant growth, i.e. no X plants were allowed to grow at the Y plant locations of no grow (tables 3-16a and 3-16b). Mortality from competition and shading are tallied as a single category. The use of the competition table for mortality has evolved in each project with the conjunctive use of the shading mortality and with better understanding of the plant characteristics and the mechanics of the competition table. Competition parameters have been another useful means of distinguishing and representing plants in numerical models.

CMP, CAGE (1 to #veg type ages). X veg type age of susceptibility
CMP, KILL_AGE (1 to # X veg type ages, 1 to # Y veg types). Y veg type age when it can kill

Table 3-16a. Competition tables from Sacramento River and San Joaquin River Alternatives Analysis

Sacramento River Alternatives Analysis

Age (yrs) when these plants will eliminate plant X

	Fc	mxf	Gbw	sbw	herb	inv
age of Fc (X)				**SacAA**		
0.1	99	99	99	99	3	2
2	99	99	99	99	99	3
3	99	99	99	99	99	99
5	99	99	99	99	99	99
age of Gbw (X)						
0.1	24	24	99	99	3	2
2	40	40	99	99	99	3
3	99	99	99	99	99	99
5	99	99	99	99	99	99
age of mxf (X)						
0.1	99	99	99	99	3	2
2	99	99	99	99	99	3
3	99	99	99	99	99	99
5	99	99	99	99	99	99
age of sbw (X)						
0.1	24	24	99	99	3	2
2	40	40	99	99	99	3
5	99	99	99	99	99	99
age of herb (X)						
0.1	6	6	6	1	99	1
1	6	6	6	2	99	1
age of inv (X)						
0.1	99	99	99	1	3	99
1	99	99	99	3	99	99
3	99	99	99	99	99	99

San Joaquin River Alternatives Analysis

Age (yrs) when these plants will eliminate plant X

	Fc	Gbw	sbw	herb	arun	red
age of Fc (X)						
0.1	99	99	1	0.25	1	1
2	99	99	99	99	2	2
3	99	99	99	99	2	2
5	99	99	99	99	99	99
age of Gbw (X)						
0.1	99	99	1	0.25	1	1
2	99	99	99	99	2	2
3	99	99	99	99	2	2
5	99	99	99	99	99	99
age of sbw (X)						
0.1	6	6	99	0.25	1	2
2	6	6	99	99	2	2
5	6	6	99	99	5	5
age of herb (X)						
0.1	6	6	1	99	1	1
1	6	6	1	99	1	1
age of arun (X)						
0.1	6	6	1	0.25	99	1
1	6	6	3	99	99	1
3	6	6	99	99	99	2
age of red (X)						
0.1	6	6	2	0.25	1	99
1	6	6	99	99	2	99
3	6	6	99	99	99	99

Table 3-16b. Competition tables from San Joaquin River Restoration Study and Rio Grande Habitat Study

San Joaquin River Restoration Study

Age (yrs) when Y plants will eliminate plant X

	Fc	Gbw	Oash	sbw	eld	rose	salt	crye	mug	Cbr	bbw	rbh
age of Fc, Gbw, Oash (X)												
0.1	99	99	99	99	99	3	3	2	99	2	99	3
5	99	99	99	99	99	99	99	99	99	99	99	99
age of sbw (X)												
0.1	15	15	15	99	3	3	3	2	99	2	15	3
3	25	25	25	99	99	99	99	99	99	99	25	99
age of eld (X)												
0.1	24	24	24	3	99	3	3	2	99	2	3	3
3	40	40	40	99	99	99	99	99	99	99	99	99
age of rose (X)												
0.1	40	40	40	3	3	99	3	2	99	2	3	3
age of salt (X)												
0.1	15	15	15	3	3	3	99	3	99	2	3	3
1	25	25	25	3	3	4	99	3	99	3	3	3
age of crye (X)												
0.1	15	15	15	2	2	2	99	99	99	2	2	99
age of mug* (X)												
0	0	0	0	0	0	0	0	0	0	0	0	0
age of Cbr (X)												
0.1	15	15	15	1	1	1	2	2	1	99	1	2
age of bbt (X)												
0.1	15	15	15	15	3	3	3	2	99	2	99	3
3	25	25	25	25	99	99	99	99	99	99	99	99
age of rbh (X)												
0.1	15	15	15	3	3	3	3	3	99	2	2	99
1	25	25	25	3	3	4	3	3	99	3	3	3

Rio Grande Habitat Study

Age (yrs) when Y plants will eliminate plant X

	Fc	Gbw	sbw	mule	hmq	fwsb	catt	Ro	tam	upgrass
age of Fc, Gbw (X)										
0.1	99	99	3	3	99	3	2	99	2	2
2	99	99	99	99	99	99	99	99	99	99
age of sbw (X)										
0.1	99	99	99	3	99	3	2	99	2	2
2	99	99	99	99	99	99	99	99	99	99
age of mule (X)										
0.1	99	99	3	99	99	99	2	99	2	99
2	99	99	99	99	99	99	99	99	99	99
age of hmq (X)										
0.1	99	99	3	3	99	99	2	99	2	99
2	99	99	99	99	99	99	99	99	99	99
age of fwsb (X)										
0.1	99	99	3	3	99	99	2	99	2	2
2	99	99	99	99	99	99	99	99	99	99
age of Ro (X)										
0.1	99	99	3	3	3	3	3	99	3	3
2	99	99	99	99	99	99	99	99	99	99
age of catt (X)										
0.1	99	99	3	3	99	3	99	99	2	99
2	99	99	99	99	99	99	99	25	3	99
age of tam (X)										
0.1	1	1	1	3	99	3	2	99	99	99
2	99	99	99	99	99	99	99	99	99	99
age of upgrass (X)										
0.1	99	99	3	3	99	3	2	99	2	99
2	99	99	3	3	99	3	2	99	2	99

Mortality Parameter - Scour

Plant removal by erosion is a function of cross sectional averaged flow velocity in the channel or in the overbank area. The values of average velocity when a plant is eroded are occasionally available in the literature from laboratory experiments or back calculated from field flood conditions. In addition to average velocity, there are secondary flows in the rivers that cannot be represented in a 1D numerical model. The local velocity at a particular location in the cross section can be substantially higher than the cross sectional average velocity and be more effective at removing plants. Subsequently, scour parameters for the simulation may be set lower than reported values of average velocities. Scour values for herbaceous/upland grass are similarly set low to promote more bare ground for seeding since the 1D model under-predicts these localized conditions. Despite reduced velocity values, scour normally removes the least area of plants of the simulated mortalities (figure 3-11). This may be due to the project areas studied to date, due to a limited area of plant coverage on the river banks (desiccation and inundation can occur more frequently in overbank areas), or could also be due to more closely spaced points on the banks (plants removed on the banks represent smaller plant coverage areas than points in the overbank area). Values used for scour parameters in previous studies are listed in table 3-17.

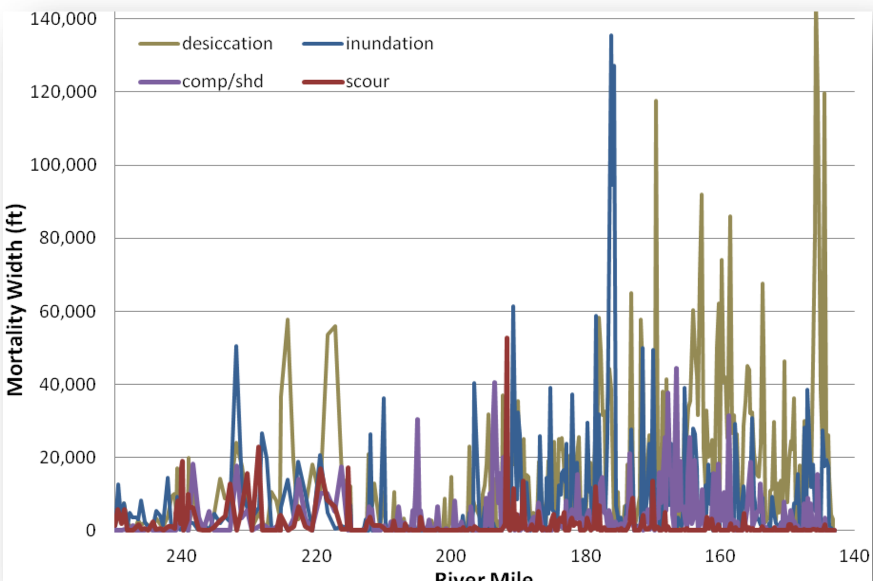


Figure 3-11. Comparison of plant mortality from the Sacramento River alternatives comparison (Fotherby and Greimann, 2011). Scour creates the smallest numbers of plant removal in this No - Action alternative. Plant mortality is shown as average width of a cross section where plants have been removed (coverage area/longitudinal distance represented by cross sections).

SVC, SAGE. Maximum age of plant associated with the critical velocity.
SVC, SVEL_CRIT. If a plant is less than the age specified and the root crown is inundated by flow, the plant will be removed by scour when the channel or overbank flow reaches this average critical velocity.

Table 3-17. Values for scour parameters (SAGE and SVEL_CRIT) from previous studies

Fc	Sac AA, SJR AA*, SJR Rest, Rio Hab
mxf	Sac AA
Gbw	SJR AA*
Ro	Rio Hab
age (years)	**critical velocity (fps)**
0	2
1	2.5
2	3
3	4
4	5
5	6
**does not have 5 yr value*	

sbw	Sac AA, SJR Rest
herb	Sac AA
eld	SJR Rest
rose	SJR Rest
mule	Rio Hab
hmq	Rio Hab
fwsb	Rio Hab
herb	Rio Hab
salt/mug	Rio Hab
age (years)	**critical velocity (fps)**
0	2
1	3
2	4

crye	Rio Hab
age (years)	**critical velocity (fps)**
0	2
1	4
2	5

Cbr	SJR Rest
arun	SJR AA
age (years)	**critical velocity (fps)**
0	1.5
1	2
2	2.5

red	SJR AA
age (years)	**critical velocity (fps)**
0	2
1	2.1
2	2.6
3	3.5
4	4

Oash	SJR Rest
age (years)	**critical velocity (fps)**
0	2
2	3
5	6

Gbw	Sac AA, SJR Rest, Rio Hab
age (years)	**critical velocity (fps)**
0	2
1	3
2	4
3	5
4	8

sbw	SJR AA
age (years)	**critical velocity (fps)**
0	2
1	2.1
2	2.6
3	3.5
4	4

herb	SJR AA
age (years)	**critical velocity (fps)**
0	0.75
0.5	1
1	1.5

bbt	SJR Rest
age (years)	**critical velocity (fps)**
0	2
1	2.5
2	3
3	4
4	6

inv	Sac AA
age (years)	**critical velocity (fps)**
0	3
1	4
2	5
3	6

tam	Rio Hab
age (years)	**critical velocity (fps)**
0	2
1	5
2	6
3	7

SacAA = Sacramento River Alternatives Analysis
SJRAA = San Joaquin River Alternatives Analysis
SJRRest = San Joaquin River Restoration Study
RioHab = Rio Grande Habitat Study

Mortality Parameter - Senescence

Senescence is valuable on projects with multi-decadal simulation periods, or where there is a large percent of old groves of woody plants. Senescence was used in earlier projects including the San Joaquin River alternatives analysis. Presently all plants are removed on the day they reach the maximum age.

ATM, AMAX. The maximum age of the vegetation type.

Mortality Parameter - Burial

Plant burial occurs when sediment is deposited during the falling limb of a high flow event. The loss of plants from large deposits can be tracked in SRH-1DV because the model links flow, sediment transport, and vegetation growth processes. This mortality was tested initially but was not used in any of the project models. Most vegetation shown in figure 3-12 was not fully covered by sediment during the high flow event and eventually recovered.

BDP, *BDEPTH*. Minimum deposition required above the top of plant to kill the plant.

Figure 3-12. Sediment deposits on vegetation from a high flow event on the Platte River in Nebraska (US Fish & Wildlife Service/Reclamation).

Plant characteristics data fields from the online USDA NRCS database (USDA NRCS Characteristics Data Definitions) that provide information for the mortality parameters and the competition tables are:

Drought Tolerance: What is the relative tolerance of the plant to drought conditions compared to other species with the same growth habit from the same geographical region? Drought tolerance is defined here in the following fashion: Imagine that in an acre of land there are low areas that have heavy soil and tend to accumulate more soil moisture, and higher areas that have course textured soil and tend to accumulate less soil moisture. Some plant species are most frequently found growing in the higher areas with the course soil texture. These plant species are considered to be more drought tolerant than the species that are frequently found in the low areas with fine textured soil.

- None, Low, Medium, High

Adapted To Coarse Textured Soils: Can this plant establish and grow in soil with a coarse textured surface layer? See table 3-18 for more information.

- Yes, No

Adapted To Medium Textured Soils: Can this plant establish and grow in soil with a medium textured surface layer? See table 3-18 for more information.

- Yes, No

Adapted To Fine Textured Soils: Can this plant establish and grow in soil with a fine textured surface layer? See table 3-18 for more information.

- Yes, No

Table 3-18. Characteristics soil texture groups and corresponding soil texture classes.

Characteristics soil texture group	Corresponding soil texture classes from the Soil Texture Triangle		
Course	Sand	Course sand	Fine sand
	Loamy course sand	Loamy fine sand	Loamy very fine sand
	Very fine sand	Loamy sand	
Medium	Silt	Sandy clay loam	Very fine sandy loam
	Silty clay loam	Silt loam	Loam
	Fine sandy loam	Sandy loam	Course sandy loam
	Clay loam		
Fine	Sandy clay	Silty clay	Clay

Source: The soil texture classes are from the Soil Science Society of America, http://www.soils.org/. An NRCS team partitioned the soil textures into the three groups.

Moisture Use: Ability to use (i.e., remove) available soil moisture relative to other species in the same (or similar) soil moisture availability region.

- Low, Medium, High

Precipitation, Minimum: Minimum tolerable rainfall (in inches), expressed as the average annual minimum precipitation that occurs 20% of the time (i.e., the probability of it being this dry in any given year is 20%) at the driest climate station within the known geographical range of the plant. For cultivars, the geographical range is defined as the area to which the cultivar is well adapted rather than marginally adapted.

Anaerobic Tolerance: What is the relative tolerance to anaerobic soil conditions?

- None, Low, Medium, High

Precipitation, Maximum: Maximum tolerable rainfall (in inches), expressed as the annual average precipitation of the wettest climate station within the known geographical range of the plant. For cultivars, the geographical range is defined as the area to which the cultivar is well adapted rather than marginally adapted.

Known Allelopath: Has this plant species been shown to be allelopathic to at least one other species?

- Yes, No

Lifespan: What is the expected lifespan (in years) of a perennial plant relative to other species with the same growth habit? For the Tree growth habit: Short: < 100; Moderate: 100 - 250; Long: >250. Life spans for other growth habits are not quantified.

- Short, Moderate, Long

Salinity Tolerance: What is the plant's tolerance to soil salinity? Tolerance to a soil salinity level is defined as only a slight reduction (not greater than 10%) in plant growth. None = tolerant to a soil with an electrical conductivity of the soil solution extract of 0-2 dS/m; Low = tolerant to 2.1-4.0 dS/m; Medium = tolerant to 4.1-8.0 dS/m; High = tolerant to greater than 8.0 dS/m.

- None, Low, Medium, High

Shade Tolerance: What is the relative tolerance to shade conditions?

- Intolerant, Intermediate, Tolerant

4. NOTES AND RESOURCES FOR SELECTING VEGETATION PARAMETERS

Parameters in the SRH-1DV vegetation file were often found in journal articles on site studies of mature plants or laboratory investigations of new seedlings. Cottonwood desiccation values based on plant stress were developed specifically for the model from plant desiccation studies in the Stockholm Environment Institute laboratory.

Federal and state plant libraries, available on the internet, became more common resources for selecting representative model parameters as the vegetation types expanded beyond cottonwood and willow. Frequently accessed resources include the USDA NRCS plant library and the USFS series of fire effects papers. A Plant Characteristics page of the online USDA NRCS plant library provides a standardized descriptor for plant characteristics used in SRH-1DV vegetation input files (see examples in Germination, Growth, Mortality, and Inundation sections of the previous chapter). Category descriptors from the USDA NRCS plant characteristics page allow relative comparisons between plant types, and help improve the process of parameter selection. The plant library also contains U.S. distribution maps and references for each plant species. USFS fire effects papers are also valuable resources. The fire papers are summaries of extensive literature reviews describing plant characteristics. The papers frequently include data pertinent to the selection of SRH-1DV parameters, or can point to studies in

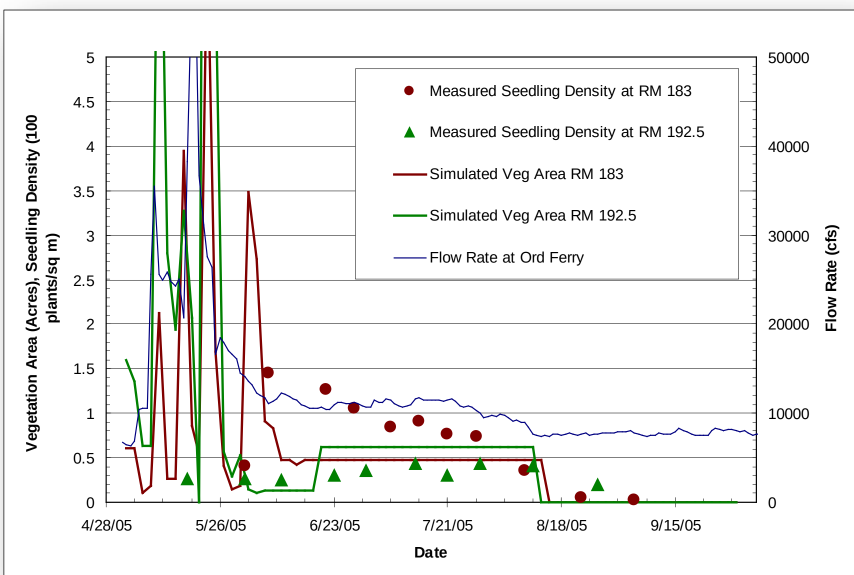


Figure 4-1. Validation of the response of cottonwood seedlings to the decline in river stage from a field study on the Sacramento River (Reclamtion, 2011).

the area of interest. Occasionally there is a range of values for the same parameter, but the range may be related to regional and climatic factors.

Once the vegetation input file is assembled, sensitivity simulations help to identify influential parameters. Calibration or verification studies using field or mapped data can be used to improve parameter definition within the reasonable range of values initially considered. There were two model calibrations with the Sacramento River NODOS Program: studies based on 2005 and 2006 cottonwood field data (figure 4-1) and a calibration based on 2 sets of GIS vegetation maps, 1999 and 2007 (Greimann et al., 2011). The model simulations can also be designed with the parameter range to bracket results. A series of simulations were used in the development of the SRH-1DV model for the San Joaquin River Alternatives Analysis to study sensitive parameters, and widely dispersed germination of invasive plants was used to bracket potential outcomes.

Presented in the next sections are notes and references that aided selection of parameters and construction of SRH-1DV vegetation input files. This is not a comprehensive collection of notes, but does provide context to the tables of parameters presented in the previous chapter. The abbreviation in each title is not the USDA assignation, but is the abbreviation used internally for short model labels. Five invasive species are included: arundo, pepperweed, scarlett wisteria, tamarisk and Russian olive (Table 2.2). A pepperweed ***(Lepidium latifolium)*** input file was developed for the San Joaquin River Restoration study, but not applied. General information on plains cottonwood has also been included as a section. Plains cottonwood was modeled previously with SedVeg, but has not been represented in SRH-1DV. References from the notes are listed under the resources and references paragraph at the end of each plant section, and may not be included a second time in the main reference section for the report. The last section of this chapter lists multi-species resources: papers or reports containing descriptions on more than one species.

Arundo/giant reed/tall cane (*Arundo donax*) - arun

Germination Season

Figure 4-2. Arundo (Reclamation)

Arundo (figure 4-2) can germinate from propagules carried downstream during high flows, or can expand to new locations through rhyzoid growth. Spencer and Ksander (2001) determined that new shoots emerged and survived at 57.2 degrees Fahrenheit (F) and 68 degrees F but could not emerge from rhizome sections at 44.6 degrees F. Shoots first appeared in a Davis, California, experiment in late March when the average daily temperature was 52.7 degrees F, and continued to emerge until November. These values were used as a guide for the seed dispersal season.

Root Growth

Invasive plants like arundo and phragmites have shallow roots and rhizomes that are more easily undercut by flow scour, similar to shallow rooted wetland plants like California bulrush or cattail (figure 4.3).

Figure 4-3. Shallow root system of arundo donax (© Avinoam Danin, Arkive.org)

Desiccation

Arundo was assigned a higher resilience in later studies using lateral root spread (5 to 50 dry days vs. 2 to 28 dry days before removal,) because of its rhizome development that allows the plant to extend laterally to a water source.

Resources and References

Spencer, D., and G. Ksander. 2001. Troublesome Water Weeds Targeted by Researchers. *Agricultural Research*, November.

USDA NRCS Plant Database, Conservation Plant Characteristics, *Arundo donax* L., giant reed, ARDO4, [9/14/2012].

Source for Figure 4-3:

© Avinoam Danin from http://www.arkive.org/arundo/arundo-donax/image-G122507.html [12/11/2012]

Bearded (creeping) rye grass *(Leymus triticoides)* - crye

Figure 4-4. Bearded rye grass in a riparian location, May (University of Califonia, Irvine)

Leymus triticoides was once called Elymus triticoides, and is also known by its common names, creeping wildrye or beardless wildrye (figures 4-4 and 4-5). It is a cool season, perennial, sod forming native grass. The grass is typically tall, strongly rhizomatous, and can develop into large patches or colonies. There are Rio or Yolo strain in California but no Shoshone strain.

Germination

Plants are established by seed or rhizomes. Seeds mature in late spring early summer (Dyer and O'Beck, 2005). There is rapid growth due to rhizomatous spread.

Growth

Based on Shoshone strains, root growth rates are 1.8 m in one season. In good soils, roots may go down 10 feet (Dyer and O'Beck, 2005).

Desiccation

Creeping rye grass has high drought tolerance, moisture use is low, and only 7 to 24 inches of precipitation are required per year (USDA NRCS Plant Characteristics).

Inundation

This plant has high tolerance for inundation (USDA NRCS Plant Characteristics).

Shading

This rye grass is intolerant of shade.

Figure 4-5. Bearded rye grass in an upland location, June (University of California, Irvine)

Competition

In spite of delayed germination of up to 1 month and poor seedling vigor, it can compete sufficiently with weeds and annual grasses to dominate a site in the 2nd year (Dyer and O'Beck, 2005).

Scour

Once established, grass lays over during high flows and protects the base from erosion.

Resources and References

Dyer, D. and R. O'Beck. Edited 2005. USDA NRCS Plant Guide, Beardless Wildrye *Leymus Triticoidus* (Buckl.) Pliger LETR5, Contributed by USDA NRCS California State Office and Lockeford Plant Materials Center, California, [12/14/2010].

Nevo, E. and G. Chen, 2010. Drought and salt tolerances in wild relatives for wheat and barley improvement, DOI: 10.1111/j.1365-3040.2009.02107.x

USDA NRCS Plant Database, Conservation Plant Characteristics, *Leymus triticoides* (Buckley) Pilg. beardless wildrye LETR5, [12/02/2010].

Wildrye Creeps to the Forefront of Grass Swale Filters http://www.albrightseed.com/wildryeswalefilter.htm , [12/2/2010]

Source for Figure 4-4 and Figure 4-5: University of California, Irvine, Natural History of Orange County, Photo Ref: May 2 87 # 20A,21A,22A; June 90 # 2,3, Identity by John Johnson, http://nathistoc.bio.uci.edu/Plants%20of%20Upper%20Newport%20Bay%20(Robert%20De%20Ruff)/Poaceae/Leymus%20triticoides.htm, [12/14/2010]

Broad-leaved cattail *(Typha latifolia)* - catt

Figure 4-6. Broad-leaved cattail upstream of a bridge at the San Joaquin River (Reclamation)

The USDA NRCS listing of salt tolerance for broad-leaved cattail is low (Plant Characteristics).

Germination

Broad-leaved cattail (cattail) can survive in 0 to 24 inches of water (figure 4-6). Finer soils may also be preferred. Gucker (2008) includes references for multiple studies with germination occurring under water (best at 1 to 2 inches of water) and a reference to cattail germinating in 2 days while submerged. Plants colonize from seeds in mid July thru mid Sept, and from lateral root spread.

Growth

Rhizome growth rate is 54 to 58 m^2 in 1 to 2 yrs (Gucker, 2008). The lateral root spread rate was used for the maximum root growth rate.

Desiccation

The longest survival period noted from the literature review was Nelson and Dietz (1966). They reported 100% mortality of cattail in Utah after 2 years of being dry but the groundwater conditions for this period are not known. Similar wetlands plants, the California bulrush in the San Joaquin River studies, were assigned only 21 days of drought tolerance but this value was increased for broad-leaved cattail to one cattail growing season of 100 days based on additional references.

Inundation

Cattail are very tolerant of inundation and can grow under 1 ft of water (Gucker, 2008) but there is variation in the reported conditions and the number of days to death. Harris and Marshall (1963) reported death at 4 to 5 years of continuous flooding.

Shading

Cattail are intolerant of shade.

Competition

Seeds can germinate on bare ground but outcompete most invasives (Stevens and Hoag, 2006). Dickerman et al. (1985) describes a "tightly packed advancing front of ramets" that successfully excluded other plants.

Scour

Dense but can be easily undercut. This plant is only found in slow flow velocities, location may or may not be driven by scour. Scour is purposely assigned a low value to allow for secondary flow forces.

Resources and References

Dickerman, J.A. and R.G. Wetzel. 1985. Clonal growth in Typha latifolia: population dynamics and demography of the ramets. *Journal of Ecology*. 73(2): 535-552.

Gucker, Corey L. 2008. Typha latifolia. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [9/14/12].

Harris, S.W. and W.H. Marshall, 1963. Ecology of water-level manipulation on a northern marsh. *Ecology* 44(2):331-343.

Nelson, N.F. and R.H. Dietz, 1966. Cattail control methods in Utah. Publication No. 66-2. Salt Lake City, UT: Utah State Department of Fish and Game. http://www.rook.org/earl/bwca/nature/aquatics/typhalat.html [9/14/2012].

Stevens, M. and Hoag, C.2006. Plant guide for broad-leaved cattail *(Typha latifolia)*. USDA-Natural Resources Conservation Service and the Idaho Plant Materials Center, Aberdeen.

USDA NRCS database, Conservation Plant Characteristics, *Typha latifolia* L., broadleaf cattail, TYLA, [12/5/2011].

Buttonbush willow (*Cephalanthus occidentalis*) - bbw

Common buttonbush contains the poison Cephalathin. Cephalathin will induce vomiting, paralysis, and convulsions if ingested (Wennerberg (2006). However it has "exceptional" wildlife value with eight species of wildfowl feeding off of seeds and three mammals browsing on twigs (USDA, 2002). Buttonbush grows well in sandy, loamy soils or alluvial soils with sand or silt surfaces, and is intolerant of alkalinity.

Germination

The plant spreads by seeds from a spherical shaped white flower.

Growth

Buttonbush is a shrub growing to 12 ft (USDA, 2002) but can also be a small tree up to 18 ft (Snyder, 1991).

Desiccation

Buttonbush willow is an obligate wetlands shrub, preferring medium to wet moisture levels and has little tolerance for dry soils.

Inundation

This shrub is a pioneer species in flooded areas in regions with a mean July temperature of 20^{o}C (figure 4-7). It can also colonize lowland marsh communities dominated by hardstem bulrush and can tolerate water depths of 3 ft (USDA NRCS, 2002). Wennerberg (2006) reports common buttonbush does not colonize along manmade waterways. It is moderately susceptible to herbicides and can be damaged by springtime flooding.

Figure 4-7. Buttonbush willow in July at the San Joaquin River (Reclamation)

Shading

The abundance of buttonbush willow increases with increased water levels and with increased light levels. Flowering is poor in the shade or in dry soils and the plant is best adapted to saturated soils and full sunlight (USDA NRCS, 2002)

Competition

One year old seedlings or rooted cuttings can be established but the biggest challenge to survival is controlling competition during the first growing season. A planting recommendation is to scalp back all vegetation in a two foot diameter (USDA NRCS, 2002).

Resources and References

Snyder, S. A. 1991. Cephalanthus occidentalis. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [11/05/2012].

USDA NRCS. 2002. Plant Fact Sheet for Common buttonbush, Cephalanthus occidentalis L., CEOC2, USDA NRCS Northeast Plant Materials Program. Last edited: 01jun06 jsp.

USDA NRCS plantbase, Conservation Plant Characteristics *Cephalanthus occidentalis* L., common buttonbrush, CEOC2 [12/02/2010].

Wennerberg, S.B. 2006. Plant guide for broad-leaved cattail *(Typha latifolia)*. USDA-Natural Resources Conservation Service, National Plant Data Center, Baton Rouge, Louisiana. Last edited 05jun06 jsp.

California mugwort/California sagebrush *(Artemisia californica)* - mug

The salt tolerance of mugwort is high (USDA NRCS Plant Characteristics).

Germination and Growth

Fire germinates many more mugwort (figure 4-8) seeds than light in the second post-fire year. There is more growth with better winter rains (Hauser, 2006). Seeds are wind spread to 15 ft from plant. Seedlings emerge during the rainy season in Nov to April and plant growth begins with the rainy season (Eliason and Allen, 19997; Miller, 1982; Montalvo and Koehler, 1984). From 98 plants sampled, only 10% exhibited adventitious rooting at basal portions of stems (Little 1981). Most growth is completed by May with the onset of the dry season. Seedling establishment is poor once plants are mature with canopy. Biomass peaks in June (Hauser, 2006). There is high mortality to young plants due to animal herbivory and grasses can out compete the young seedlings.

Figure 4-8. California mugwort, June 2006, Inglewood CA (Stonebird)

New plants will not be germinated in the model assuming only fire produces substantial numbers of new seedlings. Established plants are assigned a location and age at mapped locations, or where they have been planted in a restoration model. The growth of existing plants is simulated in the model. If the model is run for longer periods where fire would be anticipated, germination should be allowed for single years.

Desication

Desiccation is turned off in the model. Mugwort is found on south facing sage scrub sites, chaperal, dry foothill communities (Hauser, 2006; Wickipedia, 2012). Mugwort has a shallow fragile root system that allows for rapid soil moisture absorption.

Inundation

This plant "…hates being wet in the summer." (Young-Mathews, 2010).

Shading

This plant is not tolerant of shade.

Competition

Allelopath: during the first rain of December in California, the leaf drip from this plant is toxic. Rain leaches toxins from leaves and litter and deposits toxins in the soil, adding to the toxins deposited by volatilization during the dry season (Hauser, 2006). The plant is allelopathic with toxic terpenes so it can outcompete other dryland plants. However ignoring toxins, the assumption in this model is, the location is too wet for mugwort if any other riparian plant can grow there. So competition can also be set to eliminate mugwort if it attempts to germinate at the same location as an established riparian plant.

Scouring

Mugwort has a shallow fragile root system (Hauser, 2006) and presumably can be scoured more readily.

Resources and References

Eliason, S.A. and E.B. Allen. 1997. Exotic grass competition in suppressing native shrubland re-establishment. *Restoration Ecology*. 5(3): 245-255.

Hauser, A.S. 2006. Artemisia californica. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [12/8/2010].

Little, R.J. 1981. Adventitious rooting in coastal sage scrub dominants. Madrono. 28(2): 96-97.

Miller, P.C. 1982. Nutrients and water relations in Mediterranean-type ecosystems. In: Conrad, C.E.; W.C. Oeche., technical coordinators. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems, 1981, San Diego, CA.,

Montalvo, A.M., C.E. Koehler. 2004. Artemisia californica. In: Francis, J.K., ed. Wildland shrubs of the United States and its territories, thamnic descriptions: volume 1. Gen. Tech. Rep. IITF-GTR-26. San Juan, PR: U.S. Department of Agriculture, Forest Service, International Institute of Tropical Forestry; Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 52-56.

Wickipedia for Artemisia californica, and photo from Wickipedia:
http://upload.wikimedia.org/wikipedia/commons/thumb/b/bd/Artemisia_douglasiana_1.jpg/180px-Artemisia_douglasiana_1.jpg , [12/7/2010].
http://www.theodorepayne.org/mediawiki/index.php?title=Artemisia_californica [12/7/2010].

Young-Mathews, A. 2010. Plant guide for California sagebrush (*Artemisia californica)*. USDA-Natural Resources Conservation Service, Plant Materials Center. Lockeford, CA, 95237.

Source for Figure 4-8:
stonebird at http://flickr.com/photos/73431753@N00/642157970 and http://commons.wikimedia.org/wiki/File:Artemisia_douglasiana_1.jpg [9/14/2012]

California bulrush *(Schoenoplectus californicus)* - Cbr

Intolerant of shade, the bulrush (figure 4-9) survives in 0 to 24 inches of water and possibly in finer soils. Plants are not frequently observed at locations with continuous high flow velocities.

California bulrush has a low salt tolerance (USDA NRCS Plant Characteristics).

Figure 4-9. California bulrush at San Joaquin River (Reclamation)

Germination

Plants are spread through seeds and lateral root spread. The germination season was assigned from mid-July through mid-September. Seeds germinate on bare ground but can outcompete most invasives.

Dessication

The USDA NRCS data base lists drought tolerance as low.

Inundaton

Bulrush is very tolerant of inundation and grows under 1 foot of water. In a study by Van derValk (1992), Bulrush species *Scirpus acutus* and *Scirpus validus* only survived 1 to 2 years in flooded areas although some *Scirpus* species survived as tubers.

Competition

Seeds germinate on bare ground but outcompete most invasives.

Scour

There could be other mechanical factors influencing location like slower velocities and finer soils but only scour is represented in this file. The plants grow densely but the roots are shallow and can be easily undercut by flows, so scour is purposely set low in the 1D model to incorporate the effect of higher local velocities as compared to the cross sectional average velocity.

Resources and References

Neill, R.H. 2007. Plant Fact Sheet for California Bulrush (*Schoenoplectus californicus*). USDA-Natural Resources Conservation Service, Louisiana Plant Materials Center. Galliano, LA.

Stevens, M., C.Hoag. 2006. Plant guide for California Bulrush (Schoenoplectus californicus*)*. USDA-Natural Resources Conservation Service and the Idaho Plant Materials Center, Aberdeen.

USDA NRCS plant base, Conservation Plant Characteristics, *Schoenoplectus californicus* (C.A. Mey.) Palla, California bulrush, SCCA11, [12/2/2010].

Van der Valk, A.G., S.D. Swanson and R.F. Nuss, 1981. The response of plant species to burial in three types of Alaskan wetlands. *Canadian Journal of Botany* 61:1150-1164.

California wildrose *(Rosa californica)* - rose

The salt tolerance of California rose (figure 4-10) is none in the USDA NRCS Plant Characteristics list.

Germination

The germination season was similar to elderberry. Rose hips are too big for air dispersed seed so the assumption is the seeds are spread by water, or spread by birds and other animals. Also lateral root spread from "suckering roots" is used. The USDA plant base notes plants are spread by seed and cuttings. The seeds need cold stratification, so an April-May date was used as the germination season.

Like elderberry, wildrose uses precipitation for soil moisture and this may allow establishment at higher locations above water table. An assumed tolerance for dry days was allowed before germination because seeds are in a moist rose hip. No tolerance for submerged germination was assigned.

Lateral Root Spread Rate

The lateral root spread rate was assigned only slightly slower at 0.065 ft/day than sandbar willow at 0.07 ft/day.

Growth

From the USDA plant base, the root growth rate of wildrose is rapid. The assigned value matched the rate for sandbar willow at 0.065 ft/day.

Figure 4-10. California wildrose (Beatrice F. Howitt © California) Academy of Science)

Desiccation

This plant depends more on soil moisture from precipitation, so there is less emphasis on phreatic desiccation. Wildrose has a minimum root depth of 6 inches but to accommodate some allowance for precipitation generated soil moisture (precipitation not accounted for in the code), desiccation tolerance has to be increased or root depth exaggerated. A high drought tolerance was assumed at 33% more than cottonwood and sandbar willow values. The USDA NRCS plantbase reports high, drought tolerance and wildrose can grow with 10 to 40 inches/yr. The assigned desiccation value is assumed higher than sandbar willow but less than elderberry at 50% higher.

Inundation

The plant has low to moderate tolerance for inundation and no anaerobic tolerance. The USDA NRCS values for moisture use is high.

Shading

Wildrose likes moisture and can tolerate shade where it retains more moisture.

Competition

Wildrose is tolerant of shade, but it is not clear that it is a particularly competitive plant. The plant grows as a thicket that excludes other vegetation, but it establishes where there are no other plants. Competition was used in the model, however to prevent other plant growth.

Scour

Scour values were matched to sandbar willow in the absence of referenced data.

Resources and References

Calflora Taxon report 7179 online at http://www.calflora.org/cgi-bin/species_query.cgi?where-calrecnum=7179 [12/2/2010].

Jepson Manual online at http://ucjeps.berkeley.edu/ina/roses/rosa_californica.html [12/2/2010]

USDA NRCS plantbase, Conservation Plant Characteristics, *Rosa californica*, Cham. & Schltdl., California wildrose, ROCA2 [11/30/2010].

Source for Figure 4-10:
Beatrice F. Howitt © California Academy of Sciences at http://calphotos.berkeley.edu/cgi-bin/img_query?rel-taxon=begins+with&where-taxon=Rosa+californica [12/11/2012]

Elderberry *(Sambucus: nigra* or *canadensis* or *coriacea* or *orbiculata* or *velutina* or *caerulea* or *mexicana)* - eld

Elderberry plants are habitat for Valley elderberry longhorn beetles in California. The beetles bore into the stems.

Germination

Figure 4-11. Sambucus nigra: Eng. Bot. 637 (1865) (Copyrights 2009 © ePlantScience.com)

Elderberry (figure 4-11) seeds require cold moist stratification before germination in April and May, and are primarily spread by birds that consume the berries. Bushes can colonize radially outwards from an initial plant and lateral growing roots are a second means of spread. Both air dispersed seeds and lateral root spread methods can be used in SRH-1DV for this vegetation type. Days required for seed germination have to be less than 1.5 or no germination will occur (low tolerance for inundation).

Lateral Root Spread and Growth

The USDA rates root growth as moderate so 50% of sandbar willow values (sandbar willow= 0.07 and 0.11 ft/day) were used for the lateral spread rate, and 75% of root growth rates for each month. The lateral root spread season was matched to the sandbar willow season. Elderberry can use groundwater but is also dependent on precipitation for soil moisture and can grow at higher elevations despite its shallow roots.

Desiccation

The USDA plant base reports high drought tolerance, and the plants can grow in fields with 10 inch/year of precipitation similar to an upland plant. Although the plant requires little moisture, it grows better with more moisture. Desiccation values were assigned at 50% higher than cottonwood or sandbar willow desiccation values. The occurrence of elderberry is sensitive to days to desiccation.

Figure 4-12. Elderberry flowers, Sambucus nigra subspecies caerulea (Alicia Funk, © The Living Wild Project)

Inundataion

Elderberry is reported as having low inundation tolerance, but moderate inundation tolerance in the USDA plantbase, and plants can be found at higher locations (figure 4-12) than riparian plants like sandbar willow.

Resources

Crane, M.F. 1989. *Sambucus cerulea*. IN: W.C. Fischer (compiler). The fire effects information system [Data base]. USDA, Forest Service, Intermountain Research Station, Intermountain Fire Sciences Laboratory. Missoula, Montana. <http://www.fs.fed.us/database/feis/>

Holyoak, M., T. Talley and S. Hogle. 2009. The effectiveness of US mitigation and monitoring practices for the threatened Valley elderberry longhorn beetle, *J Insect Conserv*, DOI 10.1007/s10841-009-9223-4. Open access at Springerlink.com.

Holyoak M, and M. Koch-Munz. 2008. The effects of site conditions and mitigation practices on success of establishing the Valley elderberry longhorn beetle and its host plant blue elderberry. *Environ Manag* 42:444–457. doi:10.1007/s00267-008-9113-7.

River Partners. 2007. VELB Habitat and Colonization of Remnant and Planted Elderberry along the Stanislaus and San Joaquin Rivers. Prepared for Reclamation by River Partners, Modesto, CA., May 10, 83p.

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Source for Figure 4-11:
Copyrights 2009 © ePlantScience.com , http://www.eplantscience.com/botanical_biotechnology_biology_chemistry/kingdom_plantae/classification_notes_files/family/Family%20%20Sambucaceae [12/11/2012]
Source for Figure 4-12:
Alicia Funk, ©2012 The Living Wild Project, http://www.livingwild.org/videos/photos-from-wild-art-of-this-place-recipes-for-doug-fir-probiotic-soda-locust-blossom-vermouth/ [12/11/2012]

Four-wing saltbush *(Atriplex canescens)* - fwsb

Four-wing saltbush (figure 4-13) is susceptible to insects, rodents, rabbits, overgrazing, and wet roots, the only factor we can model. The Periodic large diebacks of saltbush are reported and stands of four-wing saltbush require 3 or 4 years to fully establish (Ogle and St. John, 2005).

Figure 4-13. Common name: chamizo - Scientific name: Atriplex canescens (USDA Database, Britton, N.L., and A. Brown. 1913)

Germination

Along the Colorado River in Arizona, four-wing saltbush germinated in March. Assuming mid March, the germination dates were selected as March 15 to April 30 (Julian day 74 to 120). Partly shaded sites help germination by retaining moisture (Howard, 2003). If water germination is used, the maximum dry days allowed before germination (seed longevity) are 15 to 19 years (Hull, 1973; Meyer, 2003) or 6 to 7 years (Ogle and St. John, 2005). A value of 10 yrs was assigned. The depth below groundwater that germination still occurs was assigned 0.001 since the plant is intolerant of inundation.

Growth

Four-wing salt bush has roots 30 to 40 ft deep (Anderson et al., 1979).

Desiccation

Four-wing saltbush is very drought tolerant (figure 4-14) and has a desert classification (Ogle and St. John, 2002; Schultz et al., 1995). The drought tolerance of four-wing saltbush is similar to elderberry (grows with 10 inches of precipitation per year) and mesquite.

Inundation

Four-wing saltbush does not tolerate high water tables or late winter inundation (Ogle and St. John, 2002). Sites of saltbush are where the water table is 10 to 30 ft below surface (Howard 2003). Shrub die-off from high water table and root anaerobiosis is associated with El Ninos years (Wallace and Nelson, 1990; Weber et al., 1990; and Theriot, 1993).

Figure 4-14. Four-wing saltbush (University of Arizona, Tucson AZ)

Shading

Four-wing salt bush is shade tolerant (Ogle and St. John, 2002).

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Source for Figure 4-14:
http://cals.arizona.edu/yuma/plant_index/atriplex_canescens.htm [12/12/2012]

Fremont cottonwood (*Populus fremontii*) - Fc

Fremont cottonwood is the first species included in SRH-1DV. The code was originally written to study expansion of cottonwoods in the Sacramento River floodplain.

The USDA NRCS Plant Characteristics of salt tolerance is low.

Germination Season

One of the airborne seed (figure 4-15) dispersal seasons selected for cottonwood was May 1 to July 1, based on a seed dispersal survey of the Sacramento River conducted by the CDWR (CDWR, 2005; Morgan and Henderson, 2005). Seed dispersal dates for cottonwood can vary depending on location. Values selected for the San Joaquin River are from Stilwell Sciences (2006) and Stella et al. (2006) and a germination date determined by spring air temperatures is available in SRH-1DV for the San Joaquin River. This option has not yet been used. Horton et al. (2001) reported germination in Arizona in mid-April and seeds remained viable for 7 weeks. In the mountains near Durango, CO (personal email, Environmental Division, Southern Ute Tribe) germination occurs from mid June to July. The germination season shifts with the location and climate.

Germination Parameters

In a study of cottonwood establishment and survival, Borman and Larson (2002) found that the cottonwood seedling crop would fail if the surface dried within several days after germination. The initial seedling root growth was slow, and the surface soil needed to be damp for the first 1 to 3 weeks after germination. Germination usually occurred between 8 and 24 hours after a cottonwood seed fell on a moist surface. Cottonwood seed germination was assigned a value of 36 hours in the San Joaquin River Alternatives Analysis and 12 hours in later studies.

Figure 4-15. "Populus fremontii toumeyi", foliage and seed capsules19664 U.S.D.A Forest Service., Courtesy of the Hunt Institute, signed A.E. Hoyle 1927.

A newly germinated cottonwood plant is assigned a 2-day grace period when desiccation cannot remove the plant. This period allows for moisture stored within the young plant, or moisture remaining in the drying soil to support root growth to the capillary zone. We assume cottonwood germination does not occur below the groundwater table.

Root Growth Rate

Values for cottonwood root growth used in the Sacramento model were based on several published investigations. Cederborg (2003) and Morgan (2005) observed the average growth rate for roots to be approximately 0.5 centimeters per day (cm/d) with a maximum of 1.4 cm/d. Roberts et al. (2002) reported an average rate of 2.2 cm/d, with a maximum rate of 3.2 cm/d. In a laboratory study (Auchencloss et al., 2011; Greimann, 2011), seedlings could generally sustain a water table drop of 0.5 cm/d indefinitely. These results indicate that 0.5 cm/d is a root growth rate that does not exert stress on the plant. A plant can have faster root growth rates for a period of time, but this rate of growth expends plant energy reserves and exerts stress on the plant, eventually causing mortality. The depth below the groundwater table where the root growth stops is often assumed to be 0.1 foot for Fremont cottonwood (and Gooding's black willow) in the SRH-1DV simulations.

Maximum Depth of Root Growth

Maximum root depth appears to be one of the most influential parameters in the SRH-1DV models. Zimmermann's (1969) investigation on plant ecology in Southeastern Arizona presents root depths for cottonwood, black willow, sycamore, and alder growing in areas where groundwater is generally less than 40 feet below the surface. However, older trees in this study area might depend at least part of the year on moisture in the alluvium and not strictly on groundwater. Actual root depths reported by Zimmerman (1969) were 7+ feet for cottonwood, 7 feet for black willow and 15+ feet for Hackberry. Horton et al., (2001) reported that Fremont cottonwood was commonly found in areas where groundwater was 0.5 to 4 meters below the surface.

Figure 4-16. Populus fremontii, Fremont Cottonwood, June 13, 2003, mature tree adjacent to an Arizona flow path (George and Eve Delange, Arizona Wild Flowers)

Desiccation

Desiccation values for cottonwood were based on Sacramento River field studies in 2004 and 2005 (CDWR, 2005; Morgan, 2005; Morgan and Henderson 2005) and laboratory studies (Greimann, 2011) in conjunction with the Sacramento River NODOS Project.

Inundation

Fremont cottonwood is a FACW with medium tolerance to inundation (figure 4-16) and anaerobic tolerance is listed as Medium in the USDA NRCS plant database. The Corps of Engineers Flood Tolerance Ratio is medium survival ranges from 30 to 90 days during the growing season. Hosner (1958) noted plains cottonwood seedlings will survive 8 days of inundation, but most die after 16 days. After a few years of growth, cottonwoods may become more resistant to drowning; however, prolonged inundation will still kill most plants, and inundation of more than a few weeks will stress cottonwoods (Neuman et al., 1996).

In a laboratory study by WIRME et al. (2011), Fremont cottonwood seedlings had 78 percent and 50 percent survival for one week and two week submergence of seedlings. Mortality increased linearly for seedlings based on days of complete submergence at a rate calculated by equation 1.

% mortality = 4.6 + (2.54 * days submerged)   Equation 1

76 percent of the plants died at 28 days and 100 percent at 37.5 days. Greater depths of submergence were more detrimental than shallow depths of submergence. In addition, seedlings had greater survival rates in cold water fluctuating between 11 and 18 degrees Celsius in contrast to temperatures of 18 to 24 degrees Celsius. From the same study it was observed that roots can grow up to 15 cm below the water table (Greimann et al., 2011).

In a study by Stromberg et al. (1993), inundation of saplings (<1 cm stem diameter at a height of 1 meter [m], and <1 yr), pole trees (<1- 10 cm stem diameter measured at a height of 1 m), and large trees (>10 cm stem diameter at a height of 1 m) were examined in the Sonoran desert where 2-yr, 5-yr, and 10-yr floods had occurred. Flow depths varied from 0.4 to 2.1 m. Gooding's black willow had greater rates of survival than Fremont cottonwood. Survival of poles and saplings declined sharply when depths exceeded 1.5 m and ranged from 30 percent to 78 percent for saplings, 73 percent to 93 percent for pole trees and was 100 percent for mature trees.

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Source for Figure 4-15:
"Populus fremontii toumeyi", foliage and seed capsules19664 U.S.D.A Forest Service., Courtesy of the Hunt Institute, signed A.E. Hoyle, 1927. http://www.gardeninginarizona.com/Plants/Salicaceae/Populus_fremontii.html [12/12/2012]
Source for Figure 4-16:
George and Eve Delange, Arizona Wild Flowers, http://www.delange.org/ArizWFlowersOt/AWFOt.htm [9/11/2012]

See Multi-Species Resources

Gooding's black willow *(Salix gooddingii)* - Gbw

Salt tolerance is listed as none in the USDA NRCS Plant Characteristics.

Germination

From an Arizona study by Zimmerman 1969, there is a short period for Gooding's black willow germination (figure 4-17) in the spring when seed is briefly viable. Due to climate differences between the Sacramento River study and the San Joaquin River study area, the germination season for the San Joaquin River was shifted two weeks earlier, May 5 to May 28.

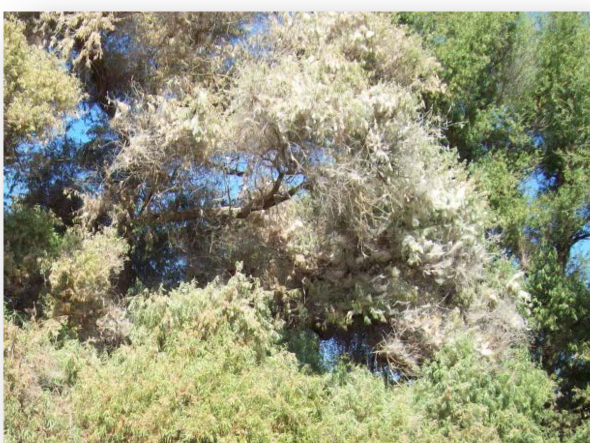

Figure 4-17. Seed dispersal period for Gooding's black willow at San Joaquin River (Reclamation)

Maximum Root Depth Below the Water Table Before Growth Stops

The depth below the groundwater table where the root growth stops was assumed to be 0.1 foot for Gooding's black willow.

Maximum Depth of Root Growth

Zimmermann's (1969) investigation on plant ecology in Southeastern Arizona reported root depths of 7+ feet for cottonwood, 7 feet for black willow and 15+ feet for Hackberry.

Gooding's black willow is more shallow-rooted than Fremont cottonwood (Stromberg, et al., 1991, 1993, 1996).

Inundation

In a study by Stromberg et al. (1993), inundation of saplings (<1 cm stem diameter at a measured height of 1 m, and <1 yr), pole trees (<1- 10 cm stem diameter measured at a height of 1 m), and large trees (>10 cm stem diameter measured at a height of 1 m) were examined in the Sonoran desert where 2-yr, 5-yr, and 10-yr floods had occurred. Flow depths varied from 0.4 to 2.1 m. Gooding's black willow had greater rates of survival than Fremont cottonwood. Survival of poles and saplings declined sharply when depths exceeded 1.5 m and ranged from 30 percent to 78 percent for saplings, 73 percent to 93 percent for pole trees and was 100 percent for mature trees.

The USDA NRCS plant database lists Gooding's black willow (figure 4-18) as a FACW, OBL and the anerobic tolerance is listed as high. Although the Corps of Engineers Flood Tolerance Index (FTI) did not list Gooding's black willow, the values for a black willow (*Salix nigra*), an OBL, is listed as tolerant of 92 to 225 days of inundation in a 225 day growing season. Whitlow and Harris (1979) provided black willow data and references:

Figure 4-18. Gooding's black willow at San Joaquin River (Reclamation)

- Hosner (1958; 1960) - 7.6 cm seedlings, crown submerged 59 and 61 cm, didn't die after 30 or 32 days despite severe chlorosis ;
- Yeager (1949) – from a flooded area - 19% black willow died at 730 days of flooding, 44% died at 1460 days, 61% died in 1946 days, and more than half the mortality occurred with a water depth of 104 cm water;
- Bell and Johnson (1974) - one flooded willow survived 189 days at an unknow depth of submergence.

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See Multi-Species Resources

Honey mesquite *(Prosopis glandulosa)* - hmq

Germination

Honey mesquite seeds (figure 4-19) can remain viable for decades, scarification of the seeds is required for germination. Germination can occur 6 hours after wetting in temperatures of 20 to 40 C. Seeds are spread mainly through the digestive track of domestic and native animals and can also be dispersed through rodent piles or by floods. The air spread method was used in the model. Seeds germinate in the spring and fall after a rainfall and seed longevity is 10 years (Steinberg, 2001). Dates used in the model were April 1, Julian Day (JD) 90 to June 1, JD 151, and Sept 1, JD 211, to Nov 1, JD 271.

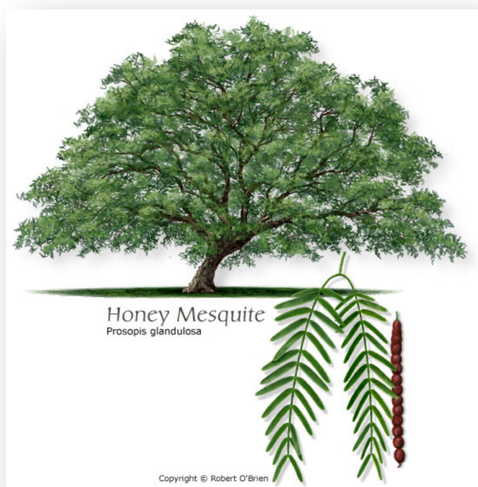

Figure 4-19. Honey mesquite sketch of form, leaves and seed (Copyright © Robert O'Brien, Texas Tree Planting Guide, Texas A&M)

Growth

Riparian honey mesquite communities are often called bosques. The growth form of the tree can vary from a low thorny shrub to a small tree. Hurteau (2008) describes the maximum plant height as 4 to 6 meters and Neuenschwanter et al. (1978) reports riparian mesquite can be up to 50 ft tall, but trees are generally 20-40 feet. Resprout growth rates after a fire can be found in Heirman and Wright (1973). In west Texas trees are dormant November to March (Wilson et al., 1975).

There were a number of rangeland articles on root growth. Paulson's (1949) rangeland root growth rates (for velvet mesquite) were similar to riparian stem rates. A root depth of forty feet is common and there is one instance of 190 feet (Steinberg, 2001). Root growth rates and depths for seedlings are also available in Derner, Tischler, Polley and Johnson (2005), and Heitschmidt et al. (1988).

Inundation

This is an upland plant that is not particularly flood tolerant (Roberts, Howe, and Jack, 1980). Similarly Stromberg et al. (1993) reports on velvet mesquite locations outside of 1-year and 5-year flood plains, and within 0.5 feet depth of a 10-year flood plain. Inundation values were assigned between seep willow and four-wing saltbush values, and the depth of submergence over the root cap was only 0.5 feet.

Figure 4-20. Honey mesquite tree (Better Hardwoods)

Desiccation

Honey mesquite is tolerant of drought and best adapted to uplands (figure 4-20) where rainfall is 15 to 20 inches (Steinberg, 2001). Desiccation characteristics are the same as four-wing saltbush, and similar to elderberry.

Shading

Pure stands of honey mesquite typically are many-aged, occur along the outer floodplain, and prefer full sun (Hurteau, 2008).

Competition

Honey mesquite, though potentially detrimental to competitive grasses, also facilitates plant growth by increasing soil organic matter content and nitrogen status (Beason et al., 1982). Tamarisk can grow faster than honey mesquite after a fire.

Senescence

The maximum age of honey mesquite is 200 years (Steinberg, 2001).

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Source for Figure 4-19:
Copyright © Robert O'Brien, Texas Tree Planting Guide, Texas A&M, http://www.bing.com/images/search?q=honey+mesquite&view=detail&id=E6D4EC4A89C2A326F38AB31A0135FE3D5FA297D3&first=1 [9/17/2012]
Source for Figure 4-20:
http://betterhardwoods.com/mesquite-burl [9/17/2012]

See Multi-Species References

Mixed forest - mxf

Germination

One of the broadest parameters selected was seed dispersal season for mixed forest (figure 4-21) used in the Sacramento River Calibration Study (SacCal) and the Sacramento River Alternatives Analysis Study (SacAA). Mixed forest includes Oregon ash (*Fraxinus latifolia*), box elder (*Acer negundo*), California sycamore (*Platanus racemosa*), and valley oak (*Quercus lobata*), although other woody species may be grouped in this community used in GIS mapping. These woody species share similar traits like water and shade tolerance but have wider variation in germination seasons. Valley Oaks germinate from acorns and the root can begin growing in December several months before the shoot appears, giving the taproot a 3 foot start on growth towards the water table (see http://phytosphere.com/oakplanting/acorns.htm).Box elder also produces airborne seeds in the fall that are dispersed throughout the winter producing a range of germination periods. Initially, a wide season was selected to represent the main woody species; however, this season was reduced to June 15 through July 10 during calibration to more closely represent the areas of GIS mapped vegetation. Testing of the initial longer germination season produced excess areas of mixed forest in the model. If the GIS mapping had not defined this vegetation type, the woody species within this vegetation type may have been better represented by reorganizing the mixed forest designation into two or three different modeled vegetation types.

Figure 4-21. Mixed forest at the Sacramento River (River Partners)

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Source for Figure 4-21:
River Partners at http://www.riverpartners.org/resources/riparian-ecology/veg-wildlife-habitat/communities-classification/mixed-riparian-forest.html [12/12/2012]

Oregon ash *(Fraxinus latifolia)* - Oash

Figure 4-22. Form of Fraxinus latifolia, Oregon Ash | Woodbrook Native Plant Nursery)

Figure 4-23. Oregon ash with its winged fruit well-formed and the pinnately compound leaf visible as seen along the Springwater Trail east of Gresham, OR between Palmblad Avenue and Rugg Road, July 8, 2011 (Slichter 2011).

The salt tolerance of Oregon Ash is rated low in the USDA NRCS Plant Characteristics.

Germination

Oregon ash produces airborne seeds (figure 4-22) in September and October that are viable for a year (Owston, 1995).The germination season is estimated at 90 to 152- average temperature days above 45 degrees for Washington and Oregon varieties. This would make a good vegetation type for temperature-driven simulation of germination in SRH-1DV.

Maximum Depth of Root Growth

This plant has a lateral growing root (figure 4-24) that may depend on soil moisture from precipitation or from frequent overbank wetting.

Desiccation

Desiccation tolerance is low (USDA NRCS Plant Characteristics). SRH-1DV assigned root depth desiccation values were 75% of Fremont cottonwood root depth desiccation values from early studies.

Inundation

An Oregon ash (figure 4-23) is more tolerant than a cottonwood of inundation, and these values are different from mixed forest values.

Figure 4-24. View of lateral root development of Oregon Ash (Seven Oaks Native Nursery)

Resources and References

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Source for Figure 4-22:
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Source for Figure 4-23:
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Pepperweed *(Lepidium latifolium)* - pw

The salt tolerance of pepperweed is high (USDA NRCS plant guide).

Germination

There is not much germination from pepperweed seeds (figure 4-22) and the seeds are suspected of having low viability (26 days) (Young et al. 1997). Germination can also occur from seed parts (Renz, 2000). Seeds should be water germinated but air germination can be used assuming there is a long enough period for invasives to spread throughout the study area. Seeds germinate in February and March (Whitson, 1987). Constant warm temperatures cause low germination rates (Miller et al., 1986).

Figure 4-25. Brassicaceae - Lepidium latifolium. From: Flora batava by Jan Kops and others. Amsterdam, J.C. Sepp, 1807, volume 2, plate 157. Hand-coloured engraving (sheet 225 x 278 mm).

Root Growth

Rhizomes may advance 3 to 6 ft from the parent plant (Young et al. 1997).
The shoots emerge in late winter/early spring (Fisher and McCaskill, 1990, Young et al. 1997). The plant roots are drought tolerant before sprouting. Plants will senesce by mid to late summer (Renz, 2000). From Zouhar (2004):

> "Perennial pepperweed roots are typically highly elongated and thick, with minimal branching. Some roots creep horizontally below the soil and others penetrate deep into the soil, but neither type forms dense clusters of roots. Roots are coarse and widely spaced (Blank and Young, 1997). Excavation of perennial pepperweed below ground biomass in a riparian habitat revealed that 19% of perennial pepperweed roots occurred in the top 4 inches (10 cm) of soil, and 85% in the top 24 inches (60 cm) (Renz et al., 1997). Some perennial pepperweed roots may extend much deeper. In excavations at Honey Lake National Wildlife Refuge, Blank and Young (1997) observed perennial pepperweed rooting depth in excess of 9 feet (3 m). Belowground biomass constitutes about 40% of perennial pepperweed's total biomass (Renz et al., 1997). This extensive creeping root system is thought to enhance the belowground competitiveness of perennial pepperweed for water and nutrients while increasing the carbohydrate reserve important for rapid shoot development in the spring (Blank and Young, 1997; Renz, 2000)."

Dessication

Roots are resistant to desiccation for an estimated 8 days (Renz, 2000).

Inundation

Inundation seems to control plant spread but the plants sprout after water is removed. Water could control pepperweed or could create more competition from wetland plants. Fredrickson and Murray, 1999, tried flooding to control pepperweed in California and Colorado. Colorado had a shorter season.

Pepperweed was controlled with an average 15 cm of water depth for a period of 90 days.

Competition

Figure 4-26. Colorado noxious weed- pepperweed

While the plants are germinating, they are susceptible to woody shade and groundcover, but after pepperweed has established (figure 4-23) they are relatively hardy. Pepperweed is susceptible to red sesbania soil toxins in the simulations. Grasses and wetland plants appear to outcompete pepperweed, but pepperweed can outcompete willows and cottonwood. Zouhar (2004) reports from Pyke (2000), perennial pepperweed is considered "highly invasive and competitive" in sagebrush (*Artemisia* spp.). The plants dominate through a system of creeping roots, leaf litter that quickly (after 1 yr of dead stems in late summer) builds up to 10 cm thick, and through action as a saline pump that creates salty soils with time (Young et al. 1997).

Senescence

Plants senesce in mid to late summer (<1 year).

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Source for Figure 4-25:

Brassicaceae - Lepidium latifolium From: Flora batava by Jan Kops and others. Amsterdam, J.C. Sepp, 1807, volume 2, plate 157. Hand-coloured engraving (sheet 225 x 278 mm). http://www.meemelink.com/prints_pages/20135.Brassicaceae%20-%20Lepidium%20latifolium.htm [9/14/2012]

Source for Figure 4-26:

Colorado Noxious Weeds Visual Identification Information - List B (Part 2). http://weeds.hotmeal.net/weeds/List_B_Part2.html [9/14/2012]

Plains/eastern cottonwood *(Populus deltoides)* - pc

Plains cottonwood (figure 4-27) was not modeled with SRH-1DV, but was a vegetation type included in the SedVeg model for Platte River studies. Although the parameters vary from SRH-1DV, inundation and resource information is included here for reference.

Inundation

Inundation studies reported in Whitlow and Harris (1979) and used in the development of the COE Flood Tolerance Index are:

- Hosner, 1958, 7.5 cm seedlings - 100% (3) died between 8 and 16 days when root crowns were submerged in 50.8 cm depth of water;
- Yeager, 1949, - 1 of 9 trees died at 240 days, remaining 8 trees died by 730 days in standing water upstream of the dam;

Figure 4-27. Populus deltoides subsp. Monilifera, plains cottonwood (Wikipedia)

- Bell and Johnson 1974, tree flooded - 7 survived 189 days flooding, don't know coverage;
- Broadfoot 1967, trees flooded - 8 survive 210 days, 90 cm max of root crown coverage;
- Peterson 1957, Nebraska, woodies colonized and thrived in area with 30-91 cm water, 30-90 days;
- Loucks and Keen 1973, Kansas seedlings flooded 1-4 wks, 61 cm over crown, at 28 days 35% died;
- Brunk et al., 1975, flooded trees in Iowa, 50% died at 119 days, 100% dead at 145 days, 6 ft or less submerged.

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Source for Figure 4-27:
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See Multi-Species Resources

Russian olive (*Elaeagnus angustifolia*) - Rolv

Russian olive tolerates broad range of soil, alkalinity, salinity, and moisture availability, and no special hydrograph is needed

Germination

Russian olive does not need bare ground or flood disturbance to germinate and can establish throughout season. Plants are disbursed by seeds in fruit (figure 4-28) through birds, animals or floating on water up to 48 hours (Lesica and Miles, 2004). For this model, seeds are disbursed by air and random distribution of air-bourne seeds is assumed to be somewhat similar to the randomness of animal and bird spread seeds. Seeds germinate over a broader range of conditions than seeds of native willow and cottonwood associates (DiTomaso and Healy 2003). Seeds germinate with combinations of light and elevation above groundwater (Shafroth, Auble, Scott, 1995).

Figure 4-28. Russian olive seeds and leaves (Craig Bremmon, CEB Tech Services)

Plants can germinate anytime the soil is moist throughout the growing season. The seeds have a tough shell that requires scarification or digestion. A longer germination period was assigned. The maximum dry days allowed before germination (seed longevity) is 3 years (1095 days).

Growth

The southwest U.S. has a 240 day growing season and Montana has a 120 day growing season. Assuming a 240 day growing season, the daily growth rate (feet/day of growing days) = (x feet)/(240 days * y years).

Figure 4-29. Silvery-green trees on hillside/banks are Russian olive invading a rare cienega in New Mexico (Una Smith, Wickipedia)

In the first season, Russian olive (figure 4-29) can grow 2 to 3 ft with good conditions. Nursery plants grow 4 to 5 ft in the first season and 8 to 12 ft in the second year. By inference, it is assumed the second season growth for native plants is 4 to 6 feet. Under Great Plains climatic conditions the plant grows 12.8 feet after 10 years and in another case, 16 feet after 44 years. In an example from Michigan, a plant grew 17 feet after 16 to 18 years. Lesica and Miles (2001) report a growth rate of 0.1 to 2.7 cm over all growth ages, and a mean value of 0.8 cm/year in Montana with a 120 day growing season.

Root Growth Rate

A 25 year old tree is 26 feet tall with roots that are 39 feet (Yeager, 1935, reported by Zouhar, 2005).

Shading

The plants can grow in shade.

Desiccation

Russian olive has high drought tolerance and plants are found where precipitation is 12-40 inches.

Inundation

Russian olive has low flood tolerance, a low anerobic rating and is a FACU and FACW wetland plant. Flooding can limit the spread of Russian olive. SRH-1DV parameters for mortality were assigned at 7 to 28 days of inundation (Theriot, 1993).

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Source of Figure 4-28:
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Source of Figure 4-29:
Photo by Una Smith, Wickapedia. http://en.wikipedia.org/wiki/Elaeagnus_angustifolia [10/5/2012]

See Multi-species Resources

Salt grass *(Distichlis spicata)* - salt

The USDA NRCS rates the salt tolerance for salt grass as high. The plant requires medium or fine soil, and does not do well in coarse soils.

Germination Season

Seeds can germinate throughout the summer but rhizomes are the best method of plant spread. The USDA NRCS Plant Characteristics lists plant germination by seed. Salt grass germinates in late spring and seeds require warm temperatures to germinate. Rhizomes (figure 4-30) can be spread by water and have higher success than seeds. Rhizomes can be planted all year but sprout best at 77 to 86 degrees F. This plant could also germinate in SRH-1DV using the water spread mechanism.

Figure 4-30. Rhizome growth and spread of distichlis spicata.

Growth

The root growth rate is slow at 0.02 cm/day.

Desiccation

Salt grass (figure 4-31) is described as a more drought tolerant wetland species (Newman and Gates, 2006). More information is needed for all grasses on days to desiccate. Similar to Fremont cottonwood and Gooding's black willow, USDA NRCS Plant Characteristics list medium drought tolerance, medium moisture use, and a required precipitation range of 5 to 70 inches per year.

Inundation

Found in irregularly flooded areas where the groundwater is 2 inches above to 6 inches below the ground (Newman and Gates, 2006). Salt grass has a high tolerance of inundation.

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Figure 4-31. salt grass at Calico Basin Red Springs, Nevada (Forest & Kim Starr Plants of Hawaii)

Source for Figure 4-30:
http://www.conabio.gob.mx/malezasdemexico/poaceae/distichlis-spicata/imagenes/tallo-estolones.jpg [9/17/2012]

Source for Figure 4-31:
Forest & Kim Starr Plants of Hawaii, Image licensed under a Creative Commons Attribution 3.0 License, permitting sharing and adaptation with attribution. http://luirig.altervista.org/cpm/albums/bot-hawaii11/05462-Distichlis-spicata.jpg [9/17/2012]

Sandbar willow/narrow leaf willow/coyote willow *(Salix exigua)* - sbw

Figure 4-32. sandbar willow at San Joaquin River (Reclamation)

USDA NRCS Plant Characteristics list the salt tolerance of sandbar willow as low.

Germination Season

Air germination and lateral root spread are used for sandbar willow (figure 4-32). In initial simulations, the germination season was May 30 (JD129) to July 8 (JD181). Stillwater (2006) noted the germination season for sandbar willow ranges widely and the propagation season for sandbar willow was later expanded to 92 days beginning on May 30.

Root Growth

Sandbar willow and invasive plants have better inundation coping mechanisms than Fremont cottonwood and Gooding's black willow. In SRH-1DV, sandbar willow roots are allowed to extend 0.2 feet below the water surface before growth stops (maximum root depth below the water table before growth stops).

Desiccation

Sandbar willow is less tolerant of drought than Fremont cottonwood.

Inundation

Sandbar willow is listed as a facultative wetland plant (FACW) and an obligate (OBL) with a high anaerobic tolerance. In Nebraska, plants with water over the root crown at a depth of 182 cm for 365 days had 100% survival. Also an established thicket survived flooding and 91 cm of sediment deposition similar to Gooding's black willow plants (Peterson, 1957).

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See Multi-Species Resources

Scarlett wisteria/red sesbania (*Sesbania punicea)* - rs

Germination

Scarlett wisteria (figure 4-33 and 4-34) can establish from large seed pods that float on the water. This plant should be water germinated but air germination can be used if the simulation represents the maximum extent of coverage after plants have had multiple years to colonize the study area. The California Exotic Pest Plant Council and the Southwest Vegetation Management Association (2003) report the seeds can remain viable in soils for 3 years or more.

Figure 4-33. Red sesbania leaves, seedpods and flowers (©Copyright Bobby Hattaway 2011 at Discover Life)

Growth

Root depth is assigned to 4 or 5 feet.

Desiccation

Similar to Gooding's black willow

Inundation

The seedlings have high tolerance to inundation so SRH-1DV values were assigned similar to Gooding's black willow. Adult plants were assigned higher SRH-1DV values than a pepper weed values.

Figure 4-34. Red sesbania in winter with seed pods still attached (Reclamation)

Shading

Likes sun but seems to tolerate shade.

Competition

Groundcover can prevent germination, but red sesbania is an allelopath and can push out other plants. In the SRH-1DV model, it is assumed red sesbania cannot outcompete other plants until 2 or 3 years when toxins build up in the soil. This is reflected in the model through the competition tables for the other plants in the model (a Y plant).

Scour

Red sesbania in the San Joaquin River was observed to be resistant to erosion at low and medium flows. The plant, however, may be susceptible to being undercut during bank erosion due to relatively shallow roots, and the scour threshold parameter might be reduced accordingly in SRH-1DV.

Senescence

Red sesbania can live 15 years.

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Source for Figure 4-33: ©Copyright Bobby Hattaway 2011 at Discover Life http://www.discoverlife.org/mp/20q?search=Sesbania+punicea [12/13/2012]

Seep willow/mulefat (*Baccharis salicifolia*) - mule

Germination

Zimmerman (1969) describes mulefat germination at locations similar to tamarisk, by small seeds blown in the wind (figure 4-35). Germination requires saturated soils for 2-4 weeks of growth, and occurs in late March through the summer (Horton, 1960).

Growth

The USDA NRCS Plant Characteristics assigns a rapid growth rate and summer growth. Mulefat roots can extend 7 feet to shallow groundwater (Zimmerman ,1969).

Desiccation

Mulefat has low drought tolerance but requires only 10 to 18 inches of precipitation per year.

Inundation

The USDA NRCS Plant Characteristics list a low inundation tolerance (low anaerobic tolerance) for mulefat and the plant is a facultative wetland (FACW). Mulefat requires sustained flows (Zimmerman 1969) but uses less water than Fremont cottonwood at medium tolerance. The COE flood tolerance index (FTI) range is 30 to 90 days of survival, and based on FACW rating, 7-28 days survival (Zimmerman, 1969).

Figure 4-35. Mulefat, Baccharis salicifolia, Asteraceae, Box Canyon Arizona, Anza-Borrego Desert State Park, February 2009 (Michael L. Charters, Calflora)

Shading

Mulefat (figure 4-35) is intolerant of shade.

Competition

From Steinberg (2001), mulefat is potentially detrimental to grasses but facilitates plant growth by providing organics and fixing nitrogen. Mulefat has low hedge tolerance.

Scour

The erosion parameters for mulefat were assumed equivalent to the values for sandbar willow.

Resources

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Figure 4-36. Baccharis salicifolia (Ruiz & Pavón) Pers. (Campbell and Lynn Loughmiller, Davis Mountains,TX, 1996)

Source for Figure 4-35:
Michael L. Charters, Calflora, February 2009, http://www.calflora.net/recentfieldtrips/boxcanyon09.html [2/11/2011]
Source for Figure 4-36:
Campbell and Lynn Loughmiller, Davis Mountains,TX, 2006, Filename: PCD2428_IMG0041.JPG, Slide Index: C32 96-64, Restrictions: Unrestricted, http://www.wildflower.org/gallery/result.php?id_image=5029 [9/14/2012]

See Multi-Species Resources

Tamarisk/salt cedar (*Tamarix* spp.) - tam

Tamarisk (figure 4-37 and 4-38) species are generally described jointly here with the common name tamarisk. Species of tamarisk include: *Tamarix chinensis* Luor, saltcedar; *Tamarix gallica* L., French tamarisk; *Tamarix parviflora* DC, small flowered tamarisk; and *Tamarix ramosissima* Ledeb, saltcedar. Tamarisk salt tolerance is high.

Germination

When the water germination option is available, it should be used for tamarisk. The germination period is July, August, and September. Seed germination is very rapid at less than 1 day (Zouhar, 2003). Seed viability is 24 days in the sun (Stevens, 1989)

Growth

Tamarisk has deep roots (Zimmerman, 1969; Horton et al., 2001). For lateral root growth and maximum root growth depth, roots can grow 6 inches in the first 8 weeks. Plants can grow 10 to 13 feet in one growing season under favorable conditions (DiTomaso, 1998). In Utah, the stem diameter increased 0.39 inches in 7.68 years in comparison to a similar increase in Arizona in 2.36 years.

Figure 4-37. Tamarisk at lake site of biocontrol program in Kansas (Kansas Department of Agriculture)

Desiccation

Small seedlings are more drought tolerant than sandbar willow. When groundwater drops, tamarisk can out-compete Fremont cottonwood.

Inundation

Tamarisk are very tolerant of inundation. At one site seedlings survived 24 days underwater and most died between 28 and 42 days. Mature plants survived 70 (Kerpez and Smith, 1987) to 90 (DiTomaso, 1998) days of inundation. In DeGruchy (1956), mature trees; *Tamarix gallica* survived 3 months (90 days) of inundation in the summer, with 36 in of submergence over the root crown. Tamarisk died at16 months of flooding with 48 in. over the root crown. Mature plants survived complete submergence for 70 days, and survived 98 days with partial submergence. Cooper et al (2003) report survival is facilitated by 3 or 4 sequential years of low flow, after which they can survive very large floods.

Competition

Tamarisk does not out compete plants, but can out survive them during floods and droughts by moving into newly formed dead zones (disturbance plant). An exception is when there is no flooding for a period, and salt builds up in the soils. There is discussion on whether Tamarisk causes the salt build up or is merely tolerant of the buildup. Tamarisk has high salt tolerance in comparison to most plants (Sher et al. 2002). The competition rules establish survival for other plants (x plant in table) in the presence of tamarisk (a y plant in the table) by age. Tamarisk is susceptible to shade from woody plants and groundcover as a seedling. It is also assumed that red sesbania soil toxins can out-compete tamarisk and prevent tamarisk related salt buildup.

At the end of two years of growth in a study of competition, tamarisk seedlings growing in the presences of sandbar willow suffered reduced growth and 15% higher mortality. Five year old sandbar willow plants suppressed salt cedar growth only slightly (Stevens 2001).

From Zouhar (2003):

A nonnative, honeydew-producing leafhopper found on tamarisk interacts with a fungus to change soil characteristics increasing saline conditions, so that plant recruitment is virtually eliminated under a tamarisk canopy (Simberloff and VanHolle 1999).

Scour

Seedlings and plants are prone to scour. Seedlings are easily detached by scour and float away (Zouhar, 2003).

Senaissance

Tamarisk can live to 100 years.

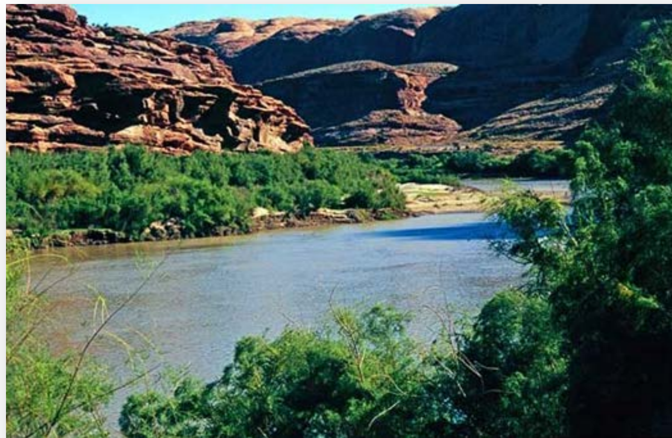

Figure 4-38. Salt cedar landscape, Utah (©Copyright Salt Lake County, Utah)

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Source for Figure 4-38:
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See Multi-Species Resources

Multi-Species Resources

tamarisk and Russian olive

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cottonwood, black willow, mesquite, mulefat, tamarisk, four wing saltbush, ash, sycamore, walnut, desert willow, catclaw acacia, hackberry

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5. FUTURE NUMERICAL VEGETATION MODELING

Without numerical modeling tools, the prediction of vegetation coverage is often based on a zone model as a function of flood elevations. Campbell and Green (1968) found a zone model to be ineffective in describing the locations of vegetation in their study of Sycamore Creek, and at other riparian locations, and report on the causative factors of variation.

> … large-scale changes in habitats caused by recurring floods, erosion, and deposition determine to a large extent the resulting vegetation complex…Because of disturbances in the flood-prone channel, species form mosaics of seral stages of communities with different combinations of species dominating each stage… Some riparian species recorded on Sycamore Creek appear to have become established primarily because geomorphological conditions influenced the microclimate**…**

Their list of channel-related causes included:

- variations in groundwater and in moisture retention due to localized conditions;
- sediment deposits and bare sites for seedling establishment following a flood;
- "chance factors" including time of year of flooding, stem-sprouting ability and the viability of seeds deposited on the site;
- competition between plants;
- variation in plant tolerance to inundation, erosion and burial; and
- the ability of select plants to re-establish from propagules after washing downstream.

A zone analysis cannot reflect these factors, yet most items noted by Campbell and Green (1968) have been included in SRH-1DV. The vast accounting capabilities of numerical models enable tracking of inter-related processes and complex responses of riparian plant growth to river flow, groundwater response and sediment transport.

At the same time, a numerical modeler strives to minimize the use of parameter-driven processes to prevent undue influence on the outcome from the selection of parameters. However, unlike flow, the laws of physical science are not useful for describing plant growth, so the vegetation module in SRH-1DV is by necessity a parameter-needy tool. A second limitation of the SRH-1DV model is the need to describe a 3D world within a 1D structure. Cross sections often do not provide sufficient coverage for detailed descriptions of vegetation at localized sites. The challenge is shared by other types of 1D river models, and interpretation of the vegetation results should be tempered by an understanding of 1D flow model limitations.

Despite the limitations, experiences from four previous studies indicate SRH-1DV has been an effective tool for analyzing general differences in vegetation coverage resulting from alternative flow management scenarios. The number of integrated vegetation factors that can be assessed with numerical vegetation modeling has expanded with the development of the model, advancing vegetation assessments beyond the previous standard of elevation zone studies. SRH-1DV vegetation studies, and the associated parameter selection, have been documented in this report to aid future vegetation modeling endeavors. Descriptions of sensitivity, calibration and verification tasks that can be incorporated to improve the quality of results have been interposed throughout the report. This tool offers advances to methods of flow and vegetation assessment, but a general recommendation, acknowledging the model limitations, is to continue to apply numerical model assessments in comparative studies where the differences between results are more relevant than the absolute values.

Based upon the simulations to date, the following conclusions have been made:

- Factors that have had a large influence on results (more sensitive) include germination season, maximum root depth, root growth rate, inundation and desiccation values. Shading and/or competition can also have a significant impact.

- Although erosion/scour as an important factor in channel roughness computations, erosion has removed less plants than the other mortalities in the projects studied to date. Erosion is mainly significant at the bank and not in overbank areas where desiccation, inundation, shading and competition can impact more vegetated area.

- The model assumes there is an unlimited supply of seed within the germination season; this has worked well so far but we may need an option in the future to limit seed to areas within a specified distance of mature plants.

- Select representative vegetation species for the model instead of vegetation alliances, i.e. vegetation types Oregon ash, valley oak, and California sycamore, instead of a single vegetation type, mixed forest.

- Results can be negatively impacted if density is not included in the translation of vegetation communities to vegetation types for assignment of initial conditions.

- There is likely no need to use two vegetation types if there is no means of distinguishing between the two growth patterns and characteristics in the vegetation input. However, it is necessary to use all vegetation types that represent significant habitat niches. Cottonwood and or Gooding's black willow, sandbar willow and a ground cover/grass have been common choices in the projects to date.

- Avoid non-essential vegetation types, i.e. exclude cottonwood if it isn't prevalent or a main focus of the study, or wetlands plants (bulrush, cattail) if there is limited standing water or backwater area.

- At the same time, consider using vegetation types that may mark future change: invasive plants that influence river morphology or ecological balance, since they can quickly invade (figure 5-1) and transform the landscape; or wetland plants like cattail and bulrush for riparian transitions.

- Although many invasive plants are spread by water not air and the water germination method is currently not dependable, include invasive plants and analyze using the air spread germination method (assume unlimited seed or plant propagules during the germination season). This approach provides insight on how the vegetation coverage would evolve if invasive plants are not controlled.

- Most effective means of distinguishing plants on previous projects have been: root growth rates, maximum root growth depth, resistance to shading, tolerance of wet roots and resistance to inundation, resistance to drought, air borne versus water borne germination, germination season, lateral root spread and competition.

- The competition mortality table is useful for simulating distinguishing characteristics of plants that fall outside of typical patterns including: bare ground requirements for germination, allelopaths that alter soil chemistry, salt producing and salt tolerant plants, and to distinguish the strength and weaknesses between plants when the reason for the dominance is still not well understood.

The following features are recommended to be added in future versions of the model for general application:

- Water Germination. Investigate the water spread means of plant expansion/germination. Many invasive plants of interest are water spread and this would be a useful component on most projects.

- Shading/Competition.

- The general formulation of plant succession and competition needs to be reconsidered. For example, the succession stages utilized in Benjankar et al (2011) could be implemented into the model.
- Separate the count of shading and competition mortality. This would improve quality control of the competition mortality and help to define the impact of shading in the study area.
- Ensure the bare ground requirement for germination is addressed in the competition rules for the vegetation types that require bare ground. Most, but not all, of the riparian plants require a ground disturbance to germinate and this is an additional means of distinguishing plants.

- Vegetation Induced Channel Roughness. Test the roughness option that incorporates changes in friction for the flow and sediment transport computations, from the growth or increased coverage of vegetation in the channel.

Figure 5-1. Dry reach of the San Joaquin River with limited surviving vegetation (Reclamation)

- Precipitation. Add precipitation- the ability to add additional moisture. This could be a random assignment based on inches per season or could be a historical input file of daily precipitation for the study area. Theoretically, the SRH-1DV model is currently best suited to semi- arid or arid study areas and riparian vegetation types when there is no precipitation component.

- Dessication (figure 5-1).
    - Combine Desiccation Methods. Advance cottonwood desiccation mortality with an option that expands the stress method to plants older than 1 year (could also link root/water table separation method for plants > 1 year).
    - Desiccation Stress Method. Expand the cottonwood desiccation stress method to other vegetation types (Gooding's black willow and sandbar willow are the second most common plants in these studies) through lab studies on seedlings less than 1 yr old, and field studies of plant desiccation and inundation stress for plants greater than 1 year old.

- Random Senescence. Advance the senescence mortality by removing plants that have reached their maximum age in a probabilistic pattern. If cottonwoods are assigned an 80 year life, also assign a range of years for mortality to occur (±x years) and have a mechanism to randomly select the plants to die over this period. Currently, with this example, all 80 year old plants in the study area will die in the same moment.

The following features may be useful in select situations:

- Degree Day Germination Season. Test and use germination season based on degree days when the function is available from the literature.

- Canopy Cover Over Water. Develop and test the computation of percent shading over water during (mean low flow?) from tracking canopy growth. This is probably a small value in most cases but could support shading computations or estimates from the temperature model. It might also link as overhanging canopy to habitat/food sources for young rearing salmon during mean low flows and also during overbank flooding.

- Results as Vegetation Communities. Develop a method to output results by looking at vegetation types in an area, and identifying the communities/alliances from the mix (the reverse of our initial mapping method of assigning types from the communities). Currently our results produce the coverage area of each vegetation type but communities are not generated from the results. In some cases we would like the results as community, i.e. how many points or areas meet base criteria to qualify as a tamerisk/honey mesquite community since areas surrounding a lone honey mesquite may have no habitat value to the species of interest. This approach may be useful in the analysis of Rio Grande results or other habitat studies.

- Plant Growth as a Function of Stress. If plant height became an important value for estimating habitat or roughness, and the results were sensitive to small adjustments in plant height, the plant height value might be improved by accounting for moisture availability and the resulting plant stress while tracking plant growth.

- Multiple Plant Ages. Consider if it is necessary to track more than one age of plant on a single point, i.e. a 2 yr and 7yr cottonwood plant germinated from different high flow events (currently the model only tracks the earliest established plant or use two vegetation types to represent the same vegetation at two different ages). If there are multiple points in an area and density assignment is used, this may not be necessary (and may not be a concern with 2D modeling). This method would improve representation of plants that germinate in niches from successive high flow events.

A 2D vegetation module is currently under development. The following features from SRH-1DV should be included in the 2D vegetation module:

- The ability to simulate groundwater elevations as a function of river stage and groundwater boundary conditions
- Means of assigning mapped vegetation density
- Means of getting good point density coverage (this should improve automatically with 2D and may not need attention)
- Automatic roughness change with vegetation growth and death, and expansion or decrease in coverage
- Water-related germination mechanisms, commonly needed for invasive plants
- Lateral root spread which should have increased effectiveness with the increased number of points in a 2D mesh
- Competition- this is a useful option that we have only begun to use effectively
- Most Used Mortalities: Desiccation, Inundation, Shading, Competition (separate shading and competition in the mortality count), and Erosion
- Lesser Used Mortalities: Burial, Improved Senescence, Ice Removal
- Add a precipitation feature
- Add a tracking feature for estimating area and percent of water surface shaded by overhanging vegetation canopies
- Compute a canopy cover value near the channel for food source and habitat estimates

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APPENDIX A – INITIAL CONDITIONS TABLES

VIV Records: SAN JOAQUIN RIVER EIS		***no density***						
VegCommunity	**ABBREV**	**1FC**	**2GBW**	**3NLW**	**4HB**	**5AR**	**6RS**	**7NoG**
ag field	AG	0	0	0	0	0	0	1
arundo 2000 veg	AR1	0	0	0	0	8	0	0
arundo 2008 pts	AR2	0	0	0	0	2	0	0
alkali sink	AS	0	0	0	0	0	0	1
cottonwood rip	CW1	40	40	0	2	0	0	0
cottonwood rip	CW2	40	40	0	0	0	0	0
cottonwood rip	CW3	25	25	0	2	0	0	0
cottonwood rip	CW3CW3	25	25	0	2	0	0	0
cottonwood rip	CW4	25	25	0	0	0	0	0
cottonwood rip	CW5	8	8	0	2	0	0	0
CW rip LD	CWLD2	40	40	0	0	0	0	0
CW rip LD	CWLD4	25	25	0	0	0	0	0
CW rip LD	CWLD6	8	8	0	0	0	0	0
disturbed	D	0	0	0	0	0	0	1
EB savannah	EB	0	0	0	1	0	0	0
exotic tree	EXO	25	25	0	1	0	0	0
herbaceous	H	0	0	0	1	0	0	0
mixed rip	MR1	40	40	0	2	0	0	0
mixed rip	MR2	40	40	0	0	0	0	0
mixed rip	MR3	25	25	0	1	0	0	0
mixed rip	MR4	25	25	0	0	0	0	0
mixed rip LD	MRLD2	40	40	0	0	0	0	0
mixed rip LD	MRLD4	25	25	0	0	0	0	0
mixed rip LD	MRLD6	8	8	0	0	0	0	0
red sespania extensive 2008 polygons	RESEE	0	0	0	0	0	3	0
red sespania scattered shrubs 2008 polygons	RESES	0	0	0	0	0	0.5	0
rip oak	OAK1	0	40	0	2	0	0	0
rip oak	OAK2	0	40	0	0	0	0	0
rip oak	OAK3	0	25	0	2	0	0	0
rip oak	OAK4	0	25	0	0	0	0	0
riparian scrub	RS	4	4	1	2	0	0	0
riverwash	RW	0	0	0	0	0	0	0
willow scrub	SW5	0	4	1	2	0	0	0
urban	URB	0	0	0	0	0	0	1
open water	WA	0	0	0	0	0	0	0
wetland/marsh	WET	0	0	0	2	0	0	0
willow riparian	WR1	0	40	2	2	0	0	0
willow riparian	WR2	0	40	0	0	0	0	0
willow riparian	WR3	0	25	2	2	0	0	0

willow riparian	WR4	0	25	0	0	0	0	0
willow rip LD	WRLD	0	40	1	1	0	0	0
willow rip LD	WRLD2	0	40	0	0	0	0	0
willow rip LD	WRLD3	0	25	2	2	0	0	0
willow rip LD	WRLD4	0	25	2	2	0	0	0
willow scrub	WS5	0	8	2	2	0	0	0
willow scrub	WS6	0	8	2	0	0	0	0
willow scrub LD	WSLD6	0	4	2	0	0	0	0

VIV Records: SACRAMENTO RIVER Alternatives Analysis (EIS) - Initial Vegetation Conditions (*d = density)*

veg community	1Fc	d	2mxf	d	3Gbw	d	4nlw	d	5herb	d	6inv	d	7ag	d	8nogr	d
Barren & Wasteland	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Berry Shrub	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1
Citrus & Subtropical	0	1	0	1	0	1	0	1	0	1	0	1	1	1	0	1
Cottonwood Forest	40	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Deciduous Fruits & Nuts	0	1	0	1	0	1	0	1	0	1	0	1	1	1	0	1
Disturbed	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Field Crops	0	1	0	1	0	1	0	1	0	1	0	1	1	1	0	1
Giant Reed	0	1	0	1	0	1	0	1	0	1	3	1	0	1	0	1
Grain & Hay Crops	0	1	0	1	0	1	0	1	0	1	0	1	1	1	0	1
Gravel	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Herb Land	0	1	0	1	0	1	0	1	1	0.5	0	1	0	1	0	1
Idle	0	1	0	1	0	1	0	1	0	1	0	1	1	1	0	1
Industrial	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1
Marsh	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Mixed Forest	0	1	40	1	0	1	0	1	0	1	0	1	0	1	0	1
Native Veg	0	1	0	1	0	1	0	1	0	1	0	1	1	1	0	1
Open Water	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Pasture	0	1	0	1	0	1	0	1	0	1	0	1	1	1	0	1
Residential	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1
Rice	0	1	0	1	0	1	0	1	0	1	0	1	1	1	0	1
Riparian Scrub	0	1	0	1	5	0.1	2	0.3	1	0.5	0	1	0	1	0	1
Riparian Veg	0	1	0	1	20	0.5	5	1	0	1	0	1	0	1	0	1
Semi Agricultural	0	1	0	1	0	1	0	1	0	1	0	1	1	1	0	1
Tamarisk	0	1	0	1	0	1	0	1	0	1	2	1	0	1	0	1
Truck & Berry Crops	0	1	0	1	0	1	0	1	0	1	0	1	1	1	0	1
Urban	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1
Urban Commercial	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1
Urban Landscape	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1
Urban Vacant	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1
Valley Oak	0	1	40	1	0	1	0	1	0	1	0	1	0	1	0	1
Vineyards	0	1	0	1	0	1	0	1	0	1	0	1	1	1	0	1
Water Surface	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

VIV Records: SAN JOAQUIN RIVER RESTORATION - Existing Vegetation Conditions

Map Vegetation Community		Fcwd		Oash		Gbw		Sbw		Eld		Rose		Salt		Crye		Mug		Cbr		Nogr	
Abbreviation	Description	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den
AG	ag field	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1
AR1	arundo 2000 veg	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
AR2	arundo 2008 pts	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
AS	alkali sink	0	1	0	1	0	1	0	1	0	1	0	1	1	0.75	0	1	1	0.5	0	1	0	1
CW1	cottonwood rip	40	1	0	1	0	1	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1
CW2	cottonwood rip	40	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW3	cottonwood rip	20	1	0	1	0	1	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1
CW3CW3	cottonwood rip	20	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW4	cottonwood rip	20	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW5	cottonwood rip	10	1	0	1	0	1	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1
CWLD2	CW rip LD	40	0.25	0	1	0	1	0	1	0	1	0	1	2	0.3	2	0.3	0	1	0	1	0	1
CWLD4	CW rip LD	20	0.25	0	1	0	1	0	1	0	1	0	1	2	0.3	2	0.3	0	1	0	1	0	1
CWLD6	CW rip LD	10	0.25	0	1	0	1	0	1	0	1	0	1	2	0.3	2	0.3	0	1	0	1	0	1
D	disturbed	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
EB	elderberry	0	1	0	1	0	1	0	1	3	1	0	1	0	1	0	1	0	1	0	1	1	1
EXO	exotic tree	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
H	herbaceous	0	1	0	1	0	1	0	1	0	1	0	1	2	0.3	2	0.3	0	1	0	1	0	1
MR1	mixed rip	40	0.5	40	0.25	40	0.3	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1
MR2	mixed rip	40	0.5	40	0.25	40	0.3	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
MR3	mixed rip	20	0.5	20	0.3	20	0.4	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1
MR4	mixed rip	20	0.5	20	0.3	20	0.4	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
MRLD2	mixed rip LD	40	0.2	40	0.1	40	0.2	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
MRLD4	mixed rip LD	20	0.2	20	0.1	20	0.2	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
MRLD6	mixed rip LD	10	0.2	10	0.1	10	0.2	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
RESEE	red sespania extensive 2008 polygons	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

Map Vegetation Community		Fcwd		Oash		Gbw		Sbw		Eld		Rose		Salt		Crye		Mug		Cbr		Nogr	
Abbreviation	Description	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den
RESES	red sespania scattered shrubs 2008 polygons	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
OAK1	rip oak	0	1	40	1	0	1	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1
OAK2	rip oak	0	1	40	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1
OAK3	rip oak	0	1	20	1	0	1	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	1	1
OAK4	rip oak	0	1	20	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1
RS	riparian scrub	10	0.1	10	0.1	10	0.2	3	0.3	0	1	0	1	0	1	0	1	1	0.1	0	1	1	1
RW	riverwash	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
SW5	willow scrub	0	1	0	1	10	0.3	3	0.5	0	1	3	0.2	0	1	0	1	0	1	0	1	0	1
URB	urban	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1
WA	open water	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
WET	wetland/marsh	0	1	0	1	0	1	0	1	0	1	0	1	2	0.5	2	0.5	0	1	3	0.5	0	1
WR1	willow riparian	0	1	0	1	40	1	3	0.25	0	1	3	0.25	2	0.1	0	1	0	1	0	1	0	1
WR2	willow riparian	0	1	0	1	40	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
WR3	willow riparian	0	1	0	1	25	1	3	0.25	0	1	3	0.25	2	0.1	0	1	0	1	0	1	0	1
WR4	willow riparian	0	1	0	1	25	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
WRLD	willow rip LD	0	1	0	1	40	0.25	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1
WRLD2	willow rip LD	0	1	0	1	40	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
WRLD3	willow rip LD	0	1	0	1	20	0.25	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1
WRLD4	willow rip LD	0	1	0	1	20	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
WS5	willow scrub	0	1	0	1	10	0.3	3	0.5	0	1	3	0.1	0	1	0	1	0	1	0	1	0	1
WS6	willow scrub	0	1	0	1	10	0.3	0	1	0	1	3	0.1	0.5	0.4	0	1	1	0.1	0	1	0	1
WSLD6	willow scrub LD	0	1	0	1	10	0.1	3	0.2	0	1	3	0.2	0.5	0.5	0	1	1	0.2	0	1	0	1

VIV Records: SAN JOAQUIN RIVER - Alternative Vegetation Conditions

Map Vegetation Community		Fcwd		Oash		Gbw		Sbw		Eld		Rose		Salt		Crye		Mug		Cbr		Bbt		Rip		Nogr	
Abbreviation	Description	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den
Bwt	black willow	0	1	0	1	2	0.4	0.5	0.1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Bbt	buttonbush	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	2	0.5	1.5	0.5	0	1
Cbm	bullrush marsh	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	0.85	0	1	0	1	0	1
Cmb	mugwort	0	1	0	1	0	1	0	1	0	1	1	0.1	0	1	0	1	1	0.75	0	1	0	1	0	1	0	1
Crg	creeping ryegrass	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0.1	1	0	1	0	1	0	1	0	1	0	1
Fallow	fallow	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Fcf	Freemont Cottonwood	1	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Oag	Oregon Ash	2	0.25	0	1	0	1	0	1	0	1	0	1	0.1	0.3	0	1	0	1	0	1	0	1	0	1	0	1
Rbh	Riparian grass	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	2	0.5	1.5	0.5	0	1
River	River	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Road	Road	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1
Sgf	Salt Grass	0	1	0	1	0	1	0	1	0	1	0	1	0.1	1	0	1	0	1	0	1	0	1	0	1	0	1
Swt	sandbar willow	0	1	0	1	0	1	0.5	0.6	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
AG	ag field	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1
AR1	arundo 2000 veg	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
AR2	arundo 2008 pts	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
AS	alkali sink	0	1	0	1	0	1	0	1	0	1	0	1	1	0.75	0	1	1	0.5	0	1	0	1	0	1	0	1
CW1	cottonwood rip	40	1	0	1	0	1	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW2	cottonwood rip	40	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW3	cottonwood rip	20	1	0	1	0	1	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW3CW3	cottonwood rip	20	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW4	cottonwood rip	20	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW5	cottonwood rip	10	1	0	1	0	1	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CWLD2	CW rip LD	40	0.25	0	1	0	1	0	1	0	1	0	1	2	0.3	2	0.3	0	1	0	1	0	1	0	1	0	1
CWLD4	CW rip LD	20	0.25	0	1	0	1	0	1	0	1	0	1	2	0.3	2	0.3	0	1	0	1	0	1	0	1	0	1
CWLD6	CW rip LD	10	0.25	0	1	0	1	0	1	0	1	0	1	2	0.3	2	0.3	0	1	0	1	0	1	0	1	0	1
D	disturbed	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
EB	elderberry	0	1	0	1	0	1	0	1	3	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
EXO	exotic tree	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
H	herbaceous	0	1	0	1	0	1	0	1	0	1	0	1	2	0.3	2	0.3	0	1	0	1	0	1	0	1	0	1
MR1	mixed rip	40	0.5	40	0.25	40	0.3	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
MR2	mixed rip	40	0.5	40	0.25	40	0.3	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
MR3	mixed rip	20	0.5	20	0.3	20	0.4	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1

Map Vegetation Community		Fcwd		Oash		Gbw		Sbw		Eld		Rose		Salt		Crye		Mug		Cbr		Bbt		Rip		Nogr	
Abbreviation	Description	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den	Age	Den
MR4	mixed rip	20	0.5	20	0.3	20	0.4	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
MRLD2	mixed rip LD	40	0.2	40	0.1	40	0.2	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
MRLD4	mixed rip LD	20	0.2	20	0.1	20	0.2	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
MRLD6	mixed rip LD	10	0.2	10	0.1	10	0.2	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
RESEE	red sespania extensive 2008 polygons	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
RESES	red sespania scattered shrubs 2008 polygons	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
OAK1	rip oak	0	1	40	1	0	1	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
OAK2	rip oak	0	1	40	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
OAK3	rip oak	0	1	20	1	0	1	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
OAK4	rip oak	0	1	20	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
RS	riparian scrub	10	0.1	10	0.1	10	0.2	3	0.3	0	1	0	1	0	1	0	1	1	0.1	0	1	0	1	0	1	0	1
RW	riverwash	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
SW5	willow scrub	0	1	0	1	10	0.3	3	0.5	0	1	3	0.2	0	1	0	1	0	1	0	1	0	1	0	1	0	1
URB	urban	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1
WA	open water	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
WET	wetland/marsh	0	1	0	1	0	1	0	1	0	1	0	1	2	0.5	2	0.5	0	1	3	0.5	0	1	0	1	0	1
WR1	willow riparian	0	1	0	1	40	1	3	0.25	0	1	3	0.25	2	0.1	0	1	0	1	0	1	0	1	0	1	0	1
WR2	willow riparian	0	1	0	1	40	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
WR3	willow riparian	0	1	0	1	25	1	3	0.25	0	1	3	0.25	2	0.1	0	1	0	1	0	1	0	1	0	1	0	1
WR4	willow riparian	0	1	0	1	25	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
WRLD	willow rip LD	0	1	0	1	40	0.25	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
WRLD2	willow rip LD	0	1	0	1	40	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
WRLD3	willow rip LD	0	1	0	1	20	0.25	3	0.25	0	1	3	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
WRLD4	willow rip LD	0	1	0	1	20	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
WS5	willow scrub	0	1	0	1	10	0.3	3	0.5	0	1	3	0.1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
WS6	willow scrub	0	1	0	1	10	0.3	0	1	0	1	3	0.1	0.5	0.4	0	1	1	0.1	0	1	0	1	0	1	0	1
WSLD6	willow scrub LD	0	1	0	1	10	0.1	3	0.2	0	1	3	0.2	0.5	0.5	0	1	1	0.2	0	1	0	1	0	1	0	1

veg_community	**Fc**	d	**Gbw**	d	**sbw**	d	**mule**	d	**hmq**	d	**fwsb**	d	**catt**	d	**Rolv**	d	**tamx**	d	**grass**	d	**nogr**	d
ATX6	0	1	0	1	0	1	0	1	0	1	3	0.5	0	1	0	1	0	1	0	1	0	1
B5	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
B5d	0	1	0	1	0	1	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1
B5s	0	1	0	1	0	1	10	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
B6	0	1	0	1	0	1	2	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
B-C5	10	0.5	0	1	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
B-C-CW6F	2	0.75	0	1	2	0.75	2	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1
B-C-RO5S	10	0.25	0	1	0	1	10	0.25	0	1	0	1	0	1	10	0.25	0	1	0	1	0	1
B-CW5	0	1	0	1	10	0.5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
B-CW5F	10	0.5	0	1	10	0.75	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1
B-CW-C5	10	0.25	0	1	10	0.5	10	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
B-CW-RO-C6	2	0.5	0	1	2	0.5	2	0.5	0	1	0	1	0	1	2	0.5	0	1	0	1	0	1
B-CW-SC5	0	1	0	1	10	0.5	10	0.25	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
B-CW-SC6	0	1	0	1	2	0.5	2	0.5	0	1	0	1	0	1	0	1	2	0.5	0	1	0	1
B-S5	0	1	0	1	0	1	10	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
B-SC5	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
B-SC5d	0	1	0	1	0	1	10	0.75	0	1	0	1	0	1	0	1	20	0.75	0	1	0	1
B-SC5s	0	1	0	1	0	1	10	0.25	0	1	0	1	0	1	0	1	20	0.25	0	1	0	1
B-SC6	0	1	0	1	0	1	2	0.5	0	1	0	1	0	1	0	1	2	0.5	0	1	0	1
B-SC-C5	10	0.5	0	1	0	1	10	0.5	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
B-SC-CW5	0	1	0	1	10	0.5	10	0.5	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
B-SC-RO5S	0	1	0	1	0	1	10	0.25	0	1	0	1	0	1	10	0.25	20	0.25	0	1	0	1
B-TW-C5	10	0.5	10	0.5	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C/B3s	30	0.5	0	1	0	1	6	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C/B-CW-SC3S	30	0.5	0	1	6	0.25	6	0.25	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
C/B-SC1S	50	0.5	0	1	0	1	12	0.25	0	1	0	1	0	1	0	1	12	0.25	0	1	0	1

veg_community	**Fc**	d	**Gbw**	d	**sbw**	d	**mule**	d	**hmq**	d	**fwsb**	d	**catt**	d	**Rolv**	d	**tamx**	d	**grass**	d	**nogr**	d
C/B-SC3S	30	0.5	0	1	0	1	6	0.25	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
C/C-B3	30	0.5	0	1	0	1	6	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C/C-CW3F	30	0.5	0	1	6	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C/C-TW-SC1	50	0.5	15	0.5	0	1	0	1	0	1	0	1	0	1	0	1	12	0.5	0	1	0	1
C/C-TW-SC3	30	0.5	9	0.5	0	1	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
C/C-TW-SC3s	30	0.25	9	0.25	0	1	0	1	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
C/CW3	30	0.5	0	1	6	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C/CW3F	30	0.75	0	1	6	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C/NMO-HME-SC1S	50	0.5	0	1	0	1	0	1	15	0.25	0	1	0	1	15	0.25	12	0.25	0	1	0	1
C/RO1	50	0.5	0	1	0	1	0	1	0	1	0	1	0	1	15	0.5	0	1	0	1	0	1
C/RO3	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	9	0.5	0	1	0	1	0	1
C/RO-SC1	50	0.5	0	1	0	1	0	1	0	1	0	1	0	1	15	0.5	12	0.5	0	1	0	1
C/RO-SC-CW3	30	0.5	0	1	6	0.5	0	1	0	1	0	1	0	1	9	0.5	6	0.5	0	1	0	1
C/SBM3S	30	0.25	0	1	0	1	0	1	9	0.25	0	1	0	1	0	1	0	1	0	1	0	1
C/SC1	50	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	12	0.5	0	1	0	1
C/SC1S	50	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	12	0.25	0	1	0	1
C/SC3	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
C/SC3s	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
C/SC3S	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
C/SC-ATX3	30	0.5	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1	0	1	0	1	0	1
C/SC-B1	50	0.5	0	1	0	1	12	0.5	0	1	0	1	0	1	0	1	12	0.5	0	1	0	1
C/SC-B1S	50	0.25	0	1	0	1	12	0.25	0	1	0	1	0	1	0	1	12	0.25	0	1	0	1
C/SC-B3	30	0.5	0	1	0	1	6	0.5	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
C/SC-B3d	30	0.75	0	1	0	1	6	0.75	0	1	0	1	0	1	0	1	6	0.75	0	1	0	1
C/SC-B3S	30	0.25	0	1	0	1	6	0.25	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
C/SC-B-A3	30	0.5	0	1	6	0.5	6	0.5	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
C/SC-B-A3S	30	0.25	0	1	6	0.25	6	0.25	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
C/SC-B-C3	30	0.5	0	1	0	1	6	0.5	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
C/SC-B-RO3	30	0.5	0	1	0	1	6	0.5	0	1	0	1	0	1	9	0.5	6	0.5	0	1	0	1

veg_community	**Fc**	d	**Gbw**	d	**sbw**	d	**mule**	d	**hmq**	d	**fwsb**	d	**catt**	d	**Rolv**	d	**tamx**	d	**grass**	d	**nogr**	d
C/SC-B-SBM3	30	0.5	0	1	0	1	6	0.5	9	0.5	0	1	0	1	0	1	6	0.5	0	1	0	1
C/SC-B-SBM-NMO1	50	0.5	0	1	0	1	0	1	15	0.5	0	1	0	1	15	0.5	12	0.5	0	1	0	1
C/SC-C3F	30	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	6	0.75	0	1	0	1
C/SC-CW3	30	0.5	0	1	6	0.5	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
C/SC-HMS3	30	0.5	0	1	0	1	0	1	9	0.5	0	1	0	1	0	1	6	0.5	0	1	0	1
C/SC-NMO1	50	0.5	0	1	0	1	0	1	0	1	0	1	0	1	15	0.5	12	0.5	0	1	0	1
C/SC-NMO1S	50	0.25	0	1	0	1	0	1	0	1	0	1	0	1	15	0.25	12	0.25	0	1	0	1
C/SC-NMO3	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	9	0.5	6	0.5	0	1	0	1
C/SC-RO1	50	0.5	0	1	0	1	0	1	0	1	0	1	0	1	15	0.5	12	0.5	0	1	0	1
C/SC-RO3	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	9	0.5	6	0.5	0	1	0	1
C/SC-SBM1	50	0.5	0	1	0	1	0	1	15	0.5	0	1	0	1	0	1	12	0.5	0	1	0	1
C/SC-SBM3	30	0.5	0	1	0	1	0	1	9	0.5	0	1	0	1	0	1	6	0.5	0	1	0	1
C/SC-TW1	50	0.5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	12	0.5	0	1	0	1
C/TW-B3	30	0.5	5	0.5	0	1	6	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C/TW-B3s	30	0.25	5	0.25	0	1	6	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C/TW-SC-B1s	50	0.25	10	0.25	0	1	12	0.25	0	1	0	1	0	1	0	1	12	0.25	0	1	0	1
C2	50	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C2S	50	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C4	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C4F	30	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C4s	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C5S	10	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C5s	10	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C6	2	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CAT5	0	1	0	1	0	1	0	1	0	1	0	1	3	0.5	0	1	0	1	0	1	0	1
CAT-CW-TW5	0	1	10	0.5	10	0.5	0	1	0	1	0	1	3	0.5	0	1	0	1	0	1	0	1
CAT-SC5	0	1	0	1	0	1	0	1	0	1	0	1	3	0.5	0	1	20	0.5	0	1	0	1
CAT-TW5	0	1	10	0.5	0	1	0	1	0	1	0	1	3	0.5	0	1	0	1	0	1	0	1

veg_community	**Fc**	d	**Gbw**	d	**sbw**	d	**mule**	d	**hmq**	d	**fwsb**	d	**catt**	d	**Rolv**	d	**tamx**	d	**grass**	d	**nogr**	d
C-B5S	10	0.25	0	1	0	1	10	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C-B-CW5	10	0.5	0	1	10	0.5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C-B-CW6	2	0.5	0	1	2	0.5	2	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C-B-RO5	10	0.5	0	1	0	1	10	0.5	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1
C-CW5	10	0.5	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C-CW5F	10	0.75	0	1	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C-CW-B5	10	1	0	1	10	0.5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C-CW-B6	2	0.5	0	1	2	0.5	2	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C-CW-RO5	10	0.5	0	1	10	0.5	0	1	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1
C-CW-RO5F	10	0.75	0	1	10	0.75	0	1	0	1	0	1	0	1	10	0.75	0	1	0	1	0	1
C-CW-RO-B5	10	0.5	0	1	10	0.5	10	0.5	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1
C-CW-SC5	10	0.5	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
C-CW-TW5F	10	0.75	10	0.75	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Channel	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C-RO/B-SC3	30	0.5	0	1	0	1	6	0.5	0	1	0	1	0	1	30	0.5	6	0.5	0	1	0	1
C-RO/C-B3S	30	0.25	0	1	0	1	6	0.25	0	1	0	1	0	1	30	0.25	0	1	0	1	0	1
C-RO/C-B-CW3	30	0.5	0	1	6	0.5	6	0.5	0	1	0	1	0	1	30	0.5	0	1	0	1	0	1
C-RO/C-RO-B3S	30	0.25	0	1	0	1	6	0.25	0	1	0	1	0	1	30	0.25	0	1	0	1	0	1
C-RO/CW-B3	30	0.5	0	1	6	0.5	6	0.5	0	1	0	1	0	1	30	0.5	0	1	0	1	0	1
C-RO/CW-SC3	30	0.5	0	1	6	0.5	0	1	0	1	0	1	0	1	30	0.5	6	0.5	0	1	0	1
C-RO/CW-SC3S	30	0.25	0	1	6	0.25	0	1	0	1	0	1	0	1	30	0.25	6	0.25	0	1	0	1
C-RO/CW-TW3	30	0.5	5	0.5	6	0.5	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1	0	1
C-RO/RO-B1	50	0.5	0	1	0	1	12	0.5	0	1	0	1	0	1	50	0.5	0	1	0	1	0	1
C-RO/RO-C3	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1	0	1
C-RO/RO-CW3	30	0.5	0	1	6	0.5	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1	0	1
C-RO/SC3	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	30	0.5	6	0.5	0	1	0	1
C-RO/SC-B-TW3	30	0.5	5	0.5	0	1	6	0.5	0	1	0	1	0	1	30	0.5	6	0.5	0	1	0	1
C-RO/SC-C-B3	30	0.5	0	1	0	1	6	0.5	0	1	0	1	0	1	30	0.5	6	0.5	0	1	0	1
C-RO/SC-CW-RO3	30	0.5	0	1	6	0.5	0	1	0	1	0	1	0	1	30	0.5	6	0.5	0	1	0	1

veg_community	**Fc**	d	**Gbw**	d	**sbw**	d	**mule**	d	**hmq**	d	**fwsb**	d	**catt**	d	**Rolv**	d	**tamx**	d	**grass**	d	**nogr**	d
C-RO/SC-RO3S	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	30	0.25	6	0.25	0	1	0	1
C-RO/SC-RO3S	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	30	0.25	6	0.25	0	1	0	1
C-RO2	50	0.5	0	1	0	1	0	1	0	1	0	1	0	1	50	0.5	0	1	0	1	0	1
C-RO4	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1	0	1
C-RO-CW-B6	2	0.5	0	1	2	0.5	2	0.5	0	1	0	1	0	1	2	0.5	0	1	0	1	0	1
C-RO-SBM-SC5S	10	0.25	0	1	0	1	0	1	10	0.25	0	1	0	1	10	0.25	20	0.25	0	1	0	1
C-RO-SC2	50	0.5	0	1	0	1	0	1	0	1	0	1	0	1	50	0.5	12	0.5	0	1	0	1
C-RO-SC-B5S	10	0.25	0	1	0	1	10	0.25	0	1	0	1	0	1	10	0.25	12	0.25	0	1	0	1
C-RO-TW/SC-B3	30	0.5	30	0.5	0	1	6	0.5	0	1	0	1	0	1	30	0.5	6	0.5	0	1	0	1
C-SBM-SC5	10	0.5	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1	20	0.5	0	1	0	1
C-SC/CW-B-C3S	30	0.25	0	1	6	0.25	6	0.25	0	1	0	1	0	1	0	1	30	0.25	0	1	0	1
C-SC/SC3	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1
C-SC/SC-NMO1	50	0.5	0	1	0	1	0	1	0	1	0	1	0	1	15	0.5	50	0.5	0	1	0	1
C-SC4	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
C-SC5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
C-SC6	2	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	2	0.5	0	1	0	1
C-SC-B5S	10	0.25	0	1	0	1	10	0.25	0	1	0	1	0	1	0	1	20	0.25	0	1	0	1
C-TW/C-SC3s	30	0.25	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
C-TW/C-TW-SC3s	30	0.25	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
C-TW/CW-SC1	50	0.5	50	0.5	12	0.5	0	1	0	1	0	1	0	1	0	1	12	0.5	0	1	0	1
C-TW/SC1	50	0.5	50	0.5	0	1	0	1	0	1	0	1	0	1	0	1	12	0.5	0	1	0	1
C-TW/SC3	30	0.5	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
C-TW/SC-B3S	30	0.25	30	0.25	0	1	6	0.25	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
C-TW/SC-C3	30	0.5	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
C-TW/SC-CW3	30	0.5	30	0.5	6	0.5	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
C-TW/SC-CW3S	30	0.25	30	0.25	6	0.25	0	1	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
C-TW/SC-TW3d	30	0.75	30	0.75	0	1	0	1	0	1	0	1	0	1	0	1	6	0.75	0	1	0	1
C-TW/SC-TW-CW3d	30	0.75	30	0.75	6	0.75	0	1	0	1	0	1	0	1	0	1	6	0.75	0	1	0	1

veg_community	**Fc**	d	**Gbw**	d	**sbw**	d	**mule**	d	**hmq**	d	**fwsb**	d	**catt**	d	**Rolv**	d	**tamx**	d	**grass**	d	**nogr**	d
C-TW/TW3	30	0.5	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C-TW/TW-C-SC3d	30	0.75	30	0.75	0	1	0	1	0	1	0	1	0	1	0	1	6	0.75	0	1	0	1
C-TW/TW-CW3s	30	0.25	30	0.25	6	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C-TW/TW-SC3	30	0.5	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
C-TW4s	30	0.25	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	0.25	0	1	0	1
C-TW5	10	0.5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C-TW-CW6	2	0.5	2	0.5	2	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW5	0	1	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW5F	0	1	0	1	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW6	0	1	0	1	2	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW-B5	0	1	0	1	10	0.5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW-B5F	0	1	0	1	10	0.75	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW-B5S	0	1	0	1	10	0.25	10	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW-B-C5	10	0.5	0	1	10	0.5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW-B-C5F	10	0.75	0	1	10	0.75	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW-B-RO-C5	10	0.5	0	1	10	0.5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW-C5	10	0.5	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW-C5F	10	0.75	0	1	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW-C5F	10	0.75	0	1	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW-C6	2	0.5	0	1	2	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW-CAT5	0	1	0	1	10	0.75	0	1	0	1	0	1	3	0.75	0	1	0	1	0	1	0	1
CW-C-B5F	10	0.75	0	1	10	0.75	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW-C-B6	2	0.5	0	1	2	0.75	2	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW-C-CAT5	10	0.5	0	1	10	0.5	0	1	0	1	0	1	3	0.75	0	1	0	1	0	1	0	1
CW-RO5	0	1	0	1	10	0.5	0	1	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1
CW-RO5F	0	1	0	1	10	0.75	0	1	0	1	0	1	0	1	10	0.75	0	1	0	1	0	1
CW-RO-SC-C5	10	0.5	0	1	10	0.5	0	1	0	1	0	1	0	1	10	0.5	20	0.5	0	1	0	1
CW-SC5	0	1	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
CW-SC6	0	1	0	1	2	0.5	0	1	0	1	0	1	0	1	0	1	2	0.5	0	1	0	1

veg_community	**Fc**	d	**Gbw**	d	**sbw**	d	**mule**	d	**hmq**	d	**fwsb**	d	**catt**	d	**Rolv**	d	**tamx**	d	**grass**	d	**nogr**	d
CW-SC-B5	0	1	0	1	10	0.5	10	0.5	0	1	0	1	0	1	0	1	12	0.5	0	1	0	1
CW-SC-C5	10	0.5	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
CW-SC-C6	2	0.5	0	1	2	0.5	0	1	0	1	0	1	0	1	0	1	2	0.5	0	1	0	1
CW-SC-RO5	0	1	0	1	10	0.5	0	1	0	1	0	1	0	1	10	0.5	20	0.5	0	1	0	1
CW-SC-RO-B	0	1	0	1	10	0.5	10	0.5	0	1	0	1	0	1	10	0.5	20	0.5	0	1	0	1
CW-SC-TW-B5	0	1	10	0.5	10	0.5	10	0.5	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
CW-TW5	0	1	10	0.5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW-TW-C5	10	0.5	10	0.5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
CW-TW-SC5	0	1	10	0.5	10	0.5	0	1	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
HME-CR5S	0	1	0	1	0	1	0	1	10	0.25	10	0.25	0	1	0	1	0	1	0	1	0	1
MH	0	1	0	1	0	1	0	1	0	1	0	1	3	0.75	0	1	0	1	0	1	0	1
MS	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	2	0.75	0	1
NMO-CW5F	0	1	0	1	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
OP	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
OW	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
RAILROAD	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	50	1
RO/CW3	0	1	0	1	6	0.5	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1	0	1
RO/CW-B3	0	1	0	1	6	0.5	6	0.5	0	1	0	1	0	1	30	0.5	0	1	0	1	0	1
RO/CW-B-SBM3F	0	1	0	1	6	0.75	6	0.75	9	0.75	0	1	0	1	30	0.75	0	1	0	1	0	1
RO/CW-C3	9	0.5	0	1	6	0.5	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1	0	1
RO/CW-SC3	0	1	0	1	6	0.5	0	1	0	1	0	1	0	1	30	0.5	6	0.5	0	1	0	1
RO/SC3	0	1	0	1	0	1	0	1	0	1	0	1	0	1	30	0.5	6	0.5	0	1	0	1
RO/SC3s	0	1	0	1	0	1	0	1	0	1	0	1	0	1	30	0.25	6	0.25	0	1	0	1
RO/SC5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	10	0.5	20	0.5	0	1	0	1
RO/SC-CW3	0	1	0	1	6	0.5	0	1	0	1	0	1	0	1	30	0.5	6	0.5	0	1	0	1
RO4	0	1	0	1	0	1	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1	0	1
ROAD	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	50	1
Road	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	50	1
ROAD	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	50	1

veg_community	**Fc**	d	**Gbw**	d	**sbw**	d	**mule**	d	**hmq**	d	**fwsb**	d	**catt**	d	**Rolv**	d	**tamx**	d	**grass**	d	**nogr**	d
RO-C/B-SC-RO3	30	0.5	0	1	0	1	6	0.5	0	1	0	1	0	1	30	0.5	6	0.5	0	1	0	1
RO-C/CW3	30	0.5	0	1	6	0.5	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1	0	1
RO-C/CW-SC3	30	0.5	0	1	6	0.5	0	1	0	1	0	1	0	1	30	0.5	6	0.5	0	1	0	1
RO-C/RO-C3	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1	0	1
RO-C/SC3	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	30	0.5	6	0.5	0	1	0	1
RO-C/SC-B-C3	30	0.5	0	1	0	1	6	0.5	0	1	0	1	0	1	30	0.5	6	0.5	0	1	0	1
RO-C/SC-B-C3	30	0.5	0	1	0	1	6	0.5	0	1	0	1	0	1	30	0.5	6	0.5	0	1	0	1
RO-C5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1
RO-C6	2	0.5	0	1	0	1	0	1	0	1	0	1	0	1	2	0.5	0	1	0	1	0	1
RO-C-TW/CW3	30	0.5	30	0.5	6	0.5	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1	0	1
RO-CW-C5	10	0.5	0	1	10	0.5	0	1	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1
RO-CW-C5S	10	0.25	0	1	10	0.25	0	1	0	1	0	1	0	1	10	0.25	0	1	0	1	0	1
RO-SBM-SC6	0	1	0	1	0	1	0	1	2	0.5	0	1	0	1	2	0.5	2	0.5	0	1	0	1
RO-SC/CW-SC3	0	1	0	1	6	0.5	0	1	0	1	0	1	0	1	30	0.5	30	0.5	0	1	0	1
RO-SC/SC3	0	1	0	1	0	1	0	1	0	1	0	1	0	1	30	0.5	30	0.5	0	1	0	1
RO-SC3	0	1	0	1	0	1	0	1	0	1	0	1	0	1	30	0.5	30	0.5	0	1	0	1
RO-SC4	0	1	0	1	0	1	0	1	0	1	0	1	0	1	30	0.5	30	0.5	0	1	0	1
RO-SC5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	10	0.5	20	0.5	0	1	0	1
RO-SC6	0	1	0	1	0	1	0	1	0	1	0	1	0	1	2	0.5	2	0.5	0	1	0	1
RO-SC-B5	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1	10	0.5	20	0.5	0	1	0	1
RO-SC-C5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	10	0.5	20	0.5	0	1	0	1
RO-SC-C6	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	2	0.5	2	0.5	0	1	0	1
RO-SC-SBM5	0	1	0	1	0	1	0	1	10	0.5	0	1	0	1	10	0.5	20	0.5	0	1	0	1
S-B5	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
SBM5	0	1	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1
SBM-C6	2	0.5	0	1	0	1	0	1	2	0.5	0	1	0	1	0	1	0	1	0	1	0	1
SBM-SC5S	0	1	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1	20	0.25	0	1	0	1
SC/SC3	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1
SC/SC3F	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	30	0.75	0	1	0	1

veg_community	**Fc**	d	**Gbw**	d	**sbw**	d	**mule**	d	**hmq**	d	**fwsb**	d	**catt**	d	**Rolv**	d	**tamx**	d	**grass**	d	**nogr**	d
SC/SC3S	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	30	0.25	0	1	0	1
SC/SC-CW3	0	1	0	1	6	0.5	0	1	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1
SC4	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1
SC4F	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	30	0.75	0	1	0	1
SC4S	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	30	0.25	0	1	0	1
SC5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
SC5d	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	20	0.75	0	1	0	1
SC5F	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	20	0.75	0	1	0	1
SC5S	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	20	0.25	0	1	0	1
SC5s	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	20	0.25	0	1	0	1
SC5S	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	20	0.25	0	1	0	1
SC6	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	2	0.5	0	1	0	1
SC-ATX5	0	1	0	1	0	1	0	1	0	1	10	0.5	0	1	0	1	20	0.5	0	1	0	1
SC-ATX6	0	1	0	1	0	1	0	1	0	1	2	0.5	0	1	0	1	12	0.5	0	1	0	1
SC-B5	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
SC-B5d	0	1	0	1	0	1	10	0.75	0	1	0	1	0	1	0	1	20	0.75	0	1	0	1
SC-B5s	0	1	0	1	0	1	10	0.25	0	1	0	1	0	1	0	1	20	0.25	0	1	0	1
SC-B5S	0	1	0	1	0	1	10	0.25	0	1	0	1	0	1	0	1	20	0.25	0	1	0	1
SC-B6	0	1	0	1	0	1	2	0.5	0	1	0	1	0	1	0	1	2	0.5	0	1	0	1
SC-B-C5	10	0.5	0	1	0	1	10	0.5	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
SC-B-CAT5	0	1	0	1	0	1	10	0.5	0	1	0	1	3	0.75	0	1	20	0.5	0	1	0	1
SC-B-C-RO5	10	0.5	0	1	0	1	10	0.5	0	1	0	1	0	1	10	0.5	20	0.5	0	1	0	1
SC-B-CW5	0	1	0	1	10	0.5	10	0.5	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
SC-B-CW-C5	10	0.5	0	1	10	0.5	10	0.5	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
SC-B-TW5	0	1	10	0.5	0	1	10	0.5	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
SC-C/SC-B3	30	0.5	0	1	0	1	6	0.5	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1
SC-C5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
SC-C6	2	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	2	0.5	0	1	0	1
SC-C-CW5	10	0.5	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1

veg_community	**Fc**	d	**Gbw**	d	**sbw**	d	**mule**	d	**hmq**	d	**fwsb**	d	**catt**	d	**Rolv**	d	**tamx**	d	**grass**	d	**nogr**	d
SC-C-TW5s	10	0.25	10	0.25	0	1	0	1	0	1	0	1	0	1	0	1	20	0.25	0	1	0	1
SC-CW5	0	1	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
SC-CW5S	0	1	0	1	10	0.25	0	1	0	1	0	1	0	1	0	1	20	0.25	0	1	0	1
SC-CW6	0	1	0	1	2	0.5	0	1	0	1	0	1	0	1	0	1	2	0.5	0	1	0	1
SC-CW-B6	0	1	0	1	2	0.5	2	0.5	0	1	0	1	0	1	0	1	2	0.5	0	1	0	1
SC-CW-C5	0	1	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
SC-HM5	0	1	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1	20	0.5	0	1	0	1
SC-HMS6	0	1	0	1	0	1	0	1	2	0.5	0	1	0	1	0	1	2	0.5	0	1	0	1
SC-NMO5S	0	1	0	1	0	1	0	1	0	1	0	1	0	1	10	0.25	20	0.25	0	1	0	1
SC-RO/SC3	0	1	0	1	0	1	0	1	0	1	0	1	0	1	30	0.5	30	0.5	0	1	0	1
SC-RO4	0	1	0	1	0	1	0	1	0	1	0	1	0	1	30	0.5	30	0.5	0	1	0	1
SC-RO5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	10	0.5	20	0.5	0	1	0	1
SC-RO5S	0	1	0	1	0	1	0	1	0	1	0	1	0	1	10	0.25	20	0.25	0	1	0	1
SC-RO5S	0	1	0	1	0	1	0	1	0	1	0	1	0	1	10	0.25	20	0.25	0	1	0	1
SC-RO5S	0	1	0	1	0	1	0	1	0	1	0	1	0	1	10	0.25	20	0.25	0	1	0	1
SC-RO6	0	1	0	1	0	1	0	1	0	1	0	1	0	1	2	0.5	2	0.5	0	1	0	1
SC-RO-B5	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1	10	0.5	20	0.5	0	1	0	1
SC-RO-B5S	0	1	0	1	0	1	10	0.25	0	1	0	1	0	1	10	0.25	20	0.25	0	1	0	1
SC-RO-C5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	10	0.5	20	0.5	0	1	0	1
SC-RO-C6	2	0.5	0	1	0	1	0	1	0	1	0	1	0	1	2	0.5	2	0.5	0	1	0	1
SC-RO-CW5	0	1	0	1	10	0.5	0	1	0	1	0	1	0	1	10	0.5	20	0.5	0	1	0	1
SC-SBM5	0	1	0	1	0	1	0	1	10	0.5	0	1	0	1	0	1	20	0.5	0	1	0	1
SC-SBM5S	0	1	0	1	0	1	0	1	10	0.25	0	1	0	1	0	1	20	0.25	0	1	0	1
SC-TW5	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
SC-TW5d	0	1	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	20	0.75	0	1	0	1
SC-TW5F	0	1	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	20	0.75	0	1	0	1
SC-TW5S	0	1	10	0.25	0	1	0	1	0	1	0	1	0	1	0	1	20	0.25	0	1	0	1
SC-TW5s	0	1	10	0.25	0	1	0	1	0	1	0	1	0	1	0	1	20	0.25	0	1	0	1
SC-TW-B5d	0	1	10	0.75	0	1	10	0.75	0	1	0	1	0	1	0	1	20	0.75	0	1	0	1

veg_community	**Fc**	d	**Gbw**	d	**sbw**	d	**mule**	d	**hmq**	d	**fwsb**	d	**catt**	d	**Rolv**	d	**tamx**	d	**grass**	d	**nogr**	d
SC-TW-C/SC-B3	30	0.5	30	0.5	0	1	6	0.5	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1
SC-TW-CW5	0	1	10	0.5	10	0.5	0	1	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
SC-TW-NMO/SC-TW-NMO3	0	1	30	0.5	0	1	0	1	0	1	0	1	0	1	30	0.5	30	0.5	0	1	0	1
TW/B3s	0	1	30	0.25	0	1	6	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/B-C3s	9	0.5	30	0.25	0	1	6	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/CAT3	0	1	30	0.5	0	1	0	1	0	1	0	1	9	0.75	0	1	0	1	0	1	0	1
TW/CAT3s	0	1	30	0.25	0	1	0	1	0	1	0	1	9	0.25	0	1	0	1	0	1	0	1
TW/CAT-CW3	0	1	30	0.5	6	0.5	0	1	0	1	0	1	9	0.75	0	1	0	1	0	1	0	1
TW/CAT-CW3s	0	1	30	0.25	6	0.25	0	1	0	1	0	1	9	0.25	0	1	0	1	0	1	0	1
TW/CAT-SC3	0	1	30	0.5	0	1	0	1	0	1	0	1	9	0.75	0	1	6	0.5	0	1	0	1
TW/Cat-TW3s	0	1	30	0.25	0	1	0	1	0	1	0	1	9	0.25	0	1	0	1	0	1	0	1
TW/CAT-TW-SC3	0	1	30	0.5	0	1	0	1	0	1	0	1	9	0.75	0	1	6	0.5	0	1	0	1
TW/CAT-TW-SC3d	0	1	30	0.75	0	1	0	1	0	1	0	1	9	1	0	1	6	0.75	0	1	0	1
TW/CAT-TW-SC3s	0	1	30	0.25	0	1	0	1	0	1	0	1	9	0.25	0	1	6	0.25	0	1	0	1
TW/CW3	0	1	30	0.5	6	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/CW3d	0	1	30	0.75	6	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/CW3s	0	1	30	0.25	6	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/CW-SC3	0	1	30	0.5	6	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/SC1	0	1	50	0.5	0	1	0	1	0	1	0	1	0	1	0	1	12	0.5	0	1	0	1
TW/SC3	0	1	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
TW/SC3d	0	1	30	0.75	0	1	0	1	0	1	0	1	0	1	0	1	6	0.75	0	1	0	1
TW/SC3s	0	1	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
TW/SC-B3	0	1	30	0.5	0	1	6	0.5	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
TW/SCB3d	0	1	30	0.75	0	1	6	0.75	0	1	0	1	0	1	0	1	6	0.75	0	1	0	1
TW/SC-B3s	0	1	30	0.25	0	1	6	0.25	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
TW/SC-CAT3	0	1	30	0.5	0	1	0	1	0	1	0	1	9	0.75	0	1	6	0.5	0	1	0	1
TW/SC-CW3	0	1	30	0.5	6	0.5	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1

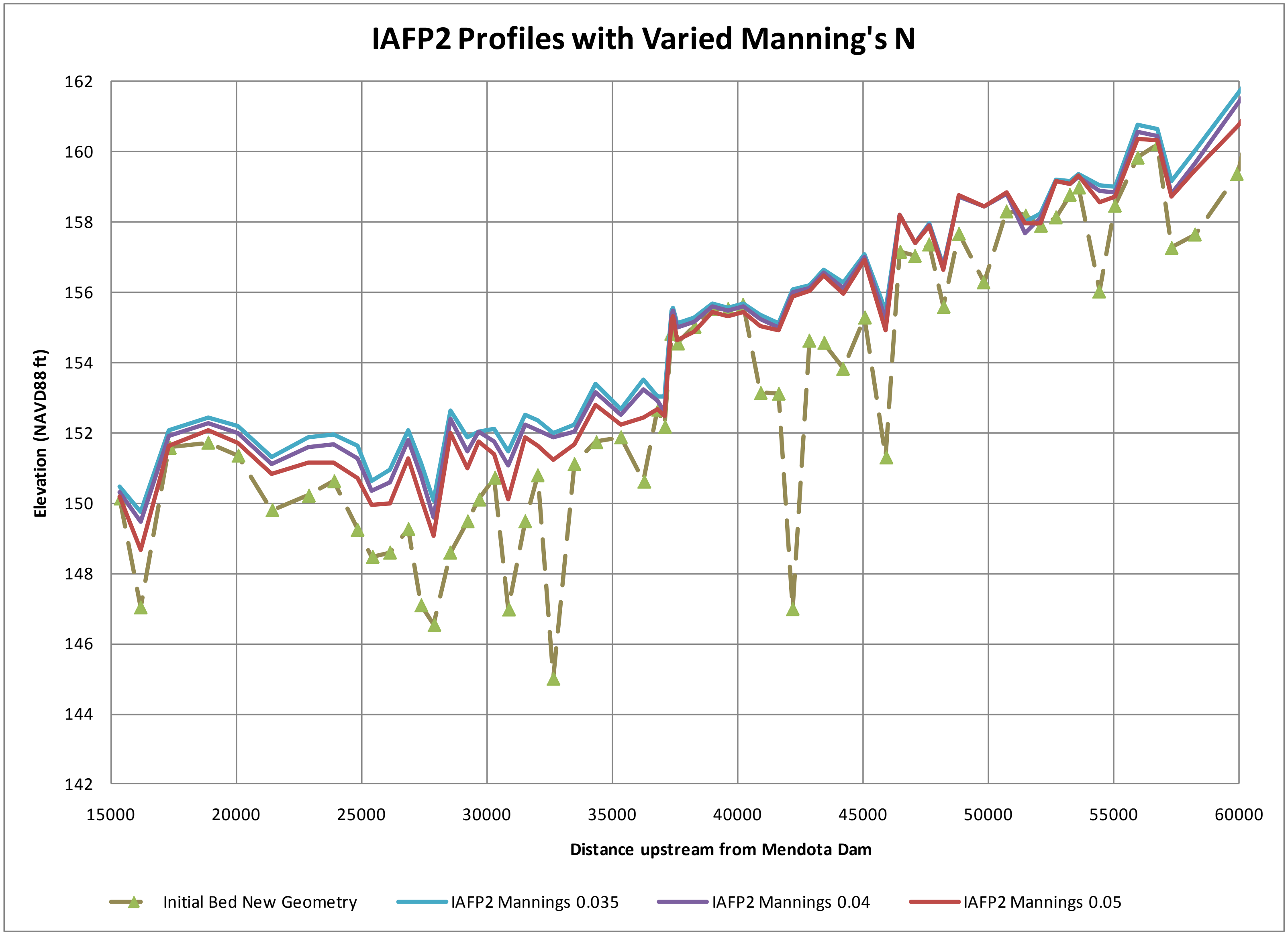
veg_community	**Fc**	d	**Gbw**	d	**sbw**	d	**mule**	d	**hmq**	d	**fwsb**	d	**catt**	d	**Rolv**	d	**tamx**	d	**grass**	d	**nogr**	d
TW/SC-CW3d	0	1	30	0.75	6	0.75	0	1	0	1	0	1	0	1	0	1	6	0.75	0	1	0	1
TW/SC-CW3s	0	1	30	0.25	6	0.25	0	1	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
TW/SC-TW3	0	1	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
TW/SC-TW3s	0	1	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
TW/SC-TW-B1	0	1	50	0.5	0	1	12	0.5	0	1	0	1	0	1	0	1	12	0.5	0	1	0	1
TW/SC-TW-B-CW3s	0	1	30	0.25	6	0.25	6	0.25	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
TW/SC-TW-C-B3	9	0.5	30	0.5	0	1	6	0.5	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
TW/TW3	0	1	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/TW3d	0	1	30	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/TW3d	0	1	30	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/TW3d	0	1	30	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/TW3s	0	1	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/TW-B3	0	1	30	0.5	0	1	6	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/TW-B3d	0	1	30	0.75	0	1	6	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/TW-C3	9	0.5	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/TW-C3d	9	0.75	30	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/TW-CAT3d	0	1	30	0.75	0	1	0	1	0	1	0	1	9	1	0	1	0	1	0	1	0	1
TW/TW-CAT-CW3s	0	1	30	0.25	6	0.25	0	1	0	1	0	1	9	0.25	0	1	0	1	0	1	0	1
TW/TW-C-B3s	9	0.25	30	0.25	0	1	6	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/TW-C-SC3	9	0.5	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
TW/TW-CW1s	0	1	50	0.25	12	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/TW-CW3	0	1	30	0.5	6	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/TW-CW3s	0	1	30	0.25	6	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW/TW-SC1s	0	1	50	0.25	0	1	0	1	0	1	0	1	0	1	0	1	12	0.25	0	1	0	1
TW/TW-SC3	0	1	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
TW/TW-SC3d	0	1	30	0.75	0	1	0	1	0	1	0	1	0	1	0	1	6	0.75	0	1	0	1
TW/TW-SC3s	0	1	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
TW/TW-SC-C3	9	0.5	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1

veg_community	**Fc**	d	**Gbw**	d	**sbw**	d	**mule**	d	**hmq**	d	**fwsb**	d	**catt**	d	**Rolv**	d	**tamx**	d	**grass**	d	**nogr**	d
TW/TW-SC-CW3	0	1	30	0.5	6	0.5	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
TW/TW-SC-CW3d	0	1	30	0.75	6	0.75	0	1	0	1	0	1	0	1	0	1	6	0.75	0	1	0	1
TW/TW-SC-CW3s	0	1	30	0.25	6	0.25	0	1	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
TW/TW-SC-CW3s	0	1	30	0.25	6	0.25	0	1	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
TW4	0	1	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW4d	0	1	30	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW4s	0	1	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW5	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW5d	0	1	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW5s	0	1	10	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW-B5	0	1	10	0.5	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW-C/B-TW3	30	0.5	30	0.5	0	1	6	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW-C/CW3	30	0.5	30	0.5	6	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW-C/CW-SC3	30	0.5	30	0.5	6	0.5	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
TW-C/SC1	50	0.5	50	0.5	0	1	0	1	0	1	0	1	0	1	0	1	12	0.5	0	1	0	1
TW-C/SC3	30	0.5	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
TW-C/SC3s	30	0.25	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
TW-C/SC-B3	30	0.5	30	0.5	0	1	6	0.5	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
TW-C/SC-B3s	30	0.25	30	0.25	0	1	6	0.25	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
TW-C/SC-CW3	30	0.5	30	0.5	6	0.5	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
TW-C/TW1	50	0.5	50	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW-C/TW3	30	0.5	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW-C/TW-B3d	30	0.75	30	0.75	0	1	6	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW-C/TW-C-SC3s	30	0.25	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1
TW-C/TW-CW-CAT3s	30	0.25	30	0.25	0	1	0	1	0	1	0	1	9	0.25	0	1	0	1	0	1	0	1
TW-C/TW-SC3	30	0.5	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
TW-C/TW-SC-B3s	30	0.25	30	0.25	0	1	6	0.25	0	1	0	1	0	1	0	1	6	0.25	0	1	0	1

veg_community	**Fc**	d	**Gbw**	d	**sbw**	d	**mule**	d	**hmq**	d	**fwsb**	d	**catt**	d	**Rolv**	d	**tamx**	d	**grass**	d	**nogr**	d
TW-C/TW-SC-CW3	30	0.5	30	0.5	6	0.5	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
TW-C3s	30	0.25	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW-C4	30	0.5	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW-C4s	30	0.25	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW-C4s	30	0.25	30	0.25	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW-C5d	10	0.75	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW-CAT5	0	1	10	0.5	0	1	0	1	0	1	0	1	3	0.75	0	1	0	1	0	1	0	1
TW-CAT-CW5	0	1	10	0.5	10	0.5	0	1	0	1	0	1	3	0.75	0	1	0	1	0	1	0	1
TW-C-CW6	2	0.5	2	0.5	2	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW-C-RO/CW3	30	0.5	30	0.5	6	0.5	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1	0	1
TW-C-SC5	10	0.5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
TW-C-SC-B5s	10	0.25	10	0.25	0	1	10	0.25	0	1	0	1	0	1	0	1	20	0.25	0	1	0	1
TW-CW/SC-TW3d	0	1	30	0.75	30	0.75	0	1	0	1	0	1	0	1	0	1	6	0.75	0	1	0	1
TW-CW5	0	1	10	0.5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW-CW-C5	10	0.5	30	0.5	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
TW-SC/TW3	0	1	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	6	0.5	0	1	0	1
TW-SC4	0	1	30	0.5	0	1	0	1	0	1	0	1	0	1	0	1	30	0.5	0	1	0	1
TW-SC5	0	1	10	0.5	0	1	0	1	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1
TW-SC5d	0	1	10	0.75	0	1	0	1	0	1	0	1	0	1	0	1	20	0.75	0	1	0	1
TW-SC5S	0	1	10	0.25	0	1	0	1	0	1	0	1	0	1	0	1	20	0.25	0	1	0	1
TW-SC-B5d	0	1	10	0.75	0	1	10	0.75	0	1	0	1	0	1	0	1	20	0.75	0	1	0	1
TW-SC-B5s	0	1	10	0.25	0	1	10	0.25	0	1	0	1	0	1	0	1	20	0.25	0	1	0	1
TW-SC-CAT5	0	1	10	0.5	0	1	0	1	0	1	0	1	3	0.75	0	1	20	0.5	0	1	0	1
TW-SC-CW5	0	1	10	0.5	10	0.5	0	1	0	1	0	1	0	1	0	1	20	0.5	0	1	0	1

APPENDIX B – RESULTS OF ROUGHNESS SENSITIVITY ANALYSIS

Results of In-Channel Manning's N Sensitivity Analysis for the San Joaquin River Restoration Analysis, Reach IAFP2


IAFP2 Profiles with Varied Manning's N
162
160
158
156
154
152
150
148
146
144
142
Elevation (NAVD88 ft)
15000
20000
25000
30000
35000
40000
45000
50000
55000
60000
Distance upstream from Mendota Dam
Initial Bed New Geometry
IAFP2 Mannings 0.035
IAFP2 Mannings 0.04
IAFP2 Mannings 0.05