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Sediment Transport and Vegetation Modeling of Reach 2B Alternatives for the San Joaquin River Restoration Program

U.S. Department of the Interior
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1 Introduction

The San Joaquin River Restoration Program (SJRRP) is developing restoration actions aimed at improving conditions for the reintroduction of spring and fall-run Chinook salmon within the San Joaquin River from Friant Dam to the Merced River confluence. Reach 2B lies between the Chowchilla Bifurcation Structure and Mendota Pool, from approximate mile post (MP) 216 to 204.7. Multiple analyses have previously been performed in this reach to evaluate the historical and present hydraulic and geomorphic conditions of the channel in support of the Programmatic Environmental Impact Statement/Report (PEIS/R; SJRRP, 2011a). In addition, sediment transport and vegetation modeling were performed to evaluate potential changes with modified flows (SJRRP, 2011a).

The formulation of alternatives for implementation of the Mendota Pool Bypass and Reach 2B Improvements Project is a phase 1 component of the SJRRP, indicating a high priority. As such, multiple alternatives are being evaluated to meet improvements outlined in Paragraph 11(a) of the Stipulation of Settlement (*NRDC, et al., v. Kirk Rodgers, et al*, 2006), which require the channel to convey 4,500 cfs and provide floodplain habitat.

As part of the analysis of alternatives for Reach 2B, Reclamation was tasked with applying a coupled sediment transport and vegetation model, SRH-1DV, to evaluate a combination of proposed levee setbacks and vegetation planting plans. Information from the modeling effort provides a comparison of vegetation germination, growth, and mortality and bed elevation adjustments over time for different levee setback options, hydrological alternatives, and vegetation management plans.

2 Model Input

SRH-1DV is a one-dimensional (1D) flow, sediment transport, and vegetation growth model used to assess river response, including impacts to vegetation, resulting from management actions. SRH-1DV is a developmental model utilizing core capabilities of sediment transport model SRH-1D (Huang and Greimann, 2007), to integrate flow regime, sediment transport, and flood topography, with vegetation growth and removal. SRH-1DV can be most effectively applied through a comparative rather than absolute analysis to evaluate proposed alternatives.

Although the focus of this report is the modeling of alternatives in Reach 2B, the entire reach from Friant Dam to Mendota Dam was modeled to adequately represent the incoming sediment load into Reach 2B. A brief description of the required model inputs is described in the following sections. More details regarding model inputs are described in Appendix N of the draft PEIS/R (SJRRP, 2011a).

2.1 Hydrology

Two hydrologic scenarios were used in the model development: Baseline and Alternative A hydrology. Both sets were derived from the hydrology used in the PEIS and based upon flows released from Friant Dam for the period between 1980 and 2003. The data were used to simulate existing and future operations of Friant Dam based on daily operations modeling documented in SJRRP (2009).

Lateral flow losses and gains were simulated throughout the modeled reach to represent flows removed through water delivery diversions and returns or flow increases or decreases resulting from interactions between the groundwater and river exchange. Losses and gains were modeled as point sources at specific cross sections or as non-point sources interpolated across multiple cross sections within a reach. The downstream most lateral flow loss was the Chowchilla Bifurcation structure.

2.2 Geometry

Within Reach 2B, HEC-RAS geometry data were provided by TetraTech for the existing conditions scenario and for the Settlement Alignment Initial Alternative Floodplains (IAFP) 1 through 5 (SJRRP, 2010a and SJRRP, 2011b). The geometry data were derived from LiDAR data from 2008 and bathymetry collected by DWR and Reclamation in 2009. For IAFP 1 through 5, levees were placed at different widths across the floodplain based on the levee footprints shown in Figure 1. IAFP 1 is most similar to the existing levee locations, while IAFP 5 represents the widest floodplain with the greatest levee setback distances. IAFP 2 and 3 levee setbacks are the same, but IAFP 3 incorporates excavated areas within the floodplain as shown in Figure 2. The initial HEC- RAS geometry files provided by TetraTech included the topography of the existing levees. While these levees have minimal effects on the cross section-averaged hydraulics if no levee element is assigned within HEC- RAS, their presence may influence the potential for vegetation to germinate and grow in these areas. To better represent the potential future conditions of the alternatives, the geometry files were modified for each alternative to remove the existing levees from each cross section in Reach 2B. In addition, cross sections immediately downstream from the Chowchilla Bifurcation Structure were removed because the sediment transport model can not accurately capture the bed scour associated with flow constrictions through the structure. Including these cross sections lead to gross overestimation of scour and overestimated quantities of sediment available for deposition at downstream cross sections.

The geometry files developed for Reach 2B were combined with existing geometry data for reaches upstream of the Chowchilla Bifurcation Structure developed by MEI (2002) and updated for use in SRH-1D as outlined in the PEIS/R (Appendix N, SJRRP, 2011a). Cross section geometry upstream of the Chowchilla Bifurcation Structure are based upon survey data from Ayers (Ayers, 1998) and COE photogrammetry (COE, 2002). All geometry files were converted to the same vertical datum of NAVD 88 feet for consistency with the refined geometries in Reach 2B.

Within Reach 1 and Reach 2A, only one of every 6 cross sections was included in the model to reduce model computation time. The exception is at the downstream end of Reach 2A, where all cross sections were incorporated in the model to ensure a smooth transition with the proximity of the cross sections in Reach 2B. Sensitivity analyses on the cross section spacing conducted for the PEIS/R (SJRRP, 2011a) indicate that one in every six HEC-RAS cross sections is sufficient for predicted sediment patterns between Friant and Mendota Dams. However, all available cross sections were used in Reach 2B to maximize understanding of predicted vegetation patterns.

To further maximize computer efficiency, cross section points were limited to 150 points using the HEC-RAS filtering scheme to minimize the change in cross sectional area. When translating the cross section points from HEC-RAS into SRH-1DV format, cross section points were permitted to be no more than 50 feet apart to ensure that at least one point was located within each vegetation polygon. If points were greater than 50 feet apart, the program automatically interpolated a point half way between the two points.

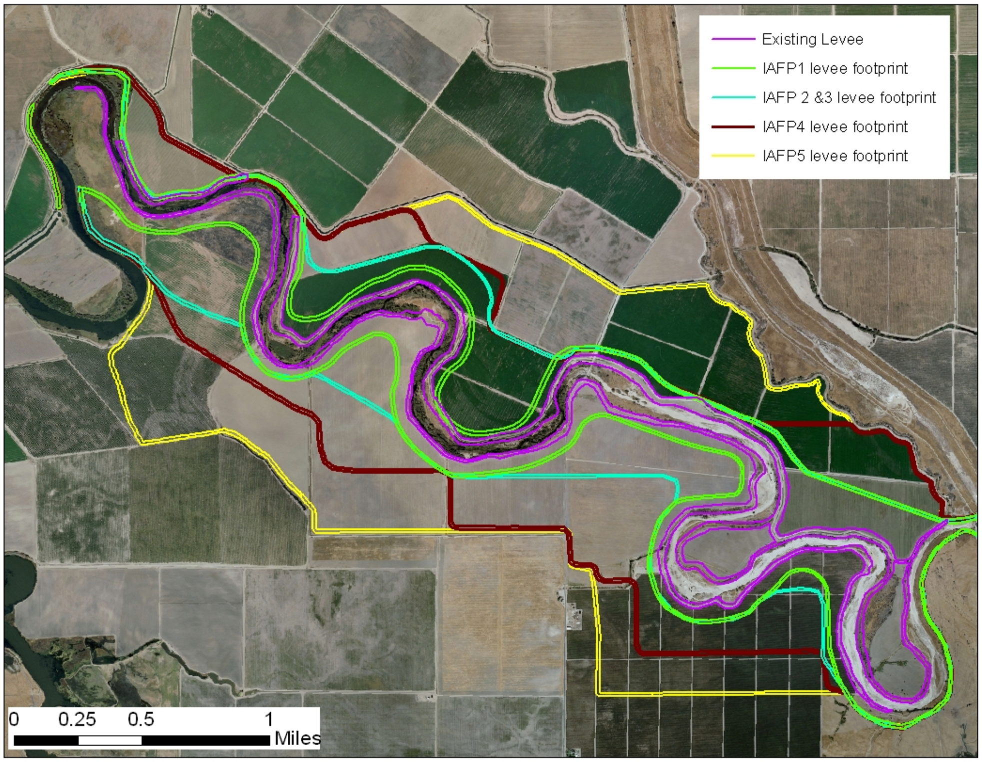

Figure 1. Existing and alternative levee footprints in Reach 2B.

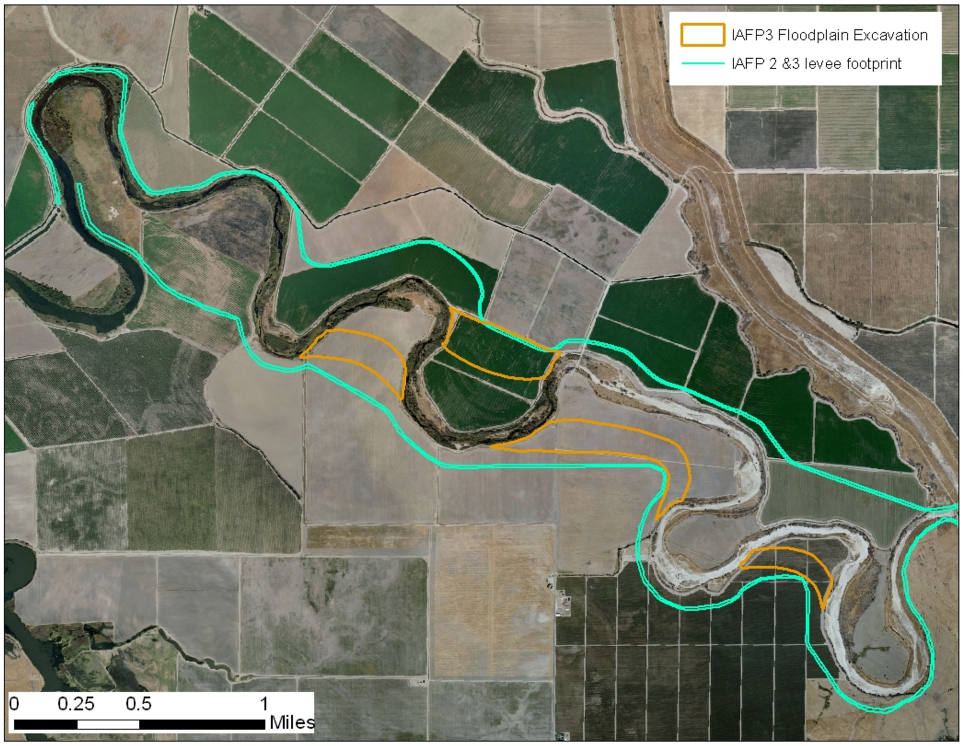

Figure 2. IAFP3 Floodplain excavation areas.

2.3 Boundary Conditions and Structures

The downstream boundary conditions for the existing conditions model and the IAFP 1 through 5 models were different due to the difference in the downstream extent of the model. The downstream boundary condition for the existing conditions model is located at Mendota Dam and was assumed to maintain a constant elevation of 154.3 ft based upon current operations of Mendota Dam. Downstream boundary conditions for the alternative model simulations were determined based on a rating curve of water surface elevation and discharge at the downstream most cross section, which was located approximately 15,000 ft upstream of Mendota Dam for all of the alternatives evaluated. The rating curve for the downstream boundary of the SRH-1DV alternative model simulations was based upon the downstream boundary used in the HEC-RAS model developed by TetraTech (SJRRP, 2011b) and is shown in Figure 3.

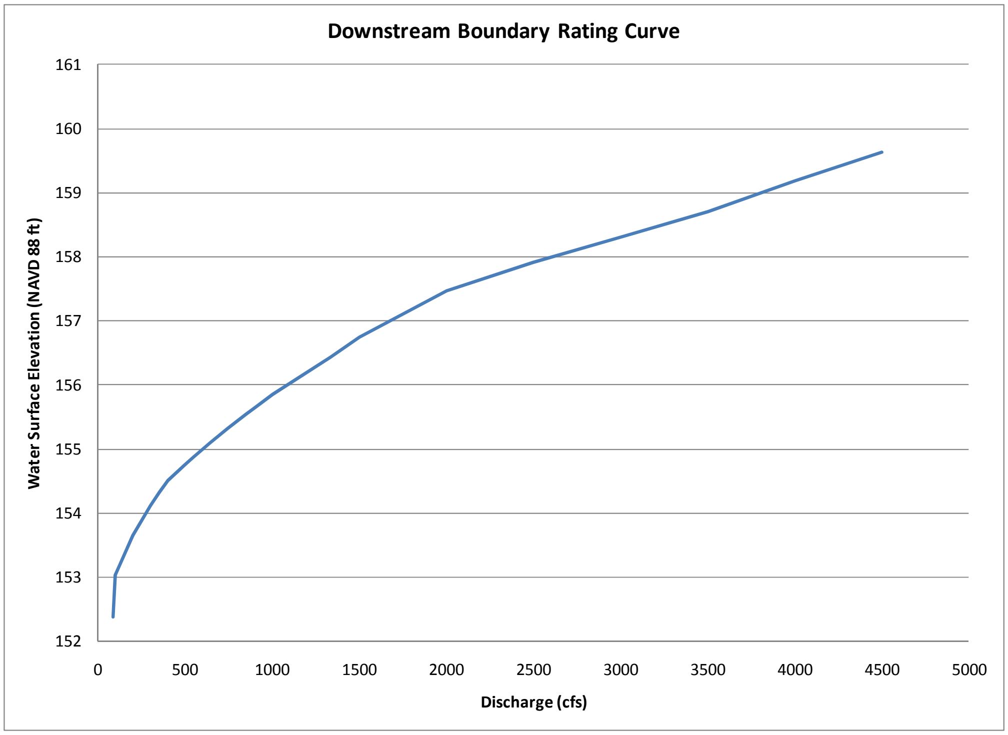

Figure 3. Rating curve for the downstream boundary for IAFP1 through IAFP5.

Internal boundary conditions were used by the model to represent major bridges, road crossings, and diversions. Only structures impacting water surface elevations by 1 foot or more were incorporated into the model. Three structures were identified as significant, of which the Lower Gravel Pit Crossing was no longer physically present and therefore not used as internal boundary condition. The other two structures, Ledger Island Bridge and Chowchilla Bifurcation Structure, were each represented by a rating curve (Figure 4 and Figure 5). The rating curves for each modeled structure was determined based upon the HEC-RAS model developed by TetraTech (SJRRP, 2011b).

At the river junction with the Chowchilla Bypass, the Chowchilla Bifurcation Structure splits flow through 2 gated diversion structures: one which directs flow to Reach 2B of the San Joaquin River and one which directs flow to the Chowchilla Bypass. Multiple hydrologic scenarios were run at the Chowchilla Bifurcation Structure to determine the controls on the water surface across the full range of expected flows. The Chowchilla Bifurcation structure rating curve was developed for each alternative assuming that the first 4,500 cfs of flow will be conveyed down the San Joaquin River in Reach 2B. Above 4,500 cfs, flows are conveyed through the Chowchilla Bifurcation Structure into the Chowchilla Bypass. The water surface just above the Bifurcation structure is controlled by the backwater created by the San Joaquin River side of the structure for the first 4,500 cfs. At flows between 4,500 cfs and approximately 7,000 cfs, the water surface elevation at the control structure is assumed to remain constant as no backwater is created by the Chowchilla Bypass side of the structure until the discharge through the bypass exceeds 2,500 cfs (or 7,000 cfs total through the system). For flows above 7,000 cfs, the water surface elevation just upstream of the bifurcation structure is controlled by backwater from the Chowchilla Bypass side of the structure. Due to the varied widths of the levees downstream of the control structure in the alternative geometries, the rating curves are slightly different across alternatives with IAFP4 and IAFP5 having nearly the same rating curve and IAPF1, IAFP2, and IAFP3 all having a similar rating curve.

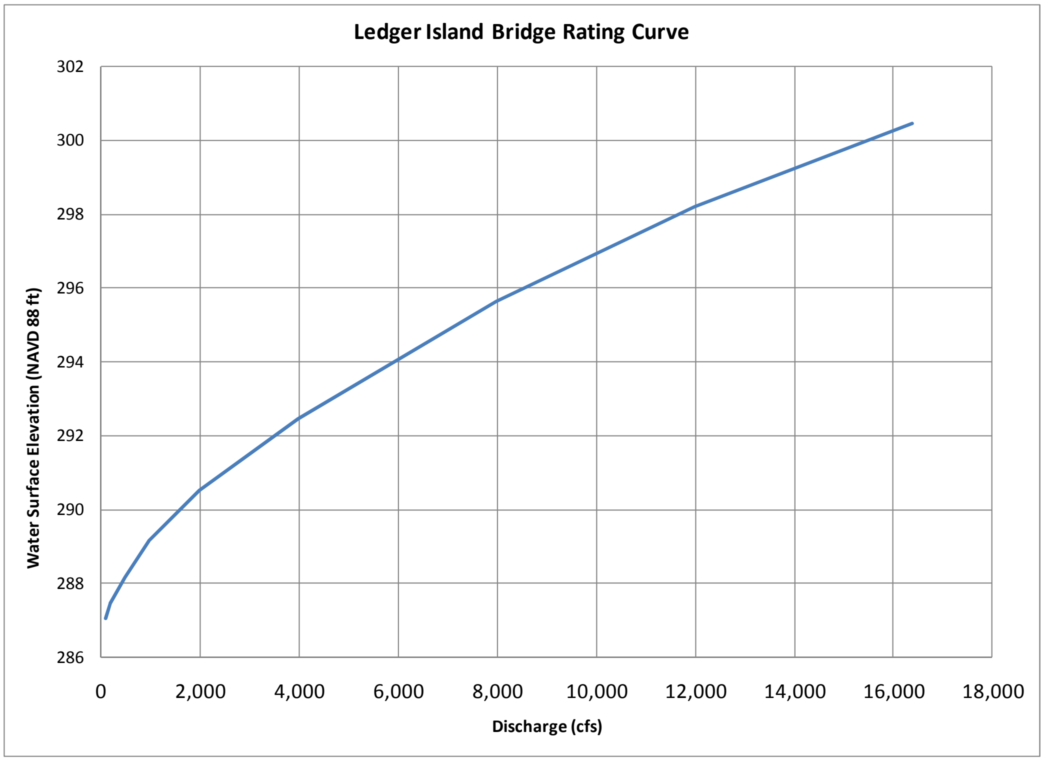

Figure 4. Ledger Island Bridge Rating Curve used for all scenarios.

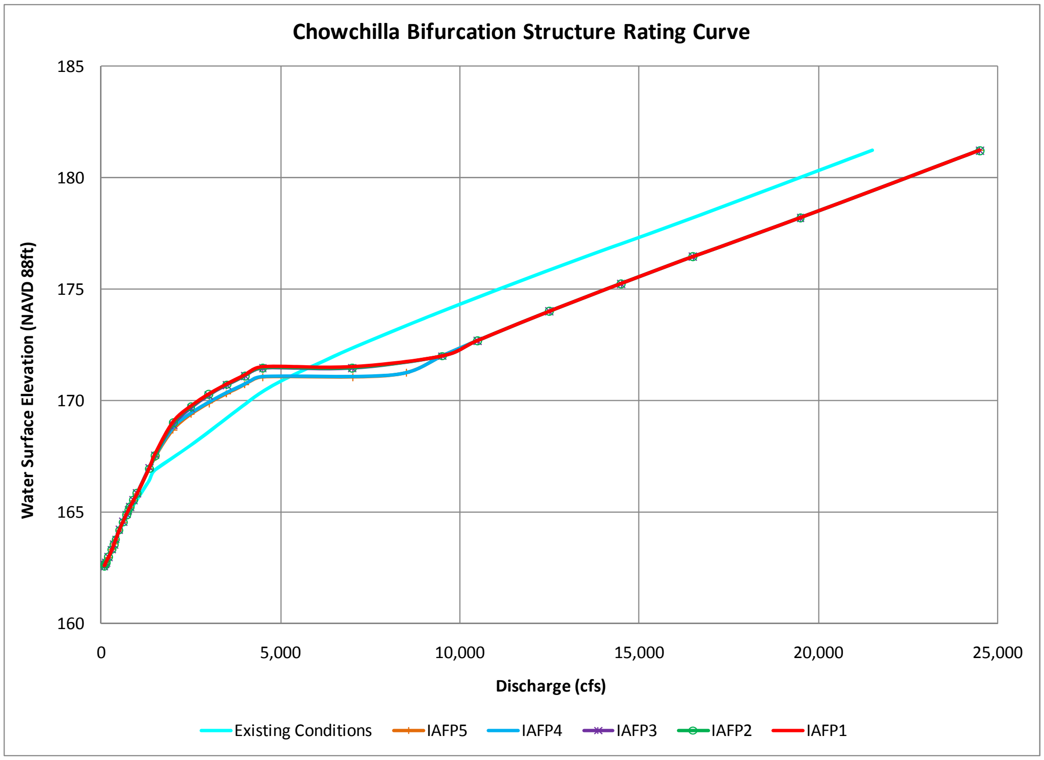

Figure 5. Chowchilla Bifurcation Structure Rating Curve.

One additional structure, the San Mateo Road culvert, is located within Reach 2B just upstream of the backwater extent of the current Mendota Dam pool. The existing structure is a single partially blocked culvert with a low water road crossing. As part of the restoration of Reach 2B, multiple box culverts are planned to replace the existing structure. The rating curve associated with this structure will be dependent upon the final design of this structure. Therefore, instead of a rating curve at this location, the San Mateo Road structure was treated as a grade control structure in the model, for which no erosion was permitted to occur at the cross sections just upstream and downstream of the structure.

2.4 Roughness

Roughness values provided in the original HEC-RAS geometry files were modified such that the channel portion of each cross section was represented by a single Manning’s roughness coefficient of 0.035. Roughness values were variable along the floodplain, typically between 0.085 and 0.1. Roughness coefficients were not varied across the alternatives, and a feedback loop between vegetation growth and roughness has not yet been incorporated into the vegetation component of SRH-1DV. Therefore, areas outside the existing levees that will likely be more vegetated under alternative conditions were represented with the same roughness values for all modeled scenarios. This is unlikely to impact the estimates of erosion and deposition, but may have some influence on vegetation mortality associated with scour or inundation. A future version of SRH-1DV will incorporate a mechanism that adjusts roughness with vegetation growth throughout the period of simulation.

Sensitivity analyses were conducted on the in-channel Manning’s roughness coefficient for IAFP2. Results of the sensitivity are shown in Appendix A.

3 Sediment parameters

3.1.1 Bed Material

Surface bed material data used in the sediment transport analysis were derived from surface samples collected in February 2008 (Reclamation, 2008), 29 of which were located in Reaches 1 and 2. Details on the bed material distributions and how they were incorporated into SRH-1D are provided in the PEIS/R (SJRRP, 2011a). Sediment samples were collected just upstream of the Chowchilla Bifurcations Structure in Reach 2A and also just downstream of the Chowchilla Bifurcation Structure in the Chowchilla Bypass. No sediment samples were collected in Reach 2B. Therefore, the bed material collected just downstream of the Chowchilla Bifurcation Structure in the bypass was assumed to be similar to the bed material present within Reach 2B.

Table 1. Bed material size distribution used to represent the surface sediment of Reach 2B in the SRH-1DV model.

Diameter (mm)	Percent Passing by weight
0.063	2.2%
0.125	3.1%
0.25	9.7%
0.5	78.1%
1	97.7%
2	100.0%
4	100.0%
8	100.0%
16	100.0%
32	100.0%
64	100.0%
128	100.0%
256	100.0%

3.1.2 Sediment Transport Computational Parameters

Transport capacity was calculated with Parker's gravel transport equation (Parker, 1990) combined with England and Hansen's sand transport equation (Engelund and Hansen, 1972). A sensitivity analysis on three different transport formulas applied to the San Joaquin River was performed for the PEIS/R (SJRRP, 2011a). These included (1) Parker's gravel transport equation combined with Engelund and Hansen's sand transport equation, (2) Wilcock and Crowe's gravel-sand-mixed transport equation(Wilcock and Crowe, 2003) combined with Engelund and Hansen's sand transport equation, and (3) Wu et al.'s non-uniform sediment transport for gravel and sand (Wu et al. 2000).

Another required input parameter is the active layer thickness, which is used to simulate channel armoring. In SRH-1D, the active layer thickness is equal to a constant times the diameter of the largest sediment size. The constant was set equal to 10 based on a sensitivity analysis performed on this parameter in the PEIS/R(SJRRP, 2011a).

3.2 Groundwater

Riparian vegetation growth processes are related to both the water surface elevation in the channel and also to the elevation of groundwater in the banks and floodplain. Groundwater parameters that determine the rise and fall of the groundwater surface and the pattern of decline extending outwards from the channel are shown in Table 2. In addition to hydraulic conductivity of the soils, capillary fringe height, and a drop velocity at the water surface boundary, a maximum value for groundwater decline is assigned if the channel goes dry for long periods. During dry periods, the groundwater table is allowed to drop to the maximum assigned depth, and recovers from this elevation as flow returns to the channel.

Table 2. Groundwater Parameters

Hydraulic conductivity of left bank (ft/day)	Hydraulic conductivity of right bank (ft/day)	Cappilary fringe height (ft)	Drop velocity (ft/day)	Maximum groundwater decline below thalweg (ft)
100,000	100,000	0.80	0.5	50.0

3.3 Vegetation Input

Vegetation data required as input to the model include germination, growth, and mortality parameters for each modeled vegetation type along with an initial vegetation conditions map.

3.3.1 Vegetation Alliances

Thirteen vegetation types or alliances were modeled for this effort. With the exception of Sand Bar Willow, California Wildrose, and Elderberry, each of these alliances is described in the Menodota Pool Bypass and Reach 2B improvements project (SJRRP, 2011b). One alliance, referred to as the No Grow alliance is used to represent areas outside of the existing or proposed levees or along roads and ditches, where none of the other alliances are permitted to grow. An attempt was made to incorporate water germinating invasive species, such as arundo and tamarix, but the germination routines have not yet been completely developed and require additional validation studies.

Table 3. Vegetation Alliances modeled in SRH-1DV.

Modeled Vegetation Alliance	Latin Name	Abbreviation
Freemont Cottonwood	*Populus fremontii*	Fcwd
Oregon Ash	*Fraxinus latifolia*	Oash
Goodings Black Willow	*Salix gooddingii*	Gbw
Sand Bar Willow/Narrow Leaf 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 or California sagebrush	*Artemisia californica*	Mug
California Bulrush	*Schoenoplectus californicus*	Cbr
Buttonbush Willow	*Cephalanthus occidentalis*	Bbw
Riparian Bank Herbs*	NA	Rbh
No Grow (ag and roads)	NA	Nogr

*Riparian bank herbs were primarily based upon characteristics of *Juncus balticus* and *Carex barbarae*

3.3.2 Initial Vegetation Conditions

SRH-1DV allows the user to input initial vegetation conditions for each point in each cross section. Identification of the vegetation present at the beginning of the simulation for each point is accomplished through a polygon shapefile containing areas assigned with a specific vegetation type. Two sets of mapping were used for the initial vegetation conditions:

(1) Existing conditions vegetation mapping completed by DWR in 2002 and updated in 2008 (SJRRP, 2011a), and
(2) Proposed restoration planting maps for each alternative, described in Attachment C of Mendota Pool Bypass and Reach 2B Improvements Project Technical Memorandum (SJRRP, 2011b).

Each mapped community of vegetation was assigned an age and density for at least one of the 13 vegetation alliances. The age and density for the existing conditions vegetation mapping were determined from descriptions provided in the PEIS/R and verified using aerial photographs of the distributions of the vegetation. For the alternatives mapping within Reach 2B, ages and densities were estimated based on descriptions of typical planting methods and spacings (George Strand, personal communication, 5/12/11). Matrices illustrating the translation of mapped vegetation communities to vegetation alliances by age and density are provided in Appendices B and C.

Some modification to the proposed restoration planting maps was necessary for incorporation into SRH-1DV. The proposed restoration planting maps included a vegetation category for "existing" vegetation. Using Spatial Analysis within ArcGis, polygons assigned with "existing" in the restoration planting maps were overlain on the existing vegetation maps, divided as necessary, and defined according to the vegetation alliances mapped in the existing vegetation maps. Therefore, one "existing" polygon from the restoration planting maps may have been divided into several polygons with different vegetation alliances as mapped by DWR in 2002 and 2008 (SJRRP, 2011a). In addition, the restoration planting maps only contained vegetation assignments within the proposed levee footprint. The restoration planting maps were extended to cover the cross sections extents and appended upstream of Reach 2B with the existing vegetation maps.

3.3.3 Germination, Growth and Mortality Parameters

The model requires germination, growth, and mortality parameters for each vegetation alliance being simulated. Information including root growth rates, stem growth rates, capillary fringe, germination seasons, germination time, longevity of seeds, basal sprouting, and days for desiccation mortality were based primarily on values from Mahoney and Rood (1998), McBride and Strahan (1984), Shafroth et. al (1998), and Stella et. al (2006). Values were also selected from USDA plant guide information and from previous flow-sediment-vegetation modeling by Reclamation's Sedimentation and River Hydraulics Group (Greimann et al., 2011, Greimann et al., 2007, and Murphy et al., 2006). When no other information was available regarding a particular species, values were assigned based on similar vegetation types or general field observations of physical attributes.

Key germination parameters required for each vegetation type include annual germination period, required germination time, required germination moisture conditions, monthly lateral spread rate and maximum elevation of germination above the low water. Required germination moisture conditions include the maximum number of days a seed can survive in dry conditions prior to germinating and the maximum depth below the water table at which germination can occur. Only species known to spread laterally are assigned lateral spread rates, including sandbar willow, elderberry, California wildrose, salt grass, creeping rye grass, California bulrush, and riparian banks herbs. Input parameters for germination of each vegetation alliance are listed in Table 4 and Table 5.

Growth parameters include monthly stalk and root growth rates by age, monthly canopy spread rate by age, maximum stalk height, maximum canopy width, maximum root depth, and maximum depth below the water table for the continued growth of the root. Input parameters for growth of each vegetation alliance are listed in Table 6 through Table 8.

Mortality of vegetation may occur through numerous methods. Currently SRH-1DV can simulate mortality associated with species competition, shading, scour, burial, inundation, desiccation, ice, and senescence. For evaluation of Reach 2B vegetation, mortality was simulated only through species competition, shading, scour, inundation, and desiccation. For species competition, a matrix is defined that specifies the age at which each vegetation alliance can outcompete another vegetation alliance. Due to differences in species tolerance to shaded conditions, the model tracks canopy growth and subsequent shading of each species at each point in each cross section throughout the course of the simulation. Alliances defined as being intolerant of shaded conditions are subject to mortality through shading of other species at that point or adjacent points. The only alliances permitted to survive shaded conditions in these model simulations include Freemont Cottonwood, Oregon Ash, Goodings Black Willow, and California Wildrose. Of these, cottonwood and black willow are considered shade tolerant at age 1, while ash and rose are considered tolerant at germination.

Mortality through scour can occur if velocities at the point where vegetation is present exceed velocities defined as critical for species survival. Vegetation is subject to inundation or drowning if the root crown of that plant is inundated by a specified depth for a specified length of time.

Lastly, during the months specified by the user, desiccation may occur by one of two coded mechanisms: (1) time of separation between the capillary fringe and the root, or (2) water stress. When the time of separation mechanism is specified, the plant may desiccate if the water table drops by a specified depth below the capillary fringe for a specified length of time. This method is applied to all vegetation alliances, except for Freemont Cottonwood. The specified depth below the capillary fringe for desiccation to occur is 0.1 feet for all vegetation alliances where this method is utilized. Note that the capillary fringe height, as defined as 0.8 feet for sand in the groundwater input parameters, represents the layer between the water table and the ground surface that is still capable of providing moisture to plants roots through capillary action. Therefore, for a plant to experience desiccation by time of separation, the water table must be separated from the root cap (tip of plant root) by 0.9 feet for the specified length of time.

The second desiccation mechanism, the water stress method, was developed from studies conducted by the Stockholm Environmental Institute (Greimann et al., 2011) on Freemont Cottonwood. This method tracks a water stress variable, which fluctuates based on whether the plant is experiencing or recovering from water stress. User-specified desiccation and recovery rates and associated rates of water table increases or decreases determine whether the plant will survive. If the water table declines more rapidly than the root can grow, the plant will begin to dry out. However, if the water table begins to increase again, the plant can recover. The days required to either completely desiccate or completely recover are a function of the water table fluctuation rate. Desiccation and recovery rates vary by soil type, and therefore the program defines one function for sand and one for gravel. Once a cottonwood has matured to the point that the root exceeds the minimum water table, desiccation is no longer a mechanism for mortality. The model does not simulate groundwater decline caused by groundwater pumping and therefore, desiccation for cottonwoods does not typically occur after the root has reached the elevation of the minimum channel bed.

Each mortality parameter may be defined for multiple ages across the life span of an alliance since the vulnerability to a specific mortality mechanism changes as vegetation matures. For example, a freshly germinated cottonwood plant is more susceptible to scour at lower velocities than a mature cottonwood. Vegetation parameters used as model input for each of the mortality types are illustrated in Table 9 through Table 13 and in Figure 6.

Table 4. Germination parameters related to seed dispersal.

Alliance	Julian days of seed dispersal season	Days to germination	Maximum days seed can endure dry conditions	Maximum height of root cap above ground water (ft)	Depth below water table germination can occur (ft)	Maximum height plant can establish above water surface (ft)
Fcwd	120-180	0.5	2	1	0.1	200
Oash	90-152	1	2	1	0.01	250
Gbw	144-162	0.5	2	1	0.2	200
Sbw	129-273	1.5	2	1	0.2	25
Eld	91-151	1.5	2	10	0.01	100
Rose	91-152	1.5	7	10	0.01	100
Salt	121-243	1	2	1	0.1	10
Crye	150-195	1	2	1	0.01	50
Mug	None*					
Cbr	198-260	1	2	0.75	0.2	50
Bbt	152-273	1	2	1	0.2	75
Rip	182-273	1	2	1	0.2	75

* California mugwort only produces a substantial number of new seedlings during fire. Therefore, no germination of new plants is modeled.

Table 5. Maximum lateral spread rate (ft/day) for each month.

Alliance	age	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sbw	0.000	0.000	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.000
	1.000	0.000	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.000
Eld	0.000	0.000	0.000	0.000	0.040	0.040	0.040	0.040	0.040	0.040	0.000	0.000	0.000
	1.000	0.000	0.000	0.000	0.050	0.050	0.050	0.050	0.050	0.050	0.000	0.000	0.000
Rose	0.000	0.000	0.000	0.000	0.065	0.065	0.065	0.065	0.065	0.065	0.000	0.000	0.000
Salt	0.000	0.000	0.000	0.000	0.000	0.030	0.030	0.030	0.030	0.030	0.000	0.000	0.000
Crye	0.000	0.000	0.000	0.000	0.000	0.420	0.420	0.420	0.420	0.420	0.000	0.000	0.000
Cbr	0.000	0.000	0.000	0.000	0.050	0.050	0.050	0.050	0.050	0.050	0.000	0.000	0.000
Rbh	0.000	0.000	0.000	0.000	0.050	0.050	0.050	0.050	0.050	0.050	0.000	0.000	0.000

Table 6. Stalk growth rates.

Veg Alliance	Maximum Stalk Growth Rates (ft/day)												
	age	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fcwd	0	0.000	0.000	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.000
	3	0.000	0.000	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.000
Oash/Gbw	0	0.000	0.000	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.003	0.000
	3	0.000	0.000	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.007	0.000
Sbw	0	0.000	0.000	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.000
Eld	0	0.000	0.000	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.000
Rose	0	0.000	0.000	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.000
Salt	0	0.000	0.000	0.000	0.000	0.030	0.030	0.030	0.030	0.030	0.000	0.000	0.000
Crye	0	0.010	0.010	0.010	0.010	0.000	0.000	0.000	0.000	0.010	0.010	0.010	0.010
Mug	0	0.010	0.010	0.010	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.010
Cbr	0	0.000	0.000	0.000	0.004	0.004	0.004	0.004	0.004	0.004	0.000	0.000	0.000
Bbt	0	0.000	0.000	0.000	0.008	0.008	0.008	0.008	0.008	0.008	0.000	0.000	0.000
Rbh	0	0.000	0.000	0.000	0.006	0.006	0.006	0.006	0.006	0.006	0.000	0.000	0.000

Table 7. Canopy growth parameters.

Veg Alliance	Maximum Canopy Growth Rates (ft/day)													Maximum Canopy Width (ft)
	age	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Fcwd/ Oash/ Gbw	0	0.000	0.000	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.000	10/ 15/ 10
	2	0.000	0.000	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.000	
	15	0.000	0.000	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.000	
	45	0.000	0.000	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.000	
Sbw	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.1
Eld	0	0.000	0.000	0.000	0.004	0.004	0.004	0.004	0.004	0.004	0.000	0.000	0.000	0.5
Rose	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.2
Salt	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.1
Crye	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.1
Mug	0	0.010	0.010	0.010	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.010	3
Cbr	0	0.000	0.000	0.000	0.004	0.004	0.004	0.004	0.004	0.004	0.000	0.000	0.000	0.4
Bbt	0	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.002	0.002	0.000	0.000	0.000	6
Rbh	0	0.000	0.000	0.000	0.003	0.003	0.003	0.003	0.003	0.003	0.000	0.000	0.000	2

Table 8. Root growth parameters used in model.

Veg Alliance	Maximum Root Growth Rates (ft/day)													Maximum depth of root below water table that root growth can occur (ft)	Maximum root depth (ft)
	age	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Fcwd	0	0.000	0.000	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.000	0.10	24.00
	6	0.000	0.000	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.000		
Oash	0	0.000	0.000	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.000	0.10	20.00
	6	0.000	0.000	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.000		
Gbw	0	0.000	0.000	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.000	0.10	22.00
	6	0.000	0.000	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.000		
Sbw	0	0.000	0.000	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.000	0.20	8.00
Eld	0	0.000	0.000	0.000	0.050	0.050	0.050	0.050	0.050	0.050	0.000	0.000	0.000	0.01	6.00
Rose	0	0.000	0.000	0.000	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.000	0.000	0.01	4.00
Salt	0	0.000	0.000	0.000	0.020	0.020	0.020	0.020	0.020	0.020	0.000	0.000	0.000	0.20	1.00
Crye	0	0.000	0.000	0.000	0.000	0.040	0.040	0.040	0.040	0.040	0.000	0.000	0.000	0.20	10.00
Mug	0	0.004	0.004	0.004	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004	0.01	2.00
Cbr	0	0.000	0.000	0.000	0.004	0.004	0.004	0.004	0.004	0.004	0.000	0.000	0.000	2.00	3.00
Bbt	0	0.000	0.000	0.000	0.010	0.010	0.010	0.010	0.010	0.010	0.000	0.000	0.000	0.20	6.00
Rbh	0	0.000	0.000	0.000	0.006	0.006	0.006	0.006	0.006	0.006	0.000	0.000	0.000	0.20	4.00

Table 9. Mortality parameters by competition. Matrix indicates age that species Y must be to results in the death of species X for multiple ages. A value of 99 indicates that species Y will not outcompete species X for a given age.

Species X	Age of Species X	Age of Species Y that will result in mortality of Species X											
		Fcwd	**Oash**	**Gbw**	**Sbw**	**Eld**	**Rose**	**Salt**	**Crye**	**Mug**	**Cbr**	**Bbt**	**Rbh**
Fcwd/Oash/Gbw	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
Sbw	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
Eld	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
Rose	0.1	40	40	40	3	3	99	3	2	99	2	3	3
Salt	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
Crye	0.1	15	15	15	2	2	2	99	99	99	2	2	99
Mug*	0	0	0	0	0	0	0	0	0	0	0	0	0
Cbr	0.1	15	15	15	1	1	1	2	2	1	99	1	2
Bbt	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
Rbh	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

*Mugwort experiences 100% competition assuming that if any other species can germinate at the location, then it is too wet for mugwort.

Table 10. Mortality parameters by scour. Table indicates the velocity required to scour a vegetation alliance at a given age.

Vegetation Alliance	Age (yr)	Critical Velocity (ft/s)	Vegetation Alliance	Age (yr)	Critical Velocity (ft/s)
Fcwd	0	2	Salt/Mug	0	2
	1	2.5		1	3
	2	3		2	4
	3	4	Crye	0	2
	4	5		1	4
	5	6		2	5
Oash	0	2	Cbr	0	1.5
	2	3		1	2
	5	6		2	2.5
Gbw	0	2	Bbt	0	2
	1	3		1	2.5
	2	4		2	3
	3	5		3	4
	4	8		4	6
Sbw/ Eld/ rose	0	2			
	1	3			
	2	4			
	3	5			
	4	6			

Table 11. Mortality parameters for inundation. Table indicates the length of time that an alliance of a specific age must be inundated bv a given depth to be subject to mortality by inundation.

Vegetation Alliance	age (yr)	time (d)	depth (ft)	Vegetation Alliance	age (yr)	time (d)	depth (ft)
Fcwd	0	15	0.5	**Eld/ rose**	0	3	0.5
	1	30	1		5	10	0.5
	2	30	2	**Salt**	0	25	0.5
	3	60	2		1	45	1
	4	120	2	**Crye**	0	7	0.1
	5	150	2		1	21	0.1
Oash	0	18	0.25	**Mug**	0	5	0.1
	1	35	1		1	12	0.1
	2	35	2	**Cbr**	0	2	0.1
	3	70	2		3	21	0.1

Vegetation Alliance	age (yr)	time (d)	depth (ft)	Vegetation Alliance	age (yr)	time (d)	depth (ft)
	5	160	2	Bbt/ Rbh	0	25	0.5
Gbw/ Sbw	0	18	0.5		1	45	1
	1	35	1				
	2	35	2				
	3	70	2				
	4	150	2				
	5	180	2				

Table 12. Months per year that desiccation is permitted as a potential mortality option.

Vegetation Alliance	Months Drying Allowed
Fcwd	April-October
Oash	April-October
Gbw	April-October
Sbw	February-November
Eld	March-November
Rose	March-November
Salt	year round
Crye	year round
Mug*	NA
Cbr	March-November
Bbt	March-November
Rbh	March-November

*Desiccation is not simulated for mugwort

Table 13. Mortality parameters for desiccation. The data indicate the age of the plant and required length of time that the root of the plant can be above the capillary fringe before mortality by desiccation occurs.

Vegetation Alliance	Age (yr)	Time (d)
Fctw*	NA	NA
Oash	0	2
	1	5
	3	21
	20	45
Gbw/ Sbw/ Bbt	0	3
	1	7
	3	28
	20	60
Eld	0	5

Vegetation Alliance	Age (yr)	Time (d)
	1	11
	3	42
	20	90
Rose	0	4
	1	9
	3	37
	20	80
Salt	0	3
	1	7
Crye	0	4
	1	10
Mug**	NA	NA
Cbr/ Rbh	0	2
	3	21

*Freemont cottonwood utilizes the water stress method for simulating desiccation.
**Desiccation is not simulated for mugwort.

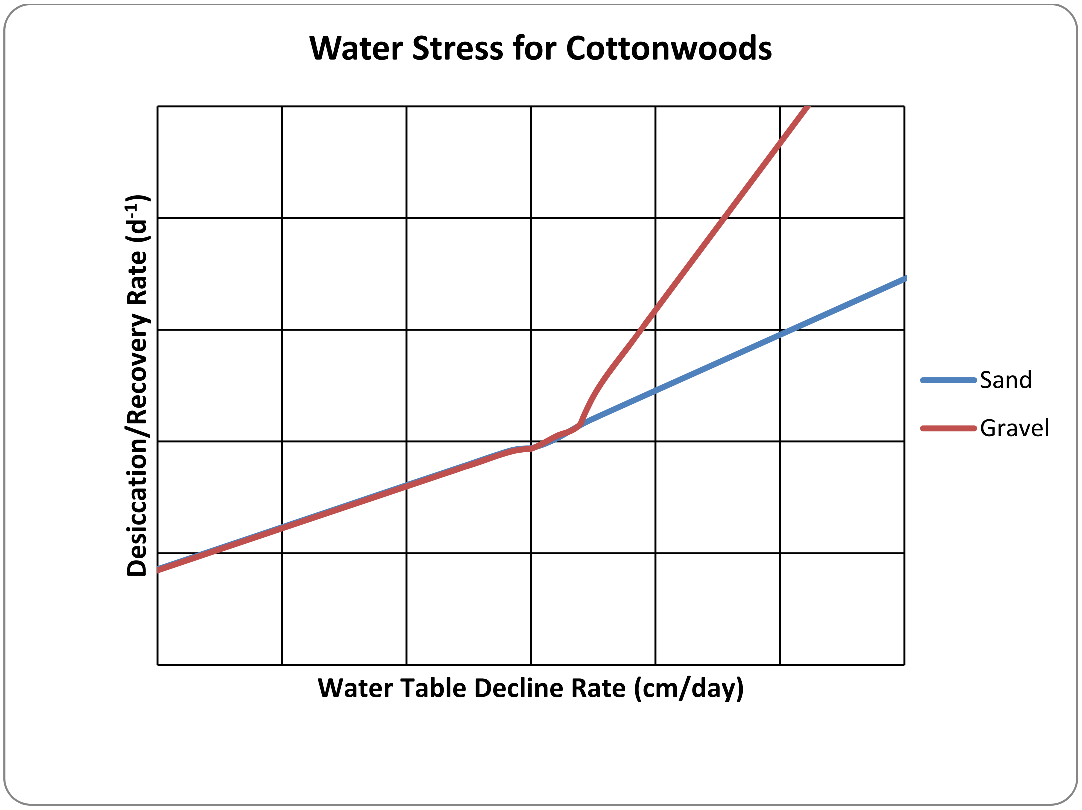

Figure 6. Relationship between desiccation rate and water table decline for Freemont Cottonwood. Positive values indicate desiccation or water table decline, while negative values indicate recovery or water table rise.

4 Model Simulations

Three sets of model simulations were initially run using combinations of geometry, hydrology, and vegetation maps. These included: (1) existing conditions geometry, existing conditions hydrology, and existing conditions vegetation maps, (2) alternative geometry, alternative A hydrology, existing conditions vegetation maps, and (3) alternative geometry, alternative A hydrology, and proposed restoration planting maps.

4.1 Existing Conditions

The existing conditions geometry was utilized for this simulation, combined with the baseline hydrology data and the vegetation mapping of existing conditions. For this analysis, no vegetation was permitted to grow outside of the levees or in agricultural areas as mapped by DWR. Both sediment transport and vegetation routines were simulated for the 23-year simulation period. These simulations represent the conditions assuming historical flow operations will be the same in the next 23 years as they were between 1980 and 2003. Because no initial geometry and vegetation data were collected in 1980 with which to compare the present conditions, no calibration of sediment transport or vegetation patterns is possible.

Modeled water surface elevations for individual flows were compared against measured data (SJRRP, 2010b; SJRRP, 2011c) to illustrate the ability of model to predict the water surface elevation. Measured water surface elevations were available for flows of 1,030 cfs and 161 cfs (Figure 7 and Figure 8). As the water surface elevations within the channel fluctuate, the influence of the roughness coefficient on hydraulic parameters also varies. In general, as flows and subsequent water surface elevations increase, the influence of the channel and floodplain boundary roughness decreases. Due to the use of a single Manning's roughness coefficient to represent all flows, the comparison illustrates that the model tends to slightly overpredict the water surface elevations at the higher discharge. It is likely that the Manning's n decreases with increasing discharge, which is typical of vegetated channels (Coon, 1998). In addition, 2D modeling performed in 2008 demonstrated the heavy influence of localized patches of thick vegetation just downstream of San Mateo Road that are not captured in this model. Despite these limitations of SRH-1D, the model is typically within 0.5 feet of the measured water surface.

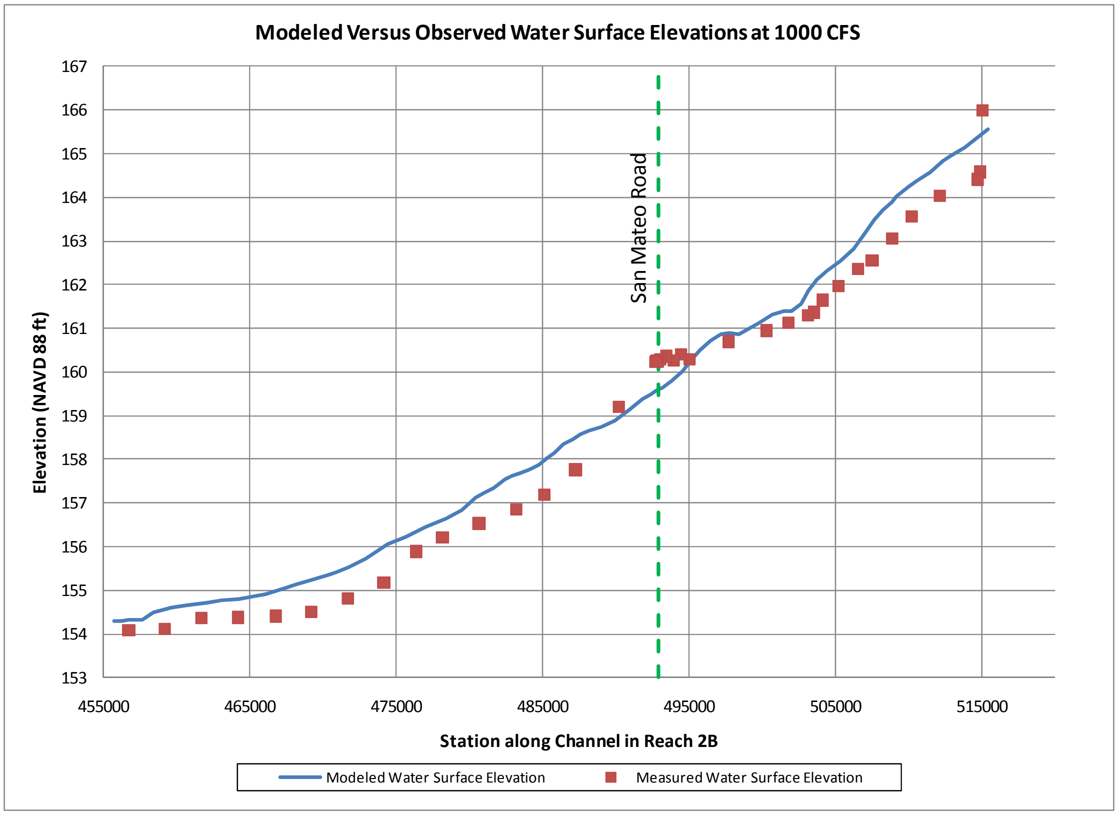

Figure 7. Modeled (1000 cfs) versus measured (~1030 cfs) water surface elevations in Reach 2B.

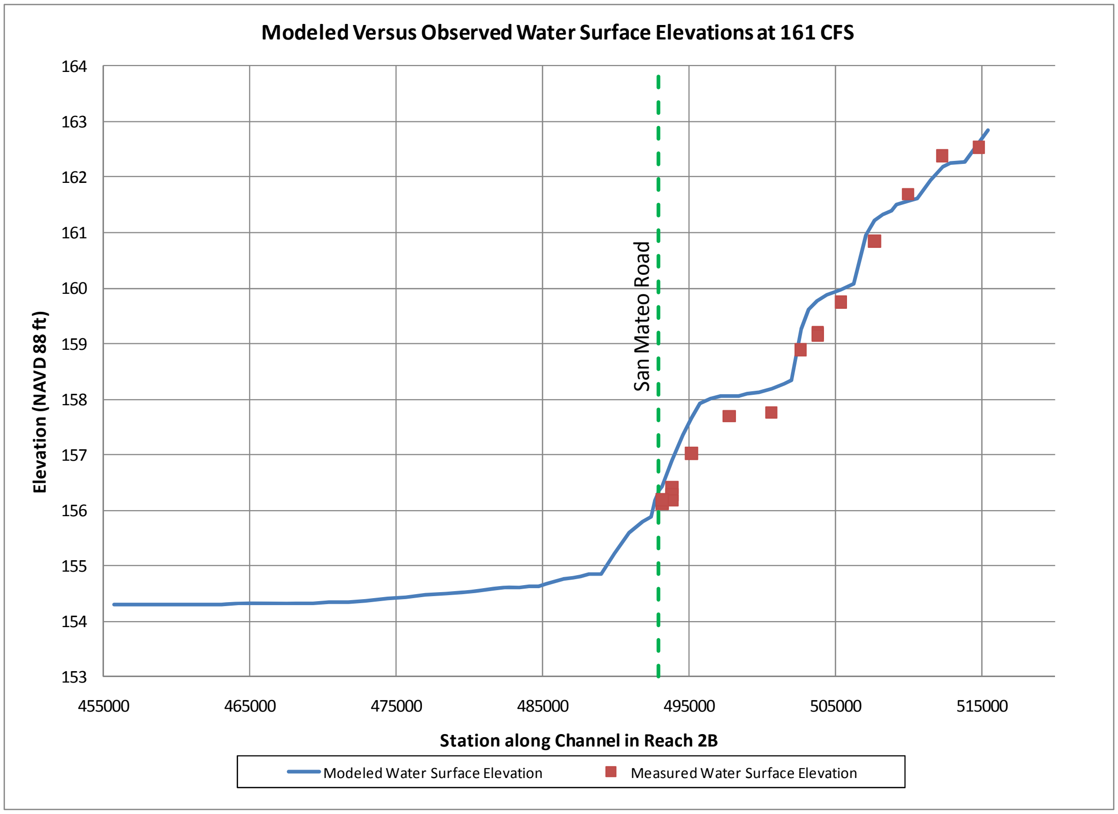

Figure 8. Modeled versus measured water surface elevations for 161 cfs in Reach 2B.

4.2 Alternative Geometry with Alternative Hydrology and Existing Vegetation

For alternative IAFP1 and IAFP5 only, models were developed to simulate potential vegetation and sediment transport patterns for the scenario under which flow operations are modified to represent Alternative A hydrology, but vegetation remains the same as existing conditions. For these models, no vegetation was permitted to grow outside the proposed levees footprint. However, vegetation was permitted to establish in areas within the levees that were defined as agriculture. These conditions represent the case where no restoration riparian planting is initially performed within the levee footprint, and the only vegetation that establishes is based upon the rules identified in the vegetation germination, growth and mortality model parameters. Only the widest and narrowest of levee setback alternatives were evaluated with these conditions in order to evaluate the range of anticipated conditions.

4.3 Alternative Geometry with Alternative Hydrology and Proposed Restoration Vegetation

For all five levee setback geometry options, models were developed to simulate vegetation and sediment transport patterns for the scenario under which flow operations are modified to represent Alternative A hydrology and alternative restoration vegetation planting plans. No vegetation was permitted to establish outside of the levee footprints defined in the alternative geometry files. The initial model simulations of the proposed restoration vegetation do not consider the potential irrigation of vegetation that may occur, at least initially, to protect against desiccation and ensure short-term survival of planted vegetation.

4.4 No Desiccation in Years 1 to 5

Following completion of the model simulations where all mortality methods were permitted, an additional condition was modeled to evaluate the influence of irrigation on vegetation establishment and survival. Irrigation is anticipated to occur for at least the first 5 years following planting, which will at a minimum reduce the potential for desiccation. To represent this in the model, desiccation was not permitted to occur for the first 5 years of the simulation period. This scenario was modeled for the existing conditions, alternative geometry with existing vegetation, and alternative geometry with proposed vegetation.

5 Model Results

5.1 Changes in Channel Bed

The sediment transport portion of the model predicts patterns of deposition and erosion along the channel. A detailed analysis of the predicted changes in channel bed over time with existing conditions geometry for the entire reach between Friant Dam and the Merced River is presented in the PEIS (SJRRP, 2011a). Within this current report, the predicted changes in bed elevations with the alternative geometries are presented within Reach 2B. Because a feedback mechanism between the vegetation growth and roughness is not yet scripted in the current model, the predicted changes in bed elevation are unaffected by the initial vegetation conditions used as input to the model. Differences in the bed elevations are related to differences in the levee setback distances and in the hydrology applied. Figure 9 illustrates the profiles predicted under existing conditions compared with the five alternatives.

The existing conditions bed elevations are predicted to remain relatively stable with a slight depositional trend upstream from San Mateo Road. For all levee setback alternatives evaluated, net deposition is anticipated to occur in the reach, with the greatest reach-averaged depth of deposition predicted for IAFP 2 and the least predicted in IAFP 5. In general, as the width of the levees increases, the reach-averaged depth of deposition decreases. Although increasing levee widths results in greater total volumes of deposition, the total area available for sediment to deposit within each cross section also increases with increasing levee setback and the depth of deposition decreases. The only exception to this pattern is between IAFP1 and IAFP2, where a slightly smaller depth of deposition is predicted under IAFP1. This is likely due to the confined levee widths in IAFP1 causing an increase in sediment transport capacity at larger flows. Transport capacities for all alternatives decrease with increasing levee widths (from IAFP1 to IAFP5), thereby causing increased volumes of deposition (Table 14). However, the differences in the transport capacities between alternatives IAFP2 and IAFP5 are not large enough to cause substantial reductions in depths of deposition.

In adidtion, the one-dimensional model cannot simulate all the details behind channel and floodplain interactions. A large portion of the sand will likely remain in the main channel and not deposit on the floodplains, but it is difficult to estimate the proportion of floodplain sediment transport versus main channel sediment transport in a 1D model. Based upon the results, the depth of deposition will likely be very similar between the alternatives

The total sediment load entering the reach is approximately 460,000 tons for existing conditions and between 1.3 and 1.4 million tons for Alternatives IAFP1 to 5 (Table 14).

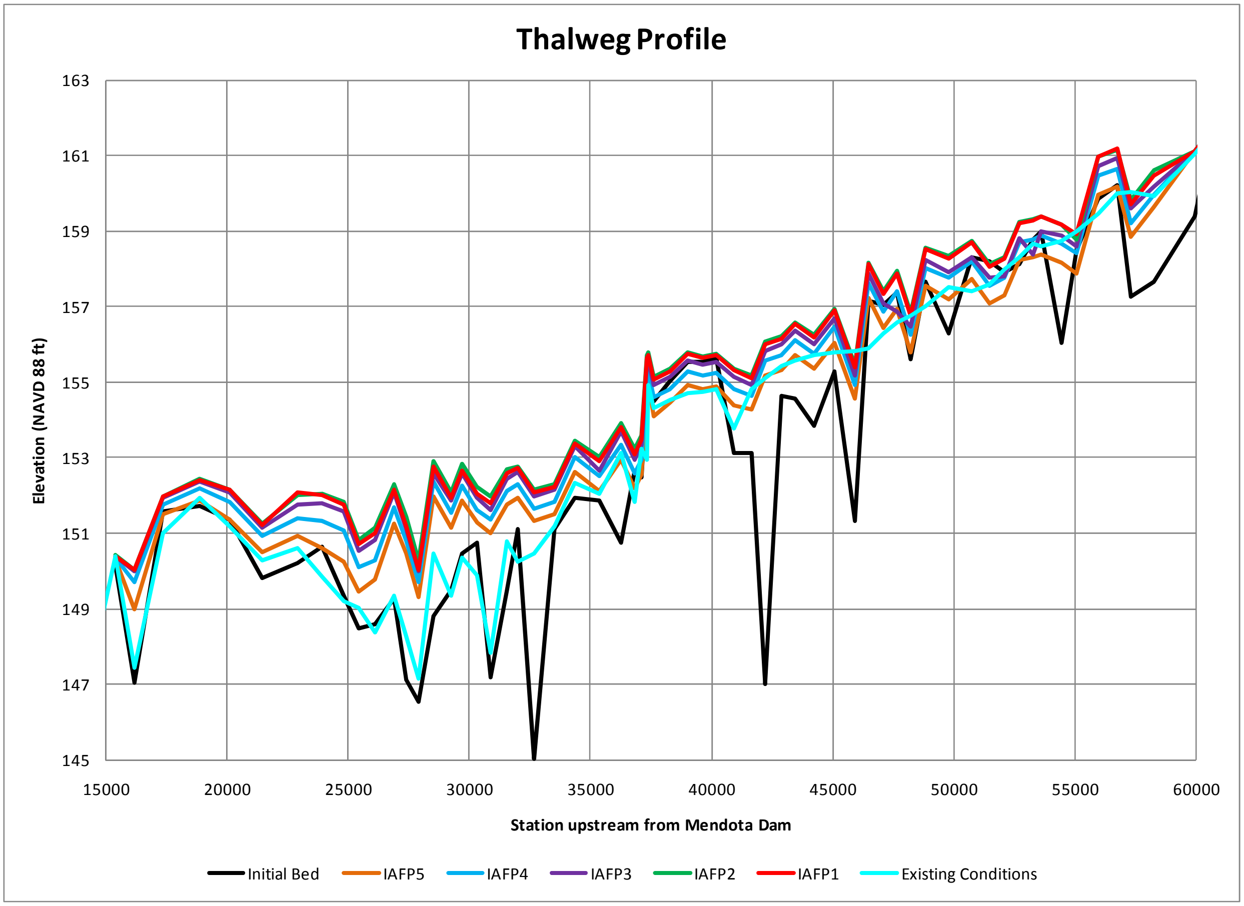

Figure 9. Profile of channel thalweg for each alternative following the 23 year simulation.

Table 14. Quantities of deposition for each alternative between Chowchilla Bifurcation Structure and the proposed Mendota Pool Bypass location.

Alternative	Total incoming sediment load to reach (tons)	% of incoming sediment deposited within reach	Reach-averaged deposition at each cross section (tons)	Reach-averaged depth of deposition along thalweg (ft)	Reach-averaged depth of deposition across channel (ft)
Existing	460,000	68%	5,000	0.51	0.90
IAFP1	1,330,000	63%	14,000	1.78	0.71
IAFP2	1,330,000	87%	19,000	1.85	0.74
IAFP3	1,360,000	88%	20,000	1.57	0.58
IAFP4	1,370,000	91%	21,000	1.32	0.34
IAFP5	1,390,000	92%	21,000	0.90	0.03

5.2 Vegetation Conditions

5.2.1 Quantities of Vegetation

Following the 23 year simulation, a comparison of the areas of surviving vegetation for each vegetation type was conducted across all alternatives. Areas are output from the model and calculated assuming that each point represents an area of half the distance to the next adjacent points within the cross section (laterally) and half the distance to the next upstream and downstream cross section (longitudinally). The model also assumes that multiple vegetation types can occupy the same point in a cross section unless defined competition or shading rules do not permit their coexistence. Therefore, the total vegetated areas for each vegetation alliance provide quantitative information that is best interpreted from a relative perspective across alternatives rather than using the absolute values of vegetated areas.

5.2.1.1 Model Simulations with All Mortality Options

Figure 10 through Figure 12 illustrate the vegetated area for each alternative and each vegetation alliance when all mortality options are included in the model simulations. Based on the comparison, all alternative levee widths promote increased vegetation growth compared with the existing conditions. The total vegetated area tends to increase with increasing levee widths for cottonwood, black willow, sand bar willow, ash, elderberry, mugwort, and buttonbush. Salt grass and rye grass tend to remain relatively consistent across all alternatives and may be related to their seasonal nature of germination and mortality due to desiccation at lower flows and possibly to a limited corridor within which they can successfully establish. Bulrush and riparian bank herbs similarly remain consistent, which may be due to the limited areas closer to the river within which they tend to thrive. The California wildrose alliance increases in total area between IAFP1 and IAFP2, but remains relatively consistent between IAFP2 through IAFP5. No buttonbush or riparian bank herbs were reported for the model runs that used the existing vegetation as the initial condition input because these vegetation alliances were not mapped in the existing vegetation conditions shapefile.

Results for IAFP2 and IAFP3 are very similar due to the similarities between their geometries. The primary differences in these two alternatives relate to excavated side channels or swales in IAFP3 that do not exist in IAFP2. These geometric differences result in very minor differences in the germination and survival of vegetation.

For IAFP1 and IAFP5, a comparison of the differences resulting from the initial vegetation input files was conducted since these alternatives were run with both the existing vegetation maps and with the proposed vegetation maps. While substantial differences were noted with IAFP1, Comparison of the results between the existing vegetation conditions and the proposed restoration planting indicates minimal differences at the end of the 23-year simulation period for both IAFP1 and IAFP5. Differences that are notable include the area of bearded creeping rye grass, mugwort, and the absence of buttonbush willow or riparian bank herbs. The predicted area of bearded creeping rye grass with the existing vegetation map is more than twice the area predicted with the proposed vegetation maps for both IAFP1 and IAFP5. The predicted area of mugwort is much greater with the proposed vegetation maps. The predicted similarities are likely related to drought that occurred within the first season of the simulation period, which resulted in mortality of nearly all vegetation for most cross sections, thereby negating any differences in the initial conditions vegetation files. These results suggest that the detailed planting plans do not provide long-term benefits over allowing vegetation to establish on its own.

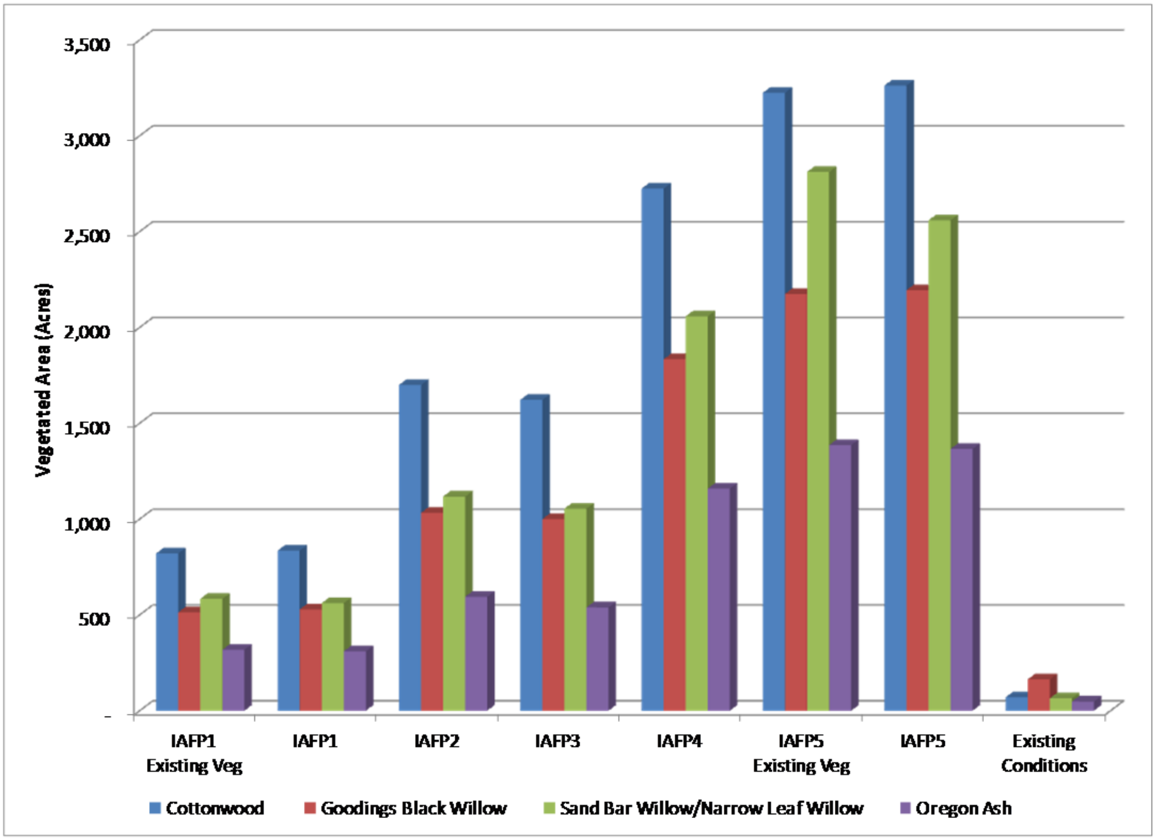

Figure 10. Total vegetated area of cottonwood, black willow, sand bar willow, and ash for each alternative at the end of the 23 year simulation period.

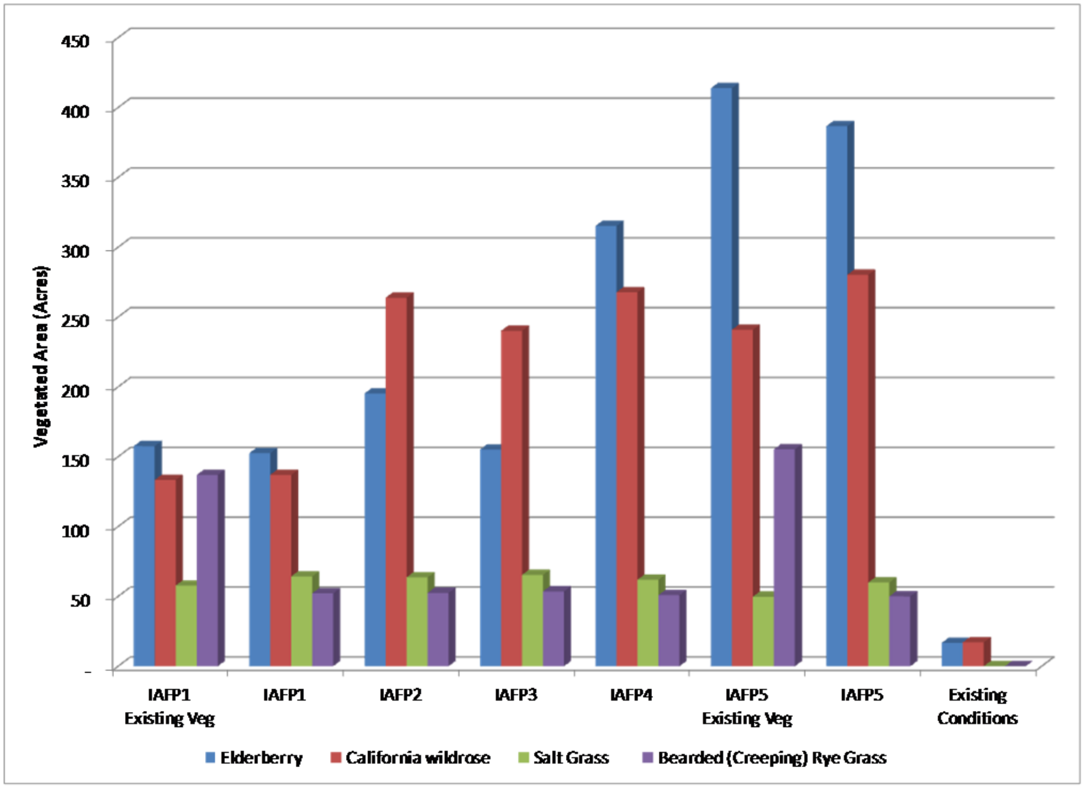

Figure 11. Total vegetated area of elderberry, wildrose, salt grass, and rye grass for each alternative at the end of the 23 year simulation period.

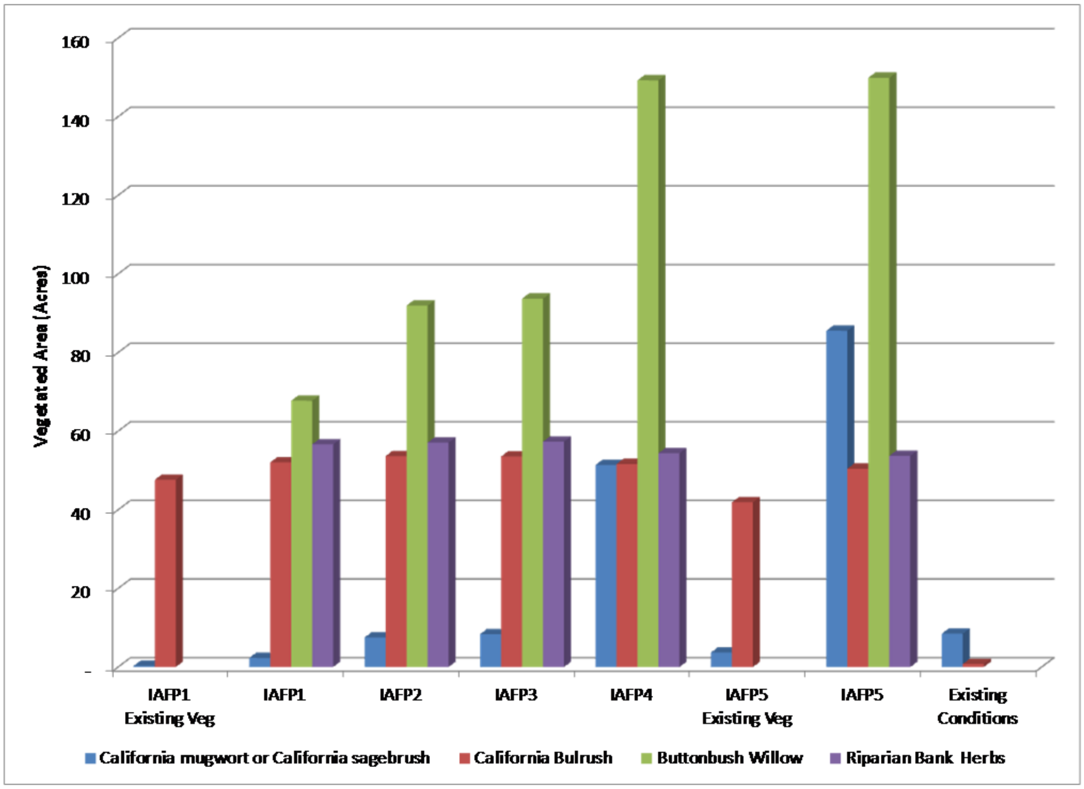

Figure 12. Total vegetated area of mugwort, bulrush, buttonbush, and riparian bank herbs for each alternative at the end of the 23 year simulation period.

5.2.1.2Model Simulations with No Desiccation in Years 1 to 5

Figure 13 through Figure 15 illustrate the total quantities of vegetated area for each alternative when no desiccation is permitted to occur for the first 5 years. This scenario is intended to represent the use of irrigation to increase the survival of vegetation during dry periods and low flows within the first five years following the implementation of the levee setbacks. Conditions were modeled for existing conditions, alternative geometries with proposed vegetation, and alternative geometries with existing vegetation (IAFP1 and IAFP5 only).

All alternative geometries indicated increased predicted vegetated area compared with existing conditions geometry and hydrology. Similar to results presented in the previous section, the model results predict an increase in the total vegetation area as the levee widths increase. This is primarily due to an increase in the area vegetated by cottonwood, black willow, sandbar willow, ash, buttonbush willow and elderberry (Figure 13 and Figure 14) as the levee widths increase. All other vegetation types only experience slight increases or remain the same in vegetated area with increased levee widths.

Compared to the results with all mortality options permitted, the total vegetated area increases when desiccation is not permitted within the first 5 years. Differences for each vegetation type are presented in Table 15. Increased areas are greatest for buttonbush willow and ash. Cottonwood, black willow, and elderberry are also predicted to substantially increase in area with irrigation. However, all other vegetation alliances experienced decreases in predicted vegetation area at the end of the 23-year simulation period. Investigation into this issue found that the successful establishment of the woody species within the first 5 years resulted in competition with other species throughout the simulation period, in which cases the woody species tended to prevail. This comparison only evaluates differences in total areas vegetated by each vegetation type with and without desiccation; it does not account for differences in ages of the vegetation types.

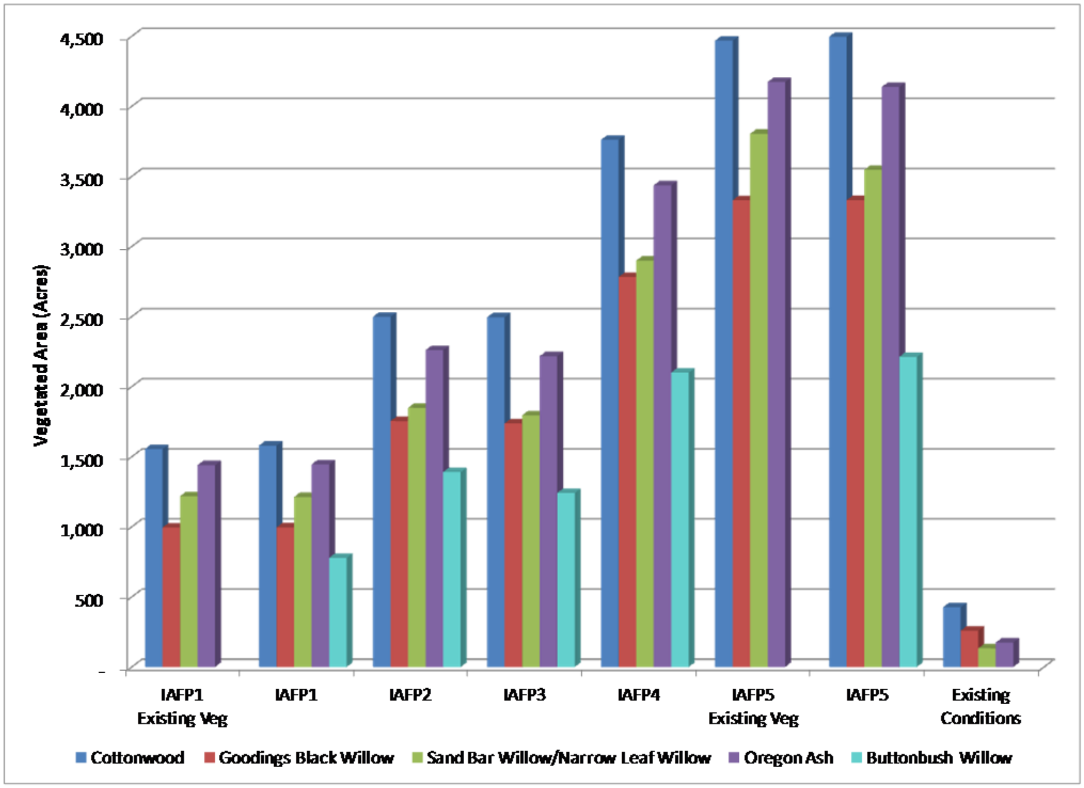

Figure 13. Total vegetated area of cottonwood, black willow, sand bar willow, ash, and buttonbush for each alternative at the end of the 23 year simulation period with no desiccation allowed for years 1 through 5.

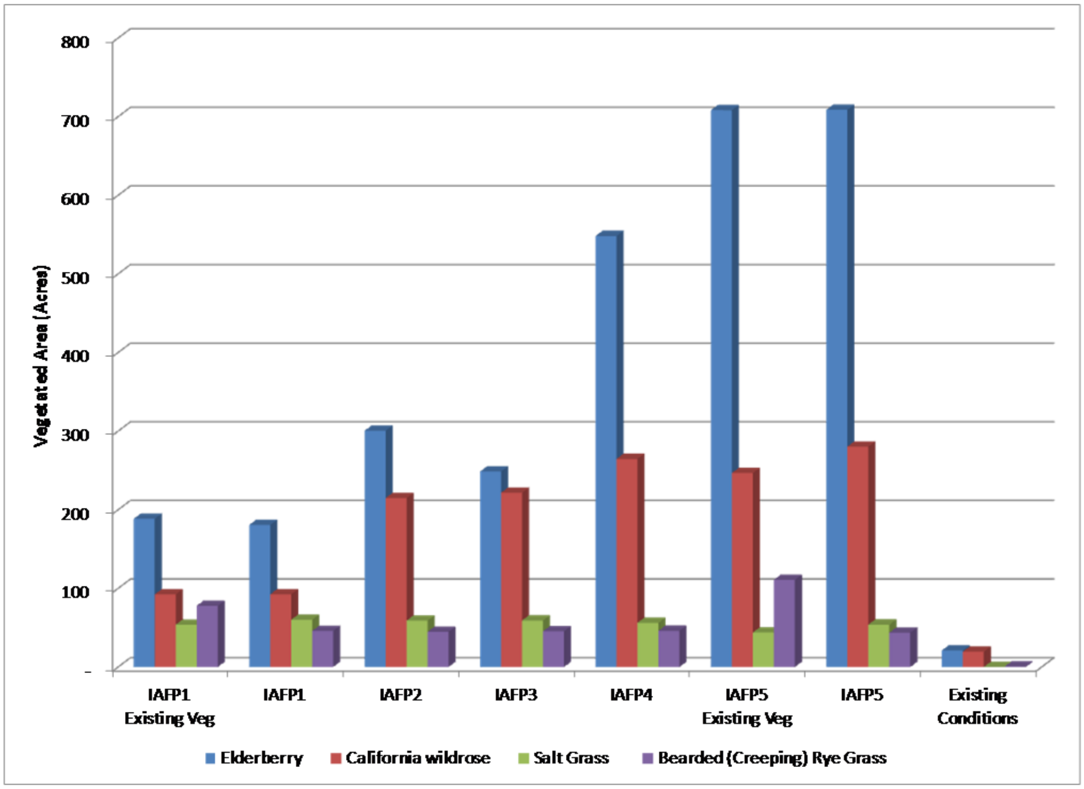

Figure 14. Total vegetated area of elderberry, wildrose, salt grass, and rye grass for each alternative at the end of the 23 year simulation period with no desiccation allowed for years 1 through 5.

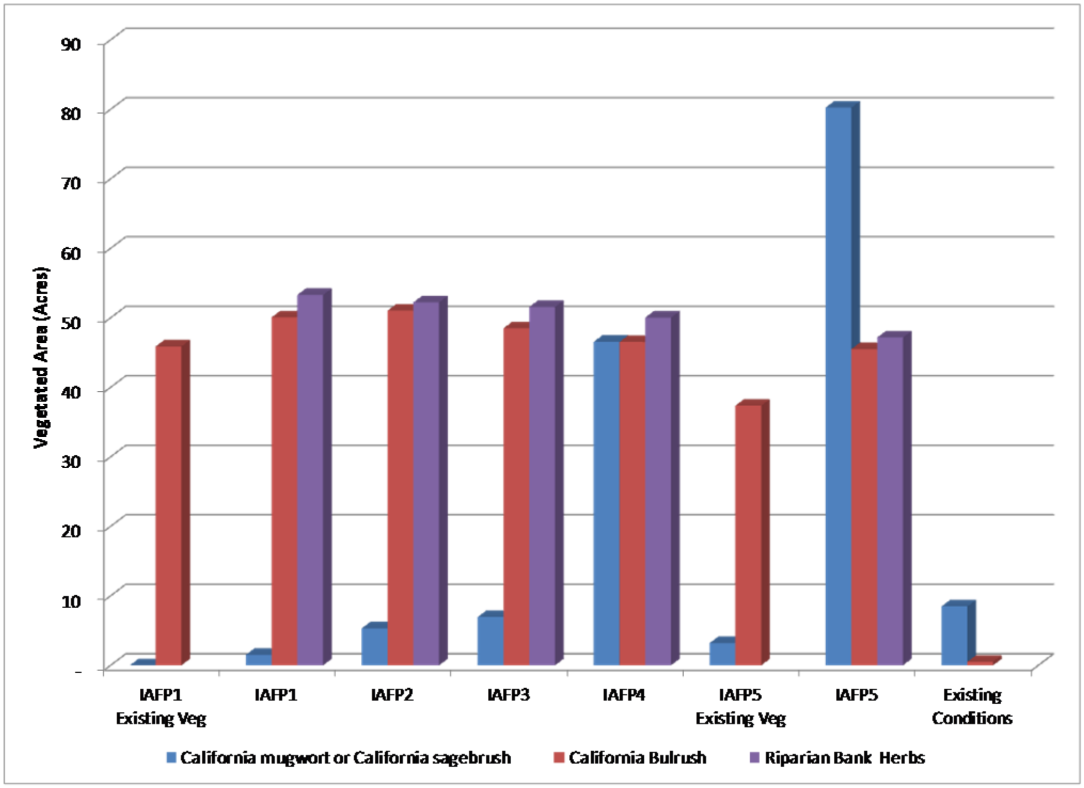

Figure 15. Total vegetated area of mugwort, bulrush, and riparian bank herbs for each alternative at the end of the 23 year simulation period with no desiccation allowed for years 1 through 5.

Table 15. Percent changes in vegetated area when desiccation is not permitted to occur during the first 5 years of simulation. Percentages are relative to model runs with all mortality options.

Alternative	Cottonwood	Oregon Ash	Goodings Black Willow	Sand Bar Willow	Elderberry	CA wildrose	Salt Grass	Rye Grass	CA mugwort	CA Bulrush	Button bush Willow	Riparian Bank Herbs
IAFP1 Existing Veg	89%	353%	94%	109%	20%	-31%	-7%	-43%	-100%	-4%	NA**	NA**
IAFP1	89%	367%	88%	116%	18%	-32%	-6%	-12%	-35%	-4%	1049%	-6%
IAFP2	47%	280%	70%	65%	54%	-19%	-7%	-15%	-29%	-5%	1412%	-9%
IAFP3	54%	311%	74%	70%	60%	-8%	-9%	-15%	-17%	-9%	1225%	-10%
IAFP4	38%	196%	52%	41%	74%	-1%	-9%	-9%	-9%	-10%	1307%	-8%
IAFP5 Existing Veg	39%	201%	53%	35%	71%	2%	-12%	-29%	-13%	-11%	NA**	NA**
IAFP5	38%	203%	52%	39%	83%	0%	-10%	-13%	-6%	-10%	1376%	-12%
Existing Conditions	508%	265%	58%	106%	26%	14%	NEG*	NEG*	0%	-33%	NA**	NA**

* NEG: negligible increase because 0 acres were predicted with all mortality options and less than 1 acre predicted without desiccation in years 1 to 5.

**NA: not applicable because these vegetation types were not present in the existing conditions mapping.

5.2.2 Location of Surviving Vegetation

The spatial distribution of vegetation at the end of the 23 year simulation period can be visualized in ArcGIS for each alternative (Electronic Appendix). Example maps are shown in Figure 16 through Figure 19.

In general, older woody species, such as cottonwoods, black willow, sandbar willow, and ash, tend to be located farther away from the channel, and younger woody species are located adjacent to the channel. The exception is within small patches close to the channel where existing older vegetation are preserved in the restoration planting plans. This pattern is likely due to the fact that the area adjacent to the channel is more frequently subjected to large fluctuations in the water table, resulting in continuous cycles of vegetation mortality and regeneration.

Several vegetation alliances within Reach 2B are less than 1 year old at the end of the simulation period, including salt grass, rye grass, bulrush marsh, and riparian bank herbs, all of which are located within 700 feet of the river. This indicates that seasonal variations in the water table do not sustain these vegetation types year round, and irrigation may improve their survival. However, all of these vegetation types typically have a lifespan of only a few years. Therefore, results with irrigation in the first 5 years of the simulation do not result in older vegetation for these vegetation types at the end of the 23 year simulation period.

Comparison of the figures illustrating cottonwood and elderberry distributions with and without simulated irrigation demonstrates differences in the age classes of vegetation present at the end of the 23 year simulation period. The variation of age classes for cottonwood indicates that most cottonwood establishes along the floodplain within the first 5 years (during irrigation) and survives throughout the remaining simulation period. Similarly, the majority of elderberry plants are within the 20-25 year age class at the end of the simulation period when irrigation is performed because of early establishment. Results suggest that when desiccation is precluded as a mortality option in the first 5 years, the age diversity of plants decreases due to early establishment and prolonged survival for cottonwood and elderberry. These conditions are similar for other shade tolerant woody vegetation and for other vegetation that are not easily outcompeted.

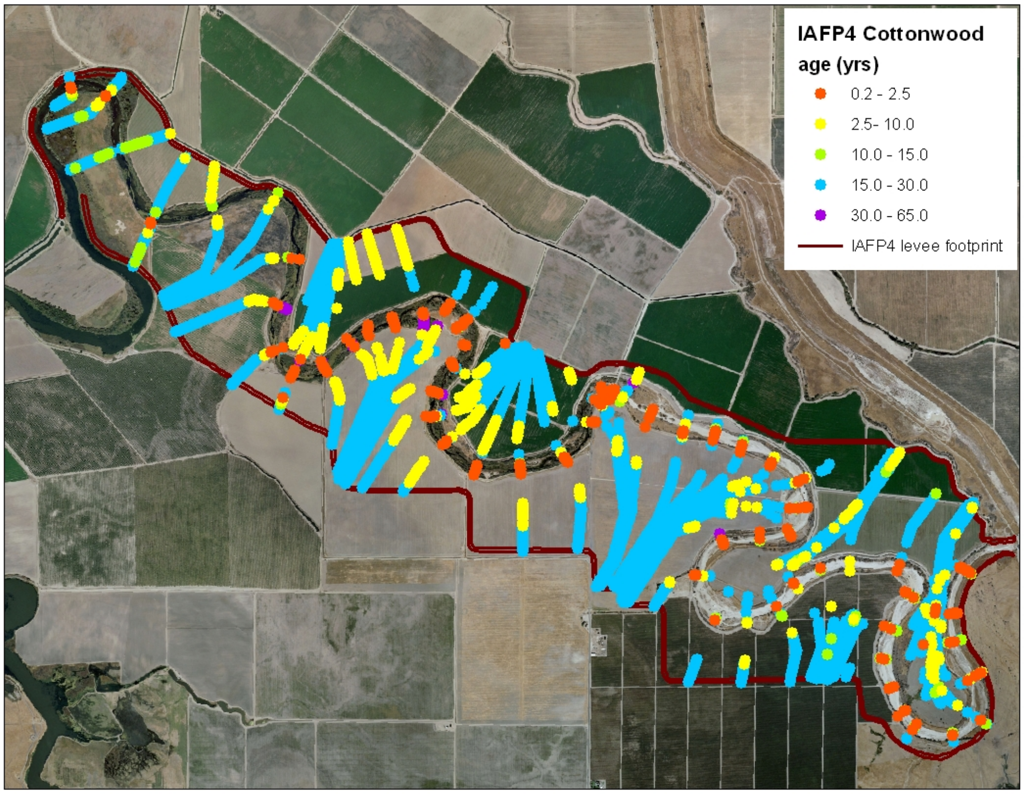

Figure 16. Cottonwood distribution at the end of 23 year simulation period for IAFP4 with all mortality options.

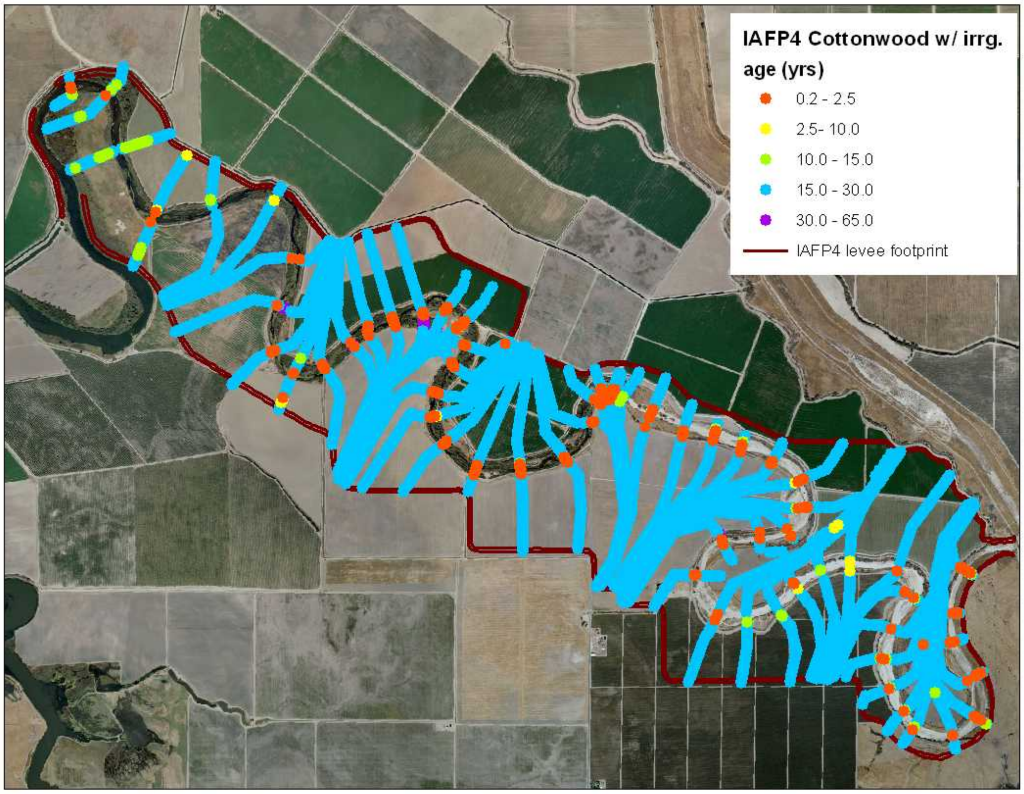

Figure 17. Cottonwood distribution at the end of 23 year simulation period for IAFP4 with irrigation in years 1-5.

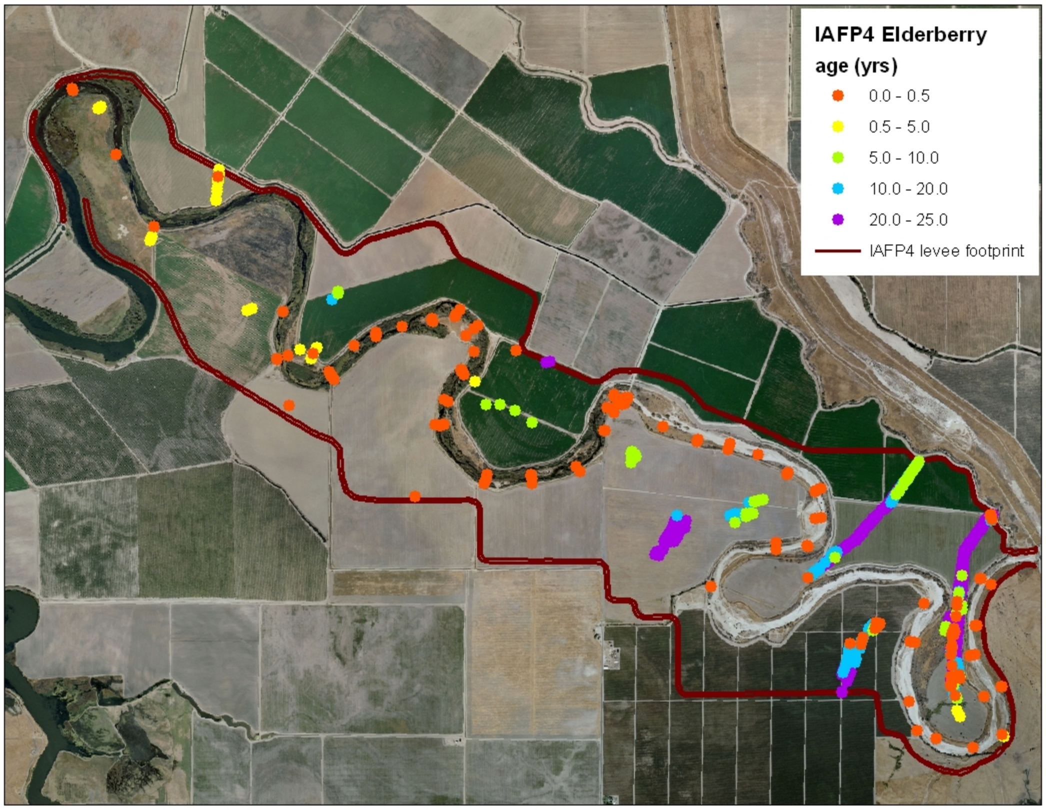

Figure 18. Elderberry distribution at the end of 23 year simulation period for IAFP4 with all mortality options

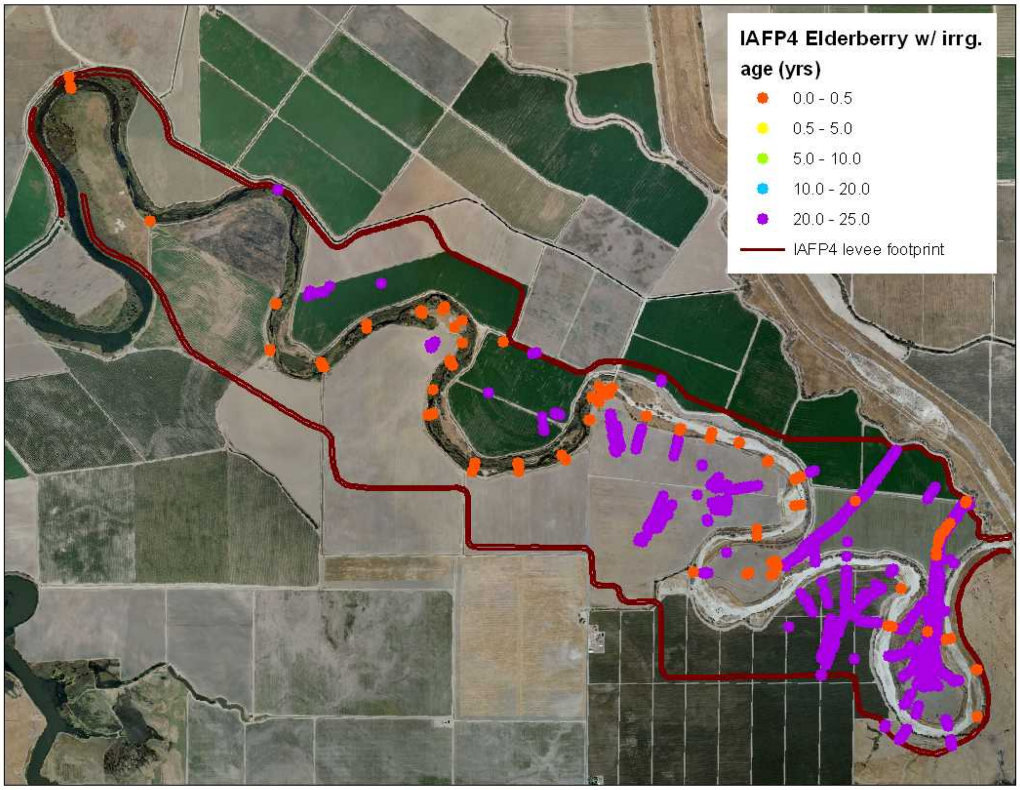

Figure 19. Elderberry distribution at the end of 23 year simulation period for IAFP4 with irrigation in years 1-5.

5.2.3 Mortality of Vegetation

Throughout the simulation period, every point between the levees in each cross section either remains vegetated based on the initial vegetation assignment or becomes vegetated with new growth. Each point may become vegetated with multiple vegetation types unless competition or shading requirements are not met by a particular species. During the simulation, the survival of vegetation at each point is tracked along with the cause of mortality. The potential mortality types include scour, inundation, desiccation, competition and shading. Because differences in shade tolerance may result in one vegetation type outcompeting another, competition and shading are grouped as one mortality mechanism. Vegetation mortality was evaluated for each alternative and for each vegetation type. In addition to total areas of mortality for each alternative, mortality of just cottonwood is presented and may be used as an indicator for woody species.

5.2.3.1Model Simulations with All Mortality Options

The model simulation began in January of 1980. By October of 1981, following the first growing season, a large percentage of planted or newly germinated vegetation had desiccated (Table 16). Because of this, future vegetation mortality was evaluated on an annual basis relative to the mortality that occurred during the first growing season, which allowed greater resolution in detecting changes of mortality over time. Vegetation mortality data were processed on an annual basis in October of each calendar year typically following an extended period of low flows. Results of the analysis indicate that by the end of the simulation period, desiccation and competition are the two leading causes of mortality for all vegetation types combined (Figure 20 to Figure 23). Relative mortality area was defined as the difference in cumulative mortality area for each year minus the mortality area that occurred during the first year (by October of 1981). A decrease in the relative mortality area for one mortality option, such as desiccation, indicates that vegetation became established in the area previously designated as experiencing death by that mortality option (e.g. desiccation).

While desiccation occurs early in the simulation and persists throughout most of the simulation period, competition increases over time as plants mature to the point where shading criteria or age criteria are resulting in mortality in one vegetation alliance over another. Inundation is experienced within the first growing season for many of the planted vegetation types, but tends to cause mortality sporadically throughout the simulation period and typically opposite years of excessive desiccation. For example, around the third year of the simulation period (1983 or day 1,400), there is a sharp increase in the inundation mortality and a notable decline in desiccation mortality. The year 1983 is classified as a wet year and was characterized by the highest unimpaired inflow at Friant Dam between 1922 and 2004 (SJRRP, 2011a). Also, around day 6000 (water year 1997), there is a sharp increase in inundation depth and decrease in desiccation depth, which is due to 1997 being a wet year with an extreme flood event. Scour accounts for a very small amount of mortality for the alternative levee widths, but has a greater influence in mortality area for existing conditions, where confined levees cause increased channel and overbank velocities.

Evaluation of the results for just cottonwoods suggests that inundation and desiccation are responsible for the greatest areas of mortality throughout the simulation period (Figure 24 to Figure 27). Cottonwood desiccation is initially high the first 5 years of the simulation, but tends to level off and eventually decrease. This may be due to the fact that once cottonwood roots reach a depth that coincides with the minimum simulated water table elevation, they are no longer subject to desiccation. During years with particularly high flows, cottonwoods are sensitive to extended periods of inundation and experience high mortality rates. Similar to results of all vegetation types combined, mortality caused by scour is not substantial. For cottonwoods, competition and shading are responsible for only small areas of mortality throughout the simulation period. Model inputs define cottonwood as being shade tolerant by the age of 1 and unable to be outcompeted by any vegetation alliance modeled by the age of 5. Therefore, the majority of cottonwood mortality by competition and shading is likely occurring during the early stages of life.

Table 16. Total area of mortality after first growing season for each alternative with all mortality options simulated.

Total Area of Mortality for All Vegetation Types after First Season (Acres)				
Alternative	**Scour**	**Inundation**	**Desiccation**	**Competition/Shading**
Existing Conditions	20	384	1,288	335
IAFP1	5	1,306	10,313	55
IAFP1 Existing Vegetation	2	323	1,950	259
IAFP2	5	2,376	15,906	54
IAFP3	6	2,432	15,750	53
IAFP4	5	3,772	23,399	57
IAFP5	4	3,913	28,765	60
IAFP5 Existing Vegetation	1	3,820	20,071	113
Total Area of Mortality for Cottonwood after First Season (Acres)				
Alternative	**Scour**	**Inundation**	**Desiccation**	**Competition/Shading**
Existing Conditions	0	2	48	29
IAFP1	0	1	527	3
IAFP1 Existing Vegetation	0	1	174	19
IAFP2	0	16	952	4
IAFP3	0	9	1,010	3
IAFP4	0	16	1,299	4
IAFP5	0	20	1,478	17
IAFP5 Existing Vegetation	0	24	1,506	27

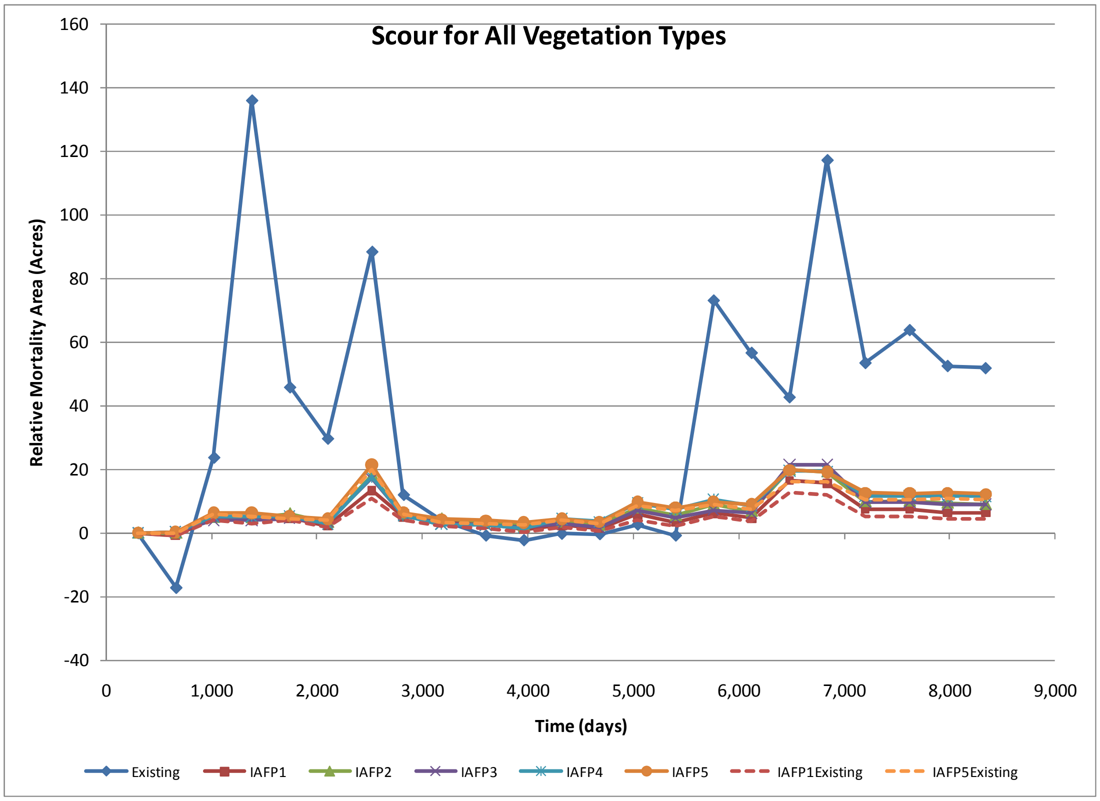

Figure 20. Relative mortality area due to scour for all vegetation types.

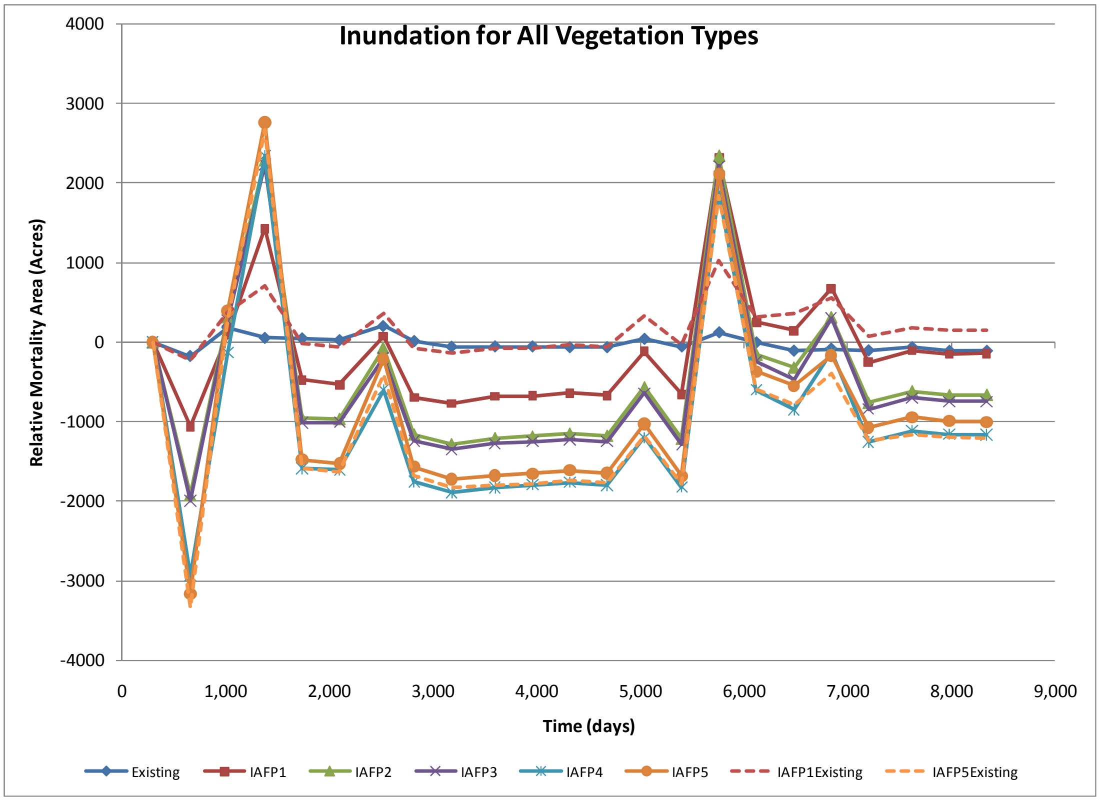

Figure 21. Relative mortality area due to inundation for all vegetation types.

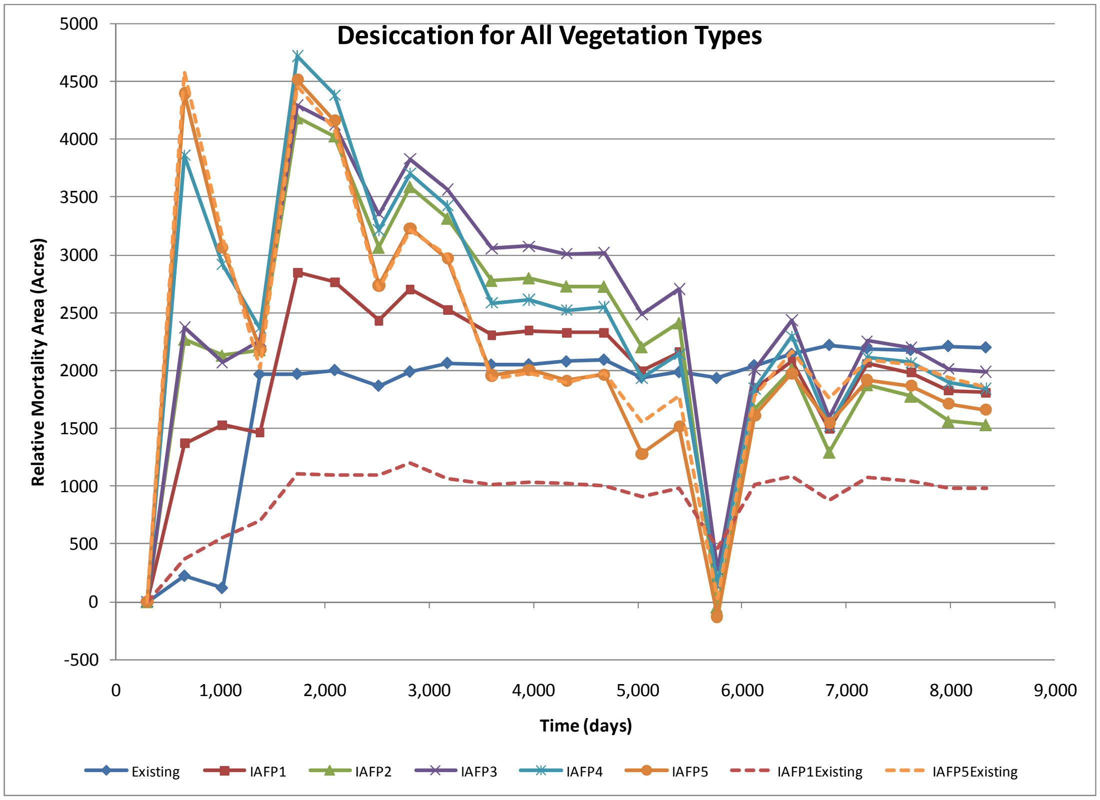

Figure 22. Relative mortality area due to desiccation for all vegetation types.

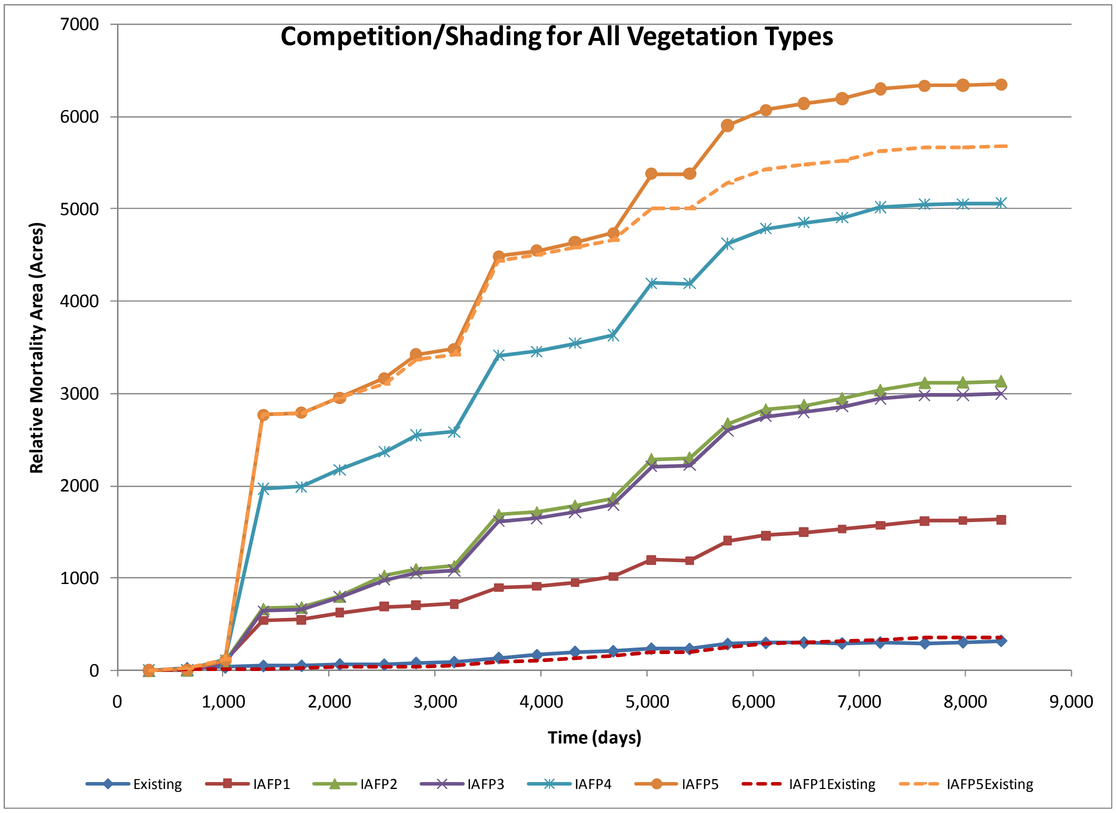

Figure 23. Relative mortality area due to competition/shading for all vegetation types.

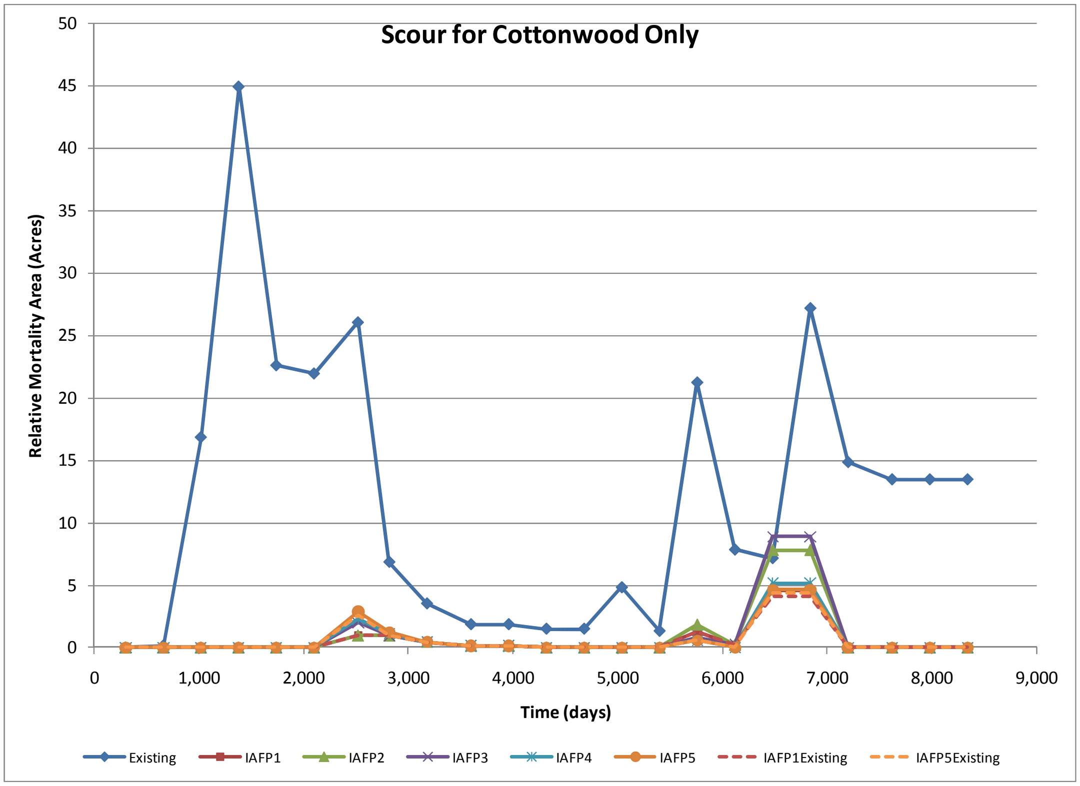

Figure 24. Relative mortality area due to scour for cottonwood only.

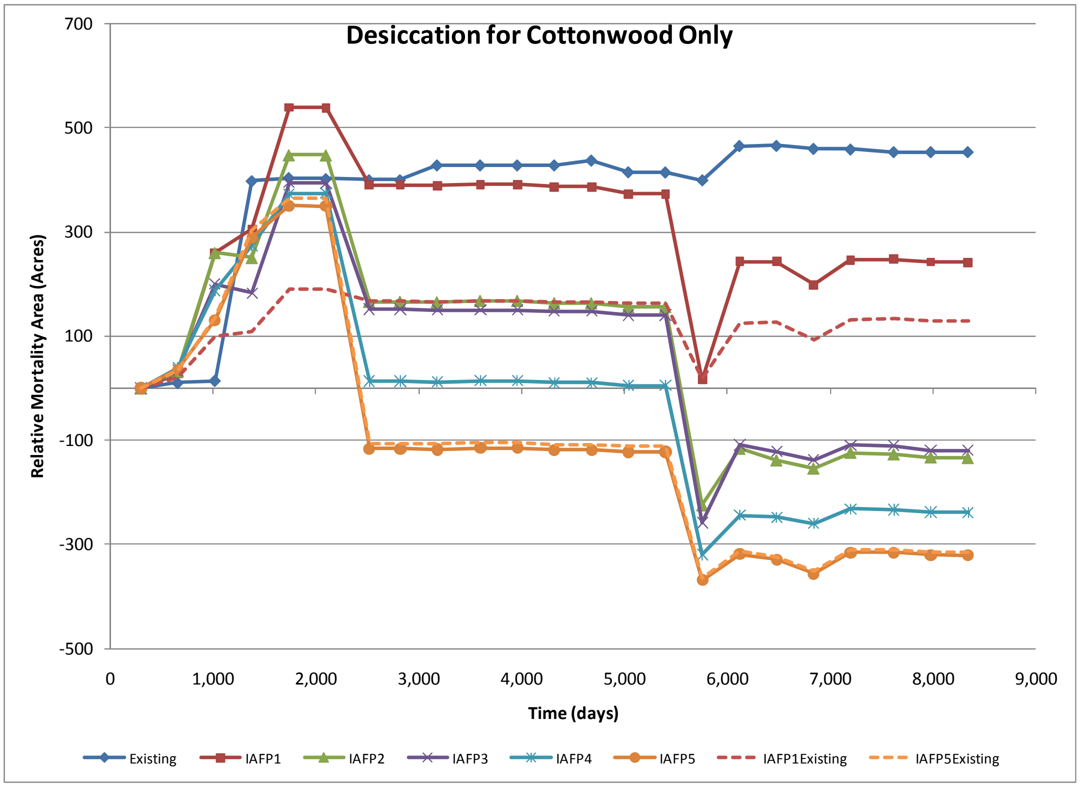

Figure 25. Relative mortality area due to desiccation for cottonwood only.

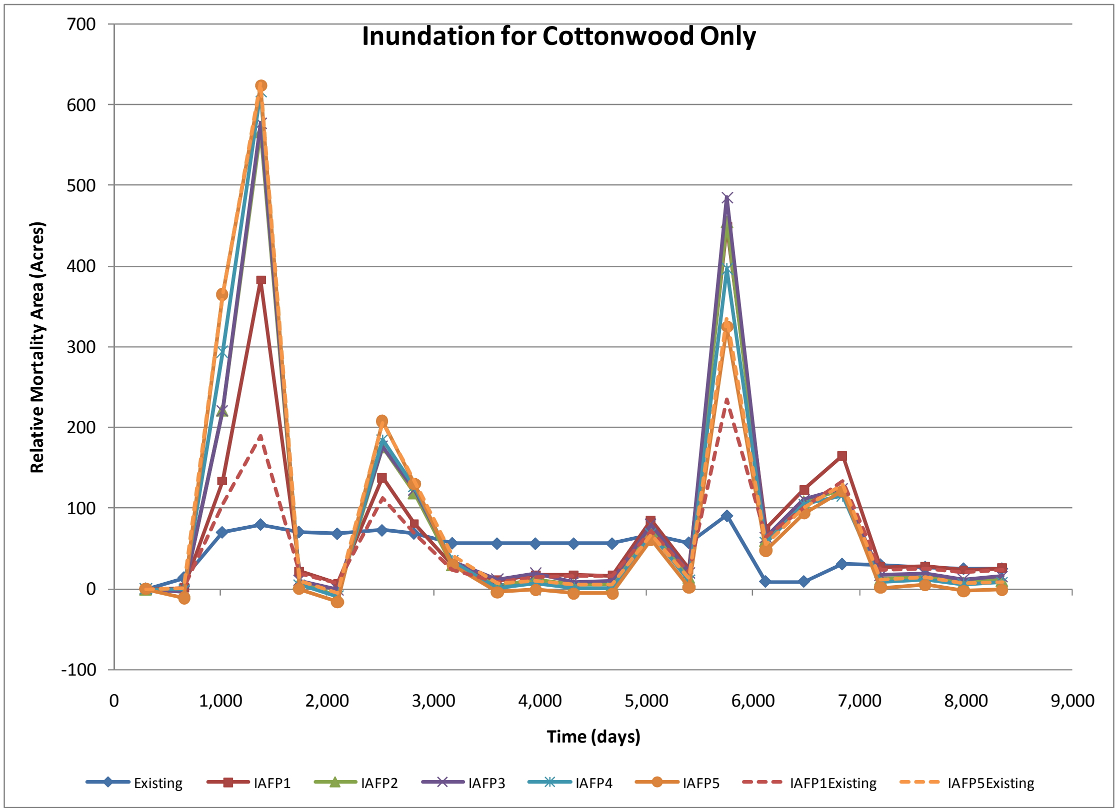

Figure 26. Relative mortality area due to inundation for cottonwood only.

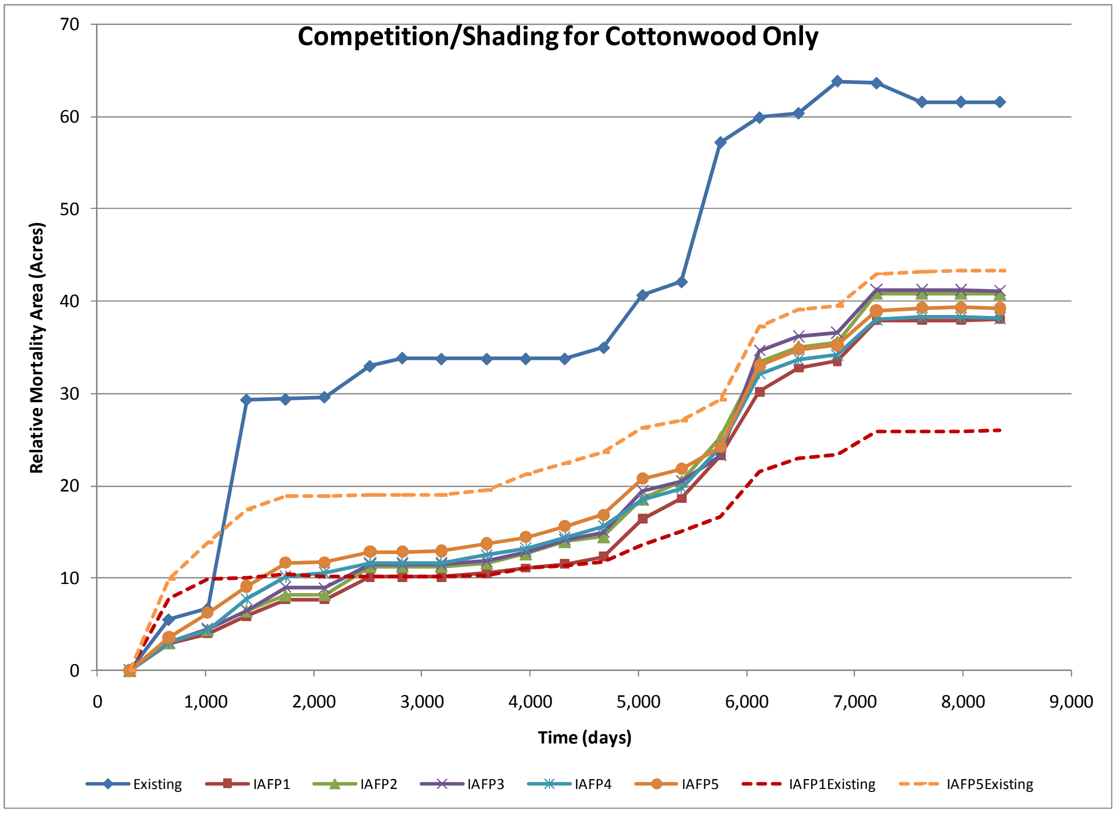

Figure 27. Relative mortality area due to competition/shading for cottonwood only.

5.2.3.2 Model Simulations with No Desiccation in Years 1 to 5

Following simulations of the model without desiccation permitted in years 1 to 5, mortality data were again processed on an annual basis in October of each calendar year. Mortality data were processed for all vegetation types combined and for each individual vegetation type. Because desiccation was excluded as a mortality option for the first five years of the simulation, the total mortality that occurred within the first growing season was substantially less than what was predicted when all mortality options were simulated (Table 17). However, for ease of results comparison, future vegetation mortality was evaluated on an annual basis relative to the mortality that occurred during the first growing season in the same manner as presented in the previous section. Results presented in Figure 28 through Figure 35 illustrate the relative mortality (mortality for each year minus predicted mortality in year 1) as a function of simulation time for each mortality category.

With desiccation eliminated during the first five years of the simulation period, the mechanism responsible for the greatest area of vegetation mortality is competition. The total area experiencing mortality by competition increases rapidly in the first 4 years and begins to level off after the fourth growing season. By this point in time, the predicted area of establishment of woody vegetation has expanded into areas dominated by other vegetation alliances and caused the mortality of grasses, herbaceous plants, and shrubs occupying the same locations due to either shading constraints or competition input parameters. Inundation is responsible for a large area of mortality in the first growing season and also by the end of the fourth growing season (day 1380). Following the five years of irrigation, the area of mortality by desiccation increases, but the predicted peak values under these simulations remains considerably less than the desiccation predicted during the first growing season without the simulation of irrigation in years 1 to 5. Mortality by scour is not a substantial contributor to total mortality area, except under existing conditions, where high flows are confined between narrow levees.

For cottonwoods, general trends in mortality are similar with and without irrigation during the first 5 years, except for mortality by desiccation. Total areas experiencing mortality by desiccation are reduced to zero during the first 5 years and not significant thereafter for any of the 5 alternative levee widths. Inundation is responsible for the greatest area of cottonwood mortality in the first 10 years, with peaks occurring during wetter years. One notable difference in cottonwood mortality predicted with irrigation from that predicted without irrigation is that cottonwood is well-enough established by the floods of 1997 (day 6000) with irrigation that a substantial area of cottonwood is not subject to mortality by inundation.

Differences in the primary mortality mechanisms for the simulations with and without irrigation during the first 5 years of the model are presented in Table 18. Without irrigation, the model predicts that desiccation is the primary mortality method for all vegetation types except California Mugwort, which is highly tolerant of long periods of drought but very sensitive to inundation. When desiccation is excluded as a mortality option for the first 5 years of the model, the primary mortality mechanisms change for most vegetation types. Inundation is predicted to be a primary mortality mechanism for Freemont Cottonwood, Elderberry and California Mugwort. Desiccation remains the primary mortality mechanism for Gooding’s Black Willow. Oregon Ash has similar areas of mortality caused by inundation and desiccation, while Buttonbush Willow had similar areas of mortality caused by desiccation and competition. All other vegetation types were characterized by the greatest mortality area resulting from competition or shading. These results suggest that when irrigation is applied during the first several years, most vegetation types spread freely to other areas, and multiple vegetation types (sometimes up to all 12) occupy a single point in each cross section until one or multiple species (typically woody species or brush with wider canopy cover and shading tolerance) outcompete the other vegetation types based on input age requirements.

Table 17. Total area of mortality after first growing season for each alternative with no desiccation in Years 1 to 5.

Total Area of Mortality for All Vegetation Types after First Season (Acres)				
Alternative	**Scour**	**Inundation**	**Desiccation**	**Competition/Shading**
Existing Conditions	23	419	0	199
IAFP1	6	1,337	0	55
IAFP1 Existing Vegetation	2	1,234	0	111
IAFP2	5	2,394	0	55
IAFP3	7	2,440	0	53
IAFP4	5	3,768	0	57
IAFP5	5	3,904	0	60
IAFP5 Existing Vegetation	2	3,803	0	112
Total Area of Mortality for Cottonwood after First Season (Acres)				
Alternative	**Scour**	**Inundation**	**Desiccation**	**Competition/Shading**
Existing Conditions	0	3	0	17
IAFP1	0	1	0	3
IAFP1 Existing Vegetation	0	1	0	7
IAFP2	0	15	0	4
IAFP3	0	9	0	3
IAFP4	0	18	0	4
IAFP5	0	23	0	3
IAFP5 Existing Vegetation	0	13	0	5

Table 18. Primary mortality mechanism for each vegetation type and model simulation condition.

	Primary Mortality Mechanism(s)	
Modeled Vegetation Alliance	All Mortality Options Simulated	No Desiccation in Years 1 to 5
Freemont Cottonwood	Desiccation	Inundation
Oregon Ash	Desiccation	Inundation/Desiccation
Goodings Black Willow	Desiccation	Desiccation
Sand Bar Willow/Narrow Leaf Willow	Desiccation	Competition
Elderberry	Desiccation	Inundation
California wildrose	Desiccation	Competition
Salt Grass	Desiccation	Competition
Bearded (Creeping) Rye Grass	Desiccation	Competition
California mugwort or California sagebrush	Inundation	Inundation
California Bulrush	Desiccation	Competition
Buttonbush Willow	Desiccation	Desiccation/Competition
Riparian Bank Herbs	Desiccation	Competition

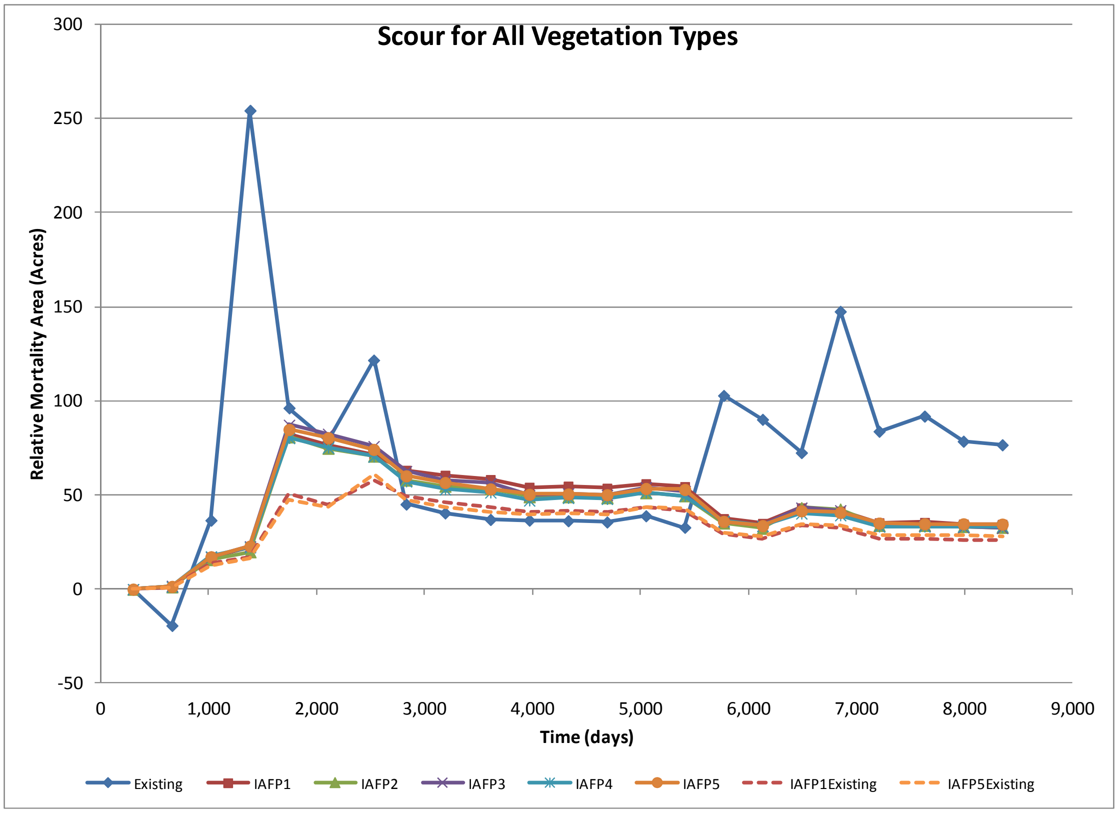

Figure 28. Relative mortality due to scour for each alternative with no desiccation in Years 1 to 5.

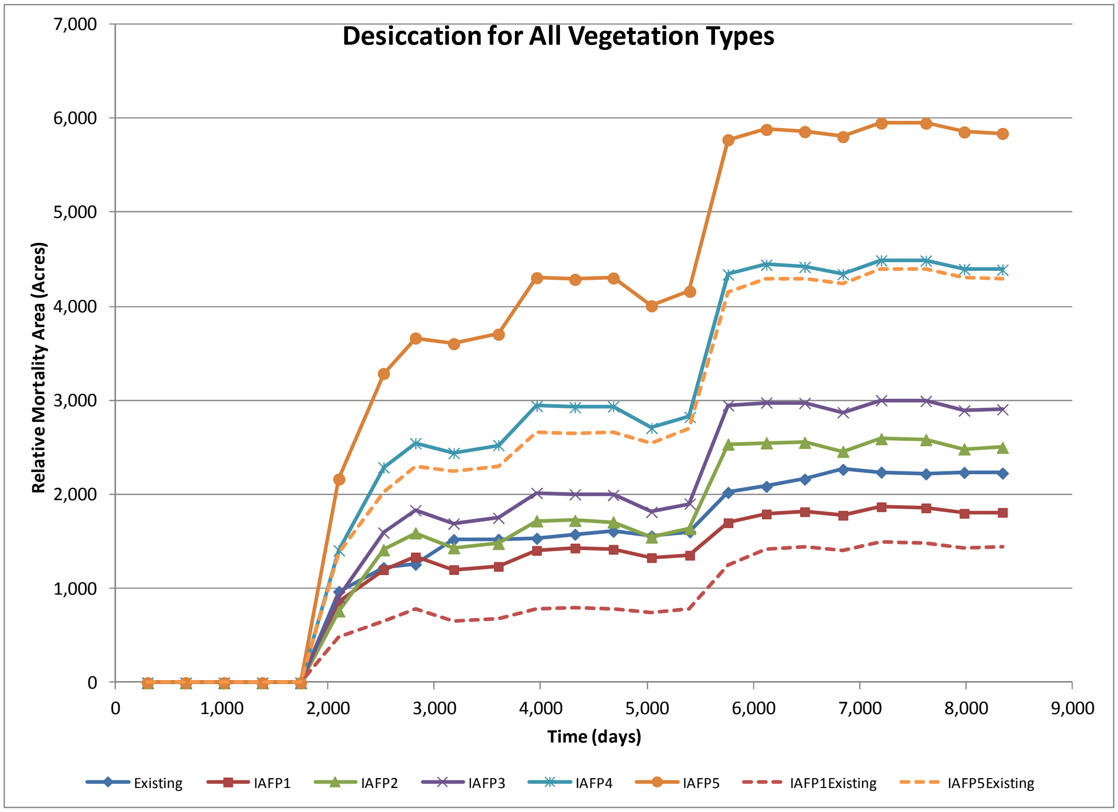

Figure 29. Relative mortality due to desiccation for each alternative with no desiccation in Years 1 to 5.

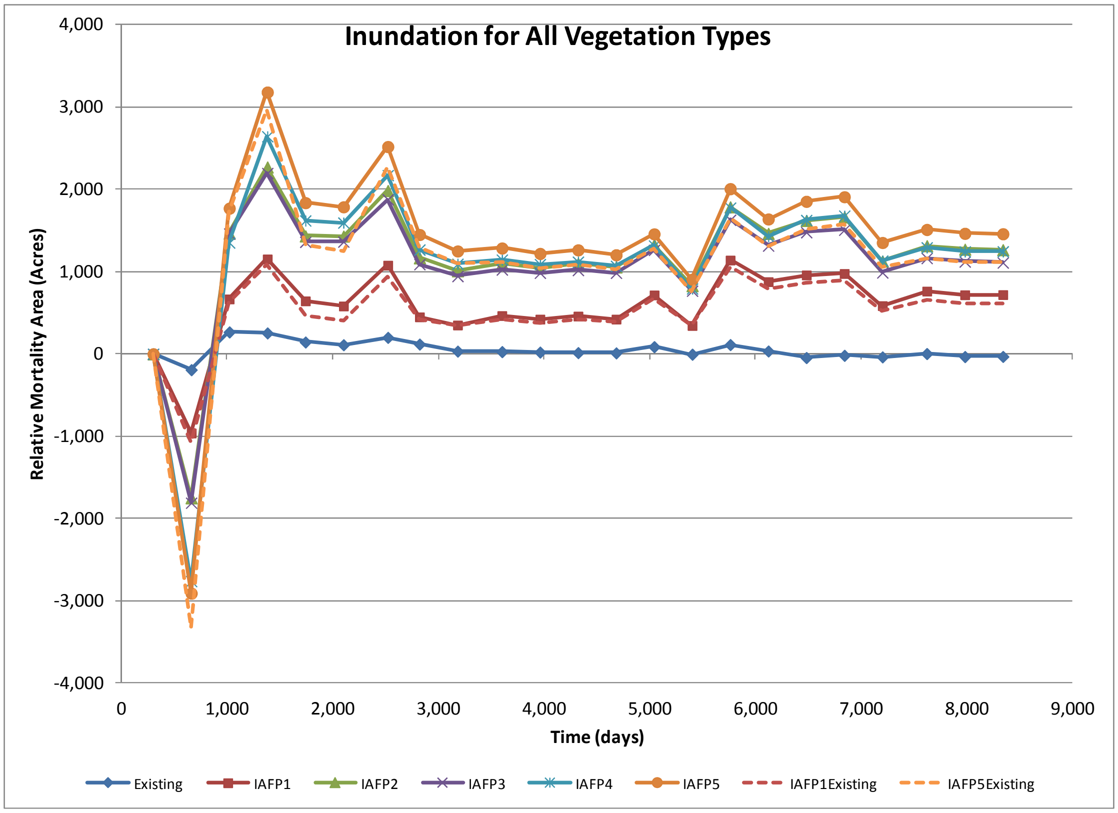

Figure 30. Relative mortality due to inundation for each alternative with no desiccation in Years 1 to 5.

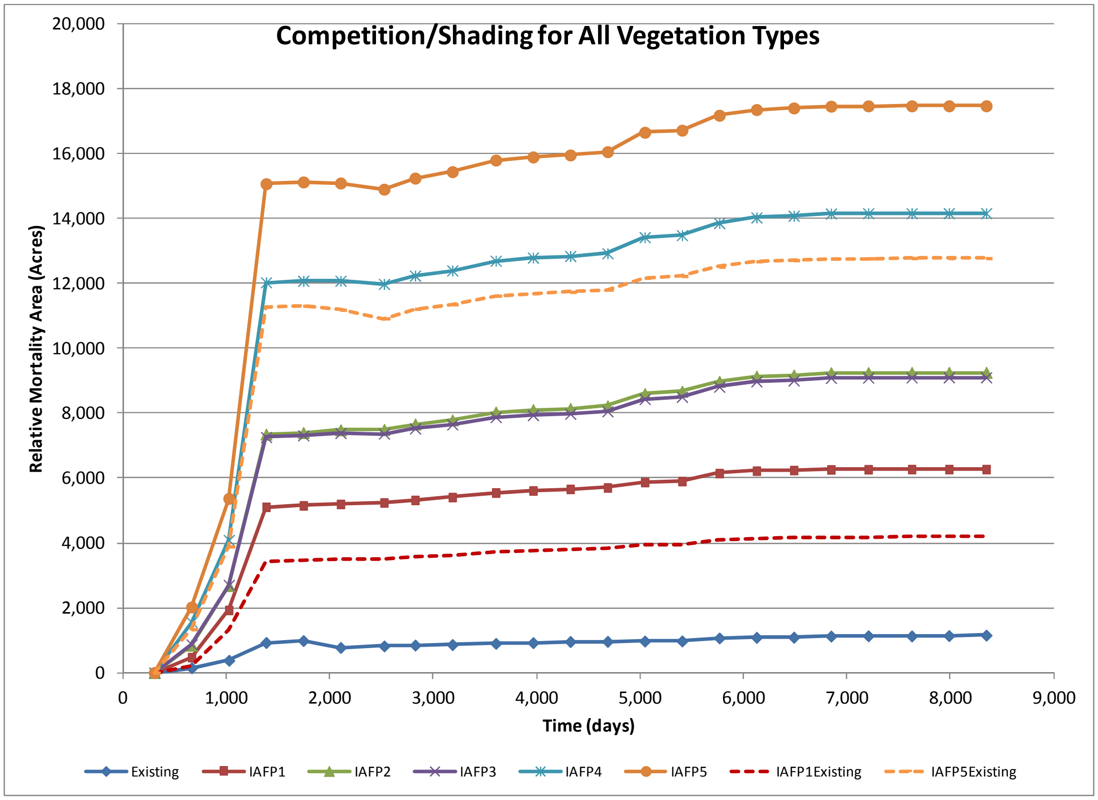

Figure 31. Relative mortality due to competition/shading for each alternative with no desiccation in Years 1 to 5.

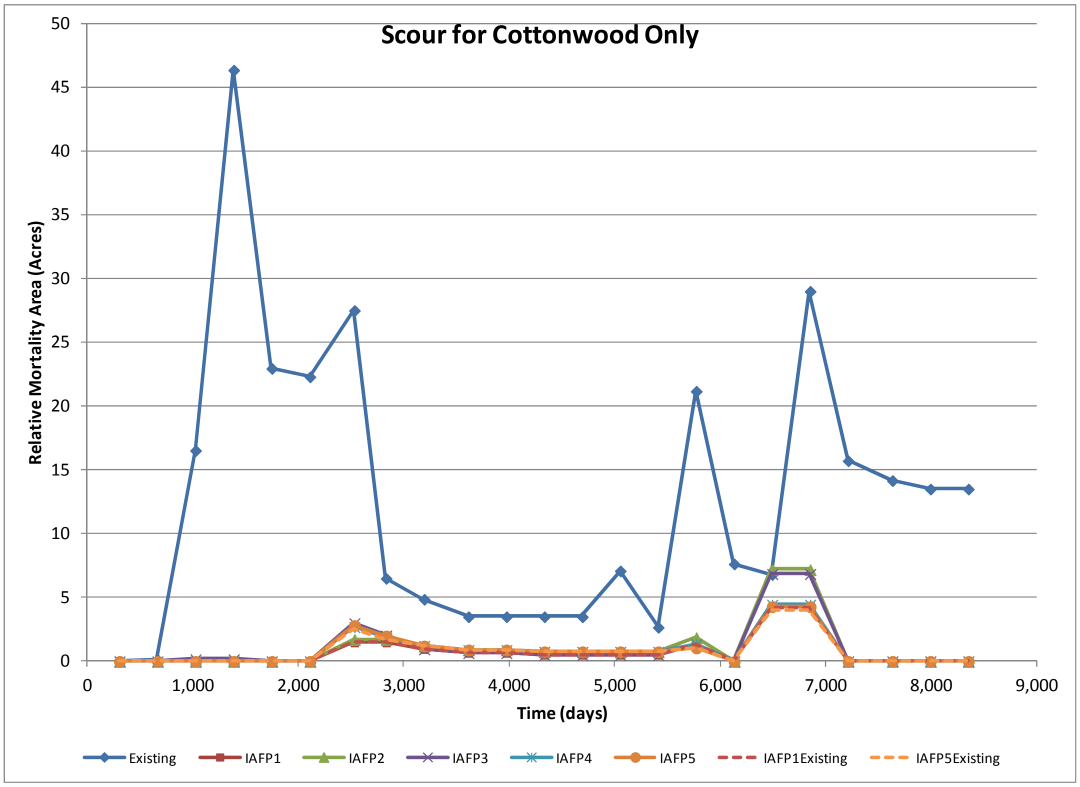

Figure 32. Relative cottonwood mortality due to scour for each alternative with no desiccation in Years 1 to 5.

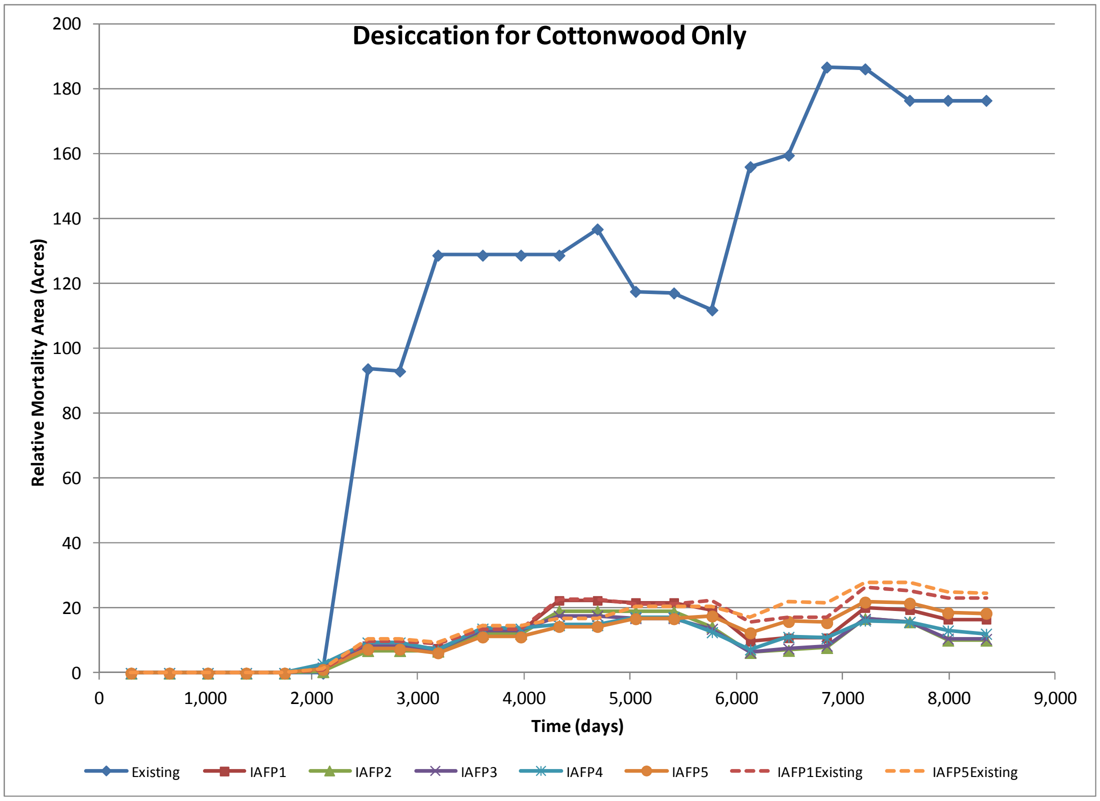

Figure 33. Relative cottonwood mortality due to desiccation for each alternative with no desiccation in Years 1 to 5.

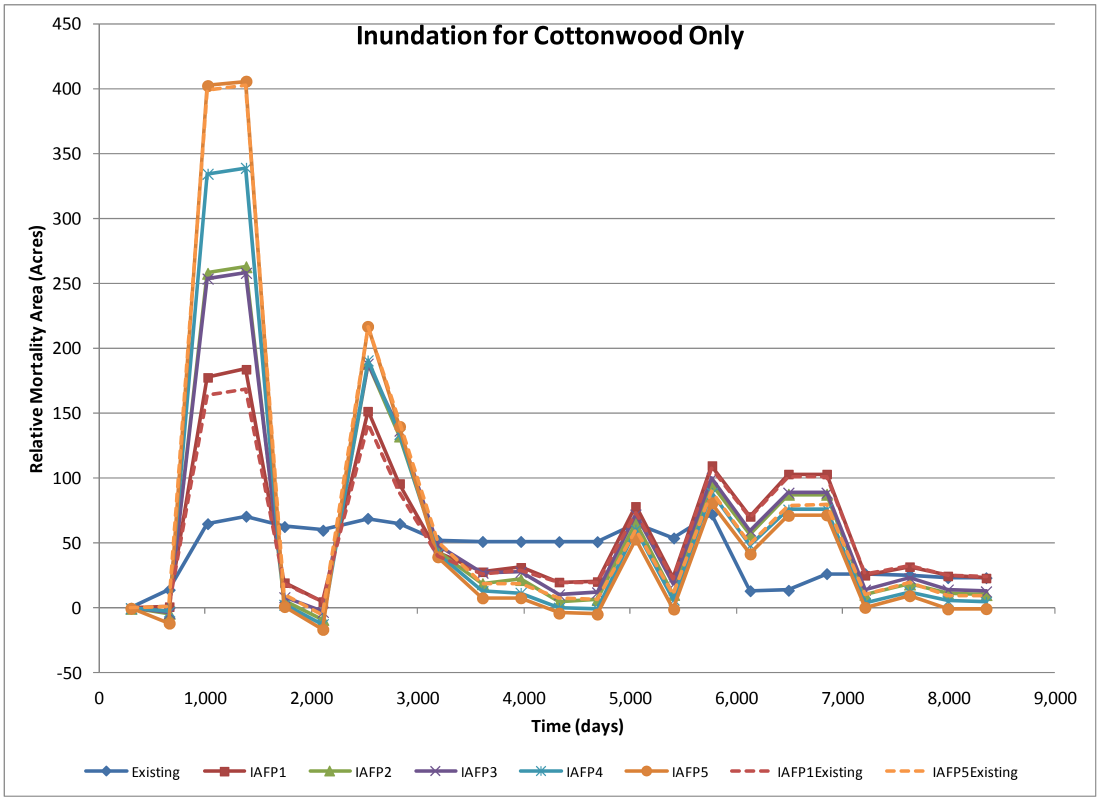

Figure 34. Relative cottonwood mortality due to inundation for each alternative with no desiccation in Years 1 to 5.

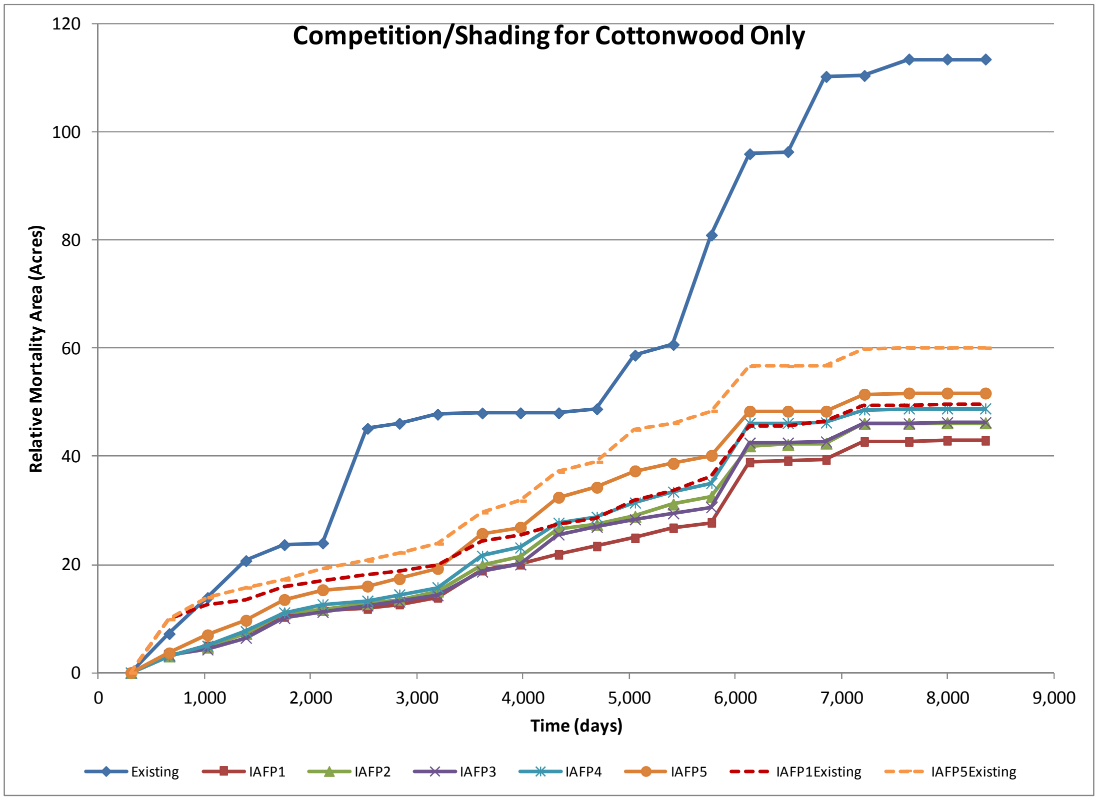

Figure 35. Relative cottonwood mortality due to competition for each alternative with no desiccation in Years 1 to 5.

6 Discussion and Conclusions

This report describes the findings of one-dimensional sediment transport and vegetation modeling efforts performed to evaluate differences between proposed alternatives within Reach 2B of the San Joaquin River. Results from this investigation can be used to inform decisions regarding the anticipated geomorphology and vegetation from five different levee setback options and the existing conditions.

Results from the sediment transport modeling indicate that deposition is expected to occur for all alternatives evaluated. As the levee width increases, the total volume of deposition increases. With increasing levee width, more area is available for sediment to deposit, and therefore, the depth of deposition along the channel tends to decrease. However, the one-dimensional model cannot simulate all the details behind channel and floodplain interactions. A large portion of the sand will likely remain in the main channel and not deposit on the floodplains, but it is difficult to estimate the proportion of floodplain sediment transport versus main channel sediment transport in a 1D model. Based upon the results, the depth of deposition will likely be very similar between the alternatives. It is expected that a large portion of the sediment entering Reach 2b will deposit with the proposed sill elevation of the Mendota Pool Bypass. We recommend that the elevation of the sill be lowered significantly. A goal of the Reach 2b design should be to balance the sediment entering the reach with the sediment exiting the reach.

The amount of sediment supplied to the reach will be influenced by the gate operations at Chowchilla Bifurcation Structure. This modeling effort assumed that the hydraulic rating curve at the bifurcation would remain similar to the existing rating curve. Modifications to the structure that result in a reduction in the backwater upstream from the structure may increase sediment supplied to Reach 2B, which would likely result in an increase in the amount of predicted deposition.

Comparison of the quantities of vegetation predicted across all alternatives suggests that a greater amount of vegetation will persist within a wider floodplain. In general, woody species tend to dominate the overall vegetated area. The amount of grasses and herbs tends to remain more consistent across the alternatives, most of which is desiccated and re-germinated on a seasonal basis. The amount of elderberry tends to increase with increasing floodplain width. Without incorporating irrigation into the model, vegetation is exposed to desiccation within the first season for almost all alternatives. As the width of the floodplain increases, the more overall area is exposed to desiccation, and therefore the area of vegetation subject to mortality by desiccation increases.

To more realistically model conditions anticipated following levee setback, irrigation was incorporated into the model by precluding desiccation as a mortality mechanism for the first five simulated years of the model. Incorporating irrigation lead to an increased successful establishment of woody vegetation types, which tended to outcompete other herbaceous and shrubby vegetation. With irrigation modeled, increased areas are predicted for Freemont Cottonwood, Gooding’s Black Willow, Oregon Ash, Buttonbush Willow and Elderberry at the end of the 23 year simulation period. However, all other vegetation alliances, including

California wildrose, salt grass, creeping rye grass, California mugwort, California Bulrush, and riparian bank herbs, are predicted to decrease with irrigation due to vegetation competition.

Simulations with the initial vegetation conditions defined by the existing conditions vegetation maps and proposed planting maps for the narrowest (IAFP1) and widest (IAFP5) levee setback alternatives evaluated the impact of the proposed planting plans on the final vegetation conditions. At the end of the 23 year simulation, minimal differences were predicted in vegetation area between results using the existing and proposed vegetation maps for both simulations with and without irrigation. When all mortality options are considered, desiccation causes early mortality of most existing and planted vegetation, thereby negating differences between existing and planted initial conditions. With desiccation excluded as a mortality option for the first 5 years, woody, shade tolerant vegetation types are predicted to become established at points where planted vegetation is already growing and tend to outcompete the planted vegetation within the first 5 years of the simulation.

Results from the vegetation modeling effort imply that without a large-scale re-vegetation effort, a mature riparian forest will eventually establish. However, the implementation of an irrigation program results in quicker establishment of a riparian forest, particularly along the floodplain. As described in section 6.1, the model likely overpredicts the total area anticipated to become vegetated due to groundwater assumptions and the ability for multiple species to occupy a single point. While planting may be necessary to accelerate the growth of vegetation along the floodplains and to prevent the establishment of non-native plants, model results indicate that hydraulic conditions are favorable to the establishment of a relatively dense riparian corridor of native species.

For all vegetation types combined, the causes of the greatest areas of mortality are desiccation when all mortality options are simulated and competition/shading when irrigation is simulated for the first 5 years. Scour has a minimal impact on overall mortality areas with and without simulated irrigation. For simulations with all mortality options modeled, increases in mortality due to inundation are correlated with high flow years and with reductions in mortality by desiccation. Cottonwood survival is most heavily influenced by desiccation and inundation. Based on the modeling methodology, after the roots of a cottonwood plant grow to the minimum water surface elevation (which is not lower than the channel bed for the alternative hydrology since Reach 2B always has some flow), that plant is no longer subject to desiccation. Compared with cottonwood results for all mortality options, the model predicts a substantial decrease in the total area experiencing mortality by desiccation with an initial period of irrigation.

6.1 Limitations and Additional Future Work

Vegetation modeling results are based upon a limited knowledge of the processes impacting vegetation. SRH-1DV remains a model that is primarily applied as a research tool. Within this modeling effort, SRH-1DV was applied to the greatest number of vegetation alliances in its history. Apart from Freemont Cottonwood, the input parameters for each vegetation alliance have not been intensively studied, and calibration of these parameters would improve the results of the model. The effort to develop the relationships for germination, growth, and mortality of each vegetation alliance is great, and additional research is needed to develop improved model input.

Areas and rates of successful vegetation establishment are predicted to be greater than what will occur following project implementation for multiple reasons. First, airborne germination basically assumes that all vegetation types have an opportunity to germinate at all points within each cross section. Second, the model assumes that multiple species can occupy a single point within a cross section until conditions exist that result in mortality of one or more vegetation types. Finally, simulated groundwater elevations within floodplain are likely higher than conditions that would occur during low flow periods and cause desiccation. The groundwater slope likely sharply increases with increasing distance from the channel due to depressed groundwater conditions from irrigation pumping.

The current groundwater module assumes that initial groundwater conditions are the same as the water surface elevation of the channel, and solves for changes in the ground water levels based upon hydraulic conductivity of the floodplain and fluctuations in the river water surface elevations. The model also assumes no ground water interaction between cross sections and no flux boundary conditions at the cross section end points. The modeled groundwater elevations likely never reach the true depth below the surface at the cross section end points, thereby allowing more vegetation to survive than is anticipated to occur. The groundwater prediction limitation has a greater influence with the wider levee setbacks IAFP4 and IAFP5, where depressed groundwater conditions will influence vegetation survival as the levee footprint widens. The model could be improved to account for slopes in groundwater elevations if known or modeled slopes were developed from well data at a few of the cross section end points over time. However, following implementation of restoration flows, the groundwater conditions may change from the current conditions.

The vegetation types modeled in this assessment were intended to cover the major types of vegetation expected to be present following implementation of a levee setback option given the current model limitations of airborne germination and lateral root spread. However, this model does not consider the influence of invasive vegetation on the predicted vegetation growth. If the restoration planting plans do not incorporate an invasive management program, vegetation along the river corridor may become dominated by invasive species, such as red sespania and arundo.

One-dimensional sediment transport and vegetation modeling is complex, and combined with a suite of geometric alternatives, offers a challenge to data management, processing, and interpretation. The results presented should be used in a relative, rather than absolute, manner to compare predicted patterns in bed elevation change and vegetation growth and survival. Absolute values can vary based upon minor adjustments to model inputs, but the general trends identified through this investigation are not expected to change. One goal of this document is to distribute the type of information available for each vegetation alliance and alternative. A large amount of information from this modeling effort was not presented within this report, such as maps of spatial distributions of each vegetation alliance for all alternatives and mortality for each vegetation alliance. Based on future need and interest, additional data processing can be accomplished for specific vegetation alliances or alternatives. Once a preferred alternative is selected, the models can be modified to represent any changes to the geometries and possibly to incorporate an irrigation component.

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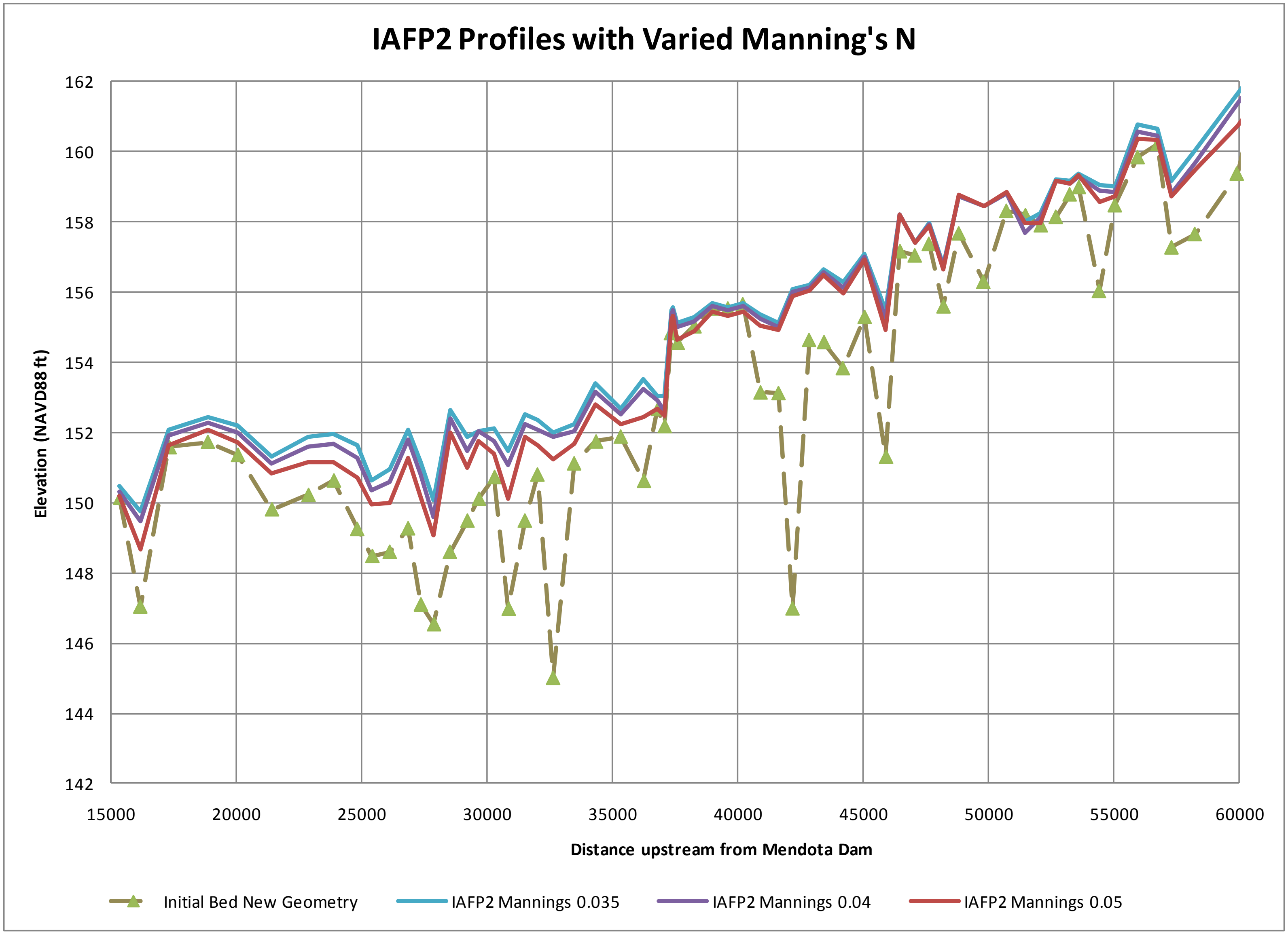
Appendix A: Results of In-Channel Manning's N Sensitivity Analysis for IAFP2



Appendix B: Vegetation Alliance Matrix for Existing Vegetation Conditions Model Runs

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

Appendix C: Vegetation Alliance Matrix for Alternative Vegetation Conditions Model Runs

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
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

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
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