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Managing Water in the West

Technical Report No. SRH-2013-01

Appraisal Revegetation Plan for Reach 4B, Eastside Bypass, and Mariposa Bypass Channel and Structural Improvements Project

San Joaquin River Restoration Program, California
Mid Pacific Region

U.S. Department of the Interior
Bureau of Reclamation

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Introduction

This document is an appraisal-level analysis of the current revegetation plan for Reach 4B of the San Joaquin River (SJR) in accordance with the San Joaquin River Restoration Program (SJRRP). The SJRRP is a comprehensive long-term effort to restore Chinook salmon fishery to the SJR from Friant Dam to the confluence with the Merced River. This analysis follows several documents regarding vegetation restoration in Reach 4B, including the Conceptual Riparian Revegetation Approach developed by Environmental Science Associates (ESA).

The Conceptual Approach outlines restoration tactics for Reach 4B over the existing alternatives for the establishment/enhancement of fish habitat and channel stabilization. The approach uses a combination of passive and active restoration to achieve these goals over a specified time period, based on site characteristics that would maximize establishment efficiency. Other procedures discussed in the approach include management of invasive vegetation, inclusion of flood-compatible agriculture, irrigation, monitoring/maintenance, and adaptive management.

Using the Conceptual Approach as a reference model for the overall implementation of the restoration plan, specific methods for preparation, installation, and maintenance of the restoration effort for support of cost estimation tables are described here.

Site Description

Reach 4B of the San Joaquin River extends from river mile 136 to 148 at the confluence with Bear Creek. This stretch of river is bordered primarily by cultivated fields. The floodplain is relatively wide and the water table is relatively shallow. This, along with generally low levels of disturbance, has created narrow riparian areas of relatively high proportions of natural habitat in Reach 4B, consisting of herbaceous vegetation, willow riparian forest, wetland/marsh, and willow scrub habitat. Relatively few invasive species are known to occupy Reach 4B.

Project Alternatives

Several alternatives for the restoration of the SJR are currently under consideration. This revegetation plan presents methodologies and material estimates for costs specific to each alternative separately, with the exception of alternatives 3A and 4A which are considered identical for vegetation restoration purposes. A total of 6 scenarios are considered with regards to vegetative restoration for fish habitat (1B, 1C, 1D, 2A1, 2B2 3/4A)

Alternative 1

All flows up to 4,500 cfs would be routed through the SJR, with median flows of approximately 170 cfs. The bypass system would only flow under conditions higher than 4,500 cfs, estimated at 15% of the time. Levee setback modifications would be required under this alternative, and have been proposed at 1,300 to 2,000 feet (Alternative 1B), 3,500 to 5,500 feet (Alternative 1C), and 5,000 to 10,000 feet (Alternative 1D) in total floodplain width.

Vegetative restoration for fish habitat will be conducted only along the SJR under this alternative.

Alternative 2

All flows up to 16,000 cfs would be routed through the bypass system. This alternative would require channel modification including a 50 foot wide low flow channel within the existing 150 foot wide channel, with the remaining 100 feet of the existing channel to be considered low floodplain. Existing levees along the bypass may be improved (Alternative 2A1) or moved to create a wider floodplain (Alternative 2A2) to accommodate for reduced flow capacity from revegetation. Up to 475 cfs would be routed down the SJR when total flows are in excess of 16,000 cfs, estimated to occur 0.05% of the time. The existing levee setback along the SJR would be preserved at 250 to 400 feet in total floodplain width (Option A), although improvements to the existing levees and road crossings will be necessary.

Vegetative restoration for fish habitat will be conducted only along the bypass system under this alternative. Site conditions under this alternative did not meet the criteria for riparian seeding; only REA and upland seeding will be conducted.

Alternative 3

Flows up to 475 cfs would be routed through the SJR; flows in excess of 475 cfs would be routed through the bypass system. The existing levee setback along the SJR would be preserved at 250 to 400 feet in total floodplain width (Option A), although improvements to the existing levees and road crossings will be necessary.

Under this alternative, vegetative restoration for fish habitat will be conducted along both the SJR and the bypass system. Species composition and planting density in the bypass system REAs will be modified in order to accommodate flood flows.

Alternative 4

Flows up to 1,500 cfs would be routed through the SJR; flows in excess of 1,500 cfs would be routed through the bypass system The existing levee setback along the SJR would be preserved at 250 to 400 feet in total floodplain width (Option A), although improvements to the existing levees and road crossings will be necessary.

The vegetative restoration process for this Alternative is considered identical to that under Alternative 3, and will be referred to as Alternatives 3/4A hereafter.

Revegetation Methodology

Restoration treatments were initially delineated by site suitability using available data on soil salinity, soil texture, and water table depth, as specified in the Conceptual Approach. Treatment areas were then refined by subtracting out estimated open water and existing riparian vegetation acreages. Acreages for restoration of the bypass system in alternative 3/4A are half that of the suitable areas within existing levees to account for flood flows. The predicted total restoration areas by treatment and alternative are described in Table 1.

Riparian Revegetation Treatment Areas

Riparian Establishment Areas

Active planting strategies and species composition are delineated by site suitability and desired function. The highest priority in the revegetation plan for the purpose of generating suitable fish habitat is active planting of Riparian Establishment Areas (REAs), as described in the Conceptual Approach. These islands of riparian vegetation supplement existing riparian stands and theoretically, with support from restoration flows, will propagate to cover the entire reach over time. Processes for delineation of REAs are described in detail in the Conceptual Approach. These areas are assumed to have the highest potential for successful establishment of riparian species based on available data and modeling.

Table 1 - Extent of riparian revegetation area, SJRRP Reach 4B.

Alternative	Revegetation Area	SJR (acres)	Bypass System (acres)
1B	REAs	1,122	-
	Riparian Seeded	722	-
	Upland Seeded	1,141	-
1C	REAs	1,982	-
	Riparian Seeded	1,635	-
	Upland Seeded	2,578	-
1D	REAs	2,313	-
	Riparian Seeded	2,540	-
	Upland Seeded	5,296	-
2A1	REAs	-	653
	Riparian Seeded	-	0
	Upland Seeded	-	1,663
2A2	REAs	-	653
	Riparian Seeded	-	0
	Upland Seeded	-	3,018
3/4A	REAs	347	653
	Riparian Seeded	609	0
	Upland Seeded	145	1,663

REAs will be planted with poles and potted transplants in order to give these priority areas a head start on the establishment and future distribution of riparian species to improve habitats. This method is more costly on a per-acre basis in comparison with traditional seeding methods, and may also incur additional costs in propagation and/or collection of planting materials. These costs may be justified by the advantage this method provides in accelerating the habitat improvement process significantly.

Riparian Seeded Areas

Other areas identified as potentially suitable for riparian recruitment in the Conceptual Approach would be seeded with grasses and forbs (referred to as riparian seeded areas). This strategy would provide some cover and exclude exotic species until riparian vegetation could establish from REAs or existing riparian stands.

Upland Seeded Areas

Upland areas not suitable for riparian species that are disturbed in the course of construction activities, present potential erosion problems, or are infested or have the potential to become infested with invasive species will also be seeded.

Species Composition and Planting Rates

Existing native riparian species composition has been described along several reaches of the SJR. However, it is unknown if altered hydrology from restoration flows would benefit similar suites of species or if different species mixes could be more efficiently restored and/or with potentially higher benefit to habitats. Furthermore, the specific composition and relative densities of vegetation along Reach 4B has not been surveyed. In order to formulate an appropriate species composition and planting rate, the known occurrence and densities of species along other reaches of the SJR were examined and weighed by their relative proximity to Reach 4B.

Other species were added to the list as potentially beneficial for restoration, either for ground-cover properties (exclusion of exotics) or for habitat benefit (per the Conceptual Approach). The species composition and planting rates provided for the REAs (Table 2), riparian seeded sites (Table 3), and upland seeding (Table 4) are therefore somewhat arbitrary, but based on best available information. Lower planting densities on a per-acre basis and flexible-stemmed or herbaceous species were selected for REAs (Table 5) and upland seeding (Table 6) in the bypass for alternative 3/4A to accommodate for flood flows.

Table 2 - Species composition, planting type, and planting rate for Riparian Establishment Areas for all alternatives except 3/4A bypass.

Common Name	Scientific Name	Planting Type	Planting Density (per acre)
Fremont cottonwood	*Populus fremontii*	Cutting	100
Goodding's willow	*Salix gooddingii*	Cutting	100
Mexican sprangletop	*Leptochloa fusca* ssp. *uninerva*	Transplant	50
Sandbar willow	*Salix exigua*	Cutting	50
Buttonbush	*Cephalanthus occidentalis*	Transplant	40
Black elderberry	*Sambucus nigra*	Transplant	30
Oregon ash	*Fraxinus latifolia*	Transplant	30
Arroyo willow	*Salix lasiolepis*	Cutting	20
Basket sedge	*Carex barbarae*	Transplant	20
Box elder	*Acer negundo*	Transplant	20
California rose	*Rosa californica*	Transplant	20
Red willow	*Salix laevigata*	Cutting	20

Table 3 - Species composition and seeding rate in pounds pure live seed (PLS) per acre for riparian seeded areas for all alternatives except 3/4A bypass.

Common Name	Scientific Name	Planting Density (pounds PLS per acre)
Mugwort	*Artemisia douglasiana*	4
Creeping wildrye	*Leymus triticoides*	5
Gumweed	*Grindelia camporum*	3

Species and planting rates designated for upland (Table 4) areas are for the purpose of soil stability and/or exclusion of exotics, and are not necessarily intended to create endemic vegetation habitats. Further site-specific studies into restoration efficiency in relation to species, planting densities, soil characteristics, and hydrology are recommended for future revisions of the restoration plan for

Reach 4B. For this appraisal-level analysis, the species and planting rates provided in Tables 2 and 3 are deemed suitable at this point for generating cost estimates.

Table 4 - Species composition and seeding rate in pounds pure live seed (PLS) per acre for upland seeded areas for all alternatives except 3/4A bypass.

Common Name	Scientific Name	Planting Density (pounds PLS per acre)
Blue wildrye	*Elymus glaucus*	5
Creeping wildrye	*Leymus triticoides*	3
Meadow barley	*Hordeum brachyantherum*	2
Purple needlegrass	*Nassella pulchra*	4

Table 5 - Species composition, planting type, and planting rate for Riparian Establishment Areas for alternative 3/4A bypass.

Common Name	Scientific Name	Planting Type	Planting Density (per acre)
Sandbar willow	*Salix exigua*	Cutting	140
Basket sedge	*Carex barbarae*	Transplant	55
California rose	*Rosa californica*	Transplant	55

Table 6 - Species composition and seeding rate in pounds pure live seed (PLS) per acre for upland seeded areas for alternative 3/4A bypass.

Common Name	Scientific Name	Planting Density (pounds PLS per acre)
Blue wildrye	*Elymus glaucus*	5
Creeping wildrye	*Leymus triticoides*	5
Saltgrass	*Distichlis spicata*	4

Sources of Plant Material

Planting materials collected within the general area of Reach 4B to be used as planting material or as nursery stock to generate the required amounts are preferred. Local genotypes are best adapted to thrive and coexist with other species within the revegetation area and will likely have the highest establishment rate. Collections should be conducted in manners that will not detriment the existing populations significantly. In some areas, the existing species populations may be insufficient for harvest and/or nursery production to the scale at which revegetation is desired. Off-site sources may be used to collect supplemental planting materials as needed and permitted. Indigenous genotypes reared by local commercial producers to generate larger amounts of planting material requires advanced planning and should be implemented some time in advance of planting (several years). Time and/or budget constraints may also make it necessary to acquire materials from commercial seed companies or nurseries. This is potentially a less costly source on a per-plant basis but may end up increasing overall costs if establishment success is low or if genotypes are aggressive and suppress natural succession in adjacent areas. It is likely that commercial seed and/or nursery stock sources for planting material may be necessary.

Improved germination of seed material should be investigated and conducted accordingly, regardless of source. This includes scarification, stratification, imbibition, etc.

Installation Methods

REAs

Species installed in REAs will need to be planted by hand, and holes or pits in which the poles/transplants are placed will need to be created by hand or mechanically. Pole plantings can be installed relatively easily with a hydrodrill, such as a Waterjet Stinger (requires a generator, pump, and means for transport). Transplants will likely need bigger openings (6 – 12 in.) dug by hand or with a mechanized auger. Several options exist but will be limited by access, site conditions, and the time window in which plantings need to occur.

Seeded sites

Seeded sites generally require some preparation before seeding and potentially incorporation after seeding depending on the existing conditions and method of seeding. Site prep can include grading for equipment access, clearing of existing vegetation, and seedbed preparation. Restoration areas on retired agricultural lands will likely require discing or other mechanical cultivation for seedbed preparation, but grading and extensive clearing should be minimal. Areas within the existing levees may require a greater degree of clearing and/or grading for large equipment access. Alternatively, seeding methods may be modified to some extent in order to produce sufficient establishment with little or no site prep in order to maintain existing vegetation. However, given the relatively large scale of the revegetation project it is likely that use of large equipment for site preparation and seeding will be the most efficient method at the expense of some existing native vegetation, which may or may not contribute toward the overall objectives.

Monitoring and Maintenance

Monitoring and maintenance will be conducted for 10 years following revegetation: Yearly for the first 6 years, then every other year up until year 10 (total of 8 monitoring years). This may ultimately be included as part of a larger overall program, but for the purpose of cost estimation they are presented here. Development of specific monitoring protocols will be based on the goals of the project. Per the currently stated goals, these would include a field-survey of successful plant establishment and coverage for both desired and invasive species, aerial or satellite imagery analysis, GIS integration, and potentially other tasks.

Monitoring costs are estimated in man-hours, but the amounts are exaggerated somewhat to include non-labor costs and are roughly based on total planted acres per Alternative. Monitoring reports should include recommendations for adaptive management strategies to be applied as data become available.

Irrigation

The REAs will be irrigated for three years to insure that the planting root systems develop into the reestablished alluvium groundwater. All other areas will be seeded immediately before the winter rain season and it's assumed these areas will become established after one season of natural precipitation.

The following discussion describes the method for estimating the irrigation demands and the conceptual design and costs for the REA irrigation systems.

The amount of irrigation water needed for a given plant is dependent upon precipitation, evapotranspiration, soil type, soil salinity, crop density, weed infestation, pest and diseases, and other crop stressors. However, since the irrigation design is at a preliminary stage, it was assumed that the water demand calculations would be based on the plant type, precipitation, and evapotranspiration (ET). It was assumed that all seed plantings would not be irrigated because if the seeding was complete at the beginning of the winter the precipitation would be sufficient for planting to become established. The only area that would need irrigation is the trees and shrubs within the REA. To establish trees and shrubs with roots that can access the water table, it is assumed a drip or micro irrigation system would be installed. Based on personal communication with NRCS and River Partners it takes about three years to ensure proper root depth for trees and shrubs to be fully established. Therefore this study assumed that the irrigation system will be designed to provide water for three years.

Crop evapotranspiration (ETc) determines when irrigation should occur and how much water should be put back into the soil. Crop evaporation is determined by

$$ET_c = K_c ET_O$$

where K_c is the crop coefficient and ET_O is reference ET measured at a local weather station . K_c not only varies by plant but also by season. Table 7 provides the monthly crop coefficients used in this study. California Irrigation Management Information System or CIMIS[1] is a weather data collection system

[1] State of California. (2009). California Irrigation Management Information Systems. California. Retrieved October 10, 2012, from http://wwwcimis.water.ca.gov/cimis/data.jsp

that has stations located through the state of California. Los Banos #56 CIMIS station is approximately 5 miles from the study site, so it was assumed its data was reasonable to use at our study site (Figure 1). Both monthly ET_O and precipitation has been recorded from 1988 to present at Los Banos (Table 8).

Table 7-Monthly crop coefficient for REA plantings.

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fremont Cottonwood	0.30	0.30	0.50	0.80	1.00	1.00	1.00	1.00	1.00	0.90	0.50	0.20
Gooding's Willow	0.30	0.30	0.50	0.80	1.00	1.00	1.00	1.00	1.00	0.90	0.50	0.20
Sandbar Willow	0.30	0.30	0.50	0.80	1.00	1.00	1.00	1.00	1.00	0.90	0.50	0.20
Arroyo Willow	0.30	0.30	0.50	0.80	1.00	1.00	1.00	1.00	1.00	0.90	0.50	0.20
California Rosa	0.30	0.30	0.60	0.85	1.15	1.15	1.15	1.15	1.15	1.00	0.60	0.20
Buttonbush	0.30	0.30	0.60	0.85	1.15	1.15	1.15	1.15	1.15	1.00	0.60	0.20
Black elderberry	0.30	0.30	0.60	0.85	1.15	1.15	1.15	1.15	1.15	1.00	0.60	0.20
Box Elder	0.30	0.30	0.5	0.80	1.00	1.00	1.00	1.00	1.00	0.90	0.50	0.20
Oregon Ash	0.30	0.30	0.5	0.80	1.00	1.00	1.00	1.00	1.00	0.90	0.50	0.20

Table 8- Monthly ET_O and precipitation at Los Banos CIMIS station (State of California, 2009).

CIMIS Station: Los Banos #56	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ETo (in)	0.97	1.67	6.40	5.54	7.29	8.21	8.62	7.44	5.52	3.77	1.82	0.93
Average Precip (in)	1.64	2.09	1.58	0.61	0.37	0.09	0.01	0.02	0.12	0.56	0.76	1.29

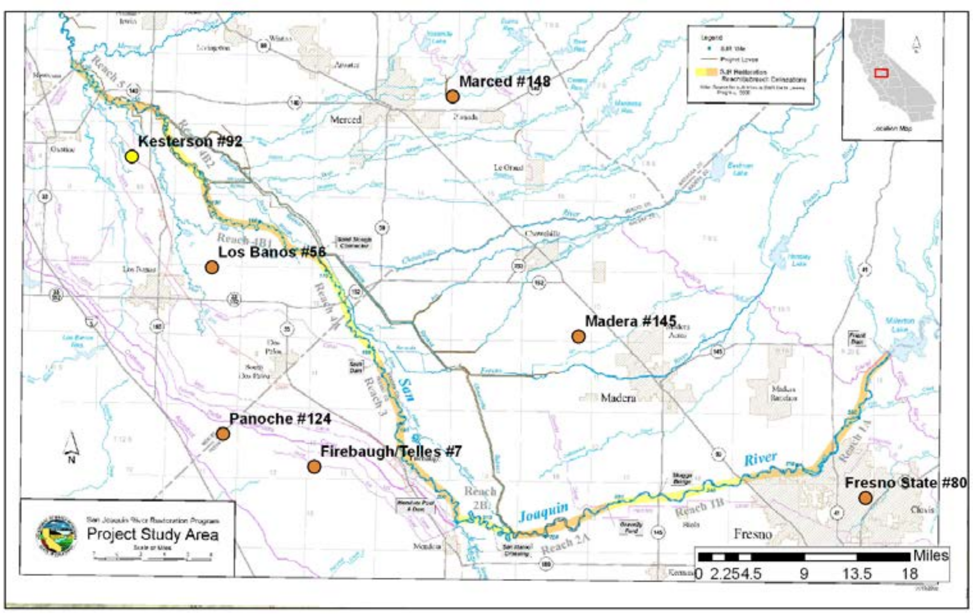

Figure 1- Location of CIMIS stations near the project location.

The monthly irrigation requirement (F_g) was calculated by

$$F_g = (ET_C - P_e)\, I_e$$

where ET_C is the crop evaporation, P_e is the effective precipitation, and I_e is the irrigation efficiency. ET_o is described in the previous paragraph. P_e is described as the portion of rainfall that can be used to meet the evapotranspiration of growing crops. The SCS method for P_e used in this study is described in the National Engineering Handbook Part 623 Chapter 2[2]. A common irrigation efficiency for drip irrigation ranges between 80 to 95 percent. This study assumed a conservative 85 percent irrigation efficiency. The F_g was calculated for each plant and then averaged to provide an irrigation requirement for the REA area. Table 9 provides the daily average water rate for the REA area.

Table 9- Irrigation requirement and rate for each month in the REA area.

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Irrigation Requirement (in)	0.00	0.00	0.90	4.80	8.60	10.20	10.80	9.30	6.80	3.70	3.70	0.00
Irrigation Rate (in/day)	0.00	0.00	0.03	0.17	0.28	0.34	0.35	0.31	0.23	0.12	0.12	0.00

To determine the total volume of water that is required, we determined how many of the REA acres were occupied by trees and shrubs. It was assumed tree and shrubs would have a planting spacing base on how large they would be as an adult (Table 11). The spacing area was multiplied by the number of plants per REA acre and then summed to give the total area of an acre occupied by plants. These calculations showed that only 59 percent of the REA area would have to be irrigated.

Table 10 - Areas that plants occupy in the REA area.

Crop	Plantings per acre	Area occupied by each plant (ft^2)	Total Area (ft^2) occupied by plants
Fremont Cottonwood	100	64	6,400
Gooding's Willow	100	90	9,000
Sandbar Willow	50	25	1,250
Arroyo Willow	20	90	1,800
California Rosa	20	9	180
Buttonbush	40	9	360
Black elderberry	30	36	1,080
Box Elder	20	90	1,800
Oregon Ash	30	130	3,900
Total	410	N/A	25,770
		Acre	**43,560**
	Percentage of REA that needs to be irrigated		**59%**

[2] NRCS Naitonal Engineering Handbook. (1993, September). *Irrigation Requirments, 623*. US Department of Agriculture.

The REA irrigation costs have been developed based on the conceptual level design information discussed below. The conceptual design is based on the following assumptions:

- Drip irrigation systems would cover 20-acre rectangular REA segments with approximate dimensions of 300 feet by 2,904 feet
- Maximum plant water demand is 0.35 inches/day and average maximum plant cover area is 60 square feet; resulting in a 20-acre demand of approximately 112,252 gallons/day or 156 gpm for 12 hours
- Water would be pumped from river and side channels into drip or micro irrigation systems for a maximum of 12 hours/day during March through November for 3 years
- Submersible pumps would be powered by portable generators
- Generator fuel requirement assumes 1 gallon/hour diesel for average of 8 hours/day
- One full time laborer would be required for operation and maintenance of each 500 acres of REA

Cost would include the initial installation of the systems and ongoing operations and maintenance (O&M) costs. The primary operations and maintenance costs include generator fuel and repairing pipe damage caused by wildlife.

Each 20-acre drip irrigation network will consist of 2,500 feet of 4-inch diameter pipe, 1,000 feet each of 3-inch and 2-inch diameter pipe, and 88,000 feet of 3/4-inch diameter pipe. The ¾-inch pipe will be polyethylene drip irrigation tubing and all other will be schedule 40 PVC. All pipe will be surface staked rather than buried. Also included with each 20-acre section will be a 4-zone controller, 8,200 drip emitters, 290 tee connections, and an unknown quantity of pressure regulators.

The 8.5 horsepower submersible supply pump is sized to provide approximately 155 gpm against 150-feet of hydraulic head. Each supply pump will be placed in a screened (#200 mesh) PVC casing (8-inch diameter and 6-feet tall) that will be anchored vertically into a concrete base in the channel bottom. The pump power supply will be a 10-kilowatt portable generator (diesel, gasoline, or natural gas fuel). A timer/controller will be included with the pump and generator package. A media tank type filter and valve with 200 gpm capacity will be located between the supply pump and pipe network (assumed less than 50-feet). It will be placed on an appropriately sized concrete pad.

Annual O&M costs will include fuel and labor costs. The estimated fuel (diesel) demand is 1,920 gallons/year. Labor tasks will include generator fueling, lubrication and miscellaneous maintenance, and repairs to the irrigation system (notably repair of pipe damage caused by coyotes, rabbits, and other animals).

Reseeding and Replanting

Maintenance activities for the vegetation revegetation effort would follow up with appropriate re-seeding/planting, invasive plant management, and other activities as situations arise (e.g. installation of erosion mitigation materials). Actions will be adapted per the monitoring results and amendments to goals on a regular basis. Cost estimates are based on 1 year post restoration estimated at 40% establishment failure rate and 10% failure over the next 4 consecutive years.

Invasive Vegetation Management

The extent of invasive vegetation within Reach 4B is considered low, but this determination is based upon limited data. Ancillary observations, reconnaissance surveys, and aerial interpretation have identified sporadic populations of salt cedar (*Tamarix* spp.), pepperweed (*Lepidium latifolium*), and red sesbania (*Sesbania punicea*) mapped in the Eastside Bypass in 2008. However, terrestrial invasive plants were not observed to any significant degree by DWR. In addition, initial biological surveys of a parcel along the San Joaquin River in Reach 4B, which was conducted by ESA biologists in May 2012, noted very limited invasive plant species. While more detailed studies are needed to determine the extent of invasive plant infestations, existing data and ancillary observations indicate that Reach 4B may have relatively low populations of invasive plant species.

Invasive plant management will be necessary to support the development of REAs, to prevent the establishment of large infestations that will inhibit riparian recruitment, and to prevent infestations in downstream areas (e.g., wildlife refuges). Invasive species typically out-compete native species and the establishment of infestations can result in the alteration of ecosystem processes such as fire frequency, erosion and sedimentation rates, and hydrologic regimes. As previously mentioned, large stands of invasive vegetation are not known to occur in Reach 4B, but this may be an artifact of limited access. However, it appears reasonable that with the lack of active flow and flooding along Reach 4B1 and the operational maintenance along the bypass system, large infestations may not currently occur. However, with the addition of several hundred to thousands of acres that may experience annual flooding and disturbance, the opportunity for invasive species colonization increases substantially.
Invasive plant management can begin prior to the implementation of other restoration actions by deep disking and application of sterile grasses mixed with other native grasses and forbs especially in areas currently occupied by agricultural lands.

Post-implementation monitoring and maintenance should include invasive pest plant management. Invasive species known to occur in the general vicinity are the most likely to establish including perennial pepperweed, giant reed, red sesbania, Chinese tallow (*Sapium sebiferum*), salt cedar, tree of heaven (*Ailanthus altissima*), and yellow starthistle (*Centaurea solstitialis*).

Invasive pest management is estimated to be required on 30% of the restoration areas in year 1 and on 10% of the restoration areas in years 2 through 10. Appraisal-level costs are based on a combination of mechanical and chemical management for year one at approximately 75% of the estimated treated areas for each method (50% of the estimated treated areas are assumed to require both mechanical and chemical treatments). Years 2 through 5 are assumed to be follow-up spot treatments with herbicides only. Herbicide treatments are estimated at 2 lbs. active ingredient per acre, although actual applications may be spray to wet based on a percent concentration. This is a general guideline for cost estimation purposes and does not indicate the specific herbicide product.

Cover cropping is another strategy for mitigation of invasive weeds. This method is currently under consideration and may be presented in more detail in future version of the vegetation management plan. For the purpose of the appraisal-level cost estimates, they are not presented here.