Appendix E. Invasive Plant Management Plan

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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1.0 Introduction

The California Department of Water Resources (DWR) developed this Invasive Plant Management Plan (or Plan) as part of the Conservation Strategy of the Central Valley Flood Protection Plan (CVFPP). The Conservation Strategy tiers from the Conservation Framework, which was an integral part of the State's preferred SSIA, identified in the 2012 CVFPP. The Conservation Strategy describes how to make progress toward meeting the environmental objectives of the Central Valley Flood Protection Act of 2008 (Act) and related legislation throughout the flood management system in the Systemwide Planning Area (SPA). The SPA comprises five Conservation Planning Areas (CPAs) in California's Central Valley: the Feather River CPA, the Upper and Lower Sacramento River CPAs, and the Upper and Lower San Joaquin River CPAs (Figure 1-1). The SSIA includes developing and implementing multipurpose projects, and this Plan will guide the invasive plant management approaches undertaken as part of these projects.

The Conservation Strategy recognizes invasive plants as a primary stressor on the habitats, species, and ecosystem processes that are the focus of conservation planning. As of 2014, at least 68 plant species considered to be invasive by the California Invasive Plant Council (Cal-IPC) potentially occur in upland, riparian, wetland, and open water habitats in the Sacramento and San Joaquin Valleys (Cal-IPC 2013a). Many are widespread and abundant in vegetation managed as part of State Plan of Flood Control (SPFC) operation and maintenance (O&M). These species degrade riverine and floodplain habitats by altering ecosystem processes and displacing native plants. In addition, some of these invasive species, such as tamarisk (or saltcedar) (*Tamarix* spp.), giant reed (*Arundo donax*), and red sesbania (*Sesbania punicea*), are stressors that increase the cost and difficulty of operating and maintaining the SPFC.

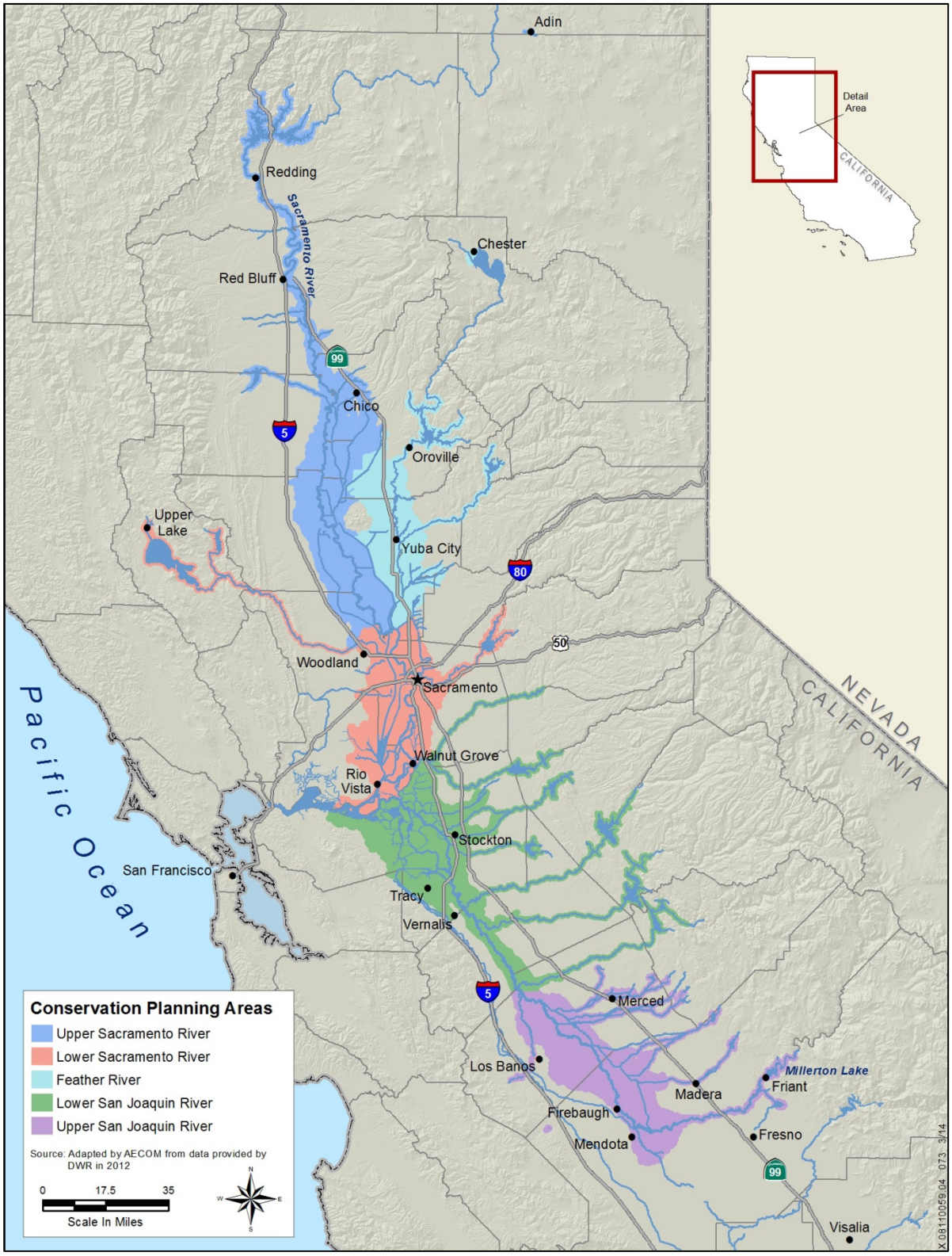
These species can alter hydrology and sedimentation rates in riparian and aquatic systems (Cal-IPC 2011a) and can degrade flood system effectiveness. Importantly, recent studies have shown that certain invasive plant species have greater impacts on channel conveyance than native species adapted to the same areas (Stone et al. 2013). Dense stands of certain invasive species can alter channel morphology by retaining sediments and increasing the hydraulic roughness of the channel, which restricts flows and reduces flood conveyance (Bossard et al. 2000). For example, saltcedar traps and stabilizes alluvial sediments, narrowing stream channels and contributing to more frequent flooding (Bossard et al. 2000). Species with shallow root systems, such as giant reed and red sesbania, promote bank undercutting, collapse, and erosion (Bossard et al. 2000; Cal-IPC 2011b). Invasive terrestrial plants can reduce groundwater availability by transpiring large amounts of water, leaving less water available for native riparian vegetation (Bossard et al. 2000).

Invasive plants can also reduce the integrity of native riparian plant communities by outcompeting native plants, reducing habitat quality and food supply for wildlife, and interfering with wildlife management (Bossard et al. 2000; Cal-IPC 2011a). Nationally, invasive species are the second greatest threat to endangered species, after habitat destruction (Cal-IPC 2011a), and

approximately 42 percent of the species listed as threatened or endangered by the federal Endangered Species Act (ESA) are at risk primarily because of the adverse effects of invasive species (Pimentel et al. 2005). Aquatic invasive plants can degrade aquatic habitat by reducing areas of open water used by waterfowl for resting, by shading out algae in the water column and thereby diminishing the basis of the aquatic food web, and by displacing native aquatic plants that are used for food or shelter by wildlife (Bossard et al. 2000). In addition, invasive aquatic plants often form dense mats that kill fish by lowering pH, dissolved oxygen, and light levels and by increasing carbon dioxide and turbidity (Bossard et al. 2000).

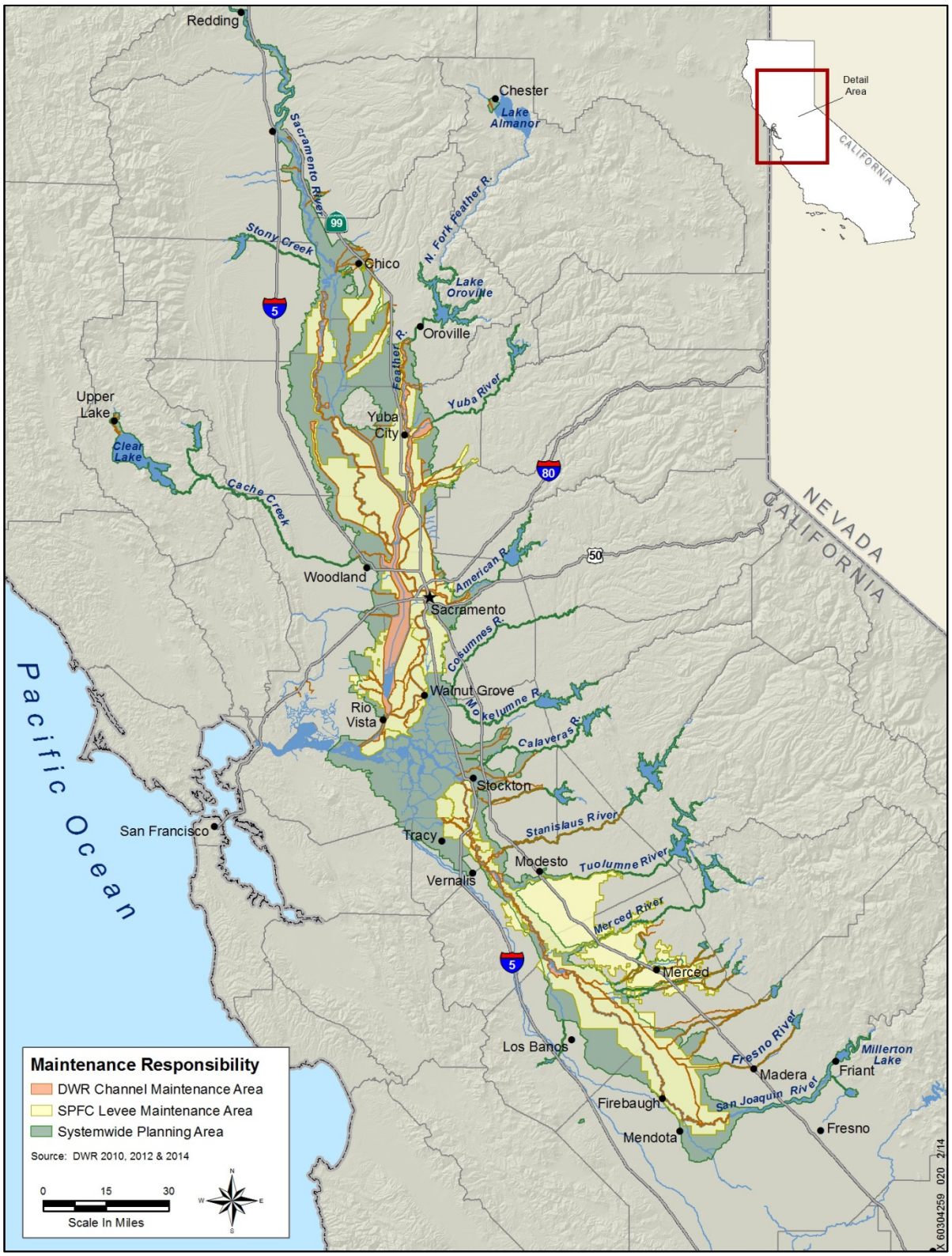
Because of these adverse effects and the threats they pose to achieving the goals of the Conservation Strategy, this Plan is driven by the following vision: *to reduce the impact of invasive plants as a stressor on conservation targets and as an impediment to the operation and maintenance of the State Plan of Flood Control*.

This Plan seeks to increase DWR institutional support for an SPA-wide invasive plant treatment program, and facilitate consistent invasive vegetation treatment actions by levee maintaining agencies and other partners such as the California Department of Fish and Wildlife and the United States Fish and Wildlife Service who are also conducting invasive plant control efforts. SPA-wide implementation of invasive plant treatment faces challenges that include ever-decreasing O&M budgets, regulatory requirements to protect sensitive resources, and the need to meet multiple and sometimes conflicting management objectives. This Plan recognizes those challenges, but it is beyond the scope of a single plan to resolve them all. Instead, the Plan provides first steps toward addressing the challenges through a series of goals, objectives, and implementation actions. The Plan includes measurable objectives for the treatment of four target species (Initial Priority Species) in Channel Maintenance Areas within the SPA (Channel Maintenance Areas; Figure 1-2) and identified in the DWR State Plan of Flood Control Descriptive Document (DWR 2010). It is the intent of this Plan to increase the resources available for invasive plant treatment actions by fashioning an approach that meets multiple needs and, therefore, may take advantage of funding sources not previously available for these actions.



Source: AECOM 2013.

Figure 1-1. CVFPP Systemwide Planning Area and Conservation Planning Areas



Sources: DWR 2010, DWR 2012, and DWR 2014.

Figure 1-2. Channel Maintenance Areas

This Plan identifies actions for DWR, levee maintaining agencies, and its partners, who share O&M duties in Channel Maintenance Areas, to address channel capacity limitations to reduce flood risk and to maintain environmental stewardship of these lands. These actions are guided by new baseline vegetation data, applied for the first time across the entire SPA. These same data guide the implementation actions proposed for partners that are outside of areas where DWR may have the ability to address them. This Plan provides resource and reference materials to facilitate consistent actions in those areas by DWR's partners.

1.1 Purpose for Invasive Plant Management Plan

The lands on which invasive plants occur in the SPA are managed by a variety of entities, including DWR, Local Maintaining Agencies (LMAs) (i.e., levee districts and reclamation districts), the California Department of Fish and Wildlife (CDFW), the U.S. Fish and Wildlife Service (USFWS), and private landowners. The diverse entities involved in invasive plant management in the SPA vary in their authorities and responsibilities making coordination between managing entities a challenge. The ability to implement the most effective SPA-wide invasive plant treatment methods is also hindered by a lack of common baseline information, shared priorities, and decreasing O&M resources. Regional factors such as upstream source populations may not be fully considered or addressed, and information characterizing the distribution of invasive plants within the SPA, which could be used to prioritize specific infestations for treatment, is lacking. A standardized SPA-wide approach to invasive plant management could improve collaboration among all maintenance entities in the SPA, and could include prioritizing the infestations that pose a threat to Conservation Strategy targets, in addition to focusing on SPFC O&M needs. It is not the intent of this Plan to propose new actions or place additional O&M burden on DWR or its partners. On the contrary, it is the intent of this Plan to increase the resources available for invasive plant treatment actions by fashioning an approach that meets multiple needs to take advantage of funding sources not previously available for these actions.

This Plan offers an SPA-wide, coordinated approach to achieving economies of scale and better treatment efficacy of invasive plant management in the SPA by providing the following:

- An inventory of invasive plants in the SPA, using the best information currently available from third parties, supplemented by information collected by DWR, to assist in preparation of the Conservation Strategy

- Identification of target invasive plant species that pose the greatest threat to the ecosystem processes, habitats, and species emphasized by the Conservation Strategy as well as negatively affecting SPFC O&M

- A method for assessing and prioritizing invasive plant populations for treatment

- Guidelines for consistent application of invasive plant treatment techniques (e.g., mechanical treatment, herbicides, grazing, and prescribed burning)

- Guidelines for restoring habitats using native species that can deter invasive plants from recolonizing treatment sites
- A proposed process to update the Plan as better information characterizing the distribution of invasive species in the SPA and potential methods to treat and eradicate these species becomes available
- Identification of other entities managing invasive plants in the SPA and throughout California, to facilitate coordination between DWR and these organizations

1.2 Legislative Direction

Legislative direction for the Conservation Strategy, of which this Plan is a part, is based on the ecological and flood management objectives of the Central Valley Flood Protection Act of 2008. Administrative direction comes from the ecosystem goals of the CVFPP and the FloodSAFE California initiative, as well as the DWR Environmental Stewardship Policy (DWR 2009). The 27 February 2009, *California Central Valley Flood System Improvement Framework* developed by the California Levees Roundtable also provides some interagency direction.

The Central Valley Flood Protection Act (California Water Code, Section 9616[a]) includes three environmental objectives:

- Promote natural dynamic hydrologic and geomorphic processes.
- Increase and improve the quantity, diversity, and connectivity of riparian, wetland, floodplain, and shaded riverine aquatic habitats, including the agricultural and ecological values of these lands.
- Promote the recovery and stability of native species populations and overall biotic community diversity.

In support of this legislation, the CVFPP sets forth a strategy to improve public safety, ecosystem functions, and economic sustainability with multi-benefit projects to the extent feasible.

In addition to the directives of the Central Valley Flood Protection Act and related CVFPP goals, a primary driving element in the development of this strategy is the DWR Environmental Stewardship Policy. Environmental stewardship is a concept of and commitment to responsibly manage and protect natural resources (water, air, land, plants, and animals) and ecosystems in a sustainable manner that ensures that they are available for future generations.

The *California Central Valley Flood System Improvement Framework* developed by the California Levees Roundtable (2009) calls for interagency direction for the development of a conservation strategy for the Central Valley flood system with an approach comparable to the

CVFPP Conservation Strategy. The California Levees Roundtable was a partnership of federal, State, and local agencies, and the framework document was developed to address vegetation issues affecting the State/federal levee system in the Central Valley. Among the elements of this framework are recommendations to develop and implement a "Multi-Species and Floodplain Conservation Strategy" and habitat enhancements as part of multi-benefit projects. Habitat enhancements implicitly include the management of invasive plants, which are a recognized stressor on the ecosystem processes, habitats, and species of plants and wildlife that are the foci of the Conservation Strategy.

1.3 Relationship to Conservation Strategy

This Plan supports the Conservation Strategy by describing goals for invasive plant and vegetation management, measurable objectives related to the goals, management actions that could be implemented to meet the goals, and indicators of success that could be monitored to indicate that the goals have been achieved or that changes in management actions are required. Furthermore, this Plan facilitates collaboration within DWR on the assessment, prioritization, and treatment of invasive plants in the SPA, as well as informing restoration actions that minimize the probability of future invasive plant establishment.

Although this Plan focuses on actions that could to be implemented by DWR within its Channel Maintenance Areas to further Conservation Strategy measurable objectives, it can be adopted by LMAs or used as a guidance document by other entities managing invasive plants in the SPA. In addition, the Plan describes the regional context within which DWR manages invasive plants, to identify the potential relationships among DWR's efforts and similar efforts being implemented outside the SPA. Although beyond the geographic scope of the Conservation Strategy, entities outside the SPA can positively contribute to the attainment of Conservation Strategy measurable objectives for invasive plants by reducing upstream source populations of these plants.

1.4 Document Organization

The remainder of this Plan is organized into the following seven sections:

- **Current DWR Practices:** This section describes, by way of introduction, current practices for DWR's SPFC O&M activities, including vegetation management; funding for these activities; and current DWR O&M practices related to invasive plant management.

- **Invasive Plant Management Approach:** This section describes DWR's proposed approach for managing invasive plants within the SPA; it includes a description of overall goals as well as objectives and implementation measures that will contribute to the goals.

- **Target Invasive Plant Species:** This section describes invasive plant species potentially found in the SPA, the processes used to select target species for this Plan, and the known distributions of these target species.

- **Invasive Plant Treatment:** This section describes general methods for prioritizing invasive plant infestations for treatment. It also summarizes relevant invasive plant treatment permitting requirements, describes recommended invasive plant management Best Management Practices (BMPs), and presents a variety of techniques that can be used by DWR to manage invasive plants. Finally, it describes guidelines for revegetating invasive plant treatment sites to minimize the potential for future infestation.

- **Monitoring and Adaptive Management:** This section describes monitoring methods that could be used to detect new infestations of invasive plants and to assess how well prior invasive plant treatment efforts have met defined goals and objectives. This section also describes measures of success and adaptive management techniques that could be implemented when monitoring indicates that goals and objectives have not been met.

- **External Partnerships and Funding Programs:** This section identifies potential collaborators and funding programs that DWR could participate in or provide support to in an effort to maximize the effectiveness of its invasive plant treatment efforts.

- **References:** This section lists the literature cited in the Plan.

2.0 Current DWR Practices

To develop a new SPA-wide approach to invasive plant management, current practices upon which the new approach may build are described first. Invasive plant management by DWR within the SPA is typically conducted as part of DWR's SPFC O&M activities when a particular infestation is in direct conflict with O&M. This section describes DWR's practices in maintaining the SPFC, the manuals and measures that guide how this maintenance is carried out, maintenance funding sources, and current vegetation management practices.

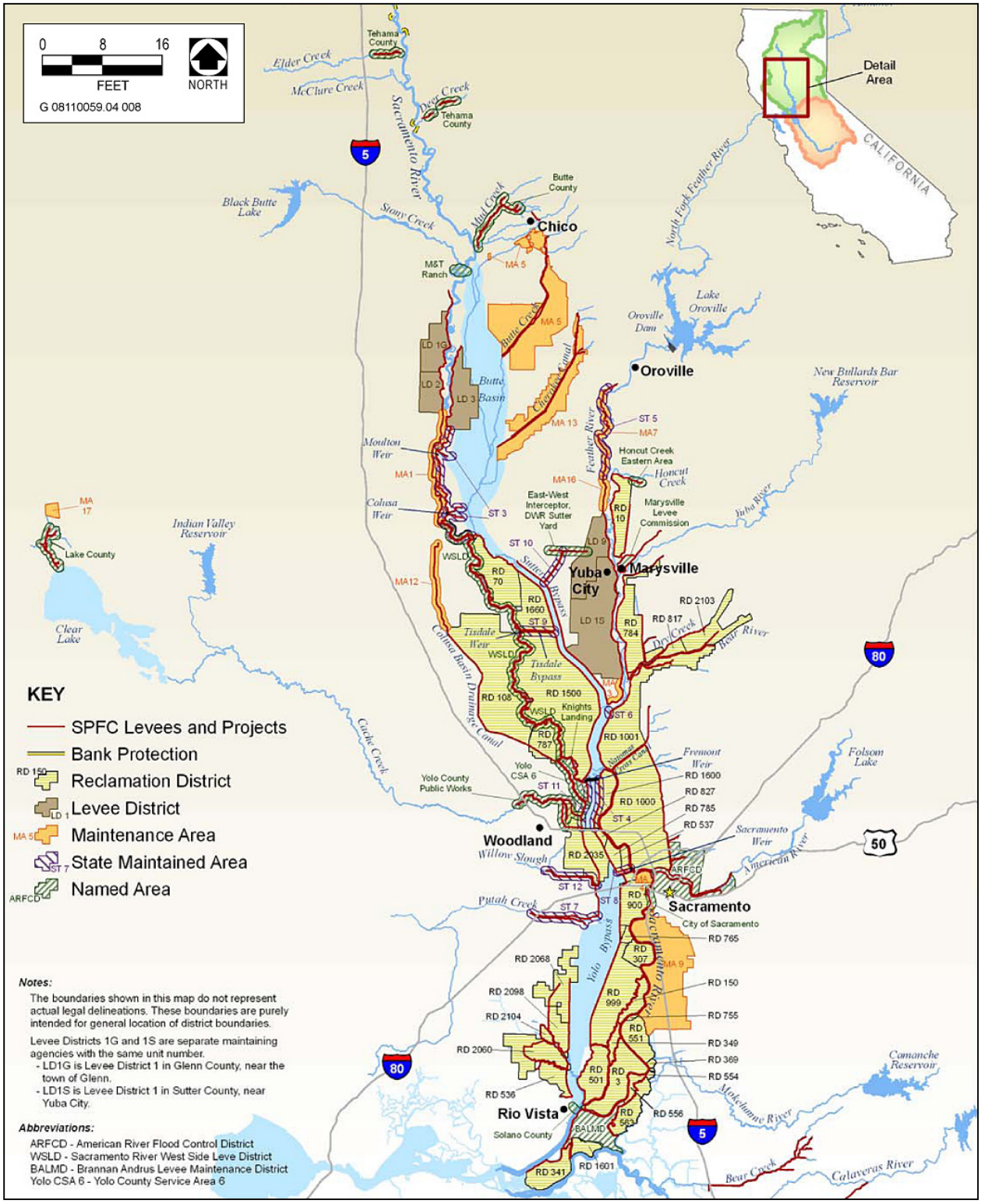
2.1 State Plan of Flood Control Operation and Maintenance

Pursuant to Title 33 of the Code of Federal Regulations, the U.S. Army Corps of Engineers (USACE) established O&M rules, regulations, and standards for flood control. These rules, regulations, and standards apply to SPFC projects, described in more detail in the SPFC Descriptive Document (DWR 2010). Title 23 of the California Code of Regulations (California Water Code) incorporates these rules, regulations, and standards, requiring the Central Valley Flood Protection Board (CVFPB) and DWR to carry them out. DWR performs inspections of the SPFC facilities and reports these findings to the CVFPB. In turn, the CVFPB provides assurances to the federal government that maintenance requirements are being fulfilled.

For maintenance purposes, the SPFC is divided into 118 different units. The management of these units is split between DWR and 81 different LMAs (Figures 2-1 and 2-2). The LMAs are primarily levee districts and reclamation districts, but they also include a variety of cities, counties, and other public agencies and municipalities.

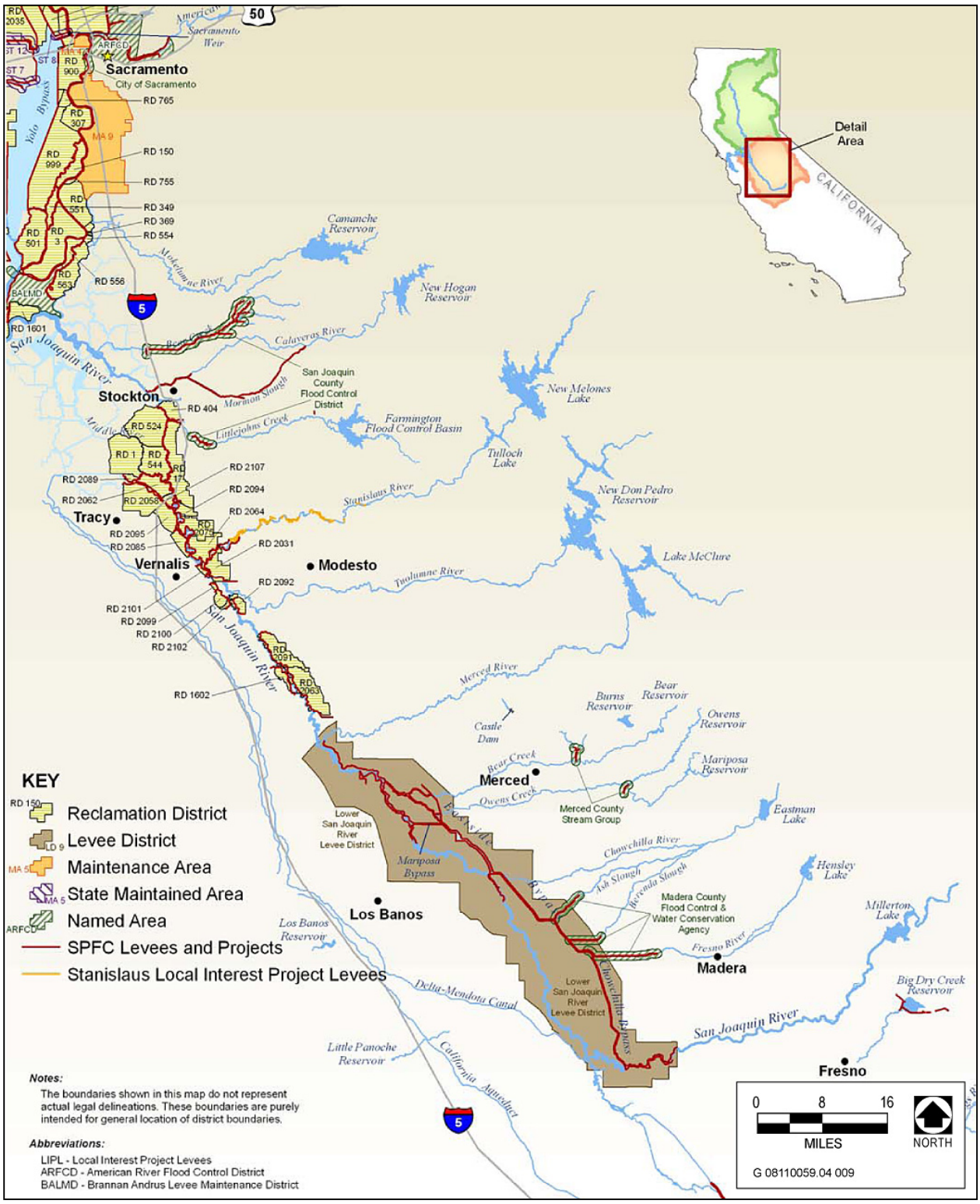
O&M requirements for most SPFC facilities are identified in two standard O&M manuals: the Standard O&M Manual for the Sacramento River Flood Control Project and the Standard O&M Manual for the Lower San Joaquin River Levees, Lower San Joaquin River and Tributaries Project. These manuals are supplemented by 118 individual project (i.e., unit-specific) O&M manuals, which can cover more than one facility. The O&M requirements for floodways (floodplain and channel areas within the bypass system) in much of the Sacramento River Basin are described in the unit-specific O&M manuals that supplement the Standard O&M Manual for the Sacramento River Flood Control Project. These manuals describe the operations and inspection responsibilities of each agency during high-water events, as well as the agencies' responsibilities for keeping the facilities in working order.

This Plan is most focused on invasive plant treatments conducted in channel areas. Because maintenance duties in these channel areas vary between DWR and LMAs within individual O&M units, this Plan refers to invasive plant treatments within the "Channel Maintenance Areas" as mapped for SPFC Descriptive Document (DWR 2010). Further planning is needed to identify and prioritize case-by-case treatments and to determine which entity or entities may implement those specific treatments.



Source: SPFC Descriptive Document, DWR 2010.

Figure 2-1. SPA Maintenance Designations, Sacramento River Region



Source: SPFC Descriptive Document, DWR 2010.

Figure 2-2. SPA Maintenance Designations, San Joaquin River Region

2.1.1 Standard Operation and Maintenance Manuals

The Standard O&M Manual for the Sacramento River Flood Control Project and the Standard O&M Manual for the Lower San Joaquin River Levees, Lower San Joaquin River and Tributaries Project were prepared by USACE in 1955 and 1959, respectively. They provide general rules and information for O&M that apply to all flood control facilities in each project area. The standard manuals conform to Title 33 of the Code of Federal Regulations, Section 208.10, which prescribes regulations that govern the maintenance and operation of flood control facilities. Examples of general rules in the standard manuals include conducting O&M for maximum benefits and in accordance with USACE prescribed regulations, maintaining a reserve supply of materials for flood emergencies, allowing no encroachments that adversely affect O&M, allowing no improvements without USACE approval, submitting a semiannual report, allowing USACE access to facilities at all times, conducting maintenance and repairs as deemed necessary by USACE, and providing coordination during flood periods. The standard manuals provide checklists for inspections; thresholds to trigger maintenance; and guidelines for maintenance efforts, including revetment work, vegetation management (which implicitly includes management of invasive plants), levee repair, burrowing animal control, and maintenance of access roads.

2.1.2 Unit-Specific Operation and Maintenance Manuals

The unit-specific O&M manuals were prepared by USACE when each unit was completed. Each manual provides details on the project authorization, flood protection features in each unit, assurances of cooperation provided by the nonfederal sponsor (usually CVFPB), supplemental O&M methods specific to that unit, and additional inspection and reporting requirements. The unit-specific O&M manuals sometimes also include as-built drawings; information on repairs or upgrades completed after construction of the original facilities; and details of ancillary features that are part of each unit, such as bridges, culverts and other drainage facilities, and other hydrographic features, such as gauges necessary for operation.

2.1.3 Superintendent's Guide

DWR produced a guide for superintendents (Superintendent's Guide) that provides another resource to explain SPFC O&M (DWR 2013). The guide provides detailed recommendations and requirements for safety measures, including pesticide application; inspections and reporting; vegetation management; levee, channel, and structure maintenance; encroachments; and emergency response. The Superintendent's Guide stresses the importance of balancing vegetation management to preserve the environment with protecting the integrity of flood control structures.

Because the Superintendent's Guide is primarily focused on vegetation management to maintain visibility for levee inspections, floodwater conveyance, and overall integrity of the SPFC, it does not specifically discuss invasive plant management as a tool for enhancing ecosystem functions. However, invasive plant management is an implicit component of vegetation management when invasive plants adversely affect levee inspections or floodwater conveyance, or otherwise threaten the integrity of the SPFC; thus, the Superintendent's Guide can be used to understand

DWR practices for invasive plant management within the context of overall levee vegetation management.

2.2 State Plan of Flood Control Operations and Maintenance Designations

Maintenance duties are shared between DWR and LMAs, and these duties vary between the Sacramento River and San Joaquin River Basins. In the San Joaquin River Basin, LMAs conduct both levee and channel/floodplain maintenance. However, in the Sacramento River Basin, levee and channel/floodplain maintenance is split between DWR and the LMAs.

For units in the Sacramento River Basin managed by LMAs, the superintendents, under the direction of the agency board of directors or board of trustees, conduct O&M of levees within their particular flood control unit. In these areas, DWR maintains channel/floodplain areas.

In areas of the Sacramento River Basin not managed by LMAs, DWR conducts maintenance both for the levees and for the channel/floodplain; these management units are called Maintenance Areas (MAs). In addition, CVFPB has the authority to form MAs if LMAs are unable to maintain the levees in their areas to State and federal standards. Maintenance responsibilities for MAs are divided between the two DWR Maintenance Yards.

Maintenance needs are identified through the inspection process. If inspections identify units where maintenance has been inadequate, CVFPB has the authority to designate the unit as an MA (California Water Code, Section 12878) and to assign maintenance responsibilities for the MA to DWR.

2.2.1 DWR Inspections

DWR inspects the SPFC facilities for compliance with federal, State, and local maintenance requirements and reports the findings of these inspections to CVFPB. It conducts two comprehensive levee inspections (spring and fall) and one channel and structure inspection (summer) each year. Representatives of DWR and the LMAs also patrol and inspect all SPFC levees during and after high-water events. Representatives of the LMAs conduct their own levee inspections in winter and summer and report their findings to DWR.

DWR inspections identify features, their types, and their locations, and document their maintenance conditions in the form of ratings. Currently, these inspections do not specifically focus on invasive plants, unless these plants are adversely affecting SPFC O&M. However, DWR does encourage LMAs to remove invasive plants wherever feasible.

DWR reports the results for individual issues by maintaining agency, levee unit, and levee mile. Based on results of these inspections, DWR and LMAs plan their maintenance activities and work toward improving the rating of features before the next inspection.

2.3 Funding for SPFC Operations and Maintenance

A reduction in O&M budget allocation in the recent past necessitates consideration of the potential budgetary implications of any future additional invasive plant treatment efforts. DFM/FMO O&M budgets are determined annually. Approximately 55–65 percent of the O&M budget is supplied by the State general fund, and the remainder is supplied through MA assessments. O&M budgets are approved through the CVFPB and are based on actual costs per task to maintain levees to State and federal standards. Funding is provided for all O&M activities, including invasive plant control, as well as support activities such as planning, environmental permitting and coordination, and design services provided by DWR's Maintenance Support Branch. Vegetation management costs are fairly consistent from year to year and vary mostly with the cost of materials. Labor and material costs associated with invasive plant control generally range from 10 to 15 percent of the total O&M budget. Although budgets are based on actual costs per task, a single budget allotment is provided for all tasks in an MA, and funds may be moved to specific tasks as needed.

2.4 Current DWR Vegetation Management Practices

Vegetation management tasks completed by DWR fall into three broad categories: levee, channel/floodplain, and structural. As stipulated by the O&M manuals, vegetation management is necessary to facilitate regular inspections of SPFC elements for functionality and safety, to enable flood fighting, and to maintain the design flood capacity of the SPFC. The scope of this management is broader than the treatment of invasive plants alone; additional guidance for the management of vegetation on levees is further described by DWR's Vegetation Management Strategy (Appendix D of the Conservation Strategy).

Vegetation management actions completed by DWR's Maintenance Yards are guided, in part, by the requirements of a California Department of Fish and Wildlife Streambed Alteration Agreement (SAA), also referred to as a Routine Maintenance Agreement (RMA), and executed between DWR and CDFW. The RMA establishes standard conditions under which maintenance can occur on specific flood control facilities and what type of maintenance work is anticipated for each covered facility. The RMA satisfies the requirements of California Fish and Game Code Section 1602, and defines where within the stream zone certain types of maintenance work may occur, defines when the work may occur, and establishes a procedure and timeline for approving work locations. The RMA can incorporate timing restrictions and other avoidance measures intended to avoid take or adverse effects on CESA-listed or California Fully Protected Species. The current RMA is due to expire in 2016 and DWR is taking steps towards an updated RMA.

DWR uses chemical and physical tools to manage vegetation consistent with RMA requirements. Physical methods include manual removal using hand tools, mechanical methods (mowing, disking, dragging, grading, mastication), burning, and grazing. Many of these methods are used in concert to reach the ultimate goal of clearing the vegetation. These methods are applied on the levee slopes, on the levee crown, and adjacent to and in the channel. Typically, with the exception of management to control invasive plants, 15-foot-wide vegetated zones extending

along both banks of low-flow channels are left intact as is existing vegetation on the lower waterside slope of the levee per DWR's vegetation management strategy.

The frequency of vegetation management for each channel depends primarily on channel capacity considerations. In general, undersized flood channels that have a flow capacity less than or equal to flows expected during a 100-year flood event (i.e., the magnitude of flood flows expected to be equaled or exceeded every 100 years on average) require more frequent maintenance to preserve capacity. Oversized channels that have the capacity to convey flows in excess of those expected during a 100-year event require less frequent channel maintenance to preserve the capacity of the channel.

Specific vegetation management methods and tools routinely used by the Maintenance Yards are summarized below. Although this description is focused on activities completed by DWR within Channel Maintenance Areas, similar methods are routinely used by LMAs for the portions of the SPFC for which they have primary maintenance responsibilities.

2.4.1 Herbicides

Herbicides are applied in fall, winter, and early spring, and are rotated when possible to reduce herbicide resistance. Nonselective herbicides are used to maintain bare ground areas (e.g., levee toe roads, crown roadways, and access points). Broadleaf selective herbicides are used to remove broadleaf weeds from levee slopes. Spot spraying is used for species-specific control and for control of brush and vines that may interfere with access or visibility. All herbicides are applied according to label specifications and by a California Licensed Qualified Applicator. The RMA defers the application of time restrictions for herbicide use along levee slopes, channel slopes, and access roads to the California Department of Pesticide Regulation, and does not restrict the timing.

2.4.2 Manual and Mechanical Control of Vegetation

Vegetation is controlled manually on levee slopes and adjacent to the channel. Manual control typically involves selectively trimming or cutting down woody and brushy vegetation Mechanical vegetation management can include dragging or grading, disking or bulldozing, operating a brush hog or similar device, or mowing. Mowing typically occurs in late spring and early fall on levee slopes that are accessible and not too steep for the mower.

2.4.3 Controlled Burning

Controlled burns typically are conducted only in rural areas during midsummer to early fall (June to October) in coordination with the local air quality management district and CDFW. Burning typically is used along levee slopes to improve visibility.

2.4.4 Livestock Grazing

The Maintenance Yards use goats and sheep for grazing in limited locations. It has applied this management method only at the Fremont Weir in the late summer and early fall.

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3.0 Invasive Plant Management Approach

This section provides further detail on DWR's SPA-wide approach for treating invasive plants, with a focus on Channel Maintenance Areas as designated in the SPFC Descriptive Document (DWR 2010). The FloodSAFE Environmental Stewardship and Statewide Resources Office (FESSRO) and DWR's Division of Flood Management/Flood Maintenance Office (DFM/FMO) staff jointly developed this approach based on the following vision: *to reduce the impact of invasive plants as a stressor on conservation targets and as an impediment to the operation and maintenance of the State Plan of Flood Control*. Consistent with this vision, DWR has formulated three goals related to the management of invasive plants:

1) **Increase DWR institutional support for an SPA-wide invasive plant management in DWR Channel Maintenance Areas.** This goal involves looking internally for system or process improvements that may build institutional support and yield greater effectiveness to future coordinated treatment efforts.

2) **Develop and implement a coordinated systemwide invasive plant treatment approach within DWR Channel Maintenance Areas and effectively track results.** Achievement of this goal requires the use of new SPA-wide data to prioritize a subset of species for initial attention, and to prioritize where best to initiate treatment efforts for the benefit of both conservation targets and O&M considerations. Implementation will also include integrating a new focus on invasive plants into current practices, tracking success, and correcting course over time. DWR's implementation will focus on DWR Channel Maintenance Areas.

3) **Develop partnership opportunities and provide resources to encourage consistency with DWR's invasive plant management approach throughout the SPA.** DWR's approach is intended to facilitate consistent actions by partners (e.g., LMAs) operating outside of DWR Channel Maintenance Areas. Facilitation will be accomplished in a variety of ways, including, for example, by providing reference materials and leveraging existing invasive plant treatment efforts. Incorporating invasive plant treatment actions in funding and project selection criteria may be a way to support these actions as part of multi-benefit projects.

Each goal is supported by numerous objectives and implementation measures, summarized in Table 3-1 and described in more detail below. Explanatory text is included to identify the implementation measures that DWR has already completed (in whole or in part) and to provide further details on how DWR will complete remaining implementation measures. Implementation measures have been developed to leverage existing DFM/FMO expertise and are based on current DWR procedures and programs wherever possible.

Table 3-1. Invasive Plant Management Strategy Implementation Summary

Implementation Measure and Collaborators	Deliverable	Status
Implementation Measure 1.1.1: Organize an invasive plant management steering committee (IPMSC) to guide development of this Plan and inform DWR's invasive plant management approach *FESSRO, DFM/FMO*	n/a	Steering committee created and guiding development of this Plan
Implementation Measure 1.1.2: Considering both the potential for adverse ecological effects and adverse effects on SPFC O&M, the IPMSC will develop a prioritized list of target invasive plants to guide implementation of DWR's invasive plant management approach and to assist in development of numerical treatment acreage objectives *IPMSC*	Initial Priority Species designated with this Plan	Completion concurrent with finalization of Plan
Implementation Measure 1.1.3: Update this Plan concurrently with CVFPP updates to reflect the best available scientific information on invasive plant management, the distribution of invasive plants within the SPA, DWR practice and guidelines, and other relevant factors as determined by the IPMSC *DWR*	Updated Plan	CVFPP update scheduled for 2017
Implementation Measure 1.2.1: Prior to the end of 2018, meet with appropriate DWR staff, including members of the IPMSC, DWR management, and key partners to discuss currently identified institutional constraints, identify other potential constraints, and develop an action plan to implement potential solutions *IPMSC, DWR, External Partners*	Action plan	January 2018
Implementation Measure 2.1.1: Combine new DWR fine-scale vegetation mapping with other relevant data, to develop a comprehensive baseline map of target invasive plants within Channel Maintenance Areas and the SPA *DWR*	New map of invasive plant distributions within the SPA in Plan	Completion concurrent with finalization of Plan
Implementation Measure 2.2.1: Collaborate with DFM/FMO leadership and/or their designees to prioritize infestations of Initial Priority Species through the application of a decision support model called WHIPPET *FESSRO, DFM/FMO*	WHIPPET analysis results vetted, and treatment areas determined	2018
Implementation Measure 2.3.1: In collaboration with DFM/FMO, identify 5-year acreage treatment targets for each Initial Priority Species *FESSRO, DFM/FMO*	213 acres of invasive species infestation treated and recorded in appropriate tracking system	2018
Implementation Measure 2.4.1: Develop a comprehensive list of potential invasive plant treatment techniques, incorporating the expertise of Maintenance Yard staff, that would be effective on target invasive plants species *FESSRO, DFM/FMO*	Treatment recommendations included in this Plan	Completion concurrent with finalization of Plan
Implementation Measure 2.5.1: In consultation with DFM/FMO staff, develop appropriate avoidance and minimization measures (to minimize the unintentional introduction and spread of invasive plants) that will be applied during all invasive plant treatments *FESSRO, DFM/FMO*	Avoidance recommendations included in this Plan	Completion concurrent with finalization of Plan

Table 3-1. Invasive Plant Management Strategy Implementation Summary

Implementation Measure and Collaborators	Deliverable	Status
Implementation Measure 2.6.1: Collaborate with DFM/FMO to track progress toward defined invasive plant treatment acreage targets by adapting existing tracking and inspection systems for vegetation management. *FESSRO, DFM/FMO*	Project tracking information captured in appropriate tracking system	2018
Implementation Measure 2.7.1: Where feasible, revegetate invasive plant treatment sites with appropriate native species to reduce the probability of reinfestation by invasive plants *DWR*	n/a	As needed
Implementation Measure 3.1.1: Document all entities with SPFC maintenance responsibilities and describe their roles for invasive plant management relative to those of DWR *DWR*	Reference material included in this Plan	Completion concurrent with finalization of Plan
Implementation Measure 3.1.2: In consultation with the IPMSC, identify entities or existing collaborative efforts with the greatest potential to optimize DWR's invasive plant management approach, and develop a resource estimate for DWR participation *FESSRO, DFM/FMO, External Partners*	Analysis of existing efforts	Completion concurrent with finalization of Plan
Implementation Measure 3.2.1: Distribute this Plan, supporting information (e.g., vegetation maps or maps of invasive species), and results of follow-up actions, to LMAs and other entities managing invasive plants within the SPA, upon request *DWR*	To be determined	Completion concurrent with finalization of Plan
Implementation Measure 3.2.2: Prioritize funding proposals that include actions to map and treat target invasive plants along with other conservation and flood risk reduction actions funded through DWR to support implementation of the CVFPP *DWR*	Funding Guidelines	As needed

Key: CVFPP = Central Valley Flood Protection Plan; DFM/FMO = DWR's Division of Flood Management/Flood Maintenance Office; DWR = California Department of Water Resources; FESSRO = FloodSAFE Environmental Stewardship and Statewide Resources Office; PLAN = Invasive Plant Management Plan; IPMSC = invasive plant management steering committee; O&M = operation and maintenance; SPA = Systemwide Planning Area; SPFC = State Plan of Flood Control.

Goal 1: Increase DWR Institutional Support for an SPA-wide Invasive Plant Management in Channel Maintenance Areas

Objective 1.1: Collaborate with DFM/FMO, and other DWR Staff as Appropriate, to Develop and Maintain an Invasive Plant Management Program that Positively Contributes to the Conservation Strategy and Meets SPFC O&M Requirements

Implementation Measure 1.1.1: Convene an internal invasive plant management steering committee (IPMSC) to guide development of this Plan and inform DWR's invasive plant management approach.

DWR convened the IPMSC to support initial scoping and development of this draft Plan. The IPMSC comprises staff from FESSRO, DFM/FMO, and the Maintenance Yards, and includes ad hoc participation by additional DWR staff as appropriate (e.g., from the Division of Environmental Services [DES]). The IPMSC will continue to meet as needed to review DWR's draft invasive plant management approach, support implementation of this Plan, and foster ongoing collaboration within DWR.

Implementation Measure 1.1.2: Considering both the potential for adverse ecological effects and adverse effects on SPFC O&M, the IPMSC will develop a prioritized list of target invasive plants to guide implementation of DWR's invasive plant management approach and to assist in development of numerical treatment acreage objectives (see Objective 2.3 below).

The IPMSC developed a list of 32 target invasive plants during preparation of this Plan (see Section 4.0). Based on the best information available, these species are known to occur or could occur within the SPA, and they have documented, adverse effects on ecosystem processes and, in some cases, on SPFC O&M. The process and rationale for selecting these species are described fully in Section 4.0.

Because effectively addressing all 32 target species would be an extensive undertaking, it is beyond the scope of DWR's existing resources to effectively target each species. Therefore, the IPMSC selected four Initial Priority Species from this list: giant reed, red sesbania, saltcedar, and Himalayan blackberry (*Rubus armeniacus*). As described in Section 4.0, these species all have documented, and significant, adverse effects on both ecosystem processes and SPFC O&M. The following additional factors were considered in selecting these four Initial Priority Species:

- Availability of distribution maps: Mapping of these species across the entire SPA is currently available, and periodic updates using aerial photography are feasible, so initial baseline acreages can be cost-effectively estimated and periodically updated using DWR's available resources. Other target species may have adverse effects similar to those of the Initial Priority Species, but their distributions cannot be cost-effectively mapped and tracked at a scale that would be appropriate for development and implementation of an SPA-wide invasive plant management approach.

- Potential for adverse hydraulic effects: Recent studies have indicated that at least some invasive species have greater relative impacts on hydraulics, and, therefore, channel capacity, compared to the native species adapted to these same habitats. For example, Stone et. al. (2013) found decreased elasticity of *Tamarix* stems to have greater impact on hydraulics than native cottonwood and willow species. Similarly, Chen et al. (2009 unpublished) conducted flume studies to determine roughness characteristics of different species. They found higher Manning's "n" values associated with blackberry than for other native species. Importantly, Chen et al. also found that all vegetation roughness values significantly decreased with increasing depth, as did Aberle and Jarvela (2013) and Anderson et al. (2006). These findings suggest that standard methods employing a single roughness value to represent vegetation, regardless of water depth, may overestimate vegetation effects on decreasing channel

capacity during high water events. Fortunately, new tools are in development to reduce this uncertainty and improve modeling results.

- Potential for adverse effects on SPFC O&M needs: Despite the limitations of the current planning approaches described above, the initial priority species commonly occur in dense thickets of woody, or wood-like, vegetation. Therefore, the effects of these species on SPFC O&M (e.g., effects on hydraulics and channel capacity) can be better assessed in the hydraulic models used to inform large-scale flood management planning than the adverse effects of herbaceous species, or other woody species that do not commonly occur in large, dense patches.

Implementation Measure 1.1.3: Update this Plan concurrently with CVFPP updates to reflect the best available scientific information on invasive plant management, the distribution of invasive plants within the SPA, DWR practice and guidelines, and other relevant factors, as determined by the IPMSC.

DWR anticipates updating this Plan every 5 years, concurrent with updates to the CVFPP and based on resource availability. Following finalization of the 2017 CVFPP (of which this Plan is a part), the CVFPP is next scheduled for update in 2022.

Objective 1.2: Identify and Address Potential DWR Institutional Constraints (e.g., Staff Capacity, Contracting Limitations, Funding) to Ongoing Support for Large-Scale Invasive Plant Treatment Efforts within DWR.

Implementation Measure 1.2.1: Prior to the end of 2014, meet with appropriate DWR staff, including members of the IPMSC, DWR management, and key partners to discuss currently identified institutional constraints, identify other potential constraints, and develop an action plan to implement potential solutions.

During development of this Plan, examples of past constraints on regional invasive plant management were identified by the IPMSC. These constraints affected actions that could have been implemented by DWR and/or LMAs in their Channel Maintenance Areas, as well as actions that could have been implemented by LMAs and other partners throughout the SPA. Examples of constraints included contractual constraints between DWR and an LMA wishing to conduct a project targeting one of the four Initial Priority Species, access limitations for external partners willing to treat target invasive species on adjacent DWR Channel Maintenance Areas, and DWR resource limitations that prevented the Maintenance Yards from assuming O&M responsibilities explicitly focused on invasive plants. Funding for new actions is a widely recognized limitation, and it is the intent of this Plan to increase funding for these actions as opposed to creating an additional burden on O&M budgets. The approach is fashioned to meet multiple objectives in order to benefit from new funding sources not previously available.

IPMSC discussions also addressed the interest, expressed in other branches of DWR, in coordinating efforts to manage invasive species on a broad scale, including treatment of other invasive taxa (e.g., aquatic invertebrates). Forming an internal DWR coordination group that

includes appropriate external partners could facilitate future invasive species management approaches, reduce duplication of effort, and identify points of contact among external partners.

Goal 2: Develop and Implement a coordinated systemwide invasive plant treatment approach within Channel Maintenance Areas and effectively track results.

Objective 2.1: Develop a New Comprehensive Baseline for the Extent of Target Invasive Plants within the SPA to Guide Management Approach within Channel Maintenance Areas and the Actions of Others throughout the SPA

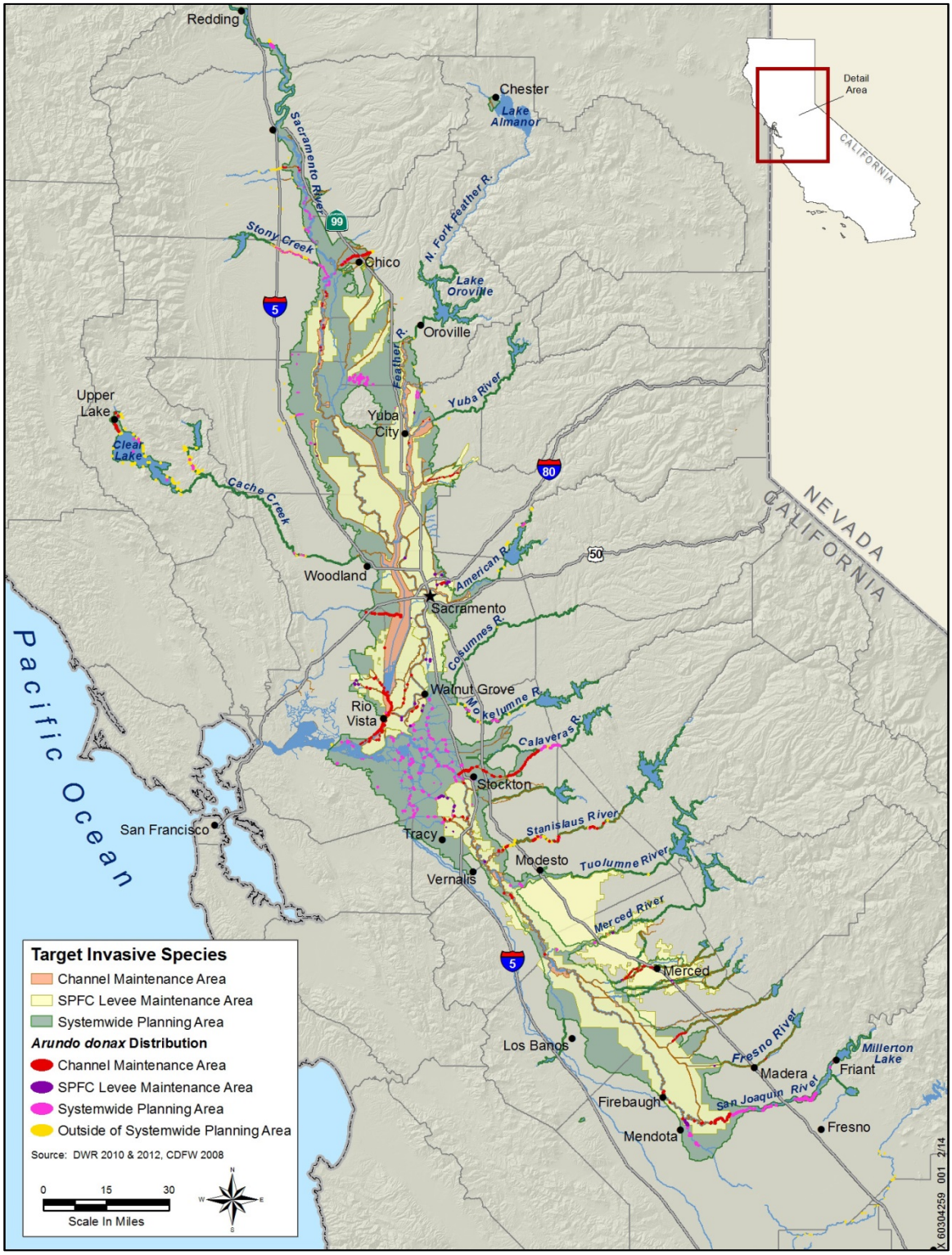
Implementation Measure 2.1.1: DWR would combine newly available, fine-scale vegetation mapping data with other relevant data to develop a baseline map of target invasive plants within Channel Maintenance Areas and the SPA.

During preparation of this Plan, recently available, fine-scale vegetation mapping covering the SPA (CDFW 2013) was combined with other geographic information system (GIS) data (CDFG 2008 and Cal-IPC 2013a) to develop a baseline map showing the acreage and spatial distribution of all four Initial Priority Species (Figures 3-1 to 3-4). Although there are acknowledged accuracy limitations with these data, they represent the best information available for estimating the distribution of the Initial Priority Species within the SPA, and the data are of sufficient accuracy to support development of DWR's approach to the management of these four species.

As described above, this Plan's initial focus on the four Initial Priority Species does not indicate that the remaining target species (identified in Section 4.0 of this Plan) are unimportant. However, DWR's approach to managing these 27 species is undetermined at this time, in part because of acknowledged resource limitations (see Implementation Measure 1.1.2) and in part because of a lack of information on the distribution and acreage of these species in the SPA. In these cases, data provided by Cal-IPC (2013b) were used to provide a coarse-scale approximation of these species' distributions within the SPA, to guide future efforts by DWR and external partners. Figures 3-5 and 3-6 show the approximate frequency of occurrence for these remaining 27 invasive species within the Sacramento River and San Joaquin River Regions, to be used as an approximate current baseline against which future conditions can be compared.

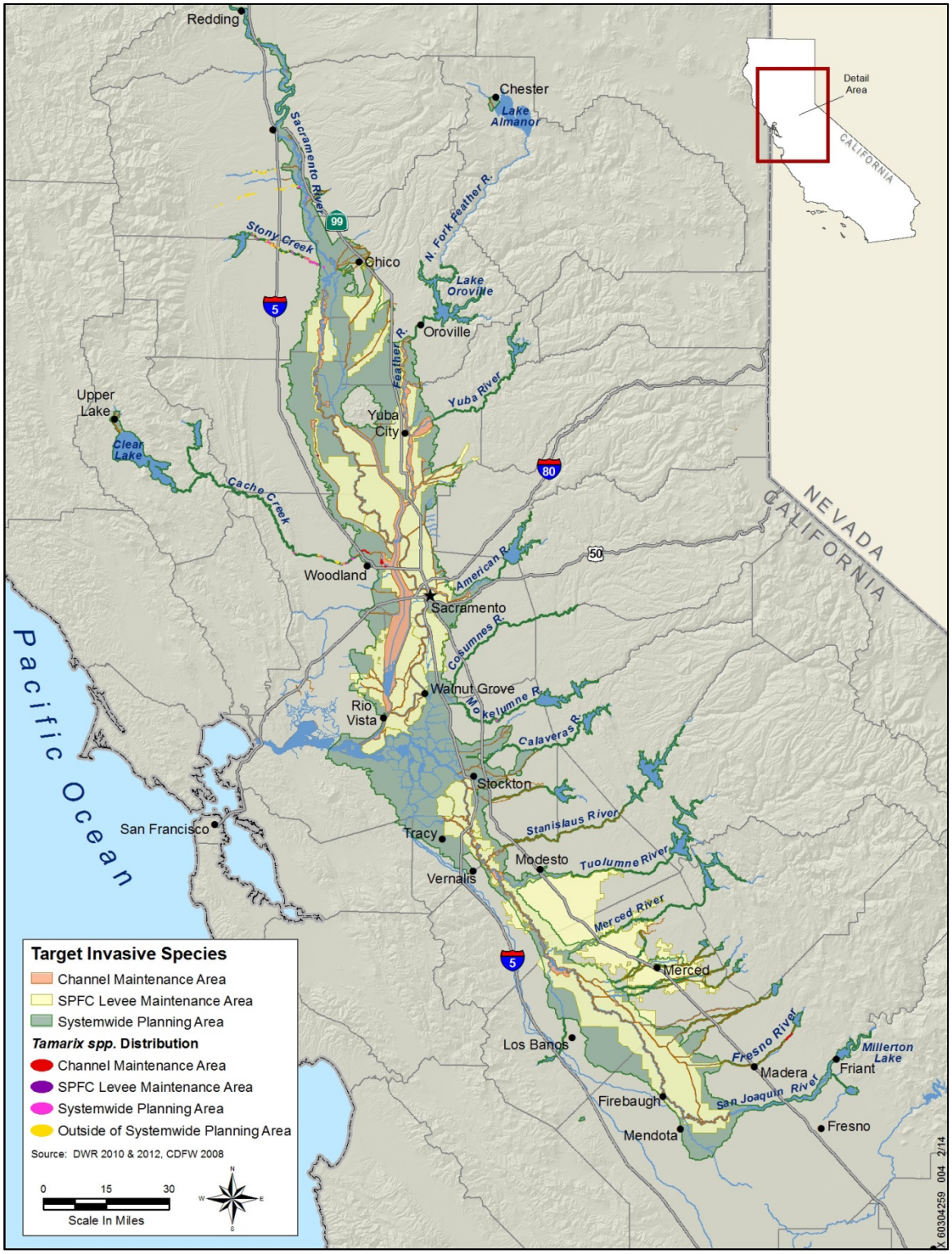
Objective 2.2: Prioritize Populations of Initial Target Species for Treatment to Create Multiple Benefits for Conservation Strategy measurable objectives and SPFC O&M

Implementation Measure 2.2.1: Collaborate with DFM/FMO to prioritize infestations of Initial Priority Species plants through the application of a decision support model called WHIPPET.



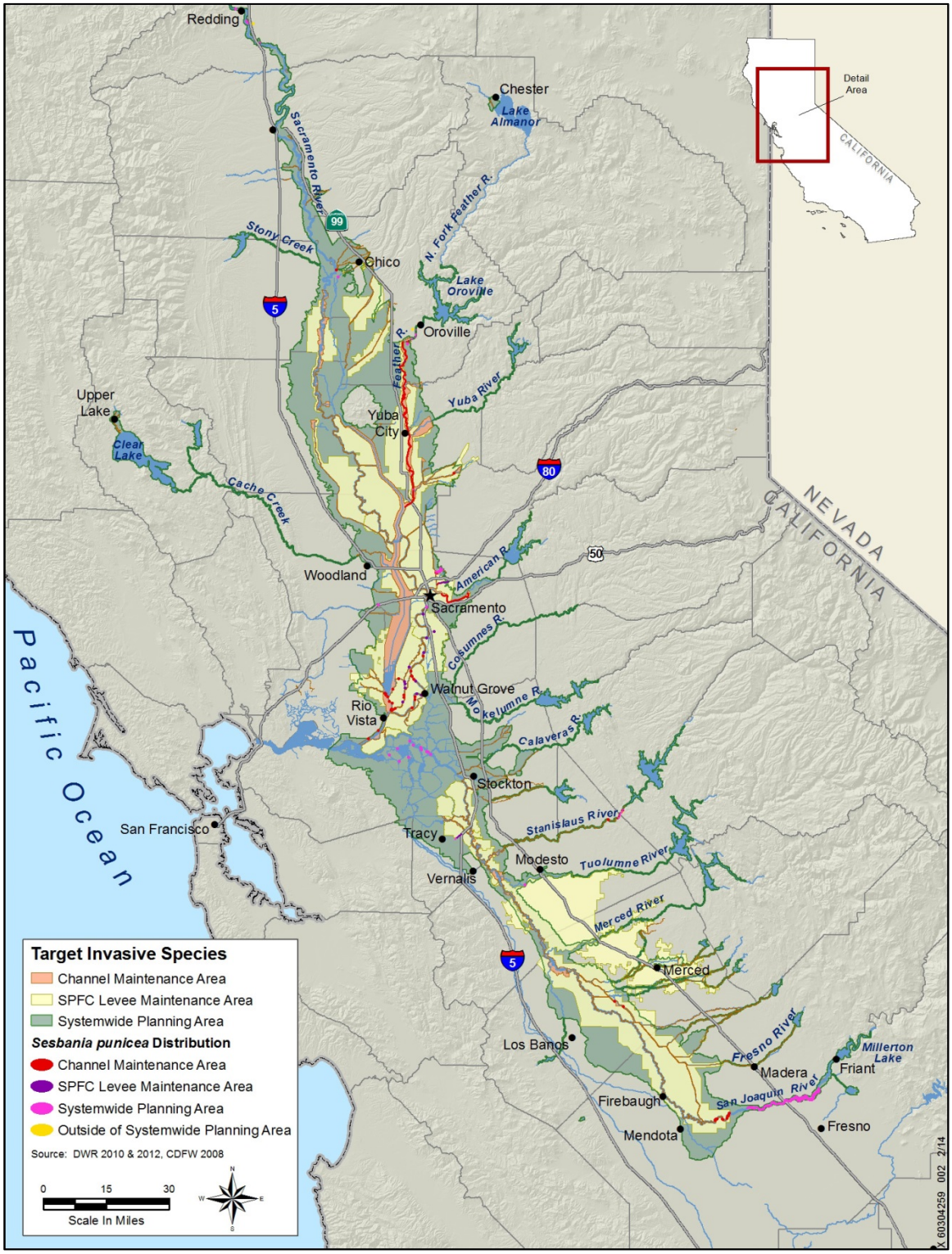
Sources: Cal-IPC 2013b, CDFG 2008, DWR 2010, and DWR 2012.

Figure 3-1. Distribution of Giant Reed within the SPA



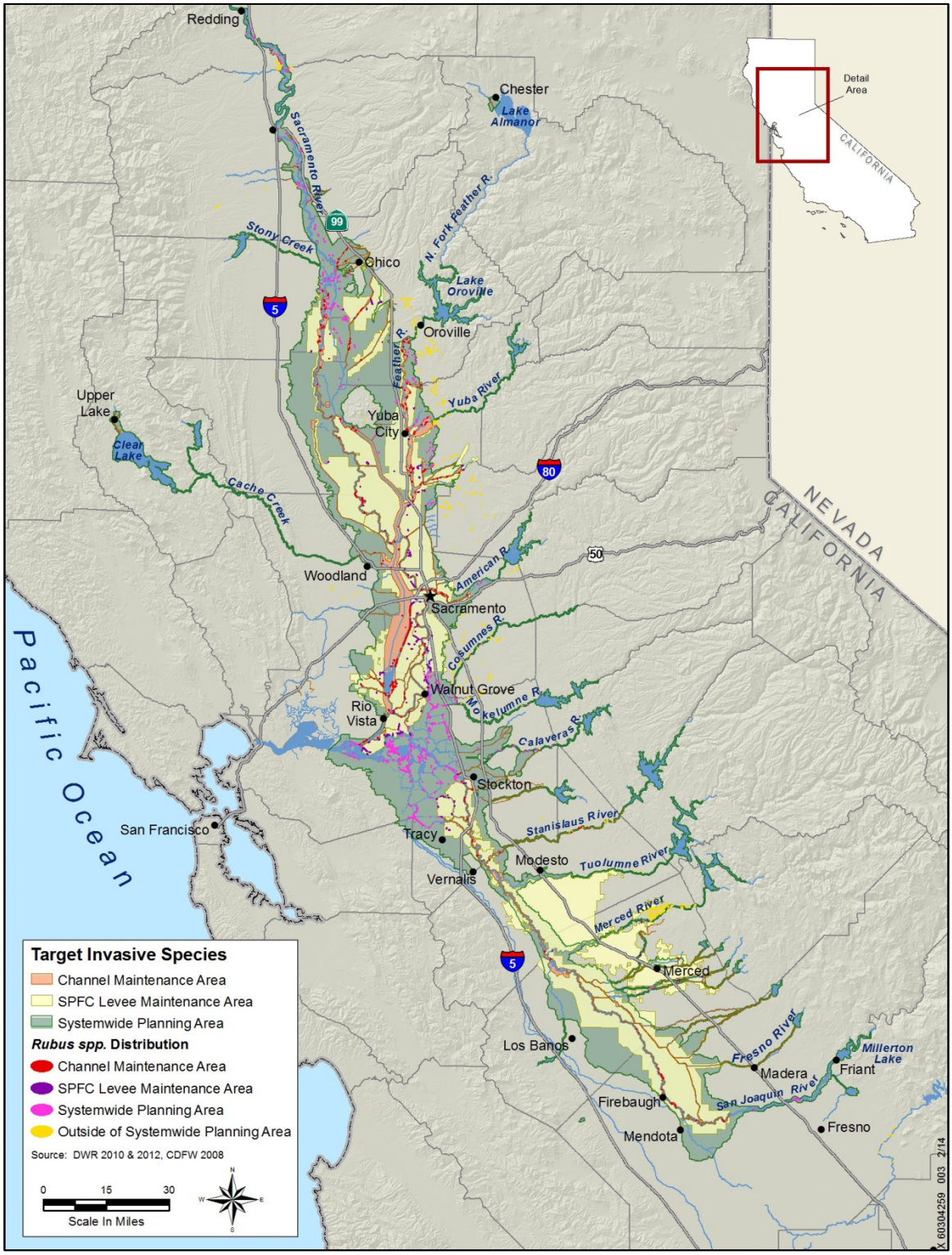
Sources: Cal-IPC 2013b, CDFG 2008, DWR 2010, and DWR 2012.

Figure 3-2. Distribution of Saltcedar within the SPA



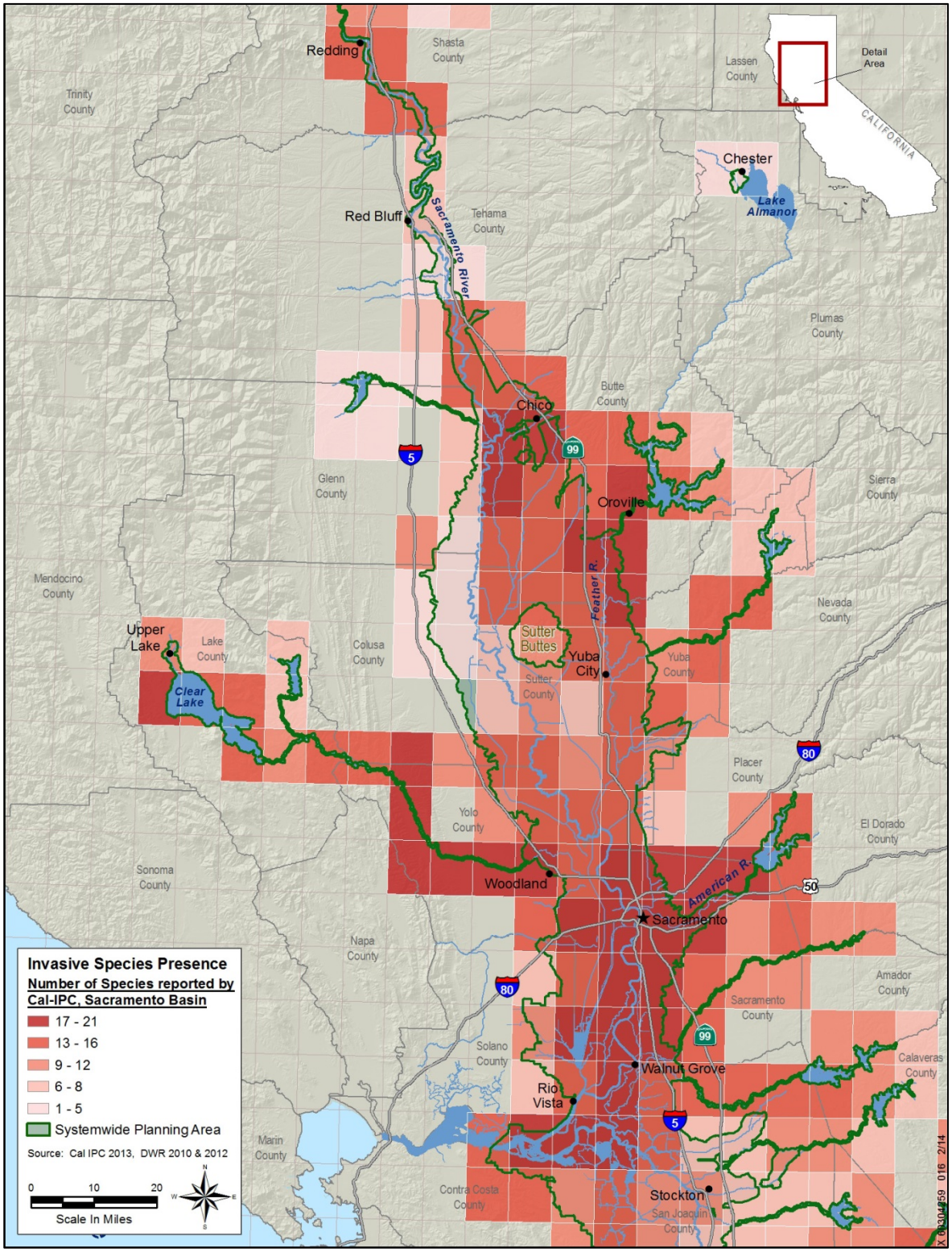
Sources: Cal-IPC 2013b, CDFG 2008, DWR 2010, and DWR 2012.

Figure 3-3. Distribution of Red Sesbania within the SPA



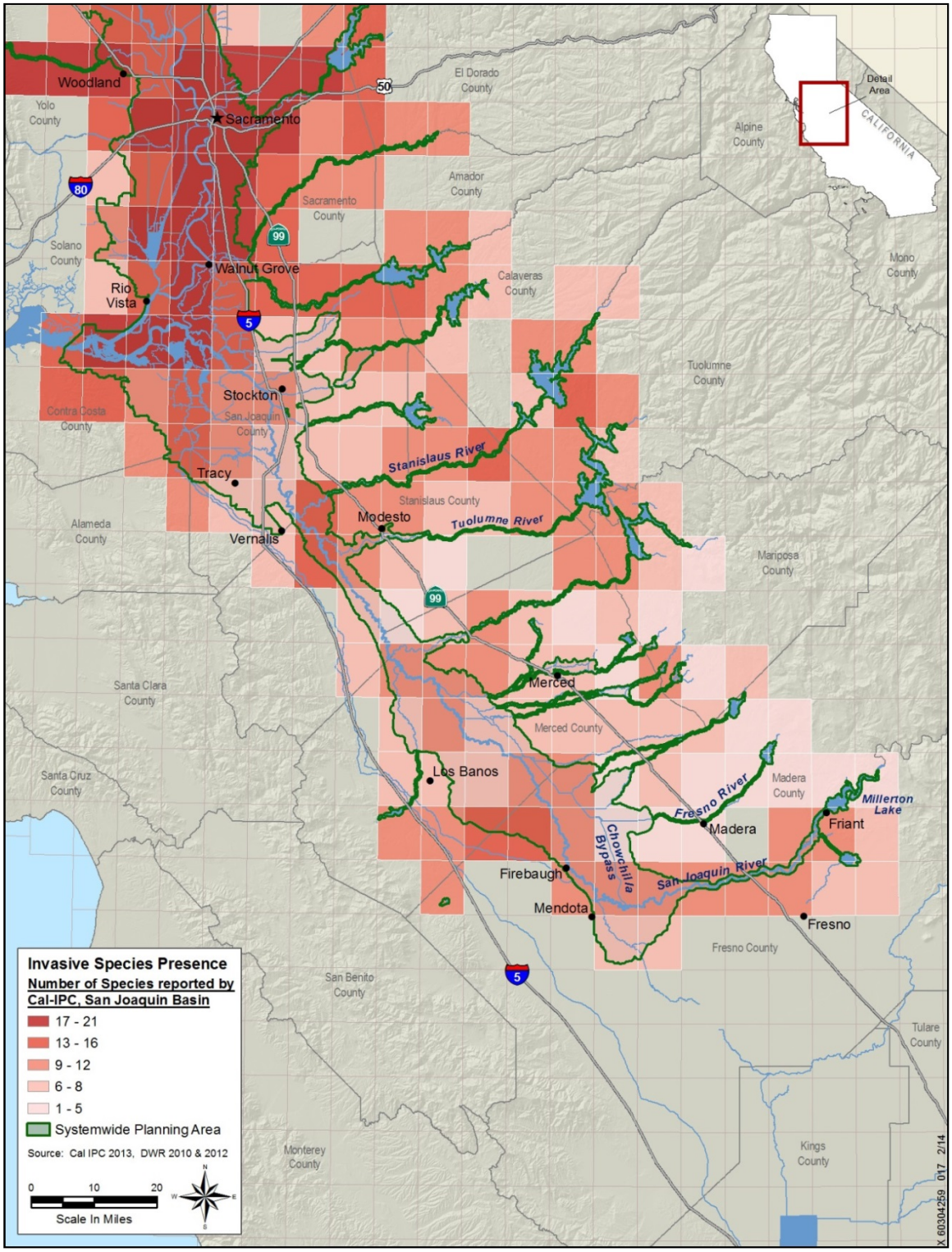
Sources: Cal-IPC 2013b, CDFG 2008, DWR 2010, and DWR 2012.

Figure 3-4. Distribution of Himalayan Blackberry within the SPA



Sources: Cal-IPC 2013b, DWR 2010, and DWR 2012.

Figure 3-5. Number of Target Invasive Plants per 7.5-Minute USGS Quadrangle, Sacramento River Region



Sources: Cal-IPC 2013b, DWR 2010, and DWR 2012.

Figure 3-6. Number of Target Invasive Plants per 7.5-Minute USGS Quadrangle, San Joaquin River Region

Initial coordination between the IPMSC and staff from DES identified an existing decision support model called the Weed Heuristics Invasive Populations Prioritization for Eradication Tool (WHIPPET) (www.cdfa.ca.gov/weedhome). WHIPPET is capable of prioritizing treatment areas in a regional setting with multiple infestations of multiple species. DWR could consider the use of WHIPPET to as a first step in prioritizing specific treatments of Initial Priority Species.

Acknowledging limited resources in DWR, application of WHIPPET would cost-effectively inform initial planning targets, guide SPA-wide treatment efforts, and better formulate treatment targets over time. In its use of WHIPPET, DWR would rely on the best available information characterizing the distribution, abundance, and effects of target invasive species, as shown in Figures 3-1 through 3-4 and as summarized in Section 4.0. Results from WHIPPET would be vetted by Maintenance Yard staff to confirm model results with field knowledge of priority infestations that are likely to adversely affect both SPFC O&M and Conservation Strategy measurable objectives.

Objective 2.3: Reduce Initial Priority Species by a Defined Acreage, Beginning with a 5-Year Target

Implementation Measure 2.3.1: In collaboration with FMO, and in consultation with the IPMSC, implement treatment of draft 5-year acreage targets of Initial Priority Species.

Consistent with the development of numerical objectives (e.g., acreage or linear foot/mileage targets) for other conservation targets or stressors in the Conservation Strategy, the IPMSC developed near- and long-term treatment targets for management of the four Initial Priority Species. Table 3-2 shows that the total acreage of these four species in the SPA is on the order of 3,776 acres, with approximately 1,065 acres occurring in Channel Maintenance Areas managed by either DWR or LMAs. The near-term, or 5-year treatment target, developed for this Plan is 213 acres of Initial Priority Species treated upon the anticipated adoption of this plan as part of the 2017 CVFPP update. This numerical objective was derived by dividing the total acreage of Initial Priority Species in Channel Maintenance Areas by the number of CVFPP updates that are planned to occur for the duration of CVFPP implementation (i.e., 25 years, with five updates). These 5-year treatment acreage targets may be updated during future updates to the CVFPP if improved information on the distribution and extent of invasive plants in the SPA becomes available. Furthermore, the designation of 5-year acreage targets does not imply that the total amount of invasive plants occurring in the SPA will be reduced by this acreage over 5 years (i.e., it does not imply that all treatments will result in complete eradication of targeted infestations).

Near-term targets have not been defined at this time for areas outside of Channel Maintenance Areas because treatments will be prioritized to meet the multiple goals of reducing stress on Conservation Strategy targets and SPFC O&M. Meeting O&M needs for channel capacity dictates prioritization of treatments within Channel Maintenance Areas first. As described in Implementation Measure 2.2.1, collaboration with DFM/FMO will prioritize treatment of Initial Priority Species following adoption of this Plan; therefore, this target is a placeholder until this analysis occurs. Additionally, because maintenance of channel areas is shared between DWR and LMAs within the SPA, designation of who may have the ability to implement treatment actions will also occur in later analysis. Long-term targets are full treatment of all currently mapped

infestations for the Initial Priority Species. Fortunately, developing planning targets for a long timeframe provides opportunities to address institutional constraints on large-scale treatment efforts by DWR and external partners.

Table 3-2. Acreages of Initial Priority Species Occurring within the SPA

Management Area	Initial Priority Species				Total (acres)	Near-Term Target (acres treated)	Long-Term Target (acres treated)
	Giant Reed (acres)	Red Sesbania (acres)	Saltcedar (acres)	Himalayan Blackberry (acres)			
Channel Maintenance Areas	252	15	76	722	1,065	213	1,065
LMA Areas in SPFC	17		4	357	378	TBD	TBD
Remainder of SPA	382	469	51	1,432	2,333	TBD	TBD
Total	**651**	**484**	**131**	**2,511**	**3,776**		

Key: SPA = Systemwide Planning Area; TBD = to be determined.
Note: Columns may not total accurately due to rounding.

To support development of numerical objectives for the Conservation Strategy, numerical objectives have also been developed for individual CPAs. These targets are provided, by CPA, for Channel Maintenance Areas (Table 3-3), for other LMA areas within the SPFC (Table 3-4), and for the remainder of the SPA (Table 3-5). These targets are intended to inform development of multi-benefit projects implemented through Regional Flood Management Plans, Corridor Management Plans, Basin-Wide Feasibility Studies, and other related planning efforts in the SPA.

Objective 2.4: Develop Treatment Methods Using the Local Knowledge and Experience of Maintenance Yard Staff, Supplemented by the Best Available Information from Recognized Leaders Engaged in Invasive Plant Research and Control

Implementation Measure 2.4.1: In consultation with the IPMSC, develop a comprehensive list of invasive plant treatment techniques, incorporating the expertise of Maintenance Yard staff, that would be effective on target invasive plant species.

Section 5.0 summarizes the best available information regarding treatment techniques for the 32 target invasive plants described in this Plan, including detailed treatment recommendations for the four Initial Priority Species.

Implementation Measure 2.5.1: In consultation with DFM/FMO staff, develop appropriate avoidance and minimization measures (to minimize the unintentional introduction and spread of invasive plants) that can be applied during all invasive plant treatments.

Table 3-3. Initial Planning Targets for Channel Maintenance Areas

Conservation Planning Area	Initial Priority Species				Total (acres)	Near-Term Target (acres treated)	Long-Term Target (acres treated)
	Giant Reed (acres)	Red Sesbania (acres)	Saltcedar (acres)	Himalayan Blackberry (acres)			
Upper Sacramento River	90	0	0	178	268	54	268
Feather River	48	0	0	209	257	51	257
Lower Sacramento River	18	0	70	276	363	73	363
Lower San Joaquin River	5	0	0	29	34	7	34
Upper San Joaquin River	92	15	6	30	143	29	143
Total	**252**	**15**	**76**	**722**	**1,065**	**213**	**1,065**

Note: Columns may not total accurately due to rounding.

Table 3-4. Initial Planning Targets for LMA Areas in the SPFC (outside of channel maintenance areas)

Conservation Planning Area	Initial Priority Species				Total (acres)	Near-Term Target (acres treated)	Long-Term Target (acres treated)
	Giant Reed (acres)	Red Sesbania (acres)	Saltcedar (acres)	Himalayan Blackberry (acres)			
Upper Sacramento River	3	0	4	44	51	10	51
Feather River	3	0	0	49	52	10	52
Lower Sacramento River	1	0	0	229	230	46	230
Lower San Joaquin River	2	0	0	25	26	5	26
Upper San Joaquin River	8	0	0	11	19	4	19
Total	**17**	**0**	**4**	**357**	**378**	**76**	**378**

Key: LMA = Local Maintaining Agency; SPFC = State Plan of Flood Control.
Note: Columns may not total accurately due to rounding.

Table 3-5. Initial Planning Targets for the Remainder of the SPA

Conservation Planning Area	Initial Priority Species				Total (acres)	Near-Term Target (acres treated)	Long-Term Target (acres treated)
	Giant Reed (acres)	Red Sesbania (acres)	Saltcedar (acres)	Himalayan Blackberry (acres)			
Upper Sacramento River	284	0	46	511	840	168	840
Feather River	30	0	0	115	145	29	145
Lower Sacramento River	4	0	5	80	89	18	89
Lower San Joaquin River	38	0	1	706	745	149	745
Upper San Joaquin River	26	469	0	20	515	103	515
Total	**382**	**469**	**51**	**1432**	**2,333**	**467**	**2,333**

Key: SPA = Systemwide Planning Area.
Note: Columns may not total accurately due to rounding.

Objective 2.5: Avoid and Minimize Adverse Effects on Nontarget Species and Unintentional Introduction of Invasive Plants during Invasive Plant Treatment into Channel Maintenance Areas.

Section 5.0 of this Plan summarizes avoidance and minimization BMPs recommended for implementation during invasive plant treatments. This list of BMPs was created by supplementing current practices used by DFM/FMO and the Maintenance Yards with information from other sources on best practices for invasive plant treatment. Implementation of these BMPs by both DWR, and other parties, such as levee maintaining agencies to the extent they are able and are involved in invasive plant treatment efforts, will contribute to standardizing a systemwide approach to invasive plant management.

Objective 2.6: Track the Success of DWR's Invasive Plant Management Approach

Implementation Measure 2.6.1: Collaborate with DFM/FMO to track progress toward defined invasive plant treatment acreage targets by adapting existing tracking and inspection systems for vegetation management. Tracking systems will also monitor incipient infestations and prioritize them for treatment to prevent further spread.

The first step in implementing this measure will be to determine, in collaboration with DFM/FMO, whether the current levee inspection process can be adapted to better guide invasive plant management. For example, LMAs are encouraged to remove invasive species from the Vegetation Management Zone of levees if such plants are detected during inspections. By tracking these detections and maintaining data on the applied treatments, DWR will begin to build a systemwide foundation of information to guide future efforts. Additionally, DWR and

LMA inspection staff and Maintenance Yard staff could adapt current inspection processes to incorporate efforts aimed at early detection of new invasive plant infestations. Early detection of new infestations will facilitate cost-effective treatment of these infestations (i.e., they will be treated before they become established and therefore more difficult and costly to treat).

A second aspect of improved tracking will involve the tracking systems used by external partners. The IPMSC reviewed several tracking systems related to invasive species, such as the Cal-IPC CalWeed Mapper, the Bay Area Early Detection Network, and early tracking efforts of the Weed Management Area (WMA) program at the California Department of Food and Agriculture (CDFA). In addition, an online database called the Natural Resources Project Inventory (NRPI) was established as a collaborative effort between the Information Center for the Environment (ICE) at the University of California, Davis, and the California Biodiversity Council (CBC). The database identifies more than 8,000 natural resource projects and is the most comprehensive statewide database of natural resource projects, including projects focused on invasive plant treatment. Using the NRPI, and encouraging its use by others, will optimize the efficacy of existing forums, improve regional collaboration and information sharing, and increase DWR's contribution to systemwide efforts.

Objective 2.7: Minimize Long-Term Invasive Plant Treatment Costs through Post-Treatment Management Actions

Implementation Measure 2.7.1: Where feasible, revegetate invasive plant treatment sites with appropriate native species to reduce the probability of reinfestation by invasive plants.

Funding and staffing resources to revegetate all treatment areas likely will not be available; however, some form of vegetation will recolonize treatment areas naturally. Therefore, in some cases, revegetation with native species will be warranted to avoid recolonization by invasive species that have more significant channel capacity impacts than natives. In Section 5.0, this Plan provides guidance for revegetation efforts within Channel Maintenance Areas as a means of facilitating a systemwide approach that is applied by LMAs and others within other parts of the SPA.

Goal 3: Develop Partnership Opportunities and Provide Resources to Encourage Consistency with DWR's Invasive Plant Management Approach throughout the SPA

Objective 3.1: Inventory Invasive Plant Treatment Programs Being Implemented by Potential Collaborators within the SPA and Identify Existing Efforts with the Greatest Potential to Benefit from DWR Participation and Positively Contribute to the Conservation Strategy

Implementation Measure 3.1.1: Document all entities with SPFC maintenance responsibilities and describe their roles for invasive plant management relative to those of DWR.

This information is provided in Section 7.0.

Implementation Measure 3.1.2: In consultation with the IPMSC, identify entities or existing collaborative efforts with the greatest potential to optimize DWR's invasive plant management approach, and develop a resource estimate for DWR participation.

Section 7.0 provides an overview of existing efforts through which DWR may optimize the results of its invasive plant management approach. For example, DWR was one of 14 agencies listed as participants in the California Interagency Noxious and Invasive Plant Committee (CINIPC), originally formed in 1995. The Memorandum of Understanding (MOU) that created the group has expired, but the group continues to meet two to three times per year. DWR may consider assisting in accomplishing the activities outlined in the group's blueprint for landscape-level management. Additionally, DWR may consider participating in the Invasive Weeds Awareness Day at the Capitol, which includes educational visits to legislators and agency leaders. Lastly, DWR could consider providing additional support for CDFW's State Wildlife Action Plan, which addresses invasive weeds for the first time in its 2015 update (http://www.dfg.ca.gov/swap/).

Objective 3.2: Facilitate Consistency with the Plan Approach among LMAs and Other Entities Managing Invasive Plants within the SPA

Implementation Measure 3.2.1: Distribute this Plan, and results of follow-up actions, to LMAs and other entities managing invasive plants within the SPA, upon request.

A first step to implement this measure would be making information available. This Plan could be posted online, along with other Conservation Strategy materials, and LMAs will be directed to this source.

Implementation Measure 3.2.2: Prioritize funding proposals that include actions to map and treat target invasive plants along with other conservation and flood-risk reduction actions funded through DWR to support implementation of the CVFPP.

Funding guidelines and selection criteria could include information about which project types and aspects are desirable. The Central Valley Flood Protection Act of 2008 and the resultant CVFPP and SSIA encourage the development of multipurpose projects. Including invasive plant treatment actions among other conservation actions, and within cost-share funding guidelines, would further the intent of the legislation and its supporting planning documents. Additional "credit" could be assigned to multi-benefit projects that include these actions, in contrast to those without multi-benefit characteristics. One example of such a system is the CDFA Weed Management Area program, which sets forth criteria for funding invasive species treatments. Facilitating invasive plant treatments as part of future projects would also serve the goal of collecting data on infestations and treatments: projects funded through DWR could be required to contribute treatment data to the appropriate tracking system.

4.0 Target Invasive Plant Species

4.1 Definition of Terminology

Within the context of this Plan, invasive plants include plants that have the potential to adversely affect Conservation Strategy measurable objectives or public safety through compromised operation and maintenance of the SPFC. In many cases, these species also meet the definition of a "noxious weed" as defined by California or federal officials (i.e., CDFA or the Secretary of Agriculture) or they may be designated by Cal-IPC's Invasive Plant Inventory (Cal-IPC 2013a) as nonnative, invasive plants that threaten California's wildlands.

However, not all species occurring in the Sacramento and San Joaquin Valleys and considered by these organizations to be noxious or invasive are addressed in this Plan. For example, Cal-IPC considers many widely naturalized species (e.g., nonnative, annual grasses) to be invasive, but treatment of these species is generally infeasible and may not be warranted in many circumstances because the plants are widely distributed, naturalized, and form major herbaceous components of plant communities that provide important wildlife habitat. Also, this Plan discusses some species that are not currently considered to be noxious or invasive by any organization because these plants have the potential to adversely affect the goals and objectives of the Conservation Strategy.

Specifically, this Plan focuses on weeds that are capable of the following:

- Degrading riverine, marsh, or riparian habitats
- Adversely affecting SPFC O&M
- Altering hydrology and sedimentation rates
- Altering riverine geomorphic processes
- Reducing water quality
- Reducing the integrity of native plant communities by displacing native species and reducing groundwater availability
- Reducing habitat quality and food supply for Conservation Strategy target wildlife species

The process used for selecting the target invasive plant species addressed by this Plan is described in detail below.

4.2 Identification of Target Invasive Plant Species

The selection of target invasive species for consideration by this Plan primarily relied on information contained in Cal-IPC's Inventory (Cal-IPC 2013a) as a starting point. The Inventory is the most comprehensive, objective, and science-based evaluation of invasive plants occurring in California. It is compiled by invasive species experts using the best available information on 13 different aspects of each species, including the plant's potential to adversely affect ecosystem processes and native habitats, the species' distribution and rate of spread, and similar factors. Based on these data, each plant is assigned one of three ranks: High, Moderate, or Limited, defined as follows:

- **High:** These species have severe ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology is conducive to moderate to high rates of dispersal and establishment. Most are widely distributed ecologically.

- **Moderate:** These species have substantial and apparent—but generally not severe—ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal, although establishment generally depends on ecological disturbance. Ecological amplitude and distribution may range from limited to widespread.

- **Limited:** These species are invasive, but their ecological impacts are minor on a statewide level, or there was not enough information to justify a higher score. Their reproductive biology and other attributes result in low to moderate rates of invasiveness. Ecological amplitude and distribution are generally limited, but these species may be locally persistent and problematic.

For this Plan, a master list of target species was compiled to include all species listed in the Inventory as potentially occurring in the Sacramento and San Joaquin Valleys (Table 4-1). The master list also included species not formally identified in the Inventory but considered to have the potential to adversely affect SPFC O&M based on the professional opinion of DWR Maintenance Yard staff (Romero pers. comm.). The following information was tabulated for each of these species, primarily by consulting the Inventory (2013a), unless otherwise noted (Table 4-1):

- The species' growth form (i.e., whether it is a tree, shrub, floating aquatic plant, perennial herb, perennial grass, annual herb, or annual grass)

- The species' Cal-IPC ranking (i.e., High, Moderate, or Limited)

- The species' Cal-IPC Alert status (species with an Alert status are believed to have the potential to spread into other ecosystems throughout California)

- The impacts of each species on SPFC O&M activities, as determined by Maintenance Yard staff (Romero pers. comm.)

Table 4-1. Invasive Plant Species Potentially Occurring within the SPA

Common Name	Scientific Name	Growth Form	Cal-IPC Ranking[1]	Cal-IPC Alert[1]	CDFA Rating[2]	SPFC O&M Impact[3]	Habitat Invaded[1, 4]		
							Rivers, Streams, Canals	Marsh	Riparian
Russian knapweed	*Acroptilon repens*	Perennial herb	Moderate	No Alert	B	Low			D
Barbed goat grass	*Aegilops triuncialis*	Annual grass	High	No Alert	B	None			D
Tree of heaven	*Ailanthus altissima*	Tree	Moderate	No Alert	C	Moderate		C	C
Alligator weed	*Alternanthera philoxeroides*	Floating aquatic	High	Alert	A	Moderate	D	D	
Giant reed	*Arundo donax*	Perennial grass	High	No Alert	B	High	B		D
Black mustard	*Brassica nigra*	Annual herb	Moderate	No Alert	n/a	Moderate			D
Italian thistle	*Carduus pycnocephalus* ssp. *pycnocephalus*	Annual herb	Moderate	No Alert	C	Moderate			D
Southern catalpa	*Catalpa bignonioides*	Tree	n/a	n/a	n/a	Low			D
Yellow star-thistle	*Centaurea solstitialis*	Annual herb	High	No Alert	C	High			B
Skeleton weed	*Chondrilla juncea*	Perennial herb	Moderate	No Alert	A	Low			
Bull thistle	*Cirsium vulgare*	Annual herb	Moderate	No Alert	C	Moderate		C	D
Poison hemlock	*Conium maculatum*	Perennial herb	Moderate	No Alert	n/a	Low		D	C
Pampas grass	*Cortaderia selloana*	Perennial grass	High	No Alert	n/a	Moderate			D
Scotch broom	*Cytisus scoparius*	Shrub	High	No Alert	C	Moderate			D
Stinkwort	*Dittrichia graveolens*	Annual herb	Moderate	Alert	n/a	Moderate			D
Brazilian waterweed	*Egeria densa*	Submerged aquatic	High	No Alert	C	High	C		
Water hyacinth	*Eichhornia crassipes*	Floating aquatic	High	Alert	Q	High	D		
Medusa head	*Elymus caput-medusae*	Annual grass	High	No Alert	C	Low			D
Blue gum	*Eucalyptus globulus*	Tree	Moderate	No Alert	n/a	Low		C	D
Edible fig	*Ficus carica*	Tree	Moderate	No Alert	n/a	Moderate		C	C
Fennel	*Foeniculum vulgare*	Perennial herb	High	No Alert	n/a	High			D
French broom	*Genista monspessulana*	Shrub	High	No Alert	C	Low			D
Shortpod mustard	*Hirschfeldia incana*	Annual herb	Moderate	No Alert	n/a	High			D
Hydrilla	*Hydrilla verticillata*	Submerged aquatic	High	Alert	A	Moderate	D		
Klamathweed	*Hypericum perforatum* ssp. *perforatum*	Annual herb	Moderate	No Alert	n/a	Low			
Perennial pepperweed	*Lepidium latifolium*	Perennial herb	High	No Alert	B	High		C	C
Privet	*Ligustrum* sp.	Tree	n/a	n/a	n/a	Low			D
American frogbit	*Limnobium spongia*	Floating aquatic	High	Alert	A	Low	D		
Dalmatian toadflax	*Linaria dalmatica* ssp. *Dalmatica*	Perennial herb	Moderate	No Alert	A	Low			
Water primrose	*Ludwigia* sp.	Floating aquatic	High	No Alert	Q	High	B	U	U
Purple loosestrife	*Lythrum salicaria*	Floating aquatic	High	No Alert	B	High	D	D	D
Pennyroyal	*Mentha pulegium*	Annual herb	Moderate	No Alert	n/a	Low	D	C	C

Table 4-1. Invasive Plant Species Potentially Occurring within the SPA

Common Name	Scientific Name	Growth Form	Cal-IPC Ranking[1]	Cal-IPC Alert[1]	CDFA Rating[2]	SPFC O&M Impact[3]	Habitat Invaded[1, 4]		
							Rivers, Streams, Canals	Marsh	Riparian
Parrot's feather	*Myriophyllum aquaticum*	Floating aquatic	High	Alert	n/a	Low	D		
Tree tobacco	*Nicotiana glauca*	Shrub	Moderate	No Alert	n/a	Moderate			D
Scotch thistle	*Onopordum acanthium* ssp. *acanthium*	Shrub	High	No Alert	A	Moderate			
Harding grass	*Phalaris aquatica*	Perennial grass	Moderate	No Alert	n/a	Low			D
Crisp-leaved pondweed	*Potamogeton crispus*	Floating aquatic	Moderate	No Alert	n/a	High	C	D	
Black locust	*Robinia pseudoacacia*	Tree	Limited	No Alert	n/a	Moderate			D
Himalayan blackberry	*Rubus armeniacus*	Shrub	High	No Alert	n/a	High		B	A
Ravenna grass	*Saccharum ravennae*	Perennial grass	Moderate	Alert	n/a	Low		D	D
Russian thistle	*Salsola tragus*	Annual herb	Limited	No Alert	C	High			
Red sesbania	*Sesbania punicea*	Tree	High	Alert	B	High		D	D
Milk thistle	*Silybum marianum*	Annual herb	Limited	No Alert	n/a	High			
Saltcedar	*Tamarix* sp.	Shrub	High	No Alert	B	High	B	B	B
Tall sock-destroyer	*Torilis arvensis*	Annual herb	Moderate	No Alert	n/a	Low			B
Chinese tallowtree	*Triadica sebifera*	Tree	Moderate	Alert	n/a	Moderate			D
Greater periwinkle	*Vinca major*	Perennial herb	Moderate	No Alert	n/a	Low		D	D

Key: Cal-IPC = California Invasive Plants Council; CDFA = California Department of Food and Agriculture; SPFC = State Plan of Flood Control; O&M = operation and maintenance.

Notes:

1 *Source: Cal-IPC 2013a.*

2 CDFA Ratings:
A = A pest of known economic or environmental detriment, and is either not known to be established in California or is present in a limited distribution that allows for the possibility of eradication or successful containment.
B = A pest of known economic or environmental detriment and, if present in California, is of limited distribution.
C = A pest of known economic or environmental detriment and, if present in California, is usually widespread.
Q = An organism or disorder suspected to be of economic or environmental detriment, but whose status is uncertain because of incomplete identification or inadequate information.
D = An organism known to be of little or no economic or environmental detriment, to have an extremely low likelihood of weediness, or to be a parasite or predator.

3 Source: Romero pers. comm.

4 Habitat Invaded Codes:
A = > 50% of habitat invaded.
B = > 20% to 50% of habitat invaded.
C = > 5% to 20% of habitat invaded.
D = Weed is present, but ≤ 5% of habitat invaded.
U = Unknown (likely present but unable to estimate percentage of occurrences invaded).

- The percentages of specific habitat types within the SPA that are thought, by Cal-IPC, to have been invaded by the species

As stated, the target species listed in Table 4-1 were categorized based on their distribution; their relationship to Conservation Strategy target ecosystem processes, habitats, and species; and their potential to adversely affect SPFC O&M activities. As a result of the categorization shown in Table 4-1, certain species were selected from this master list and designated as either Primary or Secondary species; these are the species that form the foci of this Plan (Table 4-2). The distribution of these species within the SPA, identified using data provided by Cal-IPC (2013b), is shown in Figures 4-1 and 4-2. The criteria used to select species from Table 4-1 and assign these species Primary or Secondary status are summarized below.

Primary species are those that meet the following two criteria:

1) they are likely to occur throughout the SPA (as opposed to being localized within certain regions), and

2) they have a high probability of negatively affecting Conservation Strategy target processes, habitats, or species (i.e., they have a Cal-IPC rating of High [all species] or Moderate [woody species only]), or they have a high probability of negatively affecting SPFC O&M.

Plants that have a negative effect on SPFC O&M were included as Primary species, regardless of their effect on Conservation Strategy measurable objectives, because the elimination or reduction of these species would reduce ongoing SPFC maintenance needs, assist in alleviating channel capacity limitations, and thereby positively contribute to the objectives of the Conservation Strategy. For plants that would negatively affect Conservation Strategy measurable objectives, a less strict criterion was used for assigning Primary status to woody species (trees and shrubs) because, compared to herbaceous and floating aquatic species, woody species are generally more likely to have greater negative effects on riverine geomorphic processes and riparian ecosystem processes that are related to or sustained by geomorphic processes.

Secondary species include plants with a more limited distribution in the SPA, relative to Primary species; or, species that are less likely to negatively affect SPFC O&M or Conservation Strategy target processes, habitats, and species. Although, under certain circumstances, some Secondary species may have similar, or greater, adverse ecological or O&M effects, as compared to Primary species, their distribution is more limited within the SPA and therefore, their effects are also more limited. Additionally, because of their growth habit, size, or other characteristics, some Secondary species (e.g., some annual, herbaceous species) may pose a minimal threat to Conservation Strategy measurable objectives or SPFC O&M. However, outside the SPA, these species do have significant negative effects on ecosystems. Therefore, while not a high priority for this Plan, these species are included in the Plan because they are regarded as problem species in general, and treatment of these species within the SPA would positively contribute to their eradication region-wide or California-wide.

Table 4-2. Primary and Secondary Invasive Plant Species

Status	Criteria	Species
Primary	Species invading at least 5% of any habitat type occurring in the SPA (i.e., "Habitat Invaded" code of A, B, or C for any habitat type shown in Table 4-1), and which is any of the following: • Tree or shrub with Cal-IPC rating of Moderate or High • Any other species with Cal-IPC rating of High • Any species ranked as having a High effect on SPFC O&M activities	• Tree of heaven, *Ailanthus altissima* • Giant reed, *Arundo donax*[1] • Yellow star-thistle, *Centaurea solstitialis* • Brazilian waterweed, *Egeria densa* • Blue gum, *Eucalyptus globulus* • Edible fig, *Ficus carica* • Perennial pepperweed, *Lepidium latifolium*[1] • Water primrose, *Ludwigia* sp. • Purple loosestrife, *Lythrum salicaria* • Crisp-leaved pondweed, *Potamogeton crispus* • Himalayan blackberry, *Rubus armeniacus*[1] • Milk thistle, *Silybum marianum* • Saltcedar, *Tamarix* sp. [1]
Secondary	Species not invading more than 5% of any habitat type in the SPA (i.e., Cal-IPC distribution code of D, U, or blank for all habitat types shown above in Table 4-1), but which is any of the following: • Tree or shrub with Cal-IPC rating of Moderate or High • Any other species with Cal-IPC rating of High • Any species ranked as having a High effect on SPFC O&M activities -OR- • Any Cal-IPC Alert species	• Barbed goat grass, *Aegilops triuncialis* • Alligator weed, *Alternanthera philoxeroides* • Pampas grass, *Cortaderia selloana* • Scotch broom, *Cytisus scoparius* • Stinkwort, *Dittrichia graveolens* • Water hyacinth, *Eichhornia crassipes* • Medusa head, *Elymus caput-medusae* • Fennel, *Foeniculum vulgare* • French broom, *Genista monspessulana* • Shortpod mustard, *Hirschfeldia incana* • Hydrilla, *Hydrilla verticillata* • American frogbit, *Limnobium spongia* • Parrot's feather, *Myriophyllum aquaticum* • Tree tobacco, *Nicotiana glauca* • Scotch thistle, *Onopordum acanthium* ssp. *acanthium* • Ravenna grass, *Saccharum ravennae* • Russian thistle, *Salsola tragus* • Red sesbania, *Sesbania punicea*[1] • Chinese tallowtree, *Triadica sebifera*

Key: Cal-IPC = California Invasive Plant Council; SPA = Systemwide Planning Area; SPFC = State Plan of Flood Control; O&M = operation and maintenance.

Note:

[1] Species distribution previously mapped within SPA.

The list of Primary and Secondary species presented in Table 4-2 should be considered tentative. It is based on the best readily available information on the distribution of these species in the SPA, the relationships of these species to Conservation Strategy measurable objectives, and the potential of these species to negatively affect SPFC O&M. It is expected that Primary and Secondary species will change over time as more data characterizing the distribution of these plants within the SPA are collected and as relationships between particular species and Conservation Strategy measurable objectives are better understood.

The following section describes each of the 32 Primary and Secondary weed species identified in Table 4-2. Appropriate treatment techniques for these species are discussed in detail in Section 5.0 of this Plan.

4.3 Description of Target Invasive Plant Species

The following target invasive plant species descriptions were adapted from *Aquatic and Riparian Weeds of the West* (DiTomaso and Healy 2003) and *Weeds of California and Other Western States* (DiTomaso and Healy 2007); other sources were consulted and cited accordingly. The Cal-IPC Inventory and CDFA ratings for each species are listed in Table 4-1.

4.3.1 Primary Species

Tree of Heaven

Tree of heaven (*Ailanthus altissima*) is a deciduous tree in the Simaroubaceae family. It is native to China and was introduced to the United States as a landscape ornamental, a food source for silkworm (*Bombyx mori*), and a medicinal plant for Chinese immigrants during the Gold Rush. Tree of heaven produces large numbers of winged seeds that disperse by wind and water. Seeds remain viable for only 1 year or less, so tree of heaven does not develop a persistent seedbank. This species is fast growing, reaching heights up to 70 feet. The tree produces long, lateral roots that grow suckers up to 50 feet from the adult tree. A single individual can produce dense clonal stands as large as approximately 1 acre. These large, dense stands degrade wildlife habitat and can adversely affect floodwater conveyance and SPFC maintenance. Persistent manual removal of shoots and roots, followed by an application of herbicide, may be required, because this species readily resprouts from cut stems and roots that are left in contact with moist soil, and cutting or girdling trunks stimulates rapid growth of numerous suckers.

Giant Reed

Giant reed is a perennial, reed-like grass in the Poaceae family. This grass can grow extremely quickly (up to 2 inches a day) and can reach a height of 30 feet (Hoshovsky 1987). The species is considered indigenous to the Mediterranean Basin (Hickman 1993) and was intentionally introduced to southern California in the 1820s for use as erosion control in drainage canals and thatching for roofs (Bell 2002). Giant reed can tolerate a wide range of conditions. It grows best in well-drained soils with an abundance of available moisture. Overall, giant reed is well adapted to the disturbance dynamics of riparian systems. For example, when flood events break up clumps of giant reed and spread the pieces downstream, fragmented stem nodes and rhizomes can take root and establish as new plant clones. The rapid growth rate and strong competitive ability enables giant reed to invade recently disturbed areas quickly and out-compete native vegetation (Hoshovsky 1987); their large, continuous, clonal root masses can cover several acres. Giant reed typically develops dense monocultures, displacing native vegetation, diminishing wildlife habitat, and increasing flooding and siltation. Root masses can become more than three feet thick and are capable of stabilizing streambanks and terraces, ultimately altering flow regimes. Giant reed occurs throughout the Sacramento and San Joaquin Valleys. It is found in riparian areas and floodplains of medium-sized to large streams, from wet sites to dry riverbanks

far from permanent water. It tends to favor low-gradient (less than 2 percent) riparian areas over steeper and smaller channels, but scattered colonies are found in moist sites or springs on steeper slopes.

Giant reed affects hydrologic processes, habitats, and species throughout the SPA. Giant reed displaces native plants and associated wildlife species because of the massive stands it forms (Gaffney and Cushman 1998; Bell 2002). As giant reed replaces riparian vegetation, it reduces habitat and food supply, particularly insect populations, for several special-status species such as least Bell's vireo, southwestern willow flycatcher, and yellow-billed cuckoo (Frandsen and Jackson 1994; Dudley and Collins 1995). Giant reed provides little shading to the instream and bank-edge river habitats, leading to increased water temperatures and reduced habitat quality for aquatic wildlife (Chadwick and Associates 1992). Large stands of giant reed can significantly increase water loss from underground aquifers due to its high evapotranspiration rate, which is estimated at roughly three times greater than that of native riparian vegetation. Giant reed is highly flammable, even when green, and can carry fire into a creek corridor. The dense growth habit of giant reed can more than double the available fuel for wildfires compared to native vegetation (Dudley 2006). Giant reed also alters hydrological regimes and channel morphology by retaining sediments, constricting flows, and limiting lateral migration (Gran and Paola 2001). Spencer (2010) investigated the hydraulic effects of giant reed on flow velocity and direction on Cache Creek and Stony Creek and found that channel roughness was higher when giant reed was present, resulting in higher water surface elevations during flood events.

Yellow Star-Thistle

Yellow star-thistle (*Centaurea solstitialis*) is an erect winter annual (sometimes biennial) in the Asteraceae family. This species is considered one of the most serious rangeland weeds in the western United States and has spread rapidly since its introduction into California around 1850.

Yellow star-thistle grows in open, disturbed sites, grasslands, rangelands, open woodlands, fields, pastures, and roadsides throughout most of California. It has spiny yellow-flowered heads that can grow over 3 feet tall. Taproots grow vigorously early in the season to depths of more than 3 feet, giving plants access to deep soil moisture during the dry summer and early fall months. Flower heads consist of numerous, yellow, disk flowers that produce abundant quantities of seeds capable of remaining viable for up to 10 years under field conditions. Seed germination is closely correlated with rainfall events. Large flushes of seed germinate after the first fall rains, but smaller germination flushes can occur nearly year-round. This species is highly competitive and can develop dense stands that displace native plants. Its long taproot effectively competes with native plants, particularly native perennials, for deep soil moisture during the dry summer months. Infestations reduce wildlife habitat quality and livestock forage value, displace native plants, and decrease native plant and animal diversity. A variety of management techniques (grazing, mowing, burning, etc.) can prevent seed production and control infestations when they are employed for 2–3 consecutive years, but vigilant monitoring and spot eradication may also be required.

Brazilian Waterweed

Brazilian waterweed (*Egeria densa*) is a common aquatic herb in the waterweed (Hydrochartiaceae) family that occurs in lakes, reservoirs, springs, ponds, and slow-flowing streams and sloughs. It is native to Argentina, Brazil, and Uruguay, and has been distributed elsewhere via the aquarium trade. In California, this species occurs below 7,000 feet in elevation in the Sierra Nevada, Central Valley, Central Coast, San Francisco Bay region, and San Jacinto Mountains.

Brazilian waterweed has stems up to 15 feet long that are frequently branched. It is usually rooted in bottom mud, but may be found as free-floating mats or in fragments. It reproduces by rhizomes and plant fragments, and can spread easily along existing watercourses into new habitats when stem fragments break off and float away from the parent plant during active growth in spring. This species' dense underwater growth reduces water flow, which can adversely affect irrigation projects, hydroelectric utilities, and urban water supplies. Beds of this weed also accumulate sediment and reduce the abundance and diversity of native plant seeds in lake bottoms (De Winton and Clayton 1996). Because this species readily spreads via plant fragments, care must be taken during mechanical control efforts to prevent new plants from developing; some herbicides have been moderately effective.

Blue Gum

Blue gum (*Eucalyptus globulus*), of the family Myrtaceae, is native to Australia. This species is the most common Eucalyptus in California, found below 1,000 feet in elevation on the North, Central, and South Coasts, as well as inland throughout the Central Valley. It grows quickly to 150–180 feet tall and displaces native plant communities by creating shade, causing dense leaf litter accumulation, and altering soil chemistry through the addition of chemicals from its leaves. It is long-lived and thrives in a variety of soils, but grows best on deep alluvial soils with ample moisture (Skolmen and Ledig 1990). It typically inhabits disturbed, especially riparian, areas. Blue gum reproduces by seeds released from capsules that remain attached to the tree. Seeds typically fall within 300 feet of the parent plant, although they may disperse to greater distances (assisted by water or animals). Because of its flammable plant compounds, dense growth habit, and copious leaf litter, groves of this species are highly combustible and increase the risk of fire. When trees are cut, the stumps or roots readily develop new shoots; however, continually cutting back regrowth for 4 years or more can eventually kill the tree. Also, applying an herbicide to freshly cut stumps can reduce resprouting.

Edible Fig

Edible fig (*Ficus carica*) is a deciduous tree in the Moraceae family. This species, which grows up to 30 feet tall, is native to southern Arabia and was introduced to California by Spanish missionaries in the mid- to late 1700s. In California, it invades and dominates riparian forests, streamside habitats, levees, and canal banks in and around the Central Valley, surrounding foothills, the South Coast, and the Channel Islands. Edible fig reproduces by seed and by vegetative growth (root and stem fragments). It prefers soils that stay moist throughout summer. This species can form dense thickets that outcompete native trees and understory vegetation. Such thickets are difficult to control because cutting or injuring the tree typically stimulates the development of numerous root sprouts.

Perennial Pepperweed

Perennial pepperweed (*Lepidium latifolium)* is an herbaceous perennial plant in the Brassicaceae (Mustard) family, native to southeast Europe. This plant can invade a wide variety of habitat types, including riparian, marsh, and floodplain habitats. It is found throughout California and can form large stands that exclude native plant species, thereby decreasing plant diversity and structural complexity (Cal-IPC 2013a). Perennial pepperweed seeds spread via wind, water, and waterfowl; the plant also reproduces vegetatively from underground stems and root fragments. Its root system is extensive, reaching up to 9 feet deep, giving it a competitive advantage over native plants for access to water and nutrients. However, its deep roots do not hold soil together well and may contribute to erosion and water quality issues (DiTomaso et al. 2013). Perennial pepperweed may also transport salts from lower soil horizons, drawing the salts through its roots to its leaves, then exuding and depositing them on the soil surface. This characteristic effect of pepperweed can shift plant composition to favor halophytes (salt-loving plants) (Renz 2000). Dense infestations are difficult to control; seasonal flooding during the growing season, mowing at bud set, and follow-up herbicide treatments of regrowth can reduce populations.

Water Primrose

Water primrose (*Ludwigia* sp.), of the Onagraceae family, is a widespread genus, with several species occurring throughout California, including in the Central Valley, Sierra Nevada foothills, and the San Francisco Bay region. One species is native to California (*L. peploides*), and several others have been introduced from the central and eastern United States and South America. All species, even the native species, have similar ecological effects, and all are considered invasive. Also, *Ludwigia* species readily hybridize, so that species thought to be native to California may, in fact, be hybrids with nonnative species.

Water primrose is an aquatic weed that forms dense mats above and below the water surface in shallow, stagnant, nutrient-rich pools and in areas with hydrological disturbance, such as flood control channels, irrigation ditches, and irrigation ponds (Verdone 2004). These plants can also persist in drier transition zones. They reproduce both by seed and vegetatively. Creeping stems and stem fragments that can establish new plants are dispersed by water and soil movement, and by animals. Once established, water primrose can spread very rapidly. The plant escaped from ornamental/domestic use and continues to spread via animals, boats, flooding, and flowing water (Verdone 2004). Heavy infestations of water primrose can alter water flow, cause sediments to accumulate, and diminish water quality (Verdone 2004). This weed can also outcompete native aquatic and wetland plant species, reducing species diversity and degrading waterfowl habitat (Verdone 2004). Areas that were once open water habitat become closed mats of water primrose (Verdone 2004). Because of its propensity to propagate by stem fragments, it is difficult to control; herbicide application followed by mechanical removal has been effective in some areas.

Purple Loosestrife

Purple loosestrife (*Lythrum salicaria*) is a perennial wetland herb in the Lythraceae family. It is typically less than 5 feet tall, with showy spikes of reddish-purple flowers. This species is native to Eurasia and was introduced into the northeastern United States in the early 1800s. It is found in scattered freshwater wetlands in northern and central California. Infestations occur in

Humboldt, Mendocino, Modoc, Shasta, and Siskiyou Counties, as well as in counties in the Sacramento Valley and San Francisco Bay regions.

Purple loosestrife is common in disturbed wetland habitats, including along streambanks, riverbanks, and other areas within channels (e.g., cobble bars); the edges of ponds, lakes, and reservoirs; flooded areas; ditches; and roadsides. This weed produces copious seeds that contribute to an immense seedbank. Once established, the plant forms extensive monospecific stands; plants enlarge at their base each year with more stems, sometimes becoming a rounded, bush-like clump of 30 to 50 stems arising from a single root stock. This species can rapidly degrade wetlands, displace native vegetation, and adversely affect wildlife species that rely on wetlands for habitat and food. Purple loosestrife also clogs waterways and can alter the hydrologic and soil conditions of wetland pastures, meadows, and irrigation systems. Cut stems can reroot under certain conditions, and flooding can encourage the species to spread. Mechanical removal of the plant before seed maturation occurs helps to reduce the spread of the plant.

Crisp-Leaved Pondweed

Crisp-leaved pondweed (*Potamogeton crispus*) is a fast-growing, aquatic perennial in the Potamogetonaceae family. This species is native to Eurasia and was introduced to California sometime before 1900. It is now widespread in California, occurring in rivers, canals, ponds, lakes, and marshy areas in the Central Valley. It is tolerant of slightly brackish waters, and is restricted to alkaline, calcareous waters. Crisp-leaved pondweed primarily reproduces vegetatively, forming vegetative propagules (turions) that lay dormant during summer and germinate when most native vegetation has died back. The species also produces viable seeds that are dispersed by water currents and waterfowl. It grows in dense mats that cover large areas and impede water flow, clog irrigation canals, and can deplete nutrients that are important for wildlife. Long-term management requires reducing or eliminating turions (by cutting pondweed at the sediment surface) to interrupt the plant's life cycle (McComas and Stuckert 1996). Mechanical treatments and application of herbicide can also be effective in managing this species.

Himalayan Blackberry

Himalayan blackberry is a sprawling, robust shrub in the Rosaceae family, native to western Europe. In California, it occurs in riparian areas and, occasionally, in upland areas with persistent soil moisture, throughout the Coast Ranges, Central Valley, and Sierra Nevada. Flowers are characteristic of the rose family and are white to pinkish in color. This plant produces fruit from July to September and can produce 7,000 to 13,000 seeds per square yard. Mature fruits are edible and compose a small part of the diet of both native and nonnative wildlife. This method of seed dispersal helps this invasive blackberry spread rapidly and dominate native species of blackberry, such as California blackberry (*Rubus ursinus*). Himalayan blackberry can be distinguished from California blackberry by its taller, more robust stature and larger thorns and berries. The flower petals of California blackberry are narrower at the base and do not have the crinkled appearance of the Himalayan blackberry flower (DiTomaso and Healy 2007).

Himalayan blackberry is common in riparian areas and tolerates periods of inundation by fresh or brackish water. Such periodic flooding can produce long-lived, early seral plant communities that are conducive to the growth and spread of blackberries. This species is a strong competitor and rapidly displaces native plants by forming dense, impenetrable thickets that limit the growth of understory plants. Small populations may be controlled by manual removal; however, removing only the aboveground portion of the plants usually stimulates the growth of root sprouts. To control Himalayan blackberry, all aboveground biomass should be first cut to the ground surface early in the growing season (April–May) and removed from the site. The cut vegetation should then be allowed to resprout and the new growth treated with a foliar application of herbicide in early spring and/or late summer. Regrowth has also been controlled by grazing sheep and goats in areas where mature plants have been removed (Bossard et al. 2000).

Milk Thistle

Milk thistle (*Silybum marianum*) is an erect winter or summer annual or biennial in the Asteraceae family. This species is native to the Mediterranean region and has been used medicinally for at least 2,000 years. In California, milk thistle occurs on the North and South Coasts and in the North and South Coast Ranges, Central Valley, San Francisco Bay region, and Channel Islands, to an elevation of 1,600 feet.

This plant generally grows up to 6 feet tall and blooms from April through July. It reproduces from seeds that are dispersed by wind, water, soil movement, and animals, and which are also found in crop seed. Most seeds germinate after the first fall rain, but ungerminated seeds can remain viable for several years. Disturbances that expose bare soil (e.g., heavy grazing and fire) generally improve milk thistle germination. Milk thistle often grows in dense, competitive stands, mainly on disturbed sites in pastures and fields, as well as along levees, roadsides, and similar disturbed areas. It is uncommon in undisturbed habitats. After it reproduces and dies, milk thistle skeletons can remain standing for months and preclude the regeneration of native plants. Burning can encourage seed germination and establishment of this plant. Seedlings can be discouraged through disking, and the development of milk thistle stands can be controlled by removing mature plants before flowers open.

Saltcedar

Saltcedar is a tree in the Tamaricaceae family that was introduced to the United States from eastern Asia approximately 200 years ago. Since its introduction, saltcedar has become established in several communities throughout the country, particularly in the Southwest, where it has displaced native riparian vegetation in slow-moving riverine and aquatic habitats. This tree grows in marshes, on riverbanks, in springs, and on floodplains, in mesic habitats with a high water table. Within the SPA, it occurs in the southern San Joaquin Valley and in scattered locations in the northern Sacramento Valley (e.g., Colusa and Glenn Counties).

Saltcedar has numerous, large basal branches that can grow to approximately 20 feet tall (Carpenter 1998). Its flowers produce many tiny, tufted seeds that disperse by wind and water (DiTomaso 1998). It can propagate from seed, buried or submerged stems, and adventitious roots, even after the aboveground portion of the plant has been removed (Zouhar 2003) Saltcedar is tolerant of highly saline habitats, and it concentrates assimilated salt in its leaves. Over time,

as leaf litter accumulates under the plants, the surface soil can become highly saline and impede future colonization by native plant species (Carpenter 1998). Saltcedar's roots can also drastically reduce available surface and groundwater. The combined effects of this plant cause a decrease in available water and an increase in salinity in the upper soil profile, both of which can inhibit the growth of native vegetation (DiTomaso and Healy 2007). In addition, saltcedar traps and stabilizes alluvial sediments, narrowing stream channels and causing more frequent flooding (Bossard et al. 2000). Efforts to cut or burn saltcedar to the ground have proven ineffective, because the plants will typically regenerate from the roots. Removing and/or chemically treating the root system has proven to be effective at managing invasive populations; follow-up treatments may be required. Saltcedar seedlings are easily pulled by hand and should be removed during the first year to prevent reinfestation. Young seedlings are not competitive in the presence of dense native vegetative cover, so establishing native cover after removing saltcedar discourages reinfestation (DiTomaso and Healy 2007).

4.3.2 Secondary Species

Barbed Goat Grass

Barbed goat grass (*Aegilops triuncialis*) is an annual grass in the Poaceae family that invades grassland, rangeland, and oak woodland habitats. This species is distributed throughout grassland and oak savanna/oak woodland habitats in the Coast Ranges, the San Francisco Bay region, the northern Sierra Nevada and Cascade Range foothills, the Sacramento Valley, and the northern San Joaquin Valley, generally below 3,000 feet in elevation. Evidence suggests that this species is actively expanding its range throughout California. Barbed goat grass successfully competes with native forbs and desirable annuals; its seeds are adept at germinating and can send roots down through thatch or bunch grasses. Once it is mature, the plant is essentially unpalatable to livestock, and may cause them severe injury: the disarticulated joints of the plant are sharp and can pierce the stomach linings of livestock when ingested. Early detection of barbed goat grass is critical to controlling infestations. Controlled burns during late spring, when seed heads are still attached to stems, is effective if conducted for 2 consecutive years. Herbicide treatment of small patches is effective, but is not a viable way to control large infestations. Mowing and grazing are not effective; these methods appear to increase weed density because they also eliminate other plants that compete for the same resources (Davy et al. 2008).

Alligator Weed

Alligator weed (*Alternanthera philoxeroides*) is an herbaceous perennial in the Amaranthaceae family. It is native to South America and was introduced to the United States via the aquarium trade. In California, it is found in the San Joaquin Valley (Tulare and Kings Counties) and in Los Angeles County. This species can invade lakes, streams, canals, ponds, marshes, irrigation ditches, and other slow-moving watercourses. Although typically found in aquatic habitats, alligator weed can also occur in terrestrial habitats. The aquatic form has hollow, floating, emergent and submerged stems, whereas the terrestrial form has solid stems. The plant becomes rooted in soils under shallow water and can form dense, interwoven, floating mats that extend over the surface of deeper water. This species reproduces vegetatively: the dense mats can break apart, enabling the plant to colonize new sites. Floating mats disrupt the natural ecology of infested sites by reducing light penetration and crowding out native species. Mechanical removal

is effective only if all plant parts are carefully removed; buried stems can regenerate from depths of up to 1 foot, so incomplete removal can facilitate the spread of the weed.

Pampas Grass

Pampas grass (*Cortaderia selloana*) is a large, long-lived (15–20 years) perennial grass of the Poaceae family. It was introduced from South America as an ornamental plant and for erosion control. It has escaped cultivation and has spread along sandy, moist ditch banks throughout coastal regions of California, as well as inland, in regions such as the Central Valley (especially Butte, Yolo, Sacramento, and Stanislaus Counties). Pampas grass has long basal leaves and tall, showy, plume-like inflorescences. It has dense, fibrous roots that penetrate more than 10 feet deep, and lateral rhizomes that can spread to a diameter of more than 18 feet. Each seed-bearing plume can produce up to 100,000 seeds, which can be dispersed long distances by wind and human activities. Sites with bare, moist, sandy soil are the most favorable for seed establishment. Pampas grass competes with native vegetation and, when it establishes in forests, with the seedlings of trees, ultimately slowing their establishment and growth. This species is also considered a fire hazard because it accumulates large quantities of dry leaves, leaf bases, and flowering stalks. Manually cutting or chopping out mature plants below the crown can kill the plant.

Scotch Broom

Scotch broom (*Cytisus scoparius*) is a long-lived perennial shrub in the pea (Fabaceae) family. It is native to Europe and North Africa and was introduced to California in the 1850s as an ornamental shrub. Later, it was used to stabilize dunes to prevent erosion. It is found along the California coast from Monterey north to the Oregon border. It is also prevalent in El Dorado, Nevada, and Placer Counties in the Sierra Nevada foothills. This plant grows 6–10 feet tall, has sharply angled branches, and reproduces by seed when it reaches 2–3 feet tall (2–3 years old). Scotch broom grows in sunny sites with dry, sandy soil, spreading quickly through disturbed areas such as pastures, forest edges, riverbanks, and roadsides. It is a strong competitor and displaces native plant and forage species by forming dense, monospecific stands. Seedlings are also shade-tolerant and can therefore outcompete trees, making reforestation difficult. Established populations are difficult to eliminate because of the longevity of the species' seedbanks. Cutting plants to ground level and grazing (by goats) can help reduce resprouting. Prescribed burns do not prevent resprouting and may stimulate seed germination.

Stinkwort

Stinkwort (*Dittrichia graveolens*) is an erect, fall-flowering, aromatic annual in the Asteraceae family that is native to the Mediterranean region. It was first reported in 1984 in Santa Clara County, and by 2012 had spread to 36 of the 58 counties in California. This weed is quickly spreading throughout California and the Central Valley (Brownsey et al. 2012). It grows in disturbed places, roadsides, pastures, fields, riparian woodlands, levees, washes, and the margins of wetlands and tidal marshes. It prefers well-drained, gravelly soils and thrives in arid conditions, but can also do well at the margins of wetlands. This plant grows to about 2.5 feet tall, with sticky, glandular-haired foliage and flower heads that consist of short, yellow, ray flowers and reddish disk flowers. Unlike most summer and late-season annuals, it flowers and produces seeds from September to December; one plant can produce up to 30,000 seeds, up to

90% of which may be viable (Santa Clara County Weed Abatement Program 2009). Stinkwort seeds may remain viable in the soil for 2 to 3 years, and they are capable of germinating year-round, so the weed can quickly eliminate open spaces and pastureland. Seeds are likely spread by wind, mammals, birds, and human activity (Brownsey et al. 2012).

Although only limited information about stinkwort is available, this weed likely represents a habitat-transforming threat to native species diversity and abundance. Because its root system is shallow, hand removal is the most effective control method. Mowing very close to the ground and applying certain herbicides may also be effective. Employing management actions before seed production could minimize the unintentional spread of this weed. In areas where infestations have established, 2 to 3 years of treatment may be necessary to deplete the seedbank.

Water Hyacinth

Water hyacinth (*Eichhornia crassipes*) is an aquatic herb in the pickerel-weed (Pontederiaceae) family that occurs in both natural and human-made freshwater ponds, sloughs, and waterways. It is native to South America's Amazon River basin and has spread throughout all tropical and subtropical countries. In California, this species occurs below 660 feet in elevation in the Central Valley, in the San Francisco Bay Area, along the south coast of California, and in the Peninsular Ranges.

Water hyacinth produces stout, erect stems that may be greater than 12 inches long. The stems are swollen and filled with a spongy tissue that helps the plant float on water. Its leaf blades are generally oval to round and less than 4 inches wide, and its funnel-shaped flowers range in color from pale to deep lavender to blue or white. Water hyacinth reproduces by fragmentation of rhizomes and stems and by seed. This species' rapid growth allows it to quickly dominate aquatic systems, displacing native aquatic plants, degrading habitat for waterfowl, and creating ideal breeding habitat for mosquitoes. Water hyacinth's high evapotranspiration rates increase water loss from aquatic systems. Because this species readily spreads via plant fragments, care must be taken during mechanical control efforts to prevent new plants from developing; glyphosate foliar spray can help control water hyacinth.

Medusa Head

Medusa head (*Elymus caput-medusae*) is a slender annual grass in the Poaceae family. In 1950, Medusa head was reported from only six counties in northwestern California. It now occurs in the North Coast Ranges, Cascade Range, Klamath Ranges, Sierra Nevada, Central Valley, South Coast Ranges, northern South Coast (Santa Barbara County), and Channel Islands, up to 7,000 feet, and is expanding in range.

Medusa head grows up to 2 feet tall. It matures 2–4 weeks later than most other annual grasses, displaying distinctive patches of green in otherwise brown grassland. Fibrous roots grow rapidly throughout the cool season, depleting upper soil moisture early in the growing season and accessing deep soil moisture late in the season. Medusa head is predominantly self-pollinating and reproduces by seed. Seed production is prolific. Seeds disperse locally by wind and water, and to greater distances by soil movement and human activities, and by clinging to the feet and fur of animals. Most seeds germinate in fall after the first rain, but some seeds remain dormant or

germinate in winter or spring. Seeds can germinate in dense litter under low-moisture conditions and without directly contacting a moist substrate.

Medusa head invades grasslands, oak savannahs, oak woodlands, and chaparral communities, growing best on clay soils or where deep soil moisture is available late in the growing season. Medusa head frequently outcompetes desirable nonnative annual grasses and native grasses and forbs. Once established, it can reach densities of nearly 200 plants per square foot. After seed set, the silica-rich dead plants persist as a dense litter layer for three or more growing seasons, encouraging further Medusa head dominance by preventing germination and survival of native species. The high silica content of this weed makes it unpalatable to livestock and wildlife, except in early spring. However, dense infestations tend to be completely avoided by livestock, even when the young plants are otherwise palatable, because of the dense litter layers. In infested areas with favorable growing conditions (i.e., soils with high clay content), Medusa head can approach 100% cover if left unmanaged. When surrounding vegetation has dried and Medusa head seeds have not matured, controlled burns that are slow and hot can significantly reduce populations. Disking or plowing before seed set also can greatly reduce stands.

Fennel

Fennel (*Foeniculum vulgare*) is an erect perennial herb in the Apiaceae family. This plant grows 4–10 feet tall and has finely dissected leaves. It is a culinary spice native to southern Europe and the Mediterranean region. It likely spread in the United States by escaping cultivation, and has occurred in California for more than 100 years. In this state, it is found in mesic locations below 2,000 feet in elevation. It colonizes disturbed areas, especially weedy sites adjacent to fresh or brackish water, riparian areas, pastures, abandoned lots, and roadsides.

Fennel reproduces from both root crowns and seeds. Seed production is prolific, peaking in August and September. Seeds are dispersed by water and animals, and by humans when seeds cling to clothing or mud on vehicles. Fennel is a competitive invader that can preclude the establishment of native plant species. It drastically alters the composition and structure of many plant communities by outcompeting native species for light, nutrients, and water, and can further outcompete other plants by forming dense, uniform stands. Manual removal of individual roots and plants can control infestations with limited numbers of plants. Two consecutive years of fall burning, followed by application of herbicide to new foliage, can control large stands.

French Broom

French broom (*Genista monspessulana*) is a tall (up to 10 feet) evergreen shrub in the pea (Fabaceae) family. It is native to the Mediterranean region, and was introduced to California in the mid-1800s as a landscape ornamental. Its current distribution in California includes the Coast Ranges, Sierra Nevada foothills, Transverse Ranges, Channel Islands, and San Francisco Bay region. French broom frequently occurs in disturbed places such as riverbanks and road cuts, but it can also invade grasslands and open-canopy forests. It prefers siliceous soils, but can grow in various soil moisture conditions. This species is an aggressive invader that produces abundant seeds and will resprout from the root crown if it is cut, grazed, or burned. Seeds are dispersed by ants, birds, mammals, human activity, and water movement. French broom displaces native plant and forage species and can dominate plant communities by forming dense, monospecific stands.

Eradication is made difficult by the longevity of the species' seedbank and the toxicity of its foliage to livestock. An integrated removal method that combines mechanical removal and herbicide application, with many follow-up treatments, may be the most effective way to control this species.

Shortpod Mustard

Shortpod mustard (*Hirschfeldia incana*) is a biennial, short-lived perennial forb in the Brassicaceae family, native to Europe. In California, it occurs in coastal scrub, grasslands, and disturbed areas, such as fields, pastures, ditch banks, and dry washes. It has also invaded shrublands and riparian areas. Shortpod mustard forms a flat basal rosette, and its stem bases and leaves are moderately covered with stiff hairs. It reproduces by seeds that fall near the parent plant, but seeds can also be dispersed by water, agricultural activities, and animals. This weed reduces the biomass and fecundity of coexisting species and competes with native annual plants for water. Manual removal or disking before seeds develop can control populations of shortpod mustard. Control methods implemented over a period of several years may eventually exhaust the seedbank.

Hydrilla

Hydrilla (*Hydrilla verticillata*) is a perennial, submersed aquatic plant in the Hydrocharitaceae family. It was introduced to the United States from Eurasia via the aquarium trade. In California, it occurs in the Mojave and Colorado Deserts, on the South and Central Coasts, and in the San Francisco Bay region and Central Valley. Hydrilla plants consist of a series of individual green stems that bear tightly packed whorls of two to eight triangular leaves at each node. This species has distinctive subterranean vegetative propagules (tubers) and swollen shoots (turions) in its leaf axils. Hydrilla is capable of infesting any freshwater aquatic system; it is easily spread by people and wildlife. The plant reproduces vegetatively from stem fragments, rhizomes, and root crowns, and through the production of tubers and turions. Growth is enhanced in water with agricultural runoff containing elevated nutrient levels. Hydrilla forms large mats that fill the water column and can block or severely restrict water flow (for example, in canals). It also crowds out native plants, decreases habitat for fish and wildlife, and degrades water quality. Hydrilla can be removed by raking or seining it from watercourses, but it will reestablish from any remaining fragments, roots, tubers, or other vegetative structures.

American Frogbit

American frogbit (*Limnobium spongia*) is a perennial plant of the Hydrocharitaceae family. It can be rooted or free-floating, occurring in rivers, streams, and other water bodies. In 2003, this South American native was documented in two infestations in California, in Arcata and Redding, where it was presumably introduced through the aquarium trade (Anderson 2011). By 2007, it had spread to the San Joaquin River in Fresno, and the species was found in the Sacramento–San Joaquin River Delta (Delta) in 2008 (Anderson 2011). It is currently found in the San Joaquin River and in the Delta. American frogbit forms thick mats that choke waterways and cause negative impacts on pumping and irrigation systems. The mats also reduce dissolved oxygen in the water and block light throughout the water column, adversely affecting fish and other organisms. In infested areas, open water becomes inaccessible to wildlife. American frogbit can spread rapidly by quickly producing seeds and vegetative growth. The small, floating seeds

easily disperse along watercourses by wind, currents, tidal action, and waterfowl. Mechanically removing all parts of the plant (i.e., shoots and stolons) can be effective if the plants have not yet produced many seeds, but physical control of a large infestation may require several years of repeated treatment.

Parrot's Feather

Parrot's feather (*Myriophyllum aquaticum*) is a stout, aquatic perennial of the family Haloragaceae. It was introduced from South America via the aquarium trade. It forms dense mats of intertwined brownish stems (rhizomes) in freshwater lakes, ponds, canals, and slow-moving waters of northern and central California. Parrot's feather reproduces vegetatively from its brittle and easily fragmented stems, which settle in sediment and produce new plants. These fragments can also disperse by waterfowl, other wildlife, and water. This species outcompetes native aquatic plants, often eliminating or significantly reducing their numbers in infested sites. The weed also forms dense mats that clog waterways, block irrigation pumps and water intakes, and cause similar adverse effects on agricultural and water management activities. This species may also significantly alter the physical and chemical characteristics of lakes and streams. Repeated mechanical harvesting can help reduce stem densities, but stem fragments easily develop into new plants.

Tree Tobacco

Tree tobacco (*Nicotiana glauca*), of the Solanaceae family, can be a tree or a shrub that stands 10–20 feet tall. This native of South America was introduced to California about 100 years ago. It is now found throughout California, including in the Central Valley, at elevations up to 5,000 feet. Tree tobacco grows on disturbed soils, vacant lots, and roadsides, and along streams and other riparian areas, such as washes and disturbed flats. It reproduces prolifically from seeds that are dispersed by water, soil movement, and human activities. All plant parts contain alkaloids that are highly toxic to humans and livestock when ingested. Tree tobacco competes with native plants, but its ability to outcompete native plants is not well documented. Mechanical removal is effective, but roots must be removed to prevent resprouting. Certain herbicides have also been shown to be effective (Oneto et al. 2004).

Scotch Thistle

Scotch thistle (*Onopordum acanthium* ssp. *acanthium*) is a biennial of the Asteraceae family, introduced to California from Eurasia. This plant grows 4–9 feet tall, has a thick, long taproot and broad stems, and is covered with wooly, pale-gray hairs. Scotch thistle inhabits disturbed sites, roadsides, fields, annual grasslands, pastures, rangelands, canals, ditch banks, and riparian areas throughout California. It reproduces from seeds that are dispersed short distances by wind and animals and greater distances by water, livestock, and humans. Most seeds germinate after the first fall rain, but seeds can germinate year-round. Large infestations of Scotch thistle can form tall, dense, impenetrable stands that outcompete native plants for resources. The long taproot (1 foot long or more) may affect soil moisture levels and allow Scotch thistle to outcompete native grasses that rely on water close to the surface. Minimizing open gaps and bare ground can discourage invasion by this species. Manually removing Scotch thistle before seeds mature can control small populations. Establishing or encouraging perennial grasses can discourage growth of Scotch thistle seedlings by creating strong competition for moisture.

Ravenna Grass

Ravenna grass (*Saccharum ravennae*) is a large perennial grass in the Poaceae family. It is an escaped horticultural plant from Eurasia that is rapidly spreading along Cache Creek in the Sacramento Valley. It establishes in disturbed areas and prefers moist places, such as marshes and riparian habitats. Because its growth habit is similar to that of giant reed and pampas grass, it has similar ecological impacts where it occurs. Little is known about its invasiveness and distribution, but it is considered to be an imminent problem. Its seeds are dispersed by wind and water. It alters fire dynamics, light availability, soil moisture, and the nutrient content of soils, as well as accumulating sediment. Ravenna grass may also alter streambank erosion patterns and encourage flooding. It can grow on more exposed soils than many other riparian species, so it may add significant biomass to swift streams. In some areas, it has formed monospecific stands that may outcompete native vegetation. Little is known about effective control mechanisms, but repeated mechanical and herbicide treatments may be necessary to prevent resprouting.

Russian Thistle

Russian thistle (*Salsola tragus*) is a tumbleweed-forming, spiny, summer annual in the goosefoot family (Chenopodiaceae), native to Eurasia. Russian thistle occurs throughout California, colonizing disturbed or moist areas where it can create large, monospecific stands. In general, it competes poorly with other vegetation, so it typically does not occur outside areas of bare soil or recent disturbance.

Russian thistle reproduces by seeds that are dispersed when the plant dries and breaks off at the base to form tumbleweeds. Tumbleweeds can build up in large drifts, clog drainages and roadways, and contribute to increased fire frequency or intensity. Seeds germinate throughout spring and early summer months, even in years with little to no precipitation. This species can therefore be especially problematic during periods of drought when other annual vegetation does not germinate. Although the very young seedlings are soft, nutritious, and edible for livestock, later stages of growth produce tough, spiny foliage that is often not eaten by grazing or browsing animals unless other forage species are unavailable. Also, the mature foliage contains high concentrations of oxalates, which can be toxic to livestock (DiTomaso and Healy 2007). Although Russian thistle seeds are numerous, they are generally short-lived (approximately 2 years), so control measures can be successful at eradicating infestations if repeated long enough to fully exhaust the seedbank (DiTomaso and Healy 2007). Properly timed disking of seedlings can prevent seed production and control infestations, but it may take up to 2 years to deplete the seedbank.

Red Sesbania

Red sesbania is a deciduous shrub or small tree in the pea family (Fabaceae) that generally flowers from June to August in California. The long-lasting flowers are orange to reddish in color and are characteristic of the legume family. This native of South Africa was introduced to the United States as an ornamental, then escaped cultivation to become a wildland invader. It grows up to 13 feet tall and forms thick, impenetrable clusters in riparian areas (DiTomaso and Healy 2007). This species predominantly inhabits streambanks, but also dominates the edges of ponds, marshes, canals, gravel bars, and instream islands. Currently, it is found in the southern Sacramento Valley (American River Parkway), the San Joaquin Valley (Suisun Marsh and San

Joaquin River Parkway), and the southern North Coast Ranges; it may also occur elsewhere below 150 feet in elevation. New colonies tend to establish along the banks of rivers and creeks. New colonies establish in riparian areas and spread through production of seeds and seed pods that float downstream and germinate in saturated soils. Red sesbania typically reproduces within 2 years, and is capable of producing thousands of viable seeds within a few months, leading to rapid spread of the species (DiTomaso and Healy 2007). Also, red sesbania is moderately shade-tolerant and can establish itself in the shade of other native riparian vegetation, allowing it to easily attain community dominance.

This species displaces native plants, contributes to bank erosion and flooding, and diminishes wildlife habitat. Mechanical, biological, and chemical controls have all proven effective at controlling the spread of red sesbania. The root system of red sesbania is relatively shallow and easy to remove, especially in saturated soil, making mechanical removal of young plants a feasible means of control. Mechanical removal and maintenance of red sesbania may require up to 5 successive years to effectively eradicate an infestation. Targeting small, upstream populations of red sesbania has proven most effective at slowing the spread of the invasive plant along riparian corridors. Plants in standing water can also be cut below the water line to help discourage regrowth (DiTomaso and Healy 2007).

Chinese Tallowtree

Chinese tallowtree (*Triadica sebifera*) is a fast-growing deciduous tree in the Euphorbiaceae family. This native of eastern Asia is found in riparian and wetland areas of California. It grows to 50 feet tall and has milky sap and pendent leaves. It can aggressively invade both disturbed and undisturbed terrestrial, wetland, and riparian plant communities. It reproduces by seeds that are dispersed by animals (especially birds), water, and human activities. Large stands displace native vegetation and can significantly alter soil nutrients: when its leaf litter decomposes, levels of nitrogen, phosphorous, and other mineral nutrients increase while magnesium and sodium levels decrease. Chinese tallowtree tolerates shade, drought, salinity, and flooded conditions. Manually removing trees and seedlings can control infestations, but application of herbicides may be necessary to prevent the stumps and roots from resprouting.

5.0 Invasive Plant Treatment

This section describes general permitting considerations for invasive plant treatments, recommended BMPs for invasive plant treatment, and a variety of techniques that can be effectively used to treat invasive plants, including specific recommendations for the four Initial Priority Species. This information is based on current DWR practices employed by DFM/FMO and the Maintenance Yards, supplemented by information from other sources such as Cal-IPC (Cal-IPC 2012) on best practices for invasive plant treatment.

5.1 Regulatory Permitting Requirements

Agencies that may have regulatory authority over invasive plant control activities within the SPA include USACE, USFWS, the National Marine Fisheries Service (NMFS), CDFW, the Central Valley Regional Water Quality Control Board (RWQCB), the State Historic Preservation Officer (SHPO), the California State Lands Commission, and CVFPB. A comprehensive discussion of the above agencies' permitting requirements for SPFC O&M activities, including vegetation and invasive plant management, is found elsewhere (AECOM 2011); however, the permitting requirements of the agencies most likely to review and issue permits for DWR's invasive plant management efforts are summarized below.

5.1.1 U.S. Army Corps of Engineers

Control efforts that involve soil excavation, stockpiling, or other activities, such as mechanized clearing, that could affect the substrate of a river, lake, or wetland could require permits from USACE under Section 404 of the Clean Water Act or Section 10 of the Rivers and Harbors Act. Many of DWR's SPFC O&M activities would likely qualify for authorization under USACE's Nationwide Permit (NWP) 3, which covers routine maintenance activities. Before an NWP is issued, USACE requires project compliance with additional regulations, such as the Magnuson-Stevens Fishery Conservation and Management Act for Essential Fish Habitat (regulated by NMFS), and the Migratory Bird Treaty Act (regulated by USFWS). As the lead agency for permit issuance, USACE would ensure project compliance with ESA (regulated by USFWS and NMFS) and the National Historic Preservation Act (regulated by the SHPO). Whenever a Section 404 permit is required by USACE, Section 401 certification is required by the RWQCB.

For larger projects (more than 10 acres) or those that do not qualify as routine maintenance under NWP 3 because of their location or potential species impacts, it may be possible to obtain a regional or programmatic general permit. Regional General Permits and programmatic general permits are long-term permits developed to streamline the USACE regulatory process for ongoing activities that cause minimal individual or cumulative environmental impacts. These permits are issued for a category or categories of activities and are contingent on compliance with specific environmental protective measures to ensure that environmental impacts are minimized.

5.1.2 Regional Water Quality Control Board

Any invasive plant management activities that require a Section 404 permit from USACE also require Section 401 certification or a waiver from the RWQCB before they can be initiated. In addition, the RWQCB has permitting, administrative, and enforcement authority for the National Pollutant Discharge Elimination System (NPDES) program under Section 402 of the Clean Water Act.

Under California's NPDES program, projects that disturb 1 acre or more of soil or projects that disturb less than 1 acre but are part of a larger common plan of development that, in total, disturbs 1 acre or more, are required to obtain coverage under the State's general permit for discharges of stormwater associated with construction activity. Construction activities subject to this general permit include clearing, grading, and disturbances to the ground such as stockpiling or excavation. The construction general permit requires the development and implementation of a Stormwater Pollution Prevention Plan. If construction site compliance is not covered under a Section 401 water quality certification, an NPDES/402 permit may be required.

5.1.3 U.S. Fish and Wildlife Service and National Marine Fisheries Service

If activities that require a federal permit, such as a USACE Section 404 permit or Section 10 permit, have the potential to result in the "take" of a federally listed species, compliance with ESA is accomplished by the lead federal agency (typically USACE) through consultation with USFWS or NMFS under ESA Section 7. "Take" is defined under ESA as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." USFWS consultation is required for terrestrial species. Consultation with NMFS is required for marine and anadromous aquatic species (e.g., salmonids), whereas USFWS consultation is required for other aquatic species.

For activities that do not require a USACE permit or other federal action, but that could still result in "take" of a federally listed species, incidental take authorization must be obtained from USFWS and/or NMFS under ESA Section 10. Applications for incidental take authorization are initiated by submitting a Habitat Conservation Plan that is designed to offset and mitigate the harmful effects that a proposed activity might have on a listed species.

5.1.4 California Department of Fish and Wildlife

Section 1600 et seq. of the California Fish and Game Code provides CDFW with jurisdiction over activities that would alter the bed or bank of a river, lake, or stream. In many cases, the protections afforded by Section 1600 overlap with similar provisions of Clean Water Act Section 404 and Section 401; however, CDFW's jurisdiction under Section 1600 also includes adjacent floodplain and riparian vegetation, which may not be otherwise regulated under the Clean Water Act. Activities that would alter the bed or bank of a river, lake, or stream or remove adjacent floodplain or riparian vegetation require a Lake and Streambed Alteration Agreement from CDFW.

As described in Section 2 of this Plan, CDFW and DWR have executed an RMA that streamlines compliance with Section 1600 because much of the work performed by the Maintenance Yards

occurs in the stream zone. The RMA outlines a process that allows CDFW to annually review DWR's maintenance work on flood control projects to ensure that the work does not adversely affect fish and wildlife resources. For maintenance work that is not expressly covered under the RMA, DWR must obtain an individual Lake and Streambed Alteration Agreement before the work may commence. Additionally, if any vegetation management activities could result in take of a species listed under CESA, those activities would not qualify for authorization under the RMA, and an Incidental Take Permit for the project would be required, under California Fish and Game Code Section 2080. The California Fish and Game Code defines "take" as "hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill."

5.2 Best Management Practices for Invasive Plant Treatment

Vegetation management projects that involve invasive plant control may, as described above, require permits from one or more resource agency. In these cases, permit authorizations will typically contain a series of conditions that dictate how the work will be executed to avoid or minimize adverse effects on regulated species or habitats. SAA's with CDFW can contain standard avoidance and minimization measures that DWR must implement for all SPFC maintenance activities, including invasive plant control

Aside from measures specified by the SAA, which focus on actions to be implemented during vegetation management activities to avoid and minimize adverse effects on sensitive biological resources, additional BMPs may be implemented by DWR to minimize the probability of invasive plant introduction and spread. Proactive prevention of invasive plant spread and infestation is the most cost-effective strategy for managing invasive plants. It reduces future maintenance needs and costs; reduces fire hazards and herbicide use; enhances access and safety; limits landowner liability and maintains good public relations; and protects existing wildlife habitat, endangered species, native plant populations, and beneficial insects (Cal-IPC 2012).

To proactively limit the unintentional spread or introduction of invasive plants, DWR may implement the following specific BMPs, as feasible, during invasive plant treatments and other SPFC O&M activities:

- **Develop and implement a Hazard Analysis and Critical Control Point (HACCP) plan for Maintenance Yard O&M activities.** HACCP plans focus on identifying critical control points where invasive species can be removed while documenting the BMPs used to prevent and remove these species. HACCP planning builds a framework of information with which to weigh the risk of species spread against management benefits. An HACCP planning manual, supporting documents, forms, and a database of completed HACCP plans (with BMPs) are available on the HACCP Planning for Natural Resources Management website (http://www.haccp-nrm.org/), supported by USFWS. Additional information on invasive plant BMPs is found in Cal-IPC's Preventing the Spread of Invasive Plants: Best Management Practices for Land Managers (Cal-IPC 2012) and in the U.S. Forest Service's (USFS's) Guide to Noxious Weed Prevention Practices (USFS 2001). Additionally, Cal-IPC has developed video training materials describing BMPs for invasive plant management

(http://www.cal-ipc.org/resources/booksandcds/preventionvideo.php), which could be adapted for use by DWR to train Maintenance Yard and other staff on appropriate BMPs.

- **Manage O&M activities to limit introduction and spread of invasive plants.** Modifications of activities would include limiting soil disturbance and areas of bare soil; revegetating or covering disturbed soil with locally adapted native plants, sterile nonnative plants, or certified weed-free mulches; cleaning and washing tools and equipment within designated areas before entering and leaving work sites; regularly monitoring and promptly treating invasive plants in or next to soil stockpiles, equipment staging areas, and similar areas of concentrated disturbed or bare soil; minimizing access roads and equipment staging areas; implementing measures to limit erosion and transport of weed seeds from work areas (e.g., using straw wattles or silt fencing); and avoiding work and use of heavy equipment during or after rainfall, or whenever soil disturbance is more likely (when soils are saturated).

- **Train staff, including contractors, on weed identification and methods to avoid the unintentional spread of invasive plants.** This training could occur concurrently with preactivity training focused on identifying and avoiding sensitive biological resources (where appropriate). Educational materials provided to personnel could include weed identification tools and written copies of required practices for designated locations within the work site.

- **Manage vegetation using methods that reduce the spread of invasive species and encourage desirable vegetation.** This practice includes (to the extent feasible) scheduling mowing and similar vegetation management activities for times when desirable native plants are less susceptible to defoliation (e.g., early in the growing season, during dormancy, or after production of viable seed); scheduling management of invasive plants for times when plants are most susceptible to planned treatment actions (e.g., during early vegetative growth [if using herbicides] or during flowering [if mowing]); and collecting and disposing of cut weed materials so that vegetative parts and weed seeds are not unintentionally spread after cutting.

5.3 Invasive Plant Treatment Techniques

As described previously in Section 2.0, the Maintenance Yards currently use a variety of methods to manage vegetation, including invasive species, in areas maintained by DWR inside the SPA. These methods include manual removal using hand tools, mechanical treatment (mowing, disking, dragging, grading), herbicide use, controlled burning, and livestock grazing and the BMP's described above can complement existing methods and reduce additional introduction of new invasive plant infestation. Successful control of invasive plants frequently requires a combination of these methods within an Integrated Pest Management (IPM) framework. IPM is an ecosystem-based strategy that focuses on long-term prevention and elimination of pests, or invasive plants, through a combination of techniques. These techniques include identifying and monitoring problem plant infestations, employing thresholds to determine when action is needed, preventing weed spread, and using control tactics on existing infestations. When used simultaneously, these techniques can effectively control invasive plant

populations. The overall IPM approach is not to eliminate all invasive plants, but rather to keep their populations at tolerable levels.

Potential treatment techniques, including those currently used by DWR, that could be applied either singly or in combination with other techniques to the target species identified in Section 4.0 are summarized in Table 5-1. Because the Initial Priority Species are emphasized in this Plan and in the Conservation Strategy, more detailed treatment recommendations for these four species are provided in Section 5.3.1. Additionally, each treatment technique listed in Table 5-1 is described in Section 5.3.2, based on information contained in Bossard et al. (2000), Tu et al. (2001), and DiTomaso et al. (2013), unless noted otherwise.

5.3.1 Treatment Recommendations, Initial Priority Species

Giant Reed

Description

As described previously, giant reed is a perennial, reed-like grass capable of rapid growth. The stalks of giant reed, called "culms," resemble those of bamboo and can reach diameters of 1.5 inches (Hoshovsky 1987). Giant reed has fleshy rhizomes from which tough, fibrous roots grow and penetrate deeply into the soil. Giant reed can sometimes be mistaken for the native perennial common reed (*Phragmites australis*) but can generally be distinguished by its growth habit and habitat type. Whereas common reed typically occurs only along streambanks and marshes, giant reed can also be found in upland and inland habitats. Giant reed also can be distinguished by its wider stems, with blade bases that are round-lobed, truncate, or clasping the stem instead of gradually narrowing. Additionally, unlike common reed, giant reed is generally more tolerant of high and low water tables.

Treatment and Control Considerations

Giant reed is shade-tolerant and can grow beneath riparian vegetation. The growth of giant reed can be impeded by lack of moisture during the first year, but plants 2–3 years old can survive drought conditions. Rhizomes must be removed or killed to eradicate infestations; otherwise, remnant rhizome or shoot fragments may develop into new plants. Mowing and cutting of mature plants, coupled with appropriately timed herbicide treatments from March through October may also be effective (DiTomaso and Healy 2007). Prescribed burning may exacerbate infestations of giant reed, because fire removes the stalks but does not affect the rhizomes. After fire disturbance, giant reed grows back rapidly from its roots without competition from other plants, often thicker than before the fire (California State University Sacramento and Sonoma Ecology Center 2005).

Table 5-1. General Treatment Techniques for Target Invasive Plants

Common Name	Mechanical					Cultural					Biological	Chemical
	Manual Removal	Mowing or Cutting	Girdling	Mulching	Tillage	Competition	Grazing	Prescribed Burning/Flaming	Solarization	Water Management	Insects/Fungi/Fish	Herbicide
Alligator weed	D										C	B
American frogbit	C	D										B
Barbed goatgrass	B	B			C			C				B
Blue gum	B	B						D				B
Brazilian waterweed	D	D								C	C	B
Chinese tallowtree	C	B	B									B
Crisp-leaved pondweed	C									C		B
Edible fig	B	B										B
Fennel	B	C										A
French broom	B	B		B			C	B				A
Giant reed	B	B					C	D			B/C	B
Himalayan blackberry	B	B			C		B	C				B
Hydrilla	C									C		B
Medusa head		B			B		B	B				B
Milk thistle	A	B			B							A
Pampas grass	A	B					C					B
Parrot's feather	C									B		C

Table 5-1. General Treatment Techniques for Target Invasive Plants

Common Name	Mechanical					Cultural					Biological	Chemical
	Manual Removal	Mowing or Cutting	Girdling	Mulching	Tillage	Competition	Grazing	Prescribed Burning/Flaming	Solarization	Water Management	Insects/Fungi/Fish	Herbicide
Perennial pepperweed	C	B			D		C			B		B
Purple loosestrife	B	C								B		B
Ravenna grass	A	B										A
Russian thistle	A	B			C	C	C					A
Saltcedar	B	C					C	C		B	B	B
Red sesbania	B	B						B				B
Scotch broom	B	B		B			B	C				B
Scotch thistle	A	B			C	B	C					A
Shortpod mustard	A	B							B			C
Stinkwort	A	B				C		D				A
Tree of heaven	B	B	B				C					B
Tree tobacco	A	B										A
Water hyacinth	D	D								C		B
Water primrose	B	B								B		B
Yellow star-thistle	B	B			C	C	B	B	B		C	B

Sources: Bossard et al. 2000; Tu et al. 2001; DiTomaso et al. 2013.

Notes:
A = Highly effective.
B = Effective in certain circumstances or in combination with other treatment techniques.
C = Moderately effective in certain circumstances or in combination with other treatment techniques.
D = May exacerbate the problem.

Recommended Control Methods

Generally, herbicides are the primary means used to treat giant reed. This species' ability to resprout from plant fragments and vigorously regrow following defoliation reduces the effectiveness of other control methods; however, other control methods (e.g., mowing or cutting) may be combined with herbicide use to increase effectiveness. Control can be achieved by spraying the foliage or removing aboveground biomass, followed by spraying the resultant cut culms. Recommended foliar spray applications include either glyphosate or imazapyr at 2 percent concentration or a mix of these two chemicals (1 percent glyphosate plus 1 percent imazapyr). Application to cut culms can be made with either 100 percent concentration glyphosate or imazapyr at 25 percent minimum concentration. The advantages and disadvantages of glyphosate and imazapyr for control of giant reed are summarized in Table 5-2. A California-licensed Pest Control Advisor (PCA) must prepare a written herbicide application recommendation before herbicides are used.

Table 5-2. Advantages and Disadvantages of Imazapyr and Glyphosate for Control of Giant Reed

Herbicide	Advantages	Disadvantages
Glyphosate	1. No soil residual. 2. No translocation of herbicide to nontarget species through root exudates. 3. Few restrictions on aquatic application.	1. Requires full foliar coverage on dense, uncut biomass for full systemic effect. 2. A large volume of water is required, under high pressure, to penetrate dense, uncut foliage. 3. Poor control of spring and summer resprouts.
Imazapyr	1. Needs less foliar coverage for full systemic effect. 2. Requires less water, applied with less pressure. 3. Good control of spring and summer resprouts.	1. Potential soil residual persists for up to 2 years, depending on application rate (dosage). 2. Potential for interspecific root exudates transfer. 3. Even with aquatic labels, buffer zone requirements or restrictions may apply near water. 4. Slow mode of action, with full efficacy often not apparent for 1–2 years.

For aquatic, riparian, and wetland applications where seasonal or perennial water is nearby (including shallow groundwater), use Habitat (or similar aquatic-labeled product; e.g., Polaris) for imazapyr, and Rodeo (or similar aquatic-labeled product; e.g., Aquamaster) for glyphosate. Spraying should occur during the plants' active, healthy (nonstressed) growth period (generally June through September), preferably before flower formation and well before initiation of leaf senescence. Herbicide should be applied to cut culms immediately after cutting.

Additionally, biological control agents have been developed for giant reed control. Although the effectiveness of these agents, tip-galling wasp (*Tetramesa romana*) and Arundo scale (*Rhizaspidiotus donacis*), has not been widely tested in California, both agents are approved for

use in California, and they have been released, or are planned for release, throughout the SPA (Moran pers. comm.). These agents may provide effective control of giant reed as a complement to, or alternative to, herbicides.

Saltcedar

Description

As noted previously, saltcedar has rapidly invaded native riparian areas. Saltcedar is a deciduous tree that inhabits streambanks, lake shores, gravel bars and sandbars, and washes throughout California. Saltcedar can be identified by its dense canopy of slender, often arched or drooping branches, awl-like leaves, and dense spikes of white to pink flowers. Trees typically develop a deep, extensive root system and have a high evapotranspiration rate in arid climates. Saltcedars generally reproduce by seed but can also reproduce vegetatively from root sprouts and stem fragments. Despite the prolific and rapid germination of seeds, seedlings cannot tolerate even 1 day without adequate water, so most germinated seeds do not survive to establish along streambanks. Saltcedar stem fragments may take root when buried in saturated soils, such as occurs with flooding (DiTomaso and Healy 2007).

Treatment and Control Considerations

Efforts to cut or burn saltcedar to the ground have proven ineffective, because the plants will typically regenerate from the roots. However, removing and/or chemically treating the root system has proven to be effective at managing invasive populations; follow-up treatments may be required. Saltcedar seedlings are easily pulled by hand and should be removed early to prevent reinfestation. Young seedlings are not competitive in the presence of dense native vegetative cover, so establishing native cover after saltcedar is removed discourages reinfestation (DiTomaso and Healy 2007).

Recommended Control Methods

Generally, herbicide application is the primary method used to treat saltcedar. Control can be achieved by removing and/or chemically treating the root system and spraying the foliage. For saltcedar control, it is recommended that all aboveground, exposed target biomass is treated—in other words, all foliage (with full canopy coverage) is treated with foliar spray, and every cut stem is treated with herbicide after cutting. Herbicide application should occur during the active, healthy (nonstressed) growth period (generally June through September); preferably after flowering, but before initiation of leaf senescence (i.e., leaf coloration in fall). A California-licensed Pest Control Advisor (PCA) must prepare a written herbicide application recommendation before herbicides are used.

Several treatments and herbicide concentrations are recommended; the selection of herbicide depends on the method chosen. Using imazapyr at 2 percent concentration is recommended for foliar application and treatments of resprouts. Cut-stump spraying requires imazapyr or triclopyr at a minimum of 25 percent concentration. For basal bark spraying, triclopyr with an appropriate adjuvant (e.g., JLB Improved Oil Plus) at a minimum 35 percent concentration is recommended.

Stalker is recommended for nonaquatic/ nonriparian (i.e., upland) applications. Habitat (or similar aquatic-labeled product; e.g., Polaris) is recommended for aquatic, riparian, and wetland applications where seasonal or perennial water is nearby (including shallow groundwater). Garlon 4 (or similar ester formulation; e.g., Remedy Ultra or Tahoe 4) should be used before foliage regrowth (i.e., in the late fall after leaf senescence, through early winter for basal bark spraying) in nonaquatic/ nonriparian (upland) applications. Other alternatives include glyphosate (e.g., Roundup Pro, Touchdown Pro) used at 100 percent concentration for nonaquatic/ nonriparian (upland) applications, and Rodeo (or similar, such as Aquamaster), used at 100 percent concentration for aquatic, riparian, and wetland applications where seasonal or perennial water is nearby (including shallow groundwater).

Red Sesbania

Description

As noted previously, red sesbania is a deciduous shrub or small tree that grows up to 13 feet tall and forms thick, impenetrable thickets in riparian areas (DiTomaso and Healy 2007). The long-lasting flowers are orange to reddish in color and are characteristic of the legume family. Red sesbania is currently found in the southern Sacramento Valley (American River Parkway), along the Sacramento River and Feather River in the northern Sacramento Valley, San Joaquin Valley (Suisun Marsh, San Joaquin River Parkway), and southern North Coast Ranges. It predominantly inhabits streambanks but also dominates the edges of ponds, marshes, canals, gravel bars, and instream islands. New colonies establish in riparian areas and spread through production of seeds and seed pods that float downstream and germinate in saturated soils. Red sesbania typically reproduces within 2 years and is capable of producing thousands of viable seeds within a few months, leading to rapid spread of the species (DiTomaso and Healy 2007). Red sesbania is also moderately shade-tolerant and can establish itself in the shade of other native riparian vegetation, allowing it to easily attain community dominance.

Treatment and Control Considerations

Red sesbania rapidly establishes thick stands along riparian corridors. These dense stands displace native plants and diminish food resources and habitat for native wildlife. Tall stands of red sesbania can increase the hydraulic roughness of stream channels and increase the risk of flooding by altering flood conveyance (Cal-IPC 2013a). Additionally, the foliage, flowers, and immature seeds of red sesbania contain a compound that is moderately toxic to humans and livestock.

Recommended Control Methods

Mechanical, biological, and chemical methods have all proven effective at controlling the spread of red sesbania. The root system of red sesbania is relatively shallow and easy to remove, especially in saturated soil, making mechanical removal of young plants a feasible means of control. Mechanical removal and maintenance of red sesbania may require up to 5 successive years to effectively eradicate an infestation. Targeting small, upstream populations of red sesbania has proven most effective at slowing the spread of the invasive plant along riparian corridors. Plants in standing water can also be cut below the water line to help discourage regrowth (DiTomaso and Healy 2007).

If herbicides are used, spraying the foliage during the active, healthy (nonstressed) growth period (generally June through September), preferably after flowering, but before initiation of leaf senescence (i.e., leaf coloration in fall), is recommended. Using a 2 percent glyphosate concentration for foliar and resprout spraying is recommended, and a 100 percent concentration of glyphosate is recommended for cut-stump spraying. For aquatic, riparian, and wetland applications where seasonal or perennial water is nearby (including shallow groundwater), using a 2,4-D amine formulation at 0.75 pounds active ingredient (AI)/acre equivalent, or Rodeo (or similar aquatic-labeled product, such as Aquamaster) for glyphosate, or DMA (or similar aquatic-labeled 2,4-D product) is recommended. Other alternatives include using oxyflurofen (e.g., Goal 2XL) for nonaquatic/nonriparian (i.e., upland) applications.

Where feasible, late-season disking followed by flooding can prevent reestablishment of red sesbania from seed. Additionally, rope-wick treatment may be used, if the area is accessible to wick application equipment.

Himalayan Blackberry

Description

As noted, Himalayan blackberry is a sprawling, robust, invasive shrub that spreads rapidly and dominates native species of blackberry, such as California blackberry. Himalayan blackberry can be distinguished from California blackberry by its taller, more robust stature and larger thorns and berries. The flower petals of California blackberry are narrower at the base and do not have the crinkled appearance of the Himalayan blackberry flower (DiTomaso and Healy 2007). Flowers are characteristic of the rose family and are white to pinkish in color. This species flowers from July to September and can produce 650 to 1,200 seeds per square foot. These seeds are dispersed by gravity and wind, as well as by many species of birds and mammals.

Treatment and Control Considerations

Himalayan blackberry is common in riparian areas and tolerates periods of inundation by fresh or brackish water. This periodic flooding can produce long-lived early seral communities that are conducive to the growth and spread of blackberries (DiTomaso and Healy 2007). Himalayan blackberry occurs just as commonly in upland communities as well; although, they tend to proliferate in areas with consistent soil moisture. Its ability to withstand a range of soil pH and textures allows Himalayan blackberry to outcompete native plants in both riparian and upland communities.

Recommended Control Methods

Himalayan blackberry control is most effective when a combination of mechanical and chemical methods is employed; repeated treatments are needed to effectively eradicate this species in the long term. To control Himalayan blackberry, all aboveground biomass should be cut to the ground early in the growing season (April–May) and removed from the site. Care should be taken to ensure that all live biomass has been removed, to reduce the potential reestablishment of remaining plant fragments. The cut vegetation should then be allowed to resprout, and the new growth should be treated with a foliar application of herbicide in early spring and/or late summer. Because long-term control of this species is difficult, one or two rounds of follow-up

herbicide treatments should be completed (DiTomaso 2012) between May and November during the first year of control. For optimal chemical transport to the plants' root systems, one round of herbicide application should occur during the late summer (DiTomaso 2012) or early fall. Follow-up herbicide treatments should occur two or three times during the following two growing seasons to ensure adequate control of this species. The number of follow-up herbicide treatments needed is flexible, so the treatment schedule can be adjusted if it is determined that more or fewer treatments are required for adequate control. Care should be taken to avoid damaging nontarget species.

Most of the recent literature suggests that triclopyr is the most effective herbicide for controlling Himalayan blackberry (DiTomaso 2012; Oregon State University 2008). For example, an aquatic label of triclopyr (Renovate) with the surfactant Agri-dex is preferred for controlling Himalayan blackberry on the Guadalupe River to minimize potential impacts on steelhead (Oncorhynchus mykiss) (Spahr pers. comm.). In general, using Renovate at a 1 percent solution with the surfactant Agri-dex is recommended for control of Himalayan blackberry.

5.3.2 General Treatment Recommendations

Manual Removal

General overview: Manual removal techniques involve physically removing entire plants either by hand or with tools (e.g., hoes, Pulaski, Root Talon, or Weed Wrench). These techniques generally have limited ecological impacts, cause minimal damage to neighboring plants, have low equipment and supply costs, and are good alternatives where herbicides or other methods cannot be used.

Applicable Uses: Small infestations of herbaceous plants that will not resprout from root fragments; sapling size or smaller woody species.

Benefits: Generally limited potential for adverse environmental effects compared to other treatment techniques.

Drawbacks: Only effective on small infestations of certain species; repeated treatment is often required for perennial species; can be time- and labor-intensive relative to the size of infestation treated.

Mowing or Cutting

General Overview: Mowing or cutting involves using tools (e.g., mowers, weed whackers, pruners, loppers, and saws) to defoliate plants in order to reduce plant vigor, deplete carbohydrate reserves, and remove flowers to prevent seed production.

Applicable Uses: Effective control for small or large infestations of herbaceous annual plants; most effective when plants are in flower and soils become and remain dry (Sheley and Petroff 1999). Cutting can effectively control

perennial or woody species, especially when combined with herbicide application.

Benefits: Mowing and cutting reduce vegetation heights and can remove thatch, litter, and fire fuel buildup; increase the competitiveness of desirable species; reduce or prevent seed deposition into soil seedbanks; and increase the efficacy of subsequent treatments, such as manual removal, flaming, or herbicide application.

Drawbacks: Can stimulate production of new stems in some plant species; transport and spread propagules by tools, equipment, and clothing; and cause undesirable shifts in species composition (Maron and Jefferies 2001; Hayes and Holl 2003a). Fuel exhaust from mowers can decrease air quality, and a significant fire hazard is posed by metal blades striking rocks and creating sparks. Each site may respond differently to the same mowing treatment, so site-specific management plans are needed to maximize the benefits of mowing (Hayes and Holl 2003b).

Girdling

General Overview: Girdling trees involves cutting the narrow band of living tissue (cambium) encircling the tree just beneath the bark so that the tree is unable to transport water and nutrients between the roots and the canopy.

Applicable Uses: Trees or shrubs that have a single trunk; most effective on woody species that do not resprout from the base.

Benefits: Typically requires less labor than cutting and removal, is inexpensive, kills only the target plant, leaves no residue except the standing trunk (which can provide valuable wildlife habitat), and, if left to decay, allows the nutrients of the tree to be returned to the ecosystem rather than being removed and deposited elsewhere.

Drawbacks: Some species (e.g., black locust and tree of heaven) heal damaged cambium quickly or resprout below the girdle, rendering the treatment ineffective. Standing snags might present a potential hazard to people or structures, or be undesirable aesthetically. Propagules can be transported and spread by tools, equipment, and clothing.

Mulching

General Overview: Mulching involves applying a layer or layers of material over an infestation or area of soil to reduce the amount of sunlight plants receive and cut off the energy supply they need to grow and reproduce. Commonly used mulch types include hay, manure, grass clippings, straw, rice hulls, leaf litter, sawdust, wood chips, black paper, and black plastic sheets.

Applicable Uses: Annual plants, primarily in small areas, although mulching has proven successful on some herbaceous perennial species.

Benefits: Conserves soil moisture and can improve soil productivity by introducing organic materials and attracting soil fauna.

Drawbacks: Ineffective against perennial weeds with extensive carbohydrate reserves (i.e., roots) that allow them to grow up through the mulch. Materials and application can be expensive. Mulching may not be effective in the long term; also, it may prevent germination of native plants or introduce propagules of other weeds.

Tillage

General Overview: Deep tillage controls invasive plants by burying plant propagules deep into the soil profile. Shallow tillage, using knives, sweeps, harrows, shallow disking, or other tools, detaches roots from shoots and causes plants to desiccate. The ideal time to till is when surface soil is dry and before seed production.

Applicable Uses: Large infestations of annuals in highly degraded systems, on croplands and in level areas, and at restoration sites prior to plant installation.

Benefits: Loosens and aerates topsoil; helps mix organic matter into soil.

Drawbacks: Less effective for controlling perennials. Can spread perennial invasive plants that reproduce vegetatively by rhizomes or roots when cut; also facilitates invasion by other invasive species as a result of soil disturbance. Increases atmospheric dust levels and soil erosion. Generally not practiced on rangelands or wildlands.

Competition

General Overview: Native and nonnative plants compete with one another for light, nutrients, water, and space. Competitive native species can suppress or exclude invasive plants by altering the abiotic and biotic conditions that favor invasive plant establishment and persistence. For example, native trees can be planted to exclude shade-intolerant invasive species. Invasive plant control through competition is often most successful when used as part of an IPM program. Revegetation of sites after treatment can be an effective means of long-term control.

Applicable Uses: Small or large areas that contain a suite of competitive native plants that, through manipulation of abiotic and biotic factors, gain a competitive edge over nonnative plants; also, areas dominated by nonnative plants where native plants can be introduced and managed to promote their establishment.

Benefits: Successful revegetation efforts limit the potential for nonnative species to invade and persist, reducing the need for repeated treatments. This method restores native plant communities that resist invasion by nonnative species while enhancing habitat functions and values.

Drawbacks: Managing and restoring native plants can be expensive, and may be effective only under certain conditions. Uncertainties in invasive species' response to competition limit predictability of management success.

Livestock Grazing

General Overview: Livestock grazing affects plants by damaging the plant tissues responsible for growth and reproduction. Things to consider when developing a grazing plan include livestock class, stocking rates, grazing intensity and frequency, fencing, and herding. Certain livestock kinds (e.g., sheep, cattle, and goats) and classes (e.g., calves, cows, steers, and heifers) target specific invasive plants and avoid others. Stocking rates must be optimized to maximize weed management, avoid overgrazing, and minimize soil compaction. Grazing is implemented before plants produce viable seed and when the target plant or suite of plants is most palatable to the selected kind and class of livestock. The type of fencing used, if needed, depends on livestock kind and class and grazing duration. Temporary electric fencing can be used for smaller animals in small rotating plots, whereas permanent electric or barbed-wire fencing is needed to contain large animals during long grazing periods. Livestock grazing usually requires repeated treatments to deplete the seedbanks and energy reserves of target invasive species.

Applicable Uses: Areas too large for herbicide applications, or where herbicide use would be too costly or constrained by label restrictions or policies. Some livestock (e.g., sheep and goats) are well adapted for grazing in steep or rocky terrain that is otherwise difficult to access. Severe infestations can be reduced, and small infestations may be eliminated, when grazing treatments are combined with other control techniques, such as prescribed fire and herbicides.

Benefits: Can induce shifts in plant community composition toward more desirable species, break up compact soils, reduce thatch and litter layers, lower fire hazards by reducing fuel loads, and introduce nutrients into the soil.

Drawbacks: Some invasive plants are unpalatable to livestock and require a different form of treatment; alternatively, the livestock can be allowed a period in which to adapt to consuming an unpalatable or new forage type. Trampling and removing overstory vegetation can disturb soil and enhance germination of invasive species by moving seed to the soil surface. Livestock grazing can increase light penetration to invasive

plants. High grazing intensity can lead to increased soil compaction, which can reduce the vigor of desirable plant species and lead to rapid invasive plant establishment. Seeds of some invasive species can pass, intact and viable, through the digestive systems of animals and result in dispersal of seeds to uncontaminated sites.

Prescribed Burning

General Overview: Prescribed burns destroy plant tissues using fire and heat. They require good logistical planning, coordination, careful timing with respect to weather (winds, moisture conditions), coordination with air quality agencies, and attention to other details required to carry out an effective and safe burn.

Applicable Uses: Effectively treats annual grasses and shrubs. Less effective at treating perennial species with deep roots that remain unharmed by low-intensity fire. Annual grasses must be burned before they set seed, and invasive forbs should be burned before seeds become viable.

Benefits: Can stimulate germination of desirable native species, particularly perennial grasses and legumes; remove layers of thatch and recycle nutrients; and induce germination of fire-adapted invasive species so the seedbank can be flushed and the resultant seedlings can then be killed with another fire or some other method.

Drawbacks: Fire can stimulate germination of some invasive species (e.g., milk thistle). Equipment and vehicles used for large fires and staged nearby may transport propagules and start new infestations elsewhere. Hot fires can sterilize soil, volatilizing nutrients and killing microorganisms on which native plants rely. Removal of vegetation by fire can increase soil erosion and stream sedimentation. Construction firebreaks and associated soil disturbance can increase erosion and provide a seedbed for invasive species. Fire can also kill desirable plant species and seedbanks. Other risks associated with prescribed burns include air quality issues, potential for fire escapes and liability for damage to personal property or injury to third parties, and impacts on small mammals and insects.

Flaming

General Overview: Flaming involves using torches or flamethrowers to quickly heat and destroy cell integrity, causing cellular leakage and death of the tissues of a target plant. Optimal timing for flaming treatments is in winter or early spring, after target plants germinate and while conditions are moist and fire risks are low.

Applicable Uses: Groups of small annual forbs, and the seedlings of perennials forbs and woody plants in small areas.

Benefits: Generally less expensive than herbicide treatments. Is suitable for use during wet weather. Requires relatively low level of effort, is very precise, and kills weeds before propagules have set, and therefore does not require the collection and disposal of weed material. Does not involve the use of chemical contaminants that could affect surrounding vegetation.

Drawbacks: Typically requires more time compared to herbicide treatments, and has a potential for causing injury to the applicator. Repeated treatments (about every 2–3 weeks) may be required to exhaust the energy reserves of perennial species.

Soil Solarization

General Overview: Soil solarization involves first removing aboveground vegetation so that only very short vegetation or bare soil remains. Clear polyethylene plastic is then placed on the area when high amounts of solar radiation and high temperatures are expected (typically July and August). The plastic is placed so that it covers the entire infestation and about 2 feet beyond the edges of the infested area, and the sheet is pulled tight over the ground. The plastic must then be left in place for at least 4–6 weeks.

Applicable Uses: Most often used in agricultural settings; generally effective in treating cool-season annual species that use fall precipitation to germinate and establish before growing quickly in spring.

Benefits: Can reduce the amount of retreatment needed by killing much of the latent invasive plant seedbank. Can release soluble nutrients that are tied up in the organic component of the soil.

Drawbacks: Perennials, warm-season annuals, and species adapted to high temperatures are less likely to be controlled using soil solarization. Solarization is effective only with plentiful sunlight and warm conditions, in late spring or summer, and when soils are moist. Solarization can have multiyear impacts on the biological, physical, and chemical properties of the soil, which can prevent the establishment and growth of native species and beneficial soil organisms. In addition, this technique leaves an open substrate that can be readily invaded by invasive plants once the plastic is removed.

Water Management

General Overview: Water management involves manipulating water levels to control target invasive plants. Lowering water levels, followed by manual/mechanical removal, exposure to freezing temperatures, prescribed burning, or deep flooding in spring, can control several aquatic invasive species in irrigation canals, ponds, reservoirs, and lakes. Drawdown or dewatering involves lowering water levels to expose sediments. The degree of plant

control achieved through drawdown depends on plant species and temperature. A drawdown followed by freezing temperatures provides the greatest aquatic plant control. Raising the water level can also provide some level of control for a few emergent aquatic species. For example, flooding of purple loosestrife or perennial pepperweed is effective if plants can be inundated throughout the growing season.

Applicable Uses: Aquatic invasive plants susceptible to changes in depth and duration of water inundation.

Benefits: May promote the growth and competitive ability of certain native species in some situations.

Drawbacks: Only feasible where water levels can be manipulated. Can create conditions that favor the establishment of other, nontarget invasive plants; for example, lowering water levels can produce new substrate and facilitate establishment of invasive plants. Flooding may disperse invasive plants and invasive fish into previously uncontaminated areas.

Biological Control

General Overview: Biological control is the use of animals, insects, fungi, or microbes to feed upon, parasitize, or otherwise interfere with a targeted pest species; organisms used for the purpose of biological control are called "agents." Insects are often used as biological control agents for invasive plants because they effectively exert stress on the target plant to reduce its competitive ability and dominance by boring into roots, shoots, and stems; feeding on seeds and leaves; and extracting plant fluids. There are several methods of biological control, but the most common method used for plants involves targeting a nonnative invasive plant with one or more species of biological control agents from the pest's native range; this is referred to as "classical" biological control. "Conservation" biological control is usually defined as actions that preserve, protect, or promote the abundance of organisms that may keep the abundance of pest organisms in check. Usually this method entails modifying the environment in ways that promote the abundance or impact of native or already established nonnative organisms. In general, the synchrony in the life cycles of host plant and agent, the potential for the agent to adapt to a new climate and habitat, the ability of the agent to find the host, the capacity of the agent to reproduce rapidly, and the nature, extent, and timing of the damage caused by the agent are among the factors that determine the effectiveness of the biological control. Biological control techniques should not be used unless controlled scientific experiments have shown that it is feasible for a particular agent and host, and that risks are very minimal, if not absent. In California, the use of biological control agents is regulated by CDFA.

Applicable Uses: Most often used in rangelands and aquatic systems.

Benefits: Reduces the need for chemical, mechanical, or cultural control methods; can be cost-efficient over the long term because there may be little or no cost after the initial research is complete and the agents are released, assuming the invasive plant was effectively controlled.

Drawbacks: Biological control programs often fail, primarily because the biological agent either never establishes in the field or does not cause sufficient damage to the target pest population. Often, the agent must be reared and released again each time the pest population erupts. Also, agents may affect nontarget native species, alter ecosystem functions, and become invasive themselves (Simberloff and Stiling 1996). Agents may be difficult to contain, feed on desirable species, and carry additional nonnative parasites. Some biological control programs have resulted in significant, irreversible harm to untargeted organisms and to ecological processes.

Chemical Control

General Overview: Herbicides kill plants by altering metabolic processes or damaging cells and tissues. Terrestrial and riparian herbicides are the most frequently used control tool in wildlands, natural areas, and rangelands. Because invasive plants in such areas frequently grow in association with desirable species, herbicide application must be selective. Consideration should be given to the herbicide's potential effect on the surrounding vegetation, habitats, and wildlife. Selective herbicides (e.g., herbicides effective only on certain types of broadleaf plants) should be considered wherever feasible. In some cases, preemergent herbicides may be used to more cost-effectively treat target invasive plants. Unless specifically registered for aquatic use, herbicides should never be used where they may contaminate water bodies or wetlands. Herbicides must always be used according to local and State regulations, must be recommended by a PCA, and must be applied by a Licensed Qualified Applicator (LQA), unless specific exemptions pertain, as defined by California law.

Applicable Uses: Used for management of dense or large invasive plant infestations. Herbicides can often successfully control infestations that cannot be effectively or reasonably controlled through other management actions. Spot treatments can be effective in early control of invasions or can prevent the spread of small infestations. Woody plants are difficult to treat with broadcast applications, but can be treated with foliar or wick-applied herbicides.

Benefits: Relatively easy and inexpensive, and effective in controlling and eradicating invasive plants; selective herbicides can be used to target invasive species while leaving other desirable plants unharmed.

Drawbacks: Improper use of herbicides can lead to spray or vapor drift, contaminate water, poison animals or humans, cause selection for herbicide resistance in invasive plants, and reduce plant diversity. Certain types of herbicides (e.g., preemergent herbicides) can remain active in the soil for long periods, increasing the potential for offsite drift and adverse effects on nontarget organisms. Studies of herbicide toxicity to many species of wildlife are based on studies of proxy organisms in laboratory settings; the potential for adverse effects on wildlife in wildland settings is inferred from these studies, but other, undocumented adverse effects may occur.

5.4 Post-Treatment Revegetation

Invasive plant abatement efforts are usually more successful when coupled with follow-up plantings of native vegetation. Although not all treated areas will require revegetation, without supplemental seeding, planting, and most likely temporary irrigation of native plants, treatment areas may revert back to dominance by invasive plants, requiring costly additional treatment and management. Although DWR recognizes that resources to revegetate all treatment areas will not be available, post-treatment revegetation should be considered whenever feasible. Plans for such treatment would incorporate the following components:

- A clear rationale for selection of the revegetation site
- A detailed site assessment that identifies the existing conditions, functions, and values of the planned revegetation site
- Site-specific objectives for revegetation, and a description of ecosystem functions and values to be created or enhanced through revegetation
- A detailed revegetation design that will achieve established goals and objectives
- Identification of native plant species appropriate for revegetation, as well as a description of propagation methods, propagule types (e.g., seed, cutting, plug, or container planting), and seeding rates and/or plant spacing
- A description of implementation techniques, follow-up maintenance actions, and short-term monitoring that will result in successful establishment of the revegetation site
- Required permits to receive project approval and authorization by regulatory agencies

Figure 5-1 shows lists of plants recommended for use on post-treatment revegetation sites. This is not intended to be a comprehensive list of all possible species; rather, it represents a list of species that are commonly available in native plant nurseries and that would be appropriate (from an ecological and hydraulic perspective) at specific hydrogeomorphic positions in the

major river systems of the Central Valley. The particular species to be used will be identified by qualified DWR personnel as part of the site-specific revegetation plan.

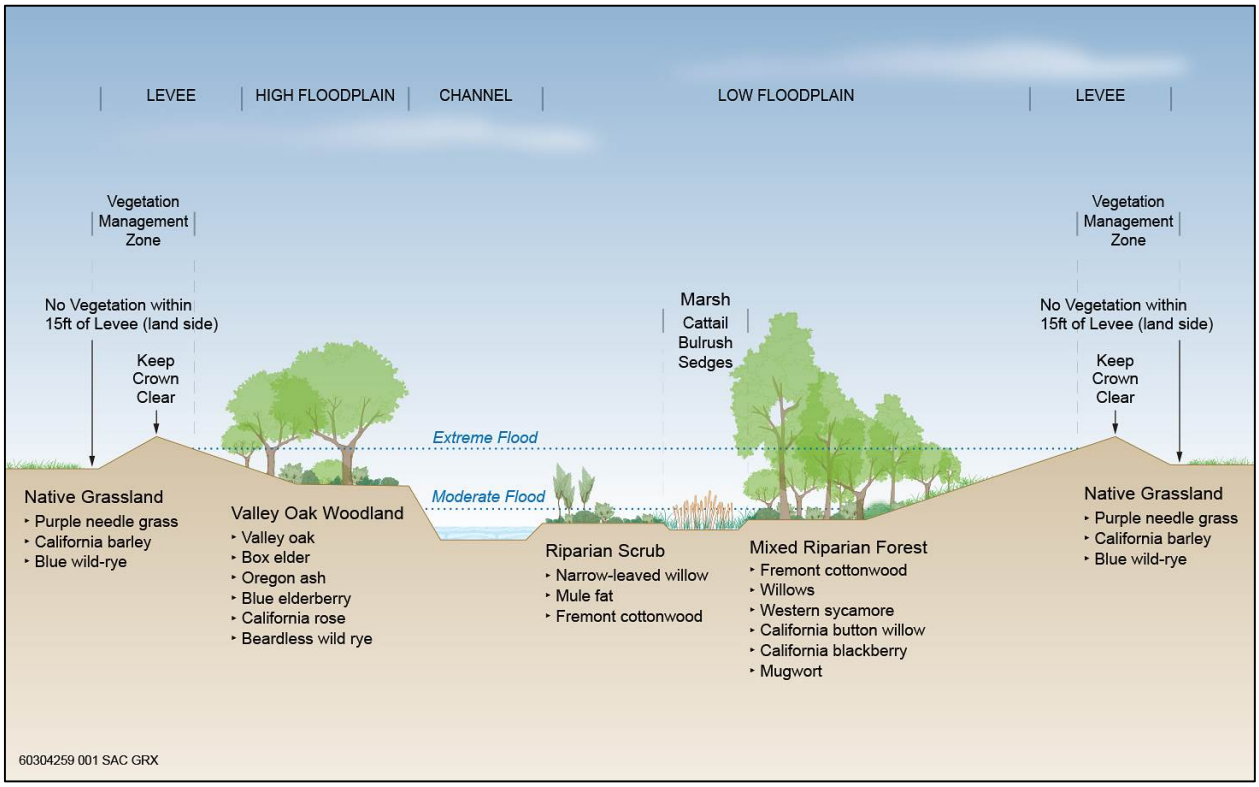


Figure 5-1. Appropriate Native Species for Revegetation in the Central Valley Flood System

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6.0 Monitoring and Adaptive Management

The Conservation Strategy defines invasive plant objectives as the number of acres of DWR-managed land where infestations of Initial Priority Species have been surveyed, treated, and maintained. Monitoring invasive plants will be essential to track areas of infestation, quickly detect new infestations, evaluate treatment effectiveness, inform management decisions, and guide adaptive management evaluations to meet the Conservation Strategy measurable objectives in the SPA. Monitoring methods could include periodic surveys before and after treatments to determine changes in the distribution, status, and demographics of target invasive plant species; reviews of GIS datasets and reports in the Cal-IPC Inventory; and communications with other landowners and managers in the SPA. To the extent feasible, monitoring will follow accepted protocols developed by the Cal-IPC (Cal-IPC 2012).

6.1 Overall Monitoring Program

To the extent feasible, DWR will monitor invasive plants within the SPA by adapting existing monitoring systems where possible, with a focus on DWR Channel Maintenance Areas. Additionally, DWR will support, where possible, the monitoring programs of others in portions of the SPA outside DWR Channel Maintenance Areas. The following monitoring could occur or be supported by DWR:

- **Compilation of invasive plant baseline.** Prior to 2017, an invasive plant baseline map will be completed using existing data sources (summarized in Section 4.0), data provided by Cal-IPC and other partners, and additional data collected by DWR. The baseline map will document existing conditions as of a specified date and provide a standard against which future conditions could- be measured to determine DWR's progress toward defined goals and objectives for invasive plant management (see Section 3.0).

- **Early detection and rapid response.** Early detection and eradication of small or incipient populations of invasive plants helps prevent their spread and significantly reduces management costs. Regular monitoring increases the chances of success. Through its Maintenance Yards and Inspections Unit, DWR regularly monitors areas of the SPFC for which it has maintenance responsibility. Further collaboration with O&M staff could target whether these tracking efforts could incorporate tracking that identifies new, incipient infestations of invasive plants. If so, these infestations will be prioritized for treatment, and treated, where feasible, as described in Section 5.0.

- **Treatment effectiveness.** DWR could monitor and maintain areas of invasive plant treatment and subsequent revegetation to ensure long-term establishment of desired plant species. These areas could be monitored over multiple growing seasons, especially at times of germination and flowering, for at least 3 years after project completion to ensure that any

invasive plants are promptly detected and controlled. If 3 years is insufficient to control invasive plants, DWR would continue monitoring and treatment until the invasion has been controlled.

- **Invasive plant tracking.** DWR would first use existing tracking systems to document the baseline acreage and distribution of invasive plants, as described above. New infestations will be recorded (e.g., during annual inspections), and acreages of invasive plants successfully treated at treatment sites would be noted. The tracking system would be used to assess progress toward defined treatment acreage targets, identified in this Plan and the Conservation Strategy (Sections 3.0 and 6.2).

- **Monitoring by partner agencies and organizations.** As described in Section 7.0 of this Plan, numerous agencies and organizations are involved in invasive plant assessment and treatment within the SPA. Some of these organizations, such as Cal-IPC, have developed invasive plant monitoring programs and tracking systems that could be supported by DWR to provide additional information on the distribution and abundance of invasive plants in areas of the SPA not maintained by DWR. In addition to supporting these programs, DWR would require recipients of multi-benefit project funding to enter invasive plant treatment information into existing tracking systems, most likely the NRPI or Calflora (www.calflora.org), a database developed by Cal-IPC.

6.2 Indicators of Success

As described in Section 3.0 of this Plan, DWR has established an initial target of 213 acres of Initial Priority Species to be treated between 2017 and 2022. Progress toward this target could be assessed using a tracking system, to be developed by DWR or adapted from systems such as Calflora or NRPI, which are already in use by potential partner organizations. Initially, nonattainment of this target will serve as the threshold for determining whether adaptive management actions are necessary. These actions may include additional conservation actions, changes to DWR's invasive plant management approach, or revision of this Invasive Plant Management Plan.

6.3 Adaptive Management

DWR plans to use an adaptive management approach to implement this Plan. Adaptive management is a systematic and iterative process that provides feedback between monitoring and management actions. This process includes reviewing invasive plant management goals and objectives, reviewing baseline data, applying treatment techniques for target invasive plants, subsequently conducting monitoring and analysis to measure achievement of goals and objectives, and refining management techniques as needed to achieve invasive plant management goals and objectives.

In general, adaptive management entails identifying triggers (or thresholds) that would initiate a management response and potential adaptive management actions. Management triggers define the specific point, or a range of values, where monitoring data indicate that outcomes may be developing along an unexpected or unfavorable trajectory, and where taking remedial actions may be necessary to meet goals and objectives. The planning targets for acres of invasive plant treatment summarized in Section 3 will serve as interim management triggers until additional analysis and further internal coordination within DWR better informs long-term goals. The following responses could be initiated if monitoring determines that a management trigger has been activated:

- Review invasive plant management goals and objectives (i.e., acreage targets in Section 3.0)
- Review invasive plant baseline data
- Review invasive plant monitoring results and treatment techniques
- Review other relevant information as needed to assess the effects of underlying causative factors that could be contributing to the observed changes (e.g., modes of invasive plant introduction and establishment, critical control points, distribution within and adjacent to the SPA, climate)
- With the assistance of invasive species experts (if required), identify potential causes of the observed changes
- Develop adaptive management and monitoring measures intended to positively affect (i.e., reverse) observed changes
- Implement identified adaptive management and monitoring measures
- Continue to implement measures until monitoring indicates that the invasive plant management goals and objectives (i.e., acreage targets in Section 3.0) are achieved

This adaptive management process is shown in Figure 6-1.

Although adaptive management measures are generally intended to be temporary, as needed to reverse observed changes in the distribution or abundance of invasive plants, if ongoing monitoring of adaptive management measures indicates that a permanent change is required, this Plan will be amended to incorporate such changes.

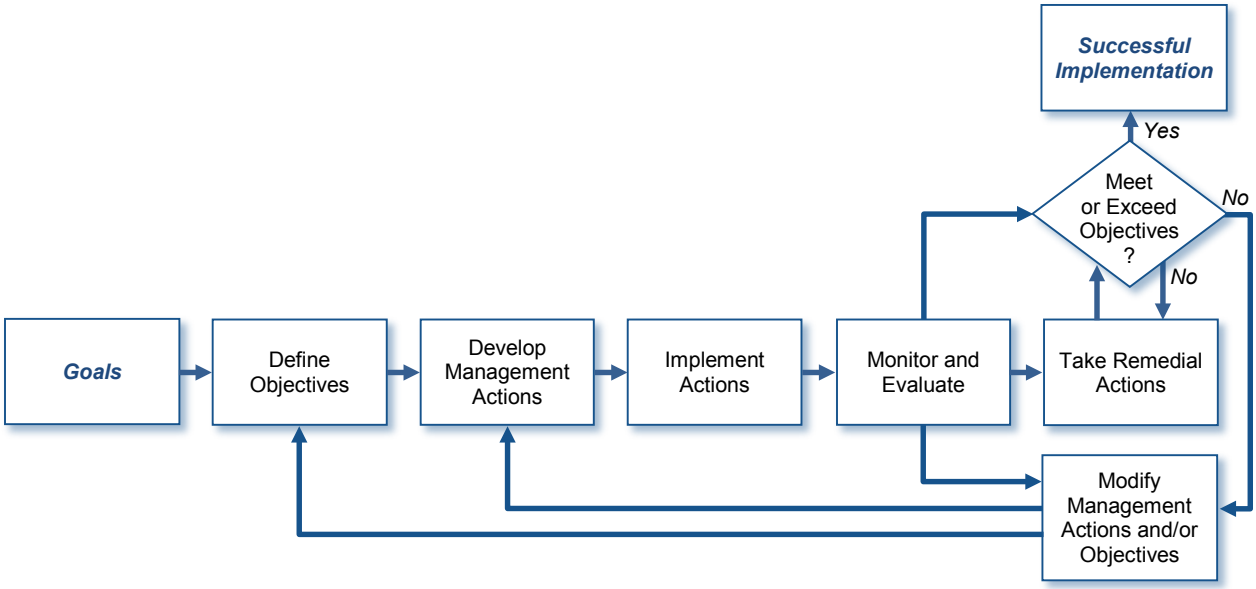


Figure 6-1. Flow Chart for Adaptive Management of Target, Invasive Plant Species in the SPA

7.0 External Partnerships

As discussed previously, numerous organizations, aside from DWR and the LMAs, share maintenance responsibilities or own and manage lands in the SPA. These organizations have enacted a variety of programs that provide additional direction or resources for collaborative planning and management and treatment of invasive plants. Additionally, numerous programs administered by the State of California, the federal government, and nonprofit organizations provide grants and other funding for invasive plant treatment. These programs and organizations represent opportunities for DWR to leverage its management efforts to better eradicate invasive plant infestations in the SPA. Evaluating these programs to gauge the opportunities and potential benefits of DWR's participation and support is an important aspect of DWR's overall strategy for managing invasive plants in the SPA. This section describes these programs and existing collaborative planning efforts.

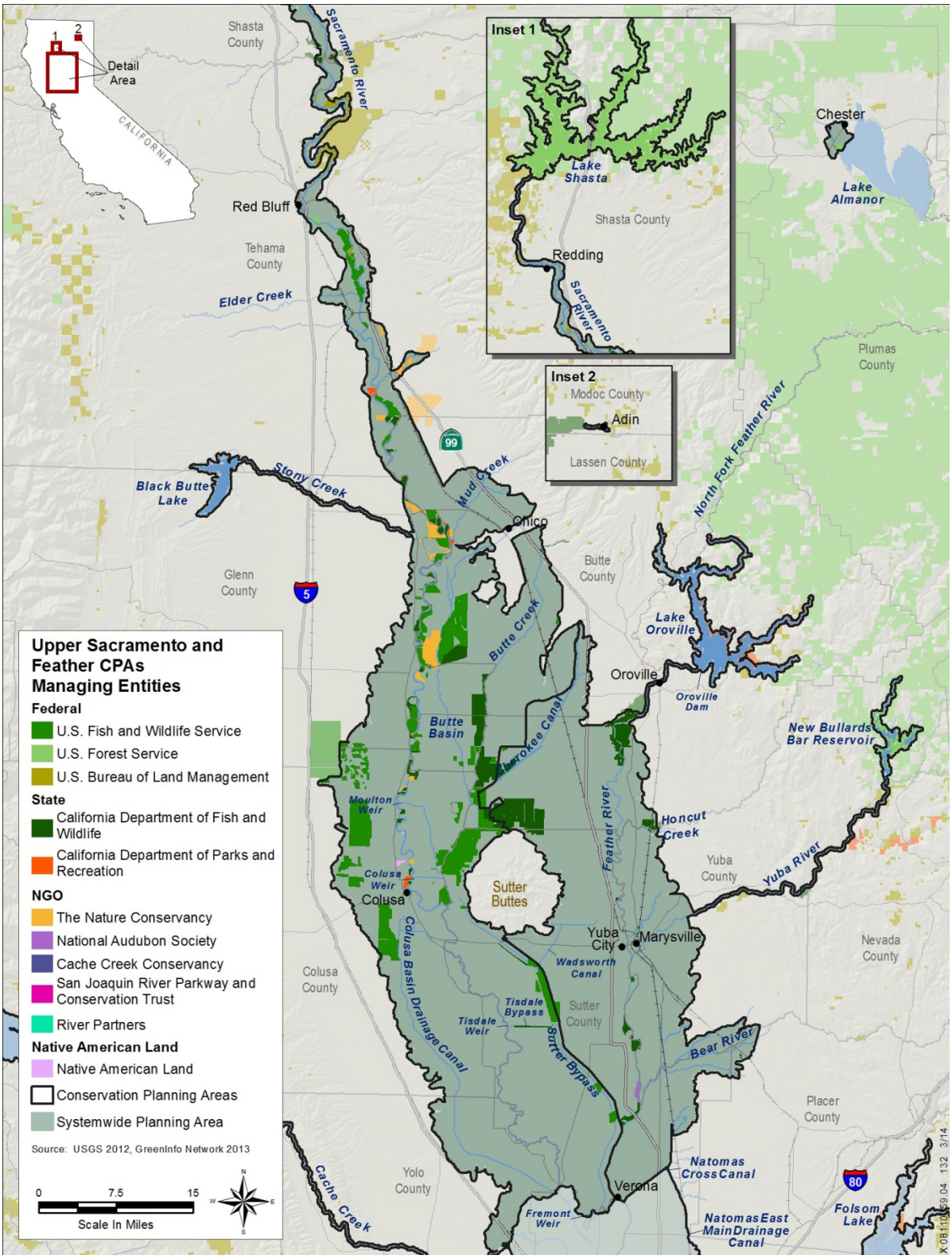
7.1 Invasive Species Management Organizations and Collaborative Planning Efforts

Throughout California, many organizations manage vegetation and control invasive species. These efforts are also conducted through various collaborative efforts at the local, State, and federal levels or by nonprofit organizations. During preparation of this Plan, representatives from these various organizations were contacted, and readily available information was collected to document the roles and responsibilities of these entities, the framework within which these entities work, the relationships among entities, and plans or guiding documents used to direct invasive species management. This information is summarized below. For those entities that actively manage invasive species within their jurisdiction, Figures 7-1 to 7-4 show the management boundaries of these entities within each of the CPAs.

7.1.1 Interagency Organizations and Collaborative Efforts

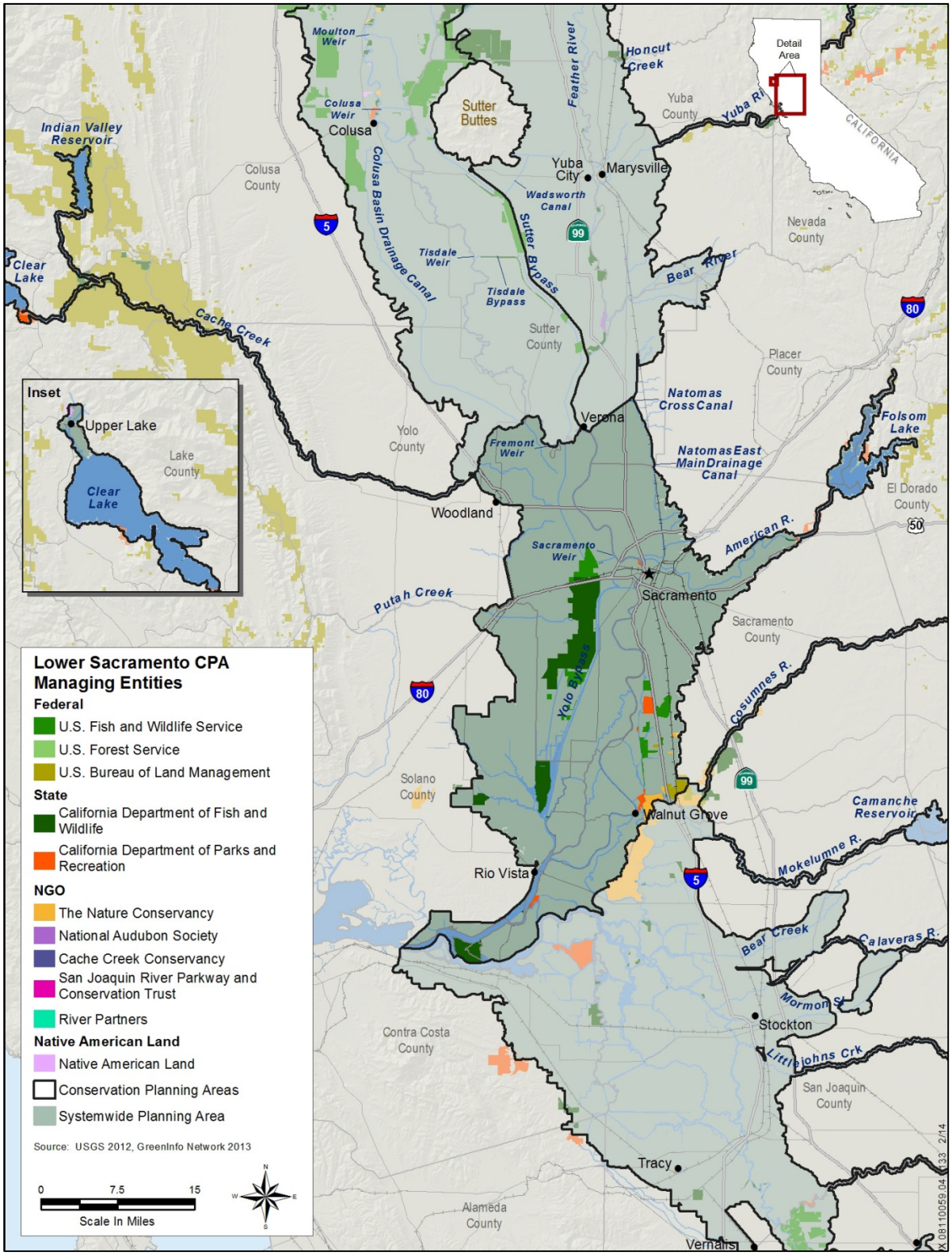
National Invasive Species Council

At the federal level, the National Invasive Species Council (NISC) is the primary agency responsible for coordinating invasive species control. The NISC is tasked by Executive Order 13112 to ensure that federal programs and activities to prevent and control invasive species are coordinated, effective, and efficient (NISC 2013). The NISC, established in 1999, is responsible for consulting with the California Invasive Species Advisory Committee (CISAC) (a nonfederal stakeholder advisory group), drafting and revising the National Invasive Species Management Plan, drafting the interdepartmental Invasive Species Performance Budget, reviewing progress under the plan, and working with the U.S. Department of State to provide input for international invasive species standards. The first National Invasive Species Management Plan was completed in 2001. The updated 2008–2015 plan was approved on 1 August 2008.



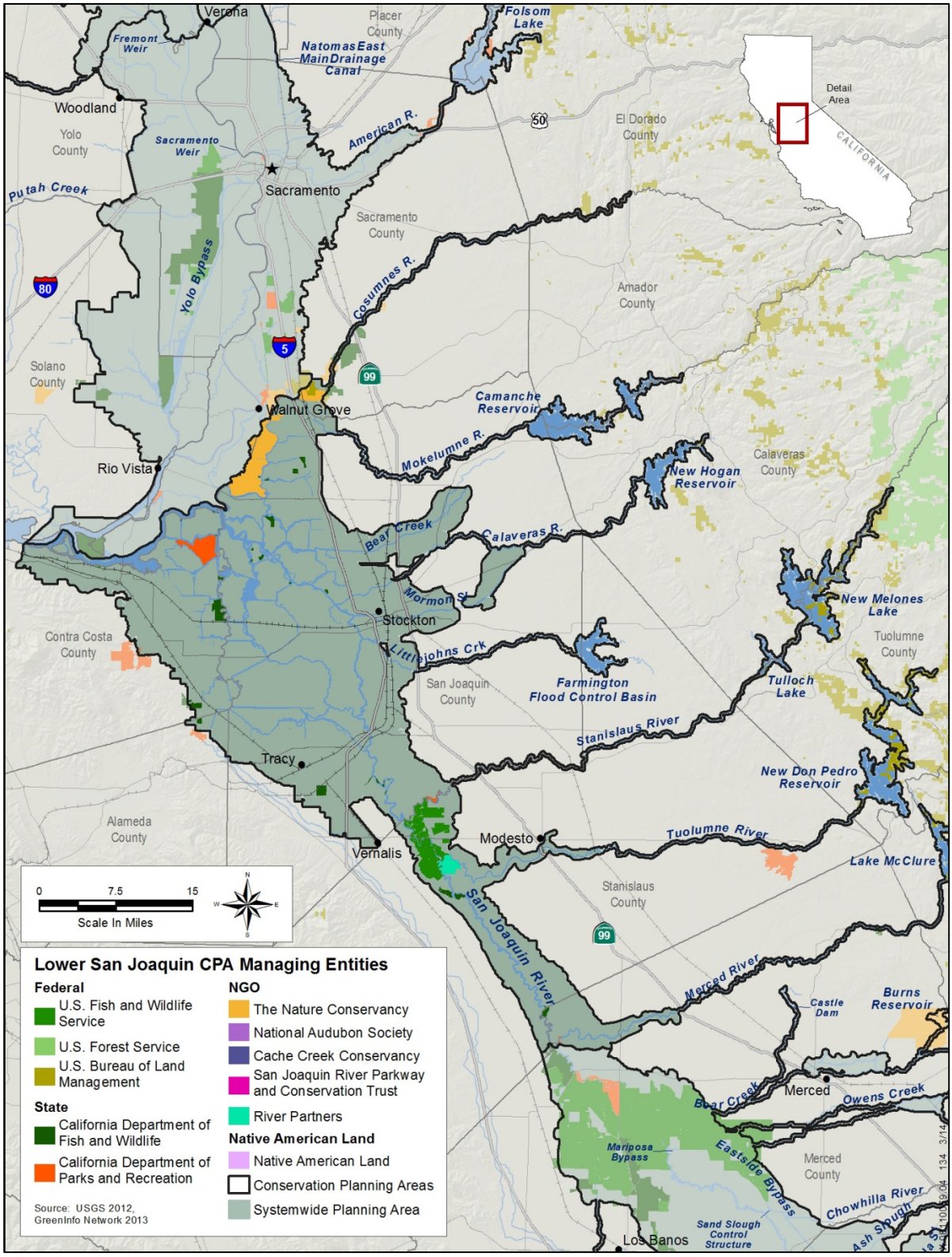
Sources: DWR 2010, Green Info Network 2013, and USGS 2012.

Figure 7-1. Upper Sacramento and Feather River CPA Land Management Entities



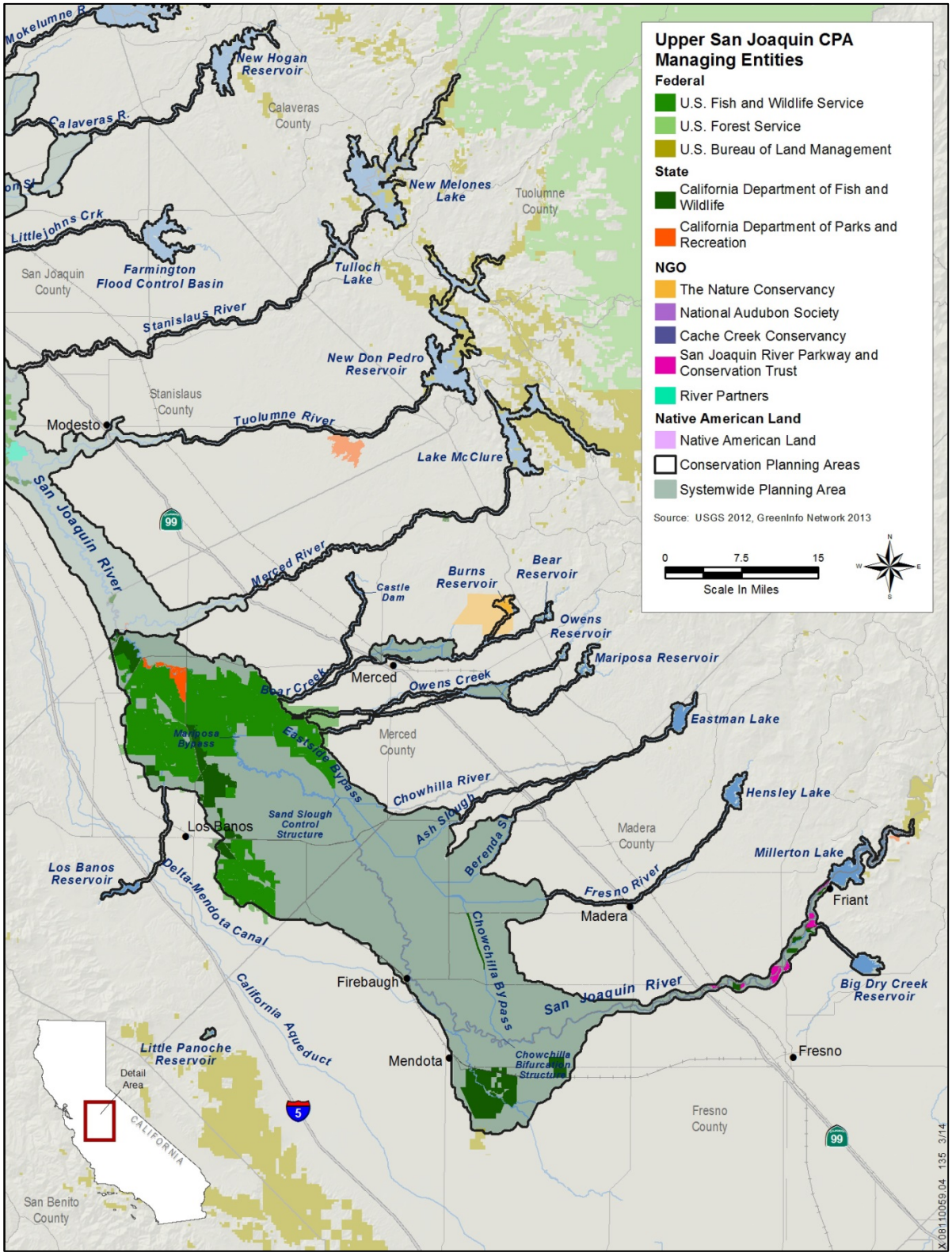
Sources: DWR 2010, GreenInfo Network 2013, and USGS 2012.

Figure 7-2. Lower Sacramento River CPA Land Management Entities



Sources: DWR 2010, GreenInfo Network 2013, and USGS 2012.

Figure 7-3. Lower San Joaquin River CPA Land Management Entities



Sources: DWR 2010, GreenInfo Network 2013, and USGS 2012.

Figure 7-4. Upper San Joaquin River CPA Land Management Entities

Federal Interagency Committee for the Management of Noxious and Exotic Weeds

The Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW), established in 1994, is a formal partnership between 16 federal agencies with direct invasive plant management and regulatory responsibilities across the United States (FICMNEW 2013). The FICMNEW's responsibilities include sharing information with public and private organizations, fostering collaborative efforts, providing recommendations for management at national and regional levels, and sponsoring conferences and workshops. A primary initiative of the FICMNEW is to link the science behind invasive species management with federal control efforts.

California Interagency Noxious Weed Coordinating Committee

The California Interagency Noxious Weed Coordinating Committee (CINWCC), formed in 1995, changed its name to CINIPC (the California Interagency Noxious and Invasive Plant Committee). CINIPC facilitates, promotes, and coordinates the establishment of an IPM partnership between public and private land managers (CDFA 2013a). The committee initiated the War on Weeds Mini-Grants Program, developed the CINIPC website, developed the CalWeed Database, and sponsored the newsletter "Noxious Times," available at http://www.cdfa.ca.gov/plant/ipc/noxioustimes/noxtimes_hp.htm. The War on Weeds Mini-Grants Program was funded in 1999 and 2000. The CalWeed Database was integrated into the more comprehensive NRPI, described in Section 3.

California Biodiversity Council

The California Biodiversity Council (CBC), formed in 1991, established an interagency committee to strengthen relationships and encourage cooperation and coordination among various resource management and environmental protection organizations at the federal, State, and local levels (CBC 2008). The CBC focuses on developing strategies and complementary policies, including those to control invasive species, to conserve California's biodiversity.

Invasive Species Council of California

The Invasive Species Council of California (ISCC), formed in 2009, represents the highest State authority in the management of invasive species (ISCC 2013). It is chaired by the secretary of CDFA and is an interagency council that helps to coordinate and ensure complementary, cost-efficient, and environmentally sound and effective state activities to control invasive species. The ISCC established CISAC in 2009 to advise the ISCC (ISCC 2013). CISAC consists of various stakeholder representatives (federal, State, and local governments; tribal representation; research institutes; industry sector representatives; environmental organizations; and affected landowners). Its responsibilities include making recommendations to develop and prioritize an invasive species action plan, developing a regularly updated statewide "living list" of invasive species, creating a strategic framework for addressing invasive species, and engaging public participation in decision making. CISAC has prepared a strategic framework to protect California from invasive species (CISAC 2011).

California Invasive Weeds Awareness Coalition

The California Invasive Weeds Awareness Coalition (CALIWAC) is a partnership of nonprofit and industry groups working together to enhance weed control efforts and increase public

awareness of noxious and invasive weeds in California (CDFA and CALIWAC 2005). Its goals include promoting sound State and national policy on invasive weeds, providing a public forum to increase awareness of the environmental and economic damage caused by invasive weeds, and increasing funding for management of invasive weeds (Cal-IPC 2013c). CALIWAC formally requested that CDFA initiate production of a statewide invasive species action plan. CALIWAC and CDFA ultimately were coauthors of the document (CDFA and CALIWAC 2005).

Natural Resources Project Inventory

The NRPI is an online database established as a collaborative effort between the ICE at the University of California, Davis, and CBC. Funding for NRPI has been provided by the U.S. Bureau of Land Management (BLM), the California Environmental Protection Agency and State Water Resources Control Board, DWR, CDFA, the California Department of Conservation, the Natural Resources Conservation Service (NRCS), CDFW, the San Francisco Bay Fund, the San Francisco Estuary Institute, the Resources Legacy Fund, the California Resources Agency, the California Coastal Conservancy, and CALFED Bay-Delta Program (ICE 2013). The NRPI database, which identifies more than 8,000 natural resource projects, is the most comprehensive, statewide database of such projects, including those focused on invasive plant treatment. The database includes projects originally identified in the CalWeed Database, created by CINIPC. The Delta Conservancy is currently updating the EcoAtlas for restoration projects; this atlas may become a more useful means of tracking treatment efforts if it effectively replaces the NRPI.

California Riparian Habitat Joint Venture

The California Riparian Habitat Joint Venture (RHJV) was started in 1994 as a collaborative project between federal, State, and private organizations to restore, enhance, and protect a network of functioning riparian habitat across California. The purpose of the project is to support the long-term viability of populations of riparian-associated birds and other wildlife (RHJV 2013). The RHJV's goals include identifying and developing technical information, based on sound science, for a strategic approach to conserving and restoring riparian areas in California; promoting and supporting riparian conservation on the ground by providing guidance, technical assistance, and a forum for collaboration; and developing and influencing riparian policies through outreach and education. In 2004, the RHJV completed the Riparian Bird Conservation Plan, a guidance document for riparian conservation actions centered on 14 riparian-associated bird species. RHJV emphasizes habitat restoration and enhancement for the focal species and, by extension, invasive species control.

Team Arundo del Norte

Team Arundo del Norte (Team) is a group of federal, State, and local organizations that came together in 1996. The Team is dedicated to the control of *Arundo donax* (giant reed) in central and northern California. The Team's responsibilities include exchanging information and cultivating partnerships in support of continuing *Arundo* eradication. The Team meets regularly in Sacramento.

7.1.2 Federal Agencies and Organizations

U.S. Fish and Wildlife Service

USFWS oversees the National Wildlife Refuge system and uses an IPM planning approach to manage invasive plant species in refuges across the United States (USFWS 2012). The agency has established a large volunteer program to help control invasive species throughout the system. In the SPA, both the Sacramento River National Wildlife Refuge and the San Joaquin River National Wildlife Refuge have been the focus of coordinated volunteer efforts.

In addition to its efforts in the refuges, USFWS works through various partnerships with other entities, including FICMNEW and NISC, to control the spread of invasive species on and off USFWS lands, and takes a proactive approach to address introductions. USFWS also has a Branch of Aquatic Invasive Species that leads the Aquatic Invasive Species Program.

U.S. Bureau of Land Management

BLM acts as the weed coordinator for almost 250 million acres of public land. It works with federal, State, and local agencies to reduce the spread of invasive species (BLM 2013). Its partners include entities working with most CDFA WMA groups in the SPA. BLM uses *Pulling Together: National Strategy for Invasive Plant Management* (FICMNEW 1998) to guide its invasive plant efforts, and emphasizes early detection of, and rapid response to, new invasions to reduce future cost and efforts. Support for the BLM Weed Management and Invasive Species Program is provided by several BLM programs affected by invasive species. The National BLM Weed Team has a representative in California, and several BLM field offices in California maintain lists of noxious weeds found in their areas. BLM also has prepared a list of weed prevention and management guidelines for public lands in California (BLM 2008).

U.S. Forest Service

USFS manages vegetation on national forest lands and provides technical and financial assistance for all forest lands through its weed coordinators (USFS 2013). Weed coordinators are designated at the national and regional levels and for each forest. The Pacific Southwest Region of USFS, which includes all of California, manages invasive species based on its Noxious Weed Management Strategy, which is modeled after the national strategy. USFS also standardizes inventory and mapping of invasive weeds across all national forest lands through its Natural Resource Information System Terra database. There are four national forests that intersect the SPA: Shasta-Trinity National Forest, Lassen National Forest, Plumas National Forest, and Stanislaus National Forest.

U.S. Geological Survey

USGS does not directly coordinate or manage invasive plant species; however, it is the primary research agency in the U.S. Department of the Interior, and invasive species ecology and management are topics of this research (USGS 2013). Through its Invasive Species Program, USGS supports cooperative efforts to document and monitor the introduction and spread of invasive species, studies the ecology of invaders and factors in the resistance of habitats to invasion, forecasts probabilities and locations of future invasions, provides methods and information to assess and manage risks, and develops methods to control and prevent the

introduction of invasive species and minimize their environmental impacts. The USGS regional branch that conducts research in and near the SPA is the Western Ecological Research Center.

Natural Resources Conservation Service

NRCS, in the U.S. Department of Agriculture (USDA), is an organization established by Congress in 1935 (originally as the Soil Conservation Service) to help people conserve, maintain, and improve natural resources and the environment. NRCS facilitates invasive species control in four ways: technical and financial assistance to manage invasive species and pests, conservation initiatives that work at a landscape scale, conservation innovation grants with partner entities to support development and implementation of innovative approaches and strategies to address invasive species, and Plant Materials Center research geared toward invasive species management and restoration of areas where invasive species have been removed. NRCS has state offices, and within each state it has local service centers, typically organized by county. NRCS has four area offices in California; three of these (Areas 1, 2, and 3) cover portions of the SPA. Within each of these areas are multiple staff and field offices.

7.1.3 California Agencies and Organizations

California Department of Food and Agriculture

CDFA is the lead state agency for noxious weed management (CDFA 2013b). It is responsible for implementing weed control programs, overseeing eradication efforts for A-rated noxious weeds, coordinating work with WMA groups, operating border control stations, and distributing biological control agents. CDFA operates its weed management efforts under the California Noxious and Invasive Weed Action Plan (CDFA and CALIWAC 2005; available at http://www.cdfa.ca.gov/plant/ipc/noxweedinfo/pdfs/noxious_weed_plan.pdf). It also maintains an official list of noxious weeds in the California Code of Regulations and maintains the Noxious Weed Information Project, the purpose of which is to collect and process data on current weed management projects and provide maps and information to CDFA, biologists, and the general public.

California Department of Parks and Recreation

The California Department of Parks and Recreation (State Parks) manages 280 park units throughout the state (State Parks 2013a). It is responsible for preserving and restoring native plants and animals, and its resource management policies call for the systematic removal of populations of exotic plant species in wildland settings in the park system. Targets and priorities for invasive plant management are set at the park district level, often through park plans. Some districts have also conducted inventories of infestations using GIS. State parks in or adjacent to the SPA include Caswell Memorial State Park, Great Valley Grasslands State Park, Sutter Buttes State Park, South Yuba River State Park, and Bidwell–Sacramento River State Park.

California Department of Fish and Wildlife

The mission of CDFW's Invasive Species Program is to reduce the negative effects of nonnative invasive species on the wildlands and waterways of California (CDFW 2013). The program is housed in the Habitat Conservation Planning Branch of the Ecosystem Conservation Division of CDFW. Program managers are tasked with preventing the introduction of invasive species into

the state, detecting and responding to introductions, and preventing the spread of nonnative invasive species that have become established. CDFW also maintains the California Aquatic Invasive Species Management Plan, which proposes actions for addressing aquatic invasive species.

CDFW began annual surveys of CDFW-managed lands in 2001. Each year, a sampling of the lands managed by CDFW is surveyed to identify the current status of weed infestations. CDFW Wildlife Areas in the SPA include the Feather River Wildlife Area and the Oroville Wildlife Area.

California State Parks, Division of Boating and Waterways

The Division of Boating and Waterways is legislatively mandated to control two invasive aquatic weeds, Brazilian waterweed and water hyacinth, in the Delta and its tributaries (State Parks 2013b). The Division maintains an extensive monitoring and reporting program to evaluate the effectiveness of its control programs for these two species.

California Department of Transportation

The California Department of Transportation (Caltrans) manages approximately 15,000 miles of highway and more than 230,000 miles of right-of-way throughout the state (Caltrans 1997). Vegetation management, including noxious weed control, is a large portion of Caltrans's management effort. In 1992, Caltrans adopted an integrated vegetation management program with a goal to reduce chemical use by 80 percent by 2012.

San Joaquin River Conservancy

The San Joaquin River Conservancy is a regionally governed State agency that was legislatively mandated to establish and manage the San Joaquin River Parkway, which extends from Friant Dam to State Route 99 (San Joaquin River Conservancy 2013). Its mission includes acquiring land to develop, operate, and manage for public access and recreation, and protecting, enhancing, and restoring riparian and floodplain habitat. The Conservancy is currently updating the Parkway Master Plan, its guiding policy document. Many projects funded or contracted by the San Joaquin River Conservancy involve invasive weed removal efforts and restoration.

University of California Division of Agriculture and Natural Resources

The University of California Division of Agriculture and Natural Resources runs the University of California Statewide Integrated Pest Management Program, which helps residents, growers, land managers, community leaders, and other professional pest managers prevent and solve pest problems with the fewest unintended impacts on people and their surroundings (Regents of the University of California 2013). The program works through the University of California Cooperative Extension to deliver information via seminars, workshops, and educational resources. The Cooperative Extension maintains the Weed Research and Information Center, which has information on invasive plant management.

Sacramento–San Joaquin Delta Conservancy

The Sacramento–San Joaquin Delta Conservancy (Delta Conservancy) was established by the 2009 Delta Reform Act to serve as a primary state agency to implement ecosystem restoration in

the Delta and support efforts that advance environmental protection and the economic well-being of Delta residents. In 2012, the Delta Conservancy completed its Strategic Plan, which calls for leading efforts in protecting, enhancing, and restoring the Delta ecosystem in coordination with other governmental and nongovernmental entities and citizens in the Delta. The Delta Conservancy has developed an Arundo Control and Restoration Program that encompasses the entire Delta. This program will identify and map giant reed infestations, prioritize the control of giant reed, remove and treat infestations, and restore native vegetation where appropriate.

7.1.4 Local Agencies and Organizations

California Department of Food and Agriculture and County Agricultural Commissioners

CDFA, through individual County Agricultural Commissioners, plays a key role in coordination and local responsibility for noxious weed eradication and prevention (http://cacasa.org/). Each county generally operates eradication or control projects within its jurisdiction and coordinates efforts with CDFA and the WMA groups (see below).

Weed Management Areas

Beginning in 1999, California state laws were passed to coordinate invasive plant management efforts. Specifically, Section 7271 of the California Food and Agriculture Code (CFAC) designates CDFA as the lead agency in noxious weed management and established the CDFA Noxious Weed Management Account for funding a statewide network of WMAs. WMAs are local stakeholder groups working on weed projects, commonly led by a county agricultural department or the local Resource Conservation District (Cal-IPC 2013d). Each WMA develops a strategic plan that identifies its top priorities for local management. WMAs are responsible for collaboratively planning and implementing on-the-ground projects, mapping invasive species in their areas, and providing public education.

Funding for WMA activities was historically provided by the California Legislature, but State funding for WMAs stopped in 2008. Nonlegislative funding for WMA activities can be provided by CDFA's Adopt-A-Riverway Program, a government-volunteer partnership. The CFAC allows CDFA, through the Adopt-A-Riverway Program, to accept funds or services from any person and provide them to WMAs to implement integrated weed management plans. Currently, there are 14 WMAs active in the SPA, despite the lack of dedicated State funding. Of these, the Sacramento WMA has adopted a strategic plan.

California Association of Resource Conservation Districts

There are 99 Resource Conservation Districts in California; these districts are leaders in on-the-ground conservation efforts (California Department of Conservation 2013). The districts are often involved in practical, hands-on conservation projects that include invasive species eradication or control. They have a strategic plan (California Association of Resource Conservation Districts 2012) that guides their conservation efforts, and each district produces annual and long-range plans to guide its work program (California Department of Conservation 2013).

7.1.5 Nongovernmental Organizations

The Nature Conservancy

The Nature Conservancy (TNC) administered the Global Invasive Species Initiative (GISI) for more than 10 years. The efforts of GISI included addressing problems posed by invasive plants through a combination of prevention, early detection, eradication, restoration, research, and outreach (University of Georgia 2011). However, the GISI team was disbanded in 2009 because of budget cuts. The website http://invasive.org/, through the University of Georgia, hosts an archival copy of GISI's website and resources, including Invasipedia, the Weeds Information Management System database, a weed control methods handbook, and a management library. TNC has local field offices throughout California; these have been involved with smaller-scale weed management projects on TNC preserves.

National Audubon Society

The mission of the National Audubon Society is to conserve and restore natural ecosystems, focusing on birds, other wildlife, and their habitats for the benefit of humanity and Earth's biological diversity (National Audubon Society 2013). The society recognizes that invasive weeds choke out and destroy valuable bird and wildlife habitat. Through invasive species workshops and the "Stop Invasive Species" campaign, the society disseminates information about invasive species and their impacts on habitat for birds and other animals. It also works to develop and pass federal legislation to curb the invasive species threat. The National Audubon Society also works at the state level: its state chapter in California has approximately 48 local chapters. Audubon California manages several preserves that conduct invasive species management.

California Invasive Plant Council

Cal-IPC coordinates with agencies, industry, and other nongovernmental organizations, supporting the IPM approach to weed management. Cal-IPC's responsibilities include assessing the impact of invasive plants, supporting restoration workers, supporting research, promoting public education, advocating policy initiatives, reducing the introduction of invasive plants through horticulture, supporting development of biological control agents, and coordinating statewide weed mapping through CalWeed Mapper (Cal-IPC 2013b). Cal-IPC also maintains the online Invasive Plant Inventory (Cal-IPC 2013a), which categorizes nonnative invasive plants based on their levels of negative ecological impact in California.

California Native Plant Society

The California Native Plant Society (CNPS) works to preserve California's native plants and promote native plant appreciation, research, education, and conservation (CNPS 2013). CNPS works with other entities, such as Cal-IPC and CDFA, to identify the highest-risk invasive plants and to find methods to eradicate them. CNPS has five statewide programs and 34 regional chapters, many of which are involved in small-scale weed control and eradication projects. CNPS invasive plant management is guided by its Policy on Invasive Exotic Plants (CNPS 1996) and its policy on wildland invasive plants and integrated weed management (CNPS 2008).

California Horticultural Invasives Prevention

California Horticultural Invasives Prevention was established in 2004 with support from Cal-IPC (Cal-IPC 2013e). Members of this group represent the nursery and landscaping industries, environmental groups, academia, and government agencies. The group is responsible for developing voluntary measures to reduce the number of invasive plant species sold in California and for preventing further invasions from horticultural sources. The group has compiled a list of invasive ornamental plants and has developed the PlantRight campaign to help provide information to nurseries, gardeners, and landscape professionals.

Other Nongovernmental Organizations in the SPA

Several local nongovernmental organizations throughout the SPA conduct invasive weed management. Most of these organizations were established to preserve and restore specific or general riparian or watershed areas and resources. They often work in partnership with the public or private landowners, are volunteer-based, and have education and stewardship programs. These organizations often lead small-scale, on-the-ground invasive weed management projects. Nongovernmental organizations in the SPA include River Partners, the Putah Creek Council, the San Joaquin River Stewardship Program, and the Cache Creek Conservancy. Also, numerous land trusts and land conservancies are located throughout the Central Valley, and these may be involved in invasive plant management efforts in the SPA. A complete list of land trusts and conservancies active in California is available from the California Council of Land Trusts.

7.1.6 Corporate/Private Landowners

Private or corporate landowners often implement conservation or stewardship policies that involve invasive weed management. These landowners include electric and gas utility companies (e.g., the Sacramento Municipal Utility District and the Pacific Gas and Electric Company), railroads, and members of the timber harvest industry. In addition, agricultural landowners are often concerned with invasive plant management because noxious weeds have a significant effect on production and economics. Native American tribes represent another type of private landowner that manages invasive weeds on private lands (CDFA and CALIWAC 2005).

7.2 Funding Sources

Funding sources for invasive plant control include a variety of grants from federal, State, or nongovernmental organizations. The various sources of funding discussed below are highlighted because they could enable collaborative planning and treatment efforts that span lands in the SPA maintained by both DWR and other entities. DWR, or other LMAs directly responsible for maintenance of the SPA, may not be eligible to participate directly in some of these programs, but these programs may provide a source of funding that other entities (e.g., Resource Conservation Districts) could leverage in partnership with DWR to increase management of invasive plants within the SPA. Additionally, these funding sources could be used to fund invasive plant management on lands outside the SPA, where collaborative management of invasive plants outside the SPA would complement invasive plant management efforts by DWR and others within the SPA.

7.2.1 Federal Grant Programs and Initiatives

Natural Resources Conservation Service

NRCS administers several grant and technical assistance programs that, although not directly focused on invasive plant management, could potentially fund a variety of conservation projects that could include components focused on invasive plant assessment, planning, and treatment along with associated habitat restoration. As described above, DWR and other LMAs may not be eligible to apply for many of these programs, but they could partner with other, eligible organizations (e.g., resource conservation districts) to fund collaborative invasive plant management efforts.

Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) provides financial and technical assistance to agricultural producers to address natural resource concerns and deliver environmental benefits, such as improved water and air quality, conserved groundwater and surface water, reduced soil erosion and sedimentation, and improved or created wildlife habitat. Eligible program participants receive financial and technical assistance to implement conservation practices, or activities like conservation planning, that address natural resource concerns on their land. Payments are made to participants after conservation practices and activities identified in an EQIP plan of operations are implemented. Contracts can last up to 10 years. Agricultural producers and owners of nonindustrial private forestland and tribes are eligible to apply for EQIP. Eligible land includes cropland, rangeland, pastureland, nonindustrial private forestland, and other farm or ranch lands.

For more details about EQIP, see
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/.

Conservation Stewardship Program

The Conservation Stewardship Program (CSP) encourages land stewards to improve their conservation performance by adopting additional activities and improving, maintaining, and managing activities on agricultural land and nonindustrial private forestland. CSP is available on tribal and private agricultural lands and nonindustrial private forestland in all 50 states and the Caribbean and Pacific Islands. The program provides equitable access to all producers, regardless of operation size, crops produced, or geographic location. Through CSP, NRCS will provide financial and technical assistance to eligible producers to conserve and enhance soil, water, air, and related natural resources on their land.

For more details about the CSP, see
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/

Agricultural Conservation Easement Program

The Agricultural Conservation Easement Program provides financial and technical assistance to help conserve agricultural lands and wetlands and their related benefits. Under the Agricultural Land Easements component, NRCS helps Indian tribes, state and local governments, and nongovernmental organizations protect working agricultural lands and limit nonagricultural uses

of the land. Under the Wetlands Reserve Easements component, NRCS helps to restore, protect, and enhance enrolled wetlands. Agricultural land easements protect the long-term viability of the nation's food supply by preventing conversion of productive working lands to nonagricultural uses. Agricultural land easements provide additional public benefits, including improved environmental quality, historic preservation, protection of wildlife habitat, and protection of open space. Wetland reserve easements protect habitat for fish and wildlife, including threatened and endangered species; reduce flooding; allow groundwater recharge; protect biological diversity; and provide opportunities for educational, scientific, and limited recreational activities.

For more details about the Agricultural Conservation Easement Program, see http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/acep/

Healthy Forests Reserve Program

The Healthy Forests Reserve Program (HFRP) helps landowners restore, enhance, and protect forestland resources on private lands through easements and financial assistance. HRFP aids the recovery of endangered and threatened species protected under the ESA, improves plant and animal biodiversity, and enhances carbon sequestration. HFRP provides landowners with 10-year restoration agreements and 30-year or permanent easements for specific conservation actions. For acreage owned by an Indian tribe, there is an additional enrollment option of a 30-year contract. Some landowners may avoid regulatory restrictions under the ESA by restoring or improving habitat on their land for a specified period. Land enrolled in HFRP easements must be privately owned or owned by Indian tribes and must be used to restore, enhance, or measurably increase the recovery of threatened or endangered species; improve biological diversity; or increase carbon storage.

For more details about HFRP, see http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/easements/forests/?cid=stelprdb1242716

Regional Conservation Partnership Program

The Regional Conservation Partnership Program (RCPP) promotes coordination between NRCS and its partners to deliver conservation assistance to producers and landowners. NRCS provides assistance to producers through partnership agreements and through program contracts or easement agreements. RCPP encourages partners to join in efforts with producers to increase the restoration and sustainable use of soil, water, wildlife, and related natural resources on regional or watershed scales. Through RCPP, NRCS and its partners help producers install and maintain conservation activities in selected project areas. Partners leverage RCPP funding in project areas and report on the benefits achieved. Conservation program contracts and easement agreements are implemented through the Agricultural Conservation Easement Program, EQIP, CSP, or HFRP. NRCS may also use the authorities under the Watershed and Flood Prevention Operations Program in the designated critical conservation areas.

For more details about RCPP, see http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/farmbill/rcpp/

California Conservation Innovation Grants Program
The Conservation Innovation Grants program, administered by NRCS, is a competitive grant program for nongovernmental organizations or individuals who use EQIP funds. The program is intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging federal investment in environmental enhancement and protection in conjunction with agricultural production. The desired result of the program is accelerated technology transfer, development and demonstration of cutting-edge ideas to improve conservation on private lands, and adoption of promising approaches that address some of the nation's most pressing natural resource concerns. Successful grant proposals demonstrate innovative approaches to improving soil health, conserving energy, managing nutrients, and enhancing wildlife habitat.

For more details about the Conservation Innovation Grants program, see http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/cig/.

Watershed and Flood Prevention Operations Program
The Watershed and Flood Prevention Operations Program provides technical and financial assistance to states, local governments, and tribes (project sponsors) to plan and implement authorized watershed project plans for the purpose of watershed protection; flood mitigation; water quality improvements; soil erosion reduction; rural, municipal, and industrial water supply; irrigation; water management; sediment control; fish and wildlife enhancement; and hydropower. Under this program, NRCS cooperates with states and local agencies to carry out improvement projects for soil conservation and other purposes, including flood prevention; conservation, development, use, and disposal of water; and conservation and proper use of land.

For more details about the Watershed and Flood Prevention Operations Program, see http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/landscape/wfpo/?cid=nrcs143_008271

National Fish and Wildlife Foundation—California ReLeaf Pulling Together Initiative
The California ReLeaf Pulling Together Initiative grant program is administered by the National Fish and Wildlife Foundation and is designed to help control invasive plant species mostly by fostering the formation of public-private partnerships, such as cooperative weed management projects. Qualifying projects must prevent, manage, or eradicate invasive species through a coordinated program of public/private partnerships, and must raise public awareness of the adverse effects of introducing invasive species. Successful grant proposals will do the following:

- Focus on a well-defined area, such as a watershed, ecosystem, landscape, county, or WMA
- Incorporate on-the-ground management, eradication, or prevention
- Target a specific and measurable conservation outcome
- Support private landowners, State and local governments, and the regional and state offices of federal agencies

- Include a project steering committee of local cooperators working together across their jurisdictional boundaries
- Present a clear, long-term management plan based on an IPM approach
- Include a specific, ongoing, and adaptive public outreach/education component
- Integrate an early detection/rapid response approach

For more details about the California ReLeaf Pulling Together Initiative, see http://californiareleaf.org/grants/pulling-together-initiative-grants.

U.S. Environmental Protection Agency—Pesticide Registration Improvement Act Partnership Grant Program

The Pesticide Registration Improvement Act partnership was established in 2008 to fund grant projects that advance public-private partnerships focusing on pesticide stewardship efforts, especially those involving the use of IPM. Qualifying projects use demonstration, outreach, and/or education to increase the adoption of reduced-risk/IPM approaches. The partnership aims to achieve the following goals:

- Promote partnerships between farmers, ranchers, scientists, cooperative extensions, and government agencies to demonstrate, promote, and expand reduced-risk/IPM approaches.
- Measure and document the effects of implementing reduced-risk/IPM approaches on the environment, human health, and the community.
- Promote the economic benefits of using IPM approaches, and provide data and analysis on costs associated with adopting IPM to pesticide users.

For more details about the partnership, see http://www.epa.gov/pesp/pria2/index.html.

U.S. Fish and Wildlife Service—Neotropical Migratory Bird Conservation Act Grant Program

The Neotropical Migratory Bird Conservation Act grant program uses a portion of the funding available to the act to support public-private partnerships that conserve Neotropical migratory birds and their habitats throughout their migratory ranges, from breeding sites in Canada and the United States to wintering sites in Mexico, Central and South America, and the Caribbean. The grant program seeks to support projects that have the highest potential to leverage resources and interest into plans or programs that contribute significantly to the conservation of high-priority species in the next 5–10 years. Birds from all taxa are included, so proposals may benefit land birds, waterbirds, shorebirds, waterfowl, raptors, and others.

Various types of projects may be eligible, including projects involving maintenance, management, protection, and restoration of Neotropical migratory bird habitat. Of particular interest are on-the-ground conservation projects that directly improve the population status of these species. The grant program also considers research, monitoring, or assessment projects for

a broader set of species of conservation concern, if the projects significantly contribute to filling information gaps that inhibit implementation of the most effective conservation actions. Successful projects demonstrate a measurable biological improvement in the population or increase knowledge and understanding of the population-limiting factors affecting these species.

For more details about Neotropical Migratory Bird Conservation Act grants, see http://www.fws.gov/birdhabitat/Grants/NMBCA/index.shtm.

U.S. Fish and Wildlife Service —Division of Bird Habitat Conservation, North American Wetlands Conservation Act of 1989—Standard Grants Program

The USFWS Division of Bird Habitat Conservation administers the North American Wetlands Conservation Act's Standard Grants Program, which is a matching grant program that supports public-private partnerships to implement projects in Canada, the United States, and Mexico. Each country has a program process through which eligible proposals are reviewed, ranked, and recommended by the North American Wetlands Conservation Council. Recommendations are then submitted to the Migratory Bird Conservation Commission for approval. Proposed projects must involve long-term protection, restoration, and/or enhancement of wetlands and associated upland habitats for the benefit of all wetlands-associated migratory birds.

For more details about the Standard Grants Program, see http://www.fws.gov/birdhabitat/Grants/NAWCA/Standard/index.shtm.

U.S. Fish and Wildlife Service—Division of Bird Habitat Conservation, North American Wetlands Conservation Act of 1989—Small Grants Program

Like the Standard Grants Program, the North American Wetlands Conservation Act's Small Grants Program is a matching grant program supporting public-private partnerships. The Small Grants Program was developed to encourage new grantees and partners to carry out smaller-scale, long-term wetlands conservation projects that might not be able to compete for a grant through the Standard Grants Program. The Small Grants Program is for projects carried out in the United Sates that aim to further the goals of the North American Wetlands Conservation Act. As with the Standard Grants Program, qualifying projects must involve long-term protection, restoration, and/or enhancement of wetlands and associated upland habitats for the benefit of all wetlands-associated migratory birds.

For more details about the North American Wetlands Conservation Act's Small Grants Program, see http://www.fws.gov/birdhabitat/Grants/NAWCA/Small/index.shtm.

Plant Conservation Alliance—Native Plant Conservation Initiative

The Native Plant Conservation Initiative is a matching grant program funded by USFWS, BLM, and USFS and conducted in cooperation with the Plant Conservation Alliance, a partnership of the National Fish and Wildlife Foundation, 10 federal agencies, and more than 209 nongovernmental organizations. Projects funded by this grant program focus on the conservation of native plants and pollinators in the context of collaboration, education, restoration, research, sustainability, and data linkages.

Proposed projects must provide conservation benefits for native plants, including associated pollinators; involve multiple partnerships; demonstrate the ability to find matching funds beyond the 1:1 federal/nonfederal minimum (including cash or in-kind contributions of goods or services, such as volunteer time); and use innovative ideas, such as a landscape approach, shareable new technologies, and teaching by example. Projects are encouraged to make connections with keystone species and habitats, as listed on the National Fish and Wildlife Foundation website. Grant applications for projects conducted on federal land should include letters of support from appropriate agency program managers familiar with the work.

For more details about the Native Plant Conservation Initiative, see http://www.nps.gov/plants/nfwf/rfp.htm.

7.2.2 State Grant Programs and Initiatives

California Department of Pesticide Regulation—Alliance Grant Program

The Alliance Grant Program funds projects that increase implementation and adoption of proven, effective IPM practices that reduce pesticide risks to human health and the environment. A key element of a successful proposal is the formation of an alliance composed of individuals representing State, local, public, private, educational, or other stakeholders interested in the adoption and implementation of urban and agricultural IPM practices. IPM practices should focus on one of these suggested areas: air quality, groundwater quality, surface water quality, worker and public health and safety, environmental health, and wildlife and endangered species health and habitat.

For more details about the Alliance Grant Program, see http://www.cdpr.ca.gov/dprgrants.htm.

California Wildlife Conservation Board—Inland Wetlands Conservation Program

Through the Inland Wetlands Conservation Program, the California Wildlife Conservation Board authorizes grants and loans to nonprofit organizations, local governmental agencies, and State departments to further the goals of the Central Valley Joint Venture to maintain a diverse, abundant, and healthy distribution of migratory bird populations in the Central Valley through habitat protection, restoration, and enhancement. All projects must satisfy one or more of the eight specific objectives identified in the *Central Valley Joint Venture 2006 Implementation Plan*:

- Protect all remaining unprotected wetlands in perpetuity.
- Restore and protect 108,527 acres of seasonal wetlands.
- Restore and protect 12,500 acres of semi-permanent wetlands.
- Enhance 23,884 acres of seasonal wetlands each year.
- Restore and protect 10,000 acres of riparian habitat over the next 5 years.
- Enhance 307,000 acres of wildlife-friendly agriculture.

- Protect wildlife-friendly agricultural lands through conservation easements in the American, Butte, Sutter, San Joaquin, and Delta basins.
- Protect agricultural lands through conservation easement in the American, Butte, Sutter, Delta, and San Joaquin basins to buffer existing wetlands from urban and residential development.

Partnerships are encouraged in the construction, operation, and maintenance of projects, and the grantee or landowner must provide a contribution of cash or in-kind services for all restoration projects on private lands. The grantee or landowner must also manage and maintain wetlands in perpetuity for easements and for 25 years for all projects on privately owned properties.

For more details about the Inland Wetlands Conservation Program, see https://www.wcb.ca.gov/Programs/Wetlands.aspx.

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9.0 List of Acronyms and Other Abbreviations

BLM ..... U.S. Bureau of Land Management
BMPs ..... Best Management Practices
Cal-IPC ..... California Invasive Plant Council
CALIWAC ..... California Invasive Weeds Awareness Coalition
Caltrans ..... California Department of Transportation
CBC ..... California Biodiversity Council
CDFA ..... California Department of Food and Agriculture
CDFW ..... California Department of Fish and Wildlife
CINIPC ..... California Interagency Noxious and Invasive Plant Committee
CINWCC ..... California Interagency Noxious Weed Coordinating Committee
CISAC ..... California Invasive Species Advisory Committee
CNPS ..... California Native Plant Society
CPA ..... Conservation Planning Area
CSP ..... Conservation Stewardship Program
CVFPB ..... Central Valley Flood Protection Board
CVFPP ..... Central Valley Flood Protection Plan
Delta ..... Sacramento–San Joaquin River Delta
Delta Conservancy.... Sacramento–San Joaquin Delta Conservancy
DES ..... Division of Environmental Services
DFM/FMO ..... DWR's Division of Flood Management/Flood Maintenance Office
DWR ..... California Department of Water Resources
EQIP ..... Environmental Quality Incentives Program
ESA ..... federal Endangered Species Act
FESSRO ..... FloodSAFE Environmental Stewardship and Statewide Resources Office
FICMNEW ..... Federal Interagency Committee for the Management of Noxious and Exotic Weeds
GIS ..... geographic information system
GISI ..... Global Invasive Species Initiative
HACCP ..... Hazard Analysis and Critical Control Point
HFRP ..... Healthy Forests Reserve Program

ICE..... Information Center for the Environment
IPM ..... Integrated Pest Management
Plan ..... Invasive Plant Management Plan
IPMSC ..... invasive plant management steering committee
ISCC ..... Invasive Species Council of California
LMAs ..... Local Maintaining Agencies
LQA ..... Licensed Qualified Applicator
MA ..... Maintenance Area
Maintenance Yards ... DWR's Sacramento and Sutter Maintenance Yards
MOU ..... Memorandum of Understanding
NISC ..... National Invasive Species Council
NMFS ..... National Marine Fisheries Service
NPDES ..... National Pollutant Discharge Elimination System
NRCS ..... Natural Resources Conservation Service
NRPI ..... Natural Resources Project Inventory
NWP ..... Nationwide Permit
O&M ..... operation and maintenance
PCA ..... Pest Control Advisor
RCPP..... Regional Conservation Partnership Program
RHJV ..... California Riparian Habitat Joint Venture
RMA..... Routine Maintenance Agreement
RWQCB..... Regional Water Quality Control Board
SAA ..... Streambed Alteration Agreement
SHPO ..... State Historic Preservation Officer
SPA ..... Systemwide Planning Area
SPFC ..... State Plan of Flood Control
SSIA ..... Systemwide Sustainable Investment Approach
State Parks ..... California Department of Parks and Recreation
TNC ..... The Nature Conservancy
USACE ..... U.S. Army Corps of Engineers
USDA..... U.S. Department of Agriculture
USFS ..... U.S. Forest Service
USFWS..... U.S. Fish and Wildlife Service

WHIPPET ..... Weed Heuristics Invasive Populations Prioritization for Eradication Tool
WMA..... Weed Management Area

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STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES