DRAFT

California Desert
Riparian Restoration Strategy

Executive Summary

Many riparian zones within the California deserts are currently infested with woody, noxious weeds[1], which lower natural biodiversity, alter stream channels and wildfire patterns, and waste scarce water. Sensitive species[2] are most vulnerable to weed infestation. The primary objective for weed control is a return of ecosystems to a natural state, increasing the natural biodiversity. Another objective for weed control is a restoration of habitat for sensitive species. A long-term strategy for weed control within the Deserts' riparian zones will help eradicate, control, isolate, and contain weed populations and therefore help agencies meet these objectives.

Purpose and Need

This strategy provides a broad framework for Integrated Vegetation Management (IVM) of invasive, exotic weeds within selected watersheds throughout the California deserts (Map 1). This strategy document focuses on tamarisk (*Tamarix spp.*), also known as saltcedar. However, when riparian woody weed species other than tamarisk exist, they should be documented and controlled. Many of the deleterious impacts associated with tamarisk can be attributed to other species as well. Therefore, this strategy will also take into account other woody riparian noxious weeds such as arundo (*Arundo donax*), Russian olive (*Elaeagnus angustifolia L.*), and tree-of-heaven (*Ailanthus altissima*).

This strategy document is designed to encourage public land managers and private landowners to undertake coordinated control and restoration. It sets the long-term objectives of a return of riparian ecosystems to a natural state therefore increasing the natural biodiversity and an improvement of habitat for sensitive species. It lays a course of action to meet and maintain these objectives and defines measures of success.

Ecological and Economic Impacts

Ecological and Economic Impacts

Weeds effectively out-compete native flora. These aggressive, woody invasive plant species are relatively long-lived, and once established, can tolerate a wide range of environmental conditions. Tamarisk has become established over as much as a million acres of floodplains, riparian areas, wetlands, and lake margins in the western United States (Johnson 1986). Its rapid spread is due to its ability to produce massive quantities of small seeds with a high dispersal capability, and its ability to also propagate from buried or submerged stems.

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[1] For the purpose of this document, a weed is a plant species that is detrimental or destructive to agriculture, silviculture, or natural ecosystems, and difficult to control or eradicate. This document focuses on woody riparian weeds/

[2] Sensitive species are generally defined as those species that have a special status such as threatened, endangered, or sensitive.

Weed invasions can replace or displace other species that occupy similar habitats, native woody species such as cottonwood, willow, and mesquite. In addition to causing a loss of habitat, weed species provide little wildlife forage and are often so dense that some animals cannot reach the associated water sources. Thus, stands of weeds generally have lower wildlife values compared to stands of native vegetation. This is especially the case for sensitive species that are often suffering from a variety of impacts.

Weeds also contribute to fire danger/hazard by increasing fire intensity and can quickly alter natural flood regimes, causing economic losses to croplands and rangelands. Additionally, tamarisk is tolerant of highly saline habitats, and it extracts and concentrates the salts in its leaves (hence the colloquial name of saltcedar). Over time, as leaf litter accumulates under the tamarisk plants, the surface soil can become highly saline, thus impeding future colonization by many native plant species.

The most deleterious effects of weeds on wetlands are site conversion to a weed monocultures and an unnaturally high loss of surface and ground water through high rates of evapotranspiration. This is especially true of tamarisk, which is a facultative phreatophyte, meaning that it can draw water from underground sources. Once established, however, tamarisk can survive without access to ground water. Tamarisk consumes large quantities of water, more than woody native plant species that occupy similar habitats.

A major source of water depletion from the riverine systems in arid to semi-arid areas is evapotranspiration. For example, in the Middle Rio Grande, NM, as much as 20-50% of the water losses from the system are due to evapotranspiration (ET) (Dahm, et. al. 2002). In a study conducted along a 320 km length of this river, mixed riparian stands of tamarisk, cottonwood (*Populus deltoides* spp.) and Russian olive had the highest rates of ET losses. These constituted about 20-33% of the total estimated water losses along the river stretch measured (Dahm, et. al. 2002). Of four types of stands measured, those consisting of mature Cottonwood with an extensive understory of tamarisk and Russian olive caused the highest water losses; i.e. annually extracting as much as 123 cm, while a dense stand of salt cedar extracted 111–122 cm of water annually. In comparison, a dense, mature cottonwood stand with a closed canopy only extracted 98 cm per year.

The removal of weeds almost always results in a tremendous increase in biological diversity due to the re-establishment of native plant and animal species, increased water resources, and a re-establishment of more original flood regimes.

Weed Biology

Tamarisk Biology

Tamarisk or saltcedar (*Tamarix spp.*), a native of Eurasia, is a deep-rooted deciduous shrub or tree that can reach up to twenty-five feet in height. While initially introduced for erosion control, it has escaped cultivation and can form dense monotypic stands along riparian and flood plain habitats and open savanna-like infestations in upland areas. According to surveys, it is widely distributed throughout the West, and in the Southwest alone, an estimated over 1.5 million acres are tamarisk-infested (Brotherson and Field 1987; Brock 1994). In the California deserts, all major watersheds have documented infestations of tamarisk.

Tamarisk establishes itself in riparian areas that are usually associated with native species such as mesquite (*Prosopis spp.*), cottonwood (*Populus spp*.), and willow (*Salix spp.*). Its seeds germinate readily in moist areas that are frequently disturbed (Horton et al. 1960; Stromberg 1997). If the correct conditions exist (moist soil for several weeks), tamarisk plants can grow up to six to nine feet in a season and produce seeds within the same year (Friederici 1995). Root growth is predominantly downward with little branching until plants reach the water table. These characteristics allow tamarisk to be very competitive and capable of displacing resident plant populations (Lovich 1994) without native plant competitors (Sher et al. 2002). Over time, the competitiveness of tamarisk has allowed it to form impenetrable thickets in many riparian areas where environmental stress is high (Brotherson and Field 1987; Sher et al. 2002).

The long distance dispersal of tamarisk is primarily through seed dispersal, but vegetative propagation is usually responsible for local spread and infestation intensification. In California, tamarisks typically bloom from April through October, while a single plant is capable of producing up to half a million seeds per year (DiTomaso 1998). Seeds are dispersed into the environment by wind and water, but are viable for only a few weeks (Brotherson and Field 1987). The plant can also spread vegetatively, resprouting from roots and stems that have been buried (Frasier and Johnsen, 1991). While stems rarely fragment naturally, some management techniques may inadvertently lead to vegetative spread.

Russian Olive Biology

Russian olive (*Elaeagnus angustifolia L.*) is a fast growing deciduous tree can reach up to 40 feet in height (Brock 1998; Whitson et al. 2000). An ornamental tree first introduced for landscaping and windbreaks in the late 1800s, Russian olive has spread and is now naturalized throughout the central and western United States. It is highly invasive in seasonally wet riparian and flood plain habitats, where it has been observed to replace native willow and cottonwood species (Crawford et al. 1993). It can grow under dense stands of saltcedar, out-compete resident plants, and eventually dominate some riparian sites (Olson and Knopf 1986).Russian olive is also very resistant to high levels of salt in the soil and drought conditions (Brock 1998).

The leaves of the Russian olive are grayish green with silvery scales, and the bark is dark brown. Established trees are very competitive and plants can grow up to five feet per year. The root system grows deep into the soil with many well-developed lateral roots. Seedlings and saplings can survive under canopies in low light conditions (Shafroth et al. 1995).

Russian olive reproduces primarily by seed, and seed-eating birds assist in the olive's long distance dissemination. Plants flower from May through June in California, and seedlings germinate from fall through spring. Seeds can survive three years in controlled conditions (Schopmeyer 1974), but in the field, seed longevity is unknown (Young and Young 1992). Plants can flower and set seed within 3 years following germination (Borell 1962). Vegetative spread can also occur as numerous root suckers are produced at the root crown after a disturbance to the shoot system.

Arundo Biology

Arundo, also known as Giant reed or Spanish Cane (*Arundo donax* L.) is a stout perennial grass with large, compact and knotty creeping rootstocks from which tough, fibrous roots emerge that penetrate deeply into the soil. Its smooth, hollow, reed-like, many-noded stems rise up to twenty feet tall and have numerous flat, smooth blades. Its flowers are large and feathery with light or yellowish-brown silky hairs.

Arundo was originally found in the Lower Himalayas and the Assams but has been introduced to many regions of the World, where it is adapted. Its broad distribution ranges from cool temperate wet, through tropical, subtropical and warm temperate, to wet forest zones. In the US today, Arundo is distributed from Arkansas and Texas to California, where it is found throughout the state, and in the east, from Virginia to Kentucky and Missouri and generally southward. It is widely planted throughout the warmer areas as an ornamental and in the Southwest, it is often used along ditches for erosion control.

Arundo is tolerant of high precipitation levels (3-40 dm), some salt, and can survive in all types of soils, from heavy clays to loose sands and gravelly soils (Duke, 1975, 1979). It can therefore be found on sand dunes near seashores, but grows best in poor sandy soil and in sunny situations, such as along riverbanks and in other wet places.

Arundo donax stands are among the most biologically productive of all communities. Under optimal conditions it can grow more than two inches per day and it can produce more than 16,000 lbs per acre of above-ground dry mass (Perdue 1958). Arundo reproduction is primarily vegetative, through rhizomes that readily root and sprout. Thus, the Arundo plant itself can float miles downstream where root and stem fragments may revegetate. Its rapid growth rate and vegetative reproduction allows it to quickly invade new areas and form monocultures at the expense of native species. Once established, Arundo can effectively out compete and completely suppress native vegetation. It uses prodigious amounts of water, as much as 161 gallons/ft of standing arundo, to supply its incredible rate of growth (Bell 2004).

Arundo, while uncommon in the desert, still poses a serious ecological threat to native habitat in riparian corridors. This alien grass readily invades riparian channels, especially in disturbed areas, is very competitive, difficult to control, and apparently provides little food or nesting habitat for native animals. It chokes riversides and stream channels, crowds out native plants, interferes with flood control, increases fire potential, and reduces habitat for wildlife, including the listed least Bell's vireo (*Vireo bellii pusillus*), and southwest willow flycatcher (*Empidonax traillii extimus*). In addition, Arundo has long, fibrous, interconnecting root mats that easily form a framework for debris dams behind bridges, culverts, and other structures that lead to damage especially from desert flash floods. It poses a fire hazard because its hollow stems ignite easily and can create intense fires.

Tree-of-heaven Biology

Tree-of-heaven (*Ailanthus altissima*) is a tall (up to sixty feet), deciduous tree that is native to China. It was introduced to the eastern US for two reasons: as a host tree for the Cynthia moth, (*Samia cynthia*), which was introduced for silk production, and as nursery stock because of its ability to grow quickly under adverse conditions. Seeds were also brought to California by Chinese miners for their medicinal and cultural importance.

Tree-of-heaven is mainly distributed from Massachusetts to Iowa and Kansas and south to southern Texas and Florida. To a lesser extent, it has established in the western United States from southern Rockies to the Pacific Coast states.

Tree-of-heaven’s rapid growth is due to its often colonizing by root sprouts, and the ability of sprouts to grow six to twelve feet in length in a single summer. The tree flowers in late May through early June and develops a large cluster of pink fruits from July to October. Its seeds are air-borne, and can disperse long distances. Because it is intolerant of deep shade, tree-of-heaven occurs most commonly in open, disturbed areas (i.e. along fencerows, roadsides, and waste areas). It can thrive in compacted, poor soils, and polluted air. It is therefore often used as an ornamental in urban areas, and is common in dusty, smoggy areas such as inner cities where most other trees fail.

Tree-of-heaven can pose a serious threat to natural areas. Its rapid growth rate means that it can rapidly spread in disturbed areas and quickly take over forest openings created by gypsy moth damage or fire. It has been found growing up to two miles from the nearest possible seed source.

Scope

Woody weeds are capable of invading a wide range of areas throughout the California deserts, especially riparian habitats. A long-term management strategy is needed to address the continued spread of these weeds and help agencies achieve the objectives of a return of riparian ecosystems to a natural state and an improvement of habitat for sensitive species. Restoration of these riparian zones will also provide benefits for economic stability and environmental quality. With planning and coordination, highly productive plant communities can be managed in a cost-effective and environmentally compatible manner.

This strategy addresses fifteen landscapes and watersheds within the California portion of the Mojave and Colorado Deserts (Map 1, Table 1). The Bureau of Land Management

(BLM), National Park Service (NPS), and/or California State agencies primarily manage each of these landscapes and watersheds. Other land mangers include the U. S. Forest Service (FS), The Nature Conservancy (TNC), and the Agua Caliente Band of Cahuilla Indians (AC). Portions of several watersheds, especially the Mojave River, include numerous private tracts (Map 2). Specific projects within these landscapes and watersheds will be developed based upon landscape objectives and a "headwaters down" approach. Some projects will require full treatment while others, that are project continuations, will only need retreatment and maintenance or monitoring. Retreatment, maintenance, and monitoring are critical for each treatment project and will protect the investment made in the future of these systems.

The Colorado River is beyond the scope of this strategy but could be included if a multi-state coordination process were established.

This strategy has not received National Environmental Policy Act (NEPA) or California Environmental Quality Act (CEQA) analysis. Individual weed control projects and watershed programs will receive analysis under NEPA and/or CEQA as required by law and agency policy. For agencies to better expedite project implementation, it will be worthwhile to develop programmatic environmental analyses for the landscapes and watershed addressed in this document.

Mechanism to Involve Private Lands and Stakeholders

Many of the treatment areas addressed in this strategy contain land that is owned by private individuals or groups. Neither the Desert Managers Group (DMG) nor its partner agencies have authority to require a private landowner to engage in weed control. However, in order to successfully treat weed invasions and restore ecosystems, all weeds from each watershed and landscape will need treatment regardless of jurisdiction.

The DMG will utilize its existing partnerships within the Mojave Weed Management Area (MWMA) to encourage private landowner participation in the projects that occur within the Mojave Desert (Map 3). Currently, the MWMA is actively mapping the occurrence of weeds and hosting public meetings to bolster support for weed control on the upper Mojave (Appendix 1). The Mojave Weed Management Area will also (Appendix 2):

- Inform the public on the adverse effects of weed invasions
- Serve as the grantee for weed control funding
- Assist private landowners with weed grants, vegetation mapping, and control projects.

There is a need to establish a Low Desert Weed Management Area (LDWMA) within the desert areas of Riverside and San Diego Counties (Map 4). The establishment of a LDWMA would provide many benefits:

- Facilitate management coordination with the existing Imperial Weed Management Area (IWMA)

- Provide a mechanism for stakeholder/private land involvement
- Provide eligibility for grant funding
- Improve communication and coordination among partner agencies

In the absence of a LDWMA, Resource Conservation Districts (RCDs) or Resource Conservation and Development Districts (RC&Ds) could be used as an alternative basis for a forum to engage private landowners.

Non-governmental organizations (NGOs) such as The Nature Conservancy (TNC) also manage land or have relationships with landowners within treatment areas. TNC has deemed restoration and protection of the Amargosa River as a priority for their work and as a result, owns land and easements and maintains relations with landowners within the watershed.

Tribal lands are not specifically addressed in this strategy except within the Santa Rosa National Monument. Input and guidance from Native American tribes and communities will be solicited at an early stage of the planning for each landscape unit. Native American coordination will be an on-going process throughout the implementation of the various weed control strategies.

Interagency Collaboration

A key component of this strategy involves interagency coordination and collaboration. The DMG will serve as the primary forum to coordinate weed control throughout the California deserts. Additional coordination will occur through the Mojave Weed Management Area (MWMA) and, if formed through the Low Desert Weed Management Area (LDWMA).

Interagency coordination and collaboration will also occur through the creation of watershed-based agreements. Such agreements should involve all agencies with an interest in the watershed, should include the entire watershed, and should have clearly stated restoration objectives. Such an agreement is in place for the San Sebastian Marsh-San Felipe Creek watershed located primarily in Anza Borrego Desert Sate Park (ABDSP), BLM's El Centro Field Office, and certain State Ecological Preserves (Appendix 3). Agreements should also be developed for the Mojave and Amargosa watersheds.

Prioritization of Projects

The long-term objectives for riparian weed control and restoration are the return of ecosystems to a natural state and the improvement of habitat for sensitive species. These objectives can be achieved by adopting management actions which be optimized by adopting a systematic approach, such as integrated vegetation management (IVM). This strategy emphasizes IVM methodology including prevention, containment, and control of exotic species. These concepts have been successfully implemented by many groups for control of other weeds in the West.

A long-term management strategy in the selected watersheds and landscapes must address all types of riparian areas: (1) those not yet infested; (2) those with light infestations; (3) areas with special considerations; and (4) areas of extensive infestation. At the same time, the strategy must be designed to result in a progressive reduction of overall infestation levels. Each watershed needs to be addressed as a whole.

Management actions will vary based on the level of infestation and the location of a site within the river system (Taylor and McDaniel 2004). All management efforts should contribute to the overall reduction of infestation levels. It is important to note that implementation of this strategy does not preclude local managers from initiating projects to achieve local objectives, although policy makers must understand that management of infestations at the top of the watershed will improve sustainability of programs downstream. The following are varying levels of infestation one, several, or all of these conditions might occur within a single watershed or landscape.

Uninfested Headwaters and Other Sites

The priority is to protect these sites from infestation, prevent upstream seed sources, and maintain or improve the health of existing native plant communities. Preventing new infestations from forming is extremely important as it helps to maintain desirable plant community structure and function. Prevention includes limiting dispersal of seeds and plant parts from nearby areas, minimizing soil disturbance, and maintaining or improving the health of competitive plant species. Generally, regeneration will not be required if natural processes enable desirable plant maintenance and recruitment.

Riparian sites that have not yet been infested by weeds and have relatively healthy native and desirable plant communities need to be conserved. Invasion of riparian sites can be a slow process and healthy native plant communities can generally offer competition to invasion by exotic trees (Sher et al. 2002). Periodic surveillance of these sites will need to be done and weeds that are discovered during surveys will need to be immediately removed.

Areas of Special Concern

Special areas of concern include the following: (1) habitat for threatened, endangered, and sensitive species; (2) dense stands of weed and riparian sites with heavy fuel accumulations that increase the risk of wildfire; (3) historical cottonwood gallery forests; (4) areas of religious and cultural significance; and (5) areas where perennial water could be restored.

Generally,

Riparian Sites with Light Infestations

Riparian areas with relatively light infestations and relatively healthy native plant communities usually can be treated and the objectives of return of ecosystems to a natural state and restoration of habitat for sensitive species can be met economically. Early detection will also minimize management costs and negative impacts these exotic trees impose on the system. Per acre costs for control increase as densities of weeds increase. The main advantage to early treatment of these areas is avoiding future costly restoration efforts.

Surveys are needed to inventory the location and size of infestations as well as other plant species present within the area. Ideally, surveys should be done annually to allow detection of new infestations and allow for prompt management. Areas with a high risk of infestation may need to be surveyed more frequently to ensure early detection. Information can be mapped, which will aid in establishing priorities and developing or adjusting local management.

Once an area is mapped, goals need to be established for management of individual infestations so that overall objectives can be met. These goals should be specific and have measurable outcomes that are realistic. Prioritization of programs based on the level of infestation and potential for natural restoration will optimize the area to be treated with existing resources.

Since water dispersal of seeds is significant for tamarisk, treatments, whenever possible, should begin at the upper reaches of a drainage and progress downstream.

Densely Infested Sites
Large reaches of several systems currently have monotypic stands of primarily tamarisk with only a few remnants of native plant communities. Without intervention, an increasingly larger area will be permanently modified by these weed infestations.

Removal of one weed species could provide an opportunity for the spread and intensification of other weed species, including the potential for invasion by herbaceous exotics. Rapid revegetation following control can provide competition against such invasions and lead better achievement of objectives (Taylor and McDaniel 2004).

In some instances, tamarisk can alter ground water hydrology as water tables decline and sites become more xeric (dry) (Lovich. 1994). Control of large, monotypic stands may increase water in some areas (King and Bawazir 2000, Dahm et al. 2002).

Funding Priorities

This strategy does not dictate funding priorities for any agency or group; however, it does provide objectives that should be used to drive funding priorities. Ultimately, funding decisions must be made on both a biologic and political basis and the two will contradict, in some instances. It is, therefore, impossible to create a concrete matrix for prioritization of funding. However, this framework should provide standard guidance for project prioritization.

When projects are evaluated from a biologic perspective, they should be prioritized by:

- The number of sensitive species that will benefit from the project. Those projects benefiting more sensitive species receive highest priority and will meet the objective of restoration of habitat for sensitive species. An overall increase in natural biodiversity will achieve the objective of restoring riparian systems and returning damaged systems to their natural state.
- The size of the area to be restored. Larger riparian usually benefit more species by providing more habitat and habitat linkages and will therefore receive a higher priority.
- The degree of weed infestation. Projects where weed has converted to a monoculture should focus on containment where as lighter infestations should focus on control.
- Projects that control the spread of weed to uninfested areas will receive a high priority.

When projects are evaluated from a political perspective, they should be prioritized by:

- Projects that enjoy a high level of public support and real or potential funding will receive a high priority.
- Management and/or land use plan priorities.
- Projects that are continuations will receive priority over new starts.
- The availability of volunteers and partners will increase a project's priority.

Methods of Control

Several methods have been shown to be effective in managing woody riparian weeds. Selection of the appropriate methods depends on a number of factors, such as infestation density, agency mission and policy, environmental concerns, costs, and social considerations. Restoration potential also is an important consideration. No method will provide 100 percent control and follow-up treatments and monitoring will be needed for many years to achieve desired objectives. As new techniques could become available during implementation of this strategy, decision makers will need to exercise managerial flexibility to adopt these new methods. An example of this could be the use of biological control agents.

Light Infestations and Areas of Special Concern
Manual Removal: Immature plants (about two feet tall or less) can often be controlled by hand pulling or grubbing. To be effective, most of the root structure must be removed and destroyed. Tamarisk can readily reproduce from cut stems and sections of buried roots. Improper removal and disposal can result in vigorous regrowth.

Selective Mechanical Grubbing: Mechanical grubbing can selectively remove individual trees on sites that have good access (Taylor and McDaniel 2004). The complete root system must be excavated and removed from the site to be effective. Mechanical removal can result in soil disturbance causing impacts to resident vegetation, but soil disturbance may be necessary on some sites to restore desired vegetation (Taylor and McDaniel 2003). The initial cost to purchase equipment for mechanical removal is high, and annual maintenance costs will be required. Equipment contracting can be a more economical approach for using mechanical methods.

Low-volume Basal Bark Herbicide Application: Small tamarisk saplings and regrowth (stems less than two to three inches in diameter at ground level and less than eight feet tall) can be controlled by a basal application of triclopyr (ester formulation) mixed with vegetable oil or another proven carrier. This technique involves the selective application of a herbicide to control individual plants or groups of plants using backpack sprayers (Parker and Williamson 2003). Applications can be done at any time of the year, although fall through spring applications are preferred. Adverse effects to desirable plants can be avoided when they are dormant. This is a cost effective method for selective control of small diameter trees. Triclopyr will have little or no effect on grasses and desirable trees and shrubs will not be affected unless directly sprayed.

Cut-stump Herbicide Application: For large trees with thick bark, a low-volume, cut stump method involves a combination of cutting and herbicidal treatment to achieve "root kill.” This involves cutting the trunk just above the ground and immediately applying an amine or ester formulation (mixed with vegetable oil) of triclopyr (Parker and Williamson 2003) or imazapyr to the cut surface (Duncan 2003). Cutting large trees with chain saws can be dangerous, but this approach is a cost effective, selective treatment. Per acre costs depend on tree density and the majority of the cost is for labor.

Foliar Herbicide Application: Foliar applications of a mixture of imazapyr and glyphosate are effective when applied between June and September. Complete foliar coverage of individual plants is necessary, and care must be taken to not adversely affect adjacent desirable vegetation. Imazapyr and glyphosate are considered broad-spectrum herbicides and will injure or kill plants that intercept the spray solution. This can be a cost effective method where infestations are accessible with backpack sprayers or ATV mounted spray equipment. Costs are density dependant and can be high due to the volume of herbicide solution that must be applied to obtain complete coverage of the foliage.

Densely Infested Sites

Treatment methods for such sites should be based on management objectives and existing conditions. As with areas with light infestations, selective methods would be most appropriate where a remnant of native or desirable plants is present. However, some sites may need extensive tree removal and restoration to achieve restoration objectives, and involve a variety of control methods.

In ecologically sensitive areas and areas of special concern, a combination of the above techniques should be used. For extremely large infestation in nonsensitive areas, the following techniques should be considered:

Mechanical Removal: For dense monotypic stands, trunk and stem removal by heavy machinery followed by root plowing and raking can be an effective method (McDaniel and Taylor 2003a, 2003b). This technique is appropriate where there is no concern about affecting associated desirable plants. Trunks and stems should be cleared during the winter to avoid overheating equipment, while root plowing and raking should occur during hot summer months to aid in desiccation of roots. As with other control programs, follow-up control will be required until plant densities are reduced to acceptable levels. Large scale clearing may require revegetation to discourage reinfestation or invasion by other exotic species (Taylor and McDaniel 2004). Control and restoration costs can be very high.

Aerial Herbicide Applications: Large, dense infestations also can be controlled through the aerial applications of imazapyr or a mixture of imazapyr and glyphosate. A nonionic surfactant is recommended for both applications. Applications must occur from late August through September prior to color change when plants are actively growing (Duncan and McDaniel 1998, McDaniel and Taylor 2003a, 2003b). The use of fixed wing aircraft can be more economical when treating large tamarisk blocks, while the use of a helicopter is more appropriate for precision application around water bodies and desirable vegetation (McDaniel and Taylor 2003b). These herbicides are slow acting and treated trees should not be removed for a period of 3 years to achieve desired "root kill". As with other treatments, follow-up control will be required until plant densities are reduced to acceptable levels. As with large-scale mechanical control programs, revegetation may be required for sustainable, long-term control. Control and restoration costs can be high.

Combination of Control Methods: Frequently large-scale mechanical and aerial herbicide treatments can be combined with burning or debris shredding to reduce costs and prepare sites for either natural regeneration or artificial regeneration (Taylor and McDaniel 2004). Regardless of control techniques used, costs are high for treating large weed monocultures. Considering restoration requirements for sustained, long-term control, sites designated for plant removal should be prioritized based on regeneration potential prior to initiating control programs. Insight into appropriate exotic vegetation control strategies is also obtained when the mechanisms for site restoration are considered.

Restoration

Natural regeneration and artificial planting are intended to return sites to plant communities dominated by native or desirable species. Desirable vegetation can protect and enhance hydrologic functions, increase wildlife habitat, and discourage reinvasion of nonnative species.

Where ground and surface water connectivity is low and/or flooding no longer occurs, artificial planting or seeding may be required to establish vegetation able to compete with exotic re-infestation or invasions by other exotic species. Artificial regeneration prescriptions are extremely rigid and are based primarily on soil type, depth to water table, and soil salinity (Taylor and McDaniel 2003).

Labor Sources

The California deserts have a variety of labor sources for weed treatment within the Southern California Region. Because each labor source has its advantages and disadvantages (Table 2), each project should be carefully evaluated to determine the most cost effective labor. Some projects will require labor from a variety of sources. The following labor sources have been utilized by DMG agencies:

Los Angeles Conservation Crew
California Conservation Crew
Prison Crews
California Department of Forestry Fire Crews
Student Conservation Crew
Ecological Careers Organization
National Park Service Exotic Plant Team

Private Contractors: In addition to cut stump and herbicide treatments, private contractors can provide a variety of specialized services such as mechanized removal, aerial application of herbicide, mapping, and remote sensing. Anza Borrego Desert State Park has successfully utilized private contractors for weed control. This document does not endorse any particular contractor or any contractor's method of treatment.

Funding Needs

Currently, none of the DMG agencies receive adequate appropriated funding to implement the projects outline in Table 1. In fact, it is doubtful that any single funding source will have the capacity to funding implement the projects in Table 1. As a result, multiple alternative funding sources will need to be identified.

The cost of weed control is difficult to estimate due to it high variability which is dependant on the degree of infestation. Thick monocultures can cost in excess of $3000 per acre to initially control while some light infestations can be hand pulled with volunteers at little to no cost. The average cost of weed control per acre used in calculations within this document's implementation plan is.

Program Evaluation

Assessments are needed for treatment and restoration programs. In general, projects should be evaluated for treatment effectiveness, achievement of management objectives, and on-going monitoring for weed presence. All evaluation plans should feed information into the ongoing control effort so an adaptive management strategy can be developed and the desired results can be achieved.

Treatment effectiveness: Periodic monitoring treatment sites will be required to evaluate treatment success. This is especially true with newer control methods and revegetation. While some anecdotal information can be determined from casual visual observation, a more detailed monitoring plan should be implemented. Transects should be established to determine the frequency of living verses dead weed and planting or the percent cover of weed versus natives. A number of excellent protocols exist for monitoring plan populations, and a complex protocol need not be used (for example see Elzinga et. al). Remember, the goal is to ensure that control techniques are effective and revegetation efforts successful.

Achievement of management objectives: Measurements should be tailored to evaluate if the specific objectives for a site were met. For example, if the objectives are to increase water availability, enhance wildlife habitat and biodiversity, and reduce wildfire risk, managers will need to establish three specific assessment measurements and conduct pre- and post-monitoring to determine if the objectives are met. Written monitoring plans should be prepared before beginning treatments. Sample monitoring plans can be found in Appendix 3.

On-going monitoring: Due to weed's persistence, it will be necessary to annually monitor treatment sites for the invasive's return. Any regrowth should be treated immediately prior to a reinvasion becoming established.

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Table One
Landscapes and Watersheds Addressed and Significant Resources

Landscape/ Watershed	Land Ownership	Special Designation	Special Status Species[1]	Other Notable Values	Estimated Acreage of Weed
Inyo Mountains/ Saline Valley	• BLM- Ridgecrest FO • Death Valley National Park • California Department of Fish and Game	• Saline Valley ACEC[2] • Saline Valley SER[3]	• Oasis Valley Springsnail (NPS)	• Springsnails • Neotropical migratory birds • Waterfowl and shorebirds	100
Argus Mountains/ Darwin Falls Canyon	• BLM- Ridgecrest FO • Death Valley National Park • California Department of Fish and Game	• Great Basin Falls ACEC • Indian Joe Spring SER	• Inyo California towhee (FT/SE)	• Springsnails • Neotropical migratory birds • Desert bighorn sheep	40
Eastern Sierra Canyon within Inyo County	• BLM- Ridgecrest FO	• Olancha Creek • Five-mile Canyon • Deadfoot Canyon • Nine-mile Canyon	• Southwestern willow flycatcher (FE/SE) • Least Bell's vireo (FE/SE)	• Springsnails • Robust salamander • Neotropical Migratory birds	16

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[1] FE- Endangered under the Federal Endangered Species Act
FT- Threatened under the Federal Endangered Species Act
SE- Endangered under the California Endangered Species Act
ST- Threatened under the California Endangered Species Act
BLM- BLM Sensitive Species
NPS- NPS Species of Special Concern

[2] ACEC- Area of Critical Environmental Concern, BLM's highest level of administrative protection.

[3] SER- State Ecological Reserve managed by California Department of Fish and Game

Panamint Mountains	• BLM- Ridgecrest FO • Death Valley National Park	• Surprise Canyon ACEC	None	• Springsnails • Panamint alligator lizard • Neotropical migratory birds • Desert bighorn sheep	20
Panamint Valley	• BLM- Ridgecrest FO • BIA or Tribal?	• Warm Sulfur Spring and Marsh ACEC	None	• Neotropical migratory birds	222
Amargosa River	• BLM- Barstow FO • The Nature Conservancy • Private Parties • Death Valley National Park	• Amargosa River ACEC • Salt Creek ACEC	• Least Bell's vireo (FE/SE) • Southwestern willow flycatcher (FE/SE) • Amargosa vole (FE/SE) • Amargosa River speckled dace (BLM) • Amargosa River pupfish (BLM/NPS) • Amargosa tyronia (NPS) • Saratoga pupfish (NPS)	• Neotropical migratory birds • Springsnails	1000
Mojave River	• BLM- Barstow FO • Mojave National Preserve • Private Parties (Mojave Weed Management Area)	• Afton Canyon ACEC • Camp Cady SWA[1]	• Southwestern willow flycatcher (FE/SE) • Least Bell's vireo (FE/SE)	• Neotropical migratory birds	330
Death Valley Springs	• Death Valley National Park	• NPS Wilderness		• Desert bighorn sheep • Neotropical migratory birds	50

[1] SWA- State Wildlife Area managed by California Department of Fish and Game

East Cronese Lake	• BLM- Barstow FO	• East Cronese Lake ACEC	None	• Neotropical migratory birds	50
Harper Lake	• BLM- Barstow FO • Private Parties	• Harper Lake ACEC	None	• Neotropical migratory birds • Shorebirds/ waterfowl	50 5 (retreat)
San Sebastian Mash/ San Felipe Creek	• BLM- El Centro FO • California Department of Fish and Game • Anza-Borrego Desert State Park • Ocotillo Wells SVRA • Private Parties	• San Felipe Creek ACEC • SERs • Imperial SWA	• Desert pupfish (FE/SE) • Least Bell's vireo (FE/SE) • Southwestern willow flycatcher (FE/SE) •	• Neotropical migratory birds	750
Dos Palmas Oasis	• BLM- Palm Springs FO • California Department of Fish and Game	• Dos Palmas ACEC • Oasis Springs SER	• Desert pupfish (FE/SE) • Yuma clapper rail (FE/SE) • Southwest willow flycatcher (FE/SE) • Least Bell's vireo (FE/SE)	• Neotropical migratory birds	400 640 (retreat)
Coachella Valley	• BLM- Palm Springs FO • California Department of Fish and Game • Lizard Preserve People	• Coachella Valley Preserve • Big Morongo Preserve ACEC • Whitewater Canyon • Hidden Palms SER	• Desert pupfish (FE/SE) • Yuma clapper rail (FE/SE) • Southwest willow flycatcher (FE/SE) • Least Bell's vireo (FE/SE) • Arroyo southwestern toad (FT/ST)	• Neotropical migratory birds	180 (retreat)

Santa Rosa and San Jacinto Mountains National Monument	• BLM- Palm Springs FO • California Department of Fish and Game • San Bernardino National Forest	• Carrizo Canyon SER • Magnesia Spring SER • Santa Rosa SWA	• Desert slender salamander (FE/SE) • Southwest willow flycatcher (FE/SE) • Least Bell's vireo (FE/SE) • Peninsular ranges bighorn sheep (FE/SE)	• Neotropical migratory birds	200
Eastern Mojave Desert Springs	• BLM- Needles FO • Mojave National Preserve • California Department of Fish and Game	• Piute Creek SER • BLM Wilderness	None	• Neotropical migratory birds • Springsnails	220