United States
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**Southwestern
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New Mexico Energy,
Minerals and Natural
Resources Department

Forestry Division

Strategy for Long-Term Management of Exotic Trees in Riparian Areas for New Mexico's Five River Systems, 2005-2014

In Honor of John Paul Taylor, Jr.

The New Mexico Interagency Weed Action Group dedicates this publication to the memory of John Taylor, supervisory wildlife biologist, U.S. Fish and Wildlife Service. John worked for over 18 years on the Bosque del Apache National Wildlife Refuge. He was devoted to developing methods to remove and control saltcedar and restore riparian habitats. His publications will be a lasting contribution to riparian vegetation management. John also played a major role in the development of this strategic plan. His work has been an inspiration to all of his friends and colleagues.

Printed on recycled paper • July 2005

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Compiled for the New Mexico Interagency Weed Action Group by: Douglas L. Parker, USDA Forest Service; Dr. Mark Renz, New Mexico State University; April Fletcher, USDI Fish and Wildlife Service; Frannie Miller, New Mexico Department of Agriculture; and Dr. James Gosz, University of New Mexico

Executive Summary

This strategy addresses the long-term management of saltcedar (*Tamarix* spp.), Russian olive (*Elaeagnus angustifolia*), and Siberian elm (*Ulmus pumila*) in the narrow belts of riparian vegetation along the main stems of the Rio Grande, Pecos, Canadian, San Juan, and Gila/San Francisco River systems, as well as the connected perennial, intermittent, and ephemeral streams. The ongoing degradation of native plant communities in riparian areas is a significant concern of citizens of New Mexico; a concern that is shared by Federal, State, and local resource managers.

This is a scientifically based strategy that provides a broad framework for Integrated Vegetation Management (IVM) of exotic tree infestations. The ultimate goal of this strategy is to prevent the spread of infestations, control existing infestations, and maintain and improve the health of native plant communities. The various adverse environmental, social, and economic consequences associated with infestations are significant, and they will continue to increase without direct intervention.

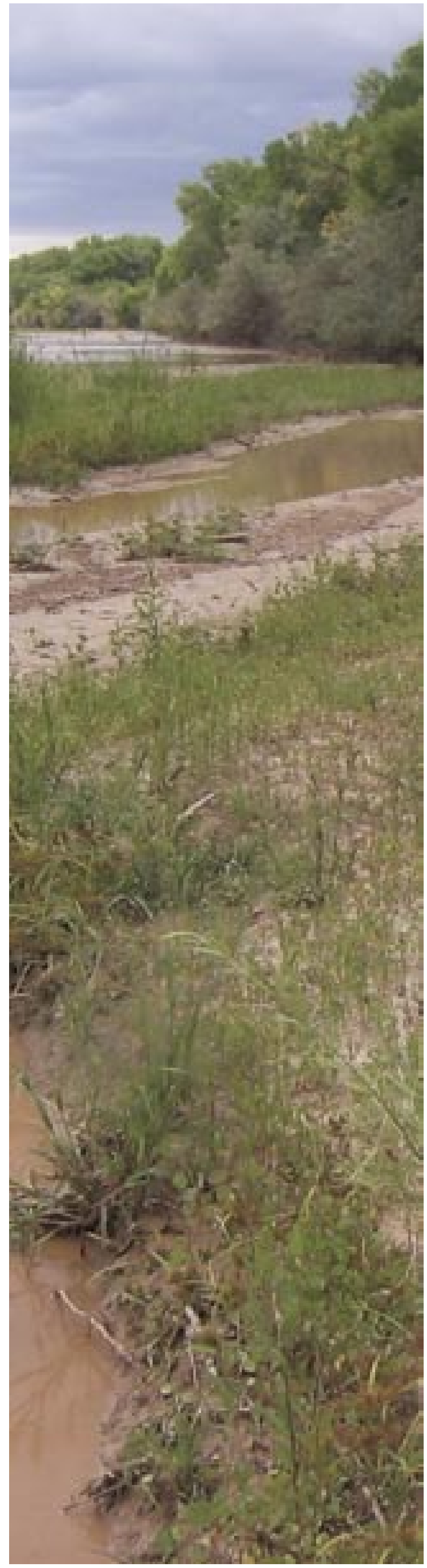
This long-term strategic approach is meant to serve as a blueprint to assist agency managers and private landowners in protection and restoration efforts, and provide a framework for development of local plans. To be successful, agency managers and landowners will need to undertake coordinated control and restoration throughout the five river systems. Although several closed water basins in New Mexico are not addressed in this plan, the same management concepts can be applied to those basins.

Since large-scale, coordinated programs require a substantial commitment of Federal and State funds, a higher level of assessment for entire river systems is needed. Participating agencies acknowledge that riparian protection and restoration efforts must extend beyond administrative boundaries, and local groups must be active participants.

The spread and abundance of exotic trees has been accelerated by management actions that have created disturbances along river systems, such as building dams and other structures. However, exotic trees have also invaded and flourished in uncontrolled river systems as well. Nevertheless, successful control and vegetation restoration efforts on controlled river systems may require addressing the underlying conditions that favor the buildup of exotic plant species. It is unlikely that exotic trees can ever be completely removed from Southwestern river systems. It is also unlikely that desirable vegetation will have the ability to thrive unless cooperative IVM efforts are part of an overall management program that incorporates reestablishment of natural functional conditions that provide a competitive edge to desirable plant species.

Adequate, consistent, and long-term funding will need to be provided to achieve successful control of exotic tree infestations and restoration of riparian areas. To address infestations in the five river systems, it is estimated that at least $64,400,000 of Federal and State cost-share funding (including volunteer and in-kind services) will be needed for the first 10-year period under this plan. Funding would need to be balanced between prevention, treatment of light infestations, protection of areas of special concern, and treatment of large-scale infestations.

The principles and priorities in this plan are consistent with those adopted by the Team



Tamarisk initiative, which brought together hundreds of scientists, policymakers, and land and water managers in 2004 to develop a cooperative, strategic approach for controlling saltcedar. These principles and priorities should be matched with the most economical opportunities for restoring desired plant communities.

In addition, two major concurrent efforts by the State of New Mexico will also create the framework needed for development of local plans: The New Mexico Forest and Watershed Health Plan, signed by Governor Richardson on March 30, 2005; and the New Mexico Statewide Policy and Strategic Plan for Nonnative Phreatophyte/Watershed Management, which is expected to be formally adopted in the summer of 2005. Both of these strategic plans focus on the need for a collaborative approach to ecological restoration, and recognize that the problems of invasive plant species and poor forest health must be addressed by focusing on long-term watershed management. A unique opportunity exists to integrate the implementation efforts of this strategy with the implementation of these two important and related State plans.

This plan is supported by the Southwest Strategy and the New Mexico Interagency Weed Action Group (NMIWAG). This project was developed under the Memorandum of Understanding for Coordinated Resource Management (CRM), which provides a mechanism for Federal, State and local interests to foster communication, cooperation, and coordination in developing and implementing sound resource management and conservation programs.

Strategic Plan

Purpose

This strategy provides a broad framework for Integrated Vegetation Management (IVM) of exotic trees throughout the five major river systems in New Mexico (Figure 1 and Table 1). It is designed to encourage public land managers and private landowners to undertake coordinated control and restoration. It identifies long-term objectives to address infestations and defines measures of success.

Scope and Background

Saltcedar, Russian olive, and Siberian elm are capable of invading a wide range of areas throughout New Mexico, including riparian habitats, rangelands with ephemeral springs, roadsides, urban areas, and mountain meadows and forests. While management plans will need to consider all infested areas, this document focuses on riparian habitats and connected perennial, intermittent, and ephemeral

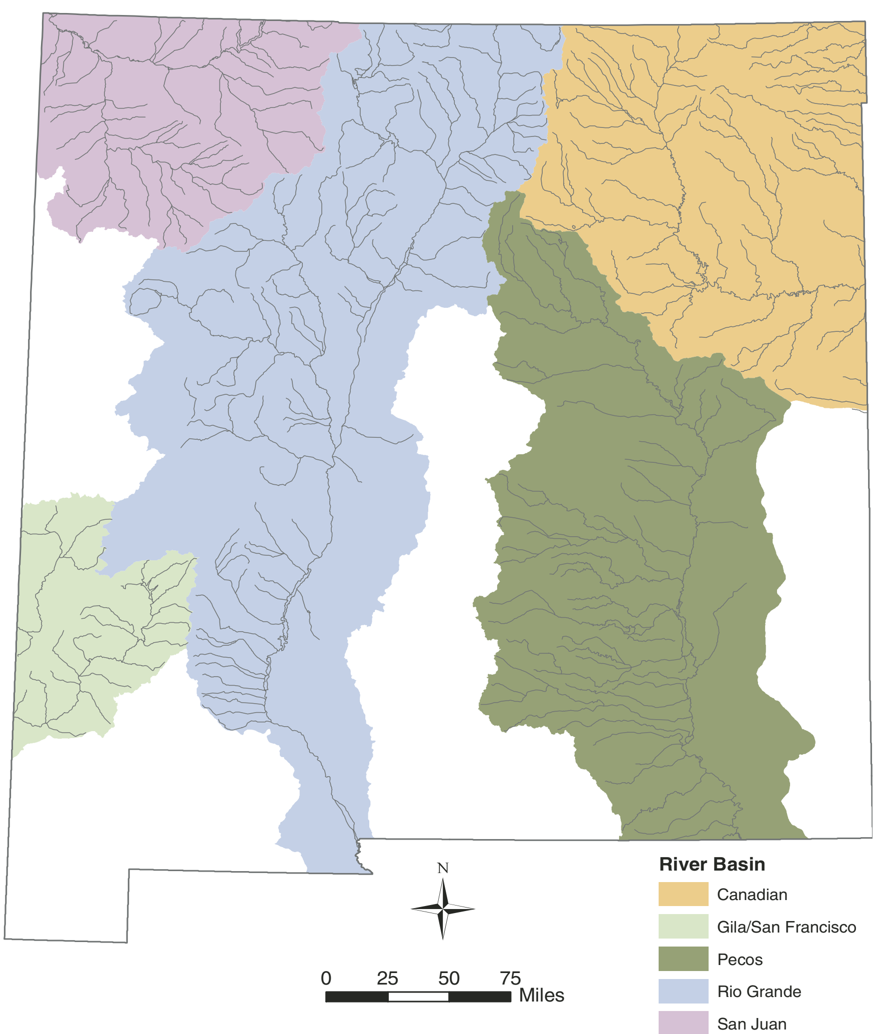


Figure 1. Major river systems in New Mexico

Table 1. Watershed area and total stream length for five river systems in New Mexico

River System	Watershed Area (square miles)	Total length of the main stem and tributaries (miles)
Rio Grande	31,960	3,410
Pecos	23,810	2,760
Canadian	17,660	2,500
San Juan	9,760	1,450
Gila/San Francisco	5,400	690

streams, as these are critical to wildlife and have high recreational value to New Mexicans.

Climatic fluctuations, combined with human activities, have resulted in significant changes to riparian woodlands in New Mexico. The introduction of saltcedar, Russian olive, and Siberian elm into New Mexico in the early 1900s has resulted in profound changes in riparian forests and nearby areas (Shurlock 1987). These exotic trees have quickly spread along the Rio Grande, Pecos River, and San Juan River systems, replacing native plant communities, and becoming the dominant species in many places. Infestations continue to spread and intensify throughout all river systems in the State.

While many citizens understand that current vegetative conditions are unnatural, they value the rivers and adjacent bosques (DeBuys 1993). Dense stands of exotic trees have limited recreational value and increased the risk for wildfires (Stuever 1997). Also, the demand for water exceeds supply in virtually every river basin in the State (New Mexico Office of the State Engineer and the Interstate Stream Commission, Framework for Public Input to a State Water Plan, 2002). The recent drought has added emphasis to the concern of excessive water use by these exotic tree species.

Long-term management is needed to address the continued spread of exotic trees and associated adverse consequences for future generations of New Mexicans. Other invasive tree species, such as tree-of-heaven (*Ailanthus altissima*), have invaded riparian areas and other woody species are expected to become established in the future. Management of these invaders must be addressed as part of any riparian restoration effort.

Figure 2. Riparian areas provide essential habitat for migrating birds

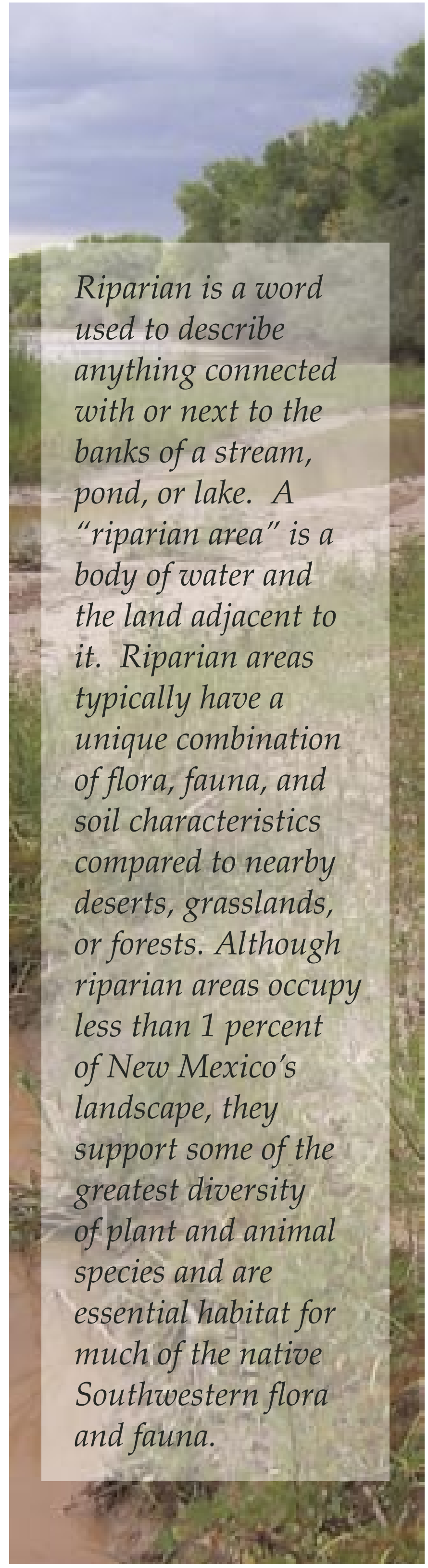
The natural and restorable riparian areas are an invaluable resource for the State. Protection and improvement of these areas will not only enhance biological diversity, but will also provide benefits for economic stability and environmental quality. With planning and coordination, the highly productive plant communities can be managed in a cost effective and environmentally compatible manner.

In addition, other invasive weeds are becoming established throughout riparian areas in New Mexico. These species can invade riparian areas and survive underneath canopies of existing native and exotic trees. Any efforts to manage the exotic tree species covered in this plan must avoid spreading or creating opportunities for these species to thrive. Whenever possible, management plans should also address other invasive species existing in the understory. Russian knapweed (*Acroptilon repens*), perennial pepperweed (*Lepidium latifolium*), camelthorn (*Alhagi pseudalhagi*), and leafy spurge (*Euphorbia esula*) are of particular concern in New Mexico (Lee 1999).

Biology and Ecology of Exotic Phreatophytes

Saltcedar (*Tamarisk* spp.): Saltcedar is a deep-rooted deciduous shrub or tree that can reach up to 25 feet in height. While originally 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. It is widely distributed throughout the West, and surveys estimate over 1.5 million acres are infested in the Southwest (Brotherson and Field 1987; Brock 1994). In New Mexico all major watersheds have documented infestations of saltcedar, with the Rio Grande, Pecos, Canadian, and San Juan River systems having large reaches dominated by saltcedar. However, the San Francisco River system and the upper reaches of the Gila River are still predominately comprised of

Figure 3. Flowering saltcedars in Pump Canyon, a tributary of the San Juan River



Riparian is a word used to describe anything connected with or next to the banks of a stream, pond, or lake. A "riparian area" is a body of water and the land adjacent to it. Riparian areas typically have a unique combination of flora, fauna, and soil characteristics compared to nearby deserts, grasslands, or forests. Although riparian areas occupy less than 1 percent of New Mexico's landscape, they support some of the greatest diversity of plant and animal species and are essential habitat for much of the native Southwestern flora and fauna.

native species. The potential exists for further spread in New Mexico.

Saltcedar establishes in areas associated with native species such as screwbean mesquite (*Prosopis pubescens*), cottonwoods (*Populus* spp.), and willows (*Salix* spp.). 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), plants can grow up to 6 to 9 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 saltcedar to be very competitive and capable of displacing resident plant populations (Lovich et al., 1994) without native plant competitors (Sher et al. 2002). Over time, the competitiveness of saltcedar has allowed it to form impenetrable thickets in many riparian areas where environmental stress is high (Brotherson and Field 1987; Sher et al. 2002).

Long distance spread of saltcedar is primarily through seed dispersal, but vegetative propagation is usually responsible for local spread and infestation intensification. Plants typically bloom from April through October in New Mexico, and 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). Plants can also spread vegetatively by resprouting from roots and stems that have been buried (Frasier and Johnsen, 1991). While stems rarely fragment naturally, some management techniques may lead to vegetative spread.

Russian olive (*Elaeagnus angustifolia L.*): This is a fast growing deciduous tree that 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 found 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 can also tolerate high salt levels in soil and drought (Brock 1998). Dense infestations are common along the San Juan River and northern sections of the Rio Grande. Note the Russian olive infestation along the edge of the Rio Grande in Figure 12.

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 5 feet per year. The root system grows deep into the soil with many well-developed lateral roots. Seedlings and saplings can survive a wide range of conditions, including low light under canopies (Shafroth et al.1995). Plants can also tolerate drought conditions.

Russian olive reproduces primarily by seed. Seed-eating birds disseminate these propagules long distances. Plants flower from May through June in New Mexico, and seedlings germinate throughout the fall and spring. Seeds can survive 3 years in controlled conditions (Schopmeyer 1974), but seed longevity in the field is unknown (Young and Young 1992). Plants can quickly become reproductively mature and 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.

Figure 4. Siberian elm leaves

Siberian elm (*Ulmus pumila*): Siberian elm is a deciduous tree that can reach over 70 feet in height. It is native to northern China, eastern Siberia, Manchuria, and Korea. The species was introduced into the United States in the 1860s as an ornamental tree. Siberian elm has escaped cultivation and is currently established throughout the central and southwestern United States. This plant is typically found along riparian areas, but it has been observed to invade roadsides, meadows, and upland areas. Infestations are present in the upper reaches of the Rio Grande, Pecos River, and other river systems, and they are rapidly spreading into higher elevations.

Siberian elms flower from February through April in New Mexico depending upon elevation, temperature, and precipitation patterns. It is often erroneously identified as Chinese elm (*Ulmus parvifolia*), an autumn-flowering species. Siberian elms produce many winged fruit, each of which contains one seed. Seeds are spread by wind and can produce blankets of seedlings in areas void of vegetation. Seeds germinate readily and seedlings grow rapidly and compete with resident vegetation. Densities as high as 4,200 plants per acre have been observed (Jim Brooks, Ciudad SWCD, personal communication). It is not known how long seeds remain viable. Rapid

Figure 5. Saltcedar has formed a sand pedestal in White Sands National Monument, National Park Service

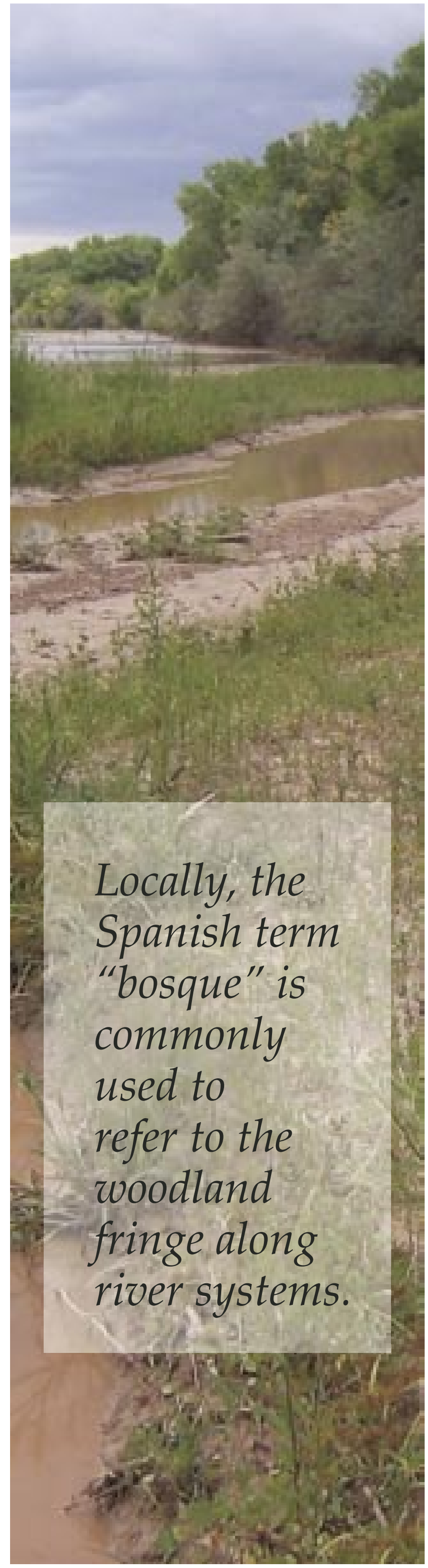


Table 2. Summary of environmental impacts of exotic tree species in New Mexico[1]

Species	Hydrology	Fire Frequency	Soil Salinity	Community Diversity
Salt-cedar	Stabilizes streambank edges leading to channelization of stream (Graf 1978). Saltcedar evapotranspir-ation rates exceed that of native replacement vegetation in many circumstances (King and Bawazir 2000, Dahm et al. 2002).	Fire adapted species that rapidly resprouts after fires, and recovers faster than native species (Busch and Smith 1995). Increased fire frequency of infested areas has been observed.	Plants take up salt from the soil, store it in the leaves, and then release it into the environment. Saltcedar is adapted to a wide range of salinity levels (Shafroth 1995).	Dense stands have low native woody and herbaceous plant diversity (Campbell and Dick-Peddie 1964). Interferes with regeneration of woody perennials such as cottonwoods (Taylor et al. 1999). Reduced avian diversity (Ellis 1995), reduced herpetofauna (Konkle 1996).
Russian olive	Alters nutrient cycling (Howe and Knopf 1991). Stabilizes streambank edges, leading to channelization of stream. Believed to be a large consumer of water, but no data are available.	No information available on fire frequency, but it rapidly resprouts after fires.	Salt tolerant compared to other species (Monk and Wiebe 1961).	Dense stands have reduced biodiversity (Waring and Tremble 1993).
Siberian elm	Could be a large consumer of water, but no data are available.	No information available on fire frequency, but it rapidly resprouts after fires.	No data are available.	No data are available.

[1] Many of these processes are density and age dependent, with dense old infestations showing the largest changes in the ecosystem.

and prolific resprouting can occur when the shoot system is disturbed, causing local vegetative spread.

Water Basins Not Currently Considered: Although some water basins are not addressed in this plan, exotic trees are considered to be a significant problem in the Little Colorado, Central Closed, Tularosa and Hueco, Salt, Southwest Closed, and Southern High Plains Basins. The management concepts addressed in this strategy can be applied in these closed basins.

Overview of Integrated Vegetation Management (IVM) Approach

Cooperating agencies, organizations, and individual landowners must have a shared long-term vision for management of exotic riparian species in the river systems in New Mexico to accomplish long-term control. Several effective strategic guides to weed management have been developed. They emphasize prevention, early detection and mapping, timely control, and adaptive management (Pulling Together, National Strategy for Invasive Plant Management, multiagency support organization; Partners Against Weeds, Bureau of Land Management, 1996; Preserving Our Natural Heritage, A Strategic Plan for Managing Invasive Nonnative Plants on National Park System Lands, 1996, and Stemming the Invasive Tide, Forest Service Strategy for Noxious and Nonnative Invasive Plant Management, 1998). This strategy addresses each of these elements.

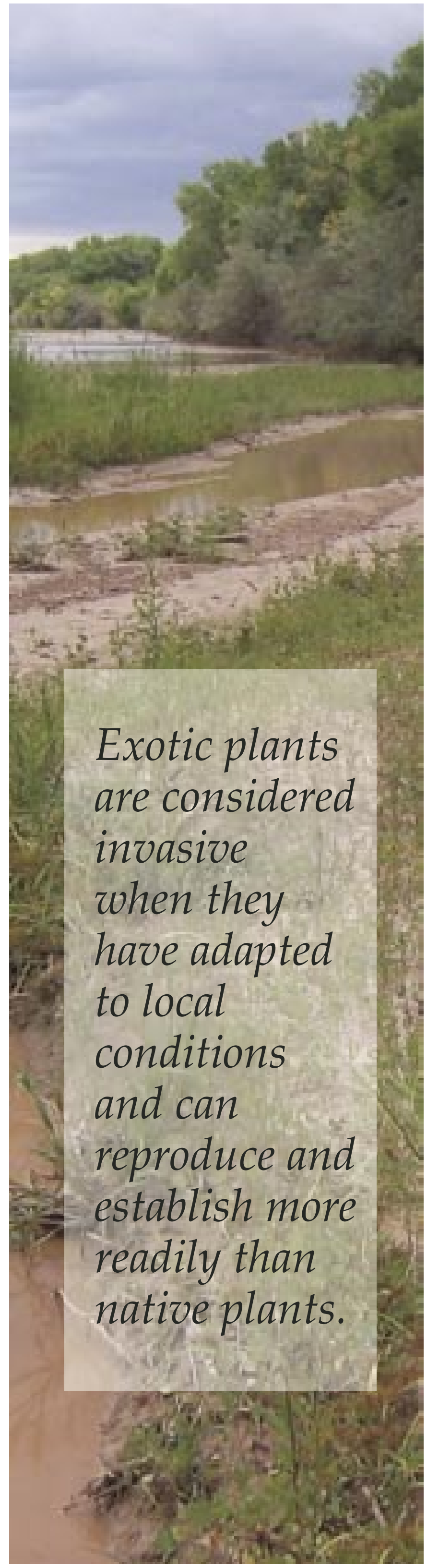
There are additional considerations that should guide management actions on all sites beyond simply removing the exotic tree species. The underlying factors that will influence restoration of desirable vegetation must be determined. Then, an assessment must be made to determine how effective and efficient restoration of desirable vegetation will be in achieving site goals as compared to leaving the exotic trees. For example, if an area is of special concern, such as habitat for a listed species like the Southwestern willow flycatcher (*Empidonas trailli extimus*), a restoration plan would include assessment of soil chemistry, potential for existing native species to recover, and other factors tht would allow natural or artificial recovery of vegetation for habitat for this endangered species (U.S. Fish and Wildlife Service 2002).

Elements of the Strategy

Management actions can be optimized by adopting a systematic approach, such as 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 river systems must address all types of riparian areas, including: (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. An overall assessment is needed for each river system.

Management objectives 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 within a river system and priorities for their management:

- **Headwaters and Other Uninfested 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.
- **Riparian Sites with Light Infestations:** The priority is to remove exotic trees, reduce upstream seed sources, and protect and enhance existing native plant communities.
- **Areas of Special Concern:** The priority is to identify riparian areas or wetlands that have a special focus (recreational uses or habitat for threatened, endangered, or sensitive species) and to preserve, create, or enhance the unique attributes on such sites.
- **Densely Infested Sites:** The priority is to remove dense or monotypic stands of exotic trees and restore desirable plant species to achieve specific objectives.

Headwaters and Other Uninfested Sites: 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 underlying natural processes enable desirable plant maintenance and recruitment.

Riparian sites that have not yet been infested by exotic trees 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). Although a detailed inventory of the five river systems has not been conducted, many uninfested areas are present in the upper reaches of drainages, especially for the Rio Grande, Pecos, and Gila/San Francisco Rivers. Periodic surveillance of these sites will need to be done and exotic trees discovered during surveys will need to be promptly removed.

Riparian Sites With Light Infestations: Riparian areas with relatively light infestations and relatively healthy native plant communities usually can be treated and economically restored. Early detection will also minimize management costs and negative impacts of these exotic trees. Per acre costs for control increase as densities of exotic trees increase. The main economic advantage to early treatment of these areas is avoiding 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 for 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 to provide for sustainable, long-term control through regeneration of native and other desirable plants (Taylor and McDaniel 2004). 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.

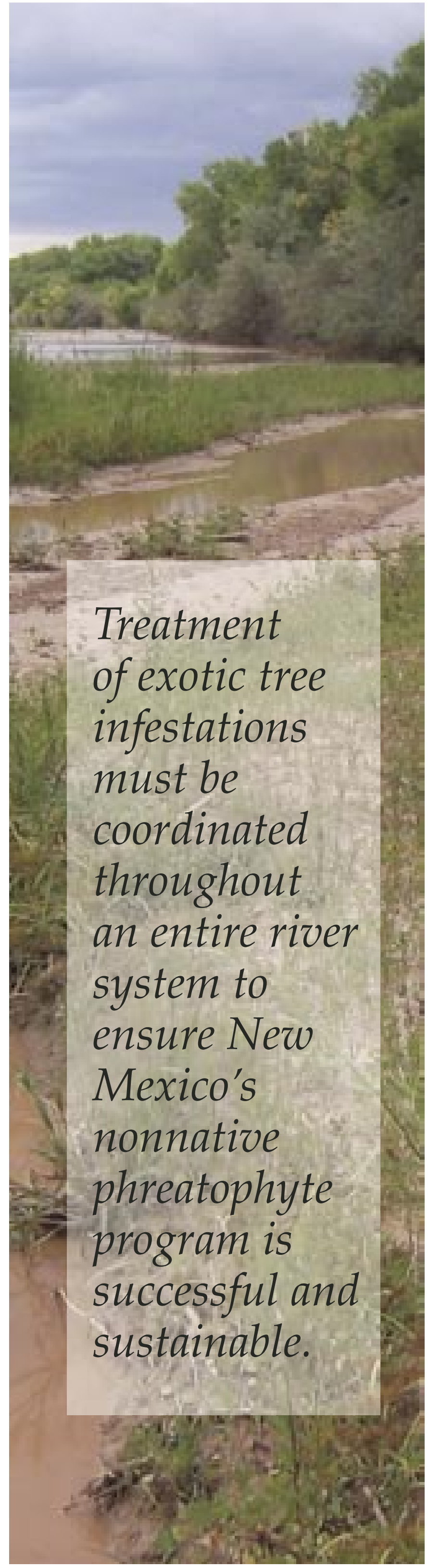
Since water dispersal of seeds is significant for saltcedar and Siberian elm, treatments, whenever possible, should begin at the upper reaches of a drainage and progress downstream. Treatment of Russian olive infestations is similar, but the long-range dispersal of seed by birds reduces the effectiveness of a watershed approach of management.

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

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 specific objectives and involve a variety of control methods.

Presently, the species of concern most closely associated with management of exotic trees in New Mexico include the endangered Southwestern willow flycatcher (*Empidonax trailii extimus*) and the yellow-billed cuckoo (*Coccyzus americanus*). The designation of critical habitat for the endangered Southwestern willow flycatcher is scheduled for completion by the U.S. Fish and Wildlife Service in late 2005, while the yellow-billed cuckoo is being considered for listing as a threatened species (Patricia Zenone and Greg Beatty, U.S. Fish and Wildlife Service, 2005, personal communication). Within various types of flycatcher habitats, specific treatments can be designed to maintain and improve vegetative conditions for the species by applying criteria and methodology described in the Southwestern Willow Flycatcher Recovery Plan, Appendix H, "Exotic Plant Species in Riparian Ecosystems of the U.S. Southwest," and Appendix K, "Habitat Restoration" (U.S. Fish and Wildlife Service 2002). The recovery plan recommends the following guidance for managing exotics in Southwestern willow flycatcher habitat: "Remove exotics in occupied, suitable but unoccupied, and potentially suitable habitats dominated by exotics only if: (1) underlying causes for dominance of exotics have been addressed; (2) there is evidence that the exotic species will be replaced by vegetation of higher functional value; and (3) the action is part of an overall restoration plan." Specific actions needed to benefit the yellow-billed cuckoo have not yet been determined. However, the criteria and methodology described in the Southwestern Willow Flycatcher Recovery Plan and Appendices may benefit this species as well. In addition, to minimize, but not necessarily eliminate, impacts to these and other species, treatments could occur in the fall or winter outside the breeding season.

Densely Infested Sites: Large reaches of the Rio Grande, Pecos, Canadian, San Juan, and Gila River



systems currently have monotypic stands of saltcedar and Russian olive with only a few remnants of native plant communities. Russian olive and Siberian elm appear to be more abundant at higher elevations, especially in the northern parts of the State. Without intervention, an increasingly larger area will be permanently modified by these exotic tree infestations. Eradication is an unrealistic objective for such large, dense infestations. Containment and annual density reduction are more practical goals.

Russian olive infestations can develop under dense stands of saltcedar and could become more dominant in some riparian areas. Removal of one species can provide an opportunity for the spread and intensification of the other species, including herbaceous exotics. Rapid revegetation following control can provide competition against such invasions and lead to lasting, sustainable control that is resistant to invasion (Taylor and McDaniel 2004).

Control of dense infestations is often done for a variety of objectives. Monotypic stands of saltcedar are at high risk from wildfire, which is of particular concern to nearby residential communities (Taylor 2000). In some instances, saltcedar can alter ground water hydrology as water tables decline and sites become more xeric (dry) (Lovich et al. 1994). Control of large, monotypic stands may increase surface waterflow in some areas (King and Bawazir 2000, Dahm et al. 2002).

Management Techniques

Several methods have been shown to be effective in managing exotic trees. Selection of the appropriate methods depends on a number of factors, such as infestation density, management objectives, environmental concerns, costs, and social considerations. Restoration potential also is an important consideration. No method will provide 100 percent control and followup treatments will be needed for many years to achieve desired results. As new techniques become available during implementation of this and related strategies, decision makers will need to exercise 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 2 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. Saltcedar, Russian olive, and Siberian elm can readily reproduce from cut stems and sections of buried roots. Improper removal and disposal can result in vigorous regrowth. Unless performed by volunteers, the cost for manual removal of dense thickets of seedlings can be prohibitively expensive.
- **Selective Mechanical Grubbing:** Mechanical grubbing can selectively

Table 3. Estimated cost per acre and expected percent of control for individual saltcedar treatments and large scale control methods (adapted from Taylor and McDaniel 2004)

Control Treatment	Cost per Acre	Percent Control
Individual Plant Treatments		
Manual Removal (Immature Plants)	0-$5,000	95-100
Mechanical Grubbing	$40-$300	97-99
Low-volume Herbicide Application[1]	$30-$60	80-95
Cut-stump Herbicide Application[2]	$1,600-$2,500[6]	60-80
Ground-based Foliar Herbicide	$40-$300	97-99
Large-scale Control		
Mechanical	$700	97-99
Airplane Herbicide-Burn	$300	93
Helicopter Herbicide-Burn[4]	$240	89
Airplane Herbicide-Shred[3,5]	$400	97-99
Helicopter Herbicide-Shred[4]	$510	97-99
Airplane Herbicide-Burn-Mechanical	$380	97-99
Helicopter Herbicide-Burn-Mechanical[4]	$490	97-99

[1] *Doug Parker, 2003, personal communication*

[2] *Duncan 2003*

[3] *McDaniel and Taylor 2003a*

[4] *McDaniel and Taylor 2003b*

[5] *Includes 2 years of followup, ground-based foliar herbicide treatment*

[6] *The majority of the cost will be for tree cutting and removal or chipping, and the herbicide cost can vary from $20-$60 per acre. National Park Service costs range from $400-$1,000 per acre with 80 to 85 percent efficacy (Gerald McCrea, IPM Coordinator, National Park Service, 2005, personal communication).*

remove individual trees on sites that can be accessed (Taylor and McDaniel 2004). To be effective, the complete root system must be excavated and removed from the site. 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. See Table 3 for cost estimates.

- **Low-volume Basal Bark Herbicide Application:** Small saltcedar, Russian olive, and Siberian elm saplings and regrowth (stems less than 2 to 3 inches in diameter at ground level and less than 8 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 an 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. Injury to desirable plants can be avoided if applications are made when they are dormant. Also, non-target plants can be injured as a result of volatilization of the spray mixture when the temperature is above 85 °F. This is a cost-effective method for selective control of small diameter trees (Table 3). If done properly, 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 formulation 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 for light infestations. Per acre costs depend on tree density, and the majority of the cost is for tree cutting and removal or chipping of the woody debris.
- **Foliar Herbicide Application:** Foliar applications of a mixture of imazapyr and glyphosate are effective when applied between June and September. The addition of a nonionic surfactant to the spray mix is

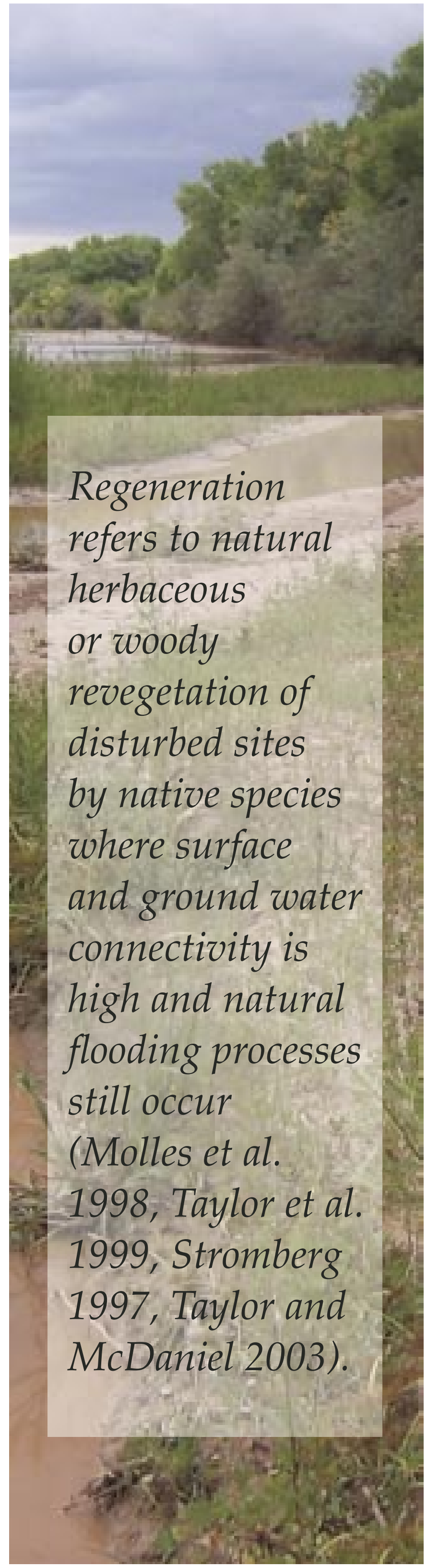
Figure 6. Selective control of Russian olive and saltcedar saplings following basal bark application

Figure 7. Cut-stump hand application of triclopyr (amine formulation) immediately following cutting of saltcedar stems with a chain saw

recommended. Glyphosate has been shown to be effective in controlling Russian olive when applied in June (McDaniel et al. 2002), but the application of imazapyr in August and September, when trees are moving carbohydrate reserves to their root systems, is more effective (Duncan and McDaniel 1998, Duncan 2003). 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 dependent and can be high due to the volume of herbicide solution that must be applied to obtain complete coverage of the foliage (Table 3). Imazapyr does not control Siberian elm.

Densely Infested Sites

- **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, followup 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). Mechanical control costs can be high (Table 3), and subsequent revegetation can add substantially to the cost.
- **Aerial Herbicide Applications:** Large, dense infestations can also be controlled through aerial applications of imazapyr or a mixture of imazapyr and glyphosate. A nonionic surfactant is recommended for both applications. For optimal control, applications should occur from late August through September prior to foliar color change when plants are actively growing (Duncan



Regeneration refers to natural herbaceous or woody revegetation of disturbed sites by native species where surface and ground water connectivity is high and natural flooding processes still occur (Molles et al. 1998, Taylor et al. 1999, Stromberg 1997, Taylor and McDaniel 2003).

Figure 8. Root plowing of saltcedar on Bosque del Apache National Wildlife Refuge

and McDaniel 1998, McDaniel and Taylor 2003a, 2003b). The use of fixed wing aircraft may be more economical when treating large saltcedar tracts, 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, followup 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. Herbicide and application costs can be high (Tables 3 and 5), and followup restoration can increase the cost by several fold.

- **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 exotic 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 gained 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.

An example of natural herbaceous regeneration is on the Pecos River, where there is a connection between high ground and surface water, which resulted in the regeneration of saltgrass (*Distichlis stricta*) and alkali sacaton (*Sporobolus airoides*) following saltcedar removal (Walthall 2004). Natural woody regeneration by cottonwoods and willows occurs on the Rio Grande where ground-surface water connectivity are high and where appropriate flooding still occurs following saltcedar removal (Taylor et al. 1999, Taylor and McDaniel 2003). In the first case, aerial herbicide application combined with burning was sufficient for natural regeneration to occur, while in the second case a combination of techniques, which included mechanical soil scarification, was required.

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). See Tables 4 and 5 for information on current techniques and costs associated with various options.

Program Requirements

Comprehensive Inventory: Although we have broad summaries of the plant communities and levels of exotic tree infestations found in riparian areas (Muldavin et al. 2000), more comprehensive surveys are needed on each river system. We need more precise information on the extent and intensity of infestations and the location and condition of native

Figure 9. Use of prescribed fire to remove saltcedar woody debris following aerial herbicide treatment, Bosque del Apache National Wildlife Refuge.

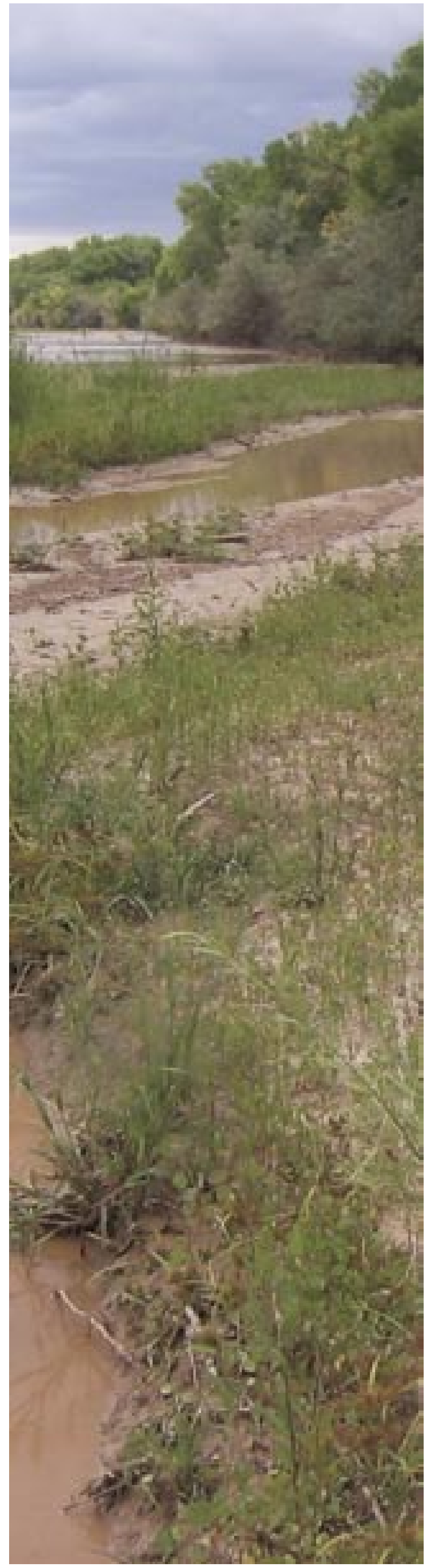


Table 4. Description of restoration and rehabilitation used successfully in New Mexico (adapted from Taylor and McDaniel 2004a)

Method	Timing	Effectiveness	Comments
Controlled flooding: Flood areas when seeds from desirable species are present.	When native or desirable seeds are available on site.	Cottonwood and willow survival 20% to 47% after 2 years.	Continuing control of invasive exotics is critical.
Pole plantings: Cutting and planting stems of willows and cottonwoods from established trees. Butt ends are soaked in water 10 days prior to planting into water table (Taylor and McDaniel 1998).	During winter months: January through March in New Mexico.	Plant survival 90%	For wildlife benefit, density should be at least 100 trees and shrubs per acre.
Nursery stock: Place understory plants with at least 30 cm of roots into holes that are augered to the water table (Dreesen et al. 2003).	Planting: August best, but requires supplemental water for 1-2 months.	Plant survival 90%	Survival decreases if water table is greater than 5 feet from the soil surface. Density should be at least 100 trees or shrubs per acre to benefit wildlife.
Rainfall harvest: Construct a long, shallow V-shaped water catchment furrow and line the sides with plastic. Seedlings are planted at 5 foot intervals at the bottom of the catchment (Fenchel et al. 1996).	Construction: Before rains Planting: During monsoon season.	Results are comparable to previous methods.	Effective in areas with a deep water table or where moderate salinity levels are present in the soil.

Table 5. Revegetation techniques and costs on the Bosque del Apache National Wildlife Refuge, New Mexico (Adapted from Taylor and McDaniel 2004)

Revegetation Technique	Cost Per Acre
Pole Planting[1]	$900
Tallpot Containerized Stock[1]	$2,700
Rainfall Harvest[2]	$7,200
Seeding[3]	$120

[1] *100 per acre*

[2] *100 foot rows with 3 foot plant spacing and 15 rainfall harvest rows per acre.*

[3] *Seeded with an Australian pitter seeder at the rate of 13.6 pounds per acre for saltbush and 1.5 pounds per acre for alkali sacaton.*

plant communities. Only with this baseline information will we be able to adequately determine the success of treatments.

A complete and detailed inventory of the five river systems and baseline vegetation maps will establish current infestation levels for saltcedar, Russian olive, and Siberian elm, and the location of existing stands of native trees and other native plant communities. This information is needed to determine where to implement projects in the various priority areas. An inventory will provide baseline information necessary to determine the success of potential treatments to reduce infestations of exotic tree species and protection and restoration of stands of native trees, shrubs, and other plants.

A specific implementation plan will be developed by the New Mexico Interagency Weed Action Group that outlines methods and costs to conduct an inventory for each of the five river systems in New Mexico. A comprehensive inventory of all river systems could take at least 2 years to complete and could cost as much as $1,500,000.

Long-term Funding: Adequate, consistent, and long-term funding is needed to prevent the continued spread of exotic tree infestations, control existing infestations, and maintain or restore native plant communities along the five major river systems in New Mexico. Several treatment and restoration programs have been successfully implemented in New Mexico, such as on the Bosque del Apache National Wildlife Refuge, where about 2,000 acres have been restored since 1987. These efforts, however, have only addressed a small percentage of the overall problem. To accomplish the objectives outlined in this strategic plan, it is estimated that at least $64,400,000 of Federal and State cost-share funding (including volunteer and in-kind services) will be needed over a 10-year period to make significant

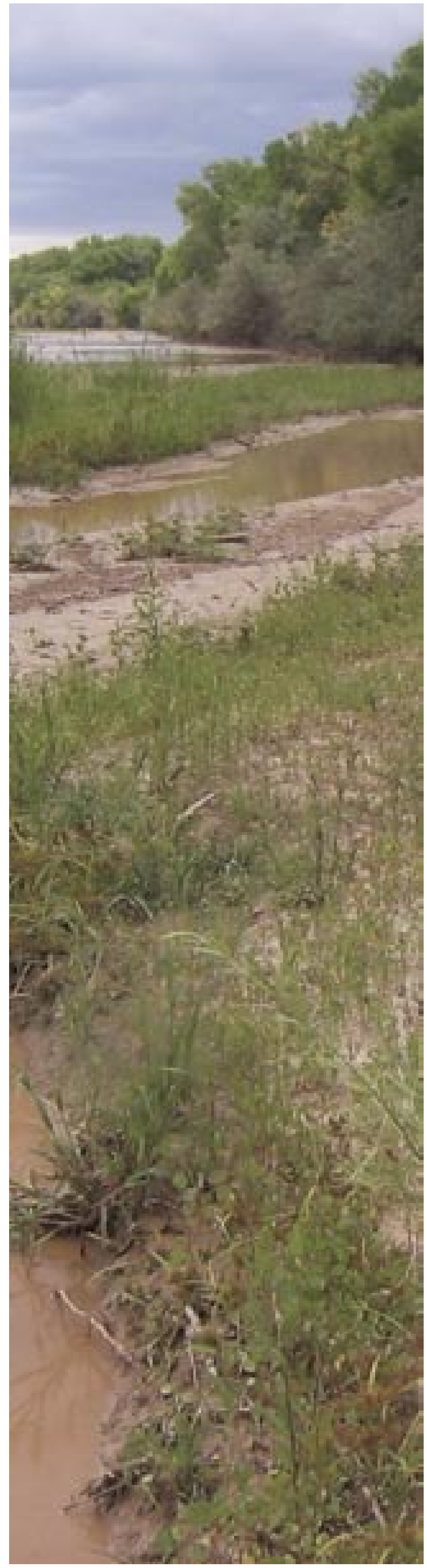


Table 6. Estimated annual funding (thousands of dollars) needed to accomplish the strategic objectives

Fiscal Year	Technical Support Organi-zation	Inventory/ Monitoring	Education/ Information	Research/ Demonstra-tion/Pilot Projects	Control/ Restoration	Total Annual Cost
2005	300	750	50	500	2,000	3,600
2006	300	750	50	750	4,000	5,850
2007	300	200	50	1,000	6,000	7,550
2008	300	50	50	1,000	6,000	7,400
2009	350	50	50	500	6,000	6,950
2010	350	50	50	300	6,000	6,750
2011	350	50	50	100	6,000	6,550
2012	350	50	50	100	6,000	6,550
2013	400	50	50	100	6,000	6,600
2014	400	50	50	100	6,000	6,600
Total	3,400	2,050	500	4,450	54,000	64,400
Percent	5	3	1	7	84	100

progress in protecting and restoring riparian areas in the State (Table 6). As better information becomes available through inventories and annual measurements of success, annual budgets can be adjusted to achieve desired control and restoration objectives for the five river systems. At this time, we can only estimate the minimal threshold for annual funding that would be needed to be successful. It must be understood that inadequate funding may not produce any significant control, and the long-term result may not be any different than taking no action. As an example, the overall acreage of saltcedar, Russian olive, and Siberian elm infestations may increase by as much as 3 to 7 percent annually. Assuming a total infestation level of 500,000 acres, which may be a conservative estimate, the existing infestations could increase and intensify on 152,400 to 419,200 acres over the next 10 years (Figure 10).

Technical Support Organization: To successfully coordinate treatment and restoration programs over the long term and promote proper and safe implementation of treatments, it will be necessary to build a strong team of technical specialists (three or more permanent employees) who have the sole responsibility of providing technical advice and assistance to local managers to help ensure the quality, consistency, and continuity of programs. Success for such a technically complex and long-term program is always derived from technically competent people working cooperatively with local managers. In addition, these specialists would provide technical information to local managers and participate in inventory, detection, education and information, demonstrations and research, control, and restoration efforts. The initial cost to support this organization would be about $300,000 per year and increase over time due to inflation.

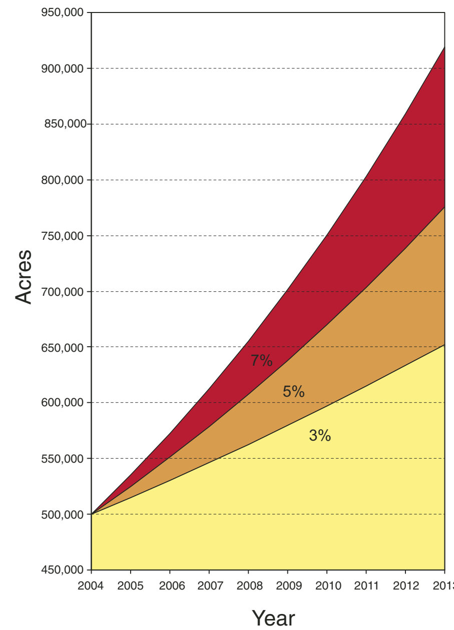


Figure 10. Potential for acreage increase of saltcedar, Russian olive, and Siberian elm infestations assuming an initial infestation level of 500,000 acres and annual rates of increase of 3, 5, and 7 percent.

Education and Information: Two separate information and education programs are needed. First, Federal, State, and local officials; tribal leaders; and private landowners will need training in prevention, suppression, and restoration techniques. Due to a turnover of participants, this activity would need to be done on a continuing basis. Second, development and implementation of outreach programs are needed to inform the public of the seriousness of the threat to riparian areas, and the consequences of failure to control exotic tree infestations. The technical support organization could accomplish a major portion of an education effort, but providing an additional $50,000 per year would optimize success.

Measuring Success: Annual assessments are needed for treatment and restoration programs. Measurements should be tailored to evaluate if specific objectives for a site were met. For example, if the objectives are to increase water availability, enhance wildlife habitat, and reduce wildfire risk, managers will need to establish three specific assessment measurements and conduct pre- and post-treatment monitoring to determine if the objectives are met. Written monitoring plans should be prepared before beginning treatments.

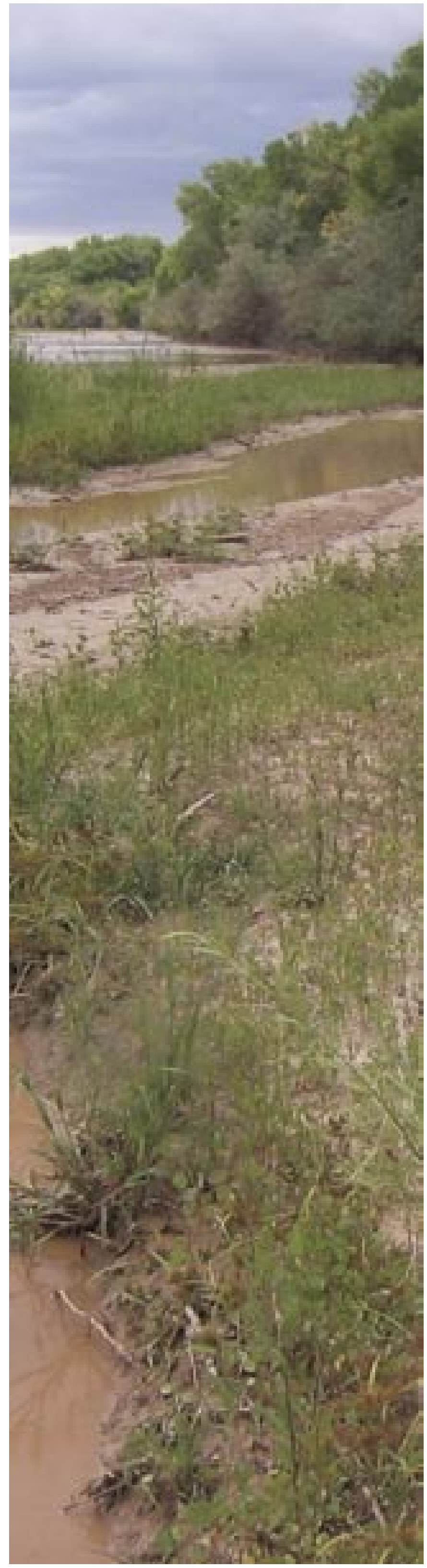
Demonstrations: Three types of demonstration areas are needed: (1) sites to show successful control and restoration methods; (2) sites for training landowners and managers in the application of IVM techniques; and (3) sites to evaluate new and innovative methods of control. These sites will be used to increase awareness of both land managers and the general public.

Research: While some progress has been made in developing successful techniques for removal of exotic trees, site restoration, and for evaluating water use by native and nonnative species, many questions remain.

Successful applied research involves assessing and comparing treatments across the different conditions that occur within landscapes over time. The establishment of multiple demonstration areas could be coupled with a strong experimental design to test hypotheses targeting long-term sustainable species control, revegetation, and water savings. Each demonstration research area should, to the extent possible, support full complements of related treatments and assessments while considering the following issues.

Needs Related to Geographic Information System (GIS) Development: Fundamental to all aspects of research within demonstration areas is the development of GIS capabilities to map relevant aspects of the physical, biological, and cultural environment. These capabilities will help to spatially describe ecosystem parameters associated with the impact and proliferation of exotic species and the sustainability of native species. The ecosystem parameters include the effects of climate, hydrology, geomorphology, and natural and anthropogenic inputs to New Mexico's riparian corridors. Spatially explicit quantifications of these parameters, coupled with knowledge of riparian species composition, will help scientists, managers, and landowners determine the potential sustainability of exotic species control and restoration. Specific needs follow:

- Create socioeconomic and environmental data layers to provide a baseline for future modeling.
- Map historical conditions and socioeconomic and environmental changes associated with demonstration areas utilizing historical documentation, aerial photographs, and satellite imagery.
- Develop impact maps to correlate water budgets, species distributions, and socioeconomic viability as changes occur in riparian demonstration areas (i.e., water, flora, and fauna).
- Develop predictive models to show how riparian ecosystems will benefit from control of exotic trees and restoration.



- Monitor control of exotic trees and restoration programs to determine appropriate strategies in demonstration areas.

Needs Related to Control of Exotic Trees: Crucial to successful control of exotic species is the ability to adaptively select from a suite of control measures to meet desired future conditions goals, including revegetation. Demonstration areas should include a range of treatments, with sufficient replication, to verify the technique under various site conditions to investigate the following aspects:

- Ecology of exotic species where existing literature is limited.
- Role of fire in contemporary ecology.
- Efficacy of a set of saltcedar, Russian olive, and Siberian elm control techniques and combinations of techniques in replicated experiments.
- Biological control efficacy of the Crete saltcedar leaf beetle.
- Effectiveness of grazing goats in control of exotic trees.
- Combined effectiveness of fire and grazing by goats.
- Long-term control costs.

Needs Related to Restoration Following Control: Where treatments are proposed on sites with extensive infestations, there is a potential for reinvasion by exotic trees or other invasive plant species. Revegetation with desirable species that competitively exclude exotic trees and invasive species may provide for sustainable, long-term control. Revegetation can occur naturally following treatments or through artificial planting and seeding. Each demonstration area should include a suite of control and revegetation methods to investigate the following:

- Ecology of native species where existing knowledge is limited.
- Ability of native species to exclude exotic trees and plants under conditions of low and high environmental stress (variable soil salinity, periodic flooding, and drought).
- Range of site preparation techniques, including use of grazing animals, conducive to natural or artificial revegetation.
- Facilitate artificial seeding with seeding establishment through seed pre-conditioning treatments and mycorrhizal inoculation.
- Establishment of regional native transitional species within seed mixes on harsh sites.
- Upland site characteristics conducive to natural regeneration of native brush and grass species.

Needs Related to Water Use. Even though it is assumed that replacement of exotic species with native plant communities will result in water savings, the amount and fate of salvaged water needs to be assessed in conjunction with water basin inputs, outputs, and exchanges between the atmosphere, plants, soil, ground water, and surface water. Changes to soil and water quality resulting from vegetation manipulations need to be quantified. Definitive information is needed for the following topics:

- Model surface and ground water hydrology and evapotranspiration in existing and converted plant communities and integrate this information with regional surface water budgets.
- Optimal evapotranspiration instrumentation method to evaluate water budgets,

vegetation competitive theory, and soil evaporation during wet and dry cycles.

Needs Related to Biodiversity. Concerns about biodiversity, especially those involving threatened and endangered species, are fundamental issues related to exotic plant control and restoration programs. Monitoring of vegetative and faunal productivity is needed to determine the effects of control and restoration programs over time as follows:

- Pre-treatment biodiversity in saltcedar and Russian olive control areas.
- Long-term measurement of post-treatment biodiversity as restoration progresses.

Needs Related to Socioeconomic Issues. Societal views are widely varied regarding control of exotic plants and restoration of native plant communities. Perception of aesthetics and concerns for water conservation, recreational values, cultural values, and changes in biodiversity are major issues that have been identified by the public. Research is needed on the following aspects to assist in responding to public concerns:

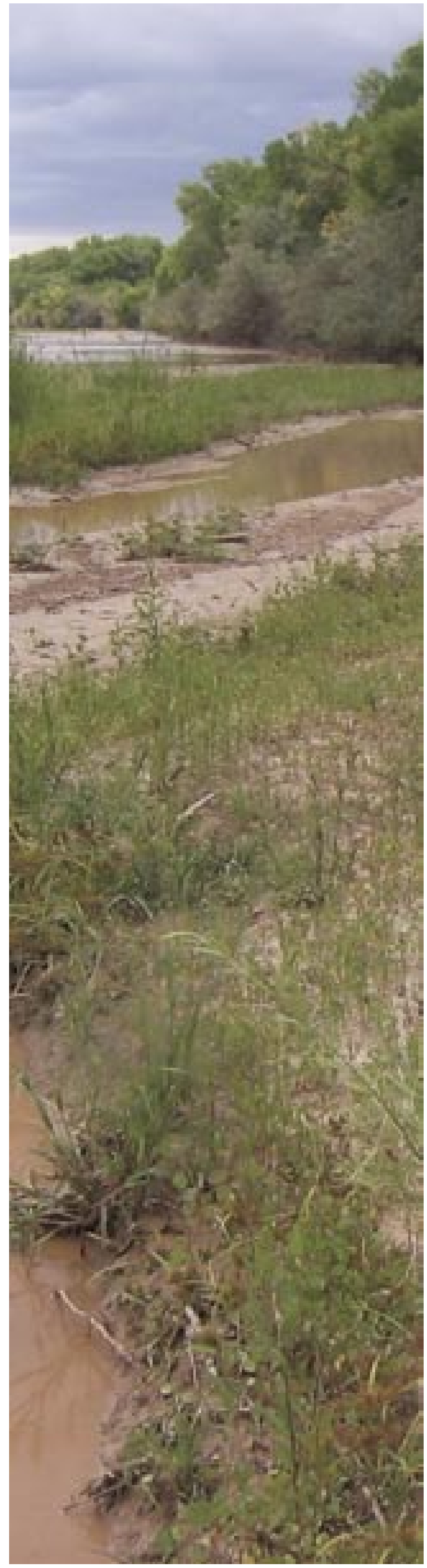
- Utilize GIS to provide an overview of control and restoration projects.
- Utilize GIS to portray local and regional economic impacts caused by control and restoration programs.
- Evaluate means to develop local private enterprises to boost economic development.
- Evaluate means to produce native plant materials by private enterprises to improve rural economies.
- Develop survey techniques to determine public perceptions about control and restoration programs.

Pilot Projects:

- **Biological Control:** Biological control, which involves introducing insects or pathogens that control a plant in its native land and only reproduces on that plant, has been used in Hawaii since 1902 and the U.S. and Canada since 1945. Ten major weeds have been effectively controlled in North America by introduced insects, and several other introductions are in progress, including saltcedar. The ecological interactions of using biological control were examined by DeLoach et al. (2000), who found this approach offered promise for controlling saltcedar.

  After extensive study, the saltcedar leaf beetle (*Diorhabada elongata*) from China and Kazakhstan, was released in 6 western states in May 2001. By September 2003, insects had defoliated 15 to 500 acres at 5 sites in Nevada, Utah, Colorado, and Wyoming (DeLoach et al., 2004). This strain of beetle, however, could not survive the winter in more southern areas of Texas and California (Lewis et al., 2003).

  A different strain of the beetle from Crete was released in Texas and on the Pecos River near Artesia, New Mexico, in 2003. Crete beetles have the same effect as the Chinese beetles, and they have survived the winter. Their spread and effects will be monitored by Dr. David Thompson (Department of Entomology, New Mexico State University) and Debra Eberts (USDI Bureau of Reclamation) (Milbrath et al., 2004).



Russian olive also is a promising target species for biological control using insects introduced from Asia.

Biological control of Siberian elm is a possibility, but it is closely related to American elms, which could pose a significant difficulty due to the possibility of the introduced organisms attacking native elms.

- **Goats:** New Mexico's Legislature has funded research to evaluate the effects of browsing by goats on saltcedar and other exotic trees (New Mexico SB 655, 2003). The first study of the use of goats to control saltcedar has begun along the Rio Grande at sites near Albuquerque, San Acacia and San Marcial. Goats readily browsed saltcedar and Russian olive, while maintaining weight and health. (Dr. Sandy Tartowski, USDA-ARS Jornada Experimental Range, 2005, personal communication).

  Nearly every saltcedar plant in the goat-treated areas was damaged by browsing, breaking branches or stripping bark. Goats had an especially severe impact on resprouts, removing about half of the vegetation in the first year of browsing on 4-year-old resprouts. Goats had much less impact on large, dense saltcedar, but cleared out the understory, reducing laddering fuels, improving access for recreation, and reducing costs for mechanical or manual clearing. After 2 years of goat treatment, the width of saltcedars was reduced by about 35 percent, but only about 4 percent of the large saltcedars were killed. It may take 5 or more years of goat browsing to deplete the root reserves of saltcedar sufficiently to increase tree mortality.

Figure 11. Goats browsing on saltcedar

Goats browsed desirable native plants as well as saltcedar, but most of the understory vegetation recovered during the following growing season. Large cottonwoods were not damaged and browsed willows resprouted vigorously. Grass cover, especially desirable grama grasses (*Bouteloua barbatus* and *B. aristoides*), increased from less than 1 percent immediately before goat browsing to about 20 percent 1 year after goat browsing.

The cumulative impact of several years of goat browsing on riparian weeds and desirable species is not yet clear. The investigation of the effectiveness and cost of goats in controlling saltcedar will be continued for the next 4 years by Dr. Sandy Tartowski (USDA-ARS Jornada Experimental Range) and Dr. Manny Encinias (NMSU Cooperative Extension Service).

Ornamental Trees in Residential Communities: The presence of saltcedar, Russian olive, and Siberian elm trees in communities and other lands adjacent to riparian areas cannot be ignored. Seed produced by ornamental trees will continue to re-infest riparian areas. Incentives for removal of these species, and restrictions on their sale, will have to be addressed, otherwise, re-infestation of riparian sites will occur and long-term and sustainable control is unlikely.

Compliance with Laws and Regulations: For Federal lands or where Federal funds will be used, compliance with the National Environmental Policy Act (NEPA) is required. To expedite project implementation, it will be worthwhile for agencies to develop a programmatic environmental analysis for the river systems in New Mexico. Prior to implementing management programs, consultation with the U.S. Fish and Wildlife Service may be required to avoid negative impacts on the Southwestern Willow Flycatcher and its habitat or other species of concern. For some projects it may also be necessary to obtain Federal, State, and or local permits of varying types (e.g., burn permits).

Conclusions

While many factors must be considered when developing a local management plan for exotic tree species, it is important to develop a plan that will enable long-term management that is adaptable to meet the specific objectives of each area. Management plans should include mapping, prevention, early detection, timely control, and adaptive management of infested areas, including regeneration. Linking management plans over entire river basins, prioritizing areas, and spending resources efficiently can contain the spread of exotic tree infestations, reduce overall infestation levels, and lead to more diverse riparian ecosystems that are healthy and sustainable.

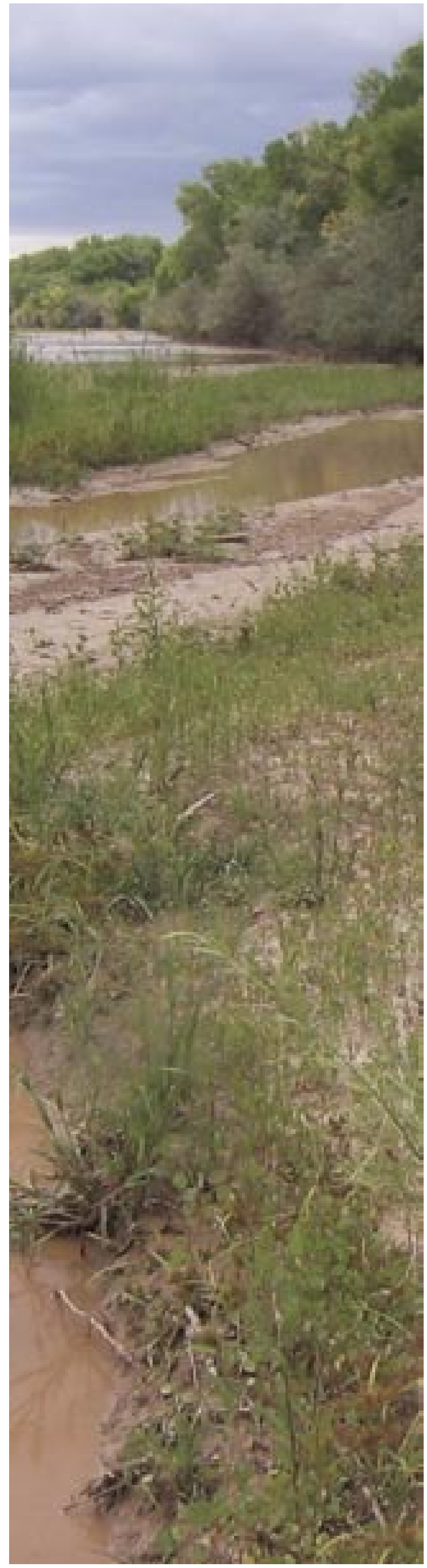


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Figure 12. Natural regeneration of cottonwood seedlings on sandy flat of Rio Grande, Overbank Demonstration Project