10 –YEAR STRATEGIC PLAN
ON
THE COMPREHENSIVE REMOVAL OF TAMARISK
AND THE
COORDINATED RESTORATION OF COLORADO'S
NATIVE RIPARIAN ECOSYSTEMS

Prepared by the Colorado Department of Natural Resources pursuant to
Executive Order # D 002 03

Submitted to Governor Bill Owens
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COLORADO
DEPARTMENT OF
NATURAL
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Table of Contents

Tables

Figures

Acknowledgements

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Executive Summary

Riparian lands in Colorado have been severely impacted by many activities and actions, but none so much as the invasive plant tamarisk (*Tamarix spp.*, also known as saltcedar). Tamarisk is a tenacious shrub/small tree that has a deep root system (up to 100 feet) and leaves a salt residue on the soil surface. These characteristics enable it to quickly replace native cottonwoods, willows, grasses, and forbs. The resulting tamarisk thickets crowd out rivers and streams; provide poor habitat for livestock, animals, and birds; increase fire hazards; limit human use of the waterways, and generally use more water than native vegetation. Infestations in Colorado are roughly estimated to occupy 55,000 acres and consume 170,000 acre-feet of water per year more than the native replaced vegetation.

Governor Owens recognized this problem and issued an Executive Order directing the Department of Natural Resources in cooperation with the Department of Agriculture to develop a 10-year plan for tamarisk control within the state. This 10-Year Strategic Plan was developed through a working group composed of representatives from these two departments and the Bureau of Land Management, Bureau of Reclamation, Colorado State University (CSU), Denver Botanic Gardens, Mesa State College, The Nature Conservancy, Tamarisk Coalition, University of Denver, and the U.S. Forest Service.

Congress also recognizes the importance of the tamarisk problem and has pending legislation that could provide $25 to $50 million per year throughout the West for tamarisk control, revegetation, and research. Colorado’s congressional delegation is taking a leadership role in both the House and Senate on formulating and moving this legislation forward. It is anticipated that a bill will be passed in early 2004 with funding potentially available in 2005.

The 10-Year Plan is founded on 19 principals that provide a solid foundation for the Plan. Some of the more important principals are:

- the objective of tamarisk control is the reestablishment of native vegetation that can be sustainable;
- the tamarisk problem in Colorado is significant but success is achievable;
- control activities should occur on a watershed scale, be partnerships between all affected interests, and have local control;
- success requires control, revegetation, monitoring, maintenance, and appropriate funding;
- existing water rights, river management infrastructure, and property rights must be respected;
- education is essential to help establish with the public the importance of the tamarisk problem, methods for solving the problem, and the need for appropriate levels of funding;
- research is important to reduce costs and improve effectiveness; and
- if no action is taken, the problem will continue to grow and degrade the state’s river systems.

Tamarisk is the primary non-native phreatophyte of concern in Colorado and thus has the dubious distinction as the "poster child" of non-native plants impacting the riparian zone of the state's rivers and streams. Other non-native invasive plants, notably Russian olive, co-habit with tamarisk and also deserve attention. If only tamarisk is controlled, the potential for Russian olive to take over much of the riparian areas is high. Therefore, within the context of the 10-Year Plan, whenever the term "tamarisk" is used it also includes Russian olive as the other principal invasive plant that may be important to control within riparian areas.

The 10-Year Plan represents a strategic approach to solving the tamarisk problem and describes specific measures to take that will support the formulation and implementation of watershed level solutions (tactical plans) for controlling tamarisk within the state. It is composed of the following ten components that include both actions and responsibilities. It is important to note that progress on many of these components is already underway.

1. **Organizational Structure** has three components: watershed, state, and advisory. The formulation and implementation of tamarisk control and revegetation plans is best done at the local watershed level with coordinating support from the state through a small team of 2-4 existing employees (Tamarisk Support Team). A volunteer advisory panel of experts would provide technical assistance to watershed partnerships of communities, agencies, and organizations, and to the Tamarisk Support Team.

2. **Inventory of the Tamarisk Problem** is the crucial element in the development of a control plan at watershed and state-wide scales. The current estimate of 55,000 acres of infestation is only a rough estimate. A more accurate inventory is needed to provide the basis for project planning (e.g., cost estimates, resource allocation, and priority setting) and tracking the long-term success of control efforts.

3. **Education** is needed to provide the public with an understanding of the problem and means of implementing solutions. Educational elements should build upon and expand the existing efforts that are already taking place in Colorado; e.g., volunteer days at state parks (such as Governor Owens' Colorado Cares Day), CSU Cooperative Extension landowner training, development of a *Handbook for Tamarisk Control and Revegetation*, and non-profit outreach programs.

4. **Research** on tamarisk has been going on for many years and much is known about the plant and how to control it. However, to gain a better understanding on how to reduce costs, improve effectiveness, and reduce impacts on water and wildlife habitat some addition research is needed. This includes changes to water availability/water quality and habitat, new biological control agents, revegetation, and innovative control techniques.

5. **Funding** is currently piece meal and inadequate to accomplish the objective of controlling tamarisk within 10 years. Long-term funding is necessary and needs to be developed from combinations of state and local in-kind support, federal funding, and new sources. Although the estimated cost is not unreasonable or prohibitive at approximately $5,000,000 per year, it will require considerable effort to address this issue.

6. **Role of Non-Profits** is predominately one of providing education, research, coordination, and active control/revegetation at the local level. This can be established through watershed partnerships, and organizations such as the Tamarisk Coalition and The Nature Conservancy.

7. **Role of Local Communities** (counties, cities, towns, and Indian tribal units) should be to participate at the watershed level and take leadership responsibilities to establish watershed partnerships that can formulate and implement tamarisk control and revegetation plans. The resulting plans are thus the product of local needs, concerns, and priorities developed by local partnerships; yet, meet the objectives of the state for tamarisk control and revegetation.

8. **Role of State Agencies** is multi-faceted. Through the proposed 2-4 person Tamarisk Support Team, the state can provide assistance, guidance, education, funding coordination, and accountability resources to watershed partnerships. Colorado Department of Agriculture and CSU Cooperative Extension offices can provide training to landowners and other state agencies on proper control and revegetation techniques. As land managers, Department of Transportation, State Land Board, State Parks, and Division of Wildlife, should participate with local watershed partnerships to formulate and implement control plans.

9. **Role of Federal Agencies** (BLM, BOR, Defense, Energy, Forest Service, Fish and Wildlife Service, and National Park Service) is to participate in local watershed partnerships to formulate and implement local plans for tamarisk control and reestablishment of native vegetation. Additional emphasis by these agencies should be placed on establishing budgets for control activities on federal lands. Scientists with these agencies should also be involved with other researchers in the state to have a coordinated approach to research.

10. **Role of the Governor and State Legislature** is fundamental to the success of the 10-Year Plan. The Governor should continue as the senior spokesman for tamarisk control and habitat restoration by encouraging Congress to pass the pending federal legislation, by working with adjoining states to encourage their development of strategic plans for tamarisk control, and by working with the legislature to help identify appropriate funding sources for shortfalls at the local level.

The 10-Year Plan should be viewed as a document that must be revisited and changed as new information becomes available.

1.0 Introduction and Purpose

On January 8, 2003 Governor Owens issued Executive Order D 002 03 (see Appendix A) directing the Department of Natural Resources (DNR) in cooperation with the Colorado Department of Agriculture (CDA) to develop a plan for tamarisk control within the state over the next 10 years. The Plan was developed through a working group composed of representatives from Bureau of Land Management (BLM), Bureau of Reclamation (BOR), CDA, Colorado State University (CSU), DNR, Denver Botanic Gardens, Mesa State College, The Nature Conservancy, Tamarisk Coalition, University of Denver, and the U.S. Forest Service.

The 10-Year Strategic Plan is composed of ten components: organizational structure, inventory of the tamarisk problem, education, research, funding, role of non-profits, role of local communities, role of state agencies, role of federal agencies, and the role of the Governor and state Legislature. The Plan represents a strategic approach to solving the tamarisk problem that describes specific measures for what to do to formulate and implement tactical plans for how to accomplish the 10-year goal of controlling tamarisk within the state. The Plan should be viewed as a document that must be revisited and changed as new information becomes available.

2.0 Background

Prior to undertaking the development of the 10-Year Plan it is important to understand the nature of the problem, the current state of research, the extent of infestation in Colorado, the solutions available, the costs involved to solve the problem, active projects within the state, and federal actions that could help.

2.1 General Background

Rivers, streams, lakes, and ponds are highly prized in the western U.S. for their recreation, fish and wildlife, and cultural values, as well as for their economic values that stem from their use for water supply, livestock production, and agriculture. The adjacent areas known as the "riparian" lands are equally valued for the same reasons (USDI/USDA 1998). Although riparian lands make up a small percentage of total land area in the West, they are essential for maintaining water quality and quantity, for ground water recharge, for erosion control, and for dissipating stream energy during flood events (NRST 1997). Unfortunately, much of these water systems and associated riparian lands have been severely degraded over the past 150 years by both man and invasive plant species, resulting in poorer water quality, less water availability, and habitat loss.

Of particular interest is the invasive plant species tamarisk (*Tamarix spp.*), also known as salt cedar. Scientists with the U.S. Department of Agriculture (USDA) have stated that . . . *tamarisk infestation has reached epidemic proportions and is one of the greatest disasters to ever befall native riparian areas in western United States* (DeLoach 2000). The National Invasives Species Council has identified tamarisk as one of its primary targets and the CDA has listed it on its noxious weed list.

2.2 Current Understanding of the Tamarisk Problem

Tamarisk is a deciduous shrub/small tree that was introduced to the western U.S. in the early nineteenth century from Central Asia and the Mediterranean for use as an ornamental, in windbreaks, and for erosion control. Tamarisk is well suited to the hot, arid climates and alkaline soils common in the western U.S., and has effectively exploited many of the conditions symptomatic of southwestern rivers today (e.g., reduced flooding, increased fire). It gradually became naturalized along minor streams in the southwest and by the mid-twentieth century, tamarisk stands dominated low-elevation (under 6,500 feet) river and stream banks from Mexico to Canada. Tamarisk is now believed to cover anywhere between 1.0 and 1.5 million acres of land in the western U.S. and may be as high as 2 million acres (Zimmerman 1997).

Although there is some disagreement as to the exact date of first introduction, it is generally understood that Eurasian tamarisk became a problem weed in riparian zones in the mid 1900's (Robinson 1965, Howe and Knopf 1991). Genetic analysis suggests that species invading in the west include *Tamarix chinensis*, *T. ramosissima*, *T. parviflora*, *T. gallica*, and *T. aphylla* (Gaskin 2002, Gaskin and Schaal 2002). The most extensive invasions appear to be from a hybrid of the first two species. Furthermore, there are several ornamental varieties of tamarisk still being marketed throughout the western United States, which are not likely the source of invasions, but are contributing genetic diversity to invading populations through hybridization.

Tamarisk reproduces primarily though wind and water-borne seed, but a stand may also spread through vegetative reproduction. Seeds require a wet, open habitat to become established, and seedlings are not strongly competitive (Sher, Marshall and Gilbert, 2000; Sher, Marshall and Taylor, 2002; Sher and Marshall, 2003). Therefore, if native plant communities are intact or conditions favor native plant establishment or growth, invasion by seed is not likely to occur. However, several conditions will allow new infestations: if the native overstory is removed due to natural or human causes and one of the following occur: 1) **Late flooding**- Tamarisk seed is generally produced for a longer period of time than native vegetation, and therefore is able to take advantage of overbank flooding at times of the year when native vegetation is not dispersing seed. 2) **Suppression of native vegetation** - herbivory (e.g., cows will eat native saplings), drought, fire, lack of seed, or other disruptive processes can prevent other plants from establishing, and therefore allow tamarisk to invade via seed. Once tamarisk seedlings are established (as great as 1,000 indiv./m^2 initially), thick stands are very competitive, preventing natives from coming in (Busch and Smith 1995, Taylor et al.1999).

Generally speaking, processes that disrupt the riparian ecosystem appear to make invasions more likely, especially alterations of hydrology (Baker 1986, Lonsdale 1993, Décamps Planty-Tabacchi and Tabacchi 1995, Busch & Smith 1995, Springuel *et al*. 97, Shafroth *et al*. 1998). However, there are also documented cases of tamarisk stands where no known disruptions have occurred.

Once a tamarisk stand is mature, it will remain dominant unless removed by human means. Tamarisk is more fire, drought, and salinity tolerant than native species (Horton et al. 1960, Busch et al. 1992, Busch and Smith 1993 & 1995, Shafroth et al. 1995, Cleverly et al. 1997, Smith *et al.* 1998, Shafroth *et al*. 1998). Tamarisk can increase fire frequency and intensity, drought (Graf 1978), and salinity (Taylor et al. 1999) of a site, thus, a strong, initial infestation will promote itself and is likely to lead to more tamarisk invasion.

In addition to affecting abiotic processes, *Tamarix* is capable of dramatically changing vegetation structure (Busch & Smith 1995) and animal species diversity (Ellis 1995) in sites where it has become dominant. Surprisingly, high invertebrate and bird diversity has been recorded in tamarisk-dominated areas, and tamarisk is valued highly by the bee industry for its abundant flower production. Although some forms of tamarisk (primarily younger, highly branching stands) are favored by cup nesting bird species such as the southwestern willow flycatcher, many other, endemic species are completely excluded by it, including eagles and other raptors (Ellis 1995). Because of its potential use by some species, mixed stands of tamarisk with native vegetation were found to have high ecological value in Arizona study sites (Stromberg 1998). This is to be contrasted highly with mature monocultures of tamarisk that have a much lower value for ecosystem services.

In 1998, The Nature Conservancy compiled a very thorough assessment of tamarisk and its impacts on riparian systems that this infestation causes throughout the West (Carpenter 1998). This information is included as Appendix B and summarized below.

- Tamarisk populations develop into dense thickets, with as many as 3,000 plants per acre that can prevent establishment of native vegetation (e.g., cottonwoods (*Populus spp*), willows (*Salix spp*), grasses, and forbs).

- As a phreatophyte, tamarisk invades riparian areas, potentially leading to extensive degradation of habitat and loss of biodiversity in the stream corridor.

- Excess salts drawn from the groundwater by tamarisk are excreted through leaf glands and are deposited on the ground with the leaf litter. This increases surface soil salinity to levels that can prevent the germination of many native plants.

- Tamarisk seeds and leaves lack nutrients and are of little value to most wildlife and livestock.

- Leaf litter from tamarisk tends to increase the frequency and intensity of wildfires which tend to kill native cottonwood and willows but not tamarisk.

- Dense stands on stream banks may gradually cause narrowing of the channel and an increase in flooding. Channel narrowing along with tamarisk-induced stabilization of stream banks, bars, and islands lead to changes in stream morphology, which can impact habitat for endangered fish.

- Dense stands affect livestock by reducing forage and preventing access to surface water.

- Aesthetic values of the stream corridor are degraded, and access to streams for recreation (e.g., boating, fishing, hunting, bird watching) is lost.

While each of these points is important to one or more constituencies, the single most critical problem that has been raised is that tamarisk has a reputation of using significantly more water than native vegetation that it displaces. This non-beneficial user of the West's limited water resources has been reported to dry up springs, wetlands, and riparian areas by lowering water tables (Carpenter 1998, DeLoach 1997, Weeks 1987).

Limited evidence indicates that water usage per leaf area of tamarisk and the native cottonwood/willow riparian communities may not be that different. However, because tamarisk grows into extreme thickets, the leaf area per acre may actually be much greater; thus, water consumption could also be greater on an acre basis (Kolb 2001). Another aspect of tamarisk and its consumption of water is that its much deeper root system (up to 100 feet compared to healthy cottonwoods and willows stands at 6 feet (Baum 1978, USDI-BOR 1995)) allows tamarisk to grow further back from the river and thus can occupy a larger area and use more water across the floodplain than would be possible by the native phreatophytes. This is especially significant, because the adjacent uplands and floodplain typically occupy a cross-sectional area several times that of the riparian zone. In these areas, less dense areas of mesic plants (such as bunch grasses, sagebrush, rabbit brush, and skunk bush) can be replaced by tamarisk resulting in overall water consumption several times that associated with these other plants (DeLoach 2002).

From thirteen different studies conducted between 1972 and 2000 on tamarisk evapotranspiration rates, the average water use reported is approximately 5.3 feet per year (Hart 2003). Recent research by the U.S. Department of Interior on the middle Rio Grande estimates evapotranspiration rates on the order of 4.3 feet per year (Interior 2003). These studies were performed using different methods of measurement, at different locations, and for different densities of infestation. Native cottonwood/willow communities have been estimated to use approximately one foot less per year than tamarisk (Weeks, 1987) while the native shallow-rooted upland plant communities of grasses, sage, etc. use only the moisture received by precipitation.

Unpublished research on the Bosque del Apache National Wildlife Refuge on the middle Rio Grande River in New Mexico indicates that Russian olive (*Elaeagnus angustifolia*) has very similar evapotranspiration rates as tamarisk (Bawazir 2003). Zavaleta (2000) demonstrates that a program of tamarisk control and revegetation would have clear economic, social, and ecological benefits. The USDA through the Forest Service is currently conducting additional research on the economic impacts of tamarisk control and riparian habitat restoration (Tamarisk Symposium 2003).

Tamarisk is the primary non-native phreatophyte of concern in Colorado and thus has the dubious distinction as the "poster child" of non-native plants impacting the riparian zone of the state’s rivers and streams. Other non-native invasive plants, notably Russian olive, co-habit with tamarisk and also deserve attention. If only tamarisk is controlled, the potential for Russian olive to take over much of the riparian areas is high. Therefore, within the context of this plan, whenever the term "tamarisk" is used it also includes Russian olive as the other principal invasive plant that may be important to control within riparian areas.

2.3 Current Tamarisk Infestations in Colorado

An inventory of infestation by tamarisk and the other principal non-native phreatophyte identified by the CDA, Russian olive, is a crucial element in the development of a control plan at the statewide scale. The inventory becomes the basis for project planning (e.g., cost estimates, resource allocation, scheduling) and tracking the long-term success of control efforts.

In 2003 the Colorado Water Conservation Board undertook a preliminary study to determine the extent of infestation in Colorado and the impacts on the water resources of the state (CWCB 2003). Information developed in this report indicates that the estimated infestation is approximately 40,000 acres for tamarisk and 15,000 for Russian olive. Infestations occur on every major river drainage in the state with the possible exception of the North Platte. Based on these acreages and the types of native vegetation that would have occupied these areas, the estimated non-beneficial water consumption in Colorado is approximately 170,000 acre-feet per year (CWCB 2003). By comparison, the Denver Water Board serviced 1,100,000 people with 250,000 acre-feet of water in 2001 (Denver 2002).

A question that is unanswered is the rate of invasiveness that will likely occur into the future. Zimmerman (1997) estimates that the rate of spread could be as high as 5 percent per year. This seems high for Colorado where the higher elevations do not offer tamarisk much competitive advantage. However, there are river systems, particularly the South Platte and Republican and the tributaries to the Arkansas in which tamarisk has a foothold and could spread rapidly. Figure 1 presents possible scenarios for future acreage occupied by tamarisk and Russian olive over the next 50 years based on a modest growth rate of 1 percent per year and a moderate growth rate of 2.5 percent per year.   These rates of invasiveness, while unknown as to their accuracy, would show increases to between 90,000 acres and 200,000 acres during this 50 year timeframe if no active control program is put into place. What is known is that tamarisk will spread. Flooding events dramatically spread tamarisk on the Colorado River during the flood of 1984 and on the Arkansas River in 1999.   Photographs of typical tamarisk infestations are presented in Figures 2 through 8.

Figure 1: Colorado Acreage Occupied by Tamarisk and Russian olive based on Different Rates of Invasiveness (Percentage/Year)

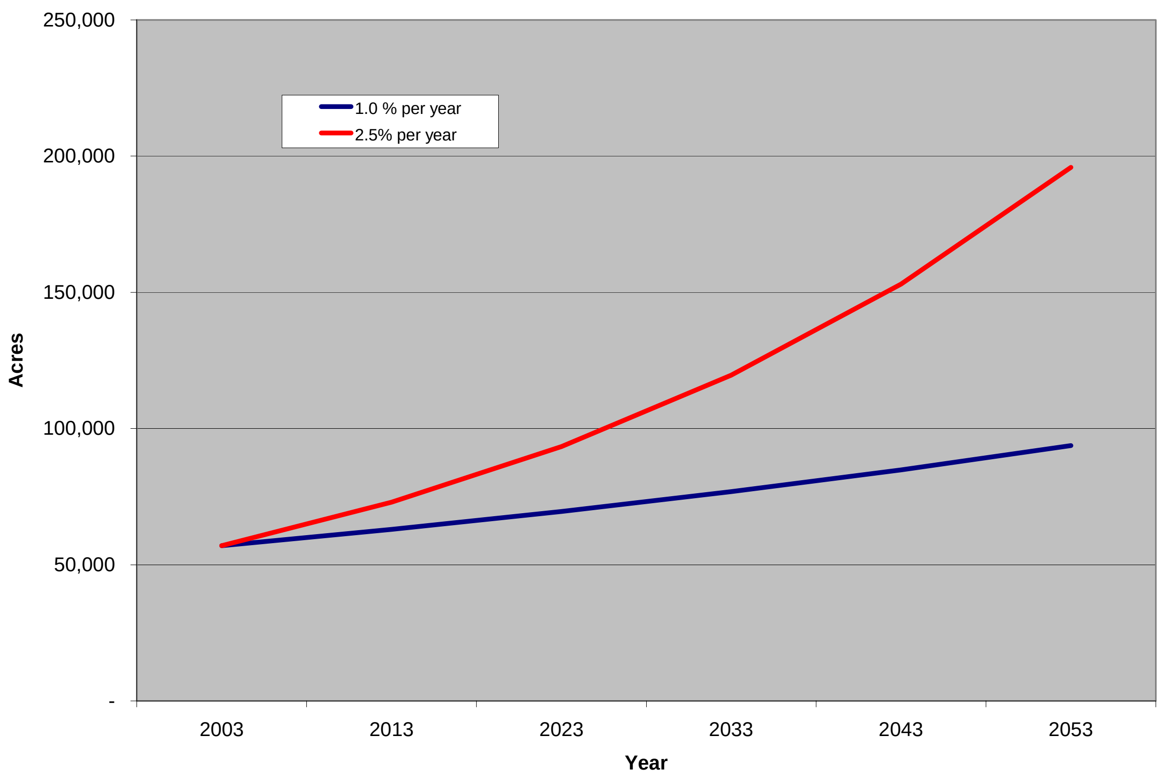


Figure 2: Tamarisk along the Colorado River, Grand Junction, CO

Figure 3: Wetland infested with Russian olive and tamarisk, Grand Junction, CO

Figure 4: Tamarisk thicket by an old gravel pit, Mesa County, CO

Figure 5: Tamarisk out competing native vegetation, Colorado River at Colorado/Utah border

Figure 6: Tamarisk thicket along the Arkansas River, Pueblo, CO

Figure 7: Tamarisk on the Huerfano River at the confluence with the Arkansas River, Boone, CO

Figure 8: Tamarisk and Russian olive on the Arkansas River at Las Animas, CO

2.4 Management

Management consists of four components – control, revegetation, monitoring, and maintenance. Without all four components it is unlikely that tamarisk control projects will be successful over the long term.

Tamarisk can be managed using successional weed management techniques, including chemical, mechanical, and biological techniques. Due to its ability to re-grow from root crown buds, mechanical removal of above ground biomass must be followed by root raking or herbicide stump treatment. Similarly, tamarisk will re-grow from the roots if burned. All of the following tamarisk control techniques are appropriate, but each must be selected based on local conditions; i.e., *Integrated Pest Management*. Integrated Pest Management or IPM is also known as the "toolbox" from which land managers pick their tools for a job. It includes prevention, cultural management (land stewardship), mechanical or physical removal, biological control, herbicide treatments, and revegetation techniques. A comparison of each control technology is presented below.

Aerial Herbicide Spray

Effectiveness: Recent helicopter spray operations in Texas and New Mexico with foliate herbicides have shown an effective kill rate for tamarisk of 90 percent or better in most cases.

These areas along the Pecos River are large expanses consisting of only tamarisk. Rate of application is several hundred acres per day (Hart 2003, Lee 2003).

Costs: $200 to $250 per acre for contracted aerial spray application. Because of the high cost associated with helicopter use and mobilization, the minimum acreage to realize these cost rates is at least 1,000 acres; thus, a minimum expenditure of $200,000 to $250,000.

Impacts: Impacts are: 1) While aerial herbicide spray is extremely effective in killing tamarisk, it also kills most other vegetation. In Colorado, most areas which are being overtaken by tamarisk still have a mix of valuable vegetation such as cottonwood, willow, grasses, and forbs that are too intermixed for spot aerial spraying. 2) Some areas in western Colorado and eastern Colorado are monocultures of tamarisk and possibly could be of sufficient size, when combined with other nearby sites, for economic aerial application. 3) Aerial spray costs do not include the removal of skeleton trees or revegetation which could be significant depending on the situation. and 4) Some spot herbicide re-application will be necessary.

Applicability to Colorado: Some areas in remote canyons in western Colorado could benefit from aerial spray technology; most of these lands are owned by BLM. Also, some areas within the lower Arkansas River watershed may be appropriate for this method.

Figure 9: Aerial herbicide application technique being demonstrated at the 2003 Tamarisk Symposium on tamarisk thicket at the Walter Walker State Wildlife Refuge.

Mechanized Mulching Equipment

Effectiveness: Recent work in the Moab, Utah area has shown that tamarisk can be effectively controlled by using newly developed, specialized, off-the-shelf, mechanized equipment followed by herbicide application to the cut stumps. The trees are mulched in a six-foot wide path through tamarisk thickets at a rate of .33 to 1.0 acres per hour depending on density and terrain with a kill rate for tamarisk at about 85 percent.

Costs: Labor, equipment depreciation, maintenance & operating costs, and herbicide costs will range from approximately $300 to $450 for high capacity equipment (0.75 to 1.0 acres/hr.), and $330 to $550 for medium capacity equipment (0.33 to 0.5 acres/hr.) for very dense tamarisk growth (CWCB 2003). Minimum expenditure to achieve these rates is approximately $10,000, which should clear approximately 20 to 50 acres depending on density, terrain, and type of equipment used.

Figure 10: Medium-sized mechanized mulching equipment

Impacts: Impacts are: 1) Very effective at removing tamarisk in a mixed vegetation stand without killing other valuable plants. 2) Requires a terrain that is relatively level and accessible. 3) The mulched materials provide a suitable seedbed for revegetation. and 4) Some spot herbicide re-application will be necessary.

Applicability to Colorado: In many areas, riparian lands and adjacent uplands in Colorado could be best controlled with mechanized mulching equipment. An approach that shares this specialized equipment with many different communities and agencies is being used by the Tamarisk Coalition as an efficient use of minimal financial resources.

Other Mechanized Equipment

Effectiveness: Other mechanical equipment, such as D-7 or D-8 dozers with brush bars to remove the above ground vegetation and root plows for below ground vegetation, has been successfully used at the Bosque del Apache National Wildlife Refuge in New Mexico (Taylor 2003). Some follow-up mechanical clearing is generally necessary. This approach does not use herbicide.

Costs: Approximately $800 per acre.

Impacts: Impacts are: 1) Not very effective at removing tamarisk in a mixed vegetation stand without killing other valuable plants. 2) Requires a terrain that is relatively level and accessible. and 3) The soil surface is severely disturbed and requires active revegetation.

Applicability to Colorado: It is unclear if there are lands in Colorado that could best be controlled with this type of large equipment.

Figure 11: Large equipment incorporating a deep root plow used to totally remove tamarisk vegetation below the root crown, Bosque del Apache National Wildlife Refuge, New Mexico.

Hand Cutting

Effectiveness: Hand work using chainsaws for the cut-stump approach is a successful method of controlling tamarisk.

Costs: Hand work is extremely expensive with an average cost of several thousand dollars per acre and can be as high as $5,000 per acre (Tamarisk Coalition 2003).

Impacts: Impacts are: 1) Very effective at removing tamarisk in a mixed vegetation stand without killing other valuable plants. 2) Is most appropriate for rough terrain that is not accessible by mechanical equipment. 3) The cut materials must either be stacked and burned, chipped, or left in piles for wildlife habitat. and 4) Some spot herbicide re-application will be necessary.

Applicability to Colorado: In western Colorado, hand clearing of tamarisk has been used in canyons, washes, irrigation ditches, and along steep river banks. These same type areas throughout Colorado would be appropriate for hand work.

Biological Control

Biological control is the use of specific organisms to control an undesirable organism. For tamarisk, two bio-control agents have been identified – goats and a Chinese leaf beetle. Goats will feed on tamarisk shrubs if fencing is provided to limit other food sources (see Figure 12). Typically, a guard dog, herding dog, and goat herder are required. Several private goat herds are available but no good cost or success information has been developed at this point.

Figure 12: Goats eating tamarisk leaves and small branches.

Investigations into biological control of tamarisk using insects began in the 1980s by the U.S. Department of Agriculture (USDA) under the direction of Dr. C. Jack DeLoach (USDA-ARS, Temple TX). *Diorhabda elongata deserticola*, a beetle from Fukang, in Xianjiang Province of NW China, had been tested extensively in quarantine to ensure safety with respect to non-target impacts. In 1995, permits for release of this beetle were about to be granted when the USFWS listed the southwestern subspecies of the willow flycatcher (*Empidonax traillii extimus*) as a federal endangered species. This bird was found to nest in tamarisk in a few areas outside of

Colorado. Permission for widespread bio-control insect releases was withheld pending further investigations of potential effects on the flycatcher. A number of research sites isolated from the southwestern willow flycatcher nesting areas were allowed and research began at these sites in 1996. These sites included one in Pueblo (see Figure 13), Colorado with research conducted by the BOR.

Figure 13: Bio-control beetles defoliated tamarisk trees at Pueblo during the summer of 2003. They did not damage any other plants, including the green cottonwoods in the background.

Research has been conducted at Pueblo and the other sites to determine the insect's life cycle, reproductive rate and dispersal; its impacts on tamarisk and surrounding vegetation; and impacts on wildlife (DeLoach et al.2003, Eberts et al. 2001, Lewis et al, 2003). One of the most important findings was that this ecotype of beetle cannot survive south of Colorado's southern border (approximately 36° N latitude). Summer day lengths south of this latitude are too short to prevent the adult insects from entering winter hibernation too early to survive until the following spring. New ecotypes of *Diorhabda elongata* from other overseas locations will be tested for southern areas of the United States.

Both the adults and the larvae of the tamarisk beetle feed on the foliage, damaging it directly or indirectly causing foliage beyond the feeding point to dry out. In 2003, the beetle caused extensive defoliation of hundreds of acres of tamarisk at the Colorado, Nevada, and Wyoming research sites. Research is still progressing to determine if the insects will cause mortality to significant numbers of tamarisk trees, as defoliated trees have resprouted each year since the insects were released into the field in 2001. Studies by USDA and BOR will continue at the research sites to determine the effectiveness of this insect. Combination of the beetle with other Integrated Pest Management methods will likely be necessary for best control of tamarisk. Based on preliminary estimates, this control technique could reduce the costs to a small fraction (less than $10/acre) of any herbicide and/or mechanical approach.

Laboratory and field studies indicate that the tamarisk bio-control beetle D*iorhabda elongata deserticola* will survive and perform best on tamarisk genotypes similar to those found in China where the insect originated (Gaskin 2002). The range of *T. chinensis* corresponds with the area where *D.e. deserticola* was collected. Studies are planned by the USDA to test several *Diorhabda* ecotypes across the range of tamarisk genotypes distributed in the U.S.

On December 18, 2003, the USDA Animal and Plant Health Inspection Service (APHIS) published its Environmental Assessment (see Federal Register Doc. 03-31311 or http://www.aphis.usda.gov/ppd/es/ppqdocs.html) outlining APHIS' intention to implement the release of the Chinese leaf beetle in 2004 in 14 western states including Colorado (Richard 2003). Note: no bio-control approach using insects for Russian olive is currently being researched.

Revegetation

Vegetative restoration after tamarisk removal is essential to **prevent reinfestation**, and is possible, especially if over-bank flooding is allowed (Taylor et al. 1999, Sher et al. 2002). Vegetative restoration of previously tamarisk-dominated sites, however, can present numerous technical challenges that must counter negative ecosystem-level effects attributed to salt cedar: altered fluvial geomorphology, nutrient recycling, and native species regeneration rates (D'Antonio and Vitousek, 1992). For example, in mature tamarisk stands, the presence of dense standing material remaining after control, limits seeding techniques and seed interception aerial techniques. Undisturbed soil surfaces restrict soil-seed contact and limit salinity reduction in surface soil layers (Ken Lair, personal communication).

Natural regeneration of native *Populus* and *Salix* spp. on drier saline sites in the absence of seasonal flooding or irrigation also is a limiting factor in vegetative recovery of sites after salt cedar removal (Horton et al, 2001; Sher, Marshall and Taylor, 2002). Research on species combinations, land treatment, and the use of mycorrhizae inoculants to facilitate revegetation, is currently underway (Ken Lair and Anna Sher, personal communication). In some cases, successful restoration of riparian habitat will require remediation of conditions that may have led to tamarisk infestation in the first place; i.e., ecosystem changes through land and water alterations.

In many ways Colorado is fortunate that the majority of infested areas within the state have an intermixture of native plants. This is true except in some areas in the Colorado River and Arkansas River watersheds and possibly in the San Juan watershed near Cortez. A rough estimate of lands that would require active revegetation is approximately 20 to 30 percent. These areas will require extensive revegetation actions.

2.5 Colorado Projects

Within Colorado there are several projects underway to control tamarisk. The following provides a representation of some of these projects and their current status.

Animas River Project – A non-profit river advocacy organization, Friends of the Animas River (FOAR), has teamed with Rhea Environmental Consulting to eliminate Russian olive and other exotics (tamarisk and Siberian elm) along the Animas River, as well as ornamental plantings that occur on private lands in proximity to the river. So far they have developed a GIS database,

begun an education program, and controlled 1.5 miles of the river, eradicating an estimated 3,500 Russian olive and tamarisk on municipal and private lands. They have also established a partnership with the City of Durango, which has now implemented its own exotic control program through the city's Parks and Forestry Department. Control work will continue along the Animas over the coming years depending on the financial resources that can be attained.
Contact: Barry Rhea, Rhea Environmental Consulting, (970) 247-2388, rhea@frontier.net

Bents Old Fort National Historic Site, Arkansas River – Nearly 350 acres of tamarisk along 2.5 miles of riparian zone have been eliminated from Bents Old Fort near La Junta since 1994. The work has been accomplished using the cut stump method by a combination of teams including the National Park Service's Exotic Plant Management Team, a private contractor, and Colorado State Correctional Facilities Community Work Crews. The relationship between the NPS and the Colorado State Correctional Facilities is well established and is mutually beneficial. The NPS has greatly reduced the tamarisk infestation and the inmates have received training as sawyers, in repair and maintenance of small engines, and in the application of herbicides. The cost of tamarisk control effort has been reduced by more than half using inmate crews. As of December 2003 there is only 0.75 acres of tamarisk remaining at the site. The Bents Old Fort effort rarely paid for labor, but for the chemicals, chain saws, sprayers and various supplies and materials, their average cost was about $1,500 per acre.
Contact: Karl Zimmerman, National Park Service, (719) 383-5010, karl_zimmermann@nps.gov

Colorado National Monument – The National Park Service has successfully cleared 100 acres of tamarisk and Russian olive intermingled throughout 100 miles of drainages in the Monument. The cut stump method was used by either a professional crew from Lake Mead or monument staff. In the areas of the Monument being treated as wilderness, foot travel was used for access and chain saws were exchanged for hand saws, pruning shears, and pulaskis. All areas were retreated within twelve months, when it was found that 10 to 15% of the invasive trees had been missed. Ongoing maintenance calls for each canyon to be checked on a three year rotation. The monument also has a unique Adopt a Canyon program where volunteers perform various stewardship tasks and wildlife monitoring including identification of new infestations.
Contact: Dave Price, National Park Service, (970) 858-3617, dave_price@nps.gov

San Miguel River – The Nature Conservancy is the lead organization for an ambitious non-native tree removal project called Saving the Natives, with the goal of eradicating tamarisk from the entire San Miguel River watershed by the end of 2006. The initial survey showed 100 miles of river and tributary with some level of tamarisk infestation. To date, approximately 30 miles of riparian areas on both public and private lands have been cleared of tamarisk, Russian olive, or Siberian elm at an average cost of $6,800 per mile. A four tiered monitoring plan is in place to evaluate the effectiveness of control efforts, changes in plant community composition over time, avian response to treatment, and invertebrate response to treatment. This effort is made possible by support from numerous federal, state, county, and private partners, and will hopefully yield sustainable results of a million acre, tamarisk free watershed well into the future.
Contact: Mallory Dimmitt, The Nature Conservancy, (970) 728 5291, mdimmitt@tnc.org

Yampa River – The newly formed Routt Invasive Plant Posse (RIPP) is a unique partnership between the Colorado Division of Wildlife, Colorado State Parks, Routt County Cooperative Extension Master Gardners, Routt County Weed Control, The Nature Conservancy, the City of Steamboat Springs, volunteers, and private landowners within the county. The goal of this group

is to involve land managers and the local community in achieving early detection and eradication of high priority invasive plants before they can become established in the Upper Yampa River Watershed. To date, RIPP has developed a survey and mapping protocol, surveyed nearly 20 miles of the river and its tributaries, and produced one coordinated map of areas surveyed and the infestations found, by species. Of the small infestations found, all have been treated. This may be very effective model of collaboration to keep relatively pristine riparian areas free of invasion by tamarisk, Russian olive, purple loosestrife, or other non-native species.
Contact: Matt Custer, Routt County Weed Supervisor, (970) 870-5246, weeds@co.routt.co.us

Dinosaur National Monument – Downstream on the Yampa River watershed, the Dinosaur National Monument has taken an aggressive approach to tamarisk control. They do not use herbicides for treating tamarisk but rather use a unique tripod and winch system to manually remove the plant below the root crown. This has proven effective but is obviously labor intensive. Tamara Naumann, National Park Service, (970) 374-2501, tamara_naumann@nps.gov

Education – Governor Owens used Colorado Cares Day on August 2, 2003 to focus attention on the importance of tamarisk control. The Governor initiated this event to promote volunteerism and community service and over 250 people participated in removing tamarisk at three state parks. As a result of this community effort, four newspaper articles and three television news stores were generated and several students at Cherry Creek and Fruita Monument High Schools are now doing independent studies on tamarisk. In October 2003 the Tamarisk Coalition and CSU Cooperative Extension Tri Rivers office sponsored the three-day 2003 Tamarisk Symposium in Grand Junction. The symposium brought together nearly 300 people from throughout the West that included key researchers, on-the-ground program managers, environmental interests, and federal/state/local agencies to understand better the nature of the tamarisk problem and to develop long-term solutions. A field demonstration of control techniques included backcountry application, goats as bio-control agents, hand chainsaw techniques using youth conservation corps, mechanical mulching systems, and aerial herbicide application using a helicopter.

The Tamarisk Coalition has also provided information and given presentations to numerous groups throughout Colorado on the nature of the tamarisk problem and solutions being sought. Additional information on the Tamarisk Symposium can be found at the following address: www.coopext.colostate.edu/TRA/saltcedar2003.html

2.6 Current Federal Activities

Legislative Activity

Over the past year, five separate bills have been introduced in Congress to tackle the tamarisk problem. The most recent bills, S.1516 and H.R. 2707, have consolidated previous language from several other bills and are the two bills that are now moving through both House and Senate committees. These bills, as they currently exist, are included in Appendix C and summarized in Table 1. In late July, the Tamarisk Coalition provided testimony on H.R. 2707 before the House Subcommittee on Forests and Forest Health and in September testimony was provided on S. 1516 before the Senate Subcommittee on Water and Power. Dr. John Redifer with Mesa State College provided testimony at the House hearing and John Marshall with DNR provided testimony at the Senate hearing. H.R. 2707 went through markup by the full Committee on Natural Resources in October and was passed by unanimous vote on October 29, 2003.

In summary, the bills provide $25 to $50 million per year for on-the-ground demonstrations of tamarisk and Russian olive control and revegetation with monitoring and research to identify changes to the environment. Demonstrations could occur in any of the western states and most of the plains states having the problem. Funding would be 75% Federal with the local share being made up of funds and in-kind contributions, including State agency provided services. Under the House bill, $5,000,000 would be authorized in fiscal year 2004 for assessment of the existing conditions and techniques for control and restoration with an additional $1,000,000 authorized to develop long-term management and funding strategies.

An important aspect of these two bills is that they are very similar in most areas which will allow them to be reconciled relatively easily after they are passed. What is very significant about the bills is that they have strong bi-partisan support. Colorado's congressional delegation has been at the forefront on both of these bills with cosponsorship by Senator Campbell and Congressmen McInnis, Udall, and Beauprez. Senator Allard has also been an active supporter of the legislation. Because of the importance Congress has placed on these bills, there are strong indications that they will move towards passage in the spring of 2004.

Table 1: Comparison of Senate and House Bills on Tamarisk Control

Bill Number & Name	S. 1516 – Salt Cedar Control Demonstration Act	H.R. 2707 – Salt Cedar and Russian Olive Control Demonstration Act
Introduction date	July 31, 2003	July 10, 2003 and Approved by Resources
Sponsor	Domenici (NM)	Pearce (NM)
Cosponors	Campbell (CO)	Beauprez (CO), Bonilla (TX), Cannon (UT), Cardoza (CA), Filner (CA), Grijalva (AZ), Hunter (CA), Matheson (UT), McInnis (CO), Moran (KS), Neugebauer (TX), Osborne (NE), Renzi (AZ), Stenholm (TX), Thornberry (TX), Udall (CO), Udall (NM), Wilson (NM)
Lead Agency	Interior, Acting through the Bureau of Reclamation	Interior, and Agriculture acting through the U.S. Forest Service
Listed Species	Salt cedar and Russian olive	
Area	Western states	AZ, CA, CO, ID, KS, MT, NE, NV, NM, OK, OR, TX, UT, WA, WY
Assessment component	Within Year 1 assess: 1) extent of both Salt cedar and Russian olive, 2) control options, 3) potential for reducing water consumption, 4) methods and challenges in land restoration, 5) costs of control and restoration, and 6) identify long-term management and funding strategies.	
Demonstration numbers & costs	Minimum of 5 not to exceed $7,000,000 per project. Costs to include planning, design, implementation, maintenance, and monitoring.	Minimum of 3 not to exceed $7,000,000 per project. Costs to include planning, design, implementation, maintenance, and monitoring. One of which must be on National Forest land. $5,000,000 to assess problem and $1,000,000 to develop long-term management and funding plans
Demonstration components	1) At a minimum, control technologies must have one project each to demonstrate airborne application of herbicide, mechanical removal, and bio-control methods such as goats or insects. 2) Monitor and document any water savings. 3) Assess optimum application approach and tools for implementing control methods. 4) Assess all costs and benefits associated with control, restoration, and maintenance. 5) Determine under what conditions removal of biomass is appropriate and the optimal methods for disposal or use. 6) Define appropriate final vegetative states and optimal revegetation methods. 7) Identify methods for preventing regrowth and reintroduction of invasive species.	
Cost Share	75% Federal, 25% local match	75% Federal, 25% local match
Local Match	Local match may be provided in the form of in-kind contributions, including services provided by State agencies.	
Cooperation	Interior shall use the expertise of Federal agencies, national laboratories [Senate bill only], Indian tribes, institutes of higher education, State agencies, and soil and water conservation districts that are actively involved in research and/or control activities.	
Funding	$50,000,000 for fiscal year 2004 and such sums as are necessary for each fiscal year thereafter.	$25,000,000 each year for fiscal year 2005 through year 2010.

Department of Interior Activity

For fiscal year 2004 the U.S. Department of Interior has identified approximately $2,000,000 of new funding for tamarisk activities in the Southwest. To determine how to best use these funds and meet the needs of the states, Interior will be holding a workshop on March 31 to April 2, 2004 in Albuquerque. The purpose of the meeting is to achieve effective tamarisk control in the Southwest through partnerships that makes the most efficient and effective use of collective resources. To accomplish this, approximately 150-250 federal, state, tribal and local governments, non-profits, industry, private sector, and academia will help develop a framework for tamarisk control, revegetation, and habitat recovery in the southwest United States (CA, AZ, NM, TX, OK, CO, UT, and NV).

The product of this workshop will be a document that identifies the problems associated with tamarisk and native habitat management, highlights critical research gaps, provides a comprehensive overview of the effectiveness of available best practices and prioritization of projects throughout the Southwest, and maps the best current understanding of the regional distribution of tamarisk. A second objective is to establish a framework for forging close, working partnerships that would lead to future on-the-ground projects.

The workshop is tentatively planned to be hosted jointly by National Invasive Species Council (in the persons of Interior Secretary Norton and USDA Secretary Veneman) and the Governors of New Mexico and Colorado (gubernatorial involvement is currently being confirmed). Planning for the workshop is being done by Secretary Norton's office with involvement by the Tamarisk Coalition.

2.7 Summary/Conclusion

Current research indicates that invasion by tamarisk, *Tamarix spp*., can have dramatic effects on riparian ecology, including species diversity and water relations. Although stands of tamarisk mixed with native vegetation may still function well for ecosystem services (including commercial uses), even mild infestations can become serious problems if native vegetation is not concurrently promoted. Chemical and mechanical means of control can be effective but also very expensive, and are likely to fail unless followed by revegetation and continued monitoring and follow-up maintenance. Biological control may prove to be a cost effective tool to combine with other means, however its development is still in its infancy and requires more research. In conclusion, current information suggests that while complete eradication is very difficult, tamarisk infestation within the state's boundaries can be reduced to the point where it will be a manageable problem within existing federal, state, and local government budgets. Restoration of tamarisk infested land to ecologically functioning and valuable plant communities is both possible and highly desirable.

3.0 Principals that Underpin the 10-Year Plan

The development of the 10-Year strategic plan for tamarisk control in Colorado is founded on a set of principals that provides the plan with a solid foundation. These principals are presented below in no particular order of importance.

A. The objective of tamarisk control is the reestablishment of native vegetation that can be sustainable.

B. Control activities should occur at the watershed scale and have local control.

C. The tamarisk problem in Colorado is significant but success is achievable.

D. Other non-native invasive plants, notably Russian olive, co-habit with tamarisk and must be part of each watershed plan.

E. Success requires long-term control, revegetation, monitoring, and maintenance.

F. Success requires long-term funding.

G. The rivers of Colorado are highly impacted by man to improve their capability to store and supply water (e.g., dams, irrigation systems) for beneficial use. Existing infrastructure is important for the continuation of these uses and tamarisk control and restoration should respect these conditions.

H. While private property owners are some of the strongest supporters of tamarisk control, it is important to acknowledge that private property rights must be respected.

I. The control of tamarisk should improve both groundwater and surface water supplies in the future. This is not the creation of new water but rather the prevention of a non-beneficial use of water and, therefore, no new water rights should be implied. Respect for existing State water law and water rights are important to maintain.

J. Protection of endangered species has been viewed in the past as a potential obstacle to tamarisk control. This is not now the case. The *Final Southwestern Willow Flycatcher Recovery Plan* (U.S. Fish and Wildlife Service 2002) does provide management approaches that will allow staged removal of tamarisk and restoration to occur in areas of Colorado that have flycatcher habitat (Cortez and San Luis Valley areas). The Upper Colorado River Endangered Fish Recovery Program also recognizes the impacts tamarisk has had on river structure and its subsequent impact on fish breeding opportunities. The Endangered Fish Recovery Program is encouraged by state efforts to develop compatible tamarisk control and revegetation strategies because these efforts can enhance fish recovery. Reestablishment of native habitat could provide the avoidance of future threatened or endangered species.

K. Habitat enhancement and water resource protection have equal value.

L. Funding should be balanced between large-scale needs (e.g., Colorado River and Arkansas River watersheds) and prevention and early detection/control (e.g., Yampa River and South Platte River watersheds).

M. The state should take the lead in coordinating efforts for the acquisition of federal funds.

N. The state should work with federal land managers as well as Indian tribal units to involve them in watershed projects.

O. Education is essential to help establish with the public the importance of the tamarisk problem, methods for solving the problem, and the need for appropriate levels of funding.

P. Integrated Pest Management should be followed, be based on sound science, and be cost effective.

Q. Research should be coordinated between state and federal agencies, universities, colleges, and non-profit organizations working on the tamarisk issue to better understand the consequences of tamarisk control on water availability, water quality, habitat, and biodiversity; and to improve efficiency of control and revegetation.

R. A comprehensive inventory of tamarisk infestation is a priority to better understand the extent of the problem and to prepare reasonable solutions.

S. If no action is taken, the “Null” alternative, tamarisk will continue to spread and environmental damage to Colorado’s river systems and loss of water will increase.

4.0 10-Year Strategic Plan

The *Colorado 10-Year Strategic Plan for Tamarisk Control* is based on the current understanding of the problem presented in Section 2.0 and the Principals that form the foundation for the plan presented in Section 3.0. The 10-Year Plan provides specific actions and a pathway forward. It is intentionally heuristic in nature; i.e., as new information becomes available, the plan should change to reflect better approaches.

4.1 Organizational Structure – Three Components

Watershed: Projects are best coordinated and developed at the local level. Local control provides assurance that local needs are being met and has the highest potential to involve most of the landowners. Partnerships with federal/state/local government agencies, local water conservancy districts, organizations, and landowners are already developed in many of the state's watersheds. These watershed partnerships can form coordinated approaches (tactical plans) for long-term management to tamarisk control and the reestablishment of native vegetation. Examples of existing partnerships include the Animas, San Miguel, Yampa, Roaring Fork, Upper Arkansas, and North Fork Gunnison watersheds. The San Miguel River restoration plan is a good example of a tactical plan that includes inventory, control, monitoring, and maintenance within its approach and meshes these with responsibilities, funding, and the use of volunteers.

State: At the state level, a small staff of 2-4 existing employees representing DNR and the CDA should be selected to provide assistance, guidance, education, funding coordination, and accountability resources to the watershed partnerships. As its first action, this small cadre of state employees referred to as the Tamarisk Support Team or TST, should help local watershed partnerships develop tactical plans for their areas. The Executive Director of DNR and the Commissioner of CDA will be responsible for coordinating who from their respective departments will serve on the TST. Due to the time commitment it will take to handle this responsibility well, it is recommended that individual job descriptions be revised to reflect this change in work requirements.

Advisory: The advisory panel that helped formulate this 10-Year Plan should continue to provide technical assistance to the state and watershed partnerships. The advisory panel has no direct responsibility or control of projects but can provide the expertise to assist the state and watershed partnerships in developing reasonable approaches to each specific area's problem. This expert panel, under the name of Tamarisk Removal & Restoration Advisory Committee or TRRAC, can also be valuable in determining the most appropriate research to undertake.

4.2 Inventory of the Tamarisk Problem

To gain support to solve any serious problem requires that a quality assessment of the problem be performed so that good solutions can be developed. That is, for tamarisk, an inventory of the infestations is the crucial element in the development of a control plan at watershed and state-wide scales. In Colorado, the area of tamarisk and Russian olive infestation is estimated to be approximately 55,000 acres of land, but this is only a rough estimate

(CWCB 2003). A more accurate inventory of tamarisk and Russian olive infestation is therefore needed at the watershed scale. The inventory becomes the basis for project planning (e.g., cost estimates, resource allocation, and priority setting) and tracking the long-term success of control efforts. For Colorado, quality inventories will also place the state in a favorable position to acquire federal funding for major demonstrations that are likely to be available in 2005-2010 under pending legislation.

With a good inventory, tactical plans can be established for each major watershed by tributary basin to determine the most appropriate control and revegetation technique to use and the timing of their use. This in turn will identify the costs. The all important aspect of the tactical plans is to identify what will be the overall costs and benefits of control and restoration. Until these are known, the public and legislators will not be likely to support long-term funding over a decade and costing 10s of millions of dollars.

What Inventory activity is occurring? At its November 2003 meeting, the Colorado Water Conservation Board (CWCB) authorized a matching grant of $52,500 to the Tamarisk Coalition and Mesa State College to perform a more detailed inventory of the Colorado River and Arkansas River watersheds. The purpose of this study is to establish and implement an inventory protocol that provides a clear understanding of the extent of the problem but is also economical to perform. The Colorado River and Arkansas River watersheds are identified because they are heavily infested and represent two distinct topographic conditions – a western slope canyon setting that is predominantly federal lands and a front range prairie setting that is predominantly private agricultural lands. The protocols developed under this study can then be used to generate accurate inventories for the other major watersheds in the state; i.e., San Juan, Rio Grande, South Platte, North Platte, and Republican rivers.

For developing future cost estimates for control, revegetation, and maintenance, the extent of infestation should be within about +/- 20 percent accuracy which will be sufficient to describe the problem and identify the impacts. The results of this work will be completed for CWCB's use in the fall of 2004.

Deliverables will include maps of the Colorado River and Arkansas River watersheds identifying location of tamarisk and Russian olive infestations. These maps will be accompanied by a report that outlines the inventory protocols; tables that record GPS coordinates, infestation density/maturity, vegetative types, and terrain; and a photo record of sites surveyed.

What should be future activities? Using the protocols established in the CWCB inventories of the Colorado River and Arkansas River watersheds, the state should perform similar inventories for the San Juan, Rio Grande, South Platte, North Platte, and Republican rivers. These inventories will be used as the basis for developing tactical plans for tamarisk control and revegetation for each of these major watersheds.

4.3 Education

Educational efforts should be directed primarily to support two efforts:

1. Engage stakeholders, partner organizations, and affected landowners to facilitate understanding of the problem and secure support for the development and implementation of a watershed-specific or statewide efforts to manage tamarisk and restore riparian health.

2. Provide technical support to affected landowners and participating public agencies in a timely manner to help ensure cost-effective and successful management and restoration efforts.

Colorado's tamarisk problem will only be resolved by a well-focused and coordinated effort that stimulates and sustains the active participation of stakeholders (e.g., public land management agencies, local governments, water districts, environmental organizations) and affected landowners, primarily comprised of private landowners. Recent, successful efforts to develop a state strategic plan to stop the spread of noxious weeds and to revise the Colorado Noxious Weed Act (C.R.S. 35-5.5) have demonstrated that a diverse array of public and private interests can be engaged to develop and implement a common vision for invasive plant management.

Colorado has already established a framework for efforts to stop the spread of noxious weeds and restore lands of significant agricultural and/or environmental value, a framework endorsed by the Governor and 43 public and private organizations. It provides a logical starting point for crafting a plan to manage tamarisk and restore riparian health that can be presented to stakeholders for comment, elaboration, and modification. However, additional stakeholders should be sought out and solicited for input in order to develop a more broadly accepted plan to achieve the vision outlined in this 10-Year Plan.

It should be clear that any plan to address Colorado's tamarisk and riparian community problem must identify the expectations that local and state government agencies will have with regard to the participation of private landowners. It is known that tamarisk has established on both private lands and, to a lesser extent, on public lands. Consequently, given the current extent of the infestation, even a well-integrated effort made by local, state, and federal agencies will be insufficient to reach the goals outlined by Governor Owens without significant and meaningful participation of affected private landowners. A successful effort to manage tamarisk in Colorado must integrate the efforts and resources of affected private landowners with the leadership and efforts put forth by public sector programs.

The educational component of the 10-Year Plan should build upon and expand the existing efforts that have taken place in Colorado. These include:

A. Expanding the idea of the Governor's Colorado Cares Day, CSU Cooperative Extension offices can provide a landowner and volunteer training day at state parks on proper techniques for tamarisk control. Highline Lake State Park had just this type of training in October 2003 and plans on repeating this in subsequent years. CSU Cooperative

Extension Tri-Rivers office has already put together some educational materials for this purpose.

B. One item that is missing in the toolbox for tamarisk control is a "Handbook" to guide private landowners down the path of tamarisk management. Information is available on treatment choices, but little is available to assist the landowner in decision making. A grant request has been submitted to the National Fish and Wildlife Foundation for CSU Cooperative Extension to develop a *Handbook for Tamarisk Control and Revegetation* that will include a "decision tree" for evaluating their tamarisk infestation as well as the current information on choice of treatment and the reestablishment of native vegetation.

C. To gain public support and understanding of the use of bio-control agents for tamarisk control requires the development of educational materials. A matching grant has been received by the Tamarisk Coalition and the CSU Cooperative Extension from the BOR to develop two publications. The first will provide general information on the bio-control approach, the stringent research requirements associated with acceptance by APHIS, and the economic and environmental advantages. The second publication will describe the protocols of release and monitoring that land managers will use in the bio-control releases. Similar types of information have been developed for the very successful bio-control program on the noxious weed, leafy spurge. The expertise of APHIS, USDA, and BOR scientists will be used to develop these materials.

D. The Tamarisk Coalition and CSU Cooperative Extension sponsor the biannual Tamarisk Symposium in Grand Junction. This is the premier conference on tamarisk and will continue into the future.

E. To provide information to the public on the tamarisk problem and what the state is doing, a traveling display would be valuable for state agencies and watershed partnerships to use throughout the state. The TRRAC could be used to develop this information.

4.4 Research

Colorado has outstanding research capabilities through the state's public and private universities and colleges, federal agencies, state agencies, and non-profit organizations. A successful model for research collaboration is the Salt Cedar Bio-control Consortium that brought together researchers to focus their efforts to achieve a common objective. The TRRAC could be used to structure such a consortium for Colorado. The value of well structured research is that it can aid in the reduction of costs and the increase of success over simply relying on today's information. The following are specific areas where research efforts can improve efficiency and gain public support. Many of these activities are now underway or could be supported by the pending federal legislation.

A. The actual non-beneficial use of water by tamarisk in Colorado's different ecological settings needs to be quantified. Existing research should be used and augmented with on-the-ground measurements of changes to both stream flow and groundwater before and after tamarisk control activities. This research will help to establish the difference in water consumption in Colorado (most research has been done in New Mexico, Texas, and Arizona climates) between non-native phreatophytes and typical riparian, floodplain, and adjacent upland plant communities on an acre-foot/year per acre basis as a function of thicket maturity, floodplain morphology, climatic conditions, geology, and geographic location. These differences will help establish the non-beneficial use of water by these non-native plants in comparison to a healthy riparian ecosystem. The understanding of this non-beneficial use value is essential to the gaining of a consensus on the impact that tamarisk has imposed, and what benefits can be expected if control and revegetation take place on a broad scale. These activities will mesh well with the large-scale demonstrations proposed under pending federal legislation.

B. Existing approaches for controlling tamarisk and habitat restoration should be evaluated for their appropriateness and evaluated when field demonstrations take place. These demonstrations can serve three purposes: 1) to document the various hand and mechanical techniques as to time, cost, efficiency, rate of success, and safety issues; 2) to document changes to wildlife habitat and biodiversity; and 3) the demonstrations can serve as an educational tool that provides visible exposure of the tamarisk issue to the general public.

C. The one area that has been often left out of control projects is revegetation. Additional research work is needed in this area especially for land areas occupied by large monocultures of tamarisk. These areas have the least success rates for the reestablishment of native plants. The TRRAC could be instrumental in providing guidance to watershed partnerships faced with these types of settings.

D. As part of any work that will involve the use of the Chinese leaf beetle as a bio-control agent for tamarisk, the establishment of insect nurseries in critical locations is essential. The primary component of this project is the establishment of four additional outdoor insect rearing nurseries on public lands in the Colorado, Yampa, South Platte and the Dolores River watersheds. These nurseries can be established by collecting insects from the existing USDA's Pueblo, Colorado, and Lovelock, Nevada sites and releasing them under the protocols established by APHIS to help guarantee the utmost success. The CDA is the appropriate agency to garner the permits from APHIS. These nurseries will use outdoor settings where there are an abundance of tamarisk plants that occupy a land area that exceeds 100 acres. No permanent structures are part of the nurseries.

   Once the nurseries are established, bi-monthly monitoring of the sites during the summer months will record the insects' acclimation to their new locations. Within three years of nursery establishment, the insects are anticipated to have multiplied to an extent that they can be collected and redistributed to other sites within Colorado. It is estimated that within 5-10 years, the major infestations of tamarisk in these watersheds may be able to be controlled with this approach supported by the other control techniques at a lower cost than traditional methods alone. Additionally, the use of bio-control agents may act as a maintenance mechanism to control new infestations. The Tamarisk Coalition has secured partial funding from the BOR and has a grant request to the National Fish and Wildlife Foundation for additional funding to support the establishment of these nurseries by CDA's Palisade Insectory and CSU Cooperative Extension.

E. The CDA, Colorado State University, and University of Denver have submitted a grant proposal to the U.S. Environmental Protection Agency to support habitat characterizations of sites designated for a variety of tamarisk mitigation strategies including biological control, herbicides, physical removal, and reseeding with native species. Site assessments will include tamarisk density and size distribution, native overstory and understory species inventory, and abiotic site characteristics. These sites will be sampled following tamarisk removal and, in some areas, adaptive management strategies will be implemented and evaluated for their contribution to the overall success of the mitigation effort. The compilation of these observations will be used to develop Best Management Practices for land managers and landowners dealing with tamarisk and riparian restoration. The goal of this project is to provide information and tools that empower land managers and landowners to initiate tamarisk removal and restoration programs that are adapted to infestation densities, preserve and protect as much native flora as possible, and incorporate complementary strategies to reduce the need for highly disruptive and expensive tactics. This work will complement research and education activities noted in previous paragraphs.

F. No bio-control research is currently ongoing for Russian olive. It is recommended that the state encourage Congress to include specific language in the final tamarisk bill to energize this effort.

G. The most difficult problem with tamarisk control is not technical in nature but rather that success requires long-term management and funding. Congress recognizes this issue and has included specific language in proposed federal legislation for developing options for these funding sources. Mesa State College has provided the leadership in articulating the importance of resolving this issue.

H. In an effort to educate the public about invasive exotic plant species and to encourage the establishment of native, drought tolerant species, an exotic tree replacement incentive program could be implemented in Colorado. This program could be modeled after the successful Mesa County program to replace backyard fruit trees with trees that do not invite breading grounds for fruit tree pests. Under this plan new trees would be given away to private landowners with a signed agreement that the invasive exotics will be cut down within a five-year period. This will allow the landowner to keep their existing exotic shade tree (typically Russian olive) until the new tree has become established. As part of this effort, a native plant nursery could be established to provide plant stock for the replacement incentive program.

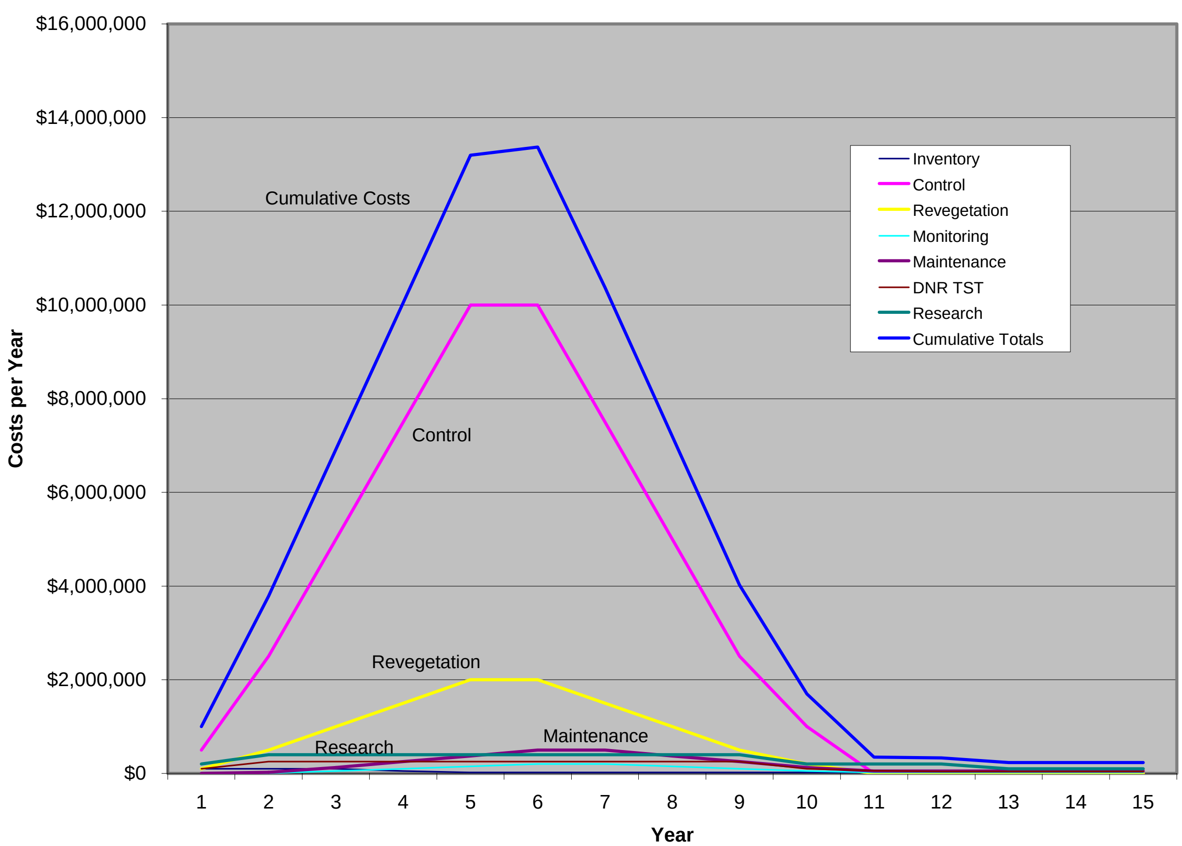
4.5 Funding

Current funding for tamarisk control can be best described as piece meal and inadequate. Existing agency budgets for federal, state, and local public land managers are woefully under funded in their efforts to combat all invasive species, much less tamarisk. The President's National Invasive Species Council has identified the need for additional financial resources as one of three related issues that must be addressed if we are going to be successful in solving this problem. Current efforts to control tamarisk in Colorado are dependent upon various annual competitive grant programs for the lion's share of their funding. Reliance upon this type of funding precludes any chance of developing an effective comprehensive long-term strategy for tamarisk control.

The cost of tamarisk control and the reestablishment of native vegetation require funding to support the inventory of the problem, research, tamarisk control, revegetation, monitoring, maintenance, and the Tamarisk Support Team. Figure 14 is provided to give a general understanding of the level of anticipated costs that Colorado might expect. The values are, at best, only a preliminary estimate based on existing knowledge of Colorado's tamarisk problem. The figure shows how costs might be distributed by task and over time. As better inventory information is developed and research on advancements on control and revegetation are refined, these costs will obviously change. Again, these costs are only a first attempt at defining the problem and are only presented to show relative differences in cost allocations over time.

As can be seen in Figure 14 the largest costs are tamarisk control and revegetation followed, to a much lesser extent, by maintenance, research, and monitoring. Also, after year 10, costs are reduced significantly with only periodic maintenance and monitoring occurring into the future.

Figure 14: Colorado Tamarisk Control -- Conceptual Cost Allocations



Securing additional funds to control tamarisk are further complicated by the state's current economic challenges and budge constraints. To adequately fund a comprehensive tamarisk control strategy from existing general operating funds would require transferring funds currently being allocated to existing agencies. After two years of budgeting in a declining economy this is not a realistic possibility. Consequently, any successful effort to control tamarisk in Colorado must come from new funding.

There are a couple of new sources of funding that could be tapped for tamarisk control. The first would be to rely on the federal government to fully fund tamarisk eradication efforts in the west. States could be allowed to provide matching in-kind contributions. Unfortunately, the federal budget picture is worse than the states so it is unlikely that federal monies in the amount necessary to address tamarisk control throughout the west will be forthcoming. Even if the federal government were to provide substantial funding, allowing states to match with in-kind contributions, it would still be difficult for the state to provide in-kind contributions since this would overburden existing state resources that are already stressed in their efforts to meet their current workloads. The Division of Wildlife and Division of State Parks and Outdoor Recreation could also pursue GOCO funds for tamarisk removal and restoration activities on identified lands where such activities would be consistent with GOCO's mission and purpose.

The second approach would involve asking the citizens of the state to appropriate new funding for tamarisk control. While this may seem politically unfeasible, there are several reasons that suggest citizens may support such an approach. The historical record of TABOR votes in the state indicate that citizens will approve new funding for projects that limit the spending of approved funds to achievement of a specific beneficial goal after which time the new tax disappears. Tamarisk control meets these requirements. A new tax would be limited to ten years. During that time monies raised would only be used for implementing the tamarisk control strategy reducing the problem to the point where after the new funding source goes away continued maintenance of the problem could easily be handled within existing agency budgets.

Opposition to a TABOR vote could be further reduced by attaching the tax to as many people as possible who would benefit from tamarisk removal. A very small tax increase on a large number of people who directly benefit from the project could dramatically decrease the likelihood of organized opposition. Since the greatest perceived benefit of tamarisk removal is an increase in the water supply, an example of one approach would be to attach a surcharge to each water user's monthly bill. This would be collected by the various water providers and turned over to the Department of Natural Resources for redistribution to each watershed's tamarisk removal partnership. Water providers would be paid a small fee to cover their costs in collecting the fee. The amount of the surcharge would be determined after the cost of the tamarisk control program was determined. Hopefully, this amount would be no more than a few cents per month.

The added benefit of this last approach is that it would demonstrate to the federal government that Colorado is serious about tamarisk control. Since the federal government owns 36% of the state, they should be responsible for paying 36% of the cost of tamarisk removal. If Colorado already has a committed funding source it could encourage the federal government to recognize and fund their fair share of the cost of tamarisk control.

4.6 Role of Non-Profits

A. Non-profits such as the Tamarisk Coalition and The Nature Conservancy can help on education and research issues as well as provide guidance to watershed partnerships.

B. Watershed organizations and water conservancy districts can take leadership roles in developing local partnerships to formulate and implement tactical plans.

C. Youth organizations such as the Western Colorado Conservation Corps have gained training in the art of tamarisk control and provide a valuable low cost approach for labor-intensive work.

D. State volunteer organizations, such as Volunteers for Outdoor Colorado, can provide training to watershed partnerships in the development of successful volunteer programs that can promote and enable citizens and visitors to be active stewards of public lands in Colorado.

4.7 Role of Local Communities

A. Counties, cities, towns, and Indian tribal units should participate with local watershed partnerships to formulate and implement tactical plans for tamarisk control and reestablishment of native vegetation.

B. Local communities can take leadership roles with watershed partnerships in developing local partnerships to formulate and implement tactical plans.

C. Local communities can facilitate arrangements for access with private landowners.

D. County weed managers can provide guidance to landowners in proper tamarisk control procedures.

4.8 Role of State Agencies

A. DNR, Colorado Water Conservation Board, Division of Wildlife, and Agriculture should participate in Interior's tamarisk strategy workshop scheduled for March 31 to April 2, 2004 to help influence federal actions so that they mesh with Colorado's 10-Year Plan.

B. The proposed Tamarisk Support Team (TST) should providing assistance, guidance, education, funding coordination, and accountability to watershed partnerships.

C. The TST with the assistance of the TRRAC should establish high quality large-scale demonstration projects and associated research activities to propose to Interior as outlined in pending federal legislation.

D. CDA through CSU Cooperative Extension offices can provide tamarisk control and revegetation training to landowners and be a resource for other state agencies.

E. Colorado Department of Transportation, State Land Board, State Parks, and Division of Wildlife, all of which manage state lands, should coordinate with the TST in participating with local watershed partnerships to formulate and implement tactical plans for tamarisk control and reestablishment of native vegetation.

F. For projects on state lands, agencies should be encouraged to award procurement contracts, grants, or cooperative agreements to entities that include Youth Conservation Corps, Americorps, or related partnerships with State, Native American, local or non-profit youth organizations where appropriate. This approach has proven beneficial to projects in western Colorado for performing many of the labor-intensive activities associated with control and restoration. The use of youth programs provides added value in the form of training, work experience, and work ethics for Colorado's youth.

4.9 Role of Federal Agencies

A. Federal land managers including BLM, BOR, Defense, Energy, Forest Service, Fish and Wildlife Service, and National Park Service should participate with local watershed partnerships to formulate and implement tactical plans for tamarisk control and reestablishment of native vegetation.

B. Federal agencies should establish budgets that provide the necessary funding for tamarisk control and reestablishment of native vegetation on federal lands.

C. For projects on federal lands, agencies should be encouraged to award procurement contracts, grants, or cooperative agreements to entities that include Youth Conservation Corps, Americorps, or related partnerships with State, Native American, local or non-profit youth organizations where appropriate.

D. Federal scientists should participate with other scientist in the state on research activities.

E. Federal agencies should provide access to appropriate public land for the development of bio-control nurseries.

4.10 Role of the Governor and State Legislature

A. Through the Governor's office, Congress should be encouraged to support federal legislation for passage in 2004 with funding beginning in 2005.

B. The Governor should continue to be the state's senior spokesman for tamarisk control and habitat restoration.

C. If federal legislation is passed, the local share of the large-scale demonstrations will require a 25 percent match. This can be in the form of in-kind goods and services and matching funds. It is anticipated that much of the local share can be identified as in-kind; however, the governor and legislature and can help to identify appropriate funding sources to fund shortfalls in the local match and overall shortfalls in funding at the watershed scale.

D. The governor and the state legislature should support efforts to provide adequate funding for tamarisk control.

E. For Colorado to prevent reinfestations in the future, it will be important that the Governor's office work with adjacent states to encourage them to develop tamarisk control strategies in their states.

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Appendix A

Executive Order D 002 03
Directing State Agencies to Coordinate Efforts for the Eradication of Tamarisk on State Lands

Pursuant to the authority vested in the Office of the Governor of the State of Colorado, I, Bill Owens, Governor of the State of Colorado, hereby issue this Executive Order directing the Colorado Department of Natural Resources, in consultation and cooperation with other appropriate state and federal agencies, to coordinate efforts to eradicate the tamarisk plant on public lands.

1. Background and Purpose

The State of Colorado, like the rest of the Western United States, faces the immense challenge of dealing with noxious weeds that cause harm to the ecosystem. The most destructive non-native invasive species in Colorado is the tamarisk plant, also known as saltcedar.

Tamarisk is rapidly spreading throughout Colorado and the surrounding region. Efforts to control this aggressive plant species have been unsuccessful. It is now estimated that the plant has overcome native species on 1.5 million acres throughout the region and it is has become apparent that the plant is causing serious ecological and environmental problems within the State of Colorado.

The tamarisk plant consumes an enormous amount of water. A single tamarisk tree can transpire up to 300 gallons of water per day. As a comparison, an average acre of native cottonwood trees uses 845,000 gallons of water per year, while an acre of tamarisk uses 1.3 million gallons of water per year. An accumulation of tamarisk plants close to a watershed can effectively limit or dry up an entire water source. The disproportionate consumption of water by a non-native invasive species is cause for serious concern for Colorado as it continues to endure one of the worst droughts in state history.

In addition, tamarisk species are inedible to most animals. As a result, wildlife over browse the surviving native plant species, further speeding the tamarisk invasion process. Finally, tamarisk trees produce extremely flammable leaf litter which promotes the incidence of wildfire.

Given the devastating effect of this non-native species, I am directing state agencies to take appropriate measures to eradicate tamarisk on public lands.

2. Mission

I hereby direct the Department of Natural Resources, the Department of Agriculture and any other state agency that may prove helpful with this project, to take measures necessary to eradicate tamarisk on public lands within ten years of this Executive Order.

State agencies participating in this project shall designate a point of contact to coordinate tamarisk assessment and removal efforts, and to identify necessary funding sources.

The Department of Natural Resources shall coordinate these efforts and, within one year of the effective date of this order, shall submit a report to the Governor's Office outlining a viable plan to achieve the eradication of tamarisk in Colorado within ten years.

3. Duration

This Executive Order shall remain in effect until modified or rescinded by Executive Order.

GIVEN under my hand and the Executive Seal of the State of Colorado, this 8th day of January, 2003.

Bill Owens
Governor

Appendix B

Element Stewardship Abstract for Tamarisk
The Nature Conservancy

Tamarix ramosissima Ledebour
Tamarix pentandra Pallas
Tamarix chinensis Loureiro
Tamarix parviflora De Candolle

Saltcedar
Salt cedar
Tamarisk

To the User:

Element Stewardship Abstracts (ESAs) are prepared to provide the Nature Conservancy's Stewardship staff and other land managers with current management related information on species and communities that are most important to protect, or most important to control. The abstracts organize and summarize data from many sources including literature and researchers and managers actively working with the species or community.

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SPECIES CODE
PDCPR030G0

SCIENTIFIC NAMES (GNAME)
Tamarix ramosissima Ledebour
Tamarix pentandra Pallas
Tamarix chinensis Loureiro
Tamarix parviflora De Candolle
Tamarix gallica L.

Tamarisk is a member of the Tamarisk Family (Tamaricaceae). There is some dispute regarding the correct taxonomy of the deciduous species of tamarisk that have escaped and become invasive in western North America. Robinson (1965) stated that two species of *Tamarix* have escaped cultivation in western North America, namely *T. pentandra* Pallas and *T. gallica* L. Horton and Campbell (1974) studied tamarisk collections from the southwestern United States and grew plants under controlled conditions. They did not find consistent differences among the plants and proposed assigning all deciduous specimens to *T. chinensis*. Welsh et al. (1987) classifies deciduous tamarisk species in Utah as either *T. ramosissima* which has flower parts in 5's (5-merous) or *T. parviflora* which has flower parts in 4's (4-merous). According to Weber (1990), some experts consider the proper name of *T. ramosissima* Ledebour to be *T. chinensis* Loureiro. Sudbrock (1993) stated that *T. ramosissima* and *T. chinensis* are difficult to distinguish, appear to hybridize and that many researchers lump them both into *T. chinensis*. Other researchers lump all deciduous tamarisk species into *T. pentandra*. For the purpose of this abstract, I will follow what appears to be the recent common practice of referring to all 5-merous deciduous tamarisk species that have become naturalized in western North America as *T. ramosissima*, while the 4-merous deciduous species will be referred to as *T. parviflora*. The 5-merous deciduous tamarisk appears to be more widespread in North America than the 4-merous species. In practice, however, little distinction is made among the deciduous tamarisk species for management purposes.

There is an evergreen species of tamarisk, the athel tree, *Tamarix aphylla* (L.) Karsten, which occasionally escapes and becomes established in hot deserts of the United States; however, it does not appear to be nearly as invasive as the deciduous tamarisk species.

COMMON NAMES
Tamarix ramosissima and *T. parviflora* are both commonly referred to as tamarisk or saltcedar. The name 'tamarisk' is clearly based on the genus name *Tamarix* but the derivation of that name is not clear. It may be derived from the Tambre (Tamariz) River in Spain but it may also come from the Tamaro River in Nepal or from the Hebrew word *tamaruk* (Crins 1989). Saltcedar refers to the plants' fine, cedar-like foliage and their ability to grow in saline or alkaline soils.

DESCRIPTION AND DIAGNOSTIC CHARACTERISTICS

As noted above, deciduous tamarisk species in the western United States are herein referred to as either *T. ramosissima* or *T. parviflora*. They can be distinguished using the characteristics in Table 1.

Both species are deciduous, loosely branched shrubs or small trees. The branchlets are slender with minute, appressed scaly leaves. The leaves are rhombic to ovate, sharply pointed to gradually tapering, and 0.5 –3.0 mm long. The margins of the leaves are thin, dry and membranaceous. Flowers are whitish or pinkish and borne on slender racemes 2-5 cm long on the current year's branches and are grouped together in terminal panicles. The pedicels are short. The flowers are most abundant between April and August, but may be found any time of the year. Petals are usually retained on the fruit. The seeds are borne in a lance-ovoid capsule 3-4 mm long; the seeds are about 0.45 mm long and 0.17 mm wide and have unicellular hairs about 2 mm long at the apical end. The seeds have no endosperm and weigh about 0.00001 gram (Wilgus and Hamilton 1962; Stevens 1990).

Table 1. Distinguishing characteristics of *T. ramosissima* and *T. parviflora* based on Welsh et al. (1987).

Characteristic	*Tamarix ramosissima*	*Tamarix parviflora*
Size	< 5 m tall	< 6 m tall
Bark	reddish brown	dark brown to deep purple
Bracts	scarcely translucent	more or less translucent
Flowers	parts in 5s	parts in 4s
Sepals	outer two narrower than inner; all more or less acute	outer two keeled and acute; outer flat or slightly keeled and obtuse
Stamen filaments	inserted under the disc near the margin between the lobes	arising gradually from disc lobes
Petals	obovate, 1-1.8 mm long	oblong to ovate, 1.9-2.3 mm long

STEWARDSHIP SUMMARY

Tamarisk is an aggressive, woody invasive plant species that 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). I found no recent precise estimate on the area occupied by tamarisk. Tamarisk is a relatively long-lived plant that can tolerate a wide range of environmental conditions once established. It produces massive quantities of small seeds and can propagate from buried or submerged stems. It can replace or displace native woody species, such as cottonwood, willow and mesquite, which occupy similar habitats, especially when timing and amount of peak water discharge, salinity, temperature, and substrate texture have been altered by human activities. Stands of tamarisk generally have lower wildlife values compared to stands of native vegetation, although tamarisk can be important to some bird species as nesting habitat. Tamarisk is a facultative phreatophyte, meaning that it can draw water from underground sources but once established it can survive without access to ground water. It consumes large quantities of water, possibly more than woody native plant species that occupy similar habitats. Tamarisk is tolerant of highly saline habitats, and it concentrates salts in its leaves. Over time, as leaf litter accumulates under tamarisk plants, the surface soil can become highly saline, thus impeding future colonization by many native plant species.

Tamarisk is commonly controlled in riparian areas and wetlands and along lake shores because of its potential to displace native vegetation and its lower value as wildlife habitat. However, control over large areas is difficult in situations where hydrologic processes have been greatly altered, due to the high control cost and the likelihood that tamarisk will re-invade areas from which it is eliminated. Areas where tamarisk is to be managed should be selected carefully to maximize the likelihood of success.

Tamarisk can be controlled by five principal methods: 1) applying herbicide to foliage of intact plants; 2) removing aboveground stems by burning or mechanical means followed by foliar application of herbicide; 3) cutting stems close to the ground followed by application of herbicide to the cut stems; 4) spraying basal bark with herbicide; and 5) digging or pulling plants. In addition, The USDA has tested and proposed the release of two species of insects for tamarisk biocontrol but releases have not yet been permitted.

Selecting an appropriate control method involves considering the size of the area where tamarisk is to be controlled, restrictions on the use of particular herbicides or herbicides generally, the presence or absence of desirable vegetation where tamarisk is growing, the presence or absence of open water, adjacent land uses that might restrict prescribed burning, and the availability and cost of labor.

For larger areas (> 2 hectares) that are essentially monotypic stands of tamarisk, the best methods would likely be foliar application of imazapyr (Arsenal®) herbicide to the intact plants or burning or cutting plants followed by foliar application of imazapyr or triclopyr (e.g. Garlon4® or PathfinderII®) to the resprouted stems. Foliar application of imazapyr or imazapyr in combination with glyphosate (e.g. Rodeo®) can be effective at killing large, established plants. Over 95% control has been achieved in field trials during the late summer or early fall. The herbicide can be applied from the ground using hand-held or truck-mounted equipment or from the air using fixed-wing aircraft. Foliar application of herbicide works especially well in monotypic stands of tamarisk, although experienced persons using ground equipment can spray around native trees and shrubs such as cottonwood and willow. As an alternative to herbicides, prescribed fire or a bulldozer can be used to open up large stands of tamarisk. Once opened, the resprouts can be sprayed when they are 1 to 2 m tall using imazapyr, or imazapyr plus glyphosate, or triclopyr.

Tamarisk eradication in areas that contain significant numbers of interspersed, desirable shrubs and trees is problematic. Depending upon site conditions, it may not be possible to rapidly kill tamarisk plants without also killing desirable shrubs and trees. It such situations, it may be necessary to cut and treat tamarisk stumps with herbicide, as outlined in the next paragraph. While this method is relatively slow and labor-intensive, it will spare desirable woody plants.

Alternatively, it may be more cost-effective to kill all woody plants at a site and replant desirable species afterward.

For modest-sized areas (< 2 hectares), cutting the stem and applying herbicide (known as the cut-stump method) is most often employed. The cut-stump method is used in stands where woody native plants are present and where their continued existence is desired. Individual tamarisk plants are cut as close to the ground as possible with chainsaws, loppers or axes, and herbicide is applied immediately thereafter to the perimeters of the cut stems. The herbicides triclopyr (e.g. Garlon4® or PathfinderII®) and imazapyr (Arsenal®) can be very effective when used in this fashion. This treatment appears to be most effective in the fall when plants are translocating materials to their roots. The efficacy of treatments is enhanced by cutting the stems within 5 cm of the soil surface, applying herbicide within one minute of cutting, applying herbicide all around the perimeter of the cut stems, and retreating any resprouts 4 to 12 months following initial treatment.

No matter how effective initial treatment of tamarisk might be, it is important to re-treat tamarisk that is not killed by initial treatment. It is also essential to continue to monitor and control tamarisk indefinitely because tamarisk is likely to re-invade treated areas. However, follow-up control is likely to require much less labor and materials than the initial control efforts.

IMPACTS (THREATS POSED BY THIS SPECIES)

During the past century, tamarisk has become naturalized along river bottoms and lake margins in the western United States, particularly in Arizona, New Mexico, California, Texas, Colorado, Utah, Nevada, Oklahoma and Wyoming. There are multiple, interacting factors involved in the invasion of tamarisk, and specific cause-and-effect relationships have not been determined (Everitt 1980). Factors that probably facilitated the spread of tamarisk include: intentional tamarisk plantings designed to protect streambanks and control erosion; conversion of native riparian forests to agricultural uses; damming of rivers fed by snowmelt which has shifted the time of peak discharge below the dams from spring to summer; creation of large areas of fine sediment that provide the ideal substrate for tamarisk colonization along the margins of reservoirs; increased salinity of rivers due to irrigation return flows and evaporation from reservoirs; reduced flood frequency downstream of reservoirs; and more stabilized base flows in rivers due to reservoir construction (Everitt 1980). Everitt (1980) noted that tamarisk has not become established in all western rivers, particularly those that still experience large floods and those where spring, rather than summer flooding still predominates. It is likely that the spread of tamarisk has been and continues to be greatly facilitated by human activities.

Tamarisk possesses a number of undesirable attributes, according to a number of authorities. It 1) crowds out native stands of riparian and wetland vegetation; 2) increases the salinity of surface soil rendering the soil inhospitable to native plant species; 3) provides generally lower wildlife habitat value than native vegetation; 4) dries up springs, wetlands, riparian areas and small streams by lowering surface water tables; 5) widens floodplains by clogging stream channels; 6) increases sediment deposition due to the abundance of tamarisk stems in dense stands; and 7) uses more water than comparable native plant communities. However, data to support these claims by various authors do not always exist.

Crowding out native vegetation
There is little doubt that tamarisk can crowd out native riparian and wetland vegetation. A variety of field observations support this view. However, it is likely that human-induced changes in hydrologic regimes of rivers, as well as other factors, have paved the way for tamarisk invasion (Everitt 1980). For example, along the lower Colorado River in Arizona and California, the elimination of flooding due to the construction of dams, the salinization of the soil and recurrent wildfires have virtually eliminated the cottonwood-willow riparian forests (R. D. Ohmart, personal communication). Tamarisk is now the dominant riparian plant species. It appears that tamarisk is much less invasive along rivers where natural hydrologic processes are relatively intact. Presumably, lack of regeneration of native shrubs and trees at a site would facilitate tamarisk invasion, but I found no studies to substantiate this. In some cases, tamarisk probably replaces rather than displaces native riparian vegetation that has been destroyed by human activities.

Increasing salinity of surface soil
It appears likely that tamarisk increases the salinity of soils. The leaves and stems contain concentrations of soluble salts in the range of 5-15% (Hem 1967) which are absorbed by the roots from deeper soil layers, transported though the plant and concentrated in the leaves. These salts are later deposited on the soil when the deciduous leaves drop. Thus, the accumulation of tamarisk litter can greatly increase the salinity of soils in tamarisk stands.

Lower wildlife values
Anderson et al. (1977) found that tamarisk stands along the lower Colorado River had lower bird density, bird species richness and diversity than did the native cottonwood-willow vegetation. Engel-Wilson and Ohmart (1978) found lower bird density and diversity in tamarisk stands along the lower Rio Grande River compared to native cottonwood-willow riparian forest. Kasprzyk and Bryant (1989) studied birds and small mammals along the Virgin River upstream from its inflow to Lake Mead in Nevada. They found that bird density and diversity were lower in tamarisk communities than native riparian vegetation. Ellis (1995) studied bird use of tamarisk and cottonwood vegetation in central New Mexico along the Rio Grande River. She found that many bird species used both habitats, with three species using only tamarisk and six species using only cottonwood. Assuming the prediction by Howe and Knopf (1991) that tamarisk may completely supplant cottonwood habitat along the middle Rio Grande River in New Mexico over the next century, the richness of riparian bird species in that area would decline.

Brown and Johnson (1990) argued that, while tamarisk habitat along the lower Colorado River was much less valuable for breeding birds than native riparian habitat, the reverse was true along the Colorado River in Grand Canyon National Park. Hunter et al. (1988) proposed that bird nests in tamarisk along the lower Colorado River experienced higher heat loads than nests in multi-layered cottonwood forests that afford more shade. Anderson (1994) studied the Apache cicada in a native riparian community and a tamarisk stand along the lower Colorado River. He found that although cicadas were abundant in both communities, the insects emerged later in the native, cottonwood and willow-dominated communities when migrating and nesting birds were present. This change in temporal availability of this key food resource may help explain the low abundance of breeding birds in tamarisk communities.

Brown and Trosset (1988) stated that tamarisk stands in Grand Canyon National Park developed after construction of the of Glen Canyon Dam; comparable vegetation was not present along the river prior to construction of the Dam, so the tamarisk vegetation represented a new habitat type for that locale. In fact, black chinned hummingbirds (*Archilocus alexandri*) nested only in tamarisk-dominated habitats along the Colorado in the Grand Canyon (Brown 1992). Thus, Brown and Trosset (1988) argued that regional tamarisk management strategies must developed with respect to bird species.

Hunter et al. (1988) studied bird use in riparian vegetation along the middle Pecos River in New Mexico. There, birds used tamarisk as much as or more than other vegetation types year round. They noted that prior to invasion by tamarisk, this portion of the Pecos River had few tall, mature stands of vegetation. Thus, birds may have expanded their local ranges as tamarisk expanded. The lack of tall vegetation along the Pecos River contrasts with the condition of other desert riparian systems prior to Euro-American settlement (Ohmart and Anderson 1982).

The Federally Endangered Southwestern Willow Flycatcher (*Empidonax trailii extimus*) is known to nest in tamarisk-dominated areas (USFWS 1993). This subspecies of the Willow Flycatcher is widely distributed in scattered remnant populations across much of the area where tamarisk is invasive. Although it also feeds and breeds in riparian woodlands dominated by native plants including willows (*Salix* spp.) arrowweed (*Pluchea* spp.) and *Baccharis* species there has been concern that it might be further threatened if a biocontrol agent controls tamarisk over wide areas of the southwest. Others point out that even a highly successful biocontrol agent won’t eliminate tamarisk and, that where it is reduced, native plants favored by breeding and feeding birds are likely to establish (Lovich and de Gouvenain 1998).

Most published studies of the value of tamarisk to wildlife in North America have focused on birds and purported benefits to certain bird species may or may not extend to other animals (Lovich and de Gouvenain 1998).

Increased water consumption

There is no doubt that tamarisk stands consume large amounts of ground water. Robinson (1965) cited studies which indicate tamarisk consumes on the order of 4 acre-feet of ground water annually (Table 2). Robinson (1965) projected that consumptive use of tamarisk in the United States would be 5 million acre-feet in 1970. To place this number in perspective, this is more than twice the quantity of water held behind the Glen Canyon Dam at full capacity. Weeks et al. (1987) reviewed studies that investigated water use by tamarisk in New Mexico and Arizona (Table 2). The estimates of water use were quite variable, presumably reflecting variations in weather and environment, as well as difficulties in estimating evapotranspiration precisely.

Table 2. Estimates of annual water use by tamarisk, with the first five references cited in Weeks et al. (1987).

Study author(s)	Estimate of water use (m / yr)
Blaney et al. (1942)	1.2 - 1.67
Gatewood et al. (1950)	1.2 – 3.0
U.S. Bu Rec (1973)	0.7 – 1.4
Van Hylckama (1974)	2.6 – 3.4
Culler et al. (1982)	0.8 – 1.0
Gay (1990)	1.73 – 1.82

Sala et al. (1996) found that individual *Tamarix ramosissima* plants used about the same amount of water per unit of leaf area as did the native riparian species *Pluchea sericea*, *Prosopis pubescens* and *Salix exigua*. Their study also confirmed previous work by Davenport et al. (1982) that indicated evapotranspiration from riparian communities with high ground water availability is more dependent on stem density than on plant species composition. Sala et al. (1996) noted that tamarisk stands may have significantly more leaf area per unit of ground area than stands of native riparian vegetation. If so, the tamarisk stands would use more water per unit of ground area than the native stands and, replacing the tamarisk stands with native species would save water.

Weeks et al. (1987) estimated that tamarisk consumed about 0.3 m more water per year than replacement vegetation along the Rio Grand River in central New Mexico. Thus, conversion of stands of native riparian forest to a tamarisk stand may result in increased consumptive use of ground water. However, I found no other studies which demonstrated increases in ground water levels or stream flows following tamarisk removal, except on a very local scale in small streams or springs.

Many land managers, however, cite cases of springs that dried up following invasion by tamarisk, with springs flowing again after the tamarisk was removed (Barrows 1993, Neill). Brotherson et al. (1982) found that the proportion of xerophytic plant species increased as the age of tamarisk stands increased. Thus, the longer a community had been occupied by tamarisk, the drier it became.

Widening floodplains and increasing deposition of sediment

Robinson (1965) claimed that dense stands of tamarisk could increase areas inundated by floods. This could occur because dense stands of tamarisk choke overflow and lateral channels, thereby reducing the capacity of a stream channel and associated flood plain to transport flood waters. Dense stands of tamarisk could increase deposition of sediment, due the increased channel roughness caused by tamarisk stems. However, Everitt (1980) said that, while vegetation can promote local sediment deposition, the idea that vegetation over large areas can increase regional deposition of sediment is unfounded.

GLOBAL RANGE

The genus Tamarisk is one of four genera of the family Tamaricaceae which is native to Africa, Asia, and Europe (Robinson 1965). The taxonomy of tamarisk is disputed. In the most recent monograph of the genus, Baum (1978) recognized over 50 species worldwide; however, other authorities lump many of these species. The natural range of the 5-merous tamarisk (here referred to as *T. ramosissima*) is from the southern Europe to Asia minor and eastward to Mongolia, Tibet, central China and North Korea (Crins 1989). The natural range of the 4-merous *T. parviflora* is southern Europe and perhaps northern Algeria (Crins 1989). Although *T. aphylla* is not regarded as invasive in North America, it is a severe pest of riparian areas in arid central Australia where it apparently has all the same bad impacts *T. ramosissima* and *T. parviflora* have in the southwestern U.S (Griffin et al. 1989).

Tamarisk has spread to all of the western and Great Plains states, with the greatest concentrations in Texas, Arizona and New Mexico (Robinson 1965). It is also abundant in California, Nevada, Utah and western Colorado. It is not clear whether or not the 5-merous species (*T. ramosissima*) dominates in some areas and the 4-merous species (*T. parviflora*) in others. Both the 5-merous species and the 4-merous species also escape from cultivation occasionally in the eastern U.S., particularly on sandy beaches and roadsides, but are not invasive there (Gleason and Cronquist 1991, Radford et al. 1968, Wunderlin 1998). Weber (1990) reported that the Spanish explorer Father Escalante mentioned tamarisk in his journals from his travels throughout the American Southwest in 1776. If this is correct, it means that the Spanish introduced this species at least 200 years ago, although Robinson (1965) provided evidence that contradicts this claim. Robinson (1965) stated that tamarisk was offered for sale to the public in California beginning in the 1850s. Apparently, tamarisk did not start to become invasive in the U.S. until about 1877 when collections of tamarisk started to appear in herbaria (Robinson 1965). The plant did not attract much attention in the United States until the 1920s, and its impact on ground water was not appreciated until years later (Robinson 1965).

HABITAT

Tamarisk can grow in many different substrates from below sea level to about 2100 m elevation (Hoddenbach 1990), although it grows mostly on fine-textured soils (Everitt 1980). Tamarisk is a facultative phreatophyte (Turner 1974), meaning that it uses but does not depend on ground water. Tamarisk occurs in areas where its roots can reach the water table, such as floodplains, along irrigation ditches and on lake shores. Plants usually grow where the depth to ground water does not exceed 3 - 5 m. Tamarisk forms dense thickets where the ground water lies from 1.5 – 6 m below the soil surface (Horton et al. 1960). Where ground water is deeper than 6 m, plants form an open shrubland (Horton and Campbell 1974). Tamarisks have a wide tolerance of saline or alkaline soils (Robinson 1965). Carmen and Brotherson (1980) found that sites with tamarisk in Utah had higher soil salinity and pH than sites without tamarisk. Brotherson and Winkel (1986) identified the major factors that contribute to tamarisk success as alkaline soils, available soil moisture, and sufficient disturbance of native vegetation to facilitate tamarisk invasion. Everitt (1980) stated that ideal conditions for first-year survival for tamarisk seedlings are on gently sloping riverbanks, or sandbars and siltbars where water levels slowly recede during the period of seed fall.

BIOLOGY – ECOLOGY

Stevens (1990) presented an overview of the biology and ecology of tamarisk based on studies in northern Arizona. He found that tamarisk was a highly fecund, relatively long-lived phreatophyte which is very tolerant of inundation, desiccation and nutrient stress. Tamarisk produces massive quantities of minute seeds that are readily dispersed by wind. Stevens (1990) found the seeds were viable for up to 45 days under ideal conditions during summer, and could complete germination within 24 hours following contract with water. Tamarisk seeds had no dormancy or after-ripening requirements. Tamarisk flowered in two flushes, one in April-May and another in late July in northern Arizona, presumably reflecting availability of spring snowmelt and summer monsoon moisture. Tamarisk flowered continuously under favorable environmental conditions but the flowers required insect pollination to set seed. Tamarisk seed lived for only a few weeks during the summer; and the few seeds that might survive over winter under cooler conditions did not appear to form a persistent seed bank (Stevens 1990).

Tamarisk will produce roots from buried or submerged stems or stem fragments (Merkel and Hopkins 1957). This allows tamarisk to produce new plants vegetatively following floods from stems torn from the parent plants and buried by sediment. Ideal conditions for first-year survival are saturated soil during the first few weeks of life, a high water table, and open sunny ground with little competition from other plants.

Tamarisk has two traits that might be exploited for its control. First, tamarisk seedlings grow more slowly than many native riparian plant species. Second, mature tamarisk plants are highly susceptible to shading (Stevens 1990)

Hem (1967) studied the salts present in leaves and stems of *T. pentandra* at locations in Arizona and New Mexico. He found that the total concentration of calcium, magnesium, chloride, and sulfate in the leaves generally ranged from 5 to 15% of their dry weight. About 10% of the total ionic concentration consisted of inorganic ions that could be readily washed off the leaves by rainfall.

RESTORATION POTENTIAL

Smith and Devitt (1996) concluded that riparian restoration efforts that involve removing dense stands of tamarisk without restoring historical flow regimes will not be successful without extensive follow-up management. Native cottonwood and willow species may fail to re-establish without intensive planting in areas where floods have been eliminated or where receding flood flows do not occur when short-lived cottonwood and willow seeds are produced. Another potential problem is the ability of tamarisk to increase the salinity of surface soil due to deposition of highly saline leaf litter. In areas subject to frequent flooding, increased soil salinity should be a fairly transient phenomenon. High salinities may persist, however, in higher terraces along rivers whose banks are dominated by tamarisk because floodwaters rarely reach these areas. This may make it difficult or impossible for native plants to colonize these areas once tamarisk is controlled. Another problem may be downcutting of stream channels downstream of dams. In such situations, surface water tables may decline to the point that cottonwood and willows can no longer survive or colonize. Wildfire may be a problem because tamarisk-dominated communities experience higher fire frequencies than native cottonwood-willow communities, eventually eliminating the fire-sensitive cottonwood and perhaps even the willows (Busch 1995; Busch and Smith 1993). A final problem may be lack of a thorough network of mycorrhizal hyphae in soils that have been dominated by tamarisk for many years (St. John 1997). Mycorrhizae are important for many native species and their absence or low abundance may impede colonization of desirable plant species.

MANAGEMENT REQUIREMENTS

Before embarking on a tamarisk control program, consult with federal, state, and local agencies to determine what permits, if any, may be required. For example, applying herbicides may require permits; certain herbicides may not be approved for use in or near open water; prescribed burns will likely require permits from the local air quality authority; the U. S. Fish & Wildlife Service may have jurisdiction if listed threatened or endangered species occupy the tamarisk habitat to be managed and a Section 404 permit may be required from the U. S. Army Corps of Engineers for mechanized control in aquatic areas (Stein 1996).

In addition, before using chemicals, managers need to understand and follow safety procedures. Workers using herbicides may need to wear protective clothing and my need face, eye and skin protection. Soap and water should be available on site to clean up after contact with chemicals.

Neill (1990) suggested that tamarisk control is most effective in canyons subject to intense flooding and at springs that are never flooded. Periodic flooding removes tamarisk plants in the active floodplain. Therefore, tamarisk control should be directed towards larger plants that occupy the higher terraces that are not flooded or are flooded very infrequently. Smaller plants in the active floodplain can be dealt with later and may be washed away by a scouring flood in the mean time. At springs, tamarisk plants should be eradicated so seeds are not produced to re-colonize cleared areas. Once eradicated, occasional follow-up should be sufficient to remove tamarisk plants that arise from seeds transported over long distances. Neill (1990) said that tamarisk control will be most difficult or impossible along rivers that flood enough to promote seed production and dispersal but not enough to dislodge established tamarisk plants.

Tamarisk should be controlled in natural areas or it will proliferate. Left uncontrolled, tamarisk can crowd out virtually all native vegetation. Proposing a contrary view, Brown and Johnson (1990) suggested that tamarisk habitat in Grand Canyon National Park, and perhaps elsewhere, is valuable for birds and ought to be reconsidered in regional management programs. They suggested that a mosaic of structurally diverse tamarisk habitats could be maintained along the Colorado River by releases of floodwaters from Glen Canyon Dam every 20 to 30 years.

MANAGEMENT PROGRAMS

Egan (1996) outlined a seven-step approach to site restoration and maintenance where tamarisk is involved. The following is modified somewhat from Egan’s original list.

1. Identify factors that allow tamarisk or desirable species to invade and maintain themselves at a site, considering the entire watershed. Develop a long-term vision.

2. Plan a sufficiently large restoration site to allow natural processes that promote natural community diversity to operate.
3. Utilize natural processes such as floods and fire as well as deliberate control methods to further site restoration and maintenance.
4. Eliminate or reduce disturbances that undermine restoration and maintenance efforts.
5. Minimize recreation conflicts in the area, particularly as they influence disturbance at the restoration site.
6. Monitor site conditions on a regular basis. Revise objectives, strategies and tactics as needed.
7. Keep informed and maintain close contract with others involved in tamarisk control work.

Control of tamarisk often involves considerable cash and labor resources, which may exceed those available from any one source. de Gouvenain and West (1996) presented ideas for developing partnerships to control tamarisk that have been successful for BLM in California. They have been able to solicit modest cash grants and in-kind contributions from a variety of partners to accomplish projects that BLM would not have been able to complete alone. Interestingly, they have found prisoners to be hard workers and to be willing to put up with hot, dry conditions. Neill (1996) outlined his considerable experience with volunteers controlling tamarisk and provides a long list of tamarisk projects that have been undertaken in California partly or entirely by volunteers.

Barrows (1993) described a very successful tamarisk control program at a 10 hectare wetland site at the Coachella Valley Preserve in Riverside County, California. This project was initiated in 1986 and was completed in 1992, and required 5000 person-hours of labor and 30 gallons of herbicide. Labor was provided mostly by California Conservation Corps crews and Nature Conservancy staff and volunteers.

Table 3 contains a partial list of tamarisk control projects in the western U.S., and many more are underway. Managers are encouraged to contact experienced resource managers (e.g., BLM, USFS, USFWS, National Park Service, state wildlife agency, county weed control authority) in their area for information about local control programs.

Table 3. Selected management programs aimed at controlling tamarisk in the western United States.

Location	Methods of control	Effectiveness	Reference
Afton Canyon ACEC, CA	Burning & herbicide; cutting & herbicide	High High	Chavez 1996 Egan 1996, 1997 West 1996
Big Bend Nat'l. Park, TX	Cutting & herbicide	Low	Fleming 1990
Bosque del Apache NWR Complex, NM	Combinations of herbicide, mechanical control & burning	High	Taylor 1996
Canyonlands, Arches Nat'l Parks; Natural Bridges Nat'l. Mon., UT	Cutting & herbicide	Moderate	Thomas et al. 1990
Coachella Valley Preserve, CA	Cutting & herbicide	High	Barrows 1993
Death Valley Nat'l. Park, NV	Mechanical & herbicide	High	Rowlands 1990
Grand Canyon Nat'l. Park, AZ	NA	NA	Sharrow 1990
Glen Canyon Nat'l. Rec. Area, UT	Cutting; burning	NA	Holland 1990
Guadalupe Mtn's. Nat'l. Park, TX	Cutting & herbicide; pulling	NA	Davila 1990
Joshua Tree Nat'l. Park, CA	Cutting & burning	High	Coffey 1990
Lake Mead Nat'l. Rec. Area, AZ	Cutting & herbicide; burning basal herbicide; mechanical	Unknown	Burke 1990 Luttrell 1983 Deuser 1996
Organ Pipe Cactus Nat'l. Mon., AZ	Digging	High	Mikus 1990
Petrified Forest Nat'l. Park, AZ	Cutting & herbicide; excavation	21-76% kill	Bowman 1990 Johnson 1985
Picacho State Rec. Area, CA	Cutting & burning	High	Jorgensen 1996
San Miguel River at Tabeguache Creek Preserve, CO	Cutting & herbicide	High initial kill	Willits 1994
Wupatki Nat'l. Mon., AZ	Cutting & herbicide	Moderate-High	Cinnamon 1990
Zion Nat'l. Park, UT	Cutting & herbicide	Moderate-High	Hays and Mitchell 1990

BIOLOGICAL CONTROL

Stevens (1990) stated that only six of the of the > 200 species of invertebrates known to occur on tamarisk in the U.S. were sufficiently common to be pests. Biological control would potentially kill tamarisk plants used in home landscaping and might reduce supplies of honey locally, as honeybees heavily use tamarisk. Landscapers and honey producers might oppose biological control programs.

In 1986, the U.S. Department of Agriculture's Agricultural Research Service (USDA-ARS) laboratory in Temple, Texas initiated a biological control program for tamarisk (DeLoach 1996). The goals for the program were to find and obtain insects that would damage *Tamarix ramosissima* without damaging native vegetation or *Tamarix aphylla*, the less invasive, evergreen species that is used for windbreaks and shade in the southwestern U.S. To date, two species of insect have been tested and proposed for release by USDA. One is a mealybug (*Trabutina mannipara*) from Israel and the other is a leaf beetle (*Diorhabda elongata*) from China. The leaf beetle defoliated tamarisks in greenhouse tests and the mealybug fed on twigs. DeLoach and Gould (1998) predict that these two insects may provide about 85% control of tamarisk and will take 3-5 years to control tamarisk at small sites and 5-10 years to control tamarisks in small to medium watersheds. Release of the two insects is pending resolution of whether the Southwestern Willow Flycatcher (*Empidonax trailii extimus*), which is listed as Endangered by the U.S. Fish and Wildlife Service, would be detrimentally affected by tamarisk control. The Flycatcher is known to nest in tamarisk dominated areas (USFWS 1993). In August 1998 the USDA requested permission from the U.S. Fish and Wildlife Service to release and monitor the impacts of one or both of these insects at thirteen sites in seven states in the western U.S. (CA, CO, NM, NV, TX, UT, WY; De Loach and Gould 1998). A decision had not been made as of late December 1998.

Several other insect species are currently in various stages of being tested.

CONTROL WITH BURNING

Tamarisk plants typically resprout vigorously after burning. However, burning followed by herbicide application to the resprouts can achieve excellent control in monotypic stands of tamarisk, as outlined in the "Control with Chemicals" section. Burning opens dense tamarisk stands and greatly reduces tamarisk biomass. Jorgensen (1996) recommended felling 20 to 25% of the largest tamarisk plants in stands several months prior to burning to create enough dry ground fuel to carry a fire. He also suggested using wildfires in tamarisk stands as an opportunity to begin tamarisk control, and following up the burn with herbicide treatment of the resprouts. Burning during the hottest part of the summer, when plants experience the greatest water stress, is likely to yield the best results. Chavez (1996), West (1996) and Egan (1996, 1997) used prescribed fire in Afton Canyon, California, to open dense stands of tamarisk for resprout treatment with herbicides. Duncan (1994) stated that repeated yearly burns can suppress tamarisk and kill some of the plants after 3 to 4 years.

Research by Busch and his colleagues in Arizona suggests fire is highly detrimental to native riparian forests. Busch and Smith (1993) noted that fire is a novel disturbance in southwestern US riparian forests. Furthermore, the dominant woody plant in many southwestern native riparian forests, Fremont cottonwood (*Populus fremontii* ssp. *fremontii*), does not re-sprout vigorously following fire, while tamarisk does. Busch (1995) concluded that the invasion of the alien tamarisk coupled with the novel disturbance of fire completely change southwestern riparian forests, based on his study of burned and unburned riparian forests along the lower Colorado River in Arizona. His results suggested that the native cottonwood – willow forest would be completely converted to tamarisk stands over the next several decades. Thus, burning does not appear to be a reasonable control method for tamarisk where it occurs as a component of native communities.

CONTROL WITH CHEMICALS

Foliar application to intact plants

Field studies in New Mexico by Duncan (1994) suggested that aerial application of the herbicide imazapyr (Arsenal®) alone or in combination with glyphosate (e.g. Roundup®, Rodeo®) is effective and practical for controlling tamarisk over thousands of hectares, particularly in dense stands where little on no native vegetation is present. Cost of aerial application of herbicide ranged from $70 to $90 per acre. Field trials along the Pecos River in New Mexico showed that fixed-wing aircraft could apply herbicide quite precisely, consistently following the 15 meter buffer line along the river bank. Several field trials have produced control rates of > 90% after one or two years. Alternatively, herbicide can be sprayed directly on tamarisk plants using truck-mounted equipment if stands are not too dense. This approach is appropriate where significant numbers of native trees and shrubs are interspersed with tamarisk plants. Duncan (personal communication) cautioned that sprayed plants should not be bulldozed or burned for two growing seasons, because disturbing the treated plants can induce some to resprout. Duncan and McDaniel (1996) have developed the following general guidelines:

- Focus treatment on young or regrowing tamarisk plants, because smaller plants are easier to kill than larger plants.
- Target areas previously plowed, mowed, burned or cleared, or areas where tamarisk appears to be invading.
- Target areas with tamarisk densities < 400 plants per hectare.
- While the optimal herbicide proportions have not yet been developed, a mixture of 0.5% (v/v) imazapyr and 0.5% glyphosate (v/v) plus 0.25% (v/v) nonionic surfactant give satisfactory results.

Kunzmann and Bennett (1990) stated that preliminary research indicates that the broad-spectrum herbicide imazapyr is the most cost-effective control technique known for tamarisk. However, they noted that more research is required to determine long-term effects of imazapyr on non-target plants and on other organisms.

Prescribed burning followed by foliar application of herbicide

This method is appropriate for larger areas, e.g., hundreds of hectares. It has been used successfully at BLM’s Afton Canyon Area of Critical Environmental Concern in the Mojave Desert near Barstow, California. BLM began this program in 1991 in order to control tamarisk and restore riparian vegetation on 280 hectares of riparian habitat (Egan 1996, 1997). Costs of removing the tamarisk and restoring native vegetation ran from $1500 to $3000 per acre. The first attempt to ignite a tamarisk stand was unsuccessful, so they cut and stacked selected tamarisk plants to create dry fuel that would carry a fire. The subsequent fire burned the majority of the tamarisk stems and opened up the stands so follow-up work could be accomplished easily (West 1996). Resprouts were treated with triclopyr using hand-held equipment; Egan (1996) recommended the Pathfinder II formulation. As of 1997, tamarisk abundance had declined dramatically in the areas where it had been controlled (Egan 1997).

Cut-stump method

The cut-stump method is appropriate for modest-sized areas 2 hectares or smaller. Neill (1990, 1996) summarized the details of cut-stump herbicide treatments for tamarisk. Persons considering using the stump-cut method for the first time should read those articles. Neill cautioned that the effectiveness of treatments is highly dependent on the skill of the field workers – poor technique leads to poor results. Based on Neill's work, the triclopyr herbicides Garlon4® or PathfinderII® appear to be the best choices for killing tamarisk due to higher phytotoxicity, low toxicity to humans, lack of restriction, and cost comparable to the other herbicides when diluted as directed. These herbicides contain the same active ingredient, triclopyr. Garlon4® is diluted 1:3 (v/v) in the field with cheap vegetable oil while PathfinderII® is sold already mixed and diluted with vegetable oil. PathfinderII® also contains a dye, which makes it easier to distinguish stumps that have been treated from those that have not. Dyes such as colorfast® purple, colorfast® red and basoil® red can be added to Garlon4®.

Diluted, Garlon4® costs about $26 per gallon, while PathfinderII® costs about $30 per gallon. One gallon is sufficient to treat hundreds of cut stumps. Neill (1990, 1996) stated that 95% mortality can be expected with either of these herbicides, with lower mortality probably being the result of not cutting close enough to ground level and/or not treating the circumference of the stump completely. However, Howard (1983) found that cuts 15 to 30 cm above the ground surface were effective when using Garlon4® in the autumn. Neill (1990, 1996) noted that tamarisk plants are best located in the spring or summer when their pink flowers are visible, and that control during this period may be advisable even though the plants are less susceptible to the herbicide. Neither Garlon4® nor PathfinderII® is labeled for aquatic use; however, stumps located near but not in or over open water can be treated with these herbicides provided that none of the herbicide enters the water. Garlon3A, an amine-based, water-soluble formulation of triclopyr, may become registered for use over water in 1999 or 2000.

Neill (1990) summarized his four cardinal rules for tamarisk control using the stump-cut method, as follows:

1. Cut stems of tamarisk within 5 cm of the ground surface.
2. Apply herbicide within a few minutes of cutting.
3. Cut and treat the entire circumference of the stem cambium.
4. Treat any resprouted foliage between 4 to 12 months after the initial treatment.

Barrows (1993) outlined an ambitious and successful tamarisk control program at the Coachella Valley Preserve in California. He suggested cutting tamarisk stems with small chainsaws or shears as close to the ground as possible, then immediately (within one minute) applying herbicide to the cut stumps. This treatment worked best in the fall when the plants translocate nutrients from the leaves and stems into their roots. Herbicide was diluted in the ratio of one part herbicide to 2 or 3 parts water to cut costs, and the diluted herbicide killed tamarisk effectively. Barrows (1993) recommended backpack sprayers to deliver the herbicide because it was much easier on the person doing the spraying. However, others recommend using hand-held spray bottles in dense stands to avoid tangling the spray equipment in the tamarisk stems. Under actual control conditions, over half of the treated stumps eventually resprouted and required follow-up treatment. In dense stands of tamarisk, cut stems were stacked in brush piles that were heavily used by birds. Over a 5-year period, the brush piles decomposed to occupy about 10% of their original volume. Work crews used protective clothing, including hand, face, and eye protection, and as a safety precaution were provided with fresh water on-site to wash skin that accidentally came in contact with herbicide.

Willits (1994) found Garlon4® to be very effective at killing tamarisk along the San Miguel River in Montrose County, Colorado, on a Nature Conservancy preserve. In the fall, tamarisk stems were cut either with a chainsaw or a compound-action lopper, and the stumps were immediately sprayed with herbicide. Casual observations suggested an initial kill rate of over 90%.

Bowman (1990) applied undiluted Garlon3A® herbicide to freshly cut stems of tamarisk in June and July at Petrified Forest National Park in Arizona, with an initial kill rate of 21%. Johnson (1985) achieved an initial kill of 76% using Garlon3A® at the Petrified Forest.

Cinnamon (1990) found that "frilling" cut stems and immediately applying Tordon® RTU to them was the most effective treatment, with initial kill ranging from 80 to 100%. He emphasized the need to grub around the bases of tamarisk plants to expose below-ground cambium and enhance uptake of herbicide by the plants.

Hays and Mitchell (1990) reported that cutting tamarisk stems and applying Garlon3A® herbicide killed 88% of the test plants in June treatments and 62% of test plants in February treatments. Although herbicide was applied the same day as the plants were cut, it is possible that herbicide application did not immediately follow cutting, thus reducing potential kill rates.

Rowlands (1990) reported satisfactory control of tamarisk in Death Valley National Park using a combination of mechanical and herbicide treatments. The herbicide used was Tordon® RTU. Burning was used occasionally to dispose of slash and to create access ways.

Basal bark treatment with herbicide

Neill (1996) reviewed the pros and cons of the basal bark method of tamarisk control. This method precludes the need to cut the tamarisk plants, resulting in major savings in labor and produces no tamarisk debris to haul away or burn. Disadvantages are the higher amount of herbicide required, up to five times that needed for stump-cut control, and lower mortality than with stump-cut. Neill (1996) noted that the basal bark method has been very effective at killing resprouts from debris piles left by a major flood. Jorgensen (1996) stated that basal bark application of Garlon4® was very effective on tamarisk plants with a basal diameter of less than 4 inches.

Carpet roller method

H. S. Mayeux with the USDA-ARS in Temple, Texas developed a carpet roller attachment for the front of a tractor. The roller is sprayed with herbicide, which is then applied to the tamarisk via the carpet roller as the tractor drives through the tamarisk stand. This method is an alternative in dense stands where desirable trees and shrubs are present. This method might also be useful in situations where standing water is interspersed with the tamarisk plants.

Table 4. Summary of herbicide information relevant to tamarisk control (Jackson 1996).

Herbicide Trade Name	Active Ingredient	Formu-lation	Signal Word	Aquatic Registration	Foliar Applic?	Aerial Applic?	Stump Cut?	Basal bark Application
Arsenal®	Imazapyr	IPA-salt	Caution	No	Yes	Yes	Yes	No
Garlon3A®	Triclopyr	Amine	Danger	No (applied for)	Yes	No	Yes	Yes
Garlon4®	Triclopyr	Ester	Caution	No	Yes	No	Yes	Yes
PathfinderII®	Triclopyr	Ester	Caution	No	No	No	Yes	Yes
Rodeo®	Glyphosate	IPA-salt	Caution	Yes	Yes	Yes	Yes	No
Roundup®	Glyphosate	IPA-salt	Caution	No	Yes	Yes	Yes	No

Sisneros (1991) reviewed herbicide control of tamarisk. Although this reference is a bit dated, it contains much information about toxicity, application methods, advantages and limitations of specific herbicides, and label data. He noted that Garlon® formulations are among the safest herbicides for mammals and other organisms, although Garlon4® is toxic to fish. Triclopyr, the active ingredient in all the Garlon® formulations decomposes rapidly after application, in less than one day in water and between 2 to 8 weeks in soil. Triclopyr will not kill grasses but it will kill native trees and shrubs.

CONTROL WITH CUTTING

A single cutting of tamarisk is ineffective, because tamarisks resprout vigorously. However, cutting combined with herbicide treatment can be very effective at controlling tamarisk, as noted above. Cutting tamarisk can reduce consumption of ground water, through reduction of transpiring leaves. Van Hylckama (1974) found that cutting tamarisk back from 3 m to 0.5 m reduced water consumption by 50%.

Burke (1990) found that scraping a site along the shore of Lake Mead with a bulldozer killed some tamarisk plants, but that many resprouted from roots that remained in the soil. Subsequent trampling from people and crushing by cars killed many of the resprouts. Also at Lake Mead, Luttrell (1983) found that a single cutting or burning would not kill tamarisk, but that repeated cutting and burning might kill the root system.

Coffey (1990) reported that Joshua Tree National Park did not use herbicide to control tamarisk, which grows primarily around isolated springs. Rather, they planned to cut tamarisk plants and burn the slash in the winter when seeds are not present on the plants. In the one burn conducted, all tamarisk was reportedly killed. Coffey (1990) noted that the success of burning may reflect the very dry conditions under which the tamarisk plants were growing.

Root plowing has been used to control tamarisk. It is important that the root plow cut the tamarisk root crowns well below the soil surface, e.g., 0.3 - 1.0 m. Root plowing works best during hot, dry conditions that help dry the cut roots. Root fragments left in the ground will often resprout after root plowing, necessitating follow-up treatment, either with hand-grubbing resprouts or spraying them with imazapyr or triclopyr. Root plowing is appropriate for large, dense stands that have little or no native vegetation and where prescribed burning and/or aerial application of herbicide is not feasible. Root plowing was used to clear about 5000 hectares of tamarisk along the Rio Grande River in central New Mexico (Weeks et al. 1987).

Cinnamon (1990) tried cutting tamarisk stems with a weed-eater, followed by application of triclopyr herbicide to the cut stems, but found this method ineffective. Small stems became tangled in the weed-eater and the person following the weed-eater could not locate all the cut stems to treat with herbicide.

CONTROL WITH GRAZING, DREDGING AND DRAINING

Tamarisk is able to extract water from deeper in the soil profile than the native species of cottonwood and willow. Therefore, draining and dredging that lead to local declines in water table depth could promote tamarisk at the expense of desirable native plants, rather than discourage tamarisk.

Cattle (and probably goats) will eat tamarisk, but grazing alone is probably not a feasible control method. However, goats might be able to control dense stands of tamarisk where little native vegetation is present, particularly if the stands are cut or burned first, with goats eating the regrowth.

CONTROL WITH MOWING, DISKING AND PULLING

Mowing might be a useful way to reduce the volume of tamarisk prior to treatment with herbicide, especially in relatively level sites where prescribed burning is not feasible. Hand pulling can be an effective way to control tamarisk in situations where the plants are small, where access is difficult, or where herbicides cannot be used. For example, hand pulling has been used to control new tamarisk plants around isolated desert springs in national parks after the larger tamarisk plants have been killed.

CONTROL WITH PLASTIC SHEETING

I found no references to controlling tamarisk with plastic sheeting. It does not appear to be a promising control technique due to the relatively fragile nature of plastic coupled with the periodic flooding that occurs in typical tamarisk habitat.

MONITORING REQUIREMENTS

A key shortcoming of many tamarisk control programs is the failure to systematically assess the efficacy of control efforts. Without such data, it is impossible to objectively gauge the value of control efforts.

There are several elements of a typical monitoring program. First, management objectives must be developed. For example, how much tamarisk is to be eliminated over what area? Second, monitoring objectives must be prepared based on the management objectives. For example, what is the minimum amount of change that you want to be able to detect and how sure do you want to be of detecting it (Elzinga et al. 1998)? Third, contingency plans must be developed and ready to be implemented in case monitoring indicates the management objectives are not met. The objectives will serve as the basis for a monitoring plan that sets forth in considerable detail the actions to be taken.

Tamarisk monitoring programs would likely involve documenting the presence, absence or abundance (e.g., canopy coverage) of tamarisk in key locations such as springs. In addition, abundance data for desirable plants could be useful if the control method might have adverse effects on those species. Certain animal species might be monitored if increases or decreases in their populations were management objectives.

Once control measures are initiated, the success or failure of the control measures should be monitored. The particulars of the monitoring program would be dictated by the management and monitoring objectives. Considerations such as the number, dispersion, size, shape, and location of sampling units; response variables for which data will be collected; frequency of data collection; whether temporary or permanent sampling units will be used; methods of data analysis; and storage protocol for data need to be considered. A useful reference for developing monitoring programs is the Bureau of Land Management's Technical Reference titled "Measuring and Monitoring Plant Populations" which was developed in conjunction with the U. S. Forest Service and The Nature Conservancy (Elzinga et al 1998).

MONITORING PROCEDURES

Everitt et al. (1996) developed a procedure using data collected with standard video from a fixed-wing aircraft in conjunction with a geographical information system (GIS) and a global positioning system (GPS) to map locations of tamarisk infestations along rivers. Managers could use such data to develop regional maps of tamarisk occurrences to help identify areas where monitoring and management would be most fruitful. The aerial images could also be used to monitor future contraction or expansion of tamarisk occurrences. Data from large areas could be obtained relatively inexpensively using this approach.

MONITORING PROGRAMS

I found little published information on monitoring programs. It appears that many management programs aimed at controlling tamarisk involve little or no systematic attempt to assess the efficacy of control treatments. Where monitoring has been attempted, it has usually been designed to assess the percentage of tamarisk clumps that are killed by the treatment(s). Descriptions of monitoring programs are typically very sketchy with little or no information provided about management or monitoring objectives, contingencies in case objectives are not achieved, sample sizes, sample allocation, frequency of data collection, etc. Several managers noted the absence or uncertainty of funding to support monitoring programs. It appears that many land managers would plan and initiate monitoring programs for tamarisk control if funds were available.

A notable exception to the general lack of monitoring is the work of Egan and his colleagues in BLM (Egan 1997; Egan 1997; West 1996; Chavez 1996) at the Afton Canyon Area of Critical Environmental Concern (ACEC) near Barstow, California. They established goals for the project: control alien plants; restore critical native plant community elements over 280 hectares of degraded riparian habitat; and improve the proper functioning condition rating of the Mojave River (which flows through the site) from non-functioning to functioning at risk. Managers developed two monitoring approaches for tamarisk. They established a total of six permanent, 2 m x 2 m photoplots across young, medium and old age tamarisk stands. In the photoplots, they visually estimated cover of tamarisk, bare soil, grass/forb and standing dead classes. Data were collected prior to treatment, shortly following treatment, after a flood (year 2), and during the second and fifth growing seasons following treatment. Egan and his colleagues also established six permanent transects, each 400 to 800 m long, which spanned the riparian area. Along each transect, they positioned between 113 and 178 frames, each 0.5 m x 0.5 m, in which they collected cover data of key riparian species. Data were collected two years prior to treatment and in the second and fifth growing seasons following treatment. Egan (1997) presented the data graphically featuring mean values across years for various response variables, and painted a compelling picture that burning followed by spraying of the resprouts with herbicide had successfully controlled tamarisk (Egan 1997).

RESEARCH NEEDS

Bennett and Burke (1990) suggested several areas for research on the ecology of tamarisk:

- Determine the present distribution of tamarisk.
- Determine the susceptibility of native riparian vegetation communities to tamarisk invasion.
- Determine how to restore native vegetation in areas invaded by tamarisk.
- Determine the autecology of tamarisk species in the US, focusing on reproduction, seed viability, phenology, and ecological amplitude.
- Determine the synecology of riparian communities invaded by tamarisk, with particular attention to soils, birds and mammals.
- Develop a standard protocol for testing herbicide effectiveness
- Determine effectiveness of herbicide control under various conditions.
- Compare the effectiveness of mechanical, herbicide and combination control programs.
- Develop a biological control program.

Brown and Johnson (1990) suggested that the relatively high value of tamarisk habitat in Grand Canyon National Park and elsewhere needs to be confirmed. Determining and rationalizing patterns of biodiversity that occur with and without tamarisk was also suggested.

Everitt (1980) suggested an interdisciplinary approach to understanding tamarisk. Issues warranting attention included the relative water use by tamarisk and native riparian communities; relationships between tamarisk invasion and alteration of hydrologic processes; relationships between tamarisk and changes in channel width, sedimentation, flow velocity, and flood hazard.

Van Hylckama (1974) stated that a satisfactory way was needed to express water use in relation to tamarisk stand density, thus being able to predict water use from measurements of selected attributes of vegetation (and a few other climatological and meteorological factors). Possibly, recent work of Gay (1990) might be an appropriate solution. Sala et al. (1996) suggested comparative studies of water use by different riparian communities; they also suggested research on structural data from riparian communities (leaf area index, aerial extent, plant species composition) and how this relates to water use in monotypic stands of deep-rooted plants (phreatophytes), like tamarisk.

Studies of the impacts of tamarisk control, particularly biocontrol, on native plants and animals are also needed.

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Appendix C

Pending Federal Legislation on Tamarisk Control

AMENDMENT IN THE NATURE OF A SUBSTITUTE
TO H.R. 2707
OFFERED BY ____________

Strike all after the enacting clause and insert the following:

SECTION 1. SHORT TITLE.

This Act may be cited as the ‘‘Salt Cedar and Russian Olive Control Assessment and Demonstration Act.”

SEC. 2. ASSESSMENT OF SALT CEDAR AND RUSSIAN OLIVE INFESTATION IN WESTERN UNITED STATES.

(a) ASSESSMENT.—Not later than one year after the date on which funds are first made available to carry out this section, the Secretary of the Interior, in consultation with the Secretary of Agriculture (in this Act referred to 9 as the ‘‘Secretaries’’), shall complete an assessment of the extent of Salt Cedar and Russian Olive invasion in the Western United States.

(b) CONTENT.—The assessment shall include the following:

(1) To the extent practicable, documentation of the quantity of water lost due to the infestation.

(2) Documentation of the quantity of water saved due to various control methods, including the portion of saved water that returns to surface water or groundwater supplies and at what rates.

(3) Determination of the optimum control method for the various land types and land uses.

(4) Determination of what conditions indicate the need to remove such growth and the optimal methods for disposal or use of such growth.

(5) The methods to prevent re-growth and reintroduction of these invasive species.

(c) REPORT ON ASSESSMENT.—

(1) PREPARATION AND CONTENT.—The Secretaries shall prepare a report containing the results of the assessment. The report shall identify long- term management and funding strategies that could be implemented by Federal, State, Tribal, and private land managers and

owners on all land management types to address the invasion of Salt Cedar and Russian Olive. The report shall also identify deficiencies or areas for further study and where actual field demonstrations would be useful in the control effort.

(2) SUBMISSION.—The Secretaries shall submit the report to the Committee on Resources and the Committee on Agriculture of the House of Representatives and the Committee on Agriculture, Nutrition, and Forestry and the Committee on Energy and Natural Resources of the Senate.

(d) SUPPORT FOR IDENTIFICATION OF LONG-TERM MANAGEMENT AND FUNDING STRATEGIES.—The Secretaries may make grants to institutions of higher education or nonprofit organizations (or both) with an established background and expertise in the public policy issues associated with the control of Salt Cedar and Russian Olive to obtain technical experience, support, and recommendations related to the identification of the long-term management and funding strategies required to be included in the report under subsection (c)(1). Each grant awarded under this subsection may not be less than $250,000.

(e) WESTERN UNITED STATES DEFINED.—In this section and section 3, the term ‘‘Western United States’’ refers to the States defined by the 1902 Reclamation Act 16 (43 U.S.C. Chapter 12), which includes Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Kansas, Oklahoma, Nevada, New Mexico, Oregon, Texas, Utah, Washington, and Wyoming.

SEC. 3. DEMONSTRATION PROGRAM FOR CONTROL OF SALT CEDAR AND RUSSIAN OLIVE IN WESTERN STATES.

(a) DEMONSTRATION PROJECTS.—

(1) PROJECTS REQUIRED.—Based on the results of the assessment and report in section 2, the Secretaries shall initiate a program of not fewer than three demonstration projects in the Western United States designed to address the deficiencies and areas for further study to address the invasion of Salt Cedar and Russian Olive, including the test of additional control methods, identified by the report.

(2) IMPLEMENTATION.—The Secretaries may enter into an agreement with a State in the Western United States to carry out a demonstration project. f the Secretaries select a demonstration project for implementation on National Forest System lands, the Secretary of Agriculture shall be responsible for implementation of the project.

(b) ELEMENTS OF PROJECTS.—

(1) DESIGN AND SCALE.—Each demonstration project shall be designed with integrated methods and adaptive management strategies and carried out over time frames and spatial scales large enough to accomplish the goals laid out in the report.

(2) SCIENTIFIC REVIEW.—Before being carried out, the methods and strategies proposed for each demonstration project shall be subject to review by scientific experts, including non-Federal experts, selected by the Secretaries. The Secretaries may use existing scientific review processes to the extent they comply with this requirement.

(c) PROJECT COSTS AND COST SHARING.—The total cost of each demonstration project may not exceed $7,000,000, including the costs of planning, design, implementation, revegetation, maintenance, and monitoring. In the case of a demonstration project conducted on lands under the jurisdiction of the Secretary of the Interior or the Secretary of Agriculture, the Secretaries may accept, but not require, funds or in-kind contributions, including State agency provided services. The Federal share of the costs of any activity on private lands funded under the project shall be no more than 75 percent of the total cost of the activity.

(d) REPORTING REQUIREMENT.—During the period in which the demonstration projects are carried out, the Secretaries shall submit to the congressional committees specified in section 2(c)(2) an annual report describing—

(1) the demonstration projects;

(2) the progress made in carrying out the projects during the period covered by the report; and

(3) the costs of the projects under subsection (c).

(e) MONITORING.—Demonstration projects shall include the following:

(1) Documentation of the quantity of water saved due to various control methods, including the portion of water saved that returns to surface water or groundwater supplies and at what rates.

(2) Optimal re-vegetative states to prevent regrowth and reintroduction of Salt Cedar and Russian Olive.

(f) COOPERATION.—The Secretaries shall use the expertise of their various agencies, as well as other Federal agencies, institutions of higher education, State and local governments and political subdivisions thereof, including soil and water conservation districts, and Indian tribes, which are actively conducting assessments on or implementing Salt Cedar and Russian Olive control activities.

SEC. 4. RELATION TO OTHER AUTHORITY.

Nothing in this Act shall be construed to affect, or otherwise bias, the use by the Secretaries of other statutory or administrative authorities to plan or conduct Salt Cedar or Russian Olive control and eradication that is not planned or conducted under this Act.

SEC. 5. AUTHORIZATION OF APPROPRIATIONS.

(a) ASSESSMENT.—There are authorized to be appropriated to the Secretaries $5,000,000 for fiscal year 2004 to conduct the assessment required by section 2.

(b) GRANTS.—There are authorized to be appropriated to the Secretaries $1,000,000 for fiscal year 2004 to award as grants under section 2(d).

(c) DEMONSTRATION PROJECTS.—There are authorized to be appropriated to the Secretaries $25,000,000 for each of the fiscal years 2005 through 2010 to carry out the program of demonstration projects under section 3. Amend the title to read as follows: ‘‘A Bill to provide for an assessment of the extent of the invasion of Salt Cedar and Russian Olive on lands in the Western United States and efforts to date to control such invasion on public and private lands, including tribal lands, and to direct the Secretary of the Interior, in consultation with the Secretary of Agriculture, to carry out a demonstration program to address any shortcomings in current control efforts, and for other purposes.’’

S 1516 IS

108th CONGRESS
1st Session
S. 1516

To further the purposes of the Reclamation Projects Authorization and Adjustment Act of 1992 by directing the Secretary of the Interior, acting through the Commissioner of Reclamation, to carry out an assessment and demonstration program to assess potential increases in water availability for Bureau of Reclamation projects and other uses through control of salt cedar and Russian olive.

IN THE SENATE OF THE UNITED STATES
July 31 (legislative day, JULY 21), 2003

Mr. DOMENICI (for himself and Mr. CAMPBELL) introduced the following bill; which was read twice and referred to the Committee on Energy and Natural Resources.

A BILL

To further the purposes of the Reclamation Projects Authorization and Adjustment Act of 1992 by directing the Secretary of the Interior, acting through the Commissioner of Reclamation, to carry out an assessment and demonstration program to assess potential increases in water availability for Bureau of Reclamation projects and other uses through control of salt cedar and Russian olive.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the ‘Salt Cedar Control Demonstration Act.’

SEC. 2. FINDINGS.

Congress finds that--

(1) the western United States is currently experiencing its worst drought in modern history;

(2) it is estimated that throughout the western United States salt cedar and Russian olive--

(A) occupy between 1,000,000 and 1,500,000 acres of land; and

(B) are non-beneficial users of 2,000,000 to 4,500,000 acre-feet of water per year;

(3) the quantity of non-beneficial use of water by salt cedar and Russian olive is greater than the quantity that valuable native vegetation would use;

(4) much of the salt cedar and Russian olive infestation is located on Bureau of Land Management land or other land of the Department of the Interior; and

(5) as drought conditions and legal requirements relating to water supply accelerate water shortages, innovative approaches are needed to address the increasing demand for a diminishing water supply.

SEC. 3. SALT CEDAR AND RUSSIAN OLIVE ASSESSMENT AND DEMONSTRATION PROGRAM.

(a) ESTABLISHMENT- In furtherance of the purposes of the Reclamation Projects Authorization and Adjustment Act of 1992 (106 Stat. 4600), the Secretary of the Interior, acting through the Commissioner of Reclamation (referred to in this Act as the `Secretary'), shall carry out a salt cedar and Russian olive assessment and demonstration program to--

(1) assess the extent of the infestation of salt cedar and Russian olive in the western United States; and

(2) develop strategic solutions for long-term management of salt cedar and Russian olive.

(b) ASSESSMENT- Not later than 1 year after the date on which funds are made available to carry out this Act, the Secretary shall complete an assessment of the extent of salt cedar and Russian olive infestation in the western United States. The assessment shall--

(1) consider past and ongoing research on tested and innovative methods to control salt cedar and Russian olive;

(2) consider the feasibility of reducing water consumption;

(3) consider methods of and challenges associated with the restoration of infested land;

(4) estimate the costs of destruction of salt cedar and Russian olive, biomass removal, and restoration and maintenance of the infested land; and

(5) identify long-term management and funding strategies that could be implemented by Federal, State, and private land managers.

(c) DEMONSTRATION PROJECTS- The Secretary shall carry out not less than 5 projects to demonstrate and evaluate the most effective methods of controlling salt ceder and Russian olive. Projects carried out under this subsection shall--

(1) monitor and document any water savings from the control of salt cedar and Russian olive;

(2) identify the quantity of, and rates at which, any water savings under paragraph (1) return to surface water supplies;

(3) assess the best approach to and tools for implementing available control methods;

(4) assess all costs and benefits associated with control methods and the restoration and maintenance of land;

(5) determine conditions under which removal of biomass is appropriate and the optimal methods for its disposal or use;

(6) define appropriate final vegetative states and optimal revegetation methods; and

(7) identify methods for preventing the regrowth and reintroduction of salt cedar and Russian olive.

(d) CONTROL METHODS- The demonstration projects carried out under subsection (c) may implement 1 or more control method per project, but to assess the full range of control mechanisms--

(1) at least 1 project shall use airborne application of herbicides;

(2) at least 1 project shall use mechanical removal; and

(3) at least 1 project shall use biocontrol methods such as goats or insects.

(e) IMPLEMENTATION- A demonstration project shall be carried out during a time period and to a scale designed to meet the requirements of subsection (c).

(f) COSTS-

(1) IN GENERAL- Each demonstration project under subsection (c) shall be carried out at a cost of not more than $7,000,000, including costs of planning, design, implementation, maintenance, and monitoring.

(2) COST-SHARING-

(A) FEDERAL SHARE- The Federal share of the costs of a demonstration project shall not exceed 75 percent.

(B) FORM OF NON-FEDERAL SHARE- The non-Federal share of the costs of a demonstration project may be provided in the form of in-kind contributions, including services provided by a State agency.

(g) COOPERATION- In carrying out the program, the Secretary shall--

(1) use the expertise of Federal agencies, national laboratories, Indian tribes, institutions of higher education, State agencies, and soil and water conservation districts that are actively conducting research on or implementing salt cedar and Russian olive control activities; and

(2) cooperate with other Federal agencies and affected States, local units of government, and Indian tribes.

SEC. 4. AUTHORIZATION OF APPROPRIATIONS.

There are authorized to be appropriated to carry out this Act--

(1) $50,000,000 for fiscal year 2004; and

(2) such sums as are necessary for each fiscal year thereafter.

END