Colorado Headwaters Invasives Partnership

A Consolidated Woody Invasive Species Management Plan for Colorado's Colorado, Gunnison, Uncompahgre, Dolores, White, and Yampa/Green Watersheds

Revised July 2008

Colorado River in Horsethief Canyon – mixed tamarisk, willow, and cottonwood.

Prepared by
Colorado River Water Conservation District
The Nature Conservancy
Tamarisk Coalition

A Joint Effort

The Colorado Headwaters Invasives Partnership (CHIP) was prepared with the input of a multitude of partners from over a dozen counties in western Colorado representing state and federal agencies, local communities, private landowners, industry, and non-governmental organizations (NGOs). Seven river systems comprising the bulk of the Colorado River's western Colorado headwaters are included in this comprehensive plan; the upper Colorado River, the Gunnison River, the Uncompahgre River, the Dolores River, and in this amended version of the plan, the White River, the Yampa River, and the Green River. This partnership was led by the Colorado River Water Conservation District and The Nature Conservancy with the Tamarisk Coalition providing staff to assemble the plan based on inputs from the other partner organizations. Funding to develop the Plan was provided through the Colorado Department of Local Affairs, Colorado Water Conservation Board, Mesa County, Garfield County, Delta County, Grand Junction, Glenwood Springs, Fruita, Palisade, The Nature Conservancy, EnCana Energy, and William's Energy. Funding for the comprehensive tamarisk inventory and mapping was provided by the Colorado Water Conservation Board. Endorsement of this plan by the CHIP partners in no way limits any government's, agency's, industry's, landowner's, or organization's existing legal authority or responsibilities.

The Plan is provided in two parts – the body of the CHIP Plan contained herein and the comprehensive tamarisk inventory and mapping Data-DVD located in the back of the Plan.

For more information on the CHIP Plan, contact the Tamarisk Coalition
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Executive Summary

In September 2005 a partnership formed to develop a strategic plan for the Colorado River's riparian areas impacted by non-native invasive trees, principally tamarisk (*Tamarix* spp., aka salt cedar) and Russian olive (*Elaeagnus angustifolia*). This partnership, known as the Colorado Headwaters Invasives Partnership (CHIP), was initiated in Garfield County through the leadership of the Colorado River Water Conservation District and The Nature Conservancy. In response to this progressive leadership the eight counties in the Gunnison/Uncompaghre and Dolores Watersheds began preparing their own woody invasive species watershed restoration plans patterned after the work performed on the Colorado River plan. During the spring of 2008, the White and Yampa/Green Watersheds completed work on their woody invasive species watershed restoration plans. These Colorado headwater initiatives are complemented by the planning efforts of the Southeastern Utah Tamarisk Partnership downstream on the Colorado River and of the 4-state, 5-Indian nation San Juan Watershed Woody Invasives Initiative Plan. State and federal agencies, local communities, private landowners, industry, and non-governmental organizations (NGOs) have cooperated to draft these plans. The Tamarisk Coalition provided the staff to assemble the plan.

CHIPs vision is an overall Colorado River watershed restored as a thriving and diverse riparian ecosystem containing minimal infestations of non-native invasive species.

Tamarisk and Russian olive, while not the only non-native invasive species present nor the only problems impacting riparian areas, serve as the "poster children" for gaining public support and future restoration funding.

The CHIP planning area was developed geographically to focus on the Colorado River mainstem from the continental divide to the CO/UT state line. As development of the CHIP plan proceeded, it became evident that the other watersheds of the Colorado River; such as the Gunnison & Uncompahgre, Dolores, White, and Yampa/Green in addition to the portion of the San Juan Woody Invasives Initiative Plan in Colorado (all 4-corner states are partners in this plan) could form a comprehensive approach for the entire Western Slope of Colorado. As a result of strong local initiatives, the Gunnison & Uncompahgre and Dolores River invasive species plans were complete enough to be included in this document. CHIP participants for the Yampa/Green and White rivers have since completed invasive species plans included in this amended version of the document. Thus, the CHIP plan represents the fundamental backbone for riparian restoration throughout western Colorado. To have a complete assessment of the Dolores River watershed, the CHIP plan includes those tributaries and the main stem within Utah.

The CHIP plan is structured around a set of Guiding Principles focusing on ecological, social-cultural, economic, education, and research considerations. In summary, the Guiding Principles recognize that successful riparian restoration must include: 1) all restoration components – planning and design, control, revegetation, biomass reduction, monitoring, and long-term maintenance; 2) respect for private property rights, state water rights, existing infrastructure, and endangered species; 3) education to gain public support and funding; 4) research to identify the most effective and efficient techniques for restoration through the practice of "adaptive management"; and 5) partnerships to optimize and leverage existing and future funding.

The CHIP plan is a collaborative document to assist in the development and implementation of future, objectives driven restoration designs for each area within the watershed impacted by tamarisk and Russian olive. **The CHIP plan is not a site-specific design for restoration.** Rather, the CHIP plan functions as the backbone of future riparian restoration work. It is also designed to complement and integrate adjacent planning efforts on the Colorado River watershed in Utah and the San Juan River watershed in the four corners area.

The **Goals** of CHIP are to 1) provide a mechanism for communication and coordination among diverse parties and land managers throughout the watershed, and 2) develop a strategy pairing timely and cost effective riparian restoration with well designed monitoring and maintenance processes.

The long-term **Objectives** of CHIP are to 1) control tamarisk and Russian olive infestations while reestablishing sustainable native plant and animal communities; 2) maintain information databases such as partnerships, funding and intellectual resources, infestations, volunteer efforts, on-the-ground project areas, and monitoring and maintenance actions; and 3) support strong localized leadership and initiative to successfully realize our vision.

Colorado's federal and state legislators recognize that tamarisk, Russian olive, and other non-native plants are severely impacting the health of Colorado's river systems. These impacts degrade water resources, agricultural value, recreational use, and wildlife habitat. These political leaders have taken positive steps to help solve this problem with legislation to fund control and revegetation efforts through Public Law 109-320.

Tamarisk infestations within the CHIP area occur primarily in the following locations:

Colorado River: The majority of tamarisk infestations in the Colorado River study area are located in Garfield and Mesa counties below 6,500 feet in elevation. Russian olive occupies a similar range although both species occur in isolated pockets at higher elevations. Tamarisk is the invasive species that predominates in most riparian habitats along the Colorado River. Tamarisk infests approximately 7,500 acres on the 200 miles of the Colorado River and its tributaries mapped and inventoried by the Colorado Water Conservation Board in 2006. Presence of Russian olive was recorded during this same period.

Gunnison & Uncompahgre Rivers: Tamarisk infestations within the Gunnison & Uncompahgre Rivers study area occur primarily in Mesa, Delta, and Montrose counties below 6,500 feet in elevation. Russian olive occupies a similar range although both species occur in isolated pockets at higher elevations. Tamarisk is the invasive species that predominates in most riparian habitats along both the Gunnison and Uncompahgre

Rivers. Tamarisk infests approximately 3,300 acres on the Gunnison River and 1,500 on the Uncompahgre River and their respective tributaries with Russian olive comingled through much of these same areas as mapped and inventoried by the Colorado Water Conservation Board in 2006.

Dolores River: Tamarisk infestations within the Dolores River study area occur primarily below 6,500 feet in elevation in Mesa, Montrose, San Miguel, Dolores, and Montezuma counties in Colorado, and Grand and San Juan counties in Utah. Russian olive is very sparse within the watershed. Tamarisk is the invasive species that predominates in most riparian habitats along the Dolores River. Tamarisk infests approximately 3,200 acres on the Dolores River and its respective tributaries in Colorado.

White River: The majority of tamarisk infestations in the White River study area are located in Rio Blanco County below 6,500 feet in elevation. Tamarisk is the invasive species that predominates in most riparian habitats along the White River. Russian olive occupies a similar range and is the invasive species that predominates lower in the watershed with isolated pockets at higher elevations. Tamarisk infests approximately 2,600 acres and Russian olive infests approximately 1,200 acres on the 105 miles of the White River and its tributaries mapped and inventoried by the Colorado Water Conservation Board in 2006.

Yampa/Green River: Tamarisk infestations within the Yampa River study occur primarily below 6,500 in elevation in Moffat County. The Routt Invasive Plant Posse has largely eliminated tamarisk from Routt County. Russian olive occupies a similar range although both species occur in isolated pockets at higher elevations. A team from Utah State University inventoried and mapped tamarisk infestations on the Yampa and a portion of the Green River in the Dinosaur National Monument in 2006. Along the areas inventoried tamarisk infests approximately 250 acres and Russian olive infests approximately 200 acres. No detailed surveys have been performed for the short section of the Green River within Colorado outside of the Monument's boundary.

Tamarisk and Russian olive infestations inflict the following estimated current net water loss in the state of Colorado:

- Colorado River system – approximately 8,000 acre-feet per year.
- Gunnison River system – approximately 2,400 acre-feet per year.
- Uncompahgre River system – approximately 700 acre-feet per year.
- Dolores River system – approximately 3,000 acre-feet per year.
- White River system – approximately 3,750 acre-feet per year.
- No estimates were made for the Yampa/Green River system.

If no actions are taken, these water losses and other ecosystem degradations have the potential of expanding significantly in the future.

Control of tamarisk and Russian olive in the watershed will utilize a full suite of techniques ranging from hand control to mechanical treatment. A promising method for tamarisk control is biological control using the tamarisk leaf beetle *Diorhabda elongata* from Asia. This insect species has been tested extensively in quarantine and field releases to ensure safety with respect to non-target species impacts. These insects have been approved for open release in Colorado and are being closely monitored by the Colorado Department of Agriculture's Palisade Insectary and entomologists at Colorado State University. Recent results from the Moab, Utah area indicate that tamarisk biological control could be successful on a large-scale. Among many benefits, biological control provides a cost advantage and greatly reduces herbicide use.

Overall costs for tamarisk and Russian olive control restoration for these rivers are approximately:

Colorado River:

1. $8,000,000 for the Colorado River mainstem and its major tributaries from the Glenwood Springs area to the CO/UT state line. To account for unsurveyed sites, an extra 20 percent contingency should be added.

2. Average costs per acre are approximately $1,000 and costs per mile are approximately $52,000 for the Colorado main stem and $13,000 for tributaries. These costs include planning/design, control, revegetation, biomass reduction, monitoring, and long-term maintenance.

Gunnison & Uncompahgre Rivers:

1. $3,300,000 for both the Gunnison and Uncompahgre Rivers and their major tributaries. To account for unsurveyed sites, an extra 20 percent contingency should be added.

2. Average costs per acre are approximately $700 and costs per mile are approximately $25,000. These costs include planning/design, control, revegetation, biomass reduction, monitoring, and long-term maintenance.

Dolores River:

1. $3,200,000 for the Dolores River and its major tributaries. To account for unsurveyed sites, an extra 20 percent contingency should be added.

2. Average costs per acre are approximately $1,000 and costs per mile are approximately $23,000. These costs include planning/design, control, revegetation, biomass reduction, monitoring, and long-term maintenance.

White River:

1. $3,750,000 for the White River and its major tributaries. To account for unsurveyed sites, an extra 20 percent contingency should be added.

2. Average costs per acre are approximately $1,000 and costs per mile are approximately $36,000. These costs include planning/design, control, revegetation, biomass reduction, monitoring, and long-term maintenance.

Yampa/Green River system:

No specific cost analysis was performed for the 450 acres of tamarisk and Russian infestation mapped by Dinosaur National Monument. However, assuming an average cost of approximately $1,000 per acre is typical for the other Colorado River watershed river systems, the restoration costs for the Yampa/Green watershed should approach $500,000.

Expected conditions following tamarisk and Russian olive control and restoration projects in the Colorado River watershed include improved aquatic, riparian, and floodplain habitat. This will result in increased habitat for fish and wildlife including endangered fish species. Opportunities for environmental education, improved aesthetics, recreation, agricultural use, and improved management of flood flows would exist in project areas. Significant conservation of water resources would also result from tamarisk and Russian olive control.

The CHIP plan lays out a specific “path forward” to implement the plan which includes the following six “Actions” as collaborative efforts between the various partners, with a lead organization and time line identified:

Action #1 – Develop a GIS dataset of land ownership for the riparian corridor impacted by the target invasive species. Establish a simple clearinghouse system so that all parties are aware of grant opportunities by December 2008. Identify a prioritization system that could be used to screen grants and appropriate locations for restoration work.

Colorado River: Mesa and Garfield counties.

Gunnison & Uncompahgre Rivers: Mesa, Delta, and Montrose counties.

Dolores River: Colorado (5) and Utah (2) counties.

White River: Rio Blanco County.

Yampa/Green River: Routt and Moffat counties.

Action #2 – Develop educational and outreach programs for local communities and visitors to the area. Some of the key elements of the program may include a “frequently asked questions” brochure, fact sheets, display boards with historical photos, river guide training on riparian issues, presentations to service groups, and demonstration sites that can be used for tours.

All watersheds: Tamarisk Coalition, July to December 2008

Action #3 – Enhance volunteer project opportunities by developing a volunteer "lessons learned" pamphlet to help others develop their own volunteer program, identify good volunteer projects, and pool resources for volunteer projects.

All watersheds: Tamarisk Coalition, July to December 2008

Action #4 – Establish a working group to develop a functioning long-term monitoring and maintenance program that crosses political jurisdictions.

All watersheds: Colorado River Water Conservation District to organize working group, complete by June 2009

Action #5 – Establish a working group to coordinate with the Palisade Insectary, CSU, Mesa State College, University of Denver, Bureau of Land Management, and the Tamarisk Coalition to identify specific research needs for the area, to utilize their and other CHIP research skills, and to ensure information sharing in the CHIP watershed.

All watersheds: Tamarisk Coalition to organize working group by December 2008

Action #6 – The partners in CHIP should work together to continue to support and leverage existing projects to gain additional funding resources. An example will be funding derived from future federal programs under PL 109-320. An active Grants and Projects Committee will be established for each watershed by December 2008 to focus on grant opportunities and to communicate progress for active projects. The lead for developing the grant committees are:

Colorado River: Colorado Big Country RC&D to organize Grants Committee.

Gunnison & Uncompahgre Rivers: Painted Sky RC&D to organize Grants Committee.

Dolores River: Painted Sky RC&D to organize Grants Committee.

White River: Rio Blanco County Extension and Weed Department to organize Grants Committee.

Yampa River: Moffat and Routt County Weed Departments to organize Grants Committee.

Green River: BLM Little Snake Field Office, US Fish & Wildlife Service, and Dinosaur National Monument to organize a Grants Committee.

Introduction

Colorado Headwaters Invasives Partnership (CHIP) – In September 2005 a partnership formed to develop a strategic plan for the Colorado River's riparian areas impacted by non-native invasive trees, principally tamarisk (*Tamarix* spp., aka salt cedar) and Russian olive (*Elaeagnus angustifolia*). This partnership, known as the Colorado Headwaters Invasives Partnership (CHIP), was initiated in Garfield County through the leadership of the Colorado River Water Conservation District and The Nature Conservancy. Following this progressive leadership the eight counties in the Gunnison/Uncompaghre and Dolores Watersheds commenced preparations of their own woody invasive species watershed restoration plans in 2006 and 2007, patterned off the work performed on the Colorado River plan. During the spring of 2008 the White and Yampa/Green Watersheds completed work on their woody invasive species watershed restoration plans. These Colorado headwater initiatives are complemented by the planning efforts of the Southeastern Utah Tamarisk Partnership downstream on the Colorado River and of the 4-state, 5-Indian nation San Juan Watershed Woody Invasives Initiative Plan.

The ***Vision of CHIP is an overall Colorado River watershed restored as a thriving and diverse riparian ecosystem containing minimal infestations of non-native invasive species.***

These combined efforts have involved state and federal agencies, local communities, private landowners, industry, and non-governmental organizations (NGOs). The Tamarisk Coalition provided the staff to assemble the plan.

This planning effort, including a comprehensive tamarisk inventory/mapping component, was completed in July 2007 and revised in 2008 to reflect the addition of the White and Yampa/Green river watersheds. The plan guides restoration work for approximately 20,000 acres of tamarisk and Russian olive infested riparian lands on several hundred miles of riparian lands. The CHIP project area or portions of it could be an ideal large-scale demonstration project as it encompasses several critical watersheds has diverse landscape characteristics, is a significant cooperative conservation effort, and provides unique opportunities for field research.

The **Goals** of CHIP are to 1) provide a mechanism for communication and coordination among diverse parties and land managers throughout the watershed, and 2) develop a strategy pairing timely and cost-effective riparian restoration with well designed monitoring and maintenance processes.

The long-term **Objectives** of CHIP are to 1) control tamarisk and Russian olive infestations while reestablishing sustainable native plant and animal communities; 2) maintain information databases such as partnerships, funding and intellectual resources, infestations, volunteer efforts, on-the-ground project areas, and monitoring and maintenance actions; and 3) support strong localized leadership and initiative to successfully realize our vision.

The CHIP plan is divided into two distinct parts, the background describing the nature of the problem with recommendations for solutions and an implementation approach with specific actions.

The CHIP plan is a collaborative document to assist in the development and implementation of future, objectives driven restoration designs for each area within the watershed impacted by tamarisk and Russian olive. While not the only non-native invasive species present or the only problems impacting riparian areas, tamarisk and Russian olive serve as the "poster children" for gaining public support. **The CHIP plan is not a site-specific design for restoration.** These designs require restoration site assessment, site prioritization, site planning, pre- and post- management monitoring, and long-term maintenance. Rather, the CHIP plan functions as the backbone of future riparian restoration work.

Section 1 – Background

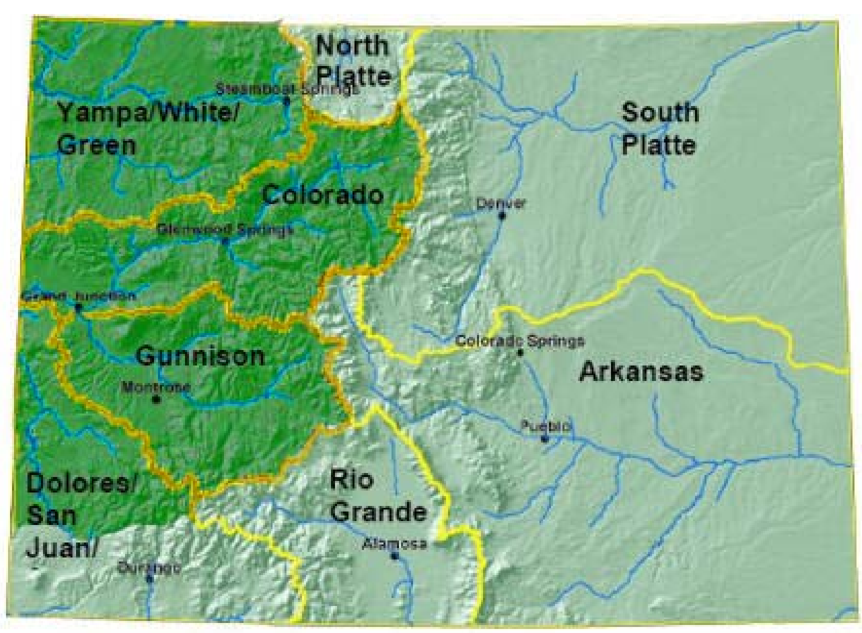
CHIP and How it Fits with Other Planning Efforts

Effective watershed management and invasive species control efforts rely on a coordinated approach that transcends artificial boundaries such as political jurisdictions. However, to get one's "arms around the problem" planning efforts are organized within the confines of political jurisdictions or at least reasonable land masses. The CHIP planning area was developed geographically to focus on the Colorado River mainstem from the continental divide to the CO/UT state line. As development of the CHIP plan proceeded, it became evident that the other watersheds of the Colorado River, such as the Gunnison & Uncompahgre, Dolores, White, and Yampa/Green rivers, could form a comprehensive approach for the entire Western Slope of Colorado.

As a result of strong local initiatives, the Gunnison & Uncompahgre and Dolores River invasive species plans were complete enough to be included in this document. The White and Yampa/Green Rivers have followed. Thus, the CHIP plan represents the fundamental backbone for riparian restoration throughout western Colorado.

Additionally, efforts downstream from the state line to Lake Powell on the Colorado River have been developed by The Southeast Utah Tamarisk Partnership. Other important watershed efforts have been completed on the San Juan River as well. All of these plans rely in some respect on the success of adjacent planning activities. The common thread among all of these invasive species/watershed efforts (see Figure 1) is the coordinating support being provided by the Tamarisk Coalition.

Figure 1: Colorado, Gunnison, Uncompahgre, Dolores, White, Yampa and Green Watersheds in Colorado



Partners

- Audubon Society
- Bureau of Reclamation
- Bureau of Land Management
- Cities and Towns
- Colorado Association of Conservation Districts and local member districts
- Colorado Big Country RC&D
- CO Department of Agriculture
- CO Department of Transportation
- CO Division of Wildlife
- CO Department of Natural Resources
- CO Department of Local Affairs
- CO River Water Conservation District
- Colorado Riverfront Commission
- CO State Parks
- Colorado State University
- CO Water Conservation Board
- Colorado Watershed Assembly
- Colorado counties of Delta, Dolores, Eagle, Garfield, Grand, Gunnison, Mesa, Montezuma, Montrose, Ouray, Pitkin, San Miguel, Summit, Routt, Moffat, and Rio Blanco
- Utah counties of Grand and San Juan
- EnCana Energy
- Mesa County Land Trust
- Mesa State College
- The Nature Conservancy
- Natural Resources Conservation Service
- National Park Service
- North Fork River Improvement Association
- Tamarisk Coalition
- US Forest Service
- US Fish and Wildlife Service
- Utah Division of Wildlife Resources
- Utah State University
- University of Utah
- Western Colorado Congress
- Williams Energy

Guiding Principles

Guiding principles provide the common ground, "the foundation," which can direct ecological restoration efforts into the future. These guiding principles reflect a broad agreement between CHIP partner organizations, agencies, communities, and individuals that are cooperating to develop this riparian management plan. These principles also reflect the priorities of many stakeholders in adjoining watersheds in both Colorado and Utah. These principles will be adjusted and changed as needed.

This community driven effort recognizes that tamarisk and associated non-native invasive plants cause economic and environmental harm, negatively affect public health and welfare, and require active long-term management programs with sustainable funding. Thus, the CHIP partners subscribe to the following guiding principles:

Ecological – Promoting ecological integrity, natural processes, and long term-resiliency is important for success.

a) Where appropriate, non-native invasive vegetation will be replaced with native plant species that can be self-sustaining.

b) Restoration will take into account the overall condition of the system, including presence of native species, species diversity, hydrologic regime, water quality, and wildlife habitat.

c) Best management practices utilizing Integrated Pest Management techniques will be used and, as research and experience dictates, updated through adaptive management.

d) Changes to hydrologic conditions can support native plant restoration efforts and will be considered, where possible, within the constraints of state and federal water law and the 1922 Colorado River Compact.

e) Efforts will be made to understand the historical, present, and future role of fire in riparian areas.

f) The removal of tamarisk and Russian olive overstory may promote the growth of other invasive plants. Management strategies will be developed to avoid additional noxious plant infestations.

g) Restoration and maintenance efforts will be monitored and evaluated on an ongoing basis to ensure effectiveness.

h) In some circumstances the protection of threatened and endangered species can be enhanced through well planned efforts to establish native riparian communities and restore natural processes. In areas of concern, threatened and endangered species surveys will be encouraged.

i) If no action is taken, tamarisk and associated non-native invasive plants will continue to spread and increase the environmental damage throughout the Colorado River watershed.

Social-Cultural – The values of the Colorado River watershed's diverse human communities will be supported and sustained by ecological restoration.

a) A comprehensive strategic approach throughout the watershed is important for success. However, the Colorado River, Gunnison River, Uncompahgre River, Dolores River, White River, Yampa/Green River watersheds are a mix of publicly managed lands, industry owned lands, and private property. Federal land management policy will be adhered to and private property rights, local customs, and local uses will be respected.

b) The Colorado, Gunnison, Uncompahgre, Dolores, White, and Yampa/Green rivers have been altered by human actions to improve their capability to store and supply water (e.g., dams, irrigation systems) for beneficial use. Tamarisk and Russian olive control and restoration can be performed without impeding these systems or uses. Effective control should result in greater stream flows for both human and environmental uses.

Economic – Economic productivity is dependent on healthy ecosystems and will be leveraged to full potential in support of long-term ecological health.

a) Existing frameworks of funding, technical assistance, and expertise will be identified, used, and publicized to optimize resources and maximize local effectiveness.

b) Partnerships will be developed to leverage existing and future funding.

c) Improvements to agricultural production will be supported by increasing grazing areas and accessibility to water for livestock and enhancing water resources for irrigation.

d) Tourism, rafting, hunting, and fishing are vital economic components of western Colorado, eastern Utah, and southwestern Wyoming. Visitors come from all over the state, the country, and the world to experience these recreational activities. Enhancing the visitor's experience and promoting a safe recreational experience is important.

e) Private sector involvement in restoration efforts can lead to employment and economic benefits to the local communities of western Colorado.

Education – Public education and outreach efforts will increase the understanding of the impacts from non-native invasive plants, safe methods for control, benefits of restoration, and the need for appropriate levels of funding to effectively control the problem.

a) Educational materials will be developed on all aspects of the restoration process. This is especially important and critical for the recent release of biological control agents.

b) Community outreach and volunteer efforts will be used to aid the public and land owners in gaining first-hand knowledge of the problem and establishing ownership of the solution.

c) Appropriate outreach will also be used to communicate successes and failures to other regions and the scientific community.

Research – Research can provide mechanisms to improve the effectiveness and efficiency of restoration actions.

a) Universities and federal and state agencies will be encouraged to use riparian restoration efforts along the Colorado, Gunnison, Uncompahgre, Dolores, White, Yampa/Green rivers as "living laboratories" to monitor changes and provide scientific support to enhance success.

b) To improve management decisions, data from inventories, monitoring, and control actions will be comparable (standardized and consistent) and shared at all levels.

c) Performance measures for all phases of the restoration effort will include quantifiable units (e.g., acres treated and restored, fuel reduction) leading to the long-term recovery of healthy, productive ecosystems.

Relevant Legislation and Government Actions

Colorado Governor Actions – In 2003 Governor Bill Owens issued Executive Order D-002-03 directing state agencies to coordinate efforts for the eradication of tamarisk on public lands (see Appendix A). As a result of the action, the Colorado Department of Natural Resources, in cooperation with the Department of Agriculture, completed the *10-Year Strategic Plan on the Comprehensive Removal of Tamarisk and the Coordinated Restoration of Colorado's Native Riparian Ecosystems, January 2004* (see "State Plans" at www.tamariskcoalition.org).

Colorado Legislation – House Bill 08-1346 was introduced in the 2008 session of the Colorado Legislature by Representative Kathleen Curry and Senator Jim Isgar, passed by both the House and Senate, and was signed by Governor Ritter on May 29th, 2008. The bill includes the establishment of a $1 million matching grant program through the Colorado Water Conservation Board (CWCB). CWCB's intent for these funds is:

1. Tamarisk and Russian olive control, revegetation, and monitoring to ensure successful restoration of riparian lands.
2. Local match of a minimum of one half of the costs of restoration as non-state cost-sharing, which may consist of in-kind and/or cash match.
3. Grants available to communities, conservation districts, non-profits, and other eligible entities through a competitive process with input from the Colorado Department of Agriculture.
4. A portion of the appropriated fund, not to exceed 10 percent, will be used for grant program administration, scientific research, and monitoring to better target projects and assess their effectiveness. The supervisory financial management role shall remain with the CWCB.
5. Use the Cost-sharing Grant Program as seed funds to take full advantage of other grant programs from Federal sources such as EPA, Corps of Engineers, and USDA; and from private foundations.

It is CWCB's intent that upon demonstration of the grant program's success, the CWCB will request additional funding in future fiscal years. Grant application rules are being developed now and should be available in the fall of 2008.

Federal Legislation – After 4 years of diligent work by the House and Senate, the *Salt Cedar and Russian Olive Control Demonstration Act* was signed into law by the President on October 11, 2006. It is referenced as HR2720 or Public Law 109-320 (see Appendix B). Colorado's congressional delegation was instrumental in its passage. Senators Wayne Allard and Ken Salazar, Congressmen John Salazar and Mark Udall, and former Congressman Scott McInnis were all involved as co-sponsors to make this law a reality. The principal components of the Act include:

- ✓ Authorization to fund $80 million for large-scale demonstrations and associated research over a five year period;
- ✓ Assessment of the tamarisk and Russian olive problem during the first year;
- ✓ Assessment of bio-mass reduction and utilization;
- ✓ Demonstration projects for control and revegetation that serve as research platforms to assess restoration effectiveness, water savings, wildfire potential, wildlife habitat, biomass removal, and economics of restoration;
- ✓ Project funding will be 75% federal and 25% local (cash and/or in-kind) with up to $7,000,000 per project for the federal share. Demonstration projects on federal lands and research will be funded at 100%;
- ✓ Development of long-term management and funding strategies; and
- ✓ Department of Interior will be the lead and will work with the USDA through a Memorandum of Understanding to administer the Act.

The next step in providing funding at the local level is the inclusion of appropriations to fully fund the Act in 2007. Several organizations and states are currently working with Interior and Congress on this measure.

California Legislation – On September 29, 2006, Governor Schwarzenegger signed Assembly Bill 984 into law (see Appendix C) which directs California state agencies to work with other Colorado River basin states to develop a comprehensive plan for tamarisk control and revegetation for the entire Colorado River system. Once the plan is completed, California will implement it upon the appropriation of funds. This provides a major step towards cooperative conservation – states and federal agencies working together to approach the problem on a watershed scale. The importance of this legislation for CHIP is that it sets precedence for all seven states within the Colorado River watershed to work together to strengthen the potential for long-term funding and success of tamarisk control and management.

Environmental Setting

Colorado River: The project area for the Colorado River watershed extends west from the continental divide to the Colorado/Utah state line. Terrain along this corridor progresses from the mountain passes of Grand, Summit, and Pitkin counties through the narrow walls of Gore, Glenwood, and DeBeque canyons to the braided channels and broad floodplain of the Grand Valley in the Grand Junction area. Vegetation surrounding this stretch of the Colorado River ranges from alpine evergreen communities to bunch grasses/sage/greasewood/rabbit brush communities and pinyon/juniper all adjacent to the riparian zone traditionally dominated by cottonwood and willow.

Tamarisk infestations occur primarily in the latter habitat, beginning in Garfield County, generally below 6,500 feet in elevation. There are isolated pockets at higher elevations such as Wolford Mountain reservoir but at these elevations more precipitation occurs and thus, tamarisk tends to be less competitive with native species. The majority of tamarisk infestations can be found within the riparian corridor stretching to the extent of the 100 year floodplain. Side canyons, perennial and ephemeral streams, and tributaries support isolated stands of tamarisk. Upland tamarisk infestations outside of the floodplain also occur in fallow fields and around cattle tanks but are typically not as common or dense.

Upstream of Glenwood Springs, Eagle County completed a three-year effort to totally eradicate tamarisk from the county. This work was completed in 2006 using county staff and volunteers. Wolford Mountain Reservoir above Kremmling also had infestations that have been controlled by the Colorado River Water Conservation District over the past several years.

Gunnison & Uncompahgre Rivers: The project area for the Gunnison & Uncompahgre Rivers watershed extends west from the headwaters of each river to the confluence with the Colorado River in Grand Junction. Terrain along this corridor progresses from mountain passes, mesa, and plateaus of western Colorado through the narrow walls of the Gunnison Gorge, to the braided channels and broad floodplains in the Montrose, Delta, Paonia, and Hotchkiss area. Downstream of Delta, the Gunnison River enters another canyon for most of its distance to Grand Junction. Vegetation surrounding this stretch of the Gunnison & Uncompahgre Rivers ranges from alpine evergreen communities to bunch grasses/sage/greasewood/rabbit brush communities and pinyon/juniper all adjacent to the riparian zone traditionally dominated by cottonwood and willow.

Tamarisk infestations occur primarily in the latter habitat, beginning in Montrose County on the Uncompahgre River and Delta County on the Gunnison River, generally below 6,500 feet in elevation. There are isolated pockets at higher elevations but at these elevations more precipitation occurs and thus, tamarisk tends to be less competitive with native species. The majority of tamarisk infestations can be found within the riparian corridor stretching to the extent of the 100 year floodplain. Side canyons, perennial and ephemeral streams, and tributaries support isolated stands of tamarisk. Upland tamarisk infestations outside of the floodplain also occur in fallow fields and around cattle tanks but are typically not as common or dense.

Dolores River: The project area for the Dolores River watershed originates from perennial and/or intermittent streams originate in the Manti-La Sal Mountains in Utah, San Juan Mountains, Uncompahgre Plateau, and surrounding plateaus along the Utah/Colorado border. The major tributary is the San Miguel River which makes up most of the Dolores River's flow beyond their confluence. The Dolores River's confluence with the Colorado River is approximately 20 miles inside the Utah border.

Terrain along this corridor progresses from mountain passes, mesa, and plateaus of western Colorado and eastern Utah through the narrow walls of sandstone canyons for much of its length. There are relatively few broad floodplains within the rivers entire length. Vegetation surrounding this stretch of the Dolores River ranges from alpine evergreen communities to bunch grasses/sage/greasewood/rabbit brush communities and pinyon/juniper all adjacent to the riparian zone traditionally dominated by cottonwood and willow.

Tamarisk infestations occur primarily in the latter habitat, beginning mostly in the west end of Montrose County in the Slickrock area generally below 6,500 feet in elevation. There are isolated pockets at higher elevations but at these elevations more precipitation occurs and thus, tamarisk tends to be less competitive with native species. The majority of tamarisk infestations can be found within the riparian corridor stretching to the extent of the 100 year floodplain. Side canyons, perennial and ephemeral streams, and tributaries support isolated stands of tamarisk. Upland tamarisk infestations outside of the floodplain also occur in fallow fields and around cattle tanks but are typically not as common or dense. There is relatively little Russian olive infestation.

The Nature Conservancy's effort on the San Miguel River, begun in 2001 and now in its final year, is a national example for obtaining a tamarisk-free watershed and provides a model of a collaborative, efficient and cost-effective way to address this threat throughout the West. When the project is complete, approximately 100 miles of the San Miguel and its tributaries will be controlled at a cost of about $1 million.

White River: The White River originates in the Flat Tops Wilderness of the White River National Forest at 11,000 feet elevation. The North Fork of the White River flows directly from the breathtakingly beautiful Trappers Lake and joins the South Fork of the White River at 7,000 feet elevation. This junction occurs just outside the White River National Forest boundary in the Oak Ridge and Lake Avery State Wildlife Area (SWA). From here the river winds westward through private lands past Meeker gaining numerous tributaries along the way, many of which are located within SWA or Bureau of Land Management (BLM) lands. Downstream of Meeker several small sections of river border or transect BLM property and a short stretch intersects the Rio Blanco Lake SWA. Other than these isolated areas, the river banks are privately owned throughout its reach in the northwest corner of Colorado until the river enters Utah just southwest of Rangely, CO. Privately owned lands adjacent to the White River are predominately used for agriculture. Hay fields, other crops, and livestock dominate the landscape. The two SWAs in the area provide wildlife habitat and hunting opportunities.

Tamarisk and Russian olive populations are sparse along upper reaches of the White River. While there are some isolated stands in these areas, sizable infestations do not occur until about 12 miles upstream of the Kenny Reservoir. Here tamarisk becomes noticeably more prolific though Russian olive populations remain rare. Below the reservoir Russian olive presence and density increases significantly and tamarisk populations are much more prevalent as well. Douglas Creek, which enters the White River just upstream of Rangely, supports a very dense tamarisk infestation but no known stands of Russian olive exist.

The White River's riparian plant communities, terrestrial and aquatic wildlife habitats, and water resources needed for agriculture are threatened by the invasion of these aggressive, non-native woody plants. The riparian zones associated with the White River mainstem and its tributaries are traditionally dominated by cottonwood and willow. Upland areas are dominated by grasslands and pinyon and juniper forests, but can also be invaded by tamarisk. The riparian lands of the White River system are integral and fragile aspects of western ecosystems due to their role in maintaining water quality and quantity, providing ground water recharge, controlling erosion, and dissipating stream energy during flood events.

Yampa/Green River: The Yampa River runs through northwest Colorado from the highlands of Routt National Forest to the Green River just east of the Utah border. The Yampa is an extraordinarily unique river in that no major dams interrupt its largely snowmelt-driven flow regime. This lack of hydrologic alteration has allowed natural sediment erosion and deposition, flooding, and native plant seed propagation and survival. Combined, these processes have preserved stands of native riparian vegetation that are becoming increasingly rare in the western United States. Such properly functioning riparian systems support ideal habitat for endangered species found in the watershed such as the razorback sucker and Colorado River pikeminnow and nearly 150 bird species including bald eagles, greater sandhill cranes, bobolinks, and great horned owls among others (Dewey 2006).

The relatively intact hydrology of the Yampa River and its major tributaries has maintained the health of its ecosystems. Though these areas are threatened by numerous invasive plant species, the relatively low occurrence of tamarisk and Russian olive, the relative health of the ecosystem, and the passionate work of several local organizations provide an extraordinary opportunity to make a real difference. Work towards invasive species management, primarily tamarisk and Russian olive control, has real potential to restore and preserve a healthy, native mosaic of vegetation that supports wildlife species. This goal is within reach but requires well planned, multi-faceted inventory, control, revegetation, monitoring, and management strategies to be successful.

The Green River, unlike the Yampa, is highly regulated by the large storage reservoir at Flaming Gorge and the lesser Fontenelle and Fremont reservoirs. Only about 43 miles of its total length of 730 miles lies within Colorado with the Yampa being its major tributary. The Green river in Colorado passes entirely through public lands (Browns Park National Wildlife refuge and Dinosaur National Monument).

The riparian lands of both the Yampa and Green river systems are integral and fragile aspects of western ecosystems due to their role in maintaining water quality and quantity, providing ground water recharge, controlling erosion, and dissipating stream energy during flood events.

Special Status Wildlife Habitat

Invasive woody species such as tamarisk and Russian olive are concentrated along rivers and waterways which contain important wildlife species and habitats. According to The Nature Conservancy, more than 22 percent of the freshwater fish species and subspecies in the Upper Colorado River are of global conservation concern. Sections of the Colorado, Gunnison, Uncompahgre, Dolores, White, Yampa, and Green rivers within the planning area are formally designated Critical Habitat for four endangered fish; the bonytail (*Gila elegans*), the Colorado pikeminnow (*Ptychochelius lucius*), the humpback chub (*Gila cypha*), and the razorback sucker (*Xyrauchen texanus*). In addition, Federally-listed or candidate threatened and endangered (T&E) bird species known to use the project area include the yellow-billed cuckoo (*Coccyzus americanus*), Mexican spotted owl (*Strix occidentalis*), and the bald eagle (*Haliaeetus leucocephalus*). Several T&E plant species also occur in the area. Locations of observed sites for these species within the study area are maintained by the Colorado Division of Wildlife, Utah Division of Wildlife Resources, and the U.S. Fish and Wildlife Service.

The Colorado, Gunnison, Uncompahgre, Dolores White, Yampa, and Green Rivers and their tributaries riparian woodlands are prime examples of a plant community or type of ecosystem that is scarce in the lower elevations of this arid region. Although riparian areas comprise only 0.5-1.0% of the overall western landscape, a disproportionately large percentage (approximately 70 to 80 percent) of all desert, shrub, and grasslands animals depend on them (Belsky et al. 1999). An estimated 60 to 70 percent of western birds species (Ohmart 1996) and as many as 80 percent of wildlife species in Arizona and New Mexico (Chaney et al. 1990) are dependent on riparian habitats. Consequently, riparian ecosystems are considered to be important repositories for biodiversity throughout the West.

In the past, there has been concern about the endangered southwestern willow flycatcher (*Empidonax trailii extimus*) nesting in the CHIP study area; however, recent determination by the U.S. Fish and Wildlife Service is that this area is no longer considered critical habitat for this avian species (USFWS 2005)

Tamarisk and Russian Olive Species

The Colorado, Gunnison, Uncompahgre, Yampa, Green, White, and Dolores Rivers and their associated riparian corridors are renowned for their ecological, recreational, aesthetic, cultural, and vital economical value for water supply, livestock production, and agriculture (USDI/USDA 1998). Riparian lands are especially integral and fragile aspects of western ecosystems due to their role in maintaining water quality and quantity, providing ground water recharge, controlling erosion, and dissipating stream energy during flood events (NRST 1997). Unfortunately, many of these water systems and associated riparian lands have been severely degraded over the past 150 years by anthropogenic activities (damming, road building, irrigation, etc.) and invasive plant species, resulting in reduced water quality, altered river regimes and reduced ecological systems and habitats.

Tamarisk (*Tamarix* spp.) and Russian olive (*Elaeagnus angustifolia*) are invasive species of particular interest due to their high profile status and negative environmental impacts.

Tamarisk Ecology and Impacts – Tamarisk is a deciduous shrub or small tree that was introduced to the western U.S. in the early nineteenth century for use as an ornamental, in windbreaks, and for erosion control. Originating in central Asia and the Mediterranean, tamarisk is a facultative phreatophyte with an extensive root system well suited to the hot, arid climates and alkaline soils common in the western U.S. These adaptations have allowed it to effectively exploit many of the degraded conditions in southwestern river systems today (e.g., interrupted flow regimes, reduced flooding, increased fire). By the mid-twentieth century, tamarisk stands dominated many low-elevation (under 6,500 feet) river, lake, and stream banks from Mexico to Canada and into the plains states. Tamarisk cover estimates range from 1 to 1.5 million acres of land in the western U.S. and may be as high as 2 million acres (Zimmerman 1997).

The exact date of introduction is unknown; however, it is generally understood that tamarisk became a problem in western riparian zones in the mid 1900's (Robinson 1965, Howe and Knopf 1991). Genetic analysis suggests that tamarisk species invading the U.S. include *Tamarix chinensis*, *T. ramosissima*, *T. parviflora*, *T. gallica*, and *T. aphylla* (Gaskin 2002, Gaskin and Schaal 2002). A hybrid of the first two species appears to be the most successful intruder. There are several ornamental varieties of tamarisk still marketed in the western United States. While these species are non-invasive they do contribute genetic diversity to invasive populations.

Tamarisk reproduces primarily through wind and water-borne seeds, but a stand may also spread through vegetative reproduction from broken or buried stems. Seeds are viable for approximately six weeks (Carpenter 1998) and require a wet, open habitat to germinate. In the presence of established native vegetation or sprouts, tamarisk 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, tamarisk invasion by seed is not likely to occur. However, the following several conditions coinciding with the removal of the native canopy due to natural or anthropogenic causes will allow new infestations to occur: 1) Late flooding - Tamarisk seed production generally has a longer season 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 native plants from establishing, and thus allow tamarisk to invade. Once tamarisk seedlings are established (as great as 1,000 indivduals/m^2 initially), thick stands are very competitive, excluding natives (Busch and Smith 1995, Taylor *et al.* 1999). Any disruption of the riparian ecosystem appears to make invasion more likely, especially alterations of hydrology (Lonsdale 1993, Décamps Planty-Tabacchi and Tabacchi 1995, Busch & Smith 1995, Springuel *et al.* 1997, Shafroth *et al.* 1998). However, there are also numerous documented cases of tamarisk stands where no known disruptions have occurred.

Once a tamarisk stand is mature, it will remain the dominant feature of an ecosystem unless removed by human means. Tamarisk has a higher tolerance of fire, drought, and salinity 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. Hence, a strong initial infestation will promote a positive feedback mechanism that will lead to more tamarisk invasion.

In addition to affecting abiotic processes, tamarisk dominance dramatically changes vegetation structure (Busch & Smith 1995) and animal species diversity (Ellis 1995). High invertebrate and bird diversity has been recorded in some 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 endangered southwestern willow flycatcher, many endemic species are completely excluded by it, including raptors such as eagles (Ellis 1995). Because of its potential usefulness to some species, stands of tamarisk mixed with native vegetation were found to have high ecological value in Arizona study sites (Stromberg 1998). In contrast, mature monocultures of tamarisk have a much lower ecosystem value.

In general, the following is an assessment of tamarisk and its impacts on riparian systems throughout the West (Carpenter 1998, McDaniel *et al.* 2004).

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

- Due to the depths of their extensive root systems tamarisk draw excess salts from the groundwater. These are excreted through leaf glands and 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 increases the frequency and intensity of wildfires which kill native cottonwood and willows but stimulate tamarisk growth.

- Dense tamarisk stands on stream banks accumulate sediment in their thick root systems gradually narrowing stream channels and increasing flooding. These changes in stream morphology can impact critical 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.

- Tamarisk has a reputation for using significantly more water than the 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 *et al.* 1987).

What are the Local Impacts? – The most critical impacts for the CHIP study area are aesthetics, agriculture, wildlife habitat loss, fire, and water usage. Aesthetics are highly valued due to the tourism industry, a major economic driver for the area. Agricultural values of riparian grazing lands are highly valued in western Colorado due to their limited availability and importance to local economies. Wildlife habitat loss is important from the ecological standpoint, while fire is a safety concern to communities. Water loss, however is considered the most critical issue. The following section provides a brief explanation of how this water loss occurs.

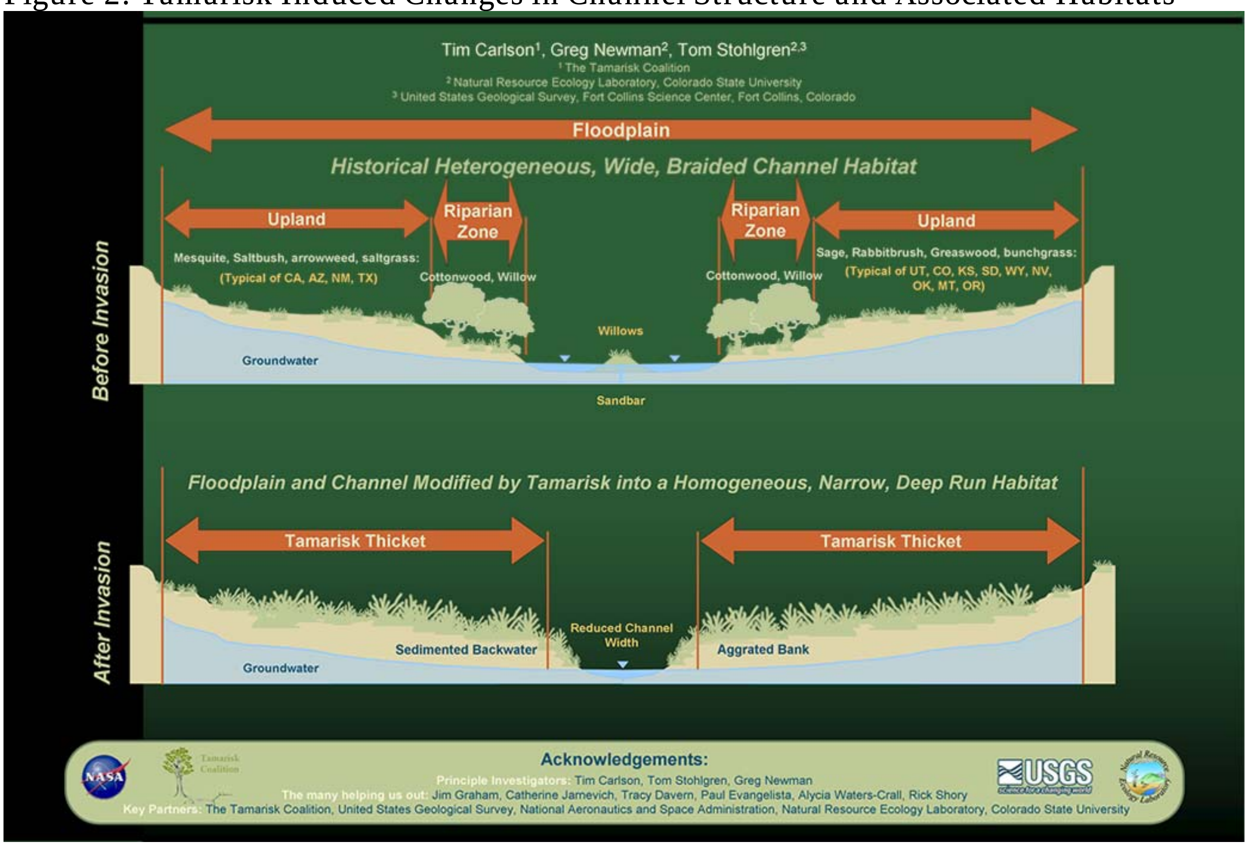
How much Water is Lost? – Limited evidence indicates that water usage per leaf area of tamarisk and the native cottonwood/willow riparian communities is very similar. However, because tamarisk grows in extremely dense thickets, the leaf area per acre may actually be much greater than native stands; thus, water consumption could be greater on a per acre basis (Kolb 2001). Another aspect of tamarisk water consumption is its deep root system. Tamarisk roots can extend down to 100 feet, much farther than healthy cottonwoods and willows stands which reach a depth of only a few meters (Baum 1978, USDI-BOR 1995). This allows tamarisk to grow further back from the river, occupy a larger area, and use more water across the floodplain than native phreatophytes. This is significant because the upper floodplain terraces adjacent to the riparian corridor typically occupy an area several times larger than the riparian zone itself. In these areas, mesic and xeric plants (such as bunch grasses, sagebrush, rabbit brush, four-wing salt bush, and skunk bush) can be replaced by tamarisk resulting in overall water consumption several times the ecosystem's natural rate (DeLoach *et al.* 2002).

Water consumption estimates vary a great deal depending on location, maturity, density of infestation, water quality, and groundwater depth. In 27 research plots, tamarisk had an average annual water usage of 4.2 acre-feet/acre (95% confidence interval = 3.85 to 4.86) (NISC 2006). This agrees strongly with the most sophisticated evapotranspiration studies using eddy-covalence measurements performed for the Bureau of Reclamation (King and Bawazir 2000) of 4.35 feet per year. Water use by Russian olive was found to be approximately the same. In many situations this water consumption is equivalent to that of cottonwood/willow vegetation at a similar density. For dry-land vegetation such as grasses/sage/rabbit brush communities, which are shallow-rooted and get their water primarily from precipitation, the difference in water use is a function of the precipitation received for the area. In the CHIP study area's riparian lands that tamarisk occupies annual precipitation ranges from a low of 8 inches in Grand Junction and Rangely to approximately 15 inches per year at the higher elevations where tamarisk exists (6,500 feet) (NOAA).

For areas that could support native phreatophytes, it is estimated that only approximately 25% would actually be occupied by these species based on a number of factors. Water loss calculations are based on these findings. Future water losses assume complete infilling of tamarisk with no expansion of range.

Figure 2 represents the differences in vegetative cover with and without tamarisk and illustrates tamarisk occupation of an area much greater than the riparian zone which typically would support phreatophytes. Significant water losses may occur as tamarisk occupy upland areas within the floodplain that would normally support only upland mesic and xeric vegetation such as grasses, sage, rabbit brush, etc.

Figure 2: Tamarisk Induced Changes in Channel Structure and Associated Habitats



Russian Olive Ecology & Impacts – Russian olive (*Elaeagnus angustifolia*) was introduced to the United States in the late nineteenth century as an ornamental shrub or small tree and has since spread from cultivation (Ebinger and Lehnen 1981, Sternberg 1996). Originating in southern Europe and central and eastern Asia (Hansen 1901, Shishkin 1949, Little 1961), Russian olives are long-lived and resilient plants. They are adapted to survive in a variety of soil types and moisture conditions, grow between sea level and 8,000 feet, can grow up to 6 feet in one year (Tu 2003), are shade tolerant (Shafroth et al. 1995), and can germinate over a longer time interval than native species (Howe & Knopf 1991).

Until the 1990's several state and federal agencies promoted the distribution of Russian olives for windbreaks and horticulture plantings in the western U.S. and in Canada (Tu 2003, Olson and Knopf 1986, Haber 1999). The seedlings were touted for their use in controlling erosion (Katz and Shafroth 2003), providing wildlife habitat (Borell 1962), and serving as a nectar source for bees (Hayes 1976). As a result, Russian olives were distributed widely in the west and continue to spread through natural sexual and vegetative reproduction (Tu 2003).

Russian olives are mature and begin producing seeds 3 to 5 years after establishment (Tu 2003). Seeds are encased in a fleshy fruit providing an attractive food source for wildlife, especially avian species. As the outer layer of the seed is impervious to digestive fluids (Tesky 1992), seed predators are a significant factor in Russian olive recruitment. Plant establishment has been documented following seed consumption by birds (USDA 1974, Shafroth et al. 1995, Lesica and Miles 1999, Muzika and Swearingen 1998). Coyotes, deer, and raccoons have also been observed consuming and distributing the seeds (USDA 2002). The seeds are dispersed in a dormant state during the cool months in fall and winter. They prefer an after-ripening period of moist conditions lasting roughly 90 days at 5 degrees Celsius to successfully germinate (Hogue and LaCroix 1970, Belcher and Karrfalt 1979). In average conditions, seeds are viable for up to 3 years (USDA 2002). This lengthy seed viability allows Russian olive more time to utilize optimal germination conditions than most native plants giving Russian olive another competitive edge (Howe and Knopf 1991, Shafroth et al 1995).

Russian olive seeds can germinate on undisturbed soils. Thus, they are not highly dependent upon the flood disturbances that sustain native species (Shafroth et al. 1995, Lesica and Miles 1999, Katz 2001) and are able to exploit the degraded conditions of southwestern rivers today (e.g., interrupted flow regimes, reduced flooding, increased fire, etc.).

Russian olives grow and compete with native plants well in dry, upland soils (Laursen and Hunter 1986) and in wet-saline soils. However, non-saline, hydric soils and soils with elevated sodium levels favor native species and the invasive plant tamarisk recruitment (*Tamarix spp.*) over Russian olive respectively (Carman and Brotherson 1982).

Russian olives, once established, will remain a dominant feature of riparian systems. The shade tolerant seedlings are able to germinate and thrive in the understory of native trees. As the native trees die, Russian olive becomes the upper canopy of the system, shading out native tree recruits (Shafroth et al.1995).

In general, the following is an assessment of Russian olives and their impacts on riparian systems throughout the West (Tu 2003):

- Russian olives form dense, monotypic stands that negatively affect vegetative structure, nutrient cycling, and ecosystem hydrology.
- Presence of Russian olive can modify plant succession in a system.
- Russian olive results in lower native plant and animal diversity
- Wide spreading throughout woodlands connects riparian forests with upland areas stabilizing floodbanks, increasing overbank deposition, and limiting cottonwood regeneration sites.
- The evapotranspiration rates of Russian olives are higher than native species, thus they consume more water resources (Carman and Brotherson 1982)
- The invasives can convert riparian areas to relative drylands with Russian olive as the climax species (Olson and Knopf 1986).
- Dense stands of Russian olives increase fuel loads leading to more frequent and intense wildfires that kill native plants (Caplan 2002).
- Russian olive trees provide inferior habitat to native vegetation and reduce abundance and diversity of wildlife (Knopf and Olson 1984, Brown 1990)

The difficulty of controlling or removing mature stands of Russian olive makes it almost impossible to eradicate from a watershed once it is established. Thus, it is important to detect new infestations of Russian olive early on and to rapidly respond to remove them. There are methods available to control Russian olives on a small scale, but the cost and intense labor demands of the work can be expensive. Techniques used include mowing, cutting, and girdling combined with herbicide application; basal bark herbicide application; and burning, excavating, and bulldozing with no herbicide application (Tu 2003).

In general, Table 1 provides an overview of adverse characteristics and potential impacts widely attributed to tamarisk (T) and Russian olive (RO). For more detailed information the reader is referred to Carpenter 1998 and Tu 2003.

It should be noted that various other non-native invasives are intermixed with tamarisk and Russian olive such as Russian knapweed, whitetop, Russian thistle, and purple loosestrife and should be considered throughout the planning and implementation of restoration actions.

Table 1: Characteristics of Tamarisk (T) and Russian Olive (RO)

CHARACTERISTICS		**DESCRIPTION**
Origin	T	Central Asia/Mediterranean
	RO	Europe/Western Asia
Estimated Cover	T	1 to 1.5 million acres in the western United States
	RO	Unknown
Elevation	T	Sea Level to 6,500 feet
	RO	Sea Level to 8,000 feet

CHARACTERISTICS		DESCRIPTION
Habitat/Range	T	Western U.S. along riverways, springs, drainages
	RO	Throughout U.S. – most dense in western states
Tolerant	T	Floods, droughts, close shearing, and burning
	RO	Floods, droughts, close shearing, burning in dormancy, seedlings and saplings are shade tolerant
Intolerant	T	Shade
	RO	Acidic conditions (pH<6.0)
Reproduction/ Distribution	T	Sexual and vegetative; seeds need moist soils/water and wind
	RO	Sexual and vegetative; seeds can propagate in undisturbed soils/water and wildlife
Growth patterns	T	Dense monotypic stands, clumps or stringers
	RO	Dense monotypic stands or scattered occurrences
Soils	T	Seedling require moist soils; ranges widely as adult; highly tolerant of and actually increases surface salinity
	RO	Can tolerate bare mineral or nitrogen poor soils, prefers sandy floodplains and open, moist riparian habitats, tolerant of prolonged inundation
Vegetation Impacts	T	Once established, grows densely and excludes natives
	RO	Shade tolerate allowing it to out compete natives through succession and exclusion
Water Use	T	Equivalent evapotranspiration to riparian native phreatophytes such as willows and cottonwoods, but deep root systems uses water even in drought, high leaf area index and tendency to grow in dense thickets can result in more water usage per acre than natives, and grows in mesic and xeric areas due to deep root depths
	RO	High rates of evapotranspiration similar to other phreatophytes, but uses more water than native upland mesic and xeric vegetation
Wildlife Impacts	T	Reduced insect prey and habitat structure negatively impacts most bird species with some exception, and poor habitat for raptors such as bald eagles; channelization of streams reduced native riparian recruitment and reduces backwaters and spawning areas for endangered fish
	RO	Provides inferior habitat in the long-term resulting in loss of species richness
Wildfire	T	Increases frequency and intensity, extremely fire tolerant
	RO	Increases fuel load; fire tolerant

CHARACTERISTICS		DESCRIPTION
Management	T	Difficult and expensive for mature stands
	RO	Difficult and expensive for mature stands
Forage	T	Poor nutrition
	RO	Poor nutrition, birds and other wildlife can feed on fruit
Livestock	T	Reduces forage area, surface water, and impedes access to flowing water
	RO	Reduces forage area, surface water, and impedes access to flowing water
Stream/River Morphology	T	Dense stands stabilize river banks, change stream structure by narrowing and deepening channels, and decreasing number and size of backwaters needed to sustain a properly functioning ecosystem with native riparian communities and wildlife habitats. Reduced carrying capacity of river channels can increase flood damage
	RO	Stabilizes river banks, increasing overbank deposition, and limit native cottonwood regeneration
Recreation	T	Can be aesthetically pleasing though generally degrades aesthetic value, obstructs access to streams/rivers, reduces native ecosystems and diversity
	RO	Can be aromatically, aesthetically pleasing, obstructs river access, reduces native ecosystems and diversity

Extent of the Problem

Inventory Background & Objectives – In 2005, the Tamarisk Coalition completed an inventory of tamarisk infestations in the Colorado River watershed and its main tributaries for the Colorado Water Conservation Board (CWCB). In 2006 and 2007, the Tamarisk Coalition completed inventories for the Colorado, Gunnison, Uncompahgre, Dolores, and White rivers for CWCB. The purpose of this work was to establish and implement an inventory protocol that would be economical to perform and would provide a clear understanding of the extent of the tamarisk problem. These inventory/mapping protocols proved to be successful and were used in 2006 to identify tamarisk infestations throughout the remainder of the state. A team from Utah State University inventoried and mapped tamarisk infestations on the Yampa and a portion of the Green River in the Dinosaur National Monument in 2006. This discussion of the extent of the problem is focused on tamarisk because it is the indicator species in the Colorado River watershed that best describes areas that have serious riparian degradation.

Inventory Approach and Findings – Inventory and mapping were performed during the summer and fall of 2005 and 2006 and coordinated with the U.S. Geological Survey's (USGS) efforts to establish a national on-line database which would conform to the weed mapping standards developed by the North American Weed Management Association. The basic approach (see Appendix D for mapping protocols) uses existing aerial photography, satellite imagery, and local knowledge available from counties, river districts, soil and water conservation districts, state agencies, Army Corps of Engineers, National Resources Conservation Service, USGS, Colorado State University (CSU), and The Nature Conservancy. This information was then "ground-truthed" by a 2-man team to confirm infestation density, maturity, accessibility, presence of native species, and several other site characteristics. GPS data and digital photo records were taken and shape files were developed utilizing GIS capabilities at Mesa State College. Nearly 470 miles on the Colorado, Gunnison, Uncompahgre, and Dolores Rivers and their major tributaries from the CO/UT state line were surveyed using this approach. This information, in the form of shapefiles and characteristics data, has been transformed into a digital GIS database which is now available on the USGS' National Institute of Invasive Species Science website, www.niiss.org .

The inventories for the Colorado, Gunnison, Uncompahgre, Dolores, White, and Yampa/Green rivers and their major tributaries are presented respectively in the following Tables 2-8 and represent a summary of the detailed information collected which is found on the supplementary Data-DVDs. The inventory process focused on an efficient economical mapping/inventory protocols to identify 85 to 90 percent of tamarisk within these watersheds. The remaining percentage represents small pockets of infestations that are scattered throughout the region and would be proportionately very expensive to map. Thus, the inventory and water loss calculations are somewhat conservative.

Inventories of on the Yampa and Green Rivers were collected in a manner different from the rest of the Colorado River watershed; therefore, information is not compatible with the following table format. Inventory and mapping by Utah State University in 2006 for Dinosaur National Monument does identify tamarisk infests approximately 250 acres and Russian olive infests approximately 200 acres on the Yampa River and its tributaries. No detailed surveys have been performed for the short section of the Green River within Colorado outside of the Monument's boundary.

Table 2: Existing and Future Water Loss Estimates due to Tamarisk Infestations in Colorado River Watershed and Estimated Control & Revegetation Costs

Colorado River Main Stem	River Miles	Average Density (%)	Total Acreage	Total Canopy Cover (acres)	% Area capable of Supporting Cottonwood/Willow	Water Loss (acre-feet/yr)	Future Water Loss (acre-feet/yr)	Cost estimates for Control & Revegetation
State Line	0							
Loma	21	50%	642	318	50%	930	1,880	$960,000
Grand Junction	38	44%	1,920	848	41%	2,550	5,770	$2,360,000
Palisade	55	48%	794	384	57%	1,100	2,280	$1,150,000
DeBeque	80	42%	930	392	42%	1,180	2,790	$1,090,000
Parachute	89	17%	800	139	65%	390	2,250	$430,000
Rifle	106	19%	837	163	47%	480	2,470	$460,000
Glenwood Springs	132	19%	726	137	62%	390	2,060	$390,000
Totals =	**132**	**36%**	**6,649**	**2,380**	**50%**	**7,020**	**19,500**	**$6,840,000**

High Range = $8,030,000 **Low Range = $5,660,000**

Average cost per acre of infestation = $1,000

Average cost per acre-foot of water preserved as groundwater and/or surface water = $1,000

Average cost per mile = $52,000

Colorado River Tributaries	River Miles	Average Density (%)	Total Acreage	Total Canopy Cover (acres)	% Area capable of Supporting Cottonwood/Willow	Water Loss (acre-feet/yr)	Future Water Loss (acre-feet/yr)	Cost estimates for Control & Revegetation
Little Salt Creek	6	34%	184	63	50%	180	540	$200,000
Mac Wash	5	19%	105	20	48%	60	310	$60,000
Adobe Creek	3	35%	26	9	81%	20	70	$13,000
Rifle Creek	6	77%	13	10	53%	30	40	$18,000
Roan Creek	21	47%	354	164	53%	480	1,030	$440,000
Parachute Creek	8	14%	50	7	46%	20	150	$18,000
Government Creek	6	14%	60	8	0%	30	200	$25,000
Plateau Creek	11	16%	117	19	56%	50	340	$49,000
Totals =	**66**	**33%**	**908**	**299**	**49%**	**870**	**2,680**	**$823,000**

High Range = $960,000 **Low Range = $700,000**

Average cost per acre of infestation = $900

Average cost per acre-foot of water preserved as groundwater and/or surface water = $900

Average cost per mile = $13,000

Table 3: Existing & Future Water Loss Estimates due to Tamarisk Infestations in Gunnison River Watershed & Estimated Control & Revegetation Costs

Gunnison River Main Stem	River Miles	Average Density (%)	Total Acreage	Total Canopy Cover (acres)	% Area capable of Supporting Cottonwood/Willow Plant Community	Current Water Loss (acre-feet/year)	Future Water Loss (acre-feet/year)	Cost estimates for Tamarisk Control & Revegetation
Grand Junction	0							
Mesa/Delta County Border	33	28%	769	212	66%	600	2,150	$650,000
Delta	61	28%	1349	374	79%	1,000	3,630	$1,100,000
Confluence w/ North Fork	76	25%	456	114	68%	320	1,270	$340,000
Totals =	**76**	27%	**2,574**	**700**	**73%**	**1,920**	**7,050**	**$2,090,000**

High Range =	**$2,340,000**
Low Range =	**$1,840,000**
Average cost per acre of infestation =	**$800**
Average cost per acre-foot of water preserved as groundwater and/or surface water =	**$1,000**
Average cost per mile =	**$27,000**

Gunnison River Tributaries	River Miles	Average Density (%)	Total Acreage	Total Canopy Cover (acres)	% Area capable of Supporting Cottonwood/Willow Plant Community	Current Water Loss (acre-feet/year)	Future Water Loss (acre-feet/year)	Cost estimates for Tamarisk Control & Revegetation
Gunnison Stream	3	15%	121	18	0%	60	400	$51,000
Tongue Creek	6	39%	238	93	82%	250	630	$280,000
Dry Creek and Lawhead Gulch	3	10%	105	11	42%	30	310	$31,000
North Fork Gunnison	8	15%	247	36	81%	100	660	$120,000
Totals =	**19**	**22%**	**710**	**159**	**62%**	**440**	**2,000**	**$480,000**

High Range =	**$540,000**
Low Range =	**$420,000**
Average cost per acre of infestation =	**$700**
Average cost per acre-foot of water preserved as groundwater and/or surface water =	**$1,000**
Average cost per mile =	**$25,000**

Table 4: Existing and Future Water Loss Estimates due to Tamarisk Infestations in Uncompahgre River Watershed and Estimated Control & Revegetation Costs

Uncompahgre River Main Stem	River Miles	Average Density (%)	Total Acreage	Total Canopy Cover (acres)	% Area capable of Supporting Cottonwood/Willow Plant Community	Current Water Loss (acre-feet/year)	Future Water Loss (acre-feet/year)	Cost estimates for Tamarisk Control & Revegetation
Delta	0							
Olathe	19	21%	1001	212	71%	590	2,760	$600,000
Montrose	32	6%	521	32	79%	90	1,400	$90,000
Totals =	**32**	**16%**	**1,521**	**244**	**74%**	**680**	**4,160**	**$690,000**

High Range = $760,000
Low Range = $620,000

Average cost per acre of infestation = $500
Average cost per acre-foot of water preserved as groundwater and/or surface water = $1,000
Average cost per mile = $22,000

Table 5: Existing and Future Water Loss Estimates due to Tamarisk Infestations in Dolores River Watershed and Estimated Control & Revegetation Costs

Dolores River Main Stem	River Miles	Average Density (%)	Total Acreage	Total Canopy Cover (acres)	% Area capable of Supporting Cottonwood/Willow Plant Community	Current Water Loss (acre-feet/year)	Future Water Loss (acre-feet/year)	Cost estimates for Tamarisk Control & Revegetation
Utah/Colorado Border	0							
Gateway	9	23%	291	67	79%	180	780	$190,000
Mesa/Montrose County Border	27	41%	396	164	73%	450	1,080	$460,000
Bedrock	54	41%	1032	421	47%	1,240	3,050	$1,200,000
Montrose/San Miguel County Border	86	31%	459	141	50%	410	1,350	$490,000
Slickrock	107	30%	174	51	51%	150	510	$140,000
Totals =	**107**	**36%**	**2,351**	**845**	**56%**	**2,430**	**6,770**	**$2,480,000**

High Range = $2,840,000
Low Range = $2,120,000
Average cost per acre of infestation = $1,000
Average cost per acre-foot of water preserved as groundwater and/or surface water = $1,000
Average cost per mile = $23,000

Dolores River Tributaries	River Miles	Average Density (%)	Total Acreage	Total Canopy Cover (acres)	% Area capable of Supporting Cottonwood/Willow Plant Community	Current Water Loss (acre-feet/year)	Future Water Loss (acre-feet/year)	Cost estimates for Tamarisk Control & Revegetation
La Sal Creek	7	21%	135	29	50%	80	400	$100,000
Atkinson Creek	1	10%	7	1	70%	2	20	$2,000
Disappointment Creek	27	25%	729	179	80%	480	1,960	$640,000
Totals =	**35**	**24%**	**871**	**209**	**75%**	**562**	**2,380**	**$742,000**

High Range = $790,000
Low Range = $690,000
Average cost per acre of infestation = $800
Average cost per acre-foot of water preserved as groundwater and/or surface water = $1,000
Average cost per mile = $21,000

Table 6: Existing & Future Water Loss Estimates due to Tamarisk Infestations in the White River Watershed and Estimated Control & Revegetation Costs

White River Main Stem	Cumulative River Miles	Average Density (%)	Total Acreage	Total Canopy Cover (acres)	% Area capable of Supporting Cottonwood/Willow Plant Community	Current Water Loss (acre-feet/year)	Future Water Loss (acre-feet/year)	*Cost estimates for Tamarisk Control & Revegetation
Upper Extent of Tamarisk	0							
Rangely	48	22%	397	87	69%	240	1,101	$240,529
CO/UTBorder	74	15%	971	148	65%	416	2,725	$422,598
Totals =	**74**	**17%**	**1,368**	**235**	66%	**657**	**3,825**	**$663,126**
							High Range =	**$729,131**
							Low Range =	**$597,157**
							Average cost/ acre=	**$485**
							Avg. cost/af of water =	**$1,009**
							Average cost/mile =	**$8,961**

White River Tributaries	River Miles	Average Density (%)	Total Acreage	Total Canopy Cover (acres)	% Area capable of Supporting Cottonwood/Willow Plant Community	Current Water Loss (acre-feet/year)	Future Water Loss (acre-feet/year)	*Cost estimates for Tamarisk Control & Revegetation
Black Gulch	4	25%	37	9	0%	30	124	$24,989
Douglas Creek	27	47%	1,231	576	20%	1,834	3,918	$1,822,403
Totals =	**31**	**46%**	**1,268**	**586**	**19%**	**1,866**	**4,042**	**$1,847,392**
							High Range =	**$2,142,792**
							Low Range =	**$1,547,516**
							Average cost/acre =	**$1,457**
							Avg. cost/af of water =	**$990**
							Average cost/mile =	**$59,593**

Table 7: Existing & Future Water Loss Estimates due to Russian olive Infestations in the White River Watershed and Estimated Control & Revegetation Costs

White River Main Stem	Cumulative River Miles	Average Density (%)	Total Acreage	Total Canopy Cover (acres)	% Area capable of Supporting Cottonwood/Willow Plant Community	Current Water Loss (acre-feet/year)	Future Water Loss (acre-feet/year)	*Cost estimates for Tamarisk Control & Revegetation
Upper Extent of Infestation	0							
Rangely	48	41%	443	180	79%	484	1,189	$504,303
CO/Utah State Border	74	35%	747	262	69%	727	2,074	$734,759
Total =	**74**	**37%**	**1,190**	**442**	**73%**	**1,213**	**3,263**	**$1,239,062**
							High Range =	**$1,439,069**
							Low Range =	**$1,039,242**
							Average cost/ acre =	**$1,041**
							Average cost/acre-foot of water =	**$1,022**
							Average cost per mile =	**$16,744**

Table 8. Invasive plant inventory areas, inventory dates, acres inventoried, and acres of Russian olive and Tamarisk from 2003 to 2005 along the Yampa River and its tributaries.

Area Inventoried	Acres Inventoried	Dates	Russian Olive (acres)	Tamarisk (acres)	Total Acres Infested
Anderson Hole	352.6	6/4/04	0	0.606	0.606
Bull Canyon	101.5	6/21/04	0	0.005	0.005
Disappointment Draw	335.7	6/6/04	0	1.204	1.204
Elkhead Reservoir	527.6	7/11/05, 7/13/05	0.178	0.01	0.188
Fish Creek	1172.2	7/13/05	0	0	0
Foidel Creek	202.1	7/13/05	0	0	0
Fortification Creek	1702.8	7/11/05	0.307	0.001	0.308
Four Mile Creek	171	7/28/05	0.001	0.003	0.004
Good Spring Creek	668.1	8/1/05	0.111	0.02	0.131
Harding Hole	68.4	7/21/04	0	0	0
King Solomon Creek	670.4	7/27/05	0	0	0
Lester Creek, Willow Creek	358	7/18/05	0	0	0
Little Snake River	4886.9	7/7/05, 7/12/05, 7/19/05, 7/29/05, 7/30/05	150.013	75.495	225.508
Mud Spring Draw	463.7	8/1/05	0	0	0
Red Rock Canyon	63.9	7/13/04	0	1.507	1.507
Sand Creek	367.2	7/12/05	0.022	15.756	15.778
Sand Wash	485.7	7/8/05	2.509	3.784	6.293
Service Creek	404	7/16/05	0	0	0
South Sand Wash	326.5	7/8/05	0	2.491	2.491
Spring Creek	307.8	7/30/05	1.751	3.872	5.623
Starvation Valley	11.1	6/7/04	0	0.7	0.7
Tepee Draw	242.2	6/5/04	0	0.902	0.902
Trout Creek	500.6	7/13/05, 7/16/05	0	0	0
Vale of Tears	189.8	7/18/04	0	0	0
Williams Fork	1799.9	7/11/05	14.958	5.25	20.208
Wilson Creek	538.7	8/1/05	0	0.85	0.85
Yampa River – Maybell to Cross Mountain	1418.6	7/12/05, 7/14/05, 7/15/05	28.483	21.28	49.763
Yampa River – Round Bottom to Morgan Gulch	1205.4	8/3/05, 8/4/05	0.471	52.359	52.83
Yampa River – Twelvemile Gulch to Deerlodge Park	670.1	7/15/05	5.455	18.237	23.692
Yampa River – Deerlodge Park to Echo Park	2983.8	8/13/03, 6/3/04 – 6/9/04	0.605	66.95	67.555
Totals	**23,196.3**		**204.864**	**271.282**	**476.146**

Inventory Findings

The following summarizes the findings depicted in Tables 2 – 8:

1. General Description of Main stem Tamarisk Infestations:

    a. The **Colorado River** from the CO/UT state line to Palisade (55 miles) has approximately 3,350 total acres of tamarisk infestation at approximately 46% average density. The Palisade to Glenwood Springs section (77 miles) has approximately the same amount of infestation (3,300 total acres) but has a lower percent average density at approximately 25%. Because the Colorado River is generally more incised than a broad floodplain river such as the Arkansas River in eastern Colorado, its tamarisk infestations are typically narrower, averaging several hundred feet in width except in the Grand Valley area around Grand Junction where the width averages nearly 900 feet.

    b. The **Gunnison River** from Grand Junction to its confluence with the North Fork of the Gunnison has 2,600 total acres of tamarisk infestation at approximately 27% average density. The broadest section of the infestation stretches from the Mesa/Delta County Line to Delta City, averaging over 400 feet in width with a 28% density, and the narrowest from Grand Junction to the Mesa/Delta County Line averaging only 191 feet at 28% density.

    c. The **Uncompahgre River** from Delta to Montrose has 1,500 total acres of tamarisk infestation at approximately 16% average density. This area has a considerable amount of Russian olive.

    d. The **Dolores River** from the CO/UT state line to Slickrock has over 2,3oo total acres of tamarisk infestation at approximately 36% average density. The broadest section of the infestation stretches from the Mesa/Montrose County boarder to Bedrock, averaging 308 feet in width with a 41% density, and narrowest from the Montrose/San Miguel County boarder to Slickrock, averaging only 65 feet at 30% density.

    e. The **White River** from the CO/UT state line has 1,200 total acres of Russian olive infestation at approximately 37% average density and 1,400 total acres of tamarisk infestation at approximately 17% density.

    f. **Yampa/Green River**: The overall total acres infested with tamarisk and Russian olive is approximately 475 acres of which tamarisk comprised 57 percent of the total acres infested and Russian olive made up the remaining 43 percent of the infested acres. No detailed surveys have been performed for the short section of the Green River within Colorado outside of the Monument's boundary.

2. General Descriptions of Tributary Tamarisk Infestations:

    a. The major tributaries for the **Colorado River** had an additional 900 acres of infestation with an average density of approximately 33%.

    b. The major tributaries of the **Gunnison River** have an additional 710 acres of infestation with an average density of approximately 22%.

    c. No tributaries of the **Uncompahgre River** were mapped.

    d. The major tributaries of the **Dolores River** have an additional 870 acres of infestation with an average density of approximately 24%.

    e. The major tributaries of the **White River** have an additional 1,300 acres of tamarisk infestation with an average density of approximately 46%.

    f. Of the total acreage infested within the **Yampa/Green River** only about 12 percent occurs in tributaries outside of the Yampa, Green, and Little Snake rivers.

3. Current water losses are based on the amount of water tamarisk is currently using under observed densities minus the water that would be used by native plants. Figure 2 illustrates the differences in vegetative cover with and without tamarisk and shows that tamarisk is able to occupy a much greater area than the riparian zone that supports cottonwoods and willows, also phreatophytes. The significant water losses occur as tamarisk occupies terrace areas within the floodplain that would normally have dryland xeric vegetation such as grasses, sage, rabbit brush, etc. The overall Colorado River system and its tributaries generally have terrace areas ranging between 35% and 60%. Based on these conditions, the estimates of current water losses above and beyond what native vegetation would use are approximately:

    Colorado River

    a. Colorado River from CO/UT state line to Palisade = 4,600 acre-feet a year.
    b. Colorado River from Palisade to Glenwood Springs = 2,400 acre-feet a year.
    c. Tributaries = 900 acre-feet a year.

    Gunnison River

    d. Gunnison River from Grand Junction to its confluence with the North Fork Gunnison = 1,900 acre-feet per year.
    e. Tributaries = 440 acre-feet per year.

    Uncompahgre River

    f. Uncompahgre River from Delta to Montrose = 670 acre-feet per year.

Dolores River

g. Dolores River from CO/UT state line to Slickrock = 2,400 acre-feet per year.
h. Tributaries = 570 acre-feet per year.

White River

i. White River from CO/UT state line to the upper extent of infestations = 1,870 acre-feet per year.
j. Tributaries = 1860 acre-feet per year.

Yampa/Green River

k. No estimates were made for the Yampa/Green river system

4. Future water losses assume an infilling of the existing infestation areas will likely occur over the next several decades based on similar conditions observed in other states (NM, UT, and NV). Future water losses from infilling only (with no expansion from existing infested areas) are estimated to be approximately:

Colorado River

a. Colorado River from CO/UT state line to Palisade = 9,900 acre-feet per year.
b. Palisade to Glenwood Springs = 9,600 acre-feet per year.
c. Tributaries = 2,700 acre-feet per year.

Gunnison River

d. Gunnison River from Grand Junction to its confluence with the North Fork Gunnison = 7,000 acre-feet per year.
e. Tributaries = 2,000 acre-feet per year.

Uncompahgre River

f. Uncompahgre River from Delta to Montrose = 4,200 acre-feet per year.

Dolores River

g. Dolores River from CO/UT state line to Slickrock = 6,800 acre-feet per year.
h. Tributaries = 2,400 acre-feet per year.

White River

i. White River from CO/UT state line to the upper extent of infestations = 7,100 acre-feet per year.
j. Tributaries = 4,000 acre-feet per year.

Yampa/Green River

k. No estimates were made for the Yampa/Green river system

5. If tamarisk control and revegetation occurs on any of these river or tributary sections, the water normally lost to the atmosphere through evapotranspiration will be conserved and will remain within the groundwater and/or surface water regimes.

6. Throughout these watersheds it is common to have Russian olive coexist with tamarisk especially in the urban corridor where Russian olive has escaped from landscape plantings. One exception is the Roaring Fork River which has essentially no tamarisk but has some moderate Russian olive infestations. Anther exception is in the lower reaches of the White River where Russian olive is the predominant nonnative phreatophyte.

Expected Ecosystem Changes to Riparian Areas – Expected conditions following tamarisk and Russian olive control projects in the Colorado, Gunnison, Uncompahgre, Dolores, White, and Yampa/Green watersheds include enhanced aquatic, riparian, and floodplain habitat. The quantity and quality of these habitats would be improved, resulting in increased habitat for fish and wildlife including endangered fish species. Opportunities for environmental education, improved aesthetics, recreation, agricultural use, and improved management of flood flows would exist in project areas. Significant conservation of water resource would also result from tamarisk and Russian olive control in these watersheds. These expected changes will occur only if all aspects of restoration are part of the solution; i.e., site specific planning and design, control, revegetation, biomass reduction, monitoring, and long-term maintenance.

Beneficial impacts of restoration also include increased resilience to future stresses such as fire, drought, climate change, or other invasive plants; creating a more self-sustaining ecosystem; providing the benefits of improved water resources; and reducing future riparian management costs.

Control, Biomass Reduction, Revegetation, Monitoring, and Long-term Maintenance

Management of non-native phreatophytes generally consists of five components – planning with inventory/mapping, control and biomass reduction, revegetation, monitoring, and maintenance. Without all five components it is unlikely that tamarisk and Russian olive control projects will be successful over time. Successful management also depends on flexible approaches open to experiential learning and new technologies. This is referred to as “adaptive management.”

For the discussion on the control component of management, the focus is on tamarisk because it is the principal non-native phreatophyte in the Colorado, Gunnison, Uncompahgre, Dolores, White, and Yampa/Green watersheds. In general, the following discussion also applies to Russian olive but may be slightly different for each (e.g., type of herbicide used). A detailed comparison of major control technologies implemented throughout the West can be found in Appendix F which describes in more detail effectiveness, impacts, applicability, cost algorithms, and time distribution of costs.

Appendix G, Templates and Protocols, provides a suggested approach to select appropriate techniques for control and biomass reduction, revegetation, monitoring, and long-term maintenance. Biomass reduction and revegetation approaches are not always needed because in many situations natural revegetation can occur and biomass reduction may not be needed. For the purposes of this Plan the term *template* defines what actions should be taken, and the term *protocol* defines how the actions could be performed. These templates and protocols are intended as suggested guidance and criteria for decision making while carrying out the activities associated with various aspects of tamarisk and Russian olive control and biomass reduction, revegetation, monitoring, and long-term management. Thus, the intent is to ensure that selected approaches are effective and efficient, and decisions are well documented.

Control

Tamarisk can be controlled using a variety of weed management techniques, including chemical, mechanical, and biological techniques. 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 the "toolbox" from which land managers select techniques for a project in a specific setting.

The IPM toolbox includes prevention, cultural management (land stewardship), mechanical or physical removal, biological control, herbicide treatments, and revegetation techniques. Appendix F provides photos and detailed comparison of each of these major control technologies. It should be noted that there are many hybrids of these technologies that fall within the general understanding of tamarisk control. Actual costs and applicability may vary for each site. The basic approaches include:

- **Hand cutting with herbicide application** – This method is referred to as the "cut stump" approach in which the tree is cut or scored with chainsaws, handsaws, or axes, and the stump is treated with an herbicide within a few minutes of cutting. This approach is considered to be very appropriate in the CHIP study area for difficult to access areas; areas of special concern; areas in close proximity to valuable native vegetation, historic and archeological sites; campgrounds; and efforts involving volunteer support.

- **Hand removal by extraction –** This method uses simple hand tools such as the Weed Wrench, tripod/hand winch, and shovels and saws to dig out the root system and cut below the root crown. These techniques have been perfected at the Dinosaur National Monument and utilize volunteer groups because of their high labor requirements. No herbicides are used with these approaches. These approaches are most appropriate for the CHIP study area in sensitive areas where volunteer labor can be used to effectively remove tamarisk. This approach may not work on larger trees.

- **Mechanical removal –** This approach uses heavy equipment to physically remove tamarisk. This is accomplished in one of two ways – root crown removal or mulching.

  - **Root crown removal** is the extraction of the root crown by either root plowing accompanied by root raking to remove the root crown from the soil or by extraction of the entire plant. These approaches do not use herbicide.

    - **Root plowing and raking** is extremely disruptive to the soil, native plants are destroyed, and the intense soil disturbance would support weed viability. It essentially removes all vegetation in a manner that would be similar to preparing land for intense agricultural production. For this reason and because much of the area is not accessible for large equipment (Cat D-7 or larger), it is unlikely that root plowing and raking would be used extensively in the CHIP area.

    - **Extraction** approaches using a large tracked excavator (Cat 325 or larger) is appropriate for some areas, especially those areas that have steep banks such as ditches and river banks and along roadway embankments. This approach results in high levels of soil disturbance and thus may require significant revegetation efforts. The removed biomass may also require disposal or additional treatment such as mulching.

  - **Mulching** uses newly developed, specialized equipment followed by herbicide application to the cut stumps. The most commonly used pieces of equipment are the Timber Ax, the Hydro Ax, and the Bull Hog. The resulting mulched materials can reduce soil disturbance, and provide a good seed bed for native plant recruitment if the mulched materials are not too thick while discouraging establishment of noxious weeds. Tracked mulching equipment provides a lighter footprint pressure than those with wheels and thus causes less soil disturbance. CHIP areas suitable for this approach are limited to wide or somewhat level floodplains or terraces in scattered locations along the Colorado River. A few larger tributaries could also be treated by mulching.

- **Aerial herbicide application –** In larger infestation areas such as in Texas and New Mexico, helicopter and fixed wing aircraft are being used to apply foliar herbicide where monotypic stands of tamarisk exist. This approach will likely be limited in the CHIP area because: 1) monotypic infestations in this region are typically not broad enough to make this approach economically feasible, 2) significant native vegetation is present within the tamarisk infestations and aerial spraying would cause mortality among these species, and 3) preliminary biological control results for this region look promising.

- **Ground application of foliar and basal bark herbicides –** Herbicides can be effectively applied by hand, from horseback, or by motorized equipment in some cases where other methods are impractical or expensive. It is recommended that this approach be used in isolated areas where other methods would unlikely be used such as scattered infestations in sparse or remote locations, upland areas, isolated stock tanks, etc.

- **Biological control –** This method for invasive plant control uses specific organisms to control an undesirable organism. For tamarisk, two biological control agents have been identified – goats and a tamarisk leaf-eating beetle. Both organisms work to control tamarisk by repeated defoliation of the plant over several years.

  - **Goats** will feed on tamarisk shrubs if fencing is provided to limit other food sources. Typically, a guard dog, herding dog, and goat herder or electric fencing pens are required. Several private goat herds are available throughout the region. For some areas this approach may be favored, especially if other noxious weeds such as knapweed are in abundance and herbicide use is restricted.

  - ***Diorhabda elongata*, tamarisk leaf-eating beetle,** has been tested extensively in quarantine and field releases to ensure safety with respect to non-target impacts. These insects (see Figure 3) are native to Asia and are currently approved for open release in Colorado. These releases are being closely monitored by the Colorado Department of Agriculture's Palisade Insectary and entomologists from CSU. Russian olive will not be controlled through this biological control agent. The use of these insects is seen as an important issue and a promising approach for tamarisk control for the main river corridor. Because of the significance of this technique to the CHIP study area, a more complete discussion on this approach is provided in the next section.

Figure 3: *Diorhabda elongata* adult beetle, actual size ~ 3/16 inch.

Biological Control of Tamarisk with the Tamarisk Leaf Beetle and Its Implications for Western Colorado

Concentrated releases of large numbers of the biological control tamarisk leaf beetle (*Diorhabda elongata*) were made in the Moab, Utah area in the fall of 2003 and spring and summer of 2004. These release sites are located along the Colorado River at Dewey Bridge on Highway 128, near Moab, and at the Potash mine site approximately 15 miles west of Moab. These releases resulted in a few tamarisk trees being defoliated in Year-1 and approximately 2 acres in Year-2. In Year-3, the insect populations were fully established and tamarisk was totally defoliated (though not killed), on over 10 miles of the Colorado River including spread to non-release sites on the opposite side of the river and along tributaries (see Figures 4, 5, and 6). In Year-4 (2007), the insect populations continued to spread and tamarisk was totally defoliated on over 100 miles of the Colorado River from the Green River confluence to several miles above Dewey Bridge near the Dolores river confluence. Natural spread was noted with beetles and spotty defoliation detected downstream all the way to Lake Powell and upstream approximately 30 miles into Colorado on the Dolores River. Some tamarisk tree mortality was noted at the original release sites.

Controlled test sites show that three to five years of sequential defoliation are required to achieve tamarisk mortality of 70 percent (Delta , Utah); however, it is unknown how many seasons of defoliation will be required to kill tamarisk in western Colorado's natural setting (Bean, 2007). The most promising characteristic of the tamarisk beetle is that it inflicts no damage to native plant populations. Preliminary evidence of effectiveness shows great potential and if biological control continues to progress it could be used as one of the main mechanisms for tamarisk control and maintenance. If this is the case, the advantages over other approaches will be significant; i.e., limited use of herbicides and a cost effective long-term solution.

Figure 4: Colorado River at Potash mine boat launch area near Moab, Utah showing defoliated tamarisk, August 15, 2006

Figure 5: Defoliated tamarisk and undamaged native vegetation along the Colorado River west of Moab, Utah; August 15, 2006.

Another point of interest is that lightly infested areas some distance from the main tamarisk infestations along the Colorado River in southeastern Utah support beetle activity and experience defoliation. However, overtime, these small stands may simply provide an insufficient food source to sustain a growing population of insects. Thus, alternative methods should be considered for these areas.

Starting in 2006 the Palisade Insectary has established western slope release sites at Horsethief, Flume, and Knowles canyons and Parachute Creek in the Colorado River watershed; Escalante Canyon on the Gunnison River; Dolores River south of Gateway; at Dinosaur National Monument on the Yampa River; Browns Park on the Green River, and McElmo Creek on the San Juan River. Between the development of sustainable insect populations at these sites and the migration of insects from Utah, it is very likely that biological control will successfully move forward in much of western Colorado.

Using biological control as the primary tamarisk control technology requires several considerations to ensure that the approach garners successful results. Monitoring will be instrumental in determining rate of spread, native plant recruitment, other weed infestations to be addressed, biomass accumulation, and dead biomass removal approaches. The expertise of the Palisade Insectary and CSU will be critically important for identifying the most appropriate protocols for disbursement, monitoring, and follow-up actions.

Although biological agents are being investigated for Russian olive, these invasive trees will require traditional methods of control for the foreseeable future.

Figure 6: Defoliated tamarisk and undamaged cottonwood along the Colorado River at Jug Handle Arch near Moab, Utah August 15, 2006

Biomass Reduction

Removal of dead tamarisk tree skeletons may be important after mechanical root crown removal, biological control, or foliar herbicide control if densities are moderate to heavy. Biomass reduction under these conditions assists planned revegetation efforts, restores aesthetic values, and reduces the wildfire potential of decomposing litter in moderately to highly infested areas. The removal of dead trees can be accomplished using mechanical mulching equipment or fire.

Mechanical mulching, by its nature manages the dead material by transforming it into mulch. However, if a large amount of biomass is mechanically mulched and piled the thickness of the layer produced may actually impede or prevent revegetation. Reducing biomass with fire may require the construction of adequate fire breaks in sensitive riparian areas to safely burn the invasive plants. In addition, air quality may be a concern for large-scale burns as carbon sequestered in the tamarisk will be released instantly. **Fire is an option that must be carefully coordinated with land managers and county air quality personnel. It should only be used for biomass reduction on dead plants, because live tamarisk will flourish after fire.** As shown in Figure 7, fire breaks and professional fire fighting staff are critical because of the intensity that tamarisk fires exhibit.

For many areas with light to moderate infestations, the dead biomass can be left standing without any actual physical biomass reduction actions. Standing dead biomass in these situations probably does not significantly impede natural or planned revegetation, affect aesthetics, or support high wildfire potential. After plant mortality, it will take an additional two to four years for root decay to occur before the dead skeletons will naturally fall over. Over the next few years the remaining biomass will decompose to a level that may not present any significant problems. These time estimates are based on site observations of tamarisk killed by herbicide in the area.

Figure 7: Removal of dead tamarisk using controlled fire at the Bosque del Apache NWR, NM 2004

Revegetation

Successful revegetation is an enormously complex undertaking with few straightforward guidelines and no universal solutions. As a result, implementing revegetation projects following the removal of invasive species is an inherently site-specific task that does not easily translate into a large scale plan. For the CHIP planning area it is recommended that local revegetation specialists, CSU Cooperative Extension, NRCS, and comprehensive revegetation and restoration texts be used to develop a course of action for individual projects. The University of Denver is currently preparing a “Best Management Practices” handbook for revegetation that will be available in the Fall of 2008. There are many excellent sources presently available to inform revegetation actions with some of them reviewed below:

- **Society for Ecological Restoration**
  Summary: This site provides a reading list for ecological restoration practices, links for many example projects and other resources and support.
  http://www.ser.org/reading_resources.asp

- **Riparian Restoration in the Southwest – Species Selection, Propagation, Planting Methods, and Case Studies**
  Summary: This document identifies the natural processes and managed activities that cause the degradation of riparian lands and provides general guidelines to restore the natural system. It details methods of selecting appropriate species for revegetation, producing riparian plants, planting techniques, and provides case studies of past projects.
  http://www.nm.nrcs.usda.gov/programs/pmc/symposium/nmpmcsy03852.pdf

- **Stream Corridor Restoration: Principles, Processes, and Practices**
  Summary: This large and detailed document has a three-tiered design. The first section provides background information describing the basics of stream corridor systems. The second section describes the steps to produce an effective restoration plan. The final section provides guidelines to implement restoration projects.
  http://www.nrcs.usda.gov/technical/stream_restoration/

- **Guidelines for Planning Riparian Restoration in the Southwest**
  Summary: This restoration guide is intended to address concerns that must be considered when developing riparian restoration projects as well as a number of responses or solutions to these potential problems.
  http://www.nm.nrcs.usda.gov/news/publications/riparian.pdf

- **Guidelines for Planting Longstem Transplants for Riparian Restoration in the Southwest: Deep Planting**
  Summary: Good possible technique if you are revegetating a riparian site that lacks overbank flooding and has a deep water table.
  http://www.nm.nrcs.usda.gov/news/publications/deep-planting.pdf

- **The Pole Cutting Solution**
  Summary: Guidelines for planting dormant pole cuttings in riparian areas of the Southwest. Planting dormant pole cuttings has proven to be a successful technique for establishing many riparian tree and shrub species.
  http://www.nm.nrcs.usda.gov/news/publications/polecutting.pdf

- **Plant Technology Fact Sheet: Tall-Pots**
  Summary: This fact sheet describes the use of tall-pots to establish plants in areas lacking sufficient soil moisture or irrigation availability to revegetate using more traditional means. A discussion of the structure, usefulness, benefits, and limitations of the tall-pot revegetation method is included.
  http://www.nm.nrcs.usda.gov/programs/pmc/factsheets/tall-pot.pdf

While the specifics of revegetation are difficult to comprehensively determine, some general information corresponding to the CHIP planning area is provided.

One of the most interesting aspects of local experience with tamarisk control is the abundance of native plants present in the tamarisk understory. Non-native weeds such as Russian knapweed and whitetop were also found and could become a problem if left unattended. Annual weeds, while a short term concern, generally find a balance that does not preclude native plant establishment (with some exceptions). A plant list is included in Appendix H as a starting point for revegetation planning, keeping in mind the importance of knowing specific site characteristics before choosing plants for revegetation purposes.

Revegetation is critical to successful long-term tamarisk and Russian olive control. Revegetation efforts may require labor, seed, plant materials, fertilizer, equipment rental, weed control, and water. Requirements for revegetation have a direct relationship to density of infestation and width of infestation. For narrow widths (less than 50 feet) natural revegetation may occur more easily because of close proximity to native plant/seed sources. However, these areas may still incur minor to moderate costs because of soil disturbance and the need for weed control. For broader widths (greater than 50 feet) costs will shift to the higher side because less native plant/seed will be available for reintroduction to the interior areas of the infestation. Other site conditions also influence revegetation such as surface and ground water dynamics, soil chemistry and texture, density of propagules of desired revegetation species, etc.

When there are many natives interspersed within the tamarisk stand (which is often difficult to determine until removal begins) removal of invasives must be executed in a manner that protects native seed sources for natural revegetation on-site and within the basin. Manual control, root extraction and Timber Ax mowing/mulching are methods capable of sparing interspersed natives, even 1-inch caliper saplings.

In broader areas of infestation, it may be important to plan a biomass removal pace that allows and encourages natural native plant regeneration rather than seeding and planting. However, in such large dense stands of tamarisk it may be advisable to create vegetative islands and paths within the tamarisk to help speed the native regeneration process, and provide fire breaks.

In some higher value areas such as wildlife habitats or high profile/high human use areas tall pot, bare root, and pole plantings and seeding may be desirable to aid in the regeneration process. However, these kinds of revegetation projects are extremely expensive and require long-term maintenance commitments.

Monitoring

For riparian restoration activities, “monitoring” is the act of observing changes that are occurring or expected to occur with, or without, remediation actions. The purpose of monitoring is to provide information in response to objectives, to make informed decisions to initiate, continue, modify, or terminate specific actions, remediation activities or programs – better known as "adaptive management."

Two considerations important to the CHIP monitoring efforts to gauge ecological changes are scale and ownership. In general there are two divisions in each of these elements: large-scale versus small-scale projects; and public ownership versus private ownership. For the purposes of this discussion it will be assumed that parcel sizes large enough to support large-scale projects are usually located on public lands and that small scale projects will be located primarily on private lands. Coordination between private land owners and public land managers is essential to gain access to private lands, create a standard monitoring protocol, and to develop and execute training in monitoring methods. Depending on the objectives of each restoration site, varying combinations of monitoring approaches may be designed based on intensity of restoration, site specifics, or capability of collaborators.

Large-scale monitoring on public lands allows policy makers, land managers, and the public to evaluate the potential impacts of remediation on water resources, vegetation, wildlife habitat, biodiversity, economic health, society, and culture. These are essential considerations for determining what level of funding should be committed to the control efforts by the local, state, and/or federal agencies. Pre-restoration monitoring is important to establish baseline data to determine if goals and objectives are being achieved on the landscape scale.

Small-scale monitoring on private lands provides useful information on the effectiveness of control and remediation activities. This information allows for modifications, if necessary, to achieve the remediation goals. In general, small-scale monitoring criteria should consist of simple and inexpensive monitoring techniques based on the needs of the management objectives.

Long-term Maintenance

Long-term maintenance is a dynamic management process, carried out over years to decades to achieve social, economic, and ecological goals associated with a watershed. The process of management encompasses the strategic implementation of actions to identify, maintain, remediate, improve, and monitor the ecological processes of the watershed. Actions, and the tools required to accomplish them, are chosen because they are consistent with and likely to achieve the watershed goals, and because they address the results of monitoring.

Monitoring is related to maintenance in that it is the act of observing changes that are occurring with, or without, remediation actions. Monitoring provides information for making informed decisions to ensure "maintenance" will continue to remediate or improve the ecological processes of the watershed. For tamarisk and Russian olive restoration these measures are important for effective control on a long-term basis and that the desired outcomes of revegetation and prevention of other noxious weed infestations are successful.

Research shows that if resources are spent only on control with no cohesive approach to long-term revegetation, monitoring, and maintenance, the potential for successful riparian restoration is limited.

Proposed Strategies for Control, Biomass Reduction, Revegetation, Monitoring, and Long-term Maintenance of Watershed Sections

The mapping and inventory work completed for the Colorado Water Conservation Board (Appendices D and E), coordination with county weed managers, and the economic algorithms developed by the Tamarisk Coalition (Appendix F) identify a range of costs for tamarisk and Russian olive control and restoration. Combining the attribute information gathered for each area of infestation (acres, percent cover, accessibility, and width) with the economic algorithms found on the supplementary Data-DVD provides a "planning-level" range of costs based on an Integrated Pest Management approach for each individual area. This detailed information is presented in the supplementary Data-DVD. A summary of this cost information is provided in Tables 2-7.

The cost information is considered to be appropriate for planning purposes to understand the basic range of costs one could expect. Based on the estimates developed, the overall costs are:

Colorado River:

- Overall costs for tamarisk and Russian olive control are approximately $8,000,000 for the Colorado River mainstem and its major tributaries from the CO/UT state line to the Glenwood Springs area. To account for unsurveyed sites an extra 20 percent contingency should be added.

- Costs per acre average approximately $1,000 and costs per mile are approximately $52,000 for the Colorado main stem and $13,000 for tributaries. These costs include planning/design, control, revegetation, biomass reduction, monitoring and long-term maintenance.

Gunnison & Uncompahgre Rivers:

- Overall costs for tamarisk and Russian Olive control are approximately $3,300,000 for both the Gunnison and Uncompahgre Rivers and their major tributaries. To account for unsurveyed sites, an extra 20 percent contingency should be added.

- Average costs per acre are approximately $700 and costs per mile are approximately $25,000. These costs include planning/design, control, revegetation, biomass reduction, monitoring, and long-term maintenance.

Dolores River:

- Overall costs for tamarisk and Russian olive control are approximately $3,200,000 for the Dolores River and its major tributaries. To account for unsurveyed sites, an extra 20 percent contingency should be added.

- Average costs per acre are approximately $1,000 and costs per mile are approximately $23,000. These costs include planning/design, control, revegetation, biomass reduction, monitoring, and long-term maintenance.

White River:

- Overall costs for tamarisk and Russian olive control are approximately $3,750,000 for the White River and its major tributaries. To account for unsurveyed sites, an extra 20 percent contingency should be added.

- Average costs per acre are approximately $1,000 and costs per mile are approximately $36,000. These costs include planning/design, control, revegetation, biomass reduction, monitoring, and long-term maintenance.

Yampa/Green River:

- No specific cost analysis was performed for the 450 acres of tamarisk and Russian infestation mapped by Dinosaur National Monument. However, assuming an average cost of approximately $1,000 per acre typical for the other Colorado River watershed river systems, the restoration costs for the Yampa/Green watershed should approach $500,000.

Proposed Watershed Strategies

The following discussions are the proposed strategies for tamarisk control, biomass reduction, and revegetation for specific geographic settings for the Colorado, Gunnison/Uncompahgre, Dolores, White, and Yampa/Green watersheds. These strategies were developed in coordination with county weed managers and land managers throughout the region.

As a component of these strategies, revegetation will likely occur naturally for lightly infested sites with some minor weed control. For moderate infestations, some reseeding will be necessary while heavy infestations will require substantial revegetation efforts. Weed control will increase proportionately with the degree of infestation. In general, revegetation efforts for all areas, when required, may consist of:

1. Pole cuttings for cottonwoods and willows in areas with shallow groundwater (less than 10 feet).

2. Longstem planting using tall pot techniques to revegetate upper terrace sites that have deeper groundwater and lack overbank flooding. This approach is very useful for some trees and shrubs such as currants and skunkbush. For more information see the revegetation section contained earlier in the plan.

3. Broadcast or seed drilling for grasses and forbs such as salt grass, alkali sacaton, sand dropseed, alkali muhley, and Indian ricegrass.

Weed control following tamarisk and Russian olive control and during revegetation efforts is necessary to prevent the establishment of noxious weeds such as Russian knapweed, perennial pepperweed, cheatgrass, hoary cress (whitetop), Canada thistle, etc. In general, weed control for all areas, when required, may utilize herbicide, mechanical, biological, and through preventive measures associated with successful revegetation approaches.

Colorado River Watershed Strategies

Colorado River, CO/UT state line to Loma – Ruby & Horsethief Canyons – This area, represented by aerial photos C-1 to C-6 in Appendix E, is located in the remote McInnis Canyons National Conservation Area. Access is limited to the river except in a few isolated locations. Tamarisk infestations are light to heavy and are concentrated in the floodplain of this canyon ecosystem. Over the past several years, the Bureau of Land Management has removed most of the Russian olive and some tamarisk around campsites. Most of the river bank and many of the islands have healthy willow plant communities with scattered groves of cottonwoods. The following discussion applies to the main stem of the river and the mouths of tributaries.

Tamarisk control in this area should primarily rely on biological control with some hand cut stump work as necessary around camp sites. For light to moderate infestations it is recommended that the dead biomass resulting from biological control be left standing. Over the next ten years these skeletons should naturally be reduced in size due to root decay in the first two to four years and biomass decomposition during subsequent years. For sites with heavy infestations, removal of biomass material may be necessary and would best be done by hand or by fire if sufficient precautions are made. Some areas, such as the mouth of Salt Creek and adjacent to the railroad right-of-way may be accessed by mechanical equipment for biomass reduction. These options must be carefully coordinated and directed by BLM and the railroad company.

Knowles, Mee, McDonald, Rattlesnake, Pollard, Devils, Kodel, Ute, Monument, and No Thoroughfare Canyons and Rabbit Valley – These are the primary canyons that descend from the Colorado National Monument and/or are in the McInnis Canyons National Conservation Area. They typically have heavier tamarisk infestations at their juncture with the Colorado River and become sparse farther upstream. Willow and cottonwood communities are also densest closer to the Colorado

River and decrease in density upstream. Hand cut stump control should be used in each of these areas starting at the upper extent of infestations and working down to the continuous infestations that connect with the Colorado River. Biological control on the mainstem of the Colorado River should provide the necessary treatment for these heavier infestations that are contiguous with river infestations. Russian olive has no significant presence in these canyons.

Biomass reduction should not be necessary for the upper portions of the canyons where hand control is performed. Natural revegetation with skunkbush, 4-wing saltbush, currants, rabbitbrush, and other shrubs, grasses, and forbs will likely occur in most areas; however, some weed control will be required.

Colorado River, Loma to Palisade – This area is in the broad floodplain of the Grand Valley and contains the greatest concentration of tamarisk on any river system in western Colorado (see aerial photos C-7 to C-16 of Appendix E). The primary management method should be biological control. Some high priority areas such as the Colorado River trail system and the Colorado River State Parks could be cleared using mechanical or hand cut stump methods. No herbicide should be needed for resprouts if biological control is active in the area. For some areas it will be appropriate to perform mechanical or hand cut stump removal to form fire breaks or to reduce wildfire potential. Along Interstate 70 between Loma and Grand Junction, mechanical removal with cut stump herbicide application or extraction should be used to assure highway safety.

Russian olive, although less abundant than tamarisk, has a significant presence throughout much of this river section. Control will require either hand or mechanical cut stump approaches with herbicide application as the primary approach in all areas.

Biomass reduction should not be needed for light infestations and some moderate infestations but should be performed for all other situations to reduce the fuel load in riparian areas. This is especially important to protect the valuable cottonwood galleries in much of these areas as well as native shrubs such as skunkbush, 4-wing saltbush, currants, and rabbitbrush. Mechanical methods are recommended with some hand work required in difficult to access areas. As with other sites, natural biomass decomposition and reduction should occur after biological control has caused a significant mortality in tamarisk.

Areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Salt Creek, Mack Wash, and Adobe Creek – These three Bookcliff drainages are typical of over a dozen small watersheds that flow into the Colorado River from the north. They generally have heavy infestations at their confluence with the Colorado River and sparser infestations upstream. Additionally, numerous deep ditches constructed to drain irrigated lands in the valley are choked with both tamarisk and Russian olive. These drainages cut through highly alkaline, silty soils derived from the marine deposited Mancos shale of the Book Cliffs; therefore, only limited areas or segments could support willow, cottonwoods, and many riparian grasses. Mechanical and hand cut stump control should be used here, starting at the upper infestations where densities are light and working down to the point of contiguous infestations that connect to the Colorado River. Biological control on the mainstem of the Colorado River should provide the necessary treatment for these heavier infestations. Many of these areas have Russian olive problems that equal or exceed tamarisk in density and will require hand and/or mechanical removal.

Biomass reduction should not be necessary because of natural decomposition for the upper portions of the canyons where hand control is performed. Some areas such as Salt Creek have significant densities of infestations that require biomass reduction either mechanically or by fire. Natural revegetation will likely occur in most lightly infested areas because of the abundance of native plants; however, other areas may require significant efforts targeting salt tolerant species such as skunkbush, 4-wing saltbush, salt grass, alkali muhley, and alkali sacaton. Revegetation on Salt Creek should be a priority. Weed control for all areas will be important.

Colorado River, DeBeque Canyon – This area is illustrated on aerial photos C-16 to C-20 of Appendix E and is bordered by I-70 on the south and the Denver Rio Grande railroad grade on the north. This area has light to moderate infestations except around the Cameo exit (see aerial photo C-17 of Appendix E). The native vegetation in this floodplain consists of cottonwood groves and upper terrace vegetation such as skunkbush, 4-wing saltbush, currants, rabbitbrush, sagebrush, and grasses. The recommended tamarisk control strategy is biological control with hand or mechanical control for Russian olive scattered throughout the area. For the Cameo area, mechanical control is recommended to reduce the fuel load in the cottonwood groves on both sides of the river. Herbicide would only be necessary to treat cut stumps. No herbicide would be needed for resprouts if biological control is active in the area.

Except for the heavily infested areas, no biomass reduction is necessary except for the interstate where safety is a concern. Revegetation will mostly be focused on areas of heavy infestation near the Cameo exit. Weed control will be needed throughout this reach.

Colorado River, DeBeque to Silt – This section of the Colorado River has heavy tamarisk infestations near the town of DeBeque gradually decreasing in density approaching the town of Silt (see aerial photos C-21 to C-33 in Appendix E). The recommendations for this area are very similar to those for the Grand Valley area. The primary tamarisk management should be biological control. Some high priority areas such as the DeBeque State Wildlife Area and west of the Rifle I-70 Rest Area could be cleared using mechanical or hand cut stump methods. No herbicide should be needed for resprouts if biological control is active in the area. For some areas it will be appropriate to perform mechanical or hand cut stump removal to form fire breaks or to reduce wildfire potential. Along Interstate 70 near Rifle, mechanical removal with cut stump herbicide application or extraction should be used to assure safety along this roadway.

Russian olive is a significant problem in some areas on this section of the Colorado River. It is present not only in the floodplain, but in fallow fields and along fence rows. Control will require either hand or mechanical cut stump with herbicide application.

Biomass reduction should not be needed for light infestations and some moderate infestations but should be performed for all other situations to reduce the fuel load in riparian areas. This is especially important to protect the valuable cottonwood galleries in many areas. Mechanical methods are recommended with some hand work required on difficult to access areas.

Areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Colorado River, Silt to Glenwood Springs – This section of the Colorado River (see aerial photos c-34 to C-35 of Appendix E) has only isolated pockets of tamarisk. Russian olive is more abundant, but not yet a major problem. Because infestations are contained within the river's narrow, incised banks, it is recommended that hand control using cut stump method with herbicide be used for control of both species. No revegetation or biomass removal is likely to be needed. Some weed control will, however, be necessary.

For areas beyond the floodplain with significant Russian olive infestations, such as the pasturelands west of the I-70 river crossing in Silt, mechanical mulching with cut stump herbicide application is recommended.

Plateau Creek, Roan Creek, Parachute Creek, Rifle Creek, and Government Creek – The tamarisk locations on these major tributaries to the Colorado River (presented in Appendix E aerial photos) vary from light, isolated infestations to large invasions extending miles upstream. Some tributaries, such as Rifle Creek, have relatively minor infestations, while others such as Roan Creek have heavy infestations. In general, where infestations are scattered, it is recommended that hand control be utilized with herbicide. Where infestations are contiguous, it is recommended that biological control be the main approach. Most of these areas should not require biomass reduction or revegetation efforts; however, weed control will be necessary.

Roaring Fork River – This river section contains very few tamarisk plants; however, there are numerous Russian olives that line the banks, especially in the Glenwood Springs area. Hand control cut stump treatment with herbicide is recommended for these areas. Because of the relatively low density of infestation, this area could be an excellent site for a volunteer effort.

Gunnison & Uncompahgre Rivers Watershed Strategies

Gunnison River: Colorado River confluence in Grand Junction to Uncompahgre River Confluence in Delta – This area, represented by aerial photos Gt-1 to Gt-15 in Appendix E, is located within a shallow canyon for most of its 60 mile length. It is immediately adjacent to the Uncompahgre Plateau on its west flank and bordered by the highly erodible Mancos Shale deposits on the east side. The Denver Rio Grande Railroad occupies the upper floodplain terrace on the east side and there are also several remote ranches within the canyon with small areas of irrigatable land. For the five-mile stretch below the Uncompahgre River confluence, the Gunnison River is contained within a broad floodplain that is in agricultural production. Tamarisk infestations are concentrated in the floodplain of this canyon ecosystem and are predominately light to moderate with a few areas of very dense vegetation. Russian olive is most prominent near Delta, Whitewater, and Grand Junction where they have spread from ornamental plantings. Except near these population centers, access is primarily limited to floating the river.

Tamarisk control in this area should rely primarily on biological control with some hand cut stump work as necessary around camp sites or mechanical treatment in high priority sites such as the Escalante DOW Wildlife Refuge. For light to moderate infestations it is recommended that the dead biomass resulting from biological control be left standing. Over the next ten years these skeletons should naturally be reduced in size due to root decay in the first two to four years and biomass decomposition during subsequent years. For sites with heavy infestations, removal of biomass material may be necessary and would best be done by hand or by fire if sufficient precautions are made. Some areas, near Grand Junction, Whitewater, and Delta and adjacent to the railroad right-of-way may be accessed by mechanical equipment for biomass reduction. These options must be carefully coordinated and directed by the respective land managers and the railroad company.

Much of this area, especially on the west side of the river (river left) supports hearty willow populations, intermixed areas of cottonwood groves, and upper terrace vegetation consisting of skunkbush, 4-wing saltbush, currants, rabbitbrush, sagebrush, and grasses. Revegetation will likely occur naturally for lightly infested sites with some minor weed control. For moderate infestations, some revegetation will be necessary while heavy infestations will require substantial revegetation efforts. Because the soils on the east side of the river (river right) are derived from Mancos shale, any necessary revegetation efforts will require the use of salt tolerant species such as skunkbush, 4-wing saltbush, salt grass, alkali muhley, and alkali sacaton. Weed control will increase proportionately with the degree of infestation. A precaution is important to note for workers in this area as well as on the rest of the Gunnison River; i.e., poison ivy exists throughout.

Gunnison River: Uncompahgre River Confluence in Delta to Austin – This area is represented by aerial photos Gt-16 to Gt-18 in Appendix E. The Gunnison River floodplain is at its widest between Delta and Austin where it supports tamarisk infestations ranging in density from light to moderate. Throughout this stretch, Russian olive is intermixed.

The primary tamarisk control method here should be biological control. Some high priority areas such as Confluence Park in Delta could be cleared using mechanical or hand cut stump methods. No herbicide should be needed for resprouts if biological control is active in the area. Russian olive control will require either hand or mechanical cut stump with herbicide application.

Most of this area sustains hearty willow and cottonwood populations along the river bank and upper terrace vegetation consisting of skunkbush, 4-wing saltbush, currants, rabbitbrush, sagebrush, and grasses. Revegetation will likely occur naturally for lightly infested sites with some minor weed control. For moderate infestations, some revegetation will be necessary. Biomass reduction should not be needed for light infestations and some moderate infestations but should be performed where necessary to reduce the fuel load in riparian areas. This may be especially important to protect the valuable cottonwood gallery in many areas. Mechanical methods are recommended with some hand work required on difficult to access areas.

Areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Gunnison River: Austin to Paonia – This area is represented by aerial photos Gt-16 to Gt-19 and NFGt-1 to NFGt-2 in Appendix E. This section of the Gunnison River passes through a shallow Mancos shale canyon running between Hotchkiss and Austin, and includes a section of the North Fork. In this stretch of the river, the floodplain is generally narrow and tamarisk infestations are predominately light. The Gunnison River upstream of the North Fork contains only a few areas of tamarisk because of control work previously performed by the National Park Service and BLM. The North Fork of the river becomes a wider braided floodplain as it moves through Hotchkiss and Paonia with light to moderate infestations of tamarisk and Russian olive throughout.

Biological control should provide the necessary treatment for the relatively contiguous infestations along the river. As infestations become lighter and more scattered above Hotchkiss on the North Fork, hand cut stump control and mechanical control should be used. These efforts should start at the upper extent of infestations and working down to the continuous infestations that exist below Hotchkiss. Where Russian olive exists in this area hand control and mechanical control will be necessary.

Biomass reduction should not be necessary for most areas within this river section except to reduce wildfire risk in some high priority sites. Natural revegetation will likely occur in most areas; however, some weed control will be required. Revegetation efforts necessary in areas with highly alkaline soils, especially the shallow canyon area upstream of Austin, will require the use salt tolerant native species. Weed control will increase proportionately with the degree of infestation.

Uncompahgre River: Gunnison River confluence in Delta to Montrose – This relatively small river system is the major tributary to the Gunnison River and is presented in aerial photos U-1 to U-12 in Appendix E. Tamarisk infestations are light to moderate throughout the entire river which has a relatively wide floodplain. Russian olive is consistently present throughout this river stretch and in many areas is the predominant species. The native plant community is dominated by cottonwoods and willows in the riparian zone and skunkbush, 4-wing saltbush, currants, rabbitbrush, sagebrush, and grasses on the upper floodplain terraces.

The primary management method for tamarisk along this stretch should be biological control. Some high priority areas such as high public use areas in Delta, Olathe, and Montrose could be cleared using mechanical or hand cut stump methods. No herbicide should be needed for resprouts if biological control is active in the area. For some areas it will be appropriate to perform mechanical or hand cut stump removal to form fire breaks or to reduce wildfire potential.

Russian olive has a significant presence throughout much of this river section. Control will require either hand or mechanical cut stump approaches with herbicide application. Russian olive control will likely be the major emphasis on the Uncompahgre.

Biomass reduction should not be needed for light tamarisk and Russian olive infestations and some moderate infestations but should be performed for denser stands to reduce the fuel load in riparian areas. This is especially important to protect the valuable cottonwood galleries and native shrubs. Mechanical methods are recommended with some hand work required on difficult to access areas. As with other sites, biomass reduction should occur after biological control has caused a significant mortality in tamarisk.

Areas using biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Gunnison & Uncompahgre Rivers tributaries – The primary tributaries that have tamarisk infestations are Leroux Creek, Current Creek, Peach Valley, Surface Creek, Tongue Creek, Louisenhing Arroyo, Dry Creek, Roubideau Creek, Escalante Creek, Dominguez Creek, Kannah Creek, Whitewater Creek, and East Creek. All have some level of tamarisk infestation, ranging from light infestations near their confluence with the Gunnison or Uncompahgre Rivers to some tributaries that have significant infestations several miles upstream; e.g., Tongue Creek.

In general, where infestations are scattered, it is recommended that hand control and mechanical control be utilized with herbicide to remove scattered tamarisk along the fringes. Where infestations are contiguous, it is recommended that biological control be the main tamarisk control method. Applying herbicide to resprouts may not be necessary if biological control is active in the area. Russian olive control will require either hand or mechanical cut stump approaches with herbicide application in all areas. Most of these areas will not require biomass reduction or revegetation efforts; however, weed control will be necessary.

Dolores River Watershed Strategies

Colorado River confluence to Gateway – This river section starts in Utah and extends approximately 30 miles to the town of Gateway in Colorado. The last ten miles of this river section are in Colorado. Mapping and inventory for the Dolores River in Utah have been developed through the Southeast Utah Tamarisk Partnership (SEUTP) planning effort. For Colorado, this river segment is depicted in aerial photos D-1 to D-3 in Appendix E. This area is relatively remote with some access along a few miles of the river from both the Utah and Colorado sides. BLM manages much of the riparian land though there is a significant amount of private property along this stretch. Tamarisk infestations are continuous in this section and range from light to heavy. The river supports a wide variety of native plant communities including areas of willows, cottonwoods, scrub oak, skunkbush, 4-wing saltbush, rabbitbrush, and other shrubs, forbs, and grasses. Russian olive is not present along this stretch of the Dolores River or elsewhere within the Dolores River watershed that was mapped.

Grand County, Utah established a biological control release site in 2004 at Dewey Bridge just downstream of the Dolores River confluence with the Colorado River. The Palisade Insectary also established a release site in Colorado on the Dolores River south of Gateway in 2006. Between the development of sustainable insect populations at these two sites and the migration of insects from Utah, it is very likely that biological control will move forward in western Colorado within a few years. Therefore, it is appropriate to consider biological control to be the most practical tamarisk control strategy for this area. Limited hand cut-stump and mechanical removal with herbicide may be necessary around camp sites, cottonwood galleries, and other high priority sites to improve restoration and reduce fire risk associated with biomass concentrations.

Revegetation will likely occur naturally for lightly infested sites with some minor weed control. For moderate infestations, some revegetation will be necessary. Biomass reduction should be performed where necessary to reduce the fuel load in riparian areas. In the Gateway area there has already been some work by private landowners to mechanically clear tamarisk from within cottonwood groves followed by several irrigation seasons to establish grass cover.

Areas necessitating biomass reduction may require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk removal.

Gateway to San Miguel River Confluence – This area is represented by aerial photos D-4 to D-14 in Appendix E. For the first 25 miles upstream of Gateway the Dolores River is within a relatively narrow sandstone canyon with highway 141 bordering river left. Land ownership is private and BLM with some ranching activities occurring in wider sections especially around Gateway. Most of the tamarisk infestations in this area are moderate with some high density thickets. For the last 5 miles before the San Miguel River confluence the river is entirely enclosed within an extremely narrow shear walled sandstone canyon known as Hanging Flume Canyon so named after the tattered remains of the flume built in the 1800's to transport water for Lone Tree Placer mine and suspended several hundred feet above the river. Within this area, tamarisk infestations are predominately light in nature.

Biological control will be the most practical tamarisk control strategy for this area. Access is good for most of the areas with moderate to high infestations which will allow a significant portion of the infestation to be mechanically removed for biomass reduction following biological control. Limited hand cut-stump and hand extraction work and herbicides may be necessary around camp sites, cottonwood galleries, and other high priority sites to improve restoration and reduce fire risk associated with biomass concentrations. Biomass reduction should not be needed for the light infestations in Hanging Flume Canyon.

Revegetation will likely occur naturally for lightly infested sites with some minor weed control. For moderate infestations, some revegetation will be necessary, especially if biomass reduction causes soil disturbance. The river supports a wide variety of native plant communities (willows, cottonwoods, scrub oak, skunkbush, 4-wing saltbush, rabbitbrush, and other shrubs, forbs, and grasses) which will aid in revegetation efforts.

San Miguel River confluence to Slickrock – This section of the Dolores River, depicted by aerial photos D-15 to D-27 in Appendix E, passes in and out of narrow canyons as the river crosses Paradox Valley, Big Gypsum Valley, and Disappointment Valley. Infestations are generally light within the canyons and are denser in the valleys where the floodplain is significantly wider.

Biological control will be the most practical tamarisk control strategy here due to the area's remote nature. Limited hand cut-stump and mechanical removal with herbicides may be necessary around camp sites, cottonwood galleries, and other high priority sites to improve restoration.

Revegetation will occur naturally for most of this lightly infested area with some minor weed control. For moderate infestations, some revegetation will be necessary. It will be important to monitor vegetative regrowth as tamarisk biological control progresses. Biomass reduction should not be needed for light infestations and some moderate infestations but should be performed where necessary to reduce the fuel load in riparian areas.

Dolores River Tributaries – The major tributaries of the Dolores River are the San Miguel River, Granite Creek, Fisher Creek, Beaver Creek, West Creek, John Brown Creek, Salt Creek, Roe Creek, Mesa Creek, West Paradox Creek, East Paradox Creek, Big Gypsum Creek, Coyote Wash, La Sal Creek, and McIntyre Canyon. These perennial and/or intermittent streams originate in the Manti-La Sal Mountains in Utah, Uncompahgre Plateau, and surrounding plateaus along the Utah/Colorado border. These tributaries support light to moderate densities of tamarisk infestations, with areas of heavy native willows, scattered cottonwood galleries, and other riparian shrubs and grasses.

Biological control will be the most practical tamarisk control strategy for these areas due to very limited accessibility. For some lightly infested areas where tamarisk is scattered, it is recommended that hand and mechanical control be utilized with herbicide to control tamarisk at the fringes. Revegetation should occur naturally as biological control progresses. Monitoring for weed infestations will be important for timely control measures. Limited hand cut-stump and hand extraction work and herbicides may be necessary around cottonwood galleries, and other high priority sites to improve restoration and reduce fire risk associated with high biomass concentrations.

White River Watershed Strategies

River Segment 1: CO/UT State Line to Kenney Reservoir

Drawings: Tamarisk -W1 to W7; Russian olive - WR1 to WR7
Photo Log No. 31-36, 38-51, 57-61
Estimated Canopy Coverage: Tamarisk - 153 acres; Russian olive - 404 acres
Estimated Average Density: Tamarisk -15%; Russian olive - 39%

The majority of this section of the White River is privately owned though the Bureau of Land Management (BLM) holds a few areas. These public lands are concentrated in drawings W 3 and W4. At the downstream end of this thirty mile river stretch a relatively narrow floodplain contains a highly meandering single channel containing a number of island complexes and a few secondary channels. The floodplain widens gradually upstream towards the Kenney Reservoir. Motorized access to the floodplain in this area is fairly good throughout, though the areas shown in drawings W1 and W2 are somewhat isolated. Around drawing W3 access becomes very good as agricultural fields and homes become more common within the floodplain and roads run along both sides of the river.

Tamarisk are consistently present in light densities with a few small patches of moderate densities in the riparian zone throughout the majority of this section. The river stretch between Rangely and the Kenney Reservoir (drawing W7) is the exception as it supports no tamarisk except for a small patch directly beneath the dam.

Russian olives are present in moderate to high densities with few exceptions. Drawing WR3 shows a short break in the infestation and W5 displays a stretch of riparian zone only lightly infested with Russian olive. The highest concentrations occur between the Kenney Reservoir and the river section a few miles below Rangely.

Tamarisk and Russian olive control in this segment will enhance some aquatic habitats, particularly secondary channels and island complexes. It will also significantly improve wildlife habitat within the riparian zone. The area supports some native vegetation which may naturally recruit and colonize many areas once the tamarisk and Russian olive are removed, though a significant revegetation effort will likely be required. The following descriptions provide control recommendations that are appropriate for this site:

Table 9: White River Segment 1: CO/UT State Line to Kenney Reservoir

Control, Biomass Reduction, & Revegetation Approach
Areas with Good Mechanical Access: Control: Remove Russian olive and tamarisk with mechanical methods. Mechanical mulching and the grab & cut stump method will be the most appropriate though some root plowing and raking may be suitable for areas planned for urban or agricultural development. Biomass: Mulched biomass can be spread for use in active revegetation efforts. It is not appropriate to leave mulch on areas where natural revegetation is expected. This suggestion is recommended for urban areas in and surrounding Rangely. Cut or plowed biomass can either be mulched for revegetation or stacked for wildlife use or for burn piles. Revegetation: Tall pot and pole plantings of cottonwood and willow will be appropriate in all riparian zones. Some other species may be appropriate for tall pot plantings as well. In areas were the hydrology is sufficient or where irrigation would allow, seeding grasses and planting potted or bare root non-phreatophytic species for wildlife benefit is desirable.
Areas with Poor Mechanical Access : Control: Hand controls for both Russian olive and tamarisk. These could include basal bark or foliar herbicide applications or hand cutting with herbicide application. If tamarisk biological control is active in the area hand control could be concentrated on Russian olive populations. Biomass: If basal bark spray, foliar spray or biological control is used for light infestations, leave biomass standing. If the cut stump method is employed, stack biomass for wildlife or burn piles. Revegetation: Tall pot and pole plantings of cottonwood, willow, and perhaps a few other species along channel edges. If hydrology is appropriate some grass seeding would be beneficial.

River Segment 2: Kenney Reservoir to Upper Extent of Infestation

Drawings: Tamarisk - W7 to W16; Russian olive - WR9 to WR12
Photo Log No. 2-30, 52-58
Estimated Canopy Coverage: Tamarisk - 82 acres; Russian olive - 38 acres
Estimated Average Density: Tamarisk - 23%; Russian olive - 27%

The majority of this section of the White River is privately owned though the Bureau of Land Management (BLM) holds a few small areas. This forty mile stretch of river contains a number of island complexes and a few secondary channels. The main channel meanders through a broad floodplain largely composed of agricultural fields. Due to the developed fields alongside the river, mechanical access is very good on both the north and south banks of the river in most areas.

The tamarisk infestation in this river segment is more fragmented than that below the Kenney Reservoir but ranges more greatly from low to high densities. The majority of the infestation occurs within approximately 12 miles of the reservoir with both frequency and density of tamarisk presence decreasing significantly upstream.

Russian olives are considerably less abundant along this stretch of the White River than they are below the Kenney Reservoir. Most of these infestations are of low to moderate densities with a few pockets of highly dense infestations.

Tamarisk and Russian olive control in this segment will enhance some aquatic habitats, particularly secondary channels and island complexes. It will also somewhat improve wildlife habitat within this riparian zone while controlling tamarisk and Russian olive seed sources. The area does not support much native vegetation and a significant revegetation effort will likely be required. The following descriptions provide control recommendations that are appropriate for this site:

Table 10: White River Segment 2: Kenney Reservoir to Upper Extent of Infestation

Control, Biomass Reduction, & Revegetation Approach
High to Moderate Density Russian Olive Areas with Good Mechanical Access: Control: Remove Russian olive and tamarisk with mechanical methods. Mechanical mulching and the grab & cut stump method will be the most appropriate though some root plowing and raking may be suitable for areas planned for urban or agricultural development. Biomass: Mulched biomass can be spread for use in active revegetation efforts. It is not appropriate to leave mulch on areas where natural revegetation is expected. Cut or plowed biomass can either be mulched for revegetation or stacked for wildlife use or for burn piles. Revegetation: Tall pot and pole plantings of cottonwood and willow will be appropriate in all riparian zones. Some other species may be appropriate for tall pot plantings as well. In areas were the hydrology is sufficient or where irrigation would allow, seeding grasses and planting potted or bare root non-phreatophytic species for wildlife benefit is desirable.
High to Moderate Density Russian Olive Areas with Poor Mechanical Access: Control: Hand controls for both Russian olive and tamarisk around valuable vegetation or high use areas. These could include basal bark or foliar herbicide

applications or hand cutting with herbicide application. If tamarisk biological control is active in the area hand control could be concentrated on Russian olive populations.
Biomass: If basal bark spray, foliar spray or biological control is used for light infestations, leave biomass standing. If the cut stump method is employed, stack biomass for wildlife or burn piles.
Revegetation: Tall pot and pole plantings of cottonwood, willow, and perhaps a few other species along channel edges. If hydrology is appropriate some grass seeding would be beneficial.

Tamarisk or Lightly Infested Russian Olive Areas:
Control: Hand controls for Russian olive around valuable vegetation or highly used areas. These could include basal bark or foliar herbicide applications or hand cutting with herbicide application. Hand control for tamarisk where it is found with Russian olive. If tamarisk biological control is active in the area hand control could be concentrated on Russian olive populations.
Biomass: If basal bark spray, foliar spray or biological control is used for light infestations, leave biomass standing. If the cut stump method is employed, stack biomass for wildlife or burn piles.
Revegetation: Tall pot and pole plantings of cottonwood, willow, and perhaps a few other species along channel edges. If hydrology is appropriate some grass seeding would be beneficial.

River Segment 3: Douglas Creek

Drawings: Tamarisk – DC1 to DC12
Photo Log No. 63-66, 68-76
Estimated Canopy Coverage: Tamarisk - 576 acres; Russian olive - 0 acres
Estimated Average Density: Tamarisk - 47%; Russian olive - 0%

Douglas Creek is a small perennial waterway with many meanders winding through a narrow floodplain. Most of the land surrounding Douglas Creek is owned almost entirely by the BLM with a few private parcels towards the southern end of the infestation and has been heavily grazed by cattle. Mechanical access is excellent throughout the area as Highway 139 runs the length of the tamarisk infestation.

The tamarisk infestation on Douglas Creek stretches continuously for almost thirty miles. The infestation is very dense from the creek's terminus with the White River to Philadelphia Creek though moderate to light tamarisk stands persist until just past Rope Canyon downstream of West Creek.

Tamarisk control in this segment will enhance some aquatic habitats and may improve wildlife habitat while reducing tamarisk seed sources. The area does not support much native vegetation and a significant revegetation effort will likely be required. Establishing healthy stands of native, upper story vegetation would provide superior shade for livestock. The following descriptions provide control recommendations that are appropriate for this site:

Table 11: White River Segment 3: Douglas Creek

Control, Biomass Reduction, & Revegetation Approach
Control: This long, continuous stretch of tamarisk is ideal for the release of the tamarisk leaf beetle biological control agent; thus, bio-control should be the main approach. Mechanical extraction should be used to clear tamarisk near valuable vegetation and high use areas as well as to create firebreaks and to clear areas for revegetation. [Aerial herbicide spray could be used but spraying such a large area so close to dense human and livestock populations could be problematic.] Biomass: In heavily and moderately infested areas biomass can be mulched and spread for use in active revegetation efforts or cut and stacked for wildlife use or for burn piles. It is not appropriate to leave mulch on areas where natural revegetation is expected. In lightly infested areas biomass can be left standing. Revegetation: Areas where tamarisk are extracted should be temporarily fenced and revegetated using tall pot and pole plantings of cottonwood and willow to provide future shade for livestock. In sections where biomass control is necessary tall pot and pole plantings of cottonwood and willow will be needed.

River Segment 4: Black Gulch

Drawings: Tamarisk – W17 to W18
Photo Log No. 3-7
Estimated Canopy Coverage: Tamarisk - 9 acres
Estimated Average Density: Tamarisk - 25%

Black Gulch is a small stream running through land owned by the BLM and some private owners. The tamarisk infestation ranges from low to high densities in small patches that extend about five miles north of the White River.

Tamarisk control in this segment will improve wildlife habitat while reducing tamarisk seed sources. The area supports some native vegetation. This seed source, coupled with the small, patchy nature of the infestation, will reduce the need for revegetation. The following descriptions provide control recommendations that are appropriate for this site:

Table 12: White River Segment 4: Black Gulch

Control, Biomass Reduction, & Revegetation Approach
Control: The tamarisk leaf beetle bio-control agent should be the main approach. Biomass: Left standing. Revegetation: Natural revegetation should occur. The site should be monitored regularly to suppress other noxious weeds and to encourage native growth.

Yampa/Green River Watershed Strategies

River Segment 1: Yampa River Mainstem from the Confluence with the Green River to the Eastern Border of Dinosaur National Monument – Summarized from the Dinosaur National Monument River Corridor Operating Plan for Invasive Plant Management 2007 (Spencer 2007)
Maps – 75-85
Acres Inventoried – 2,752.8
Estimated Acres Infested: Tamarisk – 66.95; Russian olive – 0.605

This portion of the Yampa River travels through the stunning canyon scenery of Dinosaur National Monument before joining the Green River in a journey to the Colorado. The Monument is owned and operated by the National Park Service. Recreational opportunities abound in these canyons, ranging from whitewater boating, wildlife viewing, star gazing, as well as geologic, historical, and archeological tourism. Most of this river section lies within a Recommended Wilderness boundary. The Gates of Lodore, Deerlodge, Echo Park, Rainbow Park, Split Mountain and Green River campgrounds are some examples of areas that occur outside the Recommended Wilderness. Tamarisk and Russian olive control recommendations differ according to this designation.

With the exception of the road leading to Deerlodge Park, access to the tamarisk and Russian olive infestations in this canyon is strictly limited to boats. This restricts control options to those methods that can be transported on a river craft.

Tamarisk infestations along this stretch of the Yampa River are present in substantial densities from the Green River confluence to Schoonover Buttes. Upstream of the Buttes the infestation is sparser and more sporadic. Just downstream of Deerlodge Park tamarisk become more prolific, remaining so to the eastern border of Dinosaur National Monument.

Russian olives are only present in a few isolated areas and are being treated as an early detection/rapid response invasive species in this area.

Tamarisk and Russian olive control in this segment will enhance some aquatic habitats. It will also significantly improve wildlife habitat within the riparian zone. The area supports some native vegetation which may naturally recruit and colonize many areas once the tamarisk and Russian olive are removed, though a significant revegetation effort will likely be required. The following descriptions provide control recommendations that are appropriate for this site:

Table 13: River Segment 1: Yampa River Mainstem from the Confluence with the Green River to the Eastern Border of Dinosaur National Monument.

Control, Biomass Reduction, & Revegetation Approach
Within Recommended Wilderness Areas Tamarisk Control: The most appropriate of the following options should be chosen - ▪ Where possible, tamarisk at high priority recreation sites will be removed by hand and hand driven machinery including: hand-pulling, weed wrenches, shovels, picks, pry bars, loppers, saws, and tripod/ratchet pullers. ▪ Dense stands that cannot be removed by hand on vertical or near vertical banks in the river channel will be dislodged by a gas-powered water pump. ▪ Rocky substrate, lodged root crowns, or abundant native vegetation would call for hand cut-stump or basal bark spray methods. Russian Olive Control: Early detection/rapid response of cut-stump herbicide or basal bark herbicide applications. Tamarisk Biomass: In flood prone areas, large diameter (>2.5 to 3 inches) trees will be cut for campsite firewood. Smaller diameter trees will be cut into 8 foot sections and stacked above the high water line for one year before being thrown into the river at high flows. Russian Olive Biomass: Scatter debris. Revegetation: Tall pot and pole plantings of cottonwood, willow, and other riparian plants will be used where appropriate.
Outside of Recommended Wilderness Areas: Tamarisk Control: The most appropriate of the following options should be chosen - ▪ Hand and hand driven machinery including: hand-pulling, weed wrenches, shovels, picks, pry bars, loppers, saws, and tripod/ratchet pullers. ▪ Dense stands that cannot be removed by hand on vertical or near vertical banks in the river channel will be dislodged by a gas-powered water pump. ▪ Rocky substrate, lodged root crowns, or abundant native vegetation would call for hand cut-stump or basal bark spray methods. ▪ Chainsaw, chipper or other motorized equipment (mainly for debris management). Russian Olive Control: Early detection/rapid response of cut-stump herbicide or basal bark herbicide applications. Biomass: Chip materials for use as weed control and mulch. Mulch will not be spread over cleared areas as it could inhibit native plant volunteers. Russian Olive Biomass: Scatter debris. Revegetation: Tall pot and pole plantings of cottonwood, willow, and other riparian plants will be used where appropriate.
Areas of High-Value Natural Habitat: Tamarisk Control: The most appropriate of the following options should be chosen - ▪ Cut-stump or basal bark herbicide application ▪ Biological control will be encouraged to reduce tamarisk presence. Some of these areas may require biomass removal. Russian Olive Control: Early detection/rapid response of cut-stump herbicide or basal bark herbicide applications.

<u>Biomass</u>: In flood prone areas, large diameter (>2.5 to 3 inches) trees will be cut for campsite firewood. Smaller diameter trees will be cut into 8 foot sections and stacked above the high water line for one year before being thrown into the river at high flows.
<u>Russian Olive Biomass</u>: Scatter debris.
<u>Revegetation</u>: Tall pot and pole plantings of cottonwood, willow, and other riparian plants will be used where appropriate.

River Segment 2: Yampa Mainstem – Eastern Border of Dinosaur National Monument to Craig

Maps – 31-34, 56, 73-74, 63-66, 69-72
Acres Inventoried – 3,294.1
Estimated Acres Infested: Tamarisk – 66.95; Russian olive – 34.41

This river segment alternates between meandering and braided channels through wide, gently sloped floodplains and more constricted, channelized flows through deep, incised canyons. Much of the land is privately owned. However, the Bureau of Land Management does own some sections, the most notable of which run through Cross Mountain Canyon and Duffy Mountain. State owned land is also present in some areas, the largest of which is the river's north bank just upstream of Bostori Flats.

The high percentage of private landownership limits access to the river significantly. The most prominent access points are the Yampa River State Park designated public access sites which include: Moffat County's Loudy Simpson Park, South Beach or Yampa Project Pump Station, Duffy Mountain, Juniper Canyon, Maybell Bridge, Sunbeam, East Cross Mountain, and West Cross Mountain. Again, it should be noted that significant efforts to include and support private landowners in invasive species management efforts.

The areas surveyed for tamarisk and Russian olive by Utah State University in this area include the following:

- Deerlodge Park to Twelvemile Gulch – This short river section supports consistent stands of both tamarisk (18.24 acres) and Russian olive (5.46) throughout its length. Russian olive infestations are heaviest just upstream of the Little Snake River.
- Cross Mountain to Maybell Boat Launch – The largest tamarisk infestation (21.28 acres) on this section occurs in the upstream section near Maybell Boat Launch and extending downstream for approximately 15 miles. Segments about a mile downstream of Sand Creek and eight miles upstream of Cross Mountain also support significant tamarisk stands. This section supports the most significant Russian olive population (28.48 acres) in the entire inventory. It occurs consistently throughout the river segment except for about a mile stretch just upstream of Cross Mountain Canyon.
- Morgan Gulch to Round Bottom – Tamarisk infestations (52.36 acres) are very continuous along the downstream half of this section approaching Morgan Gulch. Upstream the infestation gradually decreases as it approaches Round Bottom.

The opposite is true of Russian olive stands (.471 acres) in this section. Appearing in the upstream area surrounding Round Bottom, the Russian olive presence decreases sharply downstream and almost disappears below Mill Creek.

Tamarisk and Russian olive control in these segments will enhance some aquatic habitats, particularly secondary channels and island complexes. It will also significantly improve wildlife habitat within the riparian zone. The area supports some native vegetation which may naturally recruit and colonize many areas once the tamarisk and Russian olive are removed, though a significant revegetation effort will likely be required. The following descriptions provide control recommendations that are appropriate for this site:

Table 14: River Segment 2: Yampa Mainstem – Eastern Border of Dinosaur National Monument to Craig

Control, Biomass Reduction, & Revegetation Approach
Areas with Good Mechanical Access: Control: Remove Russian olive and tamarisk with mechanical methods. Mechanical mulching and the grab & cut stump method (or extraction for tamarisk) will be the most appropriate though some root plowing and raking may be suitable for areas planned for urban or agricultural development. Biological control should be considered as a primary approach in Moffat County only. Biomass: Mulched biomass can be spread for use in active revegetation efforts, as weed barrier, or in and around campsites. It is not appropriate to leave mulch on areas where natural revegetation is expected. Cut or plowed biomass can either be mulched or stacked for wildlife use or for burn piles (if appropriate). Revegetation: Tall pot and pole plantings of cottonwood and willow will be appropriate in all riparian zones. Some other species may be appropriate for tall pot plantings as well. In areas were the hydrology is sufficient or where irrigation would allow, seeding grasses and planting potted or bare root non-phreatophytic species for wildlife benefit is desirable.
High Priority Areas with Poor Mechanical Access: Tamarisk Control: The most appropriate of the following options should be chosen - ▪ Tamarisk leaf beetle biological control ▪ Hand and hand driven machinery including: hand cut-stump, basal bark spray, hand-pulling, weed wrenches, shovels, picks, pry bars, loppers, saws, and tripod/ratchet pullers. ▪ Dense stands that cannot be removed by hand on vertical or near vertical banks in the river channel will be dislodged by a gas-powered water pump. ▪ Chainsaw, chipper or other motorized equipment (mainly for debris management). Russian Olive Control: Hand cut-stump or basal bark spray will be the most common method. Chainsaw removal and herbicide application may be appropriate in some areas. Biomass: If basal bark spray or biological control is used for light infestations, leave biomass standing. For denser infestations biomass may need to be cut following

treatment. If the cut stump method is employed, stack biomass outside of floodplain for wildlife or burn piles or scatter for decomposition. Revegetation: Tall pot and pole plantings of cottonwood, willow, and perhaps a few other species along channel edges. If hydrology is appropriate some grass seeding would be beneficial.
Lower Priority Areas with Poor Mechanical Access: Tamarisk Control: Tamarisk leaf beetle biological control. Russian Olive Control: Cut-stump herbicide or basal bark herbicide applications. Biomass: Leave low density stands of tamarisk biomass standing. Higher density tamarisk stands or Russian olive biomass will be stacked outside of floodplain for wildlife or burn piles or scatter for decomposition. Revegetation: Tall pot and pole plantings of cottonwood, willow, and perhaps a few other species along channel edges. If hydrology is appropriate some grass seeding would be beneficial.

River Segment 3: Yampa Headwaters – Craig to Routt National Forest

Maps – None
Acres Inventoried – None
Estimated Acres Infested: Tamarisk – N/A; Russian olive – N/A

The headwaters of the Yampa River tumble down mountain passes to form a highly braided river segment that contains many meanders and oxbows and is still relatively free of heavy tamarisk and Russian olive infestation. The major challenge on this section is the large amount of private property ownership. The only portion of this river segment that is not privately owned is a small stretch of state owned land just upstream of Elkhead Creek.

Tamarisk and Russian olive control in this segment will preserve and enhance aquatic habitats, particularly secondary channels and island complexes. It will also help to conserve wildlife habitat within the riparian zone. The area supports healthy stands of native vegetation which will likely recruit and colonize many areas naturally once the tamarisk and Russian olive are removed.

The Colorado Department of Agriculture has adopted *Rules Pertaining to the Administration and Enforcement of the Colorado Noxious Weed Act* which will go into effect September 30, 2008. Section 4.7.5 specifies requirements for tamarisk control within Routt County. Under these rules, all populations of tamarisk should be eliminated by 2011. All methods commonly used to achieve this objective are appropriate except for biocontrol which, by its nature, does not provide eradication capability. These requirements are not significantly difficult to meet since there are only minor infestations with Routt County. Russian olive rules have not been developed at this time.

The following descriptions provide control recommendations that are appropriate for this section:

Table 15: River Segment 3: Yampa Headwaters – Craig to Routt National Forest

Control, Biomass Reduction, & Revegetation Approach
Areas of High-Value with Good Mechanical Access: Control: Remove Russian olive and tamarisk with mechanical methods. Mechanical mulching and the grab & cut stump method (or extraction for tamarisk) will be the most appropriate though some root plowing and raking may be suitable for areas planned for urban or agricultural development. Biological control should be considered as a primary approach in Moffat County only. Biomass: Mulched biomass can be spread for use in active revegetation efforts, as weed barrier, or in and around campsites. It is not appropriate to leave mulch on areas where natural revegetation is expected. Cut or plowed biomass can either be mulched or stacked for wildlife use or for burn piles (if appropriate). Revegetation: Tall pot and pole plantings of cottonwood and willow will be appropriate in all riparian zones. Some other species may be appropriate for tall pot plantings as well. In areas were the hydrology is sufficient or where irrigation would allow, seeding grasses and planting potted or bare root non-phreatophytic species for wildlife benefit is desirable.
Areas of High-Value with Poor Access: Tamarisk Control: The most appropriate of the following options should be chosen - ▪ Tamarisk leaf beetle biological control within Moffat County only. ▪ Hand and hand driven machinery including: hand cut-stump, basal bark spray, hand-pulling, weed wrenches, shovels, picks, pry bars, loppers, saws, and tripod/ratchet pullers. ▪ Dense stands that cannot be removed by hands on vertical or near vertical banks in the river channel will be dislodged by a gas-powered water pump. ▪ Chainsaw, chipper or other motorized equipment (mainly for debris management). Russian Olive Control: Hand cut-stump or basal bark spray will be the most common method. Chainsaw removal and herbicide application may be appropriate in some areas. Biomass: If basal bark spray or biological control is used for light infestations, leave biomass standing. For denser infestations biomass may need to be cut following treatment. If the cut stump method is employed, stack biomass outside of floodplain for wildlife or burn piles or scatter for decomposition. Revegetation: Tall pot and pole plantings of cottonwood, willow, and perhaps a few other species along channel edges. If hydrology is appropriate some grass seeding would be beneficial.
All Other Areas: Tamarisk and Russian Control: Early detection/rapid response of cut-stump herbicide or basal bark herbicide applications. Biomass: Leave low density stands of tamarisk biomass standing. Higher density tamarisk stands or Russian olive biomass should be stacked outside of floodplain for wildlife or burn piles or scatter for decomposition. Revegetation: None for sites where biomass is not removed. For other sites, tall pot

and pole plantings of cottonwood, willow, and perhaps a few other species along channel edges. If hydrology is appropriate some grass seeding would be beneficial.

River Segment 4: Little Snake River

Maps – 42-56
Acres Inventoried – 4,886.9
Estimated Acres Infested: Tamarisk – 75.5; Russian olive – 150.01

The Little Snake River enters the main stem of the Yampa approximately 3.5 miles upstream of the eastern boarder of Dinosaur National Monument. Much of its upstream section within Colorado meanders through a gently sloping, broad floodplain with fairly regular access points. As the Little Snake approaches the Yampa, it carves through an incised canyon and access becomes much more limited. The majority of the Little Snake is owned by the BLM although significant sections are owned by the state and private parties.

Tamarisk stands were found consistently throughout the inventory which followed the Little Snake River from the Yampa to the Colorado/Wyoming state line. The highest densities were found between the Yampa River and the gauging station. Significant Russian olive infestations stretch continuously between the Yampa River and Nipple Rim Ranch.

Tamarisk and Russian olive control in this segment will preserve and enhance aquatic habitats, particularly secondary channels and island complexes. It will also help to conserve wildlife habitat within the riparian zone. The area supports healthy stands of native vegetation which may recruit and colonize many areas naturally once the tamarisk and Russian olive are removed, though a significant revegetation effort will likely be required. The following descriptions provide control recommendations that are appropriate for this section:

Table 16: River Segment 4: Little Snake River

Control, Biomass Reduction, & Revegetation Approach
Areas with Good Mechanical Access: Control: Remove Russian olive and tamarisk with mechanical methods. Mechanical mulching and the grab & cut stump method (or extraction for tamarisk) will be the most appropriate though some root plowing and raking may be suitable for areas planned for urban or agricultural development. Biological control should be considered as a primary approach where acceptable to land managers. Biomass: Mulched biomass can be spread for use in active revegetation efforts, as weed barrier, or in and around campsites. It is not appropriate to leave mulch on areas where natural revegetation is expected. Cut or plowed biomass can either be mulched or stacked for wildlife use or for burn piles (if appropriate). Revegetation: Tall pot and pole plantings of cottonwood and willow will be appropriate in all riparian zones. Some other species may be appropriate for tall pot

plantings as well. In areas were the hydrology is sufficient or where irrigation would allow, seeding grasses and planting potted or bare root non-phreatophytic species for wildlife benefit is desirable.

High Priority Areas with Poor Mechanical Access:

Tamarisk Control: The most appropriate of the following options should be chosen -

- Tamarisk leaf beetle biological control.
- Hand and hand driven machinery including: hand cut-stump, basal bark spray, hand-pulling, weed wrenches, shovels, picks, pry bars, loppers, saws, and tripod/ratchet pullers.
- Dense stands that cannot be removed by hand on vertical or near vertical banks in the river channel will be dislodged by a gas-powered water pump.
- Chainsaw, chipper or other motorized equipment (mainly for debris management).

Russian Olive Control: Hand cut-stump or basal bark spray will be the most common method. Chainsaw removal and herbicide application may be appropriate in some areas.

Biomass: If basal bark spray or biological control is used for light infestations, leave biomass standing. For denser infestations biomass may need to be cut following treatment. If the cut stump method is employed, stack biomass outside of floodplain for wildlife or burn piles or scatter for decomposition.

Revegetation: Tall pot and pole plantings of cottonwood, willow, and perhaps a few other species along channel edges. If hydrology is appropriate some grass seeding would be beneficial.

Lower Priority Areas with Poor Mechanical Access:

Tamarisk Control: Tamarisk leaf beetle biological control.

Russian Olive Control: Cut-stump herbicide or basal bark herbicide applications.

Biomass: Leave low density stands of tamarisk biomass standing. Higher density tamarisk stands or Russian olive biomass will be stacked outside of floodplain for wildlife or burn piles or scatter for decomposition.

Revegetation: Tall pot and pole plantings of cottonwood, willow, and perhaps a few other species along channel edges. If hydrology is appropriate some grass seeding would be beneficial.

River Segment 5: Minor Tributaries & Elkhead Reservoir

Maps – 1-30, 35-41, 52-53, 57-63, 66-68
Acres Inventoried – 10,666.3
Estimated Acres Infested: Tamarisk – 36.96; Russian olive – 19.84

Twenty-five tributaries and the Elkhead Reservoir were included in the tamarisk and Russian olive inventory work, they include the following: Anderson Hole, Bull Canyon, Disappointment Draw, Fish Creek, Foidel Creek, Fortification Creek, Fourmile Creek, Good Spring Creek, Harding Hole, King Solomon Creek, Lester Creek, Mud Spring Draw, Red Rock Canyon, Sand Creek, Sand Wash, Service Creek, South Sand Wash, Spring Creek, Starvation Valley, Tepee Draw, Trout Creek, Vale of Tears, Williams Fork, Willow Creek, and Wilson Creek.

Large sections of these tributaries are under private ownership although substantial sections are owned by the state and BLM. Significant efforts to coordinate a multitude of partners will be extremely beneficial to achieve real results in these areas.

Tamarisk and Russian olive control in these areas will preserve and enhance aquatic habitats and help to conserve wildlife habitat within the riparian zone. Areas supporting healthy stands of native vegetation may naturally revegetate after tamarisk and Russian olive are removed. However, in some areas a significant revegetation effort will likely be required. The following descriptions provide control recommendations that are appropriate for this section:

Table 17: Yampa River Segment 5: Minor Tributaries & Elkhead Reservoir

<table>
<tr><th>Control, Biomass Reduction, & Revegetation Approach</th></tr>
<tr><td><u>High Priority Areas with Poor Mechanical Access:</u>
<u>Tamarisk Control</u>: The most appropriate of the following options should be chosen -
Tamarisk leaf beetle biological control within Moffat County only.
Hand and hand driven machinery including: hand cut-stump, basal bark spray, hand-pulling, weed wrenches, shovels, picks, pry bars, loppers, saws, and tripod/ratchet pullers.
Dense stands that cannot be removed by hand on vertical or near vertical banks in the river channel will be dislodged by a gas-powered water pump.
Chainsaw, chipper or other motorized equipment (mainly for debris management).
<u>Russian Olive Control</u>: Hand cut-stump or basal bark spray will be the most common method. Chainsaw removal and herbicide application may be appropriate in some areas.
<u>Biomass</u>: If basal bark spray or biological control is used for light infestations, leave biomass standing. For denser infestations biomass may need to be cut following treatment. If the cut stump method is employed, stack biomass outside of floodplain for wildlife or burn piles or scatter for decomposition.
<u>Revegetation</u>: Tall pot and pole plantings of cottonwood, willow, and perhaps a few other species along channel edges. If hydrology is appropriate some grass seeding would be beneficial.</td></tr>
<tr><td><u>Lower Priority Areas with Poor Mechanical Access:</u>
<u>Tamarisk Control</u>: Tamarisk leaf beetle biological control within Moffat County only.
<u>Russian Olive Control</u>: Cut-stump herbicide or basal bark herbicide applications.
<u>Biomass</u>: Leave low density stands of tamarisk biomass standing. Higher density tamarisk stands or Russian olive biomass will be stacked outside of floodplain for wildlife or burn piles or scatter for decomposition.
<u>Revegetation</u>: Tall pot and pole plantings of cottonwood, willow, and perhaps a few other species along channel edges. If hydrology is appropriate some grass seeding would be beneficial.</td></tr>
</table>

River Segment 6: Green River through Dinosaur National Monument and Browns Park NWR

This short 43 mile section of the Green River enters Colorado at the Browns Park National Wildlife Refuge (NWR) operated by the US Fish and Wildlife Service (USF&WS) as part of its migratory bird program and then flows into the Dinosaur National Monument before leaving the state into Utah.

The Refuge was formally established in 1963 by Public Land Order 4973 under the Migratory Bird Conservation Act and the Refuge Recreation Act, the purposes of Browns Park NWR are to provide sanctuary for migratory birds, protect natural resources, conserve endangered and threatened species, and offer fish and wildlife-dependent recreational opportunities. Wildlife, solitude, scenic beauty, and cultural history combine to make the refuge a national treasure.

The riparian habitat along the Green River, Vermillion, and Beaver Creek at Browns Park NWR is made up of cottonwoods, buffaloberry, willows, and many other plants that are restricted to flood plains or areas of permanent underground water supplies. These plants are dependent on water for their survival. Similarly, many species of wildlife depend on riparian plants to fulfill their life needs. Thousands of migrating songbirds like the Lazuli bunting and Wilson's warbler rely on riparian habitat for refueling when traveling further north to their breeding grounds. Other songbirds such as the black-chinned hummingbird and Bullock's oriole stop to nest. Bald eagles, several hawk species, great blue herons, moose, and river otter also raise their young in the riparian area.

Water development has caused the Refuge’s riparian habitats to change over time. Beaver Creek, although affected by water use upstream, still remains a prime example of riparian habitat in the high desert region. Like Beaver Creek, the riparian area along the Green River has also been affected by upstream water use at the Flaming Gorge Dam. Before construction of the dam, the Green River's water levels responded solely to the uncertainties of nature. Flooding usually occurred in the spring, tapering off to reduced flows in summer. Natural marshlands bordered the river, and spring flooding was the primary source of water. After construction of the dam in 1962, river flows were altered and resulted in a decrease in spring floods and a reduction in the amount of sediment carried by the river. This resulted in the gradual deepening of the river channel, further reducing the likelihood of flooding, making it difficult for tree and willow roots to reach water, and inhibiting the germination of new seedlings. Field research has confirmed that cottonwood forests are aging and not being replaced. Instead, nonnative species such as perennial pepperweed and tamarisk are overtaking this habitat. Research is ongoing to help determine how to increase the production of new cottonwoods and willows in the riparian areas.

Tamarisk infestations mapping on the Green River within Dinosaur National Monument was completed in 2005. Point data was obtained on 489 locations of which 85 percent ranging in size from less than one acre to 0.01 acres. 15 percent of the locations were one acre or larger with only 5 sites in the 2.5 acre to 5.0 acre range. Most sites exhibited densities of less than 25 percent with relatively few having densities in the 50 to 100 percent range.

Mapping of tamarisk was not performed for Browns Park NWR; however, from discussions with USF&WS staff, tamarisk infestations on the Green River, Beaver Creek, and Vermillion Creek are considered to be somewhat higher than that found along the Green River in Dinosaur National Monument.

Vermillion Creek headwaters originate in Wyoming. In several areas along its 40 mile length in Colorado it has a continuous line of tamarisk trees, 2-3 trees wide. Vermillion Creek extends primarily through BLM land during its remaining watercourse through Colorado. The number of Russian olive trees along Vermillion Creek in the NWR is less than ten. Beaver Creek has scattered tamarisk upstream of its confluence with the Green River for several miles but not to the same extent as infestations found on Vermillion Creek.

The Green River within the Browns Park NWR is approximately 13-14 miles in length. It has tamarisk in a patchy distribution pattern and in some areas is up to 10 trees deep. In some areas there are moderate infestations of mature trees. The NWR has about 30 scattered Russian olive trees widely dispersed in the riparian and bottom lands of the Refuge.

The primary approach within this area will be biologic control; thus, the exact area of the tamarisk problem is not critical because it will represent only a small component of the tamarisk problem throughout the Colorado River Watershed. During the summer of 2008 there has been a release of the tamarisk leaf beetle within the NWR on the Green River close to Vermillion Creek. After only a few months, larvae are active in significant numbers and are visually stressing the release trees.

Tamarisk and Russian olive control in this segment will enhance some aquatic habitats. It will also significantly improve wildlife habitat within the riparian zone. The area supports some native vegetation which may naturally recruit and colonize many areas once the tamarisk and Russian olive are removed, though a significant revegetation effort will likely be required. The following descriptions provide control recommendations that are appropriate for this site:

Table 18: River Segment 6: Green River and tributaries within Dinosaur National Monument and Browns Park NWR.

Control, Biomass Reduction, & Revegetation Approach
Within Recommended Wilderness Areas Tamarisk Control: The most appropriate of the following options should be chosen - ▪ Biological control as the primary approach within Browns Park NWR. Within Dinosaur National Monument the following strategy is proposed: ▪ Where possible, tamarisk at high priority recreation sites should be removed by hand and hand driven machinery including: hand-pulling, weed wrenches, shovels, picks, pry bars, loppers, saws, and tripod/ratchet pullers.

- Dense stands that cannot be removed by hand on vertical or near vertical banks in the river channel will be dislodged by a gas-powered water pump.
- Rocky substrate, lodged root crowns, or abundant native vegetation would call for hand cut-stump or basal bark spray methods.

Russian Olive Control: Early detection/rapid response of cut-stump herbicide or basal bark herbicide applications if any infection is identified. All Russian olive can be eradicated within these areas.

Tamarisk Biomass: In flood prone areas, large diameter (>2.5 to 3 inches) trees will be cut for campsite firewood. Smaller diameter trees will be cut into 8 foot sections and stacked above the high water line for one year before being thrown into the river at high flows.

Revegetation: Tall pot and pole plantings of cottonwood, willow, and other riparian plants will be used where appropriate.

Outside of Recommended Wilderness Areas:

Tamarisk Control: The most appropriate of the following options should be chosen -

- Biological control as the primary approach within Browns Park NWR.

Within Dinosaur National Monument the following strategy is proposed:

- Hand and hand driven machinery including: hand-pulling, weed wrenches, shovels, picks, pry bars, loppers, saws, and tripod/ratchet pullers.
- Dense stands that cannot be removed by hand on vertical or near vertical banks in the river channel will be dislodged by a gas-powered water pump.
- Rocky substrate, lodged root crowns, or abundant native vegetation would call for hand cut-stump or basal bark spray methods.
- Chainsaw, chipper or other motorized equipment (mainly for debris management).

Russian Olive Control: Early detection/rapid response of cut-stump herbicide or basal bark herbicide applications if any infection is identified. All Russian olive can be eradicated within these areas.

Biomass: Chip materials for use as weed control and mulch. Mulch will not be spread over cleared areas as it could inhibit native plant volunteers.

Revegetation: Tall pot and pole plantings of cottonwood, willow, and other riparian plants will be used where appropriate.

Areas of High-Value Natural Habitat:

Tamarisk Control: The most appropriate of the following options should be chosen -

- Cut-stump or basal bark herbicide application
- Biological control will be encouraged to reduce tamarisk presence. Some of these areas may require biomass removal.

Russian Olive Control: Early detection/rapid response of cut-stump herbicide or basal bark herbicide applications if any infection is identified. All Russian olive can be eradicated within these areas.

Biomass: In flood prone areas, large diameter (>2.5 to 3 inches) trees will be cut for campsite firewood. Smaller diameter trees will be cut into 8 foot sections and stacked above the high water line for one year before being thrown into the river at high flows.

Revegetation: Tall pot and pole plantings of cottonwood, willow, and other riparian plants will be used where appropriate.

Section 2 – Implementation

The CHIP plan up to this point (Section 1 – Background) has outlined the background of the CHIP planning process, the general nature of the problem, important governmental actions, the site-specific problem in the study area, the natural resource impacts to water and wildlife habitat, recommended restoration approaches, and costs associated with those control and revegetation actions. **Section 2 – Implementation** now lays out a specific "path forward" for implementing the plan including a specific set of "actions" to facilitate success. These discussions include:

1. Working with landowner
2. Education, outreach, and volunteerism
3. Research needs
4. Long-term sustainability
5. Active restoration initiatives

Working with Landowners

CHIP's main objective is to restore riparian lands within the Colorado, Gunnison, Uncompahgre, Dolores, White, and Yampa/Green watersheds that have been degraded by woody invasive plants, principally tamarisk and Russian olive. To successfully implement these restoration actions, each landowner's property rights must be respected to ensure that 1) the landowner is included in restoration decision-making and that 2) efforts coordinate with the landowner's specific objectives for the land. Landownership includes public (federal, state, county, and local communities), legal subdivisions of the state (e.g., sanitation districts, drainage districts), private landowners, non-profits (e.g., Mesa Land Trust), commercial, and industry (e.g., Denver - Rio Grande Railroad).

Because noxious weed control and riparian restoration are not normal components of most of these landowner activities, assistance is often needed to identify funding opportunities, apply for grants, and to administer grants. There is no precedence for who should be the lead for each situation; however, the following provides some general guidance for the partners in CHIP.

- ✓ For private agricultural producers, the soil and water conservation districts are the most appropriate organizations to manage many of these grants, especially those grants from the USDA. The Colorado Association of Conservation Districts, located in Grand Junction, is a good resource to assist these local districts in becoming significant partners with landowners and restoration activities.

- ✓ Counties and non-profits (e.g., The Nature Conservancy) can assist in acquiring grants for all entities, even for work on federal lands through some grant programs (e.g., National Fish and Wildlife Foundation).

- ✓ Each entity can pursue its own grant opportunities for the land that it manages.

A concern of the partners in CHIP is that without coordination between all these entities, there will be undue competition for the same funds; entities will not be aware of all of the funding resources available; and/or there will be inefficiency in using funds that are acquired. To resolve this concern, the following action is recommended.

Action #1
County weed mangers along with the Colorado Association of Conservation Districts, NRCS, RC&Ds, and BLM (the major federal landowner), and the Tamarisk Coalition should develop the following:

a) Develop a GIS dataset of land ownership for the riparian corridor impacted by the target invasive species.

b) Establish a simple clearinghouse system to inform all parties of grant opportunities. A list of grant opportunities will are available on the Tamarisk Coalition website (www.tamariskcoalition.org).

c) Create a prioritization system that could be used to screen grants and appropriate locations for restoration work. An example is provided in Appendix I.

d) Develop a communication system that informs county weed managers of all projects being conducted.

Education, Outreach, and Volunteerism

Gaining public support requires providing factual information that describes the problem and the solutions being initiated. Important information for the public understanding includes all aspects of the tamarisk and Russian olive problem; control approaches that will be used with significant emphasis on the biological control component; how things will look differently over the next 10 years; revegetation, biomass removal, monitoring, and long-term maintenance. **The overarching theme is RESTORATION not just tamarisk or Russian olive control.**

Action #2
Outreach expertise from counties, BLM, National Park Service, The Nature Conservancy and the Tamarisk Coalition could be used to develop materials appropriate for the community and visitors to the area. Some of the key elements of the program may include:

- ✓ A "frequently asked questions" brochure that will help locals and visitors understand the following: 1) What tamarisk is, where it came from, why it is a problem, and tamarisk control methods; 2) How biological control works, what to expect, monitoring of changes, etc.; 3) What will replace the tamarisk, how the process will affect wildlife; 4) Who will implement these projects and how will they be funded?

- ✓ Brochures for distribution through the NPS and BLM visitor centers, Colorado state parks, DOW wildlife refuges, etc.
- ✓ Fact sheets on tamarisk ecology, biological, control, herbicide usage and safety, etc.
- ✓ Display boards with historical photos can be utilized to compare present day conditions to the past to give a perspective on the problem.
- ✓ River guide training on the issue and provision of education cards similar to "Leave no trace" laminated waterproof cards.
- ✓ Information booths at local events, festivals, etc.
- ✓ Presentations to service groups such as Lions, Rotary, and Chamber of Commerce.
- ✓ Demonstration sites that can be used for tours.

[Note: the Tamarisk Coalition is developing many of these components with support from others. This information will be available in summer 2008.]

Volunteer Program – An important aspect of education is gaining public support for tamarisk and Russian olive control and revegetation to improve the ecosystem of the CHIP study area. One way of achieving this is through volunteer programs. A number of groups within the area have done some excellent work using volunteers for riparian restoration. These include: Roaring Fork Outdoor Volunteers at the I-70 Rifle Rest Stop, Audubon Society at Connected Lakes State Park, Eagle County tamarisk removal program, Volunteers for Outdoor Colorado, North Fork River Improvement Association, The Nature Conservancy, Routt Invasive Plant Posse, Dinosaur National Monument Weed Warriors, the Watson Island Restoration Project, and McInnis Canyons National Conservation Area (see Figure 8). By participating in these programs, people gain first-hand experience and an appreciation of ecosystem restoration. The volunteer education effort would include information concerning how and where to get involved as an individual or as an organization.

Action #3

The groups identified above and the BLM should work together to 1) develop a volunteer "lessons learned" pamphlet that can be used by others to develop their own volunteer program (a starter "cookbook"), 2) identify good volunteer projects, and 3) pool resources for volunteer projects.

Figure 8: Volunteer tamarisk control project (and happy resident) in Flume Canyon, McInnis Canyons National Conservation Area, May 2007.

Photos courtesy of Ed Kosmicki

Long-term Sustainability

Long-term sustainability of the restored riparian lands is a function of a good monitoring and maintenance program. To reiterate from previous discussions, "monitoring" is the act of observing changes that are occurring with, or without, remediation actions. The purpose of monitoring is to provide information for making informed decisions to ensure "maintenance" will maintain, remediate, and improve the ecological processes of the watershed. For tamarisk and Russian olive restoration these measures are important for effective control on a long-term basis and to ensure that the desired outcomes of revegetation and prevention of other noxious weed infestations are successful.

The questions that must be addressed for the entire Colorado River watershed is – ***Who should perform monitoring and maintenance? Do they have the legal responsibility for these actions? Do they have the necessary funding to carry out these responsibilities?*** These are complicated questions because there are multiple jurisdictions (i.e., federal, state, county, and local) and there are multiple land ownerships (i.e., private, industry, non-profit organizations, community, county, state, and federal). To be successful, an organized, collaborative approach must be found.

Action Item #4

It is clear that if resources are spent only on control and revegetation with no cohesive approach to long-term monitoring and maintenance, the potential for successful riparian restoration is limited. Therefore, the following recommendation is made to establish a workable long-term monitoring and maintenance program:

1. The Colorado River Water Conservation District has agreed to initiate the facilitation of a working group to formulate a set of solutions and policies for long-term monitoring and maintenance for the entire Colorado River system. It is recommended that the working group be co-chaired by the Colorado Department of Agriculture and the Colorado Department of Natural Resources. These two agencies are appropriate to lead this effort because their main responsibilities are to protect our natural resources and they work closely with the agricultural community.

2. The working group may include, but not be limited to, representatives from:
    - ✓ County weed management departments (the areas within the watershed with most of the infestations)
    - ✓ State representatives to the House and Senate
    - ✓ Colorado River Water Conservation District
    - ✓ CSU Cooperative Extension
    - ✓ BLM
    - ✓ National Park Service
    - ✓ US Forest Service
    - ✓ Oil and Gas Industry
    - ✓ USDA Natural Resource Conservation Service
    - ✓ Colorado Department of Local Affairs
    - ✓ Mesa State College
    - ✓ Colorado State University
    - ✓ Colorado Division of Wildlife
    - ✓ The Nature Conservancy
    - ✓ Colorado Association of Conservation Districts
    - ✓ Tamarisk Coalition

3. Within 12 months a consensus plan should be produced to implement a long-term monitoring and maintenance program describing the technical, political, and financial steps for tamarisk control implementation and responsible entities.

This will be no easy task, but it is the critical element for successful riparian restoration and should be dealt with seriously. If a workable long-term monitoring and maintenance program for the Colorado River is successfully formulated, this would be truly landmark work. It would lay the groundwork for tackling this prickly issue and would be an excellent example for other watersheds to use.

For Utah, which has a small percentage of the overall Dolores River watershed, it is recommended that San Juan and Grand Counties work with BLM to establish a reasonable long-term monitoring and maintenance program.

Research Needs

There are a number of research activities that can improve the success, effectiveness, and efficiency of restoration for the CHIP study area comprising the seven rivers. The unique nature of the upper Colorado River watershed also offers special opportunities to better understand tamarisk and Russian olive impacts to water resources and wildlife habitat as well as restoration responses. By intertwining restoration with research there is greater appeal to some funding sources to provide grants (e.g., new federal legislation under P.L. 109-320 in Appendix B). The following are current research interests at the university and federal research levels:

- ✓ CSU, Palisade Insectary, and Tamarisk Coalition are actively working together to monitor biological control on western slope releases. Four additional release sites were established in 2007 with several more were established in 2008. Monitoring of the Utah beetle releases that will be moving into Colorado will also occur.

- ✓ Utah State University and University of Utah in cooperation with San Juan and Grand Counties in Utah are performing research and monitoring of the tamarisk problem and biological control efforts at a number of sites in southeastern Utah including the Entrada Ranch on the Dolores River.

- ✓ The University of Denver (DU) has developed a "Best Management Practices" handbook for tamarisk control and will complete a similar handbook for revegetation in the summer of 2008.

- ✓ Mesa State College has an active riparian restoration program that includes field work to develop practical solutions. DU has a similar program underway for undergraduate and graduate students.

- ✓ CSU is devoting approximately $1,000,000 over the next five years for tamarisk research efforts.

- ✓ Bureau of Reclamation scientists in Denver are developing more effective measures to improve revegetation success.

Action #5

A working group should be established to collaborate with these six institutes to identify specific research needs for the area, to utilize their research skills, and to ensure information sharing throughout the entire Colorado River watershed.

Active Restoration Activities

Action #6

The partners in CHIP should work together to continue to support and leverage existing projects to gain additional funding resources. An example will be funding derived from federal legislation PL 109-320. An active Grants and Projects Committee should be established in each of the seven watersheds to focus on grant opportunities and to communicate progress for active projects. The key to successful implementation on any of the proposed restoration strategies, education, research, outreach, etc. is funding to sustain the activity. A list of grant opportunities that are available for tamarisk related issues are available on the Tamarisk Coalition website (www.tamariskcoalition.org). For further information the reader is encouraged to visit the funding sources website and contact the funding source directly.

Table 19 provides a summary of all the action items that have been developed, responsibilities for carrying out the action or organizing a working group to complete the action, and a schedule for accomplishing the action.

Table 19: Actions, Lead Responsibility, and Time Line.

Action	Lead Responsibility	Time Line
#1: Working with landowners: GIS database, clearinghouse, prioritization, and communications.	Colorado River: Mesa and Garfield counties Gunnison & Uncompahgre Rivers: Mesa, Delta, and Montrose counties Dolores River: Colorado (5) and Utah (2) counties White River: Rio Blanco County Yampa River: Routt and Moffat counties Green River: Moffat County	July to December 2008
#2 and #3: Education, Outreach, & Volunteerism	Tamarisk Coalition	July to December 2008
#4: Long-term Sustainability	Colorado River Water Conservation District to organize working group	Complete by June 2009
#5: Research Needs	Tamarisk Coalition to organize working group	July to December 2008
#6: Restoration Activities	CO Big Country RC&D, CO Painted Sky RC&D, Rio Blanco County, and Moffat County to organize Grants and Projects Committee	July to December 2008

Definitions

Adaptive management is a natural resources management process under which planning, implementation, monitoring, research, evaluation, and incorporation of new knowledge are combined into a management approach that 1) is based on scientific findings and the needs of society, 2) treats management actions as experiments, 3) acknowledges the complexity of these systems and scientific uncertainty, and 4) uses the resulting new knowledge to modify future management methods and policy.

Basal bark herbicide application refers to the application of herbicide to the smooth bark at the base of non-native phreatophytes usually through a spray.

Biodiversity refers to biological diversity in an environment as indicated by numbers of different species of plants and animals.

Biological control is the use of specific organisms to control an undesirable organism.

Collaboration means involving all affected stakeholders in a set of decisions that guide how ecological rehabilitation and maintenance is undertaken, supported, and evaluated.

Coordination means making sure that those involved are aware of what other related activity is taking place. Coordination helps to maximize the efficient use of resources, promote consistency in process and standards where appropriate, and sequence efforts to achieve the greatest impact.

Disturbance regimes are the range of events, natural to an ecosystem, that temporarily change the structure and function of the systems, such as wildfire, drought, floods and insect or disease outbreak, to which the system is adapted.

Ecological processes refer to the natural cycles, disturbances and interactions of all parts of an ecosystem, such as nutrient and mineral cycles, fire or flood incidence, and species interactions.

Ecological restoration refers to a broad framework of activities for returning ecosystems to healthy functioning conditions. Ecological restoration activities are based on specific landscapes and objectives, and should incorporate past experience as a guide to sustainable futures. These activities include, but are not limited to: reducing overly-dense woody vegetation, re-establishing native vegetation, repairing erosion and soil condition, restoring hydrological function, and monitoring all these activities for effective long-term maintenance.

Ecosystem is the complex of a community of organisms interacting with one another and with the chemical and physical factors of their environment. In Colorado, the pinyon-juniper forest is an example of an ecosystem.

Economies in Colorado take many forms, and include those that are amenity-based, such as tourism, recreation, real estate and others like industries; product-based, which refer to forest products, mining and other extractive industries; as well as those that are agriculturally based such as farming and ranching.

Ephemeral streams are streams that flow only during or immediately after periods of precipitation.

Evapotranspiration is the combined diffusion of water vapor into the atmosphere from transpiration from plants and evaporation from soil and water surfaces.

Floodplain terrace are the lands outside the riparian zone that supports native phreatophytes but still within the floodplain. Terraces are generally supportive of xeric and mesic types of vegetation.

Foliar herbicide application refers to the application of herbicide to the leaves of a plant usually through a spray.

Forb is a small, herbaceous (non-woody), broad-leaved vascular plant (excluding grasses, rushes, sedges, etc.). For example, wild flowers are a type of forb.

Health refers to a condition where the system's parts and functions are sustained over time and where the capacity for ecological self-repair is maintained within a natural range of variability, allowing goals for sustainable uses, values and services to be met.

Hydrologic cycle describes the continuum of the transfer of water from precipitation to surface water and ground water, to storage and runoff, and to the eventual return to the atmosphere by transpiration and evaporation.

Hydrologic processes refer to that part of the hydrologic cycle that includes the amount and timing of stream flow, which in turn influences ecological functions in the stream corridor.

Implementation refers to the development of teams and specific action items to address the recommendations of this Plan as well as efforts to initiate "on-the-ground efforts."

Integration means considering the other initiatives taking place as well as the impacts of these on the larger ecosystem over the long term, and having this consideration inform the effort.

Landscape means a spatial mosaic of several ecosystems, landforms, watersheds and plant communities that are repeated in similar form across a defined area irrespective of ownership or other artificial boundaries.

Mesic vegetation are plants that utilize soil moisture that is more readily available than would be present in upland drier soils.

Partners are considered to be any State, federal, local, non-governmental, individuals, industry, or private entities that cooperate in CHIP.

Phreatophyte refers to a deep-rooted plant that obtains its water from the water table or the layer of soil just above it.

Restoration is the reestablishment of the structure and function of ecosystems. It involves the recovery of ecosystem functions and processes in a degraded habitat. The restoration process reestablishes the general structure, function, and dynamic but self-sustaining behavior as closely as possible to pre-disturbance conditions and functions while respecting private property rights, state water law, existing infrastructure, and endangered species considerations.

Riparian is the geographically delineated areas with distinct resource values that occur adjacent to rivers, streams, lakes, ponds, wetlands, and other water bodies. Typical vegetation in the CHIP study area includes grasses, cottonwoods, willows, and forbes.

State refers to Colorado state government and its agencies.

Stream Morphology refers to the study of the channel pattern and the channel geometry at several points along a river channel, including the network of tributaries within the drainage basin.

Sustainable refers to a level of human use of a natural resource that can continue through time without diminishing the resource's productivity or resilience.

Watershed refers to a region or land area that is drained by a single stream, river or drainage network, and includes all of the land within the entire drainage area. The Colorado River is an example of a large watershed. Examples of smaller watersheds within the larger watershed is the Roan Creek drainage.

Xeric vegetation represents plants that are adapted to a dry environment.

References

Baum, B. R. 1978. The Genus Tamarix. Israel Academy of Sciences and Humanities, Jerusalem. 209 pp.

Bawazir, A.S., New Mexico State University, Personal communication, April 2003.

Bean, D. Director Palisade Insectary, Personal communication, March, 2007

Belcher, E. W. and R. P. Karrrfalt. 1979. Improved methods for testing the viability of Russian olive seed. Journal of Seed Technology 4:57-64.

Belsky, A.J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the Western United States. Journal of Soil and Water Conservation.

Borell, A. E. 1962. Russian-olive for wildlife and other conservation uses. U.S. Department of Agriculture, Washington, DC, USA. Leafet No. 517.

Brown, C.R. 1990. Avian use of native and exotic riparian habitats on the Snake River, Idaho. M.S. Thesis. Colorado State Univ., Fort Collins, CO. pp. 60.

Busch, D. E., and S. D. Smith. 1993. Effects of fire on water and salinity relations of riparian woody taxa. *Oecologia* 94:186-194.

Busch, D. E., and S. D. Smith. 1995. Mechanisms associated with decline of woody species in riparian ecosystems of the Southwestern US. *Ecological Monographs* 65: 347-370.

Busch, D. E., N. L. Ingraham, and S. D. Smith. 1992. Water-uptake in woody riparian phreatophytes of the southwestern United States: a stable isotope study. *Ecological Applications* 2: 450-459.

Caplan, T. 2002. Controlling Russian olives within cottonwood gallery forests along the Middle Rio Grande floodplain (New Mexico). Ecological Restoration 20(2): 138-139.

Carman, J.G., and J.D. Brotherson. 1982. Comparison of sites infested and not infested with saltceder (*Tamarix pentandra*) and Russian-olive (*Elaeagnus angustifolia*). Weed Sci. 10:360-364.

Carpenter, A. 1998. Element Stewardship Abstract for *Tamarix ramosissima* Lebedour, *Tamarix pentandra* Pallas, *Tamarix chinensis* Loureiro, and *Tamarix parviflora* De Candolle. The Nature Conservancy, Arlington, Virginia.

Chaney, E., W. Elmore, and W.S. Platts. 1990. Livestock grazing on western riparian areas. Northwest Resources Information Center, Inc. Eagle Idaho.

Cleverly, J. R., S. D. Smith, A. Sala, and D. A. Devitt. 1997. Invasive capacity of *Tamarix-ramosissima* in a Mojave desert floodplain : the role of drought. *Oecologia* 111: 12-18.

Décamps, H., A.M. Planty-Tabacchi, and E. Tabacchi. 1995. Changes in the hydrological regime and invasions by plant species along riparian systems of the Adour river, France. Regulated Rivers: Research & Management, 11:23-33.

DeLoach, J. 1997. Effects of Biological Control of Saltcedar (Tamarix ramosissima) on Endangered Species: Biological Assessment. U.S. Department of Agriculture, Temple, Texas.

DeLoach, J., R Carruthers, J. Lovich, T. Dudley, and S. Smith, 2000. "Ecological Interactions in the Biological Control of Saltcedar (*Tamarix spp.*) in the United States: Toward a New Understanding." Proceedings of the X International Symposium on Biological Control of Weeds, 4-14 July 1999, Montana State University, Bozeman, Montana.

DeLoach, J., R Carruthers, J. Lovich, T. Dudley, and S. Smith, 2002. "Ecological Interactions in the Biological Control of Saltcedar (*Tamarix spp.*) in the United States: Toward a New Understanding" – Revised.

Ebinger, J. and L. Lehnen. 1981. Naturalized autumn olive in Illinois. Transactions of the Illinois State Academy of Science 74: 83-85.

Ellis, L. M. 1995. Bird use of salt cedar and cottonwood vegetation in the middle Rio Grande valley of New Mexico, USA. Journal of Arid Environments 30:339-349.

Gaskin, John F. 2002. Hybrid *Tamarix* widespread in U.S. invasion and undetected in native Asian range. Proceedings of the National Academy of Sciences of the United States of America 99. no. 17: 11256-11259.

Gaskin, J.F. and B. A. Schaal. 2002. Hybrid Tamarix widespread in US invasion and undetected in native Asian range.

Graf, W.L. 1978. Fluvial adjustments to the spread of tamarisk in the Colorado Plateau region. Geological Society of America Bulletin 89 :1491-1501.

Haber, E. 1999. Invasive Exotic Plants of Canada Fact Sheet No.14: Russian-olive. National Botanical Services, Ottawa, ON, Canada.

Hansen, N. E. 1901. Ornamentals for South Dakota. U.S. Experiment Station, Brookings, SD, USA. Bulletin 72.

Hayes, B. 1976. Planting the *Elaeagnus* Russian and autumn olive for nectar. American Bee Journal 116:74,82.

Horton, J. S., F. C. Mounts, and J. M. Kraft. 1960. Seed germination and seedling establishment of phreatophyte species. U.S. Department of Agriculture, Rocky mountain Forest and Range Experiment Station, Fort Collins, Colorado. Paper No. 48. 26 pp.

Hogue, E. J. and L. J. LaCroix. 1970. Seed dormancy of Russian olive (*Elaeagnus angustifolia* L.). Journal of the American Society of Horticultural Science 95:449-452.

Howe, W.H. and F.L. Knopf. 1991. On the imminent decline of Rio Grande cottonwoods in central New Mexico. The Southwestern Naturalist 36:218-224.

Katz, G. L. 2001. Fluvial Disturbance, flood control, and biological invasion in Great Plains riparian forests. Ph.D. Dissertation. University of Colorado, Boulder, CO, USA.

Katz, G.L., and P.B. Shafroth. 2003. Biology, ecology and management of Elaeagnus angustifolia L. (Russian olive) in western North America. Wetlands 23(4): 763-777.

King, J.P. and Bawazir, S.A. 2000. Riparian Evaporation Studies of the Middle Rio Grande. Technical Completion report, U.S. Bureau of Reclamation.

Kolb, Thomas E. 2001 "Water Use of Tamarisk and Native Riparian Trees." Proceedings of the Tamarisk Symposium, September 26 – 27, 2001, Grand Junction, Colorado.

Knopf, F.L., and T.E. Olson. 1984. Naturalization of Russian-olive; implications to Rocky Mountain wildlife. Wildl. Soc. Bul. 12: 289-298.

Lesica, P. and S. Miles 1999. Russian olive invasion into cottonwood forests along a regulated river in north-central Montana. Canadian Journal of Botany 77: 1077-1083.

Little, E. L. 1961. Sixty trees from foreign lands. U. S. Department of Agriculture, Washington, DC, USA. Agricultural Handbook No. 212.

Lonsdale, W. M. 1993. Rates of spread of an invading species *Mimosa pigra* in northern Australia. J. of Ecology 81:513-521.

McDaniel, K.C., DiTomaso, J.M., Duncan, C.A. 2004. *Tamarisk or Saltcedar (Tamarix spp.)* Galley proof for Allen Press.

Muzika, R.-M. and J.M. Swearingen. 1998. Russian-olive (*Elaeagnus angustifolia L.*). PCA Alien Plant Working Group. (http://www.nps.gov/plants/alien/fact/elan1.htm).

National Invasive Species Council, Tamarisk Economics Impact Study, in progress – January 2006.

Ohmart, R.D. 1996. Historical and present impacts of livestock grazing on fish and wildlife resources in western riparian habitats. Pages 245-279 In: Krausman, P.R. (ed.).

1996. Range wildlife. Society for Range Management, Denver, CO.

Olson, T.E. and F.L. Knopf. 1986. Agency subsidization of a rapidly spreading exotic. Wildlife Society Bulletin: 492-493.

Robinson, T. W. 1965. Introduction, spread, and aerial extent of salt cedar (*Tamarix*) in the western states. Geological survey professional paper 491-A. United States Government Printing Office, Washington.

Shafroth, P.B, J.M. Friedman, and L.S. Ischinger. 1995. Effects of salinity on establishment of *Populus fremontii* (cottonwood) and *Tamarix ramosissima* (salt cedar) in southwestern United States. Great Basin Naturalist 55:58-65.

Shafroth, P.B., G.T. Auble, J.C. Stromberg, and D.T. Patten. 1998. Establishment of woody riparian vegetation in relation to annual patterns of streamflow, Bill Williams River, Arizona. Wetlands 18:577-590.

Shafroth, P. B., G. T. Auble, and M. L. Scott. 1995. Germination and establishment of native plains cottonwood (*Populus deltoids* Marshall subsp. *Monilifera*) and the exotic Russian-olive (*Elaeagns angustifolia*). Conservation Biology 9:169-175.

Sher, A. A. and D. L. Marshall. 2003. Competition between native *Populus deltoides* and invasive *Tamarix ramosissima* and the implications of reestablishing flooding disturbance. Conservation Biology 14:1744-1754.

Sher, A. A., D. L. Marshall, and S. A. Gilbert. 2000. Competition between native Populus deltoides and invasive Tamarix ramosissima and the implications for reestablishing flooding disturbance. *Conservation Biology* 14:1744.

Sher, A.A., Marshall, D.L., and Taylor, J.P. 2002. Establishment patterns of native *Populus* and *Salix* in the presence of invasive, non-native *Tamarix*. *Ecological Applications* 12: 760-772.

Shishkin, B. K. (ed.). 1949. Flora of the U.S.S.R. Institute of the Academy of Sciences of the U.S.S.R., Moscow, USSR.

Smith, S.D., D. A. Devitt, A. Sala, J. R. Cleverly, and D. E. Busch. 1998. Water relations of riparian plants from warm desert regions. *Wetlands* 18: 687-696.

Springuel, I.; M Sheded, and K.J. Murphy. 1997. The plant biodiversity of the Wadi Allaqi Biosphere Reserve (Egypt): Impact of Lake Nasser on a desert Wadi ecosystem. Biodiversity and Conservation 6:1259-1275.

Sternberg, G. 1996. *Elaeagnus umbellata*. P. 54. *in* J. M. Randall and J. Marinelli (eds.) Invasive Plants: Weeds of the Global Garden. Brooklyn Botanic Garden, Brooklyn, NY, USA.

Stromberg, J. 1998. Dynamics of Fremont cottonwood (*Populus fremontii*) and salt cedar (*Tamarix chinensis*) populations along the San Pedro River, Arizona. *Journal of Arid Environments* 40: 133-155.

Stromberg, J. C., R. Tiller, and B. Richter. 1996. Effects of groundwater decline on riparian vegetation of semiarid regions: The San Pedro, Arizona. *Ecological Applications* 6:113-131.

Taylor, J. P, D. B. Wester, and L.M. Smith. 1999. Soil disturbance, flood management, and riparian woody plant establishment in the Rio Grande floodplain. *Wetlands* 19:372-382.

Tesky, J.L. 1992. *Elaeagnus angustifolia*. *In*: USDA, Forest Service, Rocky Mountain Res. Sta., Fire Sci Lab. (2001, July). Fire Effects Information System, [Online]. Available: http://www.fs.fed.us/database/feis/.

Tu, M. 2003. Element Stewardship Abstract for *Elaeagnus angustifolia* L., Russian olive, oleaster. The Nature Conservancy. (http://tncweeds.ucdavis.edu/esadocs/documnts/elaeang.html).

US Department of Energy, 2005. "Remediation of the Moab Uranium Mill Tailings, Grand and San Juan Counties, Utah, Final Environmental Impact Statement." July 2005.

USDI-BOR 1995. "Vegetation Management Study: Lower Colorado River, Phase II." U.S. Department of Interior, Bureau of Reclamation, Lower Colorado River, Draft Report, Boulder City, Nevada.

USDA. 1974. Seeds of wood plants in the United States. USDA Agr. Handbook No. 450.

USDA. 2002. Technical Notes: Plant Materials No. 47. History, Biology, Ecology, Suppression and Revegetation of Russian-Olive Sites (*Elaeagnus angustifolia* L.). Available: http://www.usgs.nau.edu/SWEPIC/factsheets/ELAN.APRS.pdf.

US Fish and Wildlife Service, 2005. "Designation of Critical Habitat for the Southwestern Willow Flycatcher (*Empidonax traillii extimus*); Final Rule", Federal Register (50 CFR Part 17), October 19, 2005.

Weeks, E., H. Weaver, G. Campbell and B. Tanner, 1987. Water use by saltcedar and by replacement vegetation in the Pecos River floodplain between Acme and Artesia, New Mexico. U.S. Geological Survey, Reston, Virginia.

Zimmerman, J. 1997. Ecology and Distribution of *Tamarix chinensis* Lour and *T. parviflora* D.C., *Tamariccea*. Southwest Exotic Plant Mapping Program, U.S. Geological Survey.

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

H. R. 2720 (Public Law 109-320)

One Hundred Ninth Congress

of the

United States of America

AT THE SECOND SESSION

Begun and held at the City of Washington on Tuesday,
the third day of January, two thousand and six

An Act

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 control salt cedar and Russian olive, and for other purposes.

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 and Russian Olive Control Demonstration Act''.

SEC. 2. SALT CEDAR AND RUSSIAN OLIVE CONTROL DEMONSTRATION PROGRAM.

(a) ESTABLISHMENT.—The Secretary of the Interior (referred to in this Act as the ''Secretary''), acting through the Commissioner of Reclamation and the Director of the United States Geological Survey and in cooperation with the Secretary of Agriculture and the Secretary of Defense, shall carry out a salt cedar (Tamarix spp) and Russian olive (Elaeagnus angustifolia) assessment and demonstration program—

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

(2) to demonstrate strategic solutions for—

(A) the long-term management of salt cedar and Russian olive trees; and

(B) the reestablishment of native vegetation; and

(3) to assess economic means to dispose of biomass created as a result of removal of salt cedar and Russian olive trees.

(b) MEMORANDUM OF UNDERSTANDING.—As soon as practicable after the date of enactment of this Act, the Secretary and the Secretary of Agriculture shall enter into a memorandum of understanding providing for the administration of the program established under subsection (a).

(c) ASSESSMENT.—

(1) IN GENERAL.—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 on public and private land in the western United States.

(2) REQUIREMENTS.—In addition to describing the acreage of and severity of infestation by salt cedar and Russian olive trees in the western United States, the assessment shall—

(A) consider existing research on methods to control salt cedar and Russian olive trees;

(B) consider the feasibility of reducing water consumption by salt cedar and Russian olive trees;

(C) consider methods of and challenges associated with the revegetation or restoration of infested land; and

(D) estimate the costs of destruction of salt cedar and Russian olive trees, related biomass removal, and revegetation or restoration and maintenance of the infested land.

(3) REPORT.—

(A) IN GENERAL.—The Secretary shall submit to the Committee on Energy and Natural Resources and the Committee on Agriculture, Nutrition, and Forestry of the Senate and the Committee on Resources and the Committee on Agriculture of the House of Representatives a report that includes the results of the assessment conducted under paragraph (1).

(B) CONTENTS.—The report submitted under subparagraph (A) shall identify—

(i) long-term management and funding strategies identified under subsection (d) that could be implemented by Federal, State, tribal, and private land managers and owners to address the infestation by salt cedar and Russian olive;

(ii) any deficiencies in the assessment or areas for additional study; and

(iii) any field demonstrations that would be useful in the effort to control salt cedar and Russian olive.

(d) LONG-TERM MANAGEMENT STRATEGIES.—

(1) IN GENERAL.—The Secretary shall identify and document long-term management and funding strategies that—

(A) could be implemented by Federal, State, tribal, and private land managers in addressing infestation by salt cedar and Russian olive trees; and

(B) should be tested as components of demonstration projects under subsection (e).

(2) GRANTS.—

(A) IN GENERAL.—The Secretary may provide grants to eligible entities to provide technical experience, support, and recommendations relating to the identification and documentation of long-term management and funding strategies under paragraph (1).

(B) ELIGIBLE ENTITIES.—Institutions of higher education and nonprofit organizations with an established background and expertise in the public policy issues associated with the control of salt cedar and Russian olive trees shall be eligible for a grant under subparagraph (A).

(C) MINIMUM AMOUNT.—The amount of a grant provided under subparagraph (A) shall be not less than $250,000.

(e) DEMONSTRATION PROJECTS.—

(1) IN GENERAL.—Not later than 180 days after the date on which funds are made available to carry out this Act, the Secretary shall establish a program that selects and funds not less than 5 projects proposed by and implemented in collaboration with Federal agencies, units of State and local government, national laboratories, Indian tribes, institutions of higher education, individuals, organizations, or soil and water conservation districts to demonstrate and evaluate the most effective methods of controlling salt cedar and Russian olive trees.

(2) PROJECT REQUIREMENTS.—The demonstration projects under paragraph (1) shall—

(A) be carried out over a time period and to a scale designed to fully assess long-term management strategies;

(B) implement salt cedar or Russian olive tree control using 1 or more methods for each project in order to assess the full range of control methods, including—

(i) airborne application of herbicides;

(ii) mechanical removal; and

(iii) biocontrol methods, such as the use of goats or insects;

(C) individually or in conjunction with other demonstration projects, assess the effects of and obstacles to combining multiple control methods and determine optimal combinations of control methods;

(D) assess soil conditions resulting from salt cedar and Russian olive tree infestation and means to revitalize soils;

(E) define and implement appropriate final vegetative states and optimal revegetation methods, with preference for self-maintaining vegetative states and native vegetation, and taking into consideration downstream impacts, wildfire potential, and water savings;

(F) identify methods for preventing the regrowth and reintroduction of salt cedar and Russian olive trees;

(G) monitor and document any water savings from the control of salt cedar and Russian olive trees, including impacts to both groundwater and surface water;

(H) assess wildfire activity and management strategies;

(I) assess changes in wildlife habitat;

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

(K) assess economic and other impacts associated with control methods and the restoration and maintenance of land.

(f) DISPOSITION OF BIOMASS.—

(1) IN GENERAL.—Not later than 1 year after the date on which funds are made available to carry out this Act, the Secretary, in cooperation with the Secretary of Agriculture, shall complete an analysis of economic means to use or dispose of biomass created as a result of removal of salt cedar and Russian olive trees.

(2) REQUIREMENTS.—The analysis shall—

(A) determine conditions under which removal of biomass is economically viable;

(B) consider and build upon existing research by the Department of Agriculture and other agencies on beneficial uses of salt cedar and Russian olive tree fiber; and

(C) consider economic development opportunities, including manufacture of wood products using biomass resulting from demonstration projects under subsection (e) as a means of defraying costs of control.

(g) COSTS.—

(1) IN GENERAL.—With respect to projects and activities carried out under this Act—

(A) the assessment under subsection (c) shall be carried out at a cost of not more than $4,000,000;

(B) the identification and documentation of long-term management strategies under subsection (d)(1) and the provision of grants under subsection (d)(2) shall be carried out at a cost of not more than $2,000,000;

(C) each demonstration project under subsection (e) shall be carried out at a Federal cost of not more than $7,000,000 (including costs of planning, design, implementation, maintenance, and monitoring); and

(D) the analysis under subsection (f) shall be carried out at a cost of not more than $3,000,000.

(2) COST-SHARING.—

(A) IN GENERAL.—The assessment under subsection (c), the identification and documentation of long-term management strategies under subsection (d), a demonstration project or portion of a demonstration project under subsection (e) that is carried out on Federal land, and the analysis under subsection (f) shall be carried out at full Federal expense.

(B) DEMONSTRATION PROJECTS CARRIED OUT ON NONFEDERAL LAND.—

(i) IN GENERAL.—The Federal share of the costs of any demonstration project funded under subsection
(e) that is not carried out on Federal land shall not exceed 75 percent.

(ii) FORM OF NON-FEDERAL SHARE.—The non-Federal share of the costs of a demonstration project that is not carried out on Federal land may be provided in the form of in-kind contributions, including services provided by a State agency or any other public or private partner.

(h) COOPERATION.—In carrying out the assessment under subsection (c), the demonstration projects under subsection (e), and the analysis under subsection (f), the Secretary shall cooperate with and use the expertise of Federal agencies and the other entities specified in subsection (e)(1) that are actively conducting research on or implementing salt cedar and Russian olive tree control activities.

(i) INDEPENDENT REVIEW.—The Secretary shall subject to independent review—

(1) the assessment under subsection (c);

(2) the identification and documentation of long-term management strategies under subsection (d);

(3) the demonstration projects under subsection (e); and

(4) the analysis under subsection (f).

(j) REPORTING.—

(1) IN GENERAL.—The Secretary shall submit to Congress an annual report that describes the results of carrying out this Act, including a synopsis of any independent review under subsection (I) and details of the manner and purposes for which funds are expended.

(2) PUBLIC ACCESS.—The Secretary shall facilitate public access to all information that results from carrying out this Act.

(k) AUTHORIZATION OF APPROPRIATIONS.—

(1) IN GENERAL.—There are authorized to be appropriated to carry out this Act—

(A) $20,000,000 for fiscal year 2006; and

(B) $15,000,000 for each of fiscal years 2007 through 2010.

(2) ADMINISTRATIVE COSTS.—Not more than 15 percent of amounts made available under paragraph (1) shall be used to pay the administrative costs of carrying out the program established under subsection (a).

(l) TERMINATION OF AUTHORITY.—This Act and the authority provided by this Act terminate on the date that is 5 years after the date of the enactment of this Act.

Speaker of the House of Representatives.

Vice President of the United States and
President of the Senate.

Appendix C

California Legislation
2006 Assembly Bill No. 984

Passed the Assembly January 23, 2006
Chief Clerk of the Assembly
Passed the Senate August 24, 2006
Secretary of the Senate
This bill was received by the Governor this 6th day
Of September, 2006, at 11:15 o'clock a.m.
Private Secretary of the Governor
CHAPTER
An act to add Part 11 (commencing with Section 12999) to
Division 6 of the Water Code, relating to water.

LEGISLATIVE COUNCIL'S DIGEST

AB 984, Laird. Tamarisk plant control.
Existing law grants to the Department of Water Resources various duties relating to the supervision of the state's water resources.

This bill would authorize the department, in collaboration with other entities, to cooperate with the federal government, other Colorado River Basin states, and other entities for the purpose of preparing a plan to control or eradicate tamarisk plants in the Colorado River watershed. The bill would require the department, the Department of Food and Agriculture, the Department of Fish and Game, and the Colorado River Board of California to seek to collaborate with affected California water agencies and other appropriate entities in that preparation.

The bill would require the department, in collaboration with other entities, to implement the plan within California upon the appropriation of funds for that purpose. The bill would require the department, the Department of Food and Agriculture, the Department of Fish and Game, and the Colorado River Board of California to seek to collaborate with affected California water agencies and other appropriate entities in that implementation.

The people of the State of California do enact as follows:

SECTION 1. The Legislature finds and declares all of the following:
(a) Tamarisk is a small tree or large shrub that was imported from Eastern Europe in the 1800s for use as windbreaks and erosion control.
(b) Tamarisk is spreading across the west, including covering hundreds of thousands of acres in the Colorado River Basin, almost entirely along waterways.
(c) Tamarisk easily out-competes native habitat, such as willows and cottonwoods, and has very little habitat value compared to native vegetation.
(d) Because of its delicate and expansive leaf structure, tamarisk on a per-acre basis takes up and evaporates substantially more water than native vegetation.

(e) Colorado River flows have been very low for the last six years because of increasing human uses and very low rainfall, and because tamarisk is taking up significantly more water than the native vegetation that it replaces.
(f) If low riverflows continue, dwindling reservoir storage will be insufficient to continue historical levels of diversions and diversions will have to be curtailed, with substantial impacts to the economies of the seven states in the Colorado River watershed.
(g) Environmental mitigation and restoration programs, such as the lower Colorado River Multi-Species Conservation Program and environmental mitigation measures for the Quantification Settlement Agreement on the lower Colorado River, may include projects that will replace invasive exotic vegetation with native vegetation. The state supports the eradication of invasive species by the Colorado River Multi-Species Conservation Program and other programs and encourages cooperation with these programs to increase the available native wetland and riparian vegetation in the Colorado River watershed.
(h) The state seeks to encourage the federal government, basin states, and water agencies to develop a program to control or eradicate tamarisk within each state's jurisdiction.
(i) Controlling tamarisk in the Colorado River watershed entails a large and costly task, but if it is not undertaken, there will be significant economic and environmental consequences for California and the other basin states.

SEC. 2. Part 11 (commencing with Section 12999) is added to Division 6 of the Water Code, to read:

PART 11. TAMARISK PLANT CONTROL

12999. (a) The department, in collaboration with the Department of Food and Agriculture, the Department of Fish and Game, and the Colorado River Board of California may cooperate with the federal government, the other Colorado River Basin states, and other entities for the purpose of preparing a plan to control or eradicate tamarisk in the Colorado River watershed. The department, the Department of Food and Agriculture, the Department of Fish and Game, and the Colorado River Board of California shall seek to collaborate with affected California water agencies and other appropriate entities in that preparation. The plan shall include the reestablishment of native vegetation and the identification of potential federal and nonfederal funding sources for implementation pursuant to subdivision (b).

(b) The department, in collaboration with the Department of Food and Agriculture, the Department of Fish and Game, the Colorado River Board of California, and appropriate federal agencies, shall implement the plan within California upon the appropriation of funds for that purpose. The department, the Department of Food and Agriculture, the Department of Fish and Game, and the Colorado River Board of California shall seek to collaborate with affected California water agencies and other appropriate entities in the implementation of the plan.

(c) This section does not preclude the department or any other entity from expending bond funds or nonstate funds for the control or eradication of tamarisk in the Colorado River watershed.

Approved September 29, 2006 *Governor Arnold Schwarzenegger*

Appendix D

Colorado Tamarisk Mapping & Inventory Objectives, Protocols, and Guidelines

Purpose: The purpose of this study was to establish and implement an inventory protocol that provides a clear understanding of the extent of the tamarisk problem but is also economical to perform. Quantifying and characterizing the tamarisk infestations on each major river system provides a wealth of information for many diverse users. The data produced provides planning level information that can support policy; and state, federal, and local decision-making concerning tamarisk control and riparian restoration efforts. Land managers, however, must take into consideration the site specific conditions of each land parcel and the desires/preferences of the landowner to select the appropriate tamarisk control and revegetation approach to implement.

Goal: The goal of these mapping and inventory protocols was to identify 85 to 90 percent of the tamarisk infestations in Colorado. This goal is achieved through the efficient inventory approach described below. The remaining 10 to 15 percent of infestations are scattered among minor tributaries and headwaters which can cost more to find than to control. These small scattered infestations are best identified as a component of larger-scale control projects.

Inventory Approach: To provide a thorough understanding of tamarisk infestations, a comprehensive data set was collected. This data provides essential information for developing effective cost estimates for control and revegetation, and to better understand impacts such as water losses and wildlife habitat effects. Tamarisk infestations were mapped by the Tamarisk Coalition on the Arkansas, Colorado, Purgatoire, White, Gunnison, Uncompahgre, Dolores, San Juan, Republican, and South Platte watersheds including major tributaries of each. The Yampa River watershed was mapped under an agreement with the National Park Service at Dinosaur National Monument. The North Platte and Rio Grande watersheds have minimum infestations that were assessed based on local weed managers' input but were not directly surveyed. The mapping and inventory process had five basic components.

1) High resolution aerial and satellite photos that are ortho-rectified (usually at 1-meter resolution or better) were acquired from available sources at no cost. These include photography from Mesa County GIS, U.S. Department of Agriculture – Farm Service Agency, and TerraServer. Utilization of National Agricultural Imagery Program (NAIP-2005) aerial photographs were, in most cases, the most current, consistent source of imagery for mapping purposes (available at http://datagateway.nrcs.usda.gov/NextPage.asp).

2) A basic understanding of infestation locations was gleaned from county weed managers, the state weed coordinator, state agriculture specialists, the water conservancy district staff, federal weed managers, university researchers, private land owners, and/or others. Photo interpretation of high-resolution aerial photography proved to be valuable in determining the potential infestation extent where prior knowledge was not available.

3) A consultation with the US Geological Survey (USGS) and National Institute of Invasive Species Science was performed for technical assistance and data standardization to ensure database compatibility with the national database system (www.niss.org)

4) On-the-ground surveys were then performed by a two-person crew to verify the following attributes of the tamarisk infestation:

   - ✓ GPS coordinates of tamarisk stand (Universal Transverse Mercator-UTM)
   - ✓ Percent cover (canopy)
   - ✓ Average height (added at the request of USGS partway through the field work on the Arkansas River)
   - ✓ Percent riparian area: defined as the portion of area currently occupied by tamarisk found in the floodplain corridor where native phreatophytes such as cottonwoods and willows could exist in the future.
   - ✓ Percent upland or terrace area: defined as the remaining land within the floodplain where dryland plant species would be more prevalent after tamarisk control is achieved is classified as upland or floodplain terrace.
   - ✓ Maturity (mature or immature)
   - ✓ Accessibility (good or poor for mechanized removal)
   - ✓ Presence other significant species (Russian olive, willow, cottonwood). Note that for some rivers such as the White, South Platte, Republican, and Purgatoire that Russian olive was the dominant invasive species and additional mapping was performed to inventory these infestations.

These attributes were initially recorded on a Personal Data Assistant (PDA) system with standardized data collection software (EcoNab) integrated with a GPS unit. As the mapping work progressed, a rugged quality field laptop computer with ArcView 9 and preloaded NAIP imagery was used to allow for on-site data entry. Digital photos representing each data point were also taken to visually display the infestations. Additionally, a field notebook documenting other significant observations (i.e. access issues, land use, etc.) was recorded at every data point.

5) The field imagery data was transferred into shapefiles using ArcGIS software and attached to the tabular data listed above. These shapefiles were subsequently utilized to calculate the total areas of infestation in any specific region.

Deliverables:

1) Shape files characterizing each infestation with an attribute table including the following fields: acreage, percent cover, average height, percent riparian, maturity, accessibility, and other significant species presence. These shapefiles have added value in that they can be overlaid with other GIS referenced information; e.g., county property boundaries and ownership maps.

2) Digital photo album of the infested areas corresponding to each data point.

3) Auxiliary notebook describing significant observations.

4) PDFs of river segments showing shapefiles overlaid onto aerial photos and Excel spreadsheet tables are provided as user-friendly formats to present usable information for people without GIS expertise.

5) Excel spreadsheets provide individual details for each shapefile as well as watershed summaries. The summaries contain infestation acreage, percent cover, estimates of existing and future water losses, and estimates of total restoration costs including planning, control, revegetation, monitoring, and maintenance. These cost estimates are based on algorithms developed in *Options for Non-Native Phreatophyte Control* (See Appendix G). The cost equations incorporate best management practices coupled with an Integrated Pest Management approach based on three variables – percent tamarisk cover, accessibility, and average width of infestation.

System Requirements:

System requirements to use the inventory and mapping data require the following computer and software capability.

1) The minimum requirement for viewing the shapefiles is a free program called ArcExplorer, available at **http://www.esri.com/software/arcexplorer/**.

2) Computer specs: Access the ESRI site at www.esri.com for specific system requirements.

3) Microsoft Word and Excel software are used for viewing reports and spreadsheets. Adobe Reader is required for PDFs of river segments showing shapefiles overlaid onto aerial photos.

4) Digital photos: Any software capable of viewing JPEGs is sufficient.

a non-profit alliance working to restore riparian lands
Tamarisk Coalition P.O. Box 1907 · Grand Junction, CO 81502

Appendix E

Tamarisk Infestation presented on Aerial Photos

Tamarisk infestation maps have been developed for the Colorado Water Conservation Board as Adobe PDF files that overlain onto 1-meter high-resolution aerial photos flown by the USDA Farm Service Agency in 2005. Because of their very large number (129) and large size (11" x 17"), these photos are included on the supplementary Data-DVD located in the back of the CHIP Plan. The following is a listing of the Table of Contents for these aerial photos on all four watersheds.

Yampa/Green & Tributary Maps – [Note that the following information was collected through Dinosaur National Monument by Utah State University and provides different information than previous river segments.]

Instructions – To view the tamarisk density maps use the Data-DVD attached to this study. The PDF files provided there are quite large (>500 mb) and may bog down many computer systems. To minimize computer storage use, choose a specific section of river section desired based on the descriptive folder titles listed above. If you are unsure where your area of interest lies within these river sections, locate it the “Cover & Scales” folder to find specific sites on large scale maps.

Appendix F Riparian Restoration

Assessment of Alternative Technologies for Tamarisk Control, Biomass Reduction and Revegetation

Revised July 2008

Prepared by
Tamarisk Coalition

Funding provided by Colorado Water Conservation Board

Riparian Restoration

Assessment of Alternative Technologies for Tamarisk Control, Biomass Reduction and Revegetation

Management of non-native phreatophytes consists of five basic components – 1) planning informed by accurate inventory and mapping efforts, 2) control work, 3) biomass reduction, 4) revegetation, and 5) long-term monitoring and maintenance. Without considering all five components it is unlikely that tamarisk control projects will result in long-term success. The following discussion addresses options for the control, biomass reduction, and revegetation management components. All currently available technologies have been evaluated; however, not all are applicable for a given river location. For example, biomass reduction and revegetation are not always necessary steps in the restoration process. In many situations biomass levels may be very low and natural revegetation can occur.

The intent of invasive species management is to ensure that selected approaches are effective and efficient, and that decisions are well documented. Successful management will also remain open to new or altered approaches based on the latest information, technology, or experiences; i.e., adaptive management.

Tamarisk is the focus of this document's control component because it is the principle non-native phreatophyte in western watersheds. In general, the following discussion applies to Russian olive and other invasive trees but may differ slightly for each (e.g., herbicide used). Cost information, presented in this section, is based on the extensive experience of the Tamarisk Coalition and of the numerous Western tamarisk control efforts. The definitions used within this project for the three relevant restoration components are:

1. <u>Control</u> refers to the removal of invasive species such as tamarisk, Russian olive, and others using hand, herbicide, mechanical, or biological methods.
2. <u>Biomass reduction</u> is the removal of dead biomass through mechanical methods, natural decomposition, or controlled fire.
3. <u>Revegetation</u> refers to the reestablishment of native grasses, shrubs, forbs, wetland species, and trees on disturbed areas through seeding, planting, or enabling natural regeneration to occur.

Tamarisk and Russian Olive Control

Tamarisk can be controlled using single or successional weed management techniques, including chemical, mechanical, and biological techniques. All of the following tamarisk control techniques are viable options, 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 select control techniques for invasive species management. The IPM process is illustrated in Attachment A and considers community values, prevention, cultural management, land stewardship, mechanical or physical removal, biological control, herbicide treatments, and revegetation techniques. A description of each major control technology is presented below describing costs, effectiveness, impacts, and applicability. Note that there are many hybrids of these technologies and actual costs and applicability may vary for each site. Wherever an herbicide is identified as a control option component it is the most widely used product and the product's label application rate should be followed. It is critically important for the reader to understand that **COSTS** developed throughout this document **represent planning level values that must be adjusted for local conditions**; e.g., revegetation costs for similar infestation levels can be dramatically different because of water availability, soil conditions, replacement vegetation, etc. It is equally important to review the full cost of any approach as described in the later sections of this paper.

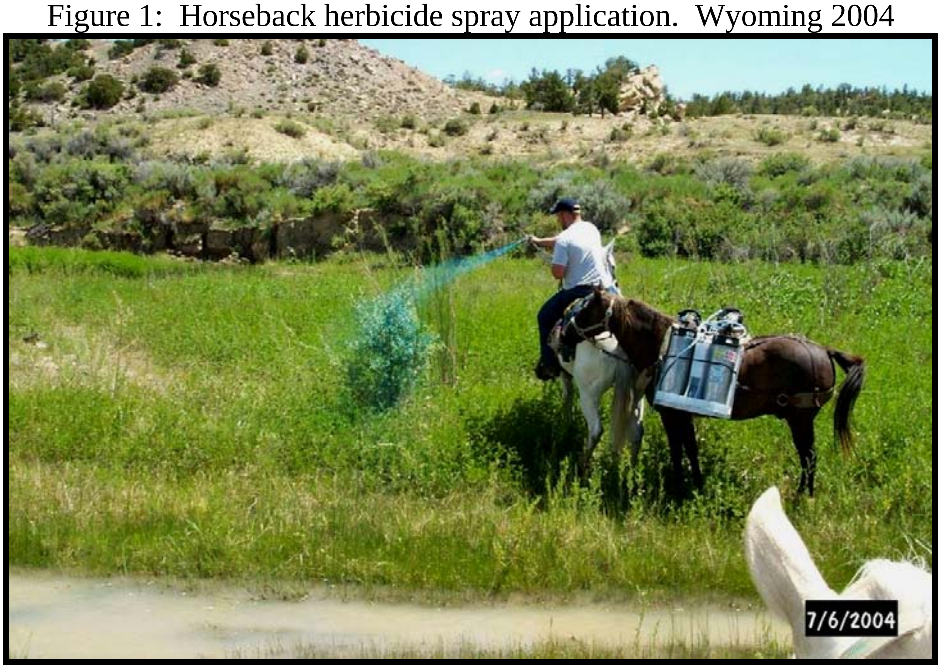
Hand Herbicide Application

There are two types of hand herbicide applications, foliar and basal bark. Foliar sprays are applied directly to vegetation foliage. Basal bark treatment controls seedlings or smaller plants with smooth (basal) bark and a stem that is less than one inch in diameter by spraying herbicide on the bottom 12-18 inches of the stem.

Effectiveness: Foliar and basal bark sprays are approximately 85 percent effective and require some level of maintenance to address resprouts. As density increases and access becomes more difficult, this method becomes more expensive and less effective due to limited abilities to spray herbicide onto all exposed basal bark or leaf surfaces. Both foliar and basal bark sprays are effective regardless of the time of year unless the temperature exceeds 85^{o} F, at which point the triclopyr herbicide used for basal bark application volatizes and can be potentially harmful to workers and surrounding vegetation. If temperatures are anticipated to be above 85^{o} F other herbicides are required. Freezing conditions may also limit its use.

Costs: A general rule of thumb is $2 to $5 per plant depending on size; thus, costs are low for very light infestations but quickly escalate in denser stands with larger trees (Tamarisk Coalition 2003).

Figure 1: Horseback herbicide spray application. Wyoming 2004



Pros of Hand Herbicide Application:

1. Inexpensive and effective for light infestations.
2. For inaccessible and remote areas, hand application using backpack, horses, or off-road vehicles is effective.
3. Generally, there is no need to remove dead biomass or to actively revegetation in the light infestations where this approach is typically used.

Cons of Hand Herbicide Application:

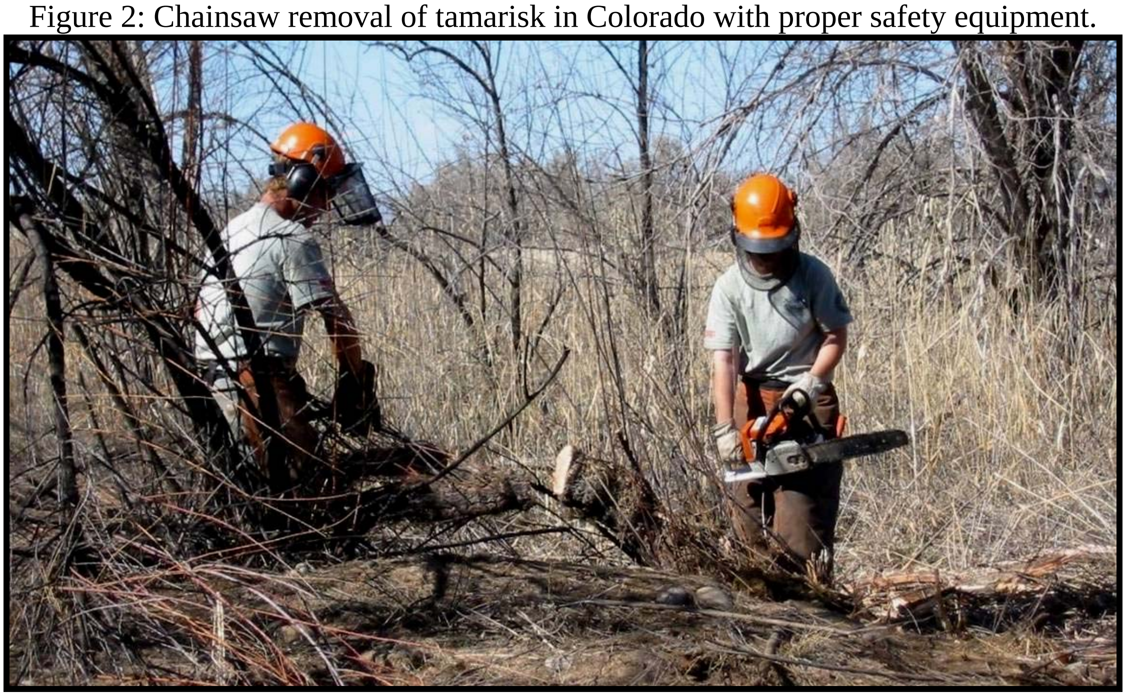
1. Not feasible for large infestations.
2. Not possible above 85^{o} F or in freezing temperatures for triclopyr herbicide
3. May require leaving tamarisk standing in an area for a period of years.

Applicability: When density of infestations are light, the use of a foliar or basal bark spray can be effective using backpack sprayers, horseback sprayers (see Figure 1), or vehicle mounted equipment. Thus, hand herbicide application is appropriate for controlling light tamarisk infestations, especially in areas that are difficult to access such as canyons, washes, irrigation ditches, and steep embankments. This approach is especially appropriate for controlling resprouts and other noxious weed control efforts.

Hand Cutting with Herbicide application

This method is referred to as the “cut-stump” approach in which the tree is cut or scored with chainsaws, handsaws, or axes. Within approximately 15 minutes, a solution of triclopyr systemic herbicide (Garlon 4 ® mixed in vegetable crop oil) must be applied to the cut stump. Cut materials are chipped, piled and burned, or piled for wildlife habitat depending on site specific circumstances. This method of tamarisk removal (see Figures 2 and 4) is probably the most widely used method. This approach requires trained sawyers and/or herbicide applicators.

Figure 2: Chainsaw removal of tamarisk in Colorado with proper safety equipment.



Effectiveness: The cut-stump approach successfully controls tamarisk with a regrowth rate of approximately 15 percent. This regrowth will require a second herbicide treatment. Herbicide sprays are effective regardless of the time of year unless the temperature exceeds 85^o F, at which point the triclopyr herbicide volatizes and can be potentially harmful to workers and surrounding vegetation. If temperatures are anticipated to be above 85^o F other herbicides are required. Freezing conditions may also limit its use.

Costs: Hand work is very expensive, ranging from $1,500 per acre in lightly infested areas to $5,000 per acre in heavily infested areas for initial removal (Tamarisk Coalition 2003). To ensure effective control, resprouts must be treated with foliar and/or basal bark herbicide applications.

Figure 3: Hand Control Cost Algorithm

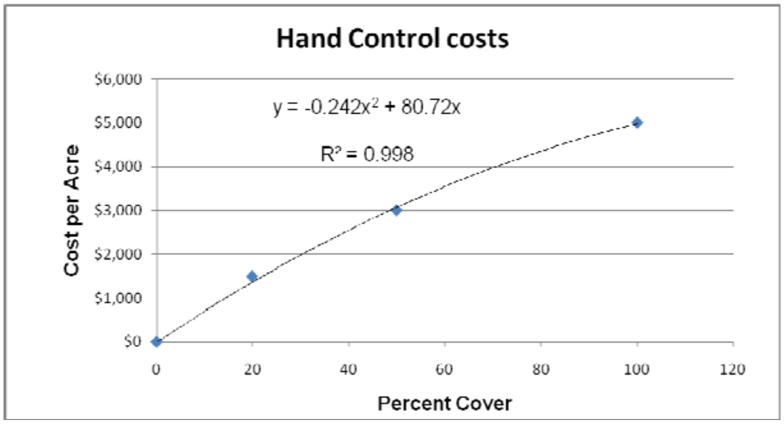


Figure 4: McInnis Canyons Volunteer Project western Colorado using the cut-stump removal technique near Grand Junction, 2007.

Pros of Hand Cutting:

1. Hand cutting effectively removes tamarisk in mixed vegetation without damaging other valuable plants.
2. Hand cutting is appropriate for rough terrain that is not accessible by mechanical equipment.

Cons of Hand Cutting:

1. Cut material must be stacked and burned, chipped, or left in piles for wildlife habitat.
2. Resprouts will require herbicide re-application.

Applicability: Hand clearing tamarisk is appropriate for canyons, washes, irrigation ditches, and along steep river banks which have a high level of access difficulty. For moderate levels of access difficulty, hand removal will be appropriate for some areas of a work site, such as steep slopes. For areas that have a low level of access difficultly, hand control is considered inappropriate because of its high costs.

Hand cutting is considered very appropriate for areas of special concern; areas in close proximity to valuable native vegetation, historic and archeological sites; areas in or around campgrounds; or for projects that involve volunteer support (Figure 4).

<u>Mechanical Removal</u>

Mechanical removal is the use of heavy equipment to physically remove tamarisk. This is accomplished in one of two ways – root crown removal or mechanical cutting with herbicide application to the cut stump. Root crown removal eliminates the need for herbicide.

Root crown removal is the extraction of the root crown by either root plowing and raking or by extraction of the entire plant.

> **Root plowing and raking** Large Caterpillar D-7 or D-8 bulldozers equipped with brush bars are used to remove the above ground vegetation (see Figure 5), root plows to cut the root system below the crown, and root rakes to remove the root crown (Taylor 2003).

Figure 5: Large equipment (Caterpillar D-8) incorporating a deep root rake, Bosque del Apache National Wildlife Refuge, NM. 2007

> This approach is extremely disruptive to the soil, destroys any native plants present, and can support weed viability. It removes vegetation in a manner similar to intense agricultural production preparation. For land managers with access to water rights, and who intend to use agricultural reseeding practices, this approach can work well (e.g. the Bosque del Apache National Wildlife Refuge, NM). This approach is not appropriate for areas with a lack of water rights and a significant presence of native plant species.

Extraction – Extraction is another root crown removal technique which uses a large excavator (such as a CAT 320 or larger) to pluck individual trees from the ground (see Figure 6). This approach has been used in mixed stands of tamarisk, Russian olive, Siberian elm, and native cottonwood throughout New Mexico. This mechanical process completely removes target trees and their root balls from the soil, along with a significant amount of their lateral roots. This approach provides an advantage for projects working to clear ditches and step river banks where other mechanical equipment cannot gain access. It also removes only the target species and does not require herbicide. The rate of removal with an experienced operator is 3 to 8 acres per day. The removed trees are stacked for future mulching, burning, or are left in place (Boss 2006). This approach can result in a significant level of soil disturbance and may require substantial revegetation efforts.

Note: For Russian olive infestations, extraction should only be used for saplings with a trunk diameter less than 3 inches since larger trees can leave behind root fragments that may resprout.

Figure 6: Extraction of tamarisk near Socorro, New Mexico

Mechanical cutting with herbicide application is the mechanical removal of above ground biomass accompanied by herbicide treatment of the cut-stump with triclopyr. This approach is accomplished with either equipment that cuts and mulches the trees or grabs and cuts the trees for removal.

- **Mulching equipment –** Recent work in several parts of Colorado and Utah (see Figure 7) shows that tamarisk can be effectively controlled with specialized equipment to mulch the trees and an herbicide application to the cut stumps. The trees are typically mulched in a six-foot wide path at a rate of 0.25 to 1.5 acres per hour depending on density, terrain, and equipment. The cutting head is either a rotary drum with knife blades or carbide teeth, or a flaying blade that resembles a lawnmower configuration. This latter approach, designed for forest thinning, is somewhat dangerous because the equipment will throw large chunks of wood up to 100 feet; thus, preventing timely herbicide application to the cut stumps. The flaying blades also shred the tree's stump, requiring a large amount of herbicide to achieve effective control. The rotary drum cutting head does not have this safety problem and leaves a relatively cleanly cut stump. The carrier equipment can run on track or rubber tire systems and typically range from 100 to 225 horsepower. 500 horsepower equipment is occasionally suitable for large diameter trees (greater than 12 inches).

Figure 7: 100 HP mulching equipment using a rotary drum cutting head, Grand Junction, CO.

The mulched materials produced can reduce soil disturbance, and provide a good seed bed for native plant recruitment while discouraging establishment of noxious weeds. Tracked mulching equipment causes less soil disturbance because of a lighter footprint than those with wheels. Areas suitable for this approach are wide and somewhat level floodplains or terraces. The distinct advantage of mechanical mulching is that it accomplishes tamarisk control and biomass reduction in one process. Foliar or basal bark herbicide applications will be needed for resprouts.

- **Grab & cut-stump –** Equipment developed for the forest products industry combines a grabbing or holding device that attaches to a tree while a shear or circular saw blade cuts the tree near ground level (see Figure 8). Herbicide is then applied to the cut stump. This equipment is commonly called a "feller buncher" and is produced by several manufactures as a tracked or rubber tired vehicle and can be equipped with a self-leveling capability to work in rough terrain. Recent work in Nebraska has shown this equipment's usefulness in clearing ditches and step stream banks where other mechanical equipment could not gain access (Beyer, 2007). As with extraction equipment, valuable native vegetation can be avoided. Removed trees are stacked for future mulching, burning, or are left in place. Unlike the extraction technology, this approach can be used to remove Russian olive.

Figure 8: Grab & cut-stump equipment being used on 9-Mile Creek, Nebraska, 2004.

Effectiveness: The efficiency of these mechanical tamarisk removal methods is approximately 85 percent. The use of this equipment is principally limited to areas with good to moderate access. Its use would not be suitable for long, steep embankments, canyons, or other remote locations. Those mechanical techniques requiring herbicide applications are effective regardless of the time of year unless the temperature exceeds 85° F, at which point the triclopyr herbicide volatizes and can be potentially harmful to workers and surrounding vegetation. If temperatures are anticipated to be above 85° F other herbicides are required. Freezing conditions may also limit its use.

Costs: Root crown removal using root plow and root rakes costs approximately $800 to $1,000 per acre (Figure 9). Costs for the extraction technique using an excavator range from $150 to $600 per acre (Figure 10). Costs of mulching and applying herbicide to tamarisk (Figure 11) will range from $350 to $1,050 for high capacity equipment (0.5 to 1.5 acres/hr.), and $400 to $1,200 for medium capacity equipment (0.25 to 0.75 acres/hr.). Grab & cut-stump removal ranges from $250 to $800 for cutting, herbicide application, and stacking of materials for later disposal (Figure 12).

Figure 9: Root Plow/Root Rake Cost Algorithm

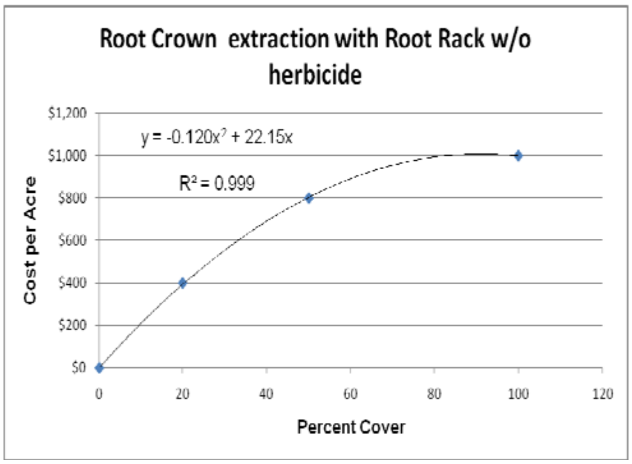


Figure 10: Mechanical Extraction Cost Algorithm

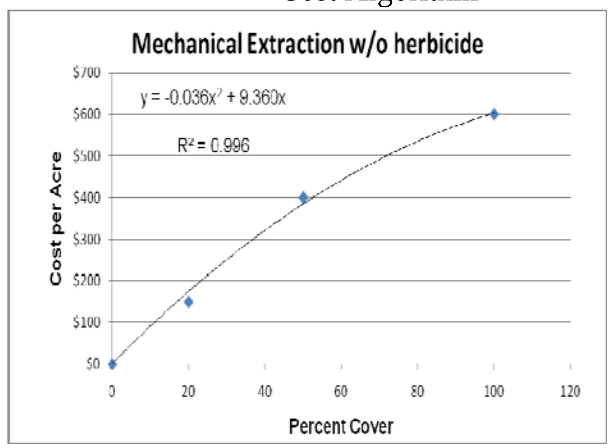


Figure 11: Mechanical Mulching Cost Algorithm

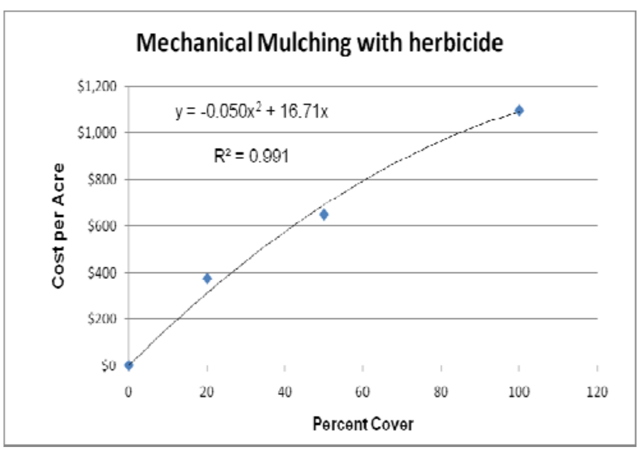
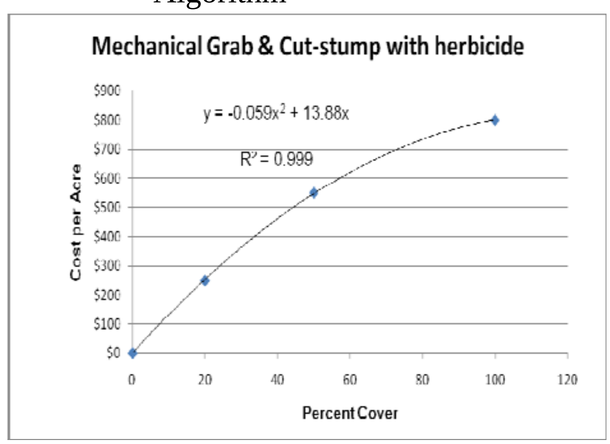


Figure 12 : Grab & Cut-stump Cost Algorithm



Pros of Mechanical Removal Techniques:

1. Extraction and grab & cut-stump equipment can very effectively remove tamarisk in a mixed vegetation stand without killing other valuable plants. Mulching equipment is a little less forgiving, but still effective in mixed stands of natives.

2. Extraction and grab & cut-stump equipment can be used in more difficult terrain and for clearing ditches and river banks. Grab & cut-stump works best on trees greater than 4-inches in diameter.
3. Mulched materials provide a suitable seedbed for revegetation. Care must be taken to prevent re-incorporating viable stems into moist soil, thus avoiding new plant growth. Fall, winter, and early spring are the best times of year for mechanical mulching.
4. Removing root crowns with root rakes greatly disturbs the soil but can benefit revegetation efforts if irrigation water is available.

Cons of Mechanical Removal Techniques:

1. Mulching and root plowing requires relatively level and accessible terrain.
2. Root crown removal using an excavator or root rake creates significant soil disturbance which can promote noxious weed growth and could destabilize embankments.
3. Herbicide re-application will be necessary to control resprouts following initial removal for all of these methods and will increase costs by approximately 20 percent.

Applicability: Root crown extraction works especially well in areas with steep embankments that other mechanical equipment cannot access. It should not be used for Russian olive control. Grab & cut-stump is also best used on steep embankments and is effective for Russian olive. Mulching equipment can be used wherever access is available. Root crown removal using a root rake is inappropriate in areas with limited water rights and significant numbers of native species that would be destroyed.

<u>Aerial Herbicide Application</u>

Aerial herbicide application (see Figure 13) now uses precision agricultural spraying techniques controlled by GPS coordinates and specific flight plans to ensure that herbicide is only delivered to desired locations. Additionally, nozzle design improvements minimize herbicide drift. Herbicide can be delivered by helicopter or fixed wing aircraft. The herbicide typically used is imazapyr (Arsenal ® or Habitat ®) which has been approved for use near water in some southwestern states.

Figure 13: Aerial herbicide application technique being demonstrated with dyed water at 2003 Tamarisk Symposium, Grand Junction, Colorado

Effectiveness: Recent foliar herbicide helicopter applications in New Mexico and Texas have demonstrated a tamarisk kill rate in a range of 85 to 95 percent. Many river corridors have large expanses of tamarisk monocultures and over the past several years large control efforts have taken place. To effectively kill tamarisk, treated trees must be left undisturbed for a minimum of two years for the herbicide to work properly. The rate of application is several hundred acres per day (Hart 2003, Lee 2003).

Costs: Contracted aerial spray application costs have increased in the past five years due to fuel costs for aircraft to a range of $250 to $300 per acre. Due to the high costs associated with helicopter use and mobilization, the minimum control acreage needed to realize these cost rates is approximately 1,000 acres (Lee 2003). Costs per acre increase for smaller acreages. Aerial spray costs do not include the removal of skeleton trees by either fire or mechanical methods, or the revegetation of the areas. This can add significant costs depending on the situation.

Pros of Aerial Herbicide Application:

1. The use of computer aided precision herbicide application allows the helicopter pilot to spray only tamarisk stands and to avoid previously identified native plants. In monotypic stands of tamarisk, such as those found in many parts of the Southwest, this may be an appropriate approach. For areas with a significant mix of native vegetation, this approach is not recommended.

Cons of Aerial Herbicide Application:

1. Aerial herbicide spray is extremely effective in killing tamarisk as well as Russian olive; however, it will also kill most other vegetation, including valuable natives. Some species, such as baccharis and Mesquite, appear to be unharmed; and saltgrass may recover within one year (Tanzy 2004).
3. Some spot herbicide re-application will be necessary.
4. If large, contiguous areas of tamarisk are killed using aerial herbicide application, there may be impacts to wildlife habitat. This is an important consideration when selecting this approach.

Applicability: This approach is recommended for areas with broad monotypic infestations with very limited native vegetation present.

<u>Biological Control</u>

Biological control is the use of specific organisms to control an undesirable organism. For tamarisk, two bio-control agents have been identified – goats (see Figure 14) and a tamarisk leaf beetle (see Figure 15). Both work to control tamarisk by repeatedly defoliating the plant over three to four years.

Goats will feed on tamarisk shrubs if fencing limits other food sources. Typically, a guard dog, herding dog, and goat herder are required. Several private goat herds are available throughout the West but there is limited cost and success information. It is too early to provide good information on the effectiveness, applicability, and pros and cons of using goats as a viable means of controlling tamarisk. A large project is currently underway on the Rio Grande in New Mexico to provide this information.

Figure 14: Goats eating tamarisk leaves and small branches

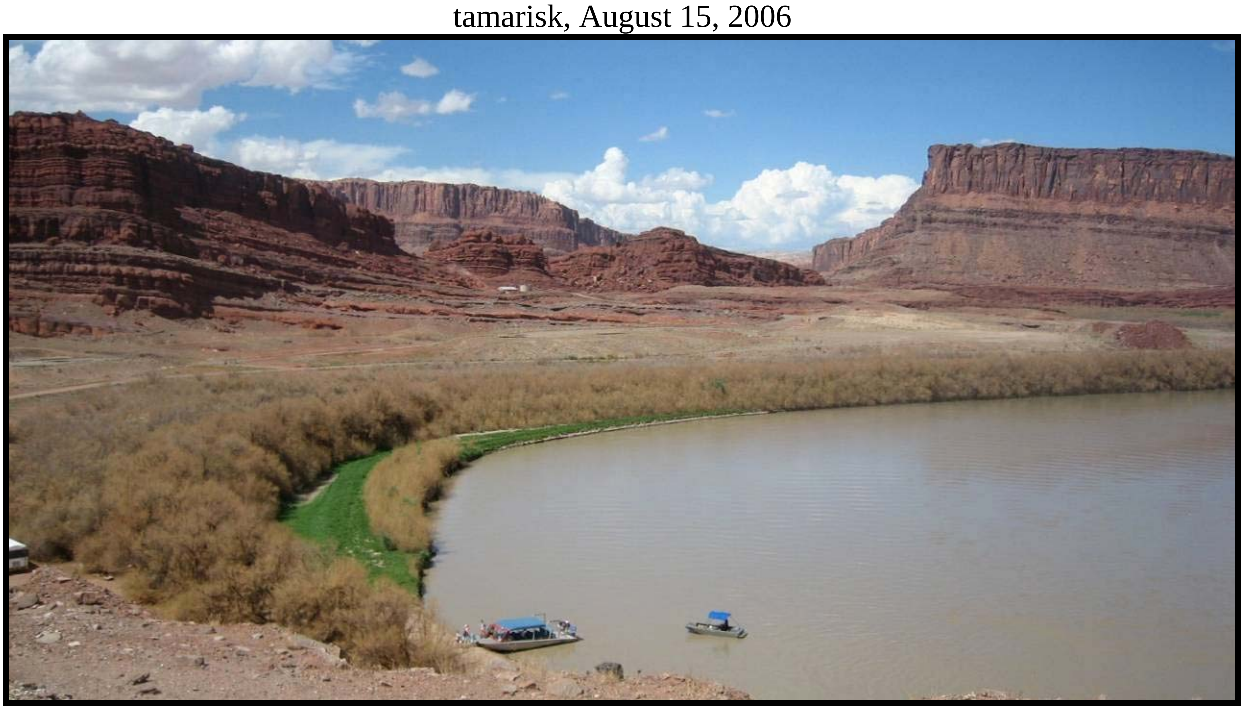
The tamarisk leaf beetle was found during investigations for an insect tamarisk biological control in the 1980s by the U.S. Department of Agriculture (USDA) under the direction of Dr. C. Jack DeLoach. *Diorhabda elongata*, a beetle from Fukang, in Xianjiang Province of NW China, was then tested extensively in quarantine to ensure safety with respect to non-target impacts. Later, different ecotypes of this beetle species were identified in Chilik, Kazakhstan and Posidi, Crete. In 1995, release permits for 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 New Mexico, Arizona, and southern parts of California, Nevada, Utah, and Colorado. Permission for widespread insect bio-control releases was withheld pending further investigations of potential effects on the flycatcher. However, a number of research sites isolated from the southwestern willow flycatcher nesting areas were allowed and research began at these sites in 1996.

Research was conducted at these sites to determine the insect's life cycle, reproductive and dispersal rates; its impacts on tamarisk and surrounding vegetation; and impacts on wildlife (DeLoach et al.2002, Eberts et al. 2001, Lewis et al, 2003). Both the adults and the larvae of the tamarisk beetle feed on foliage, damaging it directly through predation or indirectly by drying out foliage beyond the feeding point. One of the most important findings was that the Fukang and Chilik beetle ecotypes cannot survive south of approximately the 36^0 N parallel (the southern boundary of Utah and Colorado). Summer day lengths south of this latitude are shorter and prompt adult insects to enter winter hibernation too early in the summer months to survive until the following spring. Currently, the Posidi ecotype is being tested for use in this southern range.

Figure 15: Bio-control (*Diorhabda elongata* adult beetle, actual size ~ 3/16 inch) defoliating tamarisk at Pueblo, Colorado during the summer of 2003. No other plants were damaged.

On December 18, 2003, the USDA Animal and Plant Health Inspection Service (APHIS) published its Environmental Assessment (http://www.aphis.usda.gov/ppd/es/ppqdocs.html) outlining its intention for open releases of the tamarisk leaf beetle in 14 western states north of New Mexico and Arizona in 2004. The final approval for these releases was granted in August 2005. Since the 2004 release, the beetles have extensively defoliated hundreds of acres of tamarisk at the Colorado, Nevada, and Wyoming research sites.

Figure 16: Colorado River at Potash mine boat launch area near Moab, Utah showing defoliated tamarisk, August 15, 2006



Controlled test sites in Delta, Utah found that three to five years of sequential defoliation were required to achieve tamarisk mortality of 70 percent; however, it is unknown how many seasons of defoliation will be required to kill tamarisk a given location (Bean, 2007). Three to five years of consistent defoliation appears to be likely.

The most promising characteristic of the tamarisk beetle is that it inflicts no damage to native plant populations (see Figure 17). Preliminary evidence of effectiveness shows great potential. If biological control continues to progress, it could become one of the main mechanisms for tamarisk control and maintenance. If this is the case, the advantages over other approaches will be significant; i.e., limited use of herbicides and a cost effective, long-term solution. Another observation is that native plant species seem to be flourishing as tamarisk are stressed by the beetle, possibly due to increased light penetration to the understory and/or reduced competition for water and nutrients. It should be noted that Russian olive will not be controlled by this biological control agent.

Figure 17: Defoliated tamarisk and undamaged native vegetation along the Colorado River west of Moab, Utah; August 15, 2006.

Effectiveness: At the Nevada, Utah, and Colorado research sites, tamarisk plants died after three to five successive years of defoliation by *Diorhabda elongata*. It is not absolutely certain whether the insects, once established in a given area, will be more effective at killing large numbers of tamarisk or at acting as a control mechanism to prevent further spread. However, all indications show that they will perform both tasks to some degree. Studies continue at various universities and the USDA to determine the effectiveness of this insect in greater detail.

Combining the beetle with other Integrated Pest Management methods will probably be necessary to achieve the best tamarisk control.

Costs: Goat biocontrol in western Kansas, supported by the Natural Resources Conservation Service in the Arkansas River watershed, cost about $0.50 per head per day over a three year period. Based on this work in a moderately infested area, overall costs were approximately $1,100 per acre (Flowers 2005).

Based on preliminary estimates, the use of *Diorhabda elongata* as a control technique could reduce the expenses of any herbicide and/or mechanical approach to a fraction of its original costs (less than $10/acre). If *Diorhabda elongata* are used in a maintenance role following other methods of tamarisk removal, the costs would not be reduced. An additional $20/acre per year is included to this initial cost estimate to provide a five year monitoring program. Monitoring will be instrumental in determining the rate of beetle spread, rate of defoliation, rate of tamarisk mortality, native plant recruitment, other weed infestations to be addressed, biomass accumulation, and biomass removal approaches. Once the trees are killed, skeleton trees will require removal in moderately to heavily infested areas and revegetation must take place. These costs must also be considered. Removal of dead trees can be accomplished using fire or mechanical mulching equipment.

Pros of Biological Control:

1. Biological control can reduce costs and herbicide use.
2. *Diorhabda elongata* research has been more extensive than any other bio-control agent previously investigated. All indications show that there is no threat to other plant species.

Cons of Biological Control:

1. However, risk is inherent when a new species is introduced. This risk, although minimal, must be considered against the potential benefits.
2. A significant short-term impact of bio-control is the tamarisk vegetation browning that residents may consider unsightly. In response to this reaction education is important for gaining public support.
3. The use of goats as a bio-control agent is expensive, especially as a maintenance technique. Ongoing research in New Mexico should provide important effectiveness information in the near future.
4. Removal of dead trees and revegetation may be required.

Applicability: The use of the bio-control agent *Diorhabda elongata* is applicable to all levels of infestation, is not constrained by access conditions, and can be used in both riparian and floodplain terrace zones.

Dead Tamarisk and Russian olive Biomass Reduction

Removing tamarisk tree skeletons may be important after mechanical root crown removal, biological control, or foliar herbicide control if densities are moderate to heavy. Biomass reduction under these conditions assists planned revegetation efforts, restores aesthetic values, and reduces the wildfire potential of decomposing litter in moderately to highly infested areas. Standing dead biomass in lightly infested areas does not significantly impede natural or planned revegetation, affect aesthetics, or support high wildfire potential. Therefore, such stands could be allowed to naturally decompose. The removal of live tamarisk biomass in sensitive areas is also important due to high wildfire potential.

Dead trees can be removed by mechanical mulching equipment or fire (see Figures 18 - 20).

Figure 18: Large mobile chipper at work on 9-Mile Creek, Nebraska, 2004.

Mechanical mulching control, by its nature manages woody plant material by transforming it into mulch. However, if a large amount of biomass is mechanically mulched and piled, the thickness of the layer produced may actually impede or prevent revegetation. Conversely, properly mulched areas can support native plant growth while limiting weeds.

Figure 19: Fire break in Scott M. Matheson Wetlands Preserve, Moab, Utah using mechanical removal and cut stump approach, June 2004. See Figure 7 for equipment used.

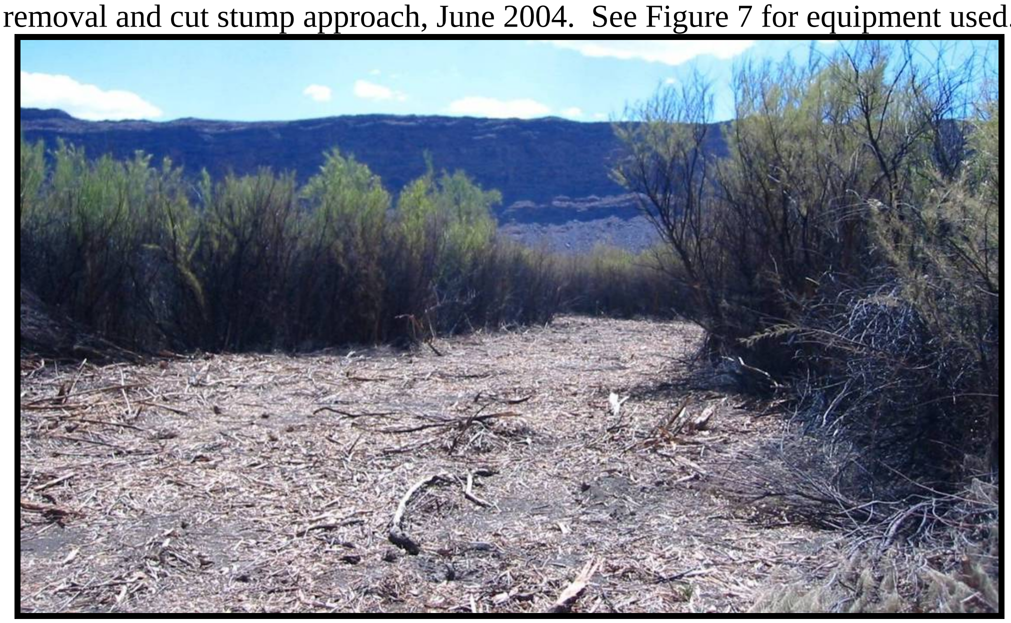


Figure 20: Controlled fire used for dead tamarisk at the Bosque del Apache NWR, NM 2004

Reducing biomass with fire requires adequate fire breaks in sensitive riparian areas to safely burn invasive plants. In addition, air quality may be a concern for large-scale burns as carbon sequestered in the tamarisk will be released instantly. In contrast, mulched or standing dead plants release carbon at a rate that is partially offset by the carbon sequestering growth of other plants. Fire is an option that must be carefully coordinated with local land managers and county air quality personnel. As shown in Figure 20, fire breaks and professional fire fighting personnel are essential because of the intensity of tamarisk fires.

Costs: Biomass removal costs could range from $50 to $150 per acre for controlled burns and from $400 to $800 per acre for mechanical mulching or for mobile chipping units, depending on the density of infestation (Figure 21). If root balls also need to be mulched from either the root plowing or extraction processes, these costs increase by approximately 50 percent (Figure 22). For moderate infestations, fire would probably not be used unless the dead materials are stacked in areas that would not impact native plants. For lightly infested areas, it may not be necessary to remove dead tamarisk trees. In these areas, existing native vegetation is likely to reoccupy the area and should not be hindered by limited numbers of skeleton trees.

Figure 21: Biomass Reduction – Above Ground materials Cost Algorithm

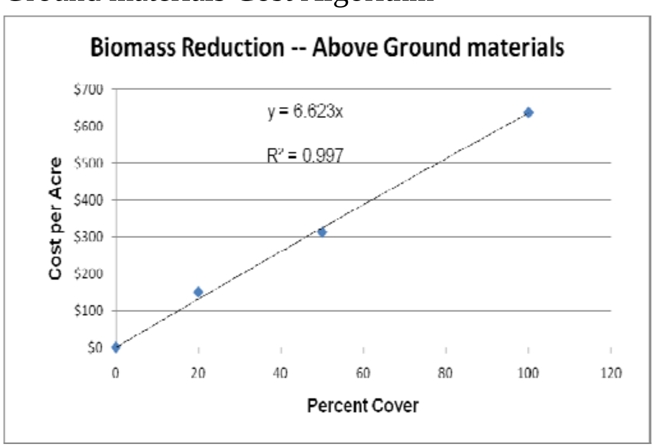
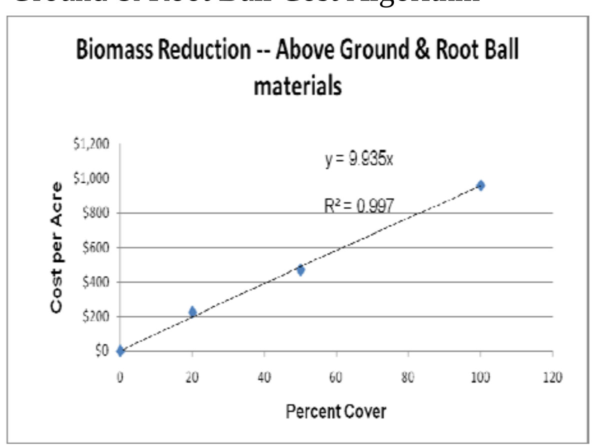


Figure 22: Biomass Reduction – Above Ground & Root Ball Cost Algorithm



Revegetation

One of the most positive aspects of tamarisk and Russian olive control discovered during site surveys is the abundance of native plants present in the understory. River systems in the West typically support an intermixed community of native species that may include:

- Wetland species such as hard-stem bulrush (*Schoenoplectus acutus*), alkali bulrush (*Scirpus maritimus*), three-square bulrush (*Scirpus americanus*), swordleaf rush (*Juncus ensifolius*), baltic rush (*Juncus balticus*), creeping spikerush (*Eleocharis fallax*), beaked sedge (*Carex rostrata*), Nebraska sedge (*Carex nebrascensis*), inland saltgrass (*Distichlis spicata*), alkali sacaton (*Sporobolus airoides*), and scratchgrass (*Muhlenbergia asperifolia*).

- Riparian species such as sanbar or coyote willow (*Salix exigual*), whiplash willow (*Salix lucida*), Fremont cottonwood (*Populus fremontii*), three-leaf sumac or skunkbush (*Rhus trilobata*), inland saltgrass (*Distichlis spicata*), hard-stem bulrush (*Schoenoplectus acutus*), alkali bulrush (*Scirpus maritimus*), three-square bulrush (*Scirpus americanus*), swordleaf rush (*Juncus ensifolius*), baltic rush (*Juncus balticus*), creeping spikerush (*Eleocharis fallax*), alkali sacaton (*Sporobolus airoides*), beaked sedge (*Carex rostrata*), Nebraska sedge (*Carex nebrascensis*), New Mexico privet (*Forestiera neomexicana*), false willow (*Baccharis* spp.), basin wildrye (*Leymus cinereus*), Canada wildrye (*Elymus* canadensis), thichspike wheatgrass (*Elymus lanceolatus*), Lewis flax (*Linum lewisii*), scratchgrass (*Muhlenbergia asperifolia*), silver buffaloberry (*Shepherdia argentea*), Wood's rose (*Rosa woodsii*), and Golden currant (*Ribes aureum*).

- Upland species such as black greasewood (*Sarcobatus vermiculatus*), basin big sagebrush (*Artemisia tridentata* Nutt. spp. *Tridentata*), screwbean mesquite (*Prosopis pubescens*), galleta (*Pleuraphis*), western wheatgrass (*Pascopyrum smithii*), snakeweed (*Gutierrezia* Lag.), scarlet globemallow (*Sphaeralcea coccinea*), bottlebrush squirreltail (*Elymus elymoides*), blue grama (*Bouteloua gracilis*), red threeawn (*Aristida*), needle and thread (*Hesperostipa comata*), shadscale (*Atriplex confertifolia*), fourwing saltbush (*Atriplex canescens*), douglas rabbitbrush (*Chrysothamnus viscidiflorus*), rubber rabbitbrush (*Ericameria nauseosa*), indian ricegrass (*Achnatherum hymenoides*), sand dropseed (*Sporobolus cryptandrus*), as well as numerous forbs.

Depending on individual site characteristics, the abundance of these species may provide natural recruitment or may require more active revegetation (e.g., pole plantings or seeding) following tamarisk or Russian olive control activities. The native plants listed above are good candidates for active revegetation. Site specific characteristics will be identified during the design phase to determine which plants should be used in a given location.

Other invasive herbaceous plants that may be encountered during tamarisk control projects and that should be addressed include the following: Russian olive (*Elaeagnus angustifolia*), Canada thistle (*Cirsium arvense*), cheatgrass (*Bromus tectorum*), diffuse knapweed (*Centaurea diffusa*), hoary cress or whitetop (*Cardaria draba*), kochia (*Kochia scoparia*), leafy spurge (*Euphorbia esula.*), perennial pepperweed (*Lepidium latifolium*), purple loosestrife (*Lythrum salicaria*), and

Russian knapweed (*Acroptilon repens*) (CHIP 2007). It is important to remember that removing other weed species may be the most important revegetation treatment performed. Annual weeds, while a concern, generally do not preclude native plant establishment.

Revegetation considerations constrain removal options. To minimize costs and water resources associated with revegetation, removal should account for the ecological potential of each site. When there are many natives interspersed within tamarisk and Russian olive stands invasive removal must be executed in a manner that protects native seed sources for natural revegetation. Manual control, root extraction, grab & cut-stump, and mechanical mulching are methods capable of sparing interspersed natives, even 1-inch caliper saplings.

The least intensive/disruptive removal and revegetation treatments are preferred when possible. This means avoiding the extensive costs associated with irrigated projects – and relying on the natural regenerative capabilities of most areas. Revegetation may not be necessary where native trees, shrubs, grasses and forbs are present within 25 to 50 feet of removal centers, or on historical sand bars or islands that were frequently inundated in both riparian and floodplain terrace settings (Hart 2003). Where precipitation values are higher such as occurs in the Plains states and a native seed bank exists very little revegetation efforts may be required. For broader areas, active revegetation may be required. Currently, monitoring activities on the Rio Grande and Pecos River in New Mexico are attempting to determine what circumstances require active revegetation.

In broad areas of infestation it is important to pace removal efforts to allow, and encourage, natural native plant regeneration. In such large, dense stands of tamarisk it may be advisable to create vegetative islands and paths within the tamarisk to help speed native regeneration process and to provide fire breaks (Figure 19).

In some higher value areas, such as wildlife habitats or high profile/high human use areas, pole plantings, shrub and tubing plantings, and seedings may be desirable to aid in the regeneration process (Figure 23). However, when these kinds of revegetation projects are appropriate, land managers should understand that they can be very expensive (often exceeding $10,000 per acre) and require long-term maintenance commitments.

Figure 23: Revegetation at the Matheson Wetlands Preserve in Moab, Utah 2006

Successful revegetation is a complex undertaking. As a result, implementing revegetation projects following the removal of invasive species is an inherently site-specific task; however, there are numerous resources available that can aid the planning process. NRCS's Los Lunas Plant Material Center in New Mexico recently compiled an excellent reference guide for riparian restoration/revegetation (USDA 2007). Also, the University of Denver is currently preparing a "Best Management Practices" handbook for revegetation available in 2008. Other resources include:

- **Society for Ecological Restoration**
  Summary: This site provides a reading list for ecological restoration practices, links for many example projects and other resources and support. www.ser.org/reading_resources.asp

- **Riparian Restoration in the Southwest – Species Selection, Propagation, Planting Methods, and Case Studies**
  Summary: This document identifies the natural processes and managed activities that cause the degradation of riparian lands and provides general guidelines to restore the natural system. It describes methods of selecting appropriate revegetation species, processes for producing riparian plants, details planting techniques, and provides case studies of past projects. www.nm.nrcs.usda.gov/programs/pmc/symposium/nmpmcsy03852.pdf

- **Stream Corridor Restoration: Principles, Processes, and Practices**
  Summary: This large and detailed document has a three-tiered design. The first section provides background information describing the basics of stream corridor systems. The second section describes the steps to produce an effective restoration plan. The final section provides guidelines to implement restoration projects.
  www.nrcs.usda.gov/technical/stream_restoration/

- **Guidelines for Planning Riparian Restoration in the Southwest**
  Summary: This restoration guide is intended to address considerations for developing riparian restoration projects and to provide a number of responses or solutions to potential problems. www.nm.nrcs.usda.gov/news/publications/riparian.pdf

- **Guidelines for Planting Longstem Transplants for Riparian Restoration in the Southwest: Deep Planting**
  Summary: This site describes a good technique for revegetating a riparian site that lacks overbank flooding and has a deep water table.
  www.nm.nrcs.usda.gov/news/publications/deep-planting.pdf

- **The Pole Cutting Solution**
  Summary: Guidelines for planting dormant pole cuttings in riparian areas of the Southwest. Planting dormant pole cuttings has proven to be a successful technique for establishing many riparian trees and shrub species. www.nm.nrcs.usda.gov/news/publications/polecutting.pdf

- **Plant Technology Fact Sheet: Tall-Pots**
  Summary: This fact sheet describes the use of tall-pots to establish plants in areas lacking sufficient soil moisture or irrigation availability to revegetate using more traditional means.

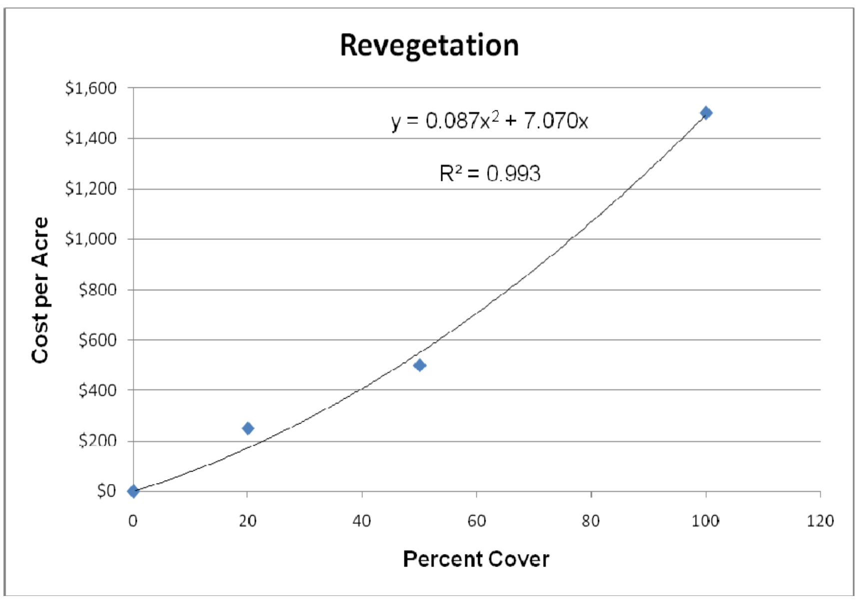
A discussion of the structure, usefulness, benefits, and limitations of the tall-pot revegetation method is included. www.nm.nrcs.usda.gov/programs/pmc/factsheets/tall-pot.pdf

Costs: Generally, the range of costs for revegetation reflects the ability to water an area either naturally or through irrigation practices. Irrigation is only appropriate in areas where water rights and topography would allow its use and where precipitation alone is insufficient. Where water is available through precipitation or is easily accessible by irrigation, revegetation costs are lower. Higher costs reflect the need for extensive irrigation where feasible and appropriate. Revegetation costs include labor, seed, plant materials, wildlife control, fertilizer, equipment rental, weed control, and water.

Revegetation costs have a direct relationship to density and width of infestation. For narrow widths less than 50 feet, natural revegetation may occur but some minor to moderate costs related to soil disturbance and weed control may be required. Costs will shift upward for broader widths (greater than 50 feet) because less native plant seed will be available for reintroduction. The general ranges of costs are: $0 costs where revegetation will be entirely natural, $50 to $250 for minor reseeding, $250 to $500 for moderate revegetation efforts, and $500 to $1,500 for major revegetation activities (Lair 2005, Taylor 1999, Tamarisk Coalition 2003). If soil conditions are poor (e.g., high salinity) cost can be significantly higher.

Successful revegetation requires a level of post-planting commitment to ensure plants are well established and capable of persisting in the future. This includes monitoring plant survival, replacing failed plants, and weed control. These elements typically occur over a three year period following initial control and revegetation activities. Costs for this post-planting component of restoration are a function of infestation levels and control technologies. Light infestations are calculated at 20% of the control and revegetation combined costs. For moderate infestations the post-planting costs are estimated at 25%, while heavy infestations are estimated at 30%.

Figure 24: Revegetation Cost Algorithm



The cost algorithm presented in Figure 24 represents an average cost for riparian revegetation in the 17 western and plains states and is extremely sensitive to availability of water, width of infestation, soil characteristics, native plant seed bank, depth to ground water, etc. For these reasons <u>costs could vary by an order of magnitude up or down</u> from those presented in this figure.

Combined Costs of Technologies for Control, Biomass Reduction, and Revegetation

Table 1 provides a list of technologies, based on the discussions above, and the situations in which they are appropriate. The table displays cost algorithm equations for each control technology and the associated restoration technologies that, together, comprise a complete restoration effort; i.e., resprout treatment, biomass reduction, revegetation, monitoring plant survival, plant replacement, and weed control. The cost equations have been updated to reflect costs in the year 2008 and are presented as cost versus density curves in Figures 25 to 31. ***Although these cost equations are appropriate for planning purposes, it is important to identify site specific conditions and restoration approaches for each project area to develop refined cost estimates.***

Planning, design, monitoring and maintenance costs during the initial 10 years of the restoration effort are not typically considered in developing cost estimates for tamarisk control. However, these components are critical to understand and should be included in the budgeting processes. These elements are a function of the degree of infestation. Light infestations are calculated at 20% of the control, biomass reduction, and revegetation combined costs. Moderate infestation costs are estimated at 25% of these same cost components, while heavy infestations have an estimated cost of 30%.

A generalized time distribution of costs would place control and biomass reduction costs in Year-1, and follow-up controls for resprouts in Year-2 and Year-3. Revegetation will begin shortly after control and biomass reduction is completed in Year-1and continue through Year-2. Monitoring plant survival, plant replacement, and weed control will be on-going in Years 3, 4, and 5. For biological control the time extends 3 additional years. During the remaining years of a 10 year restoration effort, efforts are mostly devoted to monitoring and maintenance. Each site should be assessed to determine time requirements for complete restoration efforts.

Definitions of acronyms used in the table are:

[1] Accessibility definitions:

Highly difficult to access (A^H) – Those areas that can only be accessed by foot, horse, or boat; such as, steep embankments, canyons, and roadless areas.

Moderately difficult to access (A^M) – Those areas that have a mix of level terrain where heavy equipment could be used and steep embankments that would require hand labor or specialized equipment to control tamarisk. A good example is a typical river channel where the side slope adjacent to the river is too steep for equipment use, and the broad, adjoining flood plain that has good access potential.

Low difficulty of access (A^L) – Those areas that are relatively level, near an existing road, and where heavy equipment can be used throughout.

[2] **Density definitions:** Tamarisk density is defined as its canopy cover

Light density (D^L) = 20 percent canopy cover and less

Moderate density (D^M) = 50 percent canopy cover but greater than 20 percent

Heavy density (D^H) = greater than 50 percent canopy cover.

[3] **Biomass Reduction assumptions:** When needed, mulching equipment will be used to reduce biomass three-fourths of the time. The remaining quarter of biomass reduction will be accomplished by controlled burns.

Table 1: Cost Equations for Tamarisk and Russian olive Control Technologies and associated Biomass Reduction and Revegetation

Control Approach	Applicability of Control Approach: Access[1]	Applicability of Control Approach: Density[2]	Biomass Reduction Approach [3]	Revegetation Approach	COMBINED Cost (y) Equations based on Density (x) as Percent Cover (Year 2007 $)
Hand cut-stump with herbicide Figure 25	A^M, A^H	D^L	Not required	Minimal – natural revegetation anticipated	$y = -0.068x^2+100.9x$ Tamarisk and/or Russian olive
		D^M, D^H	Mulching as primary with fire as secondary	Revegetation required because of soil disturbance	
Mechanical extraction w/o herbicide Figure 26	A^L, A^M	D^L	Not required	Some minor reseeding required because of soil disturbance	$y = 0.125x^2+26.10x$ Tamarisk only NOT appropriate for Russian olive
		D^M, D^H	Mulching as primary with fire as secondary	Revegetation required because of soil disturbance	
Mechanical root plowing & raking Figure 27	A^M, A^H	D^M, D^H	Fire	Major revegetation required because of soil disturbance is extreme.	$y = -0.001x^2+35.18x$ Tamarisk and/or Russian olive
Mechanical mulching with herbicide Figure 28	A^L, A^M	D^L	Not required	Some minor reseeding required because of soil disturbance	$y = 0.074x^2+28.13x$ Tamarisk and/or Russian olive
		D^M, D^H	Mulching as primary with fire as secondary	Revegetation required because of soil disturbance	
Mechanical grab & cut-stump with herbicide Figure 29	A^L, A^M	D^L	Not required	Some minor reseeding required because of soil disturbance	$y = 0.086x^2+29.34x$ Tamarisk and/or Russian olive
		D^M, D^H	Mulching as primary with fire secondary	Revegetation required because of soil disturbance	
Aerial herbicide application Figure 30	A^L, A^M, A^H	D^H	Mulching as primary with fire secondary	Significant revegetation required. Limited native plant availability under conditions associated with aerial herbicide application	$y = 0.102x^2+21.43x$ Tamarisk and/or Russian olive
Biological control with *Diorhabda elongata* Figure 31	A^L, A^M, A^H	D^L	Not required	Minimal – natural revegetation anticipated	$y = 0.146x^2+13.54x +110$ Available only for Tamarisk
		D^M, D^H	Mulching as primary with fire as secondary	Revegetation required because of soil disturbance	

Figure 25: COMBINED Cost equation for Hand Control with herbicide
($y = -0.068x^2+100.9x$)

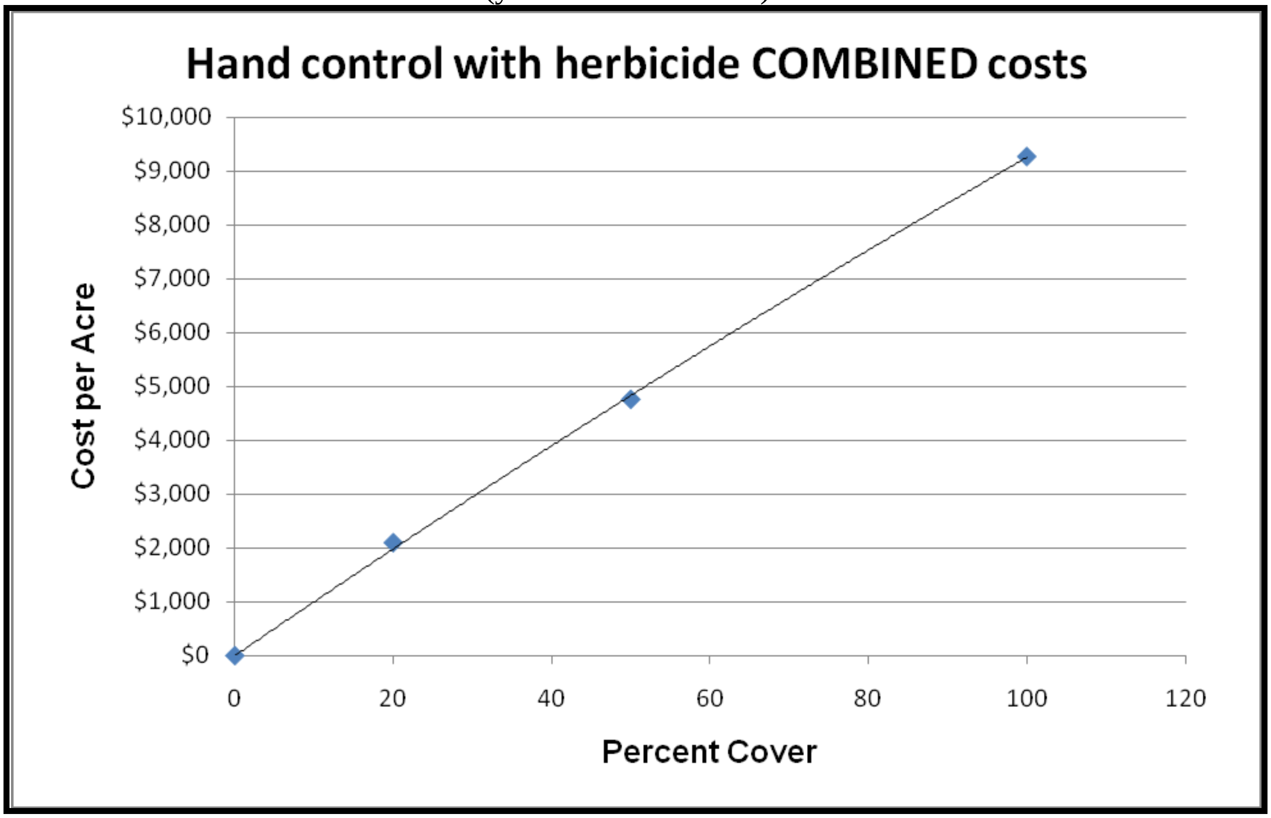


Figure 26: COMBINED Cost equation for Mechanical Extraction without herbicide
($y = 0.125x^2+26.10x$)

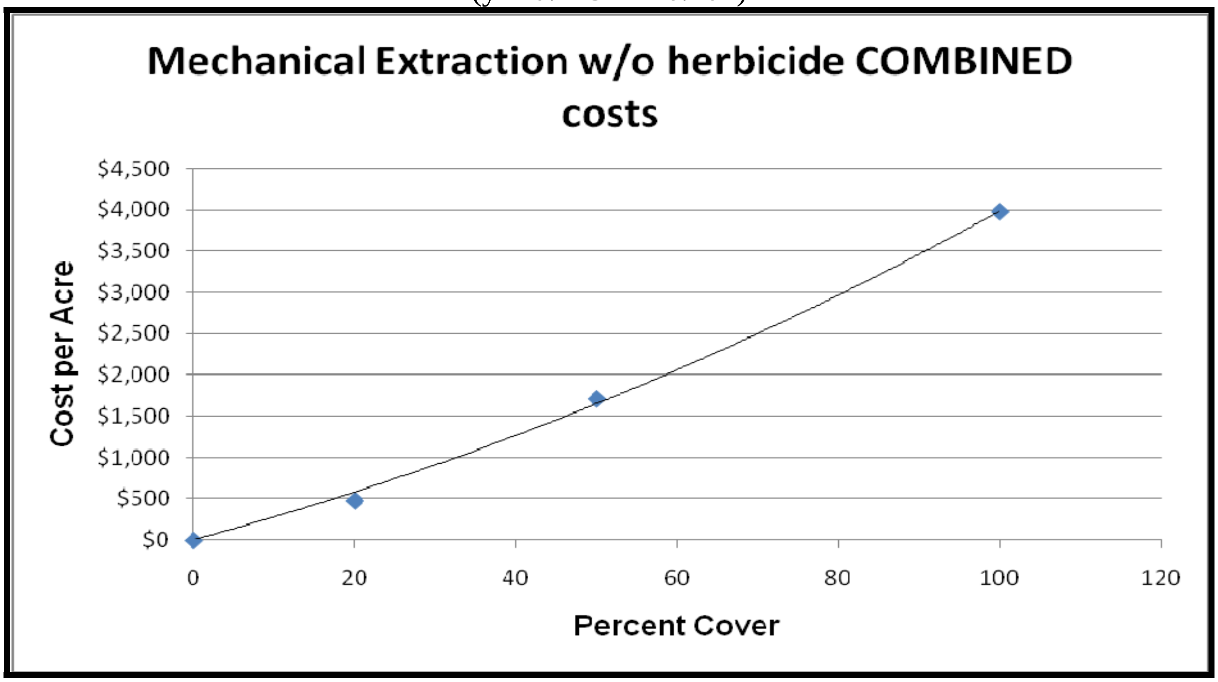


Figure 27: COMBINED Cost equation for Mechanical Root Plow & Rack Rake w/o herbicide ($y = -0.001x^2+35.18x$)

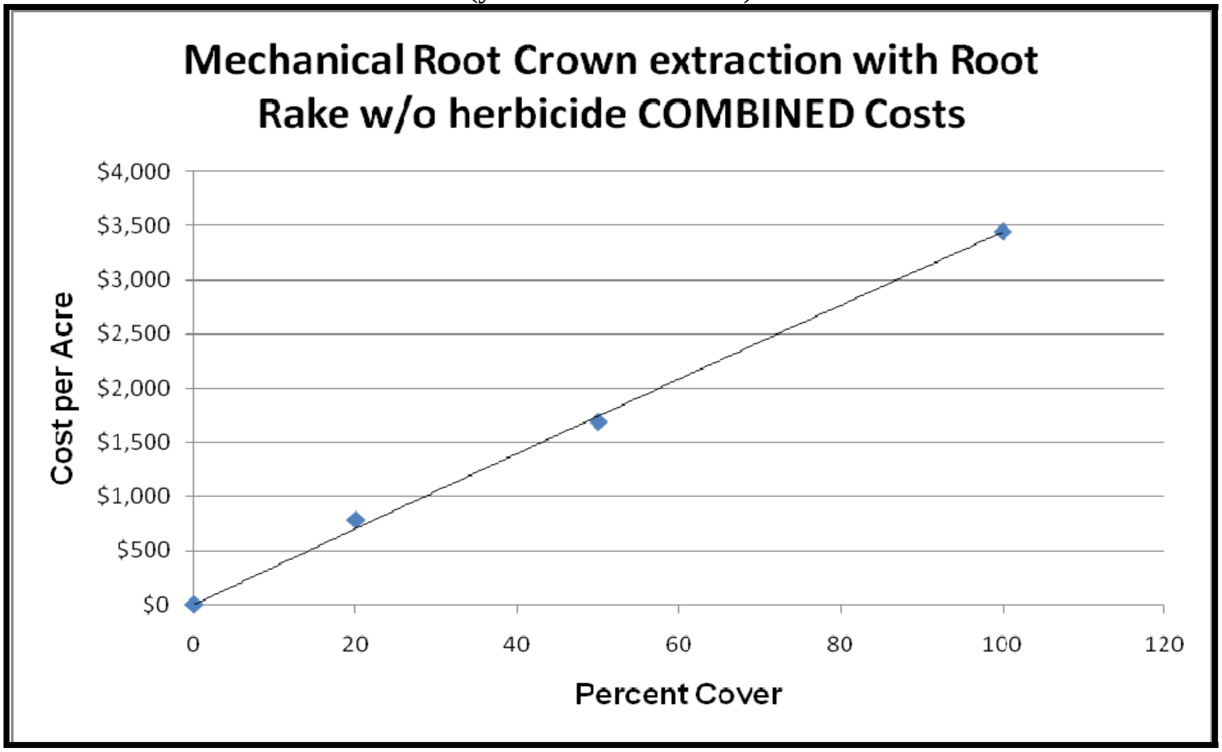


Figure 28: COMBINED Cost equation for Mechanical Mulching with herbicide ($y = 0.074x^2+28.13x$)

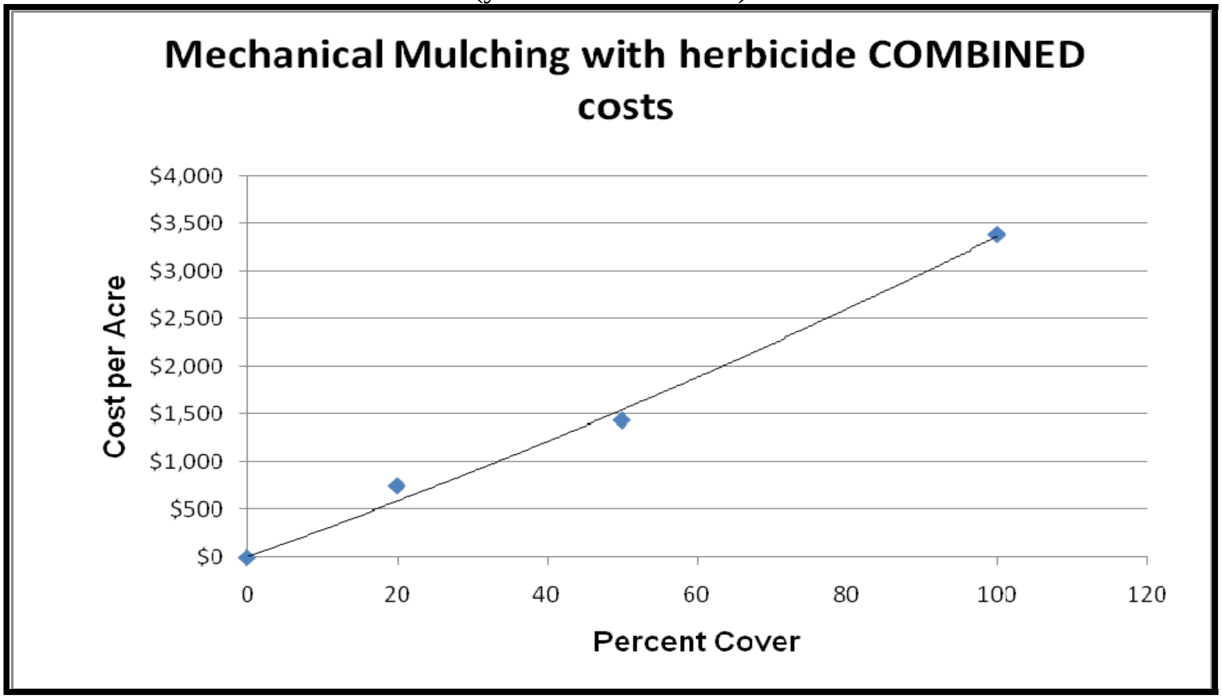


Figure 29: COMBINED Cost equation for Mechanical Grab & Cut-stump with herbicide ($y = 0.086x^2+29.34x$)

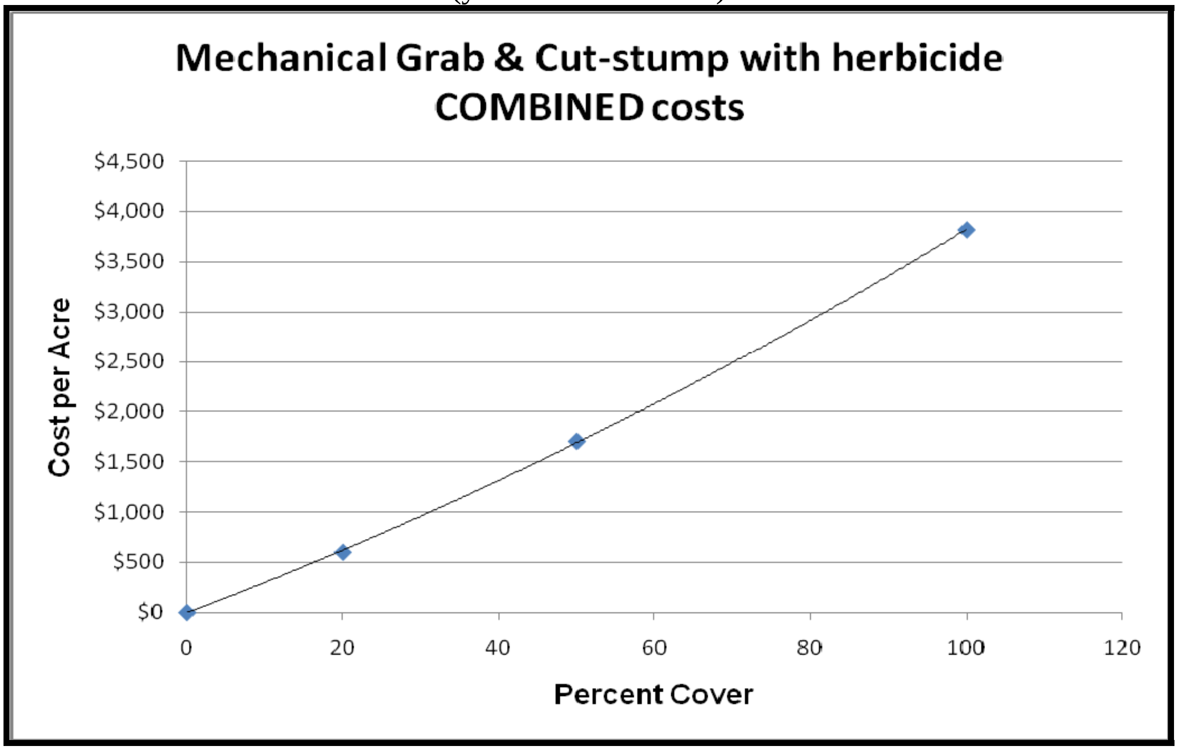


Figure 30: COMBINED Cost equation for Control by Aerial Herbicide Application ($y = 0.102x^2+21.43x$)

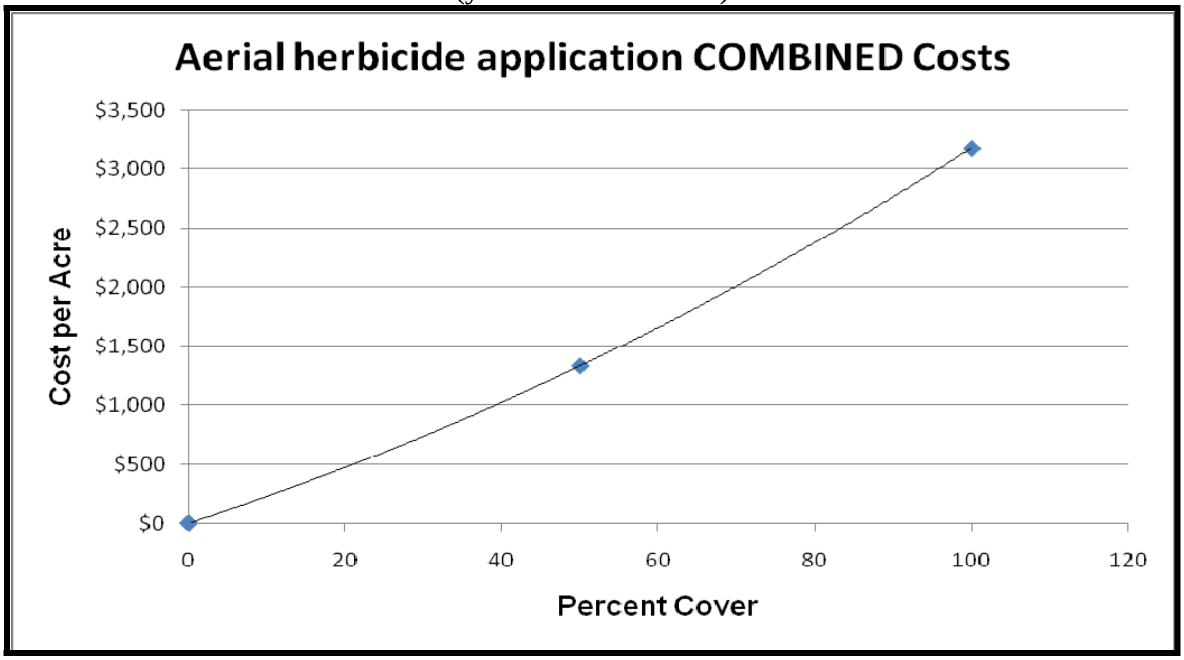
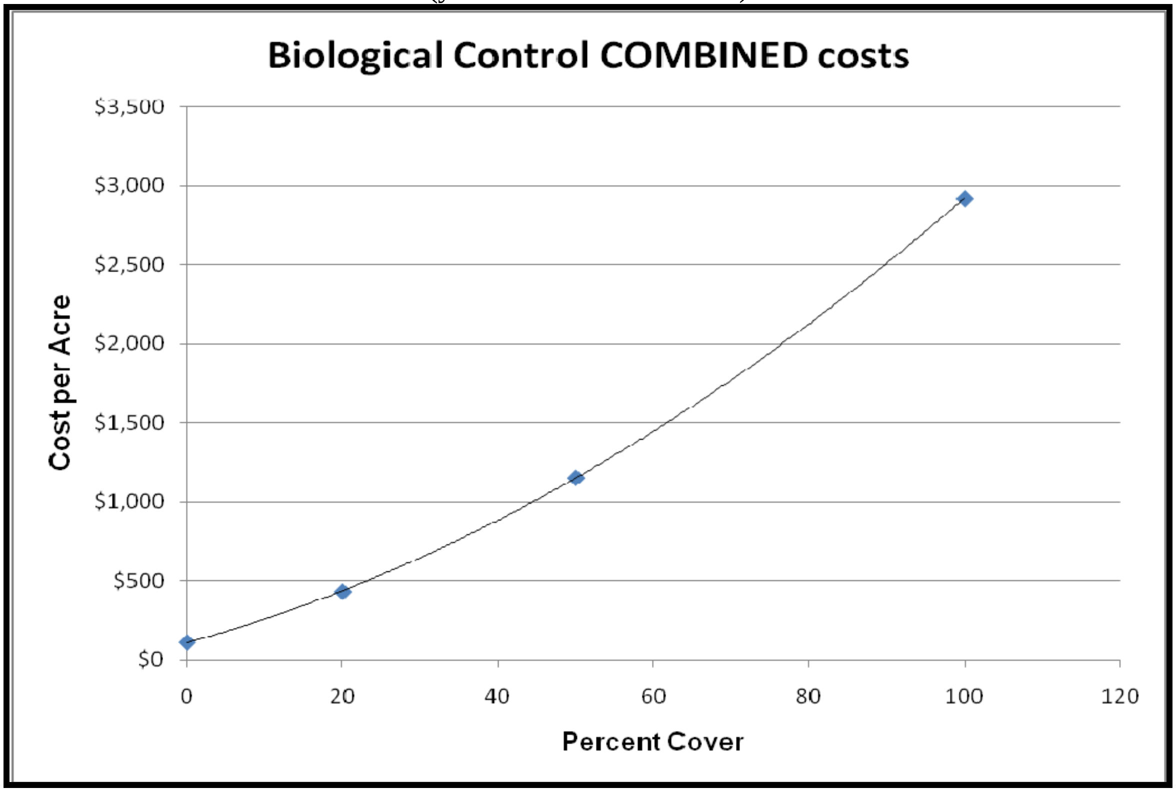


Figure 31: COMBINED Cost equation for Biolgical Control
($y = 0.146x^2+13.54x +110$)



References

Bean, D. Colorado Department of Agriculture Palisade Insectary. Personal communications, October, 2007.

Beyer, D, "Nine Mile Creek & Russian Olive Restoration" North Platte Nebraska Natural Resources District, presentation at the 2007 Tamarisk Symposium, grand Junction, CO, October 25, 2007.

Boss Reclamation LLC. Personal Communications, June, 2006.

"Colorado Headwaters Invasives Partnership (CHIP): Woody Invasive Species Management Plan." July 2007. Prepared jointly by Colorado River Water Conservation District, The Nature Conservancy, and the Tamarisk Coalition.

DeLoach, J., R Carruthers, J. Lovich, T. Dudley, and S. Smith, 2002. "Ecological Interactions in the Biological Control of Saltcedar (*Tamarix spp.*) in the United States: Toward a New Understanding" – Revised.

Eberts, Debra, L.White, S. Broderick. 2001. Biological Control of Saltcedar at Pueblo, Colorado: Summary of Research and Insect, Vegetation, and Wildlife Monitoring, 1997-2001. USBR Technical Memorandum No. 8220-01-17.

Flowers, Thomas. Natural Resources Conservation Service presentation for Kansas 10-Year Strategic Planning meeting, Garden City Kansas, February 24, 2005.

Hart, C.R., Texas A&M, Personal communication on the Pecos River Ecosystem Project. March 2003.

Lair, Ken. Bureau of Reclamation. Personal communications, November, 2005.

Lee, B., Northstar Helicopter. Personal communication, August 2003.

Lewis, Phil A., C.J. DeLoach, J.C. Herr, T.L. Dudley, R.I. Carruthers. 2003. Assessment of risk to native *Frankenia* shrubs from an Asian leaf beetle, *Diorhabda elongata deserticola* (Coleoptera: Chrysomelidae), introduced for biological control of saltcedars (*Tamarix* spp.) in the western United States. Biological Control 27:148-166.

Tamarisk Coalition, 2003. “Cost Estimates for Medium and High Capacity Tamarisk Clearing and Mulching Equipment for Different Levels of Infestation”, 2003.

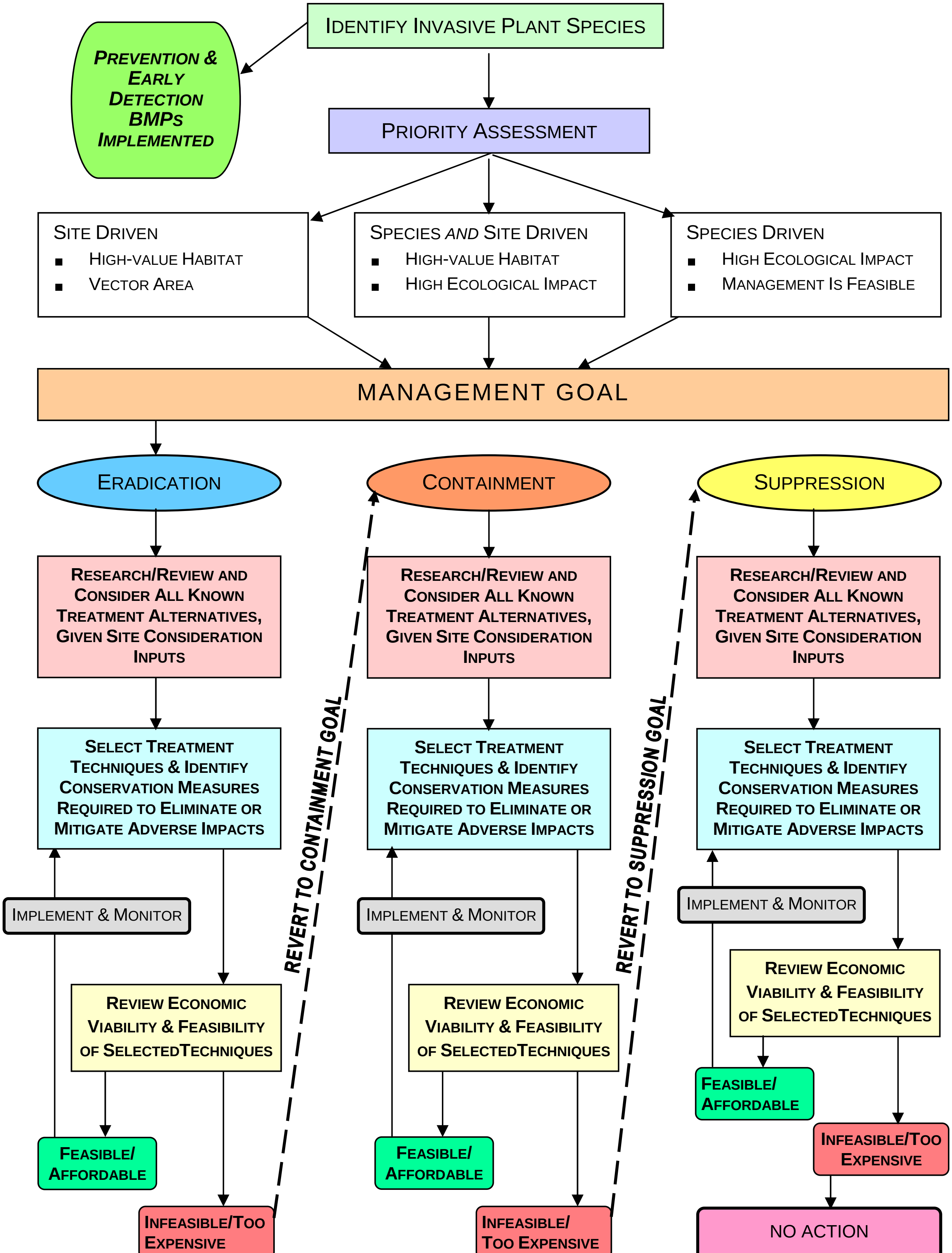
Tanzy, B., US Bureau of Reclamation. Personal communications, December 2004.

Taylor, J. P., U.S. Fish and Wildlife Service, Bosque del Apache National Wildlife Refuge, NM. Personal communications, April 2003.

Taylor, J. P, D. B. Wester, and L.M. Smith. 1999. Soil disturbance, flood management, and riparian woody plant establishment in the Rio Grande floodplain. *Wetlands* 19:372-382.

USDA, September 2007. “A Guide for Planning Riparian Treatments in New Mexico”, NRCS Los Lunas Plant Materials Center.

Attachment A
Integrated Pest Management Decision Matrix



Users Guide to
Integrated Pest Management Decision Matrix

Some sections adapted from Morse et al. (2004) and City of Boulder (2003).

IDENTIFY INVASIVE PLANT SPECIES

Invasive Species Identification Screening Questions
The following three screening questions are used to separate those species that are relatively innocuous from those that are invasive or have a high potential to become invasive and should be considered before investing substantial effort in assessing a species:

1. Is this species currently established outside cultivation as a non-native *(i.e.,* as a direct or indirect result of human activity) somewhere within the region of interest?
   - **Yes.** Proceed to screening question 2 below.
   - **No.** STOP. The Invasive Species Priority Assessment is not applicable to this species.

   Note: If this question is not readily answered, assessment of the species may either be deferred, or provisionally begun while further information on the species' status in the region is sought.

2. Is this species known or suspected to be present in conservation areas or other native species habitats somewhere within the region of interest?
   - **Yes.** Proceed to screening question 3 below.
   - **No.** STOP. This species is an insignificant threat to natural biodiversity in the region of interest.

3. Is this species known to meet criteria for invasive as defined by NPS as "an aggressive exotic plant that is known to displace native plant species in otherwise intact native vegetation communities"?
   - **Yes.** Proceed to the priority assessment and begin implementation of prevention and early detection Best Management Practices for all species identified as invasive.
   - **No.** STOP. This species is not considered invasive as defined by NPS or it needs more supporting data of its invasive nature.

PRIORITY ASSESSMENT

Taking Management Action – Priority or Not?
Because it is infeasible to control every invasive plant that occurs in a park or monument, it makes sense to focus management efforts on those species that have or *could* have the greatest impact to monument resources and to the highest value at-risk habitats.

Invasive plants are run through a ranking process that helps managers sort and prioritize invasive species and affected habitats based on several aspects of the species' relative invasiveness, relative importance, or quality of affected habitat:

1. Ecological Impact (risk to regional biodiversity, adverse impacts to soil resources, capacity to alter forage availability, etc.)
2. Current Distribution and Abundance
3. Trend in Distribution and Abundance
4. Control Feasibility / Management Difficulty

Based on consideration of all these factors, a person with good taxonomic skills and knowledge of local or regional ecology can use a ranking process to set priorities for resource allocation.

Initiating on-the-ground management action will then be determined by evaluating inventory data in combination with local priorities that can be site (location) and/or species driven. If the site and/or species of focus is identified as a priority for the monument, management action is deemed necessary. The decision process that follows will consider the potential actions to be taken to address a particular species on a particular site for a particular time period. The proposed project and site will be reviewed by the monument's NEPA interdisciplinary team staff annually to determine if the project 1) falls under the parameters of the monument-wide IPM plan and EA and 2) if sensitive natural or cultural resources or the human environment could be adversely impacted as a result of management (or continuing management).

MANAGEMENT GOAL

Determining Management Goals

Once a particular species and/or site is chosen and management action is deemed necessary, a desired outcome, or management goal, must be established. Goals for treatment of a species on a particular site will be determined by circumstances and practical realities reflected in the IPM Decision Matrix, illustrated in Figure 2 in the main document. Alternatives include:

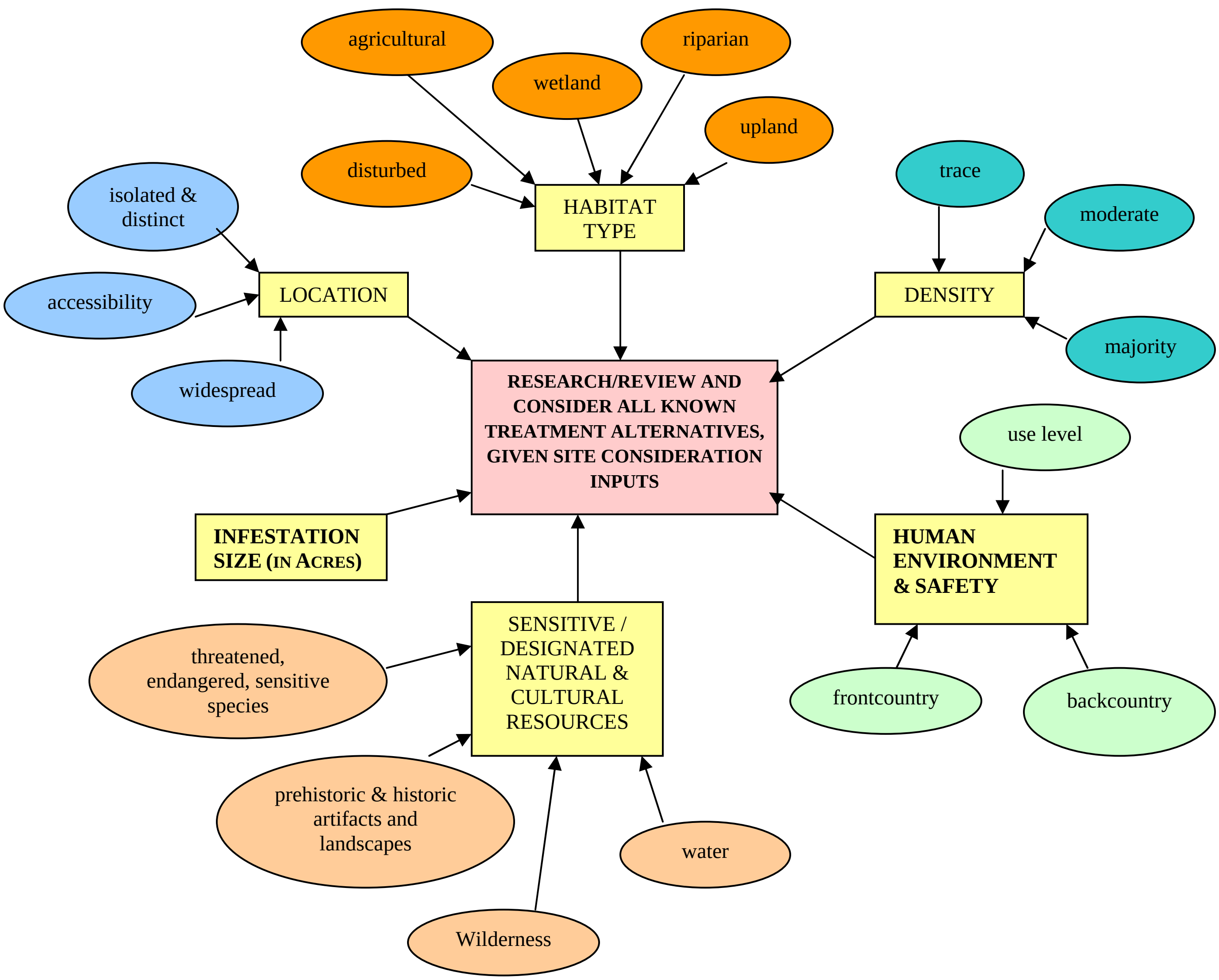
1. **Eradication**: reducing the reproductive success of a noxious weed species or specified noxious weed population in largely uninfested regions to zero and eliminating the species or population within a specified period of time. Once all specified weed populations are eliminated or prevented from reproducing, intensive efforts continue until the existing seed bank is exhausted; may be legally mandated or desirable for a new invader or new site.
2. **Containment:** maintaining an intensively managed buffer zone that separates infested regions, where suppression activities prevail, from largely uninfested regions where eradication activities prevail.
3. **Suppression:** reducing the vigor of noxious weed populations within an infested region, decreasing the propensity of noxious weed species to spread to surrounding lands, and mitigating the negative effects of noxious weed populations on infested lands. This strategy inflicts some damage on the pest with the goal of lessening the rate of spread, but does not usually mean reducing the current infestation. As better techniques are made available or environmental circumstances render a species more susceptible to containment or eradication strategies, areas identified for suppression may be upgraded to containment or eradication status.

In order to appropriately establish a management goal, invasive species problems should always be run through the decision process beginning with the highest goal of eradication. Whether or not the decision-maker(s) reverts to containment or suppression goals depends on local information known about the species itself and the site it occupies. For example, one may assume that a widespread species (such as tamarisk) would automatically be given a management goal of suppression. From a monument-wide perspective, this may be the appropriate management goal. However, if the problem site in the monument is a high-value habitat and tamarisk is present only in small and isolated infestations, then a more appropriate goal may be containment or even eradication *at the particular site,* depending on other site considerations.

RESEARCH/REVIEW AND CONSIDER ALL KNOWN TREATMENT ALTERNATIVES, GIVEN SITE CONSIDERATION INPUTS

On-the-ground Management: Review of Available Techniques

Tool and treatment technique(s) selection will depend on many different variables, called site considerations. These considerations include biotic and abiotic resources and factors that, if not considered properly, are likely to adversely affect the success of the treatment and restoration strategy. In the interest of space, this step is not fully diagramed in the matrix but is detailed on the following page. Please note that the site considerations below represent only a sample of all possible variables.



SELECT TREATMENT TECHNIQUES & IDENTIFY CONSERVATION MEASURES REQUIRED TO ELIMINATE OR MITIGATE ADVERSE IMPACTS

Treatment Selection and On-the-ground Implementation
Once appropriate treatment techniques and tools are identified, resulting impacts caused by their use also need to be identified. All tools and techniques will have some type of consequence, whether intentional or unintended, benefical or adverse, direct or indirect. At this point in the decision-making process, steps need to be identified to reduce or eliminate any potential adverse impact to the site considerations identified above. These steps can be conservation measures that are practices incorporated into the planning phase of the treatment to *prevent* potential adverse impacts (e.g.weed control treatments will occur pre-emergence or post-seed set for the threatened orchid, *Spiranthes diluvialis*) or they can be mitigation measures that fix or correct an impact after action has occurred (e.g. native trees will be planted after tamarisk is removed in riparian areas).

REVIEW ECONOMIC VIABILITY & FEASIBILITY OF SELECTED TECHNIQUES **FEASIBLE/ AFFORDABLE**

If the selected treatment techniques and conservation / mitigation measures are affordable, effective, and practical then the treatment plan is approved for implementation.

IMPLEMENT & MONITOR

At a minimum, implementation of any treatment plan will include informal documentation (monitoring) of its effectiveness. More formal monitoring will occur in cases where specific biological or ecological thresholds are identified prior to treatment implementation.

REVIEW ECONOMIC VIABILITY & FEASIBILITY OF SELECTED TECHNIQUES **INFEASIBLE/TOO EXPENSIVE**

If the treatment or conservation / mitigation measures selected are NOT affordable, effective, and practical then the treatment plan cannot be approved as it stands and the decision-maker(s) needs to revert to lesser goals of containment or suppression, as indicated in Figure 2.

NO ACTION

There may be cases when all known treatments and conservation / mitigation practices are still not affordable, effective, or practical and a determination of "No Action" must be made. This is not necessarily a decision to not address the problem at all (a "live with it" decision), rather, it is an acknowledgement that the problem may need to be monitored further and re-evaluated at a later date when more data or new control technologies/strategies become available or if changes in environmental circumstances render the problem more easily addressed using available techniques and strategies.

Appendix G

Templates and Protocols – General

For the purposes of this Plan the term *template* defines what actions should be taken, and the term *protocol* defines how the actions could be performed. The templates and protocols are intended as suggested guidance and criteria for decision making while carrying out the activities associated with various aspects of tamarisk and Russian olive control and biomass reduction, revegetation, monitoring, and long-term management. Thus, the intent is to ensure that selected approaches are effective and efficient, and decisions are well documented. They do not include technical details required for carrying out each specific action. As this watershed program matures, these templates and protocols should be continuously updated to improve the efficiency and effectiveness of actions. ***The intent of these templates and protocols is to raise the awareness of issues that might be important to be considered and not to be overly burdensome to develop an appropriate approach.*** In many cases, most of this data can be developed extremely quickly and some topics will not be applicable depending on the specifics of the project. It is suggested in both the control and revegetation sections that several alternative methods be analyzed. The reason for this approach is to ensure that a full range of options are assessed.

Control and Biomass Reduction Templates and Protocols

The control of invasive species such as tamarisk and Russian olive requires an overall approach that looks at the long-term objective as the central component for selecting an appropriate control strategy. For the Colorado River watershed, this objective is the *return of riparian areas to healthy productive states.* This objective may include the reduction in wildfire potential, increased habitat diversity, and controlling the spread of non-native plant species. To reach this objective requires that each site-specific project define the full range of actions that are necessary to accomplish this objective, including their costs and their impacts. This includes the control technology, restoration efforts, and maintenance requirements. Thus, the templates and protocols developed for control have an interactive relationship with the revegetation, and long-term maintenance sections. Specific technologies for control are presented in some detail in the supporting document *Options for Non-native Phreatophyte Management* (see Appendix E).

Table 1: Control and Biomass Reduction Templates and Protocols

Templates	Protocols
1. Identify the historic and existing setting – This baseline and historic information is essential in order to identify the reasonable approach(s) for control and will provide a point from which to compare and measure future changes.	Gather the following information: o Does the project adhere to the State and watershed plans and their priorities? o Terrain type o Land ownership o Adjacent land use o Size and shape of parcel identified for control o Type of existing and historic vegetative stand including density and diversity

<table>
<tr><th>Templates</th><th>Protocols</th></tr>
<tr><td></td><td>Susceptibility to erosion
Hydrologic integrity, floodplain connectivity, water table depth, and availability of irrigation water or periodic flood waters
Soil characteristics especially texture, depth, and salinity
Threatened or endangered species habitat and other species of concern
Local landowner attitudes and desires
State, local, and community attitudes and desires
Other legal and physical considerations/constraints</td></tr>
<tr><td>2. Identify the objective for each site – This information is critical so that all parties understand and accept the desired end condition.</td><td>Determine the objective that is acceptable by each landowner and the respective control technique(s) to use in series with revegetation efforts. Landowners may have different land use objectives for the restoration of infested lands. These land uses typically could include pasture land, crop land, wildlife habitat, recreational, cultural, and/or aesthetic uses.</td></tr>
<tr><td>3. Identify control alternatives – At least three alternatives should be considered as well as the “No Action” alternative.</td><td>Select appropriate alternatives based on the existing setting and objectives for each site.
Hand labor using chainsaws with herbicide applied to the cut stump
Hand applied herbicide to basal bark
Foliar herbicide application:
Spraying from the ground
Spraying with helicopters or fixed wing aircraft.
Mechanic removal:
Root plow
Extraction
Mulching followed by cut stump herbicide application
Roller chopping followed by cut stump herbicide application
Biological control
Goats
Chinese leaf beetle</td></tr>
<tr><td>4. Identify alternatives for dead vegetation management – Each control alternative must be linked to at least one alternative for handling the dead vegetative mass.</td><td>Select alternatives for the dead vegetation management:
Stack and burn
Burn in place
Mulch in place
Mulch in discrete areas
Remove from site for disposal
Utilize as a resource such as fuel, commercial commodity, or to support sustainable local businesses that generate a value-added product
Leave in place; i.e., no further action required</td></tr>
<tr><td></td><td></td></tr>
</table>

Templates	Protocols
5. Identify alternatives for revegetation – The success of revegetation efforts may be aided or hampered by the alternative selected for control; thus it is critical that revegetation be considered when selecting the control option.	Select specific revegetation alternatives as described in detail in the "Revegetation Templates and Protocols" section.
6. Identify necessary maintenance – Depending on the control and revegetation alternatives selected, maintenance costs and efforts can be significantly different.	Identify a preliminary understanding of the maintenance that may be required over a period of several years: o Monitoring the success of control and revegetation measures o Performing resprout treatment o Reestablishing desired vegetation o Irrigating, only if necessary, to maintain vegetation until self supporting
7. Develop cost estimates and schedule for each alternative – This will include the complete set of anticipated costs and their associated schedules to meet the objective of returning a riparian area to a healthy productive state.	Develop estimates of costs, schedules, and impacts for the following activities: o Control o Dead vegetation management o Revegetation o Landowner monitoring and maintenance o Administration
8. Develop impacts associated with each alternative	Quantify the potential impacts associated with each fully developed alternative for the following: o Community and landowner support o Re-infestation from adjacent un-controlled sources o Other noxious weeds or other undesirable plant infestations o Increase in water availability and water quality based on the establishment of the desired vegetative state o Wildlife habitat o Biodiversity o Herbicide use, both short-term and long-term impacts o Increase in sediment loads to rivers and streams and other erosion impacts o Local employment and business potential o Fire and its consequential impacts o Long-term value for the watershed and the State
9. Develop mitigation plans for negative impacts – Where negative impacts will result because of some action, it is important to know what action can be taken to mitigate these impacts.	Include mitigations measures and their costs in the development of control alternatives. Examples might include: o Erosion protection o Smaller demonstration plots to establish refined approaches for new technologies o Tours of restored sites to increase public understanding

Templates	Protocols
10. Compare each combined alternative and select the preferred control approach	Determine the preferred approach based on costs and impacts associated with the full range of activities related to each control alternative.
11. Negotiate contracts with landowners	Obtain contracts with landowners that provide written confirmation on the specific control approach(s) selected, land area that is to be controlled, anticipated outcome of control, dead vegetation management, revegetation approach, and monitoring and maintenance requirements. State any specific mitigation measures required, identify cost share and responsibility, provide an anticipated schedule, and identify method for resolving complaints. Coordinate Request for Proposal process with the landowner and establish responsibilities for contract supervision, training, monitoring, etc.
12. Provide education and public outreach	Provide education and public outreach efforts. These may include: o Public notification on the specifics of the control project; such as method, dates, participation, etc. o Development and dissemination of valuable insights derived from project experiences to the public. o Signage explaining the stage of control/revegetation. o Tours of sites in various stages of control and revegetation. o Annual landowner training through CSU Cooperative Extension and/or NRCS o Historic photo record of existing setting before, during, and after control and revegetation.

Revegetation
Templates and Protocols

For the purposes of this document, *revegetation* refers to the restoration of vegetation to a site. This is not confined to native vegetation and may occur naturally through regeneration or through induced means. Costs for non-native phreatophyte control, revegetation, and long-term maintenance can often be quite high, and specific treatment areas should be evaluated and prioritized based on revegetation potential.

Please note that templates 1, 2, 6, and 7 and their associated protocols are very similar to those identified for control actions.

Table 2: Revegetation Templates and Protocols

Templates	Protocols
1. Identify the historic and existing setting – This baseline and historic information is essential in order to identify the reasonable approach(s) for revegetation and rehabilitation and will provide a point from which to compare and measure future changes.	Gather the following information: o Terrain type o Land ownership o Adjacent land use o Size and shape of parcel to be revegetated o Type of existing and historic vegetative stand including density and diversity o Susceptibility to erosion o Hydrologic integrity, floodplain connectivity, water table depth, and availability of irrigation water or periodic flood waters o Soil characteristics especially texture, depth, and salinity o Threatened or endangered species habitat and other species of concern o Local landowner attitudes and desires o State, local, and Tribal community attitudes and desires
2. Identify the objective for each site – This information is critical so that all parties understand and accept the desired end condition.	Determine the objective that is acceptable by each landowner and the respective revegetation technique(s) to use in series with control efforts. Landowners may have different objectives for the use of rehabilitated lands. These typically could include pasture land, crop land, wildlife habitat, recreational, cultural, and/or aesthetic values.
3. Identify revegetation alternatives and impacts – At least two alternatives should be considered as well as the "No Action" alternative. Criteria for review would include costs, environmental impacts, acceptability, effectiveness, as well as others that may be appropriate.	Select appropriate alternatives based on the existing setting and objectives for each site. o Natural revegetation o Irrigation and seeding o Flooding with native seed dispersal o Pole plantings of cottonwood and willows o Nursery stock plantings o Use of livestock to facilitate seeding establishment

Templates	Protocols
4. Develop a preliminary revegetation plan	Produce a preliminary revegetation plan using information developed in the baseline survey and the landowner's desires consistent with express State limitations on expenditures of rehabilitation funds. This would include costs, timing, and long-term maintenance requirements. The plan would also define responsibilities for cost share, work efforts, and expected outcomes.
5. Identify the post-control plant inventory and adjust revegetation plan accordingly	After a suitable rest period following control efforts, perform an inventory of available plant resources that are acting as seed sources adjacent to and within the control area. Refine the revegetation and rehabilitation plan based on this knowledge. Seek advice, as appropriate, from CSU Cooperative Extension, NRCS, and other specialists.
6. Negotiate contracts with landowners	Obtain contracts with landowners that describe the proposed revegetation and rehabilitation measures that are anticipated and any monitoring and maintenance requirements. This includes schedules, any mitigation measures required (e.g., erosion control), cost share responsibility, and method for resolving complaints if they arise.
7. Provide education and public outreach	Provide education and public outreach efforts which may include: o Development and dissemination of valuable insights derived from project experiences to the public. o Signage explaining the revegetation/reclamation efforts. o Tours of sites in various stages of revegetation. o Annual landowner training through CSU Cooperative Extension and/or NRCS Historic photo records of existing setting before, during, and after control and revegetation.
8. Use adaptive management techniques	Demonstrate flexibility in revising revegetation practices to improve efficiency and effectiveness based on valuable insights derived from project experiences.

Monitoring
Templates and Protocols

For watershed and remediation activities, “monitoring” is the act of observing changes that are occurring with, or without, remediation actions. The purpose of monitoring is to provide information for making informed decisions on the initiation, continuation, modification, or termination of specific remediation activities or programs; and most importantly to assess whether or not objectives are met. Two monitoring regimes are important to the understanding of changes within an ecosystem – large-scale monitoring and small-scale monitoring.

Large-scale monitoring is essential for policy makers and the public to evaluate the potential impacts of remediation on the watershed’s water resources, vegetation, wildlife habitat, biodiversity, economic health, society, and culture – these are essential considerations for determining what level of funding should be committed to the control efforts by the state and/or federal agencies. “However, most impacts (e.g., increased fire frequency, declines in water availability or native plant and animal populations, and soil erosion) are caused by a complex array of factors, only one of which is non-native phreatophytes. Accurately determining the relative contribution of these infestations to a particular impact parameter may be difficult. In addition, these invasive species may have impacts that have not been identified yet and/or may become quantifiable only after long periods.” [1]

Small-scale monitoring provides useful information on the effectiveness of control and remediation activities to allow modifications, if necessary, to achieve the remediation goals. This is the essence of adaptive management.

Large-scale Monitoring – The approach for monitoring large-scale changes to the environment includes a number of well-developed methods. These include:

- Using appropriate techniques that best achieve the objectives of monitoring to ensure that monitoring approaches are efficient, economical, and relatively easy to implement and maintain.
- Adopting monitoring protocols agreed to by State, federal, and local governments so that monitoring data from disparate projects is compatible and easily stored in a single database.
- Providing information that can eventually be incorporated into a centralized database for storing compatible monitoring data from remediation projects across the State.

Small-scale Monitoring – Monitoring at the landowner level is needed primarily for adaptive management purposes to assure compliance with funding agreements, to identify maintenance

[1] National Invasive Species Council, *Draft Guidelines for Ranking Invasive Species Projects in Natural Areas*, August 2004.

needs, and to document ecological response to controls and remediation actions. In general, small-scale monitoring criteria should include simple and inexpensive monitoring techniques based on the needs of the landowner's management objectives.

The monitoring protocols identified are for future projects and cannot necessarily be applied retroactively to past projects. They are intended to be simple and straightforward. Basically, they are intended to provide an understanding of the baseline condition, the success of controls, the success of revegetation, and any necessary modifications to improve success. Much of this can be accomplished through fixed photo points and paced transects. CSU Cooperative Extension, and/or NRCS are good sources for providing training and assistance in any of these areas that are beyond the capabilities of individual landowners.

The determination of what parameters to measure and how they will be measured is critical so that the attainment of objectives can be properly evaluated. "Both quantitative (e.g., percent reduction in water lost to evapotranspiration), and qualitative (e.g., visitor satisfaction at a riparian area) assessments may be used. Data concerning the impacts of various actions (e.g., control operations) should also be collected, evaluated, and used to guide the adaptive management of invasive species." [2] As such, templates and protocols are presented in the following tables for large-scale and small-scale monitoring levels.

These large-scale and small-scale monitoring protocols are only guidelines to help identify information that is typically important to collect and should not be considered as absolutes. Additionally, there may be additional parameters that a project manager must evaluate, and these protocols should not be viewed as a hindrance to do so. It is also clear that many of these protocols overlap and will support different monitoring objectives.

It is important to note that monitoring in all places for all components would be extremely expensive and that much of the large-scale efforts are really research actions. Thus, scientific knowledge must be used to define monitoring requirements that match best with the monitoring objective and that the researchers at Colorado's universities and through federal agencies are in the best position to perform this type of monitoring activity.

Table 3: Large-scale level monitoring templates and protocols

Templates	Protocols
1. Water Quantity -- What is the baseline situation and the changes in water quantity that the watershed is experiencing from non-native phreatophytes and what changes to the water inventory are occurring due to control and remediation actions?	Note: For the purposes of this protocol the identification of long-term potential changes to water quantity resulting from replacing non-native phreatophytes with desired vegetation requires an understanding of the extent and type of infestation, and the water usage of both the non-native phreatophytes and the desired vegetation that would replace it. Actual changes in water quantity are determined from stream flow and groundwater measurements over time. These later changes may take years or even decades to determine. Thus, the importance of monitoring to determine both potential as well as actual water quantity changes.

[2] National Invasive Species Council, *Draft Guidelines for Ranking Invasive Species Projects in Natural Areas*, August 2004.

Templates	Protocols
2. Water Quality – What is the baseline situation and the impacts to water quality in the watershed from non-native phreatophytes and what changes are occurring due to control and remediation actions?	Measure appropriate surface and groundwater parameters that will allow direct comparison with published results
3. Wildlife Habitat and Biodiversity – What is the baseline situation and the impacts to wildlife habitat and biodiversity in the watershed from non-native phreatophytes and what changes are occurring due to control and remediation actions?	Measure appropriate aquatic and terrestrial habitat parameters that are consistent with published data from the Colorado Division of Wildlife and the U.S. Fish and Wildlife Service.
4. Soils – What is the baseline situation and the impacts to soils from non-native phreatophytes and what changes are occurring due to control and remediation actions?	A. Salinity B. Soil moisture C. Erodability D. pH
5. Economic -- What is the baseline situation and the impacts to the watershed's economy from non-native phreatophytes and what changes are occurring due to control and remediation actions?	Measure the economic impact of the cost of control and rehabilitation versus economic impacts to water, wildlife habitat, endangered species, etc.

Table 4: Small-scale monitoring templates and protocols

Templates	Protocols
1. How effective are the control measures?	Provide a photo history of pre-control and the post-control situation.
2. To what extent have treated areas revegetated without human intervention?	A. Visually identify natural revegetation and document with photos. B. Over a period of 3 to 5 years, photograph, identify, and document regrowth of invasive plants and the success of any additional control actions as a component of long-term maintenance.
3. How successful has active remediation to the desired vegetative state been?	A. Visually assess the effectiveness of active revegetation and document with photos. B. Note areas for additional active revegetation and develop adaptive management plan and future monitoring needs. C. Identify and document success of any additional control and revegetation actions as a component of long-term maintenance.

Long-term Maintenance
Templates and Protocols

Long-term maintenance is the dynamic process, carried out over time (years to decades), to achieve social, economic, and ecological goals associated with a watershed. The process of management involves the strategic implementation of actions to identify, maintain, remediate, improve, and monitor the ecological processes of the watershed. Actions, and the tools required to accomplish them, are chosen because they are consistent with and likely to achieve the watershed goals, and because they address the results of monitoring. Watershed management is necessarily adaptive because actions or tools may need to be changed or replaced to adapt to any unexpected results of monitoring.

Table 5: Templates and Protocols for Long-term Maintenance

Templates	Protocols
1. Provide funding to carry out the preferred long-term maintenance plan	Determine funding sources for long-term maintenance that is consistent from year to year and can be provided over a long time period. Sources that may be available include state, local, federal, foundations, and/or private landowner funds derived form taxes, user fees, bonds, incentives, grants, etc.
2. Implement the long-term maintenance plan	Select actions could include efforts such as: o Non-native phreatophyte control o Conservation easements o Wildlife habitat improvement o Endangered/sensitive species habitat management o Economic development
4. Monitor actions and adjust as needed	Measure appropriate parameters for each major action to determine if the goals and objectives are being met. This information will allow informed decisions on the continuation, modification, or termination of the specific action or program; i.e., adaptive management.

Appendix H

Plant Materials List for Revegetation

The following list provides a general guide for potential native plants recommended for revegetation within the CHIP study area. *It is important to note*, that species lists can vary dramatically by site, and would be designed for each revegetation project based on unique site characteristics including elevation, ecological site patterns, surface or groundwater availability, soils, and location within the basin (e.g., mainstream river or tributary canyon). The list is intended as a guide only, and has been separated according to water availability of sites, with surface or groundwater identified as less than- or greater than 10' below the ground surface. This is generally the limit at which restoration practices can be effectively implemented and revegetation can become self-sufficient. Seed mixes should be researched and planned to meet the needs of each site.

The following plants are recommended if on-site *Water table is LESS than 10' below* surface: (wet, regen or mid terrace ecosites or where upland run-in increases moisture)

Trees

-coyote willow	(*Salix exigua*)
-Gooding willow	(*Salix goodingii*)
-Fremont cottonwood	(*Populus fremontii*) (below 6,000' elevation)
-narrow leaf cottonwood	(*Populus angustifolia*) (above 6,000' elevation)
-California Oak	(*Quercus*)
-Velvet Ash	(*Fraxinus*)
-N.M. privet	(*Forestiera neomexicana*)
-Water birch	(*Betula occidentalis*) (above 5,500' elevation)
-Box elder	(*Acer negundo*)

Shrubs

-skunkbush	(*Rhus trilobata*)
-4-wing saltbush	(*Atriplex canescens*)
-alder	(*Alnus*) (above 5,000' elevation)
-silver buffaloberry	(*Shepherdia argentea*)
-wild rose	(*Rosa*)
-Fremont's mahonia	(*Mohonia fremontii*)
-currant	(*Ribes*)
-seep willow	(*Baccharis*)
-shrub willows	(*Salix bebbiana, boothii, lutea,wolfii*) (above 5,000' elevation)
-dogwood	(*Cornus sericea*)
-cinquefoil	(*Potentilla*)

Grasses

-salt grass	(*Distichlis stricta*)
-indian ricegrass	(*Oryzopsis hymenoides*)
-sand dropseed	(*Sporabolus cryptandrus*)

-alkali sacaton	(*Sporabolus airoides*)
-Western wheatgrass	(*Agropyron smithii*)
-alkali muhley	(*Muhlenbergia asperfolia*)
-horsetail	(*Equisetum*)
-wild rye	(*Elymus*)

Aquatic and riparian grasses

-bulrush	(*Scirpus)*
-rush	(*Juncus*)
-sedge	(*Carex*)
-cattail	(*Typha*) cattail will likely come on its own

Forbs (Numerous)

If *water table is GREATER than 10'below ground surface*:

There is some potential to access water tables greater than 10' below the ground surface for revegetation of riparian plants with tools such as augers and water jets. Otherwise the site is functionally limited to an upland fringe site: (mid to high terrace ecosites, uplands) and usually require irrigation for a few months until deep roots become established.

-4-wing saltbush	(*Atriplex canescense*)
-indian ricegrass	(*Orhyzopsis*)
-sand dropseed	(*Sporabolus*)
-wild rye	(*Elymus*)
-Western wheatgrass	(*Agropyron smithii*)
-rabbitbrush	(*Chrysothamnus*)

Appendix I

Example Project Prioritization System

The following criteria for prioritizing future projects for tamarisk and Russian olive control and revegetation are preliminary in nature and intended to be an example of how CHIP can approach prioritization of projects they support. They are listed in no particular order of priority. Any of several criteria may be more important depending on the funding source, landowner desires, location, etc.

Funding Type & Opportunity – Funding opportunities often have specific goals, timing, landownership status, matching requirements, etc. that enhance a projects probability of gaining funding. Also considered is whether identified funding source(s) will provide the necessary resources for performing all activities; i.e., control, revegetation, monitoring, and maintenance.

Educational Opportunities – The location of a project can sometimes provide good educational opportunities. An example is Rifle rest area on I-70 that gets significant public exposure.

Willing Landowner – Landowner support of a project is essential for funding.

Weed Management Approach – This criterion addresses the specifics of the proposed control and revegetation approach to assess how best management practices (e.g., wildfire model), and Integrated Pest Management approaches are being incorporated into the project.

Cost Effectiveness & Efficiency – Are the costs associated with a control and revegetation project being used efficiently and will the results be effective at meeting the goals of the project?

Achievement of Goals – What is the specific goal of the project (e.g., wildlife habitat enhancement, water resources, endangered species, wildfire protection, etc.), are there multiple goals, and what is the probability of them being achieved?

Overall Potential for Success – Overall, will the project's setting, approach, landowner commitments, etc. lend it to being successful in meeting the goals of the project and be sustainable? Examples of questions that might be considered are: *Will native vegetation be able to be established without much help, and if not, does the project accommodate this condition? Is the budget realistic, and are matching funds and in-kind contributions available? Is there a commitment by the landowner to prevent other weed infestations?*