Colorado Tamarisk Mapping & Inventory Summary Report

Revised February 2008

Colorado River in Horsethief Canyon – mixed tamarisk, willow, cottonwood, and upland native species

Prepared by
Tamarisk Coalition (970-256-7400, www.tamariskcoalition.org) for
Colorado Water Conservation Board
Based on surveys performed 2005-2006

Colorado Tamarisk Mapping & Inventory Summary, Revised February 2008

In 2005 and 2006, the Tamarisk Coalition completed an inventory of tamarisk infestations on all the major rivers and their main tributaries in Colorado for the Colorado Water Conservation Board (CWCB). This included Russian olive data where appropriate. The purpose of this work was to 1) establish and implement an inventory protocol that would be economical to perform, 2) provide a relatively accurate understanding of the extent of the tamarisk problem in Colorado, 3) develop water and wildlife habitat impacts, and 4) estimate the cost of restoration. An accurate assessment of impacts and costs are essential for future decisions on the tamarisk issue.

This inventory and mapping effort was preceded by the following two actions:

1. Governor Bill Owens issued Executive Order D-002-03 in 2003 directing state agencies to coordinate efforts for the eradication of tamarisk on public lands, and

2. In response to this directive, the 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.*

The direct and indirect actions that have resulted because of the completion of the tamarisk inventory and mapping by CWCB are:

1. In 2006, CSU sponsored the most complete tamarisk research conference.

2. Palisade Insectary has become the region's lead facility for research and monitoring of the biological control insect, tamarisk leaf beetle.

3. Department of Local Affairs is funding comprehensive tamarisk planning efforts for the Colorado, Gunnison, and Dolores watersheds. Similar planning efforts are underway for the Arkansas, Purgatoire, and San Juan watersheds. These planning efforts rely heavily on the inventory and mapping efforts.

4. Western Governors Association and Tamarisk Coalition are working with USDA to utilize provisions of the Farm Bill to aid agricultural lands on tamarisk control.

5. Colorado's Congressional delegation strongly supported the passage of the *Saltcedar and Russian Olive Control Demonstration Act* which was signed by President Bush on October 11, 2006. This act will support large-scale demonstrations, research, and the development of long-term management and funding strategies.

This summary report is supported by the detailed inventory and mapping data-DVDs enclosed with this document **and is revised with additional data obtained during the fall of 2007 to include all of the major and minor tributaries and reservoirs in the Arkansas River watershed. These changes added approximately 15 percent to the Colorado's overall inventory.**

Tamarisk and Russian Olive Species

The rivers in Colorado and their associated riparian corridor 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. Typical examples of these infestations are presented in Figures 1 and 2.

Figure 1:Tamarisk and Russian olive choking the Arkansas River at Las Animas, US 50 bridge.

Figure 2: Typical tamarisk infestations on the Colorado River at Grand Junction.

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 Colorado are aesthetics, wildlife habitat loss, fire, and water usage. Aesthetics is critically important to the area because tourism is a major economic driver for many areas. 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 from a state perspective. The following section provides a brief explanation of how this water loss occurs.

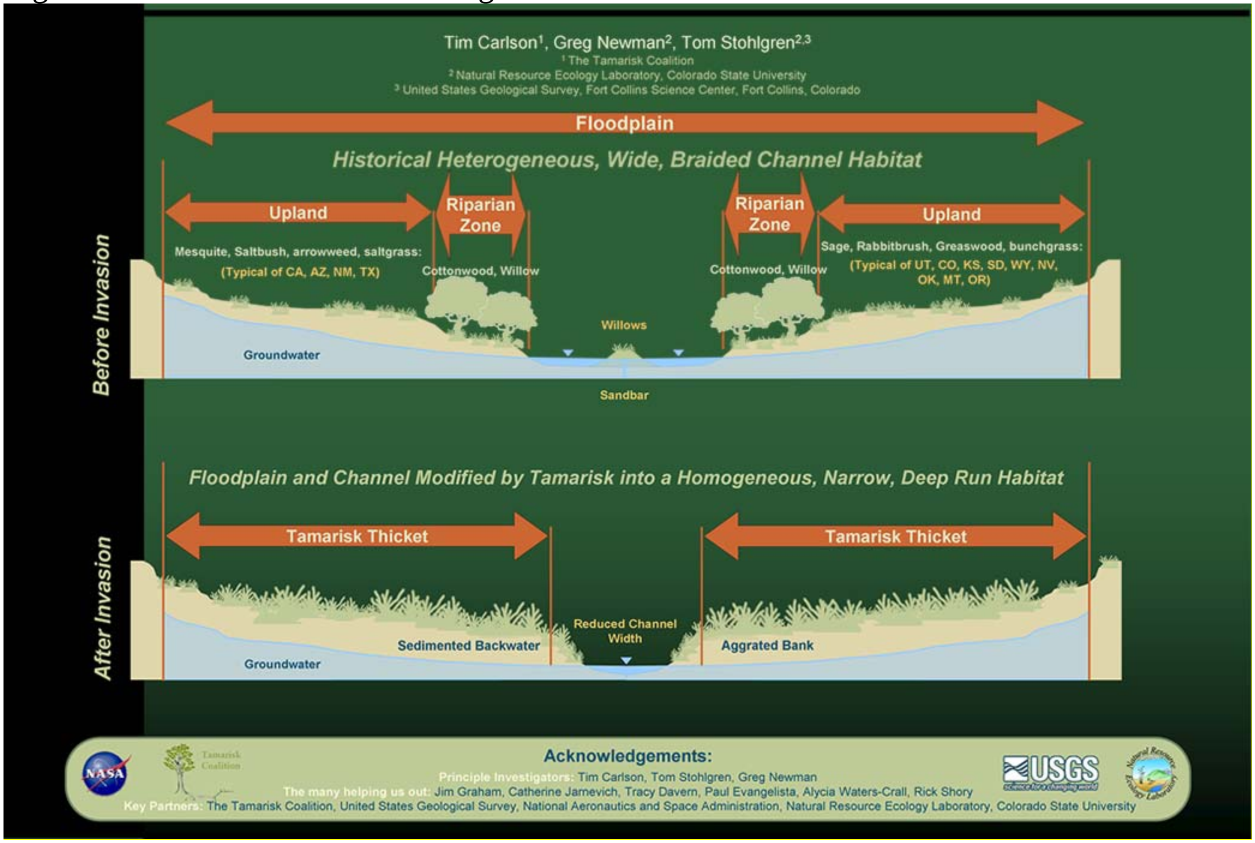
How much Water is Lost? – Limited evidence indicates that water usage per leaf area of tamarisk and the native cottonwood/willow riparian communities is very similar. However, because tamarisk grows in extremely dense thickets, the leaf area per acre may actually be much greater than native stands; thus, 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).

Estimates on water consumption vary a great deal depending on location, maturity, density of infestation, water quality, and groundwater depth. From 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 Boswier) 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 Colorado, riparian areas that tamarisk occupies have annual precipitation ranges from a low of 8 inches in Grand Junction to 1.5 feet per year along the Front Range (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 made in this study are based on these findings. Future water losses assume complete infilling of tamarisk with no expansion of range.

Figure 3 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 will 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.

It is critically important to recognize that the calculated consumptive use of water by tamarisk in Colorado is above what the native plants would use within the floodplain. Additionally, this predicted savings in water does not mean that this water is available for use, but rather that this water is preserved within the groundwater and surface water regimes.

Figure 3: 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 (Elemental Stewardship, 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 the 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 tolerate 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 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).

- The dense stands of 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 stands 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 2002 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
Habitat/Range	T	Western U.S. along riverways, springs, drainages
	RO	Throughout U.S. – most dense in western states

CHARACTERISTICS		DESCRIPTION
Tolerant	T	Floods, droughts, close shearing, and burning
	RO	Floods, droughts, close shearing, burning in dormancy, seedlings/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
Management	T	Difficult and expensive for mature stands
	RO	Difficult and expensive for mature stands
Forage	T	Poor nutrition

CHARACTERISTICS		DESCRIPTION
	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

Inventory Background – Tamarisk inventory data is summarized in this 20-page report from the detailed mapping and inventory data for each river system compiled on the enclosed data-DVDs. This format was required because the total data set exceeds 15 gigabits of information. The information contained on these data-DVDs includes:

- Colorado Mapping Project – Objectives, Protocols, and Guidelines
- Instructions for Utilizing Shapefiles
- Options for Non-Native Phreatophyte Control which include cost algorithms and time distribution of costs
- [specific river name] River and Tributary Mapping & Inventory Summary
- [specific river name] River and Tributary data Tables 1-4
- Figure 1: Tamarisk Induced Changes in Channel Structure and Associated Habitats
- [specific river name] River and Tributaries aerial photos – Tamarisk location and density
- GIS data including shapefiles & attribute tables
- Photo journal of mapping effort

Inventory Approach – Inventory and mapping was coordinated with the U.S. Geological Survey's (USGS) efforts to establish a national on-line database conforming to the North American Weed Management Association's weed mapping standards. The basic approach utilized existing aerial photography, satellite imagery, and local knowledge gathered from counties, river districts, soil and water conservation districts, state agencies, Army Corps of Engineers, National Resources Conservation Service, USGS, Colorado State University, 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. Over **2,800** miles of tamarisk and **200** miles of Russian olive throughout Colorado were surveyed using this approach. This information, in the form of shapefiles and site specific characteristics data, has been transformed into a digital GIS database which is now available on the USGS invasive species website: www.niiss.org .

The Tamarisk Coalition mapping protocols consisted of 7 steps designed to maximize time and cost efficiency in the mapping process, while maintaining an 85-90% degree of accuracy.

1. Prioritize mapping areas by acquiring local land/resource management knowledge of tamarisk infestations.

2. Arrange prior access to private or closed lands when possible for mapping.

3. Systematically map each river's mainstem and major tributaries for significant tamarisk infestations.

4. Record the locations of tamarisk using a combination of GPS/GIS technology. Data was also recorded digitally on high resolution aerial photography using remote sensing and photo interpretation.

5. Record attribute data for each infestation including percent cover, average height, accessibility for mechanized removal and a digital photo point for tamarisk stands. Each section of a river was ground-truthed by raft, car, mountain bike, or by foot.

6. Create cartographic mapbooks displaying the infestations on high resolution aerial photography.

7. Utilize attribute data (e.g. acreage) to develop cost-of-removal and water-use models for each mapped area.

Separate inventories were performed by the National Park Service for the Yampa River and by the Ute Mountain Ute Tribe for the San Juan River watershed in southeastern Colorado. The minor amount of tamarisk infestation that exists for the Rio Grande watershed is currently in development by the local conservancy district.

Cost Algorithms – The process for developing costs algorithms by the Tamarisk Coalition was a product of an economics assessment by the National Invasive Species Council. These algorithms are a comprehensive assimilation of all aspects of the costs associated with a successful approach to tamarisk management (i.e., planning, control, revegetation, monitoring, and maintenance) to develop equations that can support comprehensive planning. They are presented as low-end, high-end, and most-likely average costs per acre. Costs used to develop the equations assume an "Integrated Pest Management" approach will be used; i.e., use all the tools available and apply the best to each specific situation. The cost equations are based on three primary variables – infestation as a percentage of canopy cover (0 to 100%), accessibility (good or poor), and width of infestation (less than or greater than 50 feet). ***Although these cost equations are appropriate for planning purposes, it is important for individual project areas to identify the specific site conditions and control/revegetation approaches to be used to develop refined cost estimates.***

Finding – The inventory of Colorado's rivers and their major tributaries is summarized in Table 2. Information is organized by watershed and includes: total area of infestation, average density or canopy cover, estimated current water and future water losses associated with the tamarisk and Russian olive infestations as well as estimated costs for control and revegetation. These water losses and cost estimates are based on the most recent research and statistical analysis available through the USDA, NOAA, USGS, CSU, National Invasive Species Council, Tamarisk Coalition, and others. The following represents a summary of these findings:

1. Riparian areas in Colorado with non-native woody infestations are tamarisk dominated **95 %** of the time on an acreage basis, although some rivers (White and Republican) have infestations that are predominately Russian olive. These infestations stress water resources and degrade wildlife habitat. Totals for the state are:

   a. Total area of Colorado's riparian land with tamarisk infestations is approximately **92,000** acres at an average density of **38%**.

   b. Total area of Colorado's riparian land with Russian olive infestations is approximately **5,000** acres at an average density of **24%**. It is important to note that throughout Colorado's river systems, Russian olive is normally present with tamarisk, but normally at a much smaller level of infestation.

2. Current water losses are based on the amount of water tamarisk and Russian olive, both water-loving or phreatophytic plants, are currently using under observed densities minus the water that would be used by native plants. The significant water losses occur as tamarisk and Russian olive occupy upland areas within the floodplain that would normally support only dry land xeric vegetation such as grasses, sage, rabbit brush, etc. Based on the percentage of upland tamarisk and Russian olive infestations in Colorado, the estimates of current water losses above and beyond what native vegetation would use are approximately **98,000** acre-feet per year.

3. Future water losses assume an infilling of the existing infestation areas that 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 (no expansion from existing infested areas) are estimated to be approximately **270,000** acre-feet per year. *For comparison, the Denver Water Board used 210,000 acre-feet of water in 2005 to serve over 1,100,000 people.*

4. Costs for tamarisk and Russian olive control and revegetation are based on current work being performed by the National Invasive Species Council on an economic model that incorporates *Integrated Pest Management* practices with planning, design, control, revegetation, monitoring, and maintenance activities. Estimated costs for the rivers and their major tributaries in the Colorado study area are approximately **$96,000,000.**

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

6. The costs of water retained within the hydrologic system of approximately **$1,000 per acre-foot** should be compared to the value placed on the purchase of senior water rights because tamarisk is always using water even during a drought. For Colorado, these rights often exceed $10,000 per acre-foot.

7. The method used to develop this inventory information is predicted to identify 85 to 90 percent of tamarisk within Colorado. The remaining percentage represents small pockets of infestations that are scattered throughout the region. Because these outlying infestations are not included in the cost development, approximately a 20% contingency should be added to these cost values to account for their identification and remediation.

Table 2: Tamarisk (T) and Russian olive (RO) Infestations and Water Resources & Economic Assessment.

River	**Total Acres***	**Average Density**	**Current Water Loss (acre-feet per year)**	**Future Water Loss (acre-feet per year)**	**Total Costs**	**Average Cost per Acre Treated**	**Average Cost per Acre-foot of Water Preserved**	**Average Cost per Mile**
Arkansas River (T)	31,000	52%	48,600	93,000	$45,000,000	$1,450	$940	$162,000
Arkansas R. Trib. (T)	26,000	27%	20,000	76,000	$20,000,000	$800	$1,000	$21,000
Colorado River (T)	6,600	36%	7,000	19,500	$6,800,000	$1,030	$980	$52,000
Colorado R. Trib. (T)	900	33%	900	2,700	$850,000	$910	$950	$13,000
Dolores River (T)	2,350	36%	2,400	6,800	$2,500,000	$1,050	$1,020	$23,000
Dolores R. Tributaries (T)	850	24%	550	2,400	$750,000	$850	$1,300	$21,000
Gunnison River (T)	2,600	27%	1,900	7,000	$2,100,000	$810	$1,090	$27,000
Gunnison R. Trib. (T)	700	22%	450	2,000	$500,000	$670	$1,060	$25,000
Purgatoire River (T)	9,250	29%	8,000	27,000	$8,000,000	$870	$1,010	$45,000
Purgatoire R. Trib. (T)	750	26%	600	2,000	$600,000	$810	$1,100	$2,000
Republican River (RO)	3,300	19%	1,600	8,400	$1,800,000	$550	$1,110	$31,000
Republican River (T)	350	30%	350	1,200	$300,000	$840	$850	N/A
San Juan River in Montezuma County (T)	2,000	27%	1,600	5,900	$1,700,000	$820	$1,040	N/A
San Juan River on Ute Tribal Lands (T)	3,900	39%	Not available	Not available	Not available	Not available	Not available	Not available
South Platte River (T)	900	20%	550	2,700	$500,000	$550	$920	$2,200
Uncompahgre River (T)	1,500	16%	650	4,200	$700,000	$460	$1,040	$22,000
White River (RO)	1,200	37%	1,200	3,300	$1,250,000	$1,040	$1,020	$17,000
White River (T)	1,350	17%	650	3,800	$700,000	$480	$1,000	$9,000
White River Trib. (T)	1,250	46%	1,900	4,000	$1,850,000	$1,460	$990	$60,000
Yampa River & Trib. (T)	250	Not avail.	Not available	Not available	Not available	Not available	Not available	Not available
Yampa River & Trib. (RO)	200	Not avail.	Not available	Not available	Not available	Not available	Not available	Not available
Totals = **(adjusted for unavailable data)**	**92,450 (T)** **4,700 (RO)**	**38% (T)** **24% (RO)**	**98,300**	**271,900**	**$95,900,000**	**$990**	**$980**	**N/A**

Notes: Data on the Rio Grande and North Platte River were not compiled because infestations are less than 200 acres. The inventory for the Arkansas River, Purgatoire River, and their respective tributaries were updated based on additional mapping performed fall 2008.

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