APPENDIX 6
Reference material from **http://parks.state.co.us/cnap/iwm_handbook/iwm_index.htm**

INTEGRATED WEED MANAGEMENT
No single management technique is perfect for all weed control situations. Multiple management actions are required for effective control. The strategy of using an integrated selection of management techniques has been developed for use in a variety of "pest" control situations, including plant pests, or weeds. As used in this guide, Integrated Weed Management (IWM) is a process by which one selects and applies a combination of management techniques (biological, chemical, mechanical, and cultural) that, together, will control a particular weed species or infestation efficiently and effectively, with minimal adverse impacts to non-target organisms. Ideally, these management techniques should be selected and applied within the context of a complete natural resource management plan. Most traditional weed management treats only the symptoms of weed infestation, typically by using herbicides to kill weeds. IWM differs from ordinary weed management in attempting to address the ultimate causes of weed infestation, rather than simply focusing on controlling weeds. Although focusing on the fundamental causes of weed invasion and persistence is more demanding than simply spraying weeds, the rewards are far greater and are worth the effort. Over the long run, IWM should lead to greater success in meeting management objectives. IWM is "predicated on ecological principles and integrates multidisciplinary methodologies in developing ecosystem management strategies that are practical, economical and protective of public and environmental health" (Piper 1991). IWM seeks to combine two or more control actions which will interact to provide better control than any one of the actions might provide. However, even if multiple control actions do not interact, their additive effects can mean the difference between success and failure. In addition, employing multiple control actions should increase the likelihood that at least one of them will control the target weed species. *IWM is species-specific, tailored to exploit the weaknesses of a particular weed species, site specific, and designed to be practical with minimal risk to the organisms and their habitats.*

GENERAL PRINCIPLES
IWM requires landowners and managers to understand the biology and ecology of the weed species and its environment before selecting control actions. With scientifically valid information, landowners and managers can select the most effective, efficient, environmentally sound and socially acceptable methods to control weeds (Brown et al. 1999). Read the relevant weed profiles in Appendix 1 carefully before you develop IWM approaches for your problem weed species. Now that you have identified which species and which infestations are high priorities for control, use the following general principles and strategies in your selection of control measures and formulation of an IWM plan.

1. WORK TO ESTABLISH AND MAINTAIN FUNCTIONING NATIVE COMMUNITIES.
Grazing Management.
Grazing is the most extensive land use in Colorado, and poorly managed livestock grazing can contribute greatly to the invasion and spread of noxious weeds. Therefore, proper management of livestock is an essential component of integrated weed management for managing weeds on lands that are grazed. Perhaps the most important elements of a grazing plan are moving livestock from

pasture to pasture to avoid overgrazing and to provide plants with adequate time to recover following grazing.

Other Land Use Practices.

Land use practices other than grazing can also help or hinder the spread of weeds. Look for instances where irrigation, haying, or recreational use may be contributing to the degradation of native plant communities, or otherwise promoting the invasion and spread of noxious weeds, and take steps to alter these practices as necessary. In some situations, a conservation easement may motivate these changes in land management practices.

Restoration and Revegetation.

One way to combat the problem of invasive noxious weeds is to use native plants for landscaping, revegetation, and reclamation. IWM considers the broader natural systems in which a weed species or infestation occurs and attempts to manipulate these systems in ways that result in control of the weeds in question. Control often is geared toward improving the health of desirable plant communities so they can withstand future weed invasion. Use native species for reseeding, and plant native trees or shrubs as appropriate. Encourage the growth and persistence of native species by taking care not to damage them or alter their habitat with unsuitable land management practices. For detailed information see the *Native Plant Revegetation Guide for Colorado* (CNAP 1998).

2. IMPLEMENT APPROPRIATE PREVENTION METHODS.

IWM also includes combining preventive measures with normal land management activities and weed control actions. Preventing weeds from invading a site is the most effective and least costly method for controlling weeds. As you consider control actions, remember that you will need to ensure that application of these actions does not contribute to the spread of noxious weeds.

3. CHOOSE APPROPRIATE CONTROL ACTIONS.

Selecting appropriate control actions requires a detailed knowledge of the biology and ecology of the target weed species. The selected control actions should ideally be ones that are:

Applied at the most effective time.

Most control actions are effective only during certain periods of the target species' life cycle. Treatments should be applied at the point in the life-cycle of the weed when it is most vulnerable, *and* at a time when the least damage will be done to its natural predators and other non-target species.

Least damaging to non-target organisms, including natural weed control organisms.

Landowners and managers should carefully consider the likely effects of available control techniques on both target and non-target species before deciding which combination of control measures to use. Non-target organisms may include sensitive species, native plant communities, wildlife, areas revegetated to control weeds, insect pollinators, insects that feed on target weed species, and plant species that compete with the weeds you are trying to control. The selected control actions must not significantly damage these non-target organisms or lead to the creation of further problems.

Least hazardous to human health.

Herbicides can be injurious to human health if not used correctly. In fact, one of the driving forces behind IWM is the reduction of unnecessary pesticide use. Chemicals should be carefully chosen to minimize their potential toxicity to humans. Successful weed management involves more than just spraying weeds. Similarly, mechanical tools such as mowers and chainsaws can be

dangerous if not handled properly. Make sure you are familiar with the proper operation of such tools.

Least damaging to the general environment.

Using herbicides judiciously is important to avoid environmental contamination, especially around water. Certain formulations of herbicides cannot be used in aquatic situations or where ground water is close to the ground surface. In addition, timing of herbicide application is important to maximize the effectiveness of the chemical on the target weed, as well as to reduce the possibility of adverse side effects.

Most likely to reduce the need for weed control actions over the long-term.

Control techniques fall into two general categories: those that seek to prevent weeds from establishing, and those that deal with weeds which are already present. Preventive and cultural measures to reduce soil disturbances or to reduce the input of weed seeds to an area, re-seeding existing disturbed lands, and altering grazing practices to promote more vigorous stands of perennial plants are actions which work to prevent weed establishment. Actions which address existing weeds include pulling, mowing, applying herbicide, prescribed
burning, grazing or releasing biological control insects. Any combination of these management actions which addresses the underlying causes of weed infestation and spread is likely to be the most beneficial for controlling weeds over the long run.

Most easily implemented.

Control techniques which are easier to apply are more likely to be completed, and therefore most likely to have an effect on weeds.

Most cost-effective in the short and long term.

Consider the benefits and the costs of the possible control actions. For example, is the potential damage to desirable vegetation from an herbicide worth the risk? Is the potential for contaminating a stream with an herbicide outweighed by the benefits of controlling a noxious weed? Is the potential for spreading weed seeds by driving your vehicle into an area infested by weeds outweighed by the increased ease of controlling weeds?

GENERAL STRATEGIES

Remember that weed management actions need to support your land management goals and your weed management objectives. Generally speaking, weed control objectives will be to eradicate, suppress or contain weed populations.

- **Eradicate** means completely eliminating all weed plants, including live roots, rhizomes and seeds. Eradicating a weed species on a management area is very difficult unless it is present in small numbers.
- **Suppress** means to reduce the abundance of a weed species, typically as measured or estimated in terms of canopy cover or plant density.
- **Contain** means confining an infestation so it does not expand, but does not usually mean reducing the current infestation.

Tailor your management actions to the level of control you are seeking. For example, biocontrol agents might be appropriate for suppressing a weed population but not for eradicating a population.

IWM programs for large weed infestations generally select actions from the following list:

- Preventing weeds from becoming established in the first place.

• Altering livestock grazing practices to promote more vigorous plant growth.
• Using appropriate types of livestock to graze and thereby weaken weed plants and/or reduce seed production without damaging desirable plants.
• Re-seeding with a mixture of competitive, desirable plants, especially grasses, that spans the spectrum of growth periods (cool- and warm-season plants) and rooting depths (shallow and deep rooted).
• Releasing biological control insects to weaken weed plants and reduce seed production.
• Spraying with an herbicide selected to provide maximum weed control without damaging existing or newly seeded desirable plant species. A successful IWM program must be tailor-made for each situation. There is no cook-book solution that will work everywhere.

However, certain combinations of control actions have been successful and are worthy of your consideration:

• Mowing or cutting plus herbicide.
• Spraying with herbicide followed by reseeding with competitive plant species followed by hand-pulling of residual weed plants.
• Altering grazing regimes plus introducing biological control insects.
• Cutting woody plants followed by herbicide application.
• Grazing with goats plus reseeding with competitive plant species plus introducing biological control insects.
• Introducing biological control insects with periodic herbicide application.
• Spraying with herbicide followed with re-seeding with competitive perennial grasses.
• Re-seeding with competitive grasses followed by altered livestock grazing regime.

Remember that herbicides **must** be applied in conformance with the label. With herbicides, the label is the law. **Applying an herbicide beyond the bounds specified on the label is illegal**. Do not increase the concentration of an herbicide beyond the limits set by the manufacturer. More is NOT necessarily better, and higher herbicide concentrations can damage animals and non-target plants. The presumed safety of a chemical is based on the manufacturer's recommended concentrations only. IWM prescriptions potentially include the full range of control actions discussed in this handbook, including pulling, mowing and cutting, livestock, cultural controls, herbicides, prescribed burning, and biological control agents. The IWM approach contrasts with the traditional approach of using a single control action, such as applying herbicides, to treat all weed problems. Herbicides are one useful technique but they are not the only method to control weeds, and may not always be the most effective.

WEED MANAGEMENT TECHNIQUES

The need to take action to control weeds should be self-evident. All the planning in the world is worthless unless it is followed by action. A variety of specific weed management actions are presented below. As you consider the possibility of employing any of these actions to control noxious weeds, remember two key points:

1. An abundance of weeds is often symptomatic of certain environmental conditions. It is important to understand and deal with the underlying causes of weed infestation, and to take steps to counter them. If the factors permitting weed establishment and expansion are not addressed, weed problems will continue indefinitely.

2. A single control technique is rarely sufficient to control a particular weed species. The best results in weed control are usually obtained by combining different control methods in a coordinated effort. This strategy is known as Integrated Weed Management, and is the primary focus of this handbook. Weed management actions seek to achieve various levels of control. They are listed below in order of decreasing degree of control:

- Eradication, where a population of a weed species (including seeds) is completely eliminated.
- Killing an entire population of plants, with the expectation that they will repopulate an area from seeds in the soil.
- Weakening established plants with the hope that they will be more susceptible to mortality in the future or that their seed production will diminish.
- Thinning plants, where some plants in a population are killed but many are not.
- Eliminating seed production by damaging the top growth of plants. It is tempting to try to eradicate all weed populations because this represents the highest degree of control. However, eradication is not practical for most weed species and infestations because of the high level of effort involved. Eradication is generally appropriate only for small infestations of high-priority weed species.

PREVENTION

The most important weed management action is to prevent weeds from becoming established in the first place. The old adage that "an ounce of prevention is worth a pound of cure" certainly applies to weed management. There are two fundamental characteristics of weedy species that help explain why weeds become established where they do:

- Weeds specialize in colonizing highly disturbed ground. Weeds possess a number of physical traits that allow them to arrive at disturbed sites sooner and grow faster than other plants. With these advantages they are able to out compete native species, at least for a time. To counter this factor, avoid wholesale disturbance or destruction of existing vegetation whenever possible. Such disturbance, resulting in bare soil and lack of competing vegetation, creates ideal opportunities for weed colonization. If disturbance cannot be avoided, re-seed or re-plant disturbed areas immediately after the disturbance has ceased. Use native species or carefully chosen non-invasive introduced species so that "vacant" ground is quickly occupied by desirable plants. Extensive disturbances include house, pipeline, service or utility line, road and gravel pit construction, as well as road maintenance. On many properties road maintenance may be the most significant source of drastic disturbance. Work with local road district or state transportation office personnel to control weeds of rights-of-way that affect your property or management area.
- Weeds tend to invade plant communities that have been degraded by poor land management. Healthy native plant communities resist invasion. For information about establishing and maintaining native plant communities, see the *Native Plant Revegetation Guide for Colorado* (Colorado Natural Areas Program 1998). One of the best ways to avoid damaging plant communities is to manage livestock grazing so it maintains or increases the vigor of native perennial plants, especially grasses. Recreationists can also damage vegetation by overusing popular camping areas and creating social trails. Dense, vigorous stands of perennial grasses are especially resistant to weed invasion. However, certain highly aggressive noxious weeds such as leafy spurge, diffuse knapweed and Canada thistle can invade well-managed lands that have dense, vigorous vegetation.

PULLING

Pulling refers to using your hands or simple implements to uproot plants.

Pulling works best for.

• Small infestations of weeds that can be pulled one patch at a time.
• Annual and biennial plants (although seed banks will remain for some time).
• Shallow-rooted plant species that do not resprout from any residual roots.
• Plants growing on sandy or gravelly soils. If possible, concentrate pulling when the soil is moist and soft; for example, after a heavy, soaking rain.
• Situations where chemicals, motorized equipment or livestock cannot be used or are undesirable.
• Eliminating or reducing seed production in small infestations.

Pulling has limitations such as.

• Pulling generally does not remove the entire weed root system except under the most favorable circumstances. Thus, pulling is often ineffective for killing rhizomatous weed species such as Canada thistle, field bindweed, Russian knapweed, leafy spurge, or yellow toadflax even if used in conjunction with other techniques. However, if your goal is reducing seed production, pulling may be very effective. ***If pulled weeds contain seeds, they should be removed from the site and burned or disposed of in a landfill. Don't compost this material!***
• Pulling will not reduce a soil seed bank, although it can keep a seed bank in the soil from increasing.
• It is not cost effective for large infestations, due to the labor involved.
• Temporarily creating bare soil and providing more sites for weed seed germination and establishment.
• Some weeds produce chemicals that can cause allergic reactions or dermatitis in some people. Always wear work gloves and a long-sleeved shirt for pulling plants. Wash your hands with soap and water afterwards.

These weed species are good
candidates for pulling:
Blue mustard
Common mullein
Dalmatian toadflax
Flixweed
Green foxtail
Yellow foxtail
Jointed goatgrass
Musk thistle
Oxeye daisy
Puncture vine
Russian thistle
Plumeless thistle
Scotch thistle
Bull thistle
Myrtle spurge

Cost of pulling.

• Labor is the primary cost associated with pulling. Labor costs vary widely depending on local conditions. A recent study in Montana found that hand pulling alone was effective at reducing flower production of spotted knapweed, but that it was 70 – 500 times more expensive per acre than the other treatments tested (Heap 1999).

• Disposal of flowering or post-flowering plants.

MOWING AND CUTTING

Mowing and cutting employ mechanical or hand tools to sever the aboveground portion of a plant from its roots.

Mowing and cutting work best for.

• Large, relatively flat and dry areas that can be mowed with few safety or equipment concerns.

• Preventing tall, erect biennial weed species such as mullein and teasel from setting seed when other control techniques are not feasible.

• Preventing the "tumbling" action of certain weed species such as diffuse knapweed, kochia and Russian thistle that spreads seeds of these species across wide areas.

• Weakening weed plants by depleting root and rhizome reserves through repeated mowing, in cases where such mowing can be conducted efficiently.

• Combining with other control methods, such as herbicide treatment. Cutting can be extremely effective for killing certain trees and shrubs if it is combined with herbicide treatment of the cut stumps. For example, cutting the stems as close to the ground as possible in the fall and immediately (within 30 seconds) painting the cut stumps with triclopyr herbicide kills tamarisk, Russian olive, Siberian elm, and crack willow.

• Large-scale restorations where weeds need to be controlled during the first growing season or two. In these situations, set the mower blade height relatively high so as to cut the taller weeds but to not cut the shorter, slower-growing desirable species.

• Relatively small areas where adequate labor is available.

• Small infestations of fleshy-stemmed biennial thistles are easy to cut with a sharp machete. These thistles include Scotch, musk, plumeless, and bull thistles.

Mowing and cutting have limitations such as.

• Rarely killing weeds.

• Sites that are inaccessible or too rocky cannot be mowed, although weed whips and machetes can be effective in such situations.

• Having to repeat mowing frequently for control to be effective.

• Cut plants resprouting to larger sizes than prior to cutting (tamarisk, Russian olive).

• Weakening some rhizomatous plants only slightly (for example, Russian knapweed) unless the frequency of cutting is very high.

Pitfalls of mowing and cutting include.

• Failing to remove and dispose of cut stems if they contain seeds.

• Dislodging rocks from the mower may be dangerous to the mower operator.

• Turning annual or biennial plants such as diffuse knapweed into short-lived perennials through repeated mowing.

• Weed seeds spread by mowing equipment to areas previously free of infestations. Clean equipment which has been used in weed infested areas before moving it to another area. Make sure that borrowed or rented equipment is free of weed seeds by inspecting equipment before it enters your property. Or you can insist that the equipment must be cleaned first.

Cost of mowing and cutting.

• Can be relatively low per acre for large areas that can be mowed.

• Can be reduced if you can trade goods or services with a neighbor, especially if the neighbor is motivated by the prospect of reduced weed infestations on his or her property.

• A tractor with a brush hog rotary mower costs about $80 per hour or about $50 - $75 per acre.

• A three-person crew with weed whips costs about $30 per hour.

• Equipment cost for cutting is modest, with a weed whip, a chain saw and a double-action lopper costing about $800 total.

• Labor costs can be a barrier to cutting large areas of weeds such as tamarisk or Russian olive.

CULTURAL CONTROLS

Cultural controls seek to control weed problems by establishing desired plant species. Cultural techniques manipulate the plant community through cultivating (cutting through and turning over the soil), re-seeding, fertilizing and irrigating.

Cultural controls are most useful for.

• Large restoration projects. Cultivating is often necessary to reduce the number of weed seeds in the soil before planting desirable plant species. Cultivating for a year prior to reseeding kills weeds that have sprouted since the last cultivation and progressively reduces the bank of weed seeds. *Cultivation is not usually appropriate for natural areas because cultivation causes major disruption of established plant communities, and renders them susceptible to weed infestation.*

• Re-establishing native plant communities on disturbed or depleted areas so desirable plants can prevent or reduce weed infestation. *Disturbances such as pipelines, temporary roads, and construction sites need to be re-seeded immediately once the work is completed.* The *Native Plant Revegetation Guide for Colorado* (Colorado Natural Areas Program 1998) discusses this subject in great detail and provides practical advice to
landowners and land managers. Copies are available from the Colorado Natural Areas Program.

Cultural controls have limitations such as.

• Cultivating is not normally suitable for natural communities.

• Cultivating is appropriate only for restoration of drastically disturbed sites.

• Lack of seeds from locally adapted plants.

• Lack of seeds of certain native species, especially forbs and shrubs.

Pitfalls of cultural controls include.

• Seed mixes may be contaminated with weed seeds.

• Cultivation may result in wholesale germination and establishment of weed species if there is not adequate follow-up weed control.

• Temporary cover crops such as wheat, rye or barley used to reduce soil erosion must be mowed or grazed to eliminate their seed production.

• Promoting weed growth by adding unneeded nitrogen fertilizers. Native plant species are generally adapted to low-nitrogen conditions, while weed species are adapted to high nitrogen

conditions. Only add nitrogen fertilizer if tests show that soil nitrogen levels are insufficient to support native species.

• Common components of commercial seed mixes such as yellow sweetclover, smooth brome, and Kentucky bluegrass are often considered weeds in the context of natural lands and natural areas.

• Importing weed seeds on borrowed or rented equipment. You can reduce this risk by inspecting equipment before it enters your property or you can insist that the equipment must be cleaned first.

Cost of cultural controls and reseeding.

• A typical cost of contracting out the cultivation of a 10-acre restoration area can range from about $40 - $100/acre, and may include a base fee for mobilizing equipment of something on the order of $1000, assuming the equipment is available for hire locally.

• The cost of reseeding a construction site should be included in the cost of the project.

• The cost of seed is highly variable depending on species and availability. Common native perennial grasses commonly cost between $3 - $10 per pound. The cost of seed alone for reseeding an acre of land could vary from $10 - $50 per acre.

• A low-cost alternative to seeding is to use native (weed free) hay as a mulch and seed source.

LIVESTOCK GRAZING

Land managers can use cattle, sheep and goats to selectively overgraze certain weed species, thereby weakening them. In cases where desirable native species are not attractive to livestock, grazing may favor these species over weeds.

Livestock are most useful for.

• Weeds that are palatable (at least at some point during the year) and non-toxic to livestock. Weeds vary greatly in their palatability to types of livestock. Generally speaking, the preference for grasses declines from horses to cattle to sheep to goats. Furthermore, goats and sheep are more likely than horses or cattle to relish broadleaf weeds (forbs).

• Leafy spurge control. Goats and sheep are very effective control agents for all but the smallest infestations, especially in riparian areas.

• Low-level, widespread weed infestations where other control techniques are not cost effective.

Livestock have limitations such as.

• Lack of availability of goats and sheep or even cattle when and where you need them.

• Need for water and fencing or herding to control livestock movement.

• The need to manage the intensity and duration of livestock grazing carefully to avoid overgrazing, and allow desirable species to recover from grazing impacts.

• Areas where predators such as coyotes, mountain lions and black bears may kill grazing animals, especially sheep and goats.

• Using the proper kind of animal to manage the weeds on your property.

• Need for someone with knowledge of animal husbandry to manage the animals.

• Palatability of weeds varying widely throughout the growing season. For example, young shoots of Canada thistle are very palatable to cattle, while old, mature stalks are not. However, palatability of many weeds can be greatly increased by spraying them with a dilute solution of molasses.

Pitfalls of livestock include.

• Expecting livestock to control weeds without close management. Simply turning animals into a pasture and expecting weed problems to vanish would likely be counterproductive.

• Failing to manage the intensity and duration of livestock grazing to prevent the animals from depleting the desirable plant species they are grazing, or creating disturbance which favors the establishment of weeds.

• Spreading weed seeds in fur or in manure when animals are moved from one area to another. Grazing should be done before weeds set seed.

• Toxicity of weeds such as poison hemlock, halogeton, St. Johnswort and Russian knapweed to grazing animals; toxicity can vary greatly by type of animal.

Resources for livestock include.

• Contract grazing operators, typically using sheep and goats, are now entering the market place for the express purpose of controlling weeds.

• Neighbors with livestock are obvious allies in weed control and sources of grazing animals. They may be willing to provide the animals free of charge to you in exchange for a free grazing opportunity.

• There may be a potential profit opportunity where weeds could be turned into dollars in the form of specialized animal products.

Cost of livestock include.

• Infrastructure such as fencing and water, including capital and maintenance. Cost of fencing is highly variable depending on soil conditions, access and the type of fencing. Modern electric fencing is available that is much less expensive than barbed-wire fencing. Electric fence can be erected on a temporary basis while the animals are grazing then removed once grazing is finished. There are many sources of electric fence
materials.

• The cost of contracting with a person to supply and manage grazing animals. You can expect to pay from $19 - $38 per acre to rent goats and sheep for the grazing season.

• Cost of creating a holding area to confine animals (for 10-14 days) which have been grazing weedy areas where weed seeds are present.

BIOLOGICAL CONTROL AGENTS (INSECTS)

Biological control agents are organisms (usually insects) that are deliberately introduced to an area to control weeds. The aim of biological control is not eradication, but rather to exert enough pressure on a weed to reduce its abundance to acceptable levels (Wilson and McCaffrey 1999).

Biological control agents are most useful for.

• Reducing seed production or weakening plants.

• Large, dense infestations where other control methods are not cost-effective.

• Situations where a reduced but effectively permanent presence of a noxious weed species is acceptable.

These noxious weed species have biological control programs in Colorado:

• Leafy spurge

• Diffuse and spotted knapweed

• Russian thistle
• Puncturevine
• Musk thistle
• Yellow and Dalmatian toadflax
• Bull thistle
• Canada thistle
• Russian knapweed
• Purple loosestrife

Biological control has limitations such as.

• Failing to eradicate the target plant species. Do not use biocontrol agents where you seek to eradicate a weed population. Eradication of weeds with biological agents never occurs.
• Use of biological control is effectively an admission that a particular weed species is here to stay and that this is acceptable.
• Feasible for only a handful of weed species due to the high cost of finding, screening and testing potential control organisms. Biological controls have a mixed record with some tremendous successes but also with many failures.
• Rarely successful as the sole means of control of a weed species.
• Lack of effective biological control agents for most noxious weed species.
• Biological control agents being unavailable when you want them.
• Necessity of having a reservoir of host weeds to support biological agents over the long term. Thus, it may be necessary to leave some weeds to support populations of control organisms. This may be unpopular with neighbors or the public.
• Degree of control is variable and will take several years to achieve.

Pitfalls of biological control agents include.

• Insects attacking beneficial, non-target plants. For example, the seed weevil *Rhinocyllus conicus* that has been used to control musk thistle also attacks native thistles. There are indications that this weevil is adversely affecting a rare thistle (*Cirsium ownbeyi*) in Colorado (C. Dawson, pers. comm.). The weevil *Larinus planus*, introduced for control of Canada thistle, has been reported to attack native thistle species as well (S. Louda, pers. comm.). Insects that have been released to control St. Johnswort also feed on native *Hypericum* species, and some insects released for leafy spurge control also attack native spurge species (Wilson and McCaffrey 1999).
• Inability to establish populations of biological control organisms for reasons relating to climate, soils and so forth that are not well understood.

The biology behind biological control.

In its native environment, a plant is constantly attacked by a variety of organisms. Herbivory by insects and other invertebrate animals, and infection by fungi, bacteria and viruses reduces the ability of plants to grow and reproduce, which regulates the population size of a species. When plants are transported to a completely new environment, insects and other organisms in the new environment may not be adapted
to feed on or otherwise control the plant species. If this is the case, the introduced plant species may be able to expand its population size enough to become a troublesome weed. One method of

controlling weeds involves finding organisms in the plant's native environment that attack the plant and reduce its growth and/or reproduction. After a lengthy period of laboratory and field testing to determine if the organism is likely to attack non-target plants, these organisms may be released to control the weed in its new environment. The federal government approves individual insect species for release as biological control agents. Generally, federal land management agencies are not required to perform additional reviews to release approved biocontol agents. Other organizations may have internal policies that govern the intentional release of biological control agents.

The Biological Pest Control Section of the Division of Plant Industry has ongoing biological control programs for thirteen noxious or problem weed species. The primary function of the Section is the rearing and releasing of natural enemies for control of specific plant and insect pests. The rearing is done at the Insectary at Palisade. Currently, a total of 29 species of weed predators are being cultured, released, and established on weed infestations throughout the State. Most of these species are available if they have been established in Colorado. The Biological Pest Control Section encourages anybody who is interested in these programs to call for the insects. The requests are put on a list and when the insects are available, the land manager is contacted to arrange the release.

Resources for biological control agents include.

• The Colorado Department of Agriculture's Insectary in Palisade rears biological control insects and provides them free of charge to Colorado residents. Consult your county weed supervisor to find out if biological control agents have been used successfully in your area or call the Insectary at (970) 464-7916.

Cost of biological control agents.

• Biological control agents are available free of charge from the Insectary. Availability is limited.

• Insects are available for sale from commercial sources, often for several hundred dollars for a sufficient number of insects for one release.

HERBICIDES

Herbicides are chemicals that kill or injure plants. There are many kinds of herbicides; some are derived from plants and others are manufactured synthetically. Herbicides can be classified in terms of their mode of action. These chemicals include growth regulators, amino acid inhibitors, grass meristem destroyers, cell membrane destroyers, root and shoot inhibitors and amino acid derivatives which interfere with plant metabolism in a variety of ways.

Herbicides work best for.

• Eradicating some weed species in certain situations. Herbicides are most effective on pure stands of a single weed species where desirable non-target plants are scarce or absent. In this situation, one often has the option of selecting from several different herbicides.

• Rhizomatous weed species that are unpalatable to livestock, require repeated pulling or cutting for control, or are located in remote areas where pulling or cutting are not feasible.

• Small patches of weeds where hand pulling or cutting is not effective or feasible.

• Use in combination with other control methods. For example, Canada thistle can be controlled by repeated cutting during the growing season followed by treatment with clopyralid herbicide in the fall. As noted previously, tamarisk, Russian olive and Siberian elm can be controlled very

effectively by cutting stems very close to the ground in the fall then immediately spraying or painting the cut stems with triclopyr herbicide.

Herbicides have limitations such as.

• Damaging or killing non-target plants. Herbicides are not completely selective in their toxicity to the target plant species. Effects on non-target plants can be minimized by selecting an appropriate herbicide and using a wick or a backpack sprayer. A wick is made from adsorbent material and saturated with herbicide. This wick is rubbed directly against the weeds so the herbicide is not applied to adjacent, desirable plants.

• Difficulty of using herbicides to control small weeds when they occur among taller desirable plant species.

• Toxicity to humans to varying degrees. Thus, their use is regulated by federal and state laws. People who use herbicides need to know these regulations. Certain herbicides are classified as "restricted use herbicides" whose application is limited by federal and state regulations.

• Restricted use herbicides are often available only at licensed outlets such as your local farm coop or by ordering through reputable distributors.

• Property owners must possess a private applicator's license to apply a restricted use herbicide on their property. This license is obtained by passing a test administered by the U. S. Environmental Protection Agency in Denver. Call the Private Pesticide Applicator office at (303) 312-7283 for more information.

• Herbicides must be applied in conformance with the label. With herbicides, the label is the law, and applying an herbicide beyond the bounds specified on the label is illegal.

• Certain herbicides may not be used around or on water. This is an important consideration for weeds such as Canada thistle, perennial pepperweed, purple loosestrife, and tamarisk that grow in wetlands or riparian areas.

• One must possess the proper equipment and requisite knowledge to apply chemicals safely. Proper clothing must be used, and materials to contain spills must be on hand when using herbicides.

• Herbicides can move beyond the area where they are applied and affect non-target plants and animals. This drift can be eliminated by using a wick or reduced by spraying under calm wind conditions and by adjusting the sprayer apparatus to produce large droplets.

• Populations of weeds may develop resistance to a particular herbicide over time.

• Opposition to the use of chemicals in the environment, especially in urban areas. Local opposition in some areas may pose challenges for the use of some or all herbicides.

• Like most other control methods, herbicides are short-term solutions that do not address reasons for weed
problems in the first place. Therefore, spraying an herbicide treats a symptom of a problem. Even if an herbicide eradicates a weed infestation, another infestation may appear if the underlying cause of the infestation persists.

Pitfalls of herbicides include.

• Simplifying diverse plant communities by suppressing certain plant species, although this effect may be temporary.

• Herbicide applicators who cannot distinguish noxious weeds from desirable plant species, resulting in
accidental damage to the latter.

Resources for herbicides include.

• The Division of Plant Industry in the Colorado Department of Agriculture can direct you to information about herbicides.

• Herbicide labels are an important source of information that people who use herbicides need to read carefully.

• Professional, licensed herbicide applicators are knowledgeable about herbicides. Most readers of this handbook will probably want to use the services of an applicator familiar with natural area situations, rather than just lawns and turf. Your county weed supervisor can provide you with the names of licensed applicators in your area. A directory of commercial applicators is also available from the Colorado Weed Management
Association web site: http://www.cwma.org/3_weed_control.html.

• Chemical company sales persons are also sources of information, particularly about the products they sell.

Some herbicide terminology.

Formulation refers to how the herbicide is packaged. Sprayable formulations are diluted with water or oil-based carriers and sprayed on vegetation or soil. Dry formulations are granules or pellets and are spread directly on the soil. A herbicide **formulation** consists of an active ingredient, an inert carrier, and possibly adjuvants. The **active ingredient**
(a.i.) is the chemical which is primarily responsible for the herbicide's toxicity to plants. The **inert ingredient**(s) or **carrier** is a solvent or dilutant that makes the active ingredient soluble and able to penetrate plant tissues. Water is the most commonly used carrier. Hard or dirty water can decrease herbicide effectiveness, especially for glyphosate and 2,4-D salt or amine formulations (Bussan and Dyer 1999). **Adjuvants** are substances added to a formulation to increase the effectiveness of the active ingredient. These include surfactants, antifoaming agents, activators, drift control chemicals and dyes. The actual volume of spray solution is called the **spray gallonage**. Using the correct spray gallonage is important for ensuring good coverage of weed foliage with foliar-active herbicides (Bussan and Dyer 1999). Note that herbicide manufacturers are not required to disclose all ingredients in their products. Inert ingredients and adjuvants may also be dangerous chemicals -- always check the Material Safety Data Sheet (MSDS) for an herbicide. Remember, **THE LABEL IS THE LAW.** It is illegal to apply herbicides beyond the amounts specified on the label. If you have questions about a particular herbicide, call the 1-800 number on the label, or contact your county weed supervisor.

Cost of herbicides.

• The cost of herbicide alone commonly runs from about $5 – $20 per acre.

• The cost of herbicide application (not counting the chemical) depends greatly on the size of the area being treated, the chemical(s) are being used, and whether you apply the herbicide yourself or hire someone to do it for you. Cost for custom application runs from about $50 - $75 per acre for areas from one to one hundred acres using small equipment. For larger areas that are accessible for large equipment, costs can drop dramatically. Aerial application can run about $20 per acre (not including the cost of the herbicide) for areas over one hundred acres. Note that any person who applies herbicide for a fee must be licensed by the State of Colorado.

Herbicide resistance.

Starting with the introduction of 2, 4-D in 1946, agrochemical companies have manufactured and brought to market a wide variety of herbicides. The success of herbicides and other crop protection chemicals have revolutionized weed management, farm practices and food production. However, the utility of herbicides is being threatened by the appearance of herbicide resistant weeds. In any weed population, there are likely to be individual plants which are able to survive herbicide treatments which kill most of the population. This naturally occurring heritable characteristic enables these individuals to survive and reproduce, producing a population which becomes resistant to herbicides over time. Currently, there are over 216 herbicide resistant weed biotypes worldwide with an average of nine new cases per year (Heap 1999). In Colorado, three weed species have been listed as herbicide resistant (Heap 1999). Redroot pigweed (*Amaranthus retroflexus*) has become resistant to atrazine, wild oat (*Avena fatua*) has become resistant to dicoflop-methyl, and kochia (*Kochia scoparia*) has become resistant to both atrazine and metsulfuron-methyl (Heap 1999).

PRESCRIBED BURNING

Prescribed burning is planning, setting and managing fires to accomplish resource management objectives. Prescribed burning is a complicated subject and will not be discussed in great detail here. Consult land managers and scientists who have experience with local conditions if you are contemplating prescribed burning.

Prescribed burning works best when.

• The noxious weed species you want to control is much more susceptible to the effects of burning than are the intermingled desirable plant species.
• Controlling cool-season grasses in prairie restorations.
• A proper monitoring plan is in place to evaluate the effects and success of the project.

Limitations of prescribed burning include.

• The need for intensive planning to insure that the burn will be safe and accomplish the intended resource management objectives.
• Smoke management problems, especially in urban areas, that limit your ability to burn.
• Availability of crew members who have “red cards” that signify a minimal level of fire training.
• Availability of experienced crews to manage the prescribed burn in your particular fuel type(s).

Pitfalls of prescribed burning include.

• The possibility of burns getting out of control and damaging property and endangering human life.
• Liability issues if a fire gets out of control.
• Arid environments can not tolerate frequent burning.
• Massive germination and establishment of weed seeds following burning. However, this may be advantageous, in that it may assist in the depletion of the bank of weed seeds in the soil, if you are prepared to control the resulting weeds.

Resources for prescribed burning include.

• Colorado State Forest Service. Trained CSFS staff can prepare prescribed burn plans for private landowners for a modest charge.
• In-house fire experts of state and federal land management agencies can advise public land managers about prescribed burning and prepare prescribed burn plans.

• Certain county open space programs have in-house fire experts who may be willing to share their experience with you and to direct you to additional knowledgeable people.
• Private consultants and contractors who specialize in prescribed burning.