ROCKY MOUNTAIN NATIONAL PARK

VEGETATION RESTORATION MANAGEMENT PLAN VERSION 2

JULY 2006

121/146814

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Vegetation of Rocky Mountain National Park

Rocky Mountain National Park (RMNP) was established in 1915. At that time, it included 92,738 hectares, of which 4,543 hectares were private lands. Today, RMNP covers 107,323 hectares, of which 166 hectares are private lands. Elevation ranges from approximately 2300 m to 4345 m (Longs Peak).

The climate in and around Rocky Mountain National Park is described as temperate semi-arid steppe. The primary factors controlling climate are the north-south orientation of the Rocky Mountains and its elevational gradient. Weather arriving from the west tends to leave its moisture on the western slopes; hence the eastern slopes are typically drier and warmer. This rain shadow effect is region wide and is exemplified in the Park by the mean annual precipitation of both the *Pinus contorta* and *Picea engelmannii - Abies lasiocarpa* zones on the east and west sides of the continental divide.

Rocky Mountain National Park lies within the Dry Domain, Temperate Steppe Division and Southern Rocky Mountain Steppe - Open woodland - Coniferous Forest - Alpine Meadow Province. This ecoregion is characterized by dramatic vertical zonation of vegetation. This zonation is a consequence of abrupt elevation gradients between flatlands and mountains. Topographic relief is quite dramatic and in a short distance, one may see various life zones.

Rocky Mountain National Park has all but the lower two life zones present (Upper and Lower Sonoran). The pinyon-Juniper (Upper Sonoran) life zone begins a short distance to the east of the Park and a few foothill communities occurs close to the eastern side of the park boundary on warm aspects.

The late-seral forest formations at lower elevations (below approximately 2700 m) are ponderosa pine (*Pinus ponderosa*) savanna on southern exposures and Douglas fir (*Psuedotsuga menziesii*)-lodgepole pine (*Pinus contorta)* forest on northern exposures. Drier slopes and shrubland openings are dominated by big sagebrush (*Artemisia tridentata*) and antelope bitterbrush (*Purshia tridentata*). Willow (*Salix* sp.) communities dominate the wetter riparian zones, and aspen (*Populus tremuloides*) dominates the transition zone between the meadows and the forest on northern and upper-elevation sites. Various grassland communities dominate the meadows between the riparian and woodland/forest zones.

The subalpine zone extends from approximately 2700 m to approximately 3500 m and is dominated by spruce-fir forest, with significant areas of limber pine (*Pinus flexilis*), lodgepole pine, and aspen. A spruce-fir krummholz zone dominates the transition to alpine tundra. Alpine tundra occurs above approximately 3500 m. This complex formation consists of a number of dwarf shrubland and grassland communities, with areas of fell fields, snowbanks, and glaciers.

A vegetation-mapping program began in 2001 and finished in 2005, classified 172 distinct vegetation types based on species composition, structure, and environmental characteristics. Of these, 167 are recognized National Vegetation Classification (NVC) types, while an additional 5 are "Local" types specific to the Park, but not yet recognized in the NVC.

1.2 Anthropic Disturbance Types in RMNP

Prior to the establishment of RMNP, numerous anthropic disturbances occurred on sites now within the Park. Some settlement and private recreational activities continued after the establishment of RMNP, and some privately-owned properties still remain within the Park boundaries. It has been the policy of the National Park Service (NPS) since the earliest days of RMNP to acquire these properties whenever possible and to remove most buildings post acquisition after each building is reviewed for its cultural significance. Some national register historic sites have remained in the park and managed for their cultural significance. Disturbed areas in these landscapes are managed somewhat differently than the rest of the park and maybe revegetated with plant material not appropriate in other areas of the park.

The anthropic disturbances vary considerably as to type, intensity, and duration of disturbance. Disturbances included mines, homesteads, sawmills, roads, settlements, lodges, cabins, camps, ski slopes and lifts, a golf course, livestock grazing, haying, asphalt mixing plant, and human caused wild fires. Some of these activities began in the 1870s. Logging and most mining operations ended by 1920, but ranching operations continued on some homesteads until the mid 1930s. Large-scale removal of settlements, lodges, and cabins began in the 1930s and continued through the 1960s. Three CCC camps were in RMNP from 1933 until 1943, and the last of these buildings was not removed until the late 1960s. There are many abandoned roads, some dating back to the 1870s. Most were simply abandoned, and recovery has been exclusively by natural secondary succession. A few had significant artificial revegetation efforts applied to them. The asphalt mixing plant located in Hollowell Park ended operations in the 1970s and most of the waste asphalt at the site was collected and removed in the early 1980s. The ski slope, lift, and lodge ended operations in 1992 and restoration of these sites began in 1993.

These sites, along with recently abandoned trails and campsites, form a mosaic of disturbances located throughout RMNP in a wide range of elevations and vegetation types. Some have been allowed to recover naturally through secondary succession. Others have had revegetation actions applied to them. These revegetation efforts have varied significantly as to methods and purposes and have, over the long period of practice (from 1933), resulted in variable effects on vegetation redevelopment patterns. The revegetation effort, sometimes using species exotic to the park, resulted in the development of more stringent guidelines, including a 1985 park policy that local genotypic material would be used to the degree possible. This policy resulted in the park building a greenhouse and nursery in 1995 where on average 20,000 to 30,000 plants are developed each year for restoration projects. The greenhouse facility is used for relatively small restoration sites because of its limited capacity.

Restoration approaches, in turn, have contributed to the mosaic of seral communities that currently exists in RMNP. Some seral communities are now mid- or late-seral and are relatively similar to the surrounding less disturbed communities. However, other seral communities remain distinctly early-seral, some of which are dominated by non-native species, and are strikingly dissimilar to the surrounding vegetation.

1.3 Problem Statement

One of the reasons the RMNP was established is to perpetuate the natural ecosystems within the Park as near pristine conditions as possible. This requires two types of efforts. First, future anthropic disturbances of native plant communities must be minimized. Second, decisions must be made and implemented relative to restoration of past anthropic disturbance sites. Numerous practical and philosophical questions arise relative to restoring these sites, whether by artificial means or by secondary succession without human intervention. From a philosophical viewpoint, if the purpose is to minimize anthropic influences on ecosystems in RMNP, then human-induced restoration techniques may need to be considered as contributing to anthropic influences. On the other hand, from the practical viewpoint, what if the past anthropic disturbance resulted in conditions that cause continued disturbance or decline of surrounding ecosystems, such as soil erosion? Since NPS management policy directs restoration of degraded resources, then the question becomes, what level of manipulation is appropriate?

A coordinated management plan is necessary to develop solutions to such complex restoration questions. This management plan will address both philosophical and practical aspects and provide the means by which guidelines, procedures, and techniques can be developed, refined, and applied to restoration activities in RMNP. It will integrate the experience of field personnel and scientists and be sensitive to the needs and desires of management, the scientific community, and the general public. It should be flexible enough to allow for the incorporation of future knowledge and yet be firm enough to provide stability during times of bureaucratic change and public pressure.

Finally, and most importantly, it must work (i.e., it must be effective in protecting the unique resource that is RMNP for present and future generations).

1.4 Approach

This document is a revision of an Ecological Restoration Plan that was prepared in 1994. The revision occurred in four stages. First, a workshop was held in March 2005 that involved a panel of 14 agency, industry, and university persons active in revegetation and ecological restoration efforts (Table 1). The purpose of this workshop was to secure a diverse background of opinions and concepts relative to the revision of the existing plan. The second stage consisted of revising the existing plan, based on input from the panel and RMNP natural resource personnel. The third stage consisted of peer review of the revised plan by the experts that were on the panel. The final stage was the incorporation of suggestions from the reviewers.

2.0 CONCEPTS

Any plan or program must have a reference context. What overall concepts define the plan? Other considerations (e.g., resource limitations, lack of knowledge, inadequate methodologies) may also exist that further restrict development of the plan, but the overall concepts set the conceptual limits. In the case of this plan, these basic concepts may be thought of as the goals of ecological restoration in RMNP.

2.1 Selection of Endpoints

The first concept relates to selection of the endpoints of the ecological restoration efforts in RMNP. What are the ultimate goals of restoration? The answer to this question will define much of the direction the efforts should take.

There appear to be at least three legitimate endpoints to restoration efforts in RMNP: 1) site stabilization, 2) control of non-native species, and 3) restoration of late-seral communities. The first should be relatively short-term. Anthropic disturbances often result in conditions that make the site vulnerable to destabilization and erosion. Vegetation removal opens a site to increased water and wind erosion and to invasion by non-native species. Trails and abandoned roads become channels for waterflow. Roadcuts increase the probability of landslides. The first goal of restoration, natural or artificial, should be to stabilize the site to minimize further deterioration of the site. A number of restoration efforts may be considered successful and completed if this endpoint, site stabilization, is achieved.

A second possible goal of restoration efforts in RMNP is to control the establishment and perpetuation of non-native species. Most non-native species currently in, or potential to, RMNP are early-seral invader species. These species have the characteristics of rapid dissemination, adaptability to a wide set of habitats, and rapid establishment and growth rates. However, these species generally are not good competitors against established species, at least in the case of plants. These species establish most easily, and become most abundant, on disturbed sites. Therefore, more rapid revegetation of disturbed sites by native species, including early seral native, should reduce the window available for undesirable species to become established and reduce their production potential. Once a non-native species becomes established in RMNP, it becomes difficult to control its spread to other sites in the Park. The goal of limiting the establishment and perpetuation of non-native species should be a relatively short-term endpoint for revegetation efforts. RMNP developed an Exotic Plant Management Plan in 2003 to manage invasive exotic plants.

The long-term goal and, therefore, the primary endpoint of restoration management should be the restoration of appropriate late-seral vegetation on disturbed sites. In an absolute sense, restoration efforts can be judged successful if, and only if, the appropriate late-seral community becomes established on the site in such a manner that the community maintains and perpetuates itself without further inputs from humans. The key phrase of this concept is "appropriate late-seral community."

Definition of what constitutes "appropriate late-seral community" may be difficult, and the idea is discussed in more detail in Section 3.0. At this point, it is sufficient to state that the community should be as similar as possible to the community that would have been on the site had the disturbance not occurred. This similarity should include ecological integrity and, as far as possible, genetic integrity.

2.2 Preservation of Ecological Integrity

Preservation of ecological integrity refers to maintaining the species composition, structural and spatial characteristics, and functional processes and levels of the plant, animal, and microbial above- and belowground components of an ecological community, along with all pertinent interactions. Rocky Mountain National Park was designated an International Biosphere Reserve in 1977. One component of this designation was to preserve the genetic integrity of native flora and fauna and have the park act as a seed source for surrounding disturbed communities.

In the context of ecological restoration, preservation of ecological integrity refers to the reestablishment, on a disturbed site, of an ecological community that has a high degree (1:1 in the absolute case) of ecological integrity with the community that would have been present on the site had the disturbance not occurred.

Two major problems occur when this concept is put into practice: lack of knowledge and lack of ability. We do not know everything about any community, and we know much about very few communities and little about most communities. There are probably very few communities in RMNP that we know more about other than the most basic aboveground plant and mammal compositional and structural characteristics. In addition, we do not know the seral dynamics of any ecosystem in RMNP, nor can we do more than estimate what the late-seral communities should be on most disturbed sites. These may be good estimates, but they remain estimates. This lack of knowledge eliminates the possibility of preservation of pure ecological integrity in practice, since we do not know what we are supposed to be preserving.

Even if we knew what we were preserving, it is doubtful that we could achieve a perfect match in our restoration efforts. Disturbed sites no longer have the same edaphic and in some cases, topographic conditions they had prior to disturbance. Therefore, they are no longer able to support precisely the same ecological communities they did prior to disturbance, and it is doubtful that we could restore these conditions exactly even if we had sufficient resources to attempt to do so.

Our lack of knowledge of, and inability to restore, precise pre-disturbance conditions should not detract us from attempting to restore ecological integrity to the best of our current knowledge and ability. Restoration efforts should attempt to restore assumed pre-disturbance conditions as closely as possible. We should be able to estimate edaphic and topographic condition sufficiently well to reasonably approximate non-disturbance conditions. Likewise, we have sufficient understanding of plant and animal communities in RMNP to reasonably estimate which species should be present and, at least for the major species, in what amounts. This level of understanding should be sufficient to allow us to match general compositional and structural characteristics of disturbed sites with the appropriate landscape units. In addition, reconstruction of compositionally and structurally similar communities should be within our scientific and technical abilities in most cases in RMNP, with the possible exception of the tundra. Therefore, preservation of ecological integrity should be a primary aspect of our attempts to restore "appropriate late-seral communities" on disturbed sites.

2.3 Preservation of Genetic Integrity

Preservation of genetic integrity involves maintaining the intra-specific genetic composition in an ecological community. Ecological integrity is concerned with the proper mix of species. Genetic integrity is concerned with the proper mix of genetic material within these species. No two individuals of animal and most plant and microbial taxons are exactly the same. Therefore, once an individual is eliminated from a community, the genetic integrity of that community has been compromised and can never be restored in a pure sense (unless the eliminated individual has a clone).

Although absolute genetic integrity cannot be restored on disturbed sites, relative genetic integrity can be. If individuals, seeds, vegetative, or microbial material used to re-establish a site are taken from nearby populations, the genetic integrity of the restored community will be similar to that of the community on the site had it not been disturbed. The closer the nearby communities are to the disturbed site. The more genetically similar the material is likely to be. However, removing material from the nearby communities violates their genetic integrity, since part of their genetic pool has been removed. If this removal consists of only a portion of the viable seed, the removal may not have measurable effects.

For certain species, either among or within populations, significant intra-specific genetic variations are known to occur at relatively small scales, and these genetic variations may cause significant variations in ecological responses of the species. Therefore, it is important to integrate the concept of genetic integrity into restoration efforts. Plant, animal, and microbial material should be collected as near to the disturbed site as possible. However, care should be taken not to over-collect in one location, which would significantly impact the genetic integrity of the donor community.

Over-collecting can be defined as collecting at a level that significantly decreases the genetic integrity of the site. However, it becomes very difficult to precisely define over-collecting from a practical standpoint because of variations in genetic variability among sites, species, and local populations within species. A general guideline is to collect a small amount of material from each of a large number of individuals. More specific guidelines are discusses in Section 4.3 and in the Appendix—Best Management Practices Vegetation Restoration RMNP. Collections should also be evenly distributed, on an area basis, among all appropriate locations to avoid unnecessary bias of the collections with genetic material from one particular location.

2.4 Driving Forces and Constraints

One of the reasons that RMNP was established is to perpetuate the natural ecosystems within the Park in as near pristine conditions as possible. Disturbed sites, early-seral communities, and radically-altered mid-seral communities are usually not beautiful to most of the general public and are not part of the integrity of the ecological communities characteristic of the region. Most people would probably desire these areas to be returned to their "natural" conditions. However, the term "natural" implies that the area has not been significantly impacted by anthropic actions since the 1800s. Most, if not all, areas of RMNP have been either directly or indirectly impacted by man. The elimination of some predator species, the importation of alien plant species, and atmospheric deposition of nutrients and pollutants are examples of ecological factors that have impacted even remote areas of RMNP. There are many pristine areas in RMNP, areas only slightly impacted by industrialized man and which are very near natural conditions in most of their ecological characteristics, however, most people do not recognize any difference between natural and pristine or even exotic and natural. For many park visitors, "green is green."

National Park Service policy is to return disturbed sites in RMNP to conditions approximating pre-disturbance conditions as closely as possible. Therefore, it is the policy of the NPS, and probably the desire of the majority of the concerned public, that the ultimate end point of restoration efforts in RMNP is the re-establishment of appropriate late-seral communities on disturbed sites. This driving force is strengthened by the short-term requirements of site stabilization and control of non-native species, both of which are aided by rapid restoration of stable late-seral communities.

Two major constraints operate to counter these driving forces. The first constraint is economic. Adequate funding is not available for rapid restoration of all disturbed sites to late-seral communities. Consequently, a priority ranking is required, with a few sites receiving relatively high levels of resources, more sites receiving low to moderate levels, and most sites not receiving any resources. In addition, funding is often inadequate to do all that could be done to assure ecological or genetic integrity at a site, or to conduct the research necessary to increase our knowledge of the ecological characteristics of the communities.

The second major constraint is time. Many ecological processes take decades or centuries to result in significant changes. Humans and human institutions generally function more on time scales of weeks, months, and years. Construction, repair, or removal of a segment of roadway may be completed in days or weeks. However, the exposed surfaces may be severely eroded if we wait decades for secondary succession to heal the scars. Early- and mid-seral species establish and grow much faster than late-seral species. Rapid establishment of an early-seral grassland or a mid-seral woodland of relatively low ecological and genetic integrity may be more acceptable under these conditions than slower establishment of a late-seral forest with high ecological and genetic integrity.

3.0 SITE CONSIDERATIONS

Rocky Mountain National Park is not used uniformly by visitors. Some areas receive much greater use than other areas, and type of use varies throughout the Park. This was true in the past as well as today. Restoration efforts, from both techniques and policy standpoints, must take these differences into consideration in order to be successful.

3.1 Remote Areas

Rocky Mountain National Park contains sizable areas, especially in the north and the south-central regions, that receive very little human use. The Park has three Research Natural Areas (RNA) that were designated in the late 1970's that are considered in pristine condition representing various vegetation types. To minimize disturbance, these RNAs have no hiking trails through them, and livestock and overnight camping are not allowed. These areas contain the largest amounts of pristine area in RMNP. Every effort should be made to assure that these pristine areas are maintained. Any disturbed sites within these areas should be allowed to recover through natural secondary succession, without human intervention. If undesirable structures remain, they should be removed by hand, with maximum care given to preservation of the existing vegetation and soil. There should be no introduction of biotic material into these areas.

Non-native species do not appear to be a problem in these areas. The best defense against their invasion is probably the maintenance of healthy native communities. If populations of non-natives are located, they should be monitored. If their abundance increases, treatment methods may be warranted. Treatment of these populations should be through manipulation of secondary succession, by hand removal of individuals, or by other methods that would have minimum impact on the native species and soil.

These remote sites may have some disturbance sites where the potential for erosion is significant (e.g., abandoned trails). If so, these sites should be monitored and if erosion appears to be occurring, physical methods of erosion control should first be attempted. Examples would be placing downed logs across or within the gulleys, creating small spreader dams from surrounding logs and rocks, or placing logs and branches on denuded slopes or ridges. Revegetation should be conducted if it is obvious that this will enhance the effectiveness of other methods, if it appears that native species are slow to colonize these areas, and if plant materials from the vicinity of the disturbed area are used.

3.2 High-Use Areas

From a management standpoint, these areas are opposite to the remote areas. High-use areas are those areas where the intensity of human use is great enough to eliminate the possibility of maintaining pre-disturbance conditions. These include designated backcountry campsites, front-country vehicle campgrounds, roadways, active trails, viewpoints, and areas around buildings. Both the intensity and type of use of these areas precludes the restoration of late-seral communities.

Vegetation management in these areas should be based on the following order of priorities: 1) human safety, 2) erosion control, 3) control of non-native species, and 4) aesthetics. Native species should be used to accomplish each of the priorities. Plant material (seeds or transplants) from within RMNP should be used, and material from as near the site as possible is desirable. However, if the supply of local material is too limited, material from outside the Park, but of the appropriate species and ecological source, could be used on front-country sites. Short-lived (ecosystem-basis as well as individual-basis) non-native species such as sterile wheat may be used on these sites if there are no appropriate native species.

Physical disturbance, past and present, will generally be significant at these sites. Consequently, most communities at or surrounding these sites will remain in early- or mid-seral stages. Moderate to high levels of early-seral species, including some non-natives, should be expected. Control of these early-seral species should be through manipulation of secondary succession rather than through chemical or mechanical methods. Bare areas should be reseeded as quickly as possible, and mid-seral shrubs and grasses used where feasible. It should be possible to maintain mid-seral grassland, shrubland, or open woodland communities on most of these sites and these, rather than late-seral communities, should be the appropriate seral stages to manage for.

Vegetation management at some of these sites may involve the limitation of seral development. For example, it might be desirable, from a traffic safety standpoint, that shoulders of some roadways remain in mid-seral grass stages rather than progress to later-seral forest communities. Forest redevelopment might also be limited near some campsites and along some trailways, and shrubland development might be limited around buildings to reduce fire hazard.

3.3 Heavily-Impacted Areas

High-use areas have high frequency of use. Heavily-impacted areas have high intensity of use. Either type of use can result in significant disturbance, and the two types are not mutually exclusive. However, there are potential differences. Heavily-impacted areas that do not receive frequent use have higher potential for successful late-seral revegetation than high-use areas.

The major revegetation consideration on heavily-impacted sites is whether or not the impact has sufficiently altered the physical conditions at the site to preclude restoration of a late-seral community similar to the assumed pre-disturbance community. If so, these physical conditions must be restored to pre-disturbance conditions. It is unlikely that the effect of the disturbance can be totally eliminated from heavily-impacted areas in reasonable time periods. Therefore, it is unlikely that the pre-and post-disturbance late-seral communities can be as similar as they might be on less severely disturbed sites. Consequently, a one-to-one relationship between pre- and post-disturbance late-seral community, or between the post-disturbance late-seral community on the disturbed site and that on less-disturbed adjacent areas, should not be expected. What can be expected is that the disturbed site, late-seral community should have similar structural and compositional characteristics as the pre-disturbance or surrounding late-seral communities.

Once restoration of the physical environment has been accomplished, revegetation can begin. Overall guidelines to revegetation of these sites are similar to those of the high-use areas. Native species should be used, but short-lived non-native species can be used for short-term erosion control if necessary. Non-native early-seral species are likely to be a problem on these sites if the sites are near other disturbed sites. Secondary succession, rather than chemical or mechanical methods, will be preferred to control these non-native species. Their residency should be relatively short on these sites, provided that high-use of the disturbed area does not continue, and the Park should make every effort possible to prevent further disturbance to these sites. Use of locally-collected plant material is desirable on these sites, but materials from other parts of the Park (or sites adjacent to, but outside the boundaries of RMNP) could be used if local materials are too limited. Where late-seral species typical of the area are not suitable to site conditions, managers should consider a suite of species that will be complementary to the surrounding landscape.

3.4 Vicinity of Aggressive Alien Species

The primary consideration on sites near significant concentrations of aggressive non-native species is control of the spread of the non-native species. Most non-native species that have established in RMNP are early-seral species that are well-adapted to disturbed sites. In general, the potential for expansion of these species is limited in well-established late-seral native communities. Therefore, the restoration strategy on disturbed sites near concentrations of non-native species should center on two goals: 1) rapid colonization of the site by native species, and 2) reestablishment of a stable late-seral community as soon as possible. Some early- to mid-seral native grasses that may serve as rapid colonizers in the Park include *Elymus elymoides*, *Elymus trachycaulus*, *Poa palustris*, and *Bromus marginatus*.

Species native to RMNP, but not necessarily part of the pre-disturbance late-seral community at the site, may be used to initially revegetate the site if their establishment rate is more rapid than site specific-native species. The use of these species may alter the normal pattern of secondary succession. This would not be an acceptable management practice on most sites in RMNP. However, if the alternative would be heavy invasions by the non-native species, modified successional patterns may be acceptable, provided native species are used. This would hold true even if the late-seral community that would most likely develop on the site following revegetation lacks a high degree of similarity to the presumed pre-disturbance community. First restoration priority on disturbed sites near populations of non-native species should be resistance to invasion by the non-native species. Second and third priorities should be preservation of ecological and genetic integrity, respectively.

3.5 Rare, Fragile, and Unstable Sites

National Parks such as RMNP play an important role in the global effort to conserve biological diversity. It is a goal of RMNP management and planning to protect in perpetuity the natural world within the Park. Rocky Mountain National Park preserves examples of rare communities and species that outside of Park boundaries are threatened by a wide range of human pressures that diminish biological diversity (Bureau of Reclamation 2005). Several globally and state rare communities and species were located during the 2001-2005 vegetation mapping project. These include 19 globally rare communities and three globally rare plant species. These rare, fragile, and unstable sites require specific consideration in restoration efforts. Every possible effort should be expended in the preservation of sites containing rare species or that support ecological communities that are rare to RMNP, or to the regions, and sites that are ecologically fragile. Preservation of ecological and genetic integrity should have the highest priority on these sites. Every effort should be made to minimize anthropic disturbances from occurring in these areas, and those areas that have been disturbed should be restored as soon as possible by techniques that minimize disturbance to surrounding areas (e.g., use of hand rather than mechanical methods) and that maximize ecological and genetic integrity. Prior to any disturbance in the Park, a threatened and endangered (T&E) plant survey needs to be conducted to identify the existence of any T&E species.

Unstable sites may be naturally unstable (e.g., steep talus slopes) or may be unstable because of human activities (e.g., steep roadcuts, flood scars from dam failures, deforested slopes). Naturally occurring talus slopes are a natural feature of mountain environments and should not be the subject of artificial revegetation. Sites that are unstable because of human activities should be restored if feasible. Restoration goals, in order of highest priority, on these sites should be: 1) restoration of substrate and surface stability, 2) control of non-native species, 3) reestablishment of a late-seral community, 4) preservation of ecological integrity, and 5) preservation of genetic integrity.

3.6 Disturbance Area Designations

The differences in Park use, distribution of disturbances, and restoration strategies discussed above have been recognized by RMNP personnel and are the basis for the disturbance classification system used in the Park. This system divides disturbances into three categories: Natural Areas (Class I), High Use Areas (Class II), and Heavily Impacted Areas (Class III). Restoration objectives, standards, and policies are defined for each category, and these serve as guidelines for restoration and revegetation efforts throughout the Park.

3.6.1 Natural Areas (Class I)

Most of the Park would be included in this category, including all tundra, but excluding all roadslopes. A Class I disturbance would be completely surrounded by relatively undisturbed vegetation, with no exotic species adjacent to the disturbance. Exotic species may be present in a Class I area, as long as they have a low probability of migrating onto the disturbance site. Examples of typical disturbances in Class I areas include sites with some trampling of the vegetation, limited historic logging, old cabin sites, back-country campsites, back-country trails, and dams built on natural lakes flooding surrounding plant communities. Four dams have been removed from lakes well within the backcountry of the Park. The flooded lakeshores, re-exposed, have been recovering under Class I guidelines.

3.6.1.1 Objectives

The intent of revegetation efforts for Class I areas is to establish an ecosystem that is correct in two respects: 1) the kind of plants present, and 2) how those plants interact with one another. Interactions include succession, competition, and gene flow. There are four objectives pursuant to this intent:

1) to insure that the disturbed site is ecologically appropriate for the area and resembles an undisturbed community growing under similar environmental conditions;
2) to preserve natural interactions, including genetic integrity, between individuals growing on the disturbed site and those on sites adjacent to the disturbance;
3) to manage recreational use to preserve the natural ground cover so restoration will not be necessary; and
4) to insure that preservation of local plant communities is the top priority and that any disturbance connected with restoration work is the minimum amount necessary to accomplish the job.

Meeting the last objective could mean that some projects may be denied during the review process because it would be too damaging to the site. Projects proposed in the tundra should be carefully reviewed to determine if they are of the utmost importance for the preservation of the rest of the Park.

3.6.1.2 Standards

Stability of the disturbed site will be the standard for work proposed in a Class I area. The amount of work done will be the minimum amount necessary to prevent unnatural erosion from occurring. Unnatural erosion is defined as any erosion caused by humans or by animals due to human influence. Examples would be erosion occurring at a back-country campsite, overgrazed areas around hitching posts, or human caused wildfires.

The restored plant community will be ecologically appropriate when its species composition is similar to an undisturbed community growing under similar environmental conditions.

Natural vegetative interactions are preserved when individual members of the plant community are present in spatial patterns that are similar to those occurring in undisturbed, ecologically similar communities.

Genetic integrity is preserved when no genotype is introduced to a point on the ground to which it would not have probably immigrated under natural circumstances.

3.6.1.3 Policies

Eleven policies are defined for restoration of Class I areas:

1) recognize successional influences and employ the minimum intervention consistent with achieving the desired results;
2) recognize that restoration by natural succession may take decades or longer;
3) restore the natural gradient as closely as possible;
4) if necessary, artificially stabilize slopes by mechanical means or seeding early seral natives;

5) soil enhancement will be limited to breaking up and loosening the top horizon (e.g., scarifying, rototilling);

6) actively monitor the site by significant documentation of the soil and vegetation conditions or status (e.g., plant colonization species and rate, soil erosion);

7) recognize the fact that significant effort may be required on some sites to keep slopes stable (i.e., planting early seral natives for more than 3-4 years);

8) it will be appropriate and necessary to control visitor access to some areas;

9) utilize compost and sand mixture only in those areas where soil must be added to restore natural topographical contours;

10) plant material (including transplants, collected seeds, or propagation) will not be used, with the exception of short-lived species identified at a later date; and

11) no fertilizer will be used unless it is used in conjunction with sterile wheatgrass or other species used to stabilize the soil.

3.6.2 High Use Areas (Class II)

Disturbed areas within this category would be restored with a moderately conservative approach. A typical disturbance in Class II areas would be Moraine Park, where alien plant species are abundant and where development such as cabins, pipelines, and a golf course had occurred in past years or the former Hidden Valley Ski Area that is now a picnic area in the summer and a sledding area in the winter. Natural succession in these disturbed areas has been altered, and some plant species that should occur in these habitats may be absent. A Class II area could be within a Class III area when the vegetation is of special value, such as "native" vegetation between residence houses in the utility area. All roadslopes in the Park are treated as Class II.

A Class II area may provide a buffer between Class I and Class III areas. Natural succession in some Class II areas may be used if it is determined that the adjacent plant community is correct as to species composition, including the absence of nearby populations of exotic species. It will probably not be possible to preserve the kinds of interactions characteristic of undisturbed communities. Individual plants will not necessarily be distributed in natural spatial patterns, but allowing natural succession to occur may have the same end result as intensive manipulation. If natural succession is used, it will be discussed and standards will be set to monitor success in an approved site-restoration plan.

3.6.2.1 Objectives

The intent is to establish an ecosystem that is appropriate in that any species observed there would also be found in an undisturbed, environmentally similar community. It may not be possible to preserve the kinds of interactions found in an undisturbed community. Individual species may not necessarily be distributed in natural spatial patterns. Genotypes will not necessarily be those that would have naturally immigrated to a particular point on the ground. There are two objectives pursuant to this intent:

1) to restore a community in which the species composition is a subset of an undisturbed plant community that would be found in a similar environment, and

2) to restore a community in which the genetic composition is a subset of adjacent plant communities.

3.6.2.2 Standards

There are three standards applied to restoration of Class II areas. The species composition is a subset when species on the disturbed site can also be found in an undisturbed community growing under similar environmental conditions. The genetic composition is made up of local genotypes when genotypes introduced to the disturbed site came from nearby plant communities. Vegetation in the disturbed site may be a combination of those species that have migrated to the site naturally and those that have been manually introduced.

3.6.2.3 Policies

Eight policies are defined for restoration of Class II areas.

1) A considerable amount of work is permitted on a Class II site; however, natural succession should be the technique of choice whenever feasible.
2) The natural gradient is to be restored as closely as possible.
3) If necessary, artificially stabilize road slopes by mechanical means, planting sterile wheatgrass or with retaining walls.
4) Soil enhancement can be done, either by breaking up and loosening the top horizon (e.g., scarifying, rototilling) or by introducing a soil medium rich in organic matter and nutrients (e.g., compost).
5) No fertilizing will be done unless it is used in conjunction with sterile wheatgrass.

6) The site will be actively monitored by significant documentation of the soil and vegetation condition or status.

7) It is appropriate to collect seed and/or cuttings prior to disturbance or when that is not possible, from the closest undisturbed plant communities when discussed and approved in a restoration plan. Propagation of local genotypes is appropriate, but for no more than six generations. When collecting seeds, cuttings, or plants from a specific area, a minimum of 50 plants will be sampled to maintain genetic diversity. Collection of seeds and/or plants should not adversely impact the source area.

8) All disturbed sites, to the greatest degree possible, will be restored to a successional stage appropriate for the plant community the disturbance site is within. For example, restoring a disturbed site to only grasses in a forest community will not be appropriate unless: 1) those grass species occur in an earlier successional stage, 2) the site has been so modified by the disturbance that the former late-seral community is no longer adapted to the site, or 3) the site is a road shoulder and due to sight visibility concerns such as a switchback, or at a scenic turnout where the vista is important, the site will remain herbaceous instead of restoring to a forest community.

3.6.3 Heavily Impacted Areas (Class III)

Very little of the Park will be in this category. These are the most disturbed sites and include the east-side utility and residential area, the Grand Lake utility complex, various campgrounds, and the permanent ranger residences of Wildbasin and Fall River.

Within these areas are pockets of undisturbed vegetation. To the greatest extent possible, these inclusions should be preserved.

3.6.3.1 Objectives

The intent is to stabilize the soil and landscape for aesthetic purposes. Three objectives have been defined pursuant to this intent:

1) to restore the site to a condition that is stabilized from erosion and is visually aesthetic using plant materials of species that are native to the Park (plant material origin is not critical, but the Park is encouraged to purchase plant material with a regional origin; i.e., State of Colorado and similar elevation range).
2) to minimize disturbances outside previously disturbed areas; and
3) to restore Class III areas to Class II areas, where possible.

3.6.3.2 Standards

There are three standards applied to restoration of Class III areas. The site is stabilized from erosion when rilling or gullying do not occur, aesthetics is left to the discretion of the landscape architect, and purchased seed or plants are acceptable as long as they are species native to the Park. Areas away from any structure will be carefully analyzed to determine if the site may, in fact, be a Class II area.

3.6.3.3 Policies

Six policies are defined for restoration of Class III areas.

1) Only native plants may be used in landscaping. Origin of plant material is not critical, but it is encouraged to be plants with an origin from the State of Colorado.

2) Blue grama (*Bouteloua gracilis*) is the only grass that will be used on residence yards on the eastside of the park. No *Poa* species may be used. Over the long-term, the Kentucky bluegrass (*Poa pratensis*) presently found in residence yards will be phased out and replaced with blue grama. The extent of a residence yard will be determined by the landscape architect. To date, this issue has not been a concern on the westside of the park. Blue grama may not be adaptable on the westside and a substitute native species should be selected according to the environmental conditions of the site in question.

3) A nursery was established on the eastside utility area for growing herbaceous plants, trees and shrubs that can be used in landscape projects.

4) Some areas that are presently Class II may become Class III as development occurs (e.g., building a residence, ranger station, kiosk or office in a Class II area). A Class I area may not become a Class II or Class III area.

5) Non-native trees or shrubs are not allowed to be planted in the Park. A list of native plants from which the landscape architect can choose will be developed for each project.

6) Vegetable and flower gardens are permitted around residences. Plants known to be noxious or aggressive (e.g., yellow toadflax [*Linaria vulgaris*] "Butter and eggs") or other non-native plants listed in the 2003 Exotic Plant

Management Plan will not be permitted. Other species planted in a flower or vegetable garden may be disallowed if they become a threat to native plants.

4.0 MANAGEMENT APPROACHES

4.1 Project Proposal/Clearance Form

In Appendix B is the Revegetation Assessment Form. The completion of this form is the first step in any restoration project within RMNP. This form calls for information on location, proposed activity, time schedule, type of plants present (native and exotic), condition of the soil, and proposed revegetation strategy for the site. The second step is to complete the Project Proposal/Clearance Form. Pertinent information that is included in this form includes: title of project, cost of project; location of project; proposed start date; project review period start date; and project review period closing date. The form must be reviewed by the appropriate management personnel, specify what compliance is required and finally obtain superintendent approval. In addition, the Minimum Tool Analysis Form (Appendix B) is required for any work in recommended or designated wilderness areas.

4.2 Natural Seeding or Artificial Seeding

Whenever possible, natural seeding should be practiced in RMNP. Natural seeding requires 1) the presence of an adequate supply of seed or vegetative material close to the disturbed site, 2) the lack of significant barriers to the movement of these propagules onto the disturbed site, 3) the lack of significant erosion threat during the establishment stage, and 4) the lack of a significant non-native species problem at the site.

Artificial seeding should be used if any of the four requirements for natural seeding cannot be met. In addition, artificial seeding may be necessary in disturbed alpine environments where harsh growing conditions may significantly slow seed germination and seedling growth. Artificial seeding includes all human-assisted propagation of plant material at a site. Source of seed (or vegetative material) and planting technique are both factors that must be considered in artificial seeding plans in RMNP. Artificial seeding techniques are discussed in Section 4.7 and in Appendix A.

4.3 Source of Plant Materials

Disturbed sites that are relatively small and surrounded by well-developed and stable late-seral communities should be artificially seeded using plant materials collected from the site prior to disturbance, if possible, or from the appropriate adjacent late-seral community. Although genetic integrity may be compromised somewhat in the adjacent late-seral community by the removal of plant material, genetic integrity of the overall site will be maximized. Plant material should be collected from as many individual plants surrounding the disturbed site as possible to minimize the genetic input from, and the genetic loss to, individual plants and sub-community units. As a general guideline, material should be collected from a minimum of 50 plants, and collection from any individual plant should be limited to a maximum of 20% of the available material in the case of seeds and 10% in the case of vegetative material. Collections should not be made from adjacent communities if the communities are small and the collections would significantly impact their ecological or genetic integrity.

Adjacent later-seral communities, if sufficiently large and stable, are the first-choice plant material sources for artificial reseeding. However, as disturbance size increases, the quantity of plant material required for restoration increases. As the ratio of disturbed area to area of surrounding late-seral community increases, the impact of plant material removal from the late-seral community also increases. As long as the ratio is relatively small (perhaps ≤ 0.2), the negative impact on the ecological and genetic integrity of the late-seral community is probably acceptable. However, as the ratio increases, this impact becomes unacceptable and alternative sources of plant material are required.

The second-choice for plant material is within the same landscape unit as the disturbed area. This minimizes geographic and ecological differences that may give rise to ecotypes. In addition, this restriction should minimize violation of ecological and genetic integrity, since most landscape units in RMNP are slope-drainage physiographic units in which plant material tends to move downslope under natural conditions, thereby somewhat genetically integrating many within-landscape communities.

Plant material collections for large-scale revegetation projects may have to be park-wide, especially in the case of rare species and rare or fragile communities. When this is necessary, collections should be labeled as to collection site and the material should be used in plantings as near to these cataloged locations, or in as similar micro-environments, as possible.

There may be situations where supply of plant material from within RMNP is not sufficient to meet restoration needs. This might especially be true when temporal considerations are included. For example, a disturbed area with high-erosion potential may require that restoration efforts begin before that year's seed is produced in the Park. The choices would then be: 1) collect the RMNP seed a year before the project begins, 2) collect the RMNP seed that year, revegetate next year, and risk high erosion losses, 3) use seed immediately available but from sources outside RMNP, 4) revegetate with seed of other species collected in RMNP in previous years, or 5) use sterile wheatgrass to stabilize the site and then plant with native material the following year. If outside plant material is used, the material should be from sites as near RMNP as possible, the site of origin should be documented, the genetic integrity of significant areas of RMNP should not be initially compromised, and care should be taken to ensure that the seed is pure. There is an inherent risk in collecting seed a year or more before a project begins that if the project is delayed and the seed is not properly stored the viability of the seed is significantly reduced, resulting in a waste of resources and funds.

Seed increase programs provide a means for increasing the amount of seed available from RMNP genetic sources. These programs increase the quantity of seed available, but also increase the time required to produce useable supplies. Therefore timing is a critical issue that requires advanced planning to ensure that seed is available when needed. Seeds produced through a seed increase program would be more desirable for use in RMNP than seed produced from sources outside the Park, but might not be as desirable as seed collected directly within the Park for two reasons. First, the seeds would be produced from a limited subset of the natural population and, therefore, would be genetically biased toward the individuals from which the original seed was collected. Reseeding with progeny of individuals from restricted populations might, over time, bias the genetic variation in the natural population in favor of the selected sub-population. This potential problem could be reduced by limiting seed increase programs to six generations of seed produced. Second, environmental factors at the site where the plants are grown may differ significantly from those at the collection site in RMNP. If so, the different conditions might alter the relative success of individuals from within the RMNP collection. Over time, this might result in certain traits becoming more or less abundant in the re-introduced population than in the native population. Both of these concerns could be significant in a preservation environment such as RMNP, especially in rare communities. However, these concerns would be largely negated if the only alternative was importation of seed collected outside the Park.

Finally, it should be noted that the use of genetically modified organisms (GMO) for restoration is a concept that is relatively new and little information exists as to the appropriateness of this material in RMNP. Any opportunities that may arise in the future for using a GMO should be evaluated with caution.

4.4 Seed and Vegetative Propagule Collection

A. Seed or vegetative materials must be collected from a diverse set of individuals within the target population.

1. Obtain from as many plants and as diverse of phenotype as possible.
2. Sometimes the most unattractive materials or those with the poorest seed production can represent the best traits.

3. All collection decisions, whether intentional or accidental, have selection, therefore genetic diversity, implications.

B. Do not collect more than 20% of the available seed from any stand and no more than 30% of the available seed from any plant. Vegetative collection must be minimal in impact with as small of as sample size and footprint as possible. Do not collect more than 10% of the vegetative material present.

C. The collected seed must be tested for purity and viability in order to establish a benchmark from which to judge germination and establishment of the subsequent materials. If AOSCA-Approved standards are unavailable or testing protocols are unavailable, tetrazolium testing for seed viability may be used as an alternative method of determination.

D. Often multiple years of collection and, perhaps increase, are required to obtain enough seed. If adequate seed cannot be obtained in a given season, storage of the collected propagules will be necessitated until adequate numbers have been obtained for establishment.

4.5 Seed Storage

A number of situations in RMNP will require reseeding of disturbed areas. This reseeding may be either natural or artificial. If artificial, policy questions arise as to source of seed and planting method.

Seed must be clearly labeled as to species name, collection site, collection date, and existing ecological conditions (soil type, aspect, elevation, approximate coordinates, surrounding plant community, etc.). Vegetative propagules are very hard to store for any period of time. Materials should be maintained in a cool, moist state away from light, insects, rodents, and desiccation. Mold and fungus are potential issues.

Proper seed storage is a vital step in the seed collection process to guarantee viable seed. The two major concerns in storing seed are temperature and moisture. Two rules of thumb that relate to the influence of moisture and temperature on the rapidity of seed deterioration are: 1) each 1% reduction in seed moisture doubles the life of the seed and 2) each 10°F reduction in seed temperature doubles the life of the seed.

If seed moisture content is high enough (above 30%), nondormant seed will germinate. From about 18 to 30%, heating due to microbial activity will occur if oxygen is present, resulting in rapid death of the seed. From about 10% seed moisture for oily seeds and about 13 to 18% for starchy seeds, storage fungi grow actively and destroy the seed embryo. Therefore, seed should be dried as quickly as possible to below 13% seed moisture and should be stored below this moisture content at all times. However, drying to below 4 to 5% seed moisture will also result in more rapid deterioration than if seed is dried to a range of 6 to 10%.

To dry seeds, the relative humidity of the air must be below the equilibrium with seed moisture so there will be a moisture gradient from the seed to the air. Seeds can be dried in heated or unheated air but in most cases unheated air will not be effective in producing a safe moisture content. Therefore, heated air is most commonly used with an air temperature not to exceed 100°F. There should be good air flow around the seed and it is critical not to dry seed too rapidly because if the moisture gradient from the seed surface is steeper than the moisture gradient from the interior of the seed to the seed surface, the surface will dry rapidly and cause cracking of the tissue or even shrink the outer cells and create a layer impervious to moisture.

The rule of thumb for temperature is applicable down to at least 32°F. If seed moisture is below 14%, no ice crystals form below the temperature at which seed freezes, so storage of dry seed at subfreezing temperatures should improve longevity. Unfortunately, most storage units that produce subfreezing temperatures also have high humidity and seeds will take on moisture over time unless the seed is placed in moisture-proof containers.

After seeds are dried to the desired moisture content, they must be kept at this level or the cost and benefit of drying the seed are lost. Maintaining the seed in a dry condition can be done in three different ways: 1) the storage unit is made moisture proof and has dehumidification equipment, 2) the seeds may be stored in moisture-proof containers, or 3) the seeds may be placed in gasketed containers with dry indicator silica gel (2 lbs of gel for every 10 pounds of seed).

4.6 Recommendations for Greenhouse Propagation

A. Seed, plants, or obtained vegetative propagules used as "foundation stock" must periodically be re-collected and replaced with wildland collected materials to minimize genetic drift. While drift varies by species and reproductive biology, usually from 5 to 7 generations is considered a good rule of thumb.

B. With maintained collections, one must be cognizant of the reproductive biology of the species, i.e., how does the target species pollinate? One must establish whether the target species is self-pollinated, cross-pollinated, or partially self/cross-pollinated.

1. Both insect-pollinated and wind-pollinated species are very easy to cross pollinate from non-target sources, thus creating the potential for genetic pollution.
2. Wind pollinated species should be separated by a minimum of 1000-feet. This is even better if augmented by vegetative hedgerows between the accessions or species.
3. Insect pollinated species must be propagated under isolated conditions with active steps taken to minimize pollution from non-target pollen sources.
4. Insect induced cross pollination can occur at distances up to and exceeding 1-mile from the target population. Successful isolation requires the use of isolation houses with "clean zones" or individual cloches within an isolation house with induced accession-specific pollinators.

C. Vegetatively propagated materials must be maintained as "true-to-type" and isolated from neighboring populations to minimize cross-contamination. Individual plants need to be maintained as to discourage tillering or migration, as to prevent erosion from the true source genetics.

1. This requires containment from neighboring accessions and species.

D. It should be remembered that an incredible array of diversity within the same trait can occur between populations or even within a given population between years. This diversity can include distinction in seed and/or propagules production, germinability, and survivability, as well as phonological expression.

1. Weather conditions, the timing and degree of moisture, individual genetics, predation, and associated other factors are largely responsible.

4.7 Artificial Seeding Techniques

The twofold objective of artificial seeding is to achieve successful establishment of the seeded species with a minimum of additional disturbance to the site. In some cases, the two parts of the objective may be in conflict. For example, extensive seedbed preparation followed by drilling of seed may maximize establishment of a species, but the techniques may require repeated traffic by mechanized equipment which negatively impacts the surrounding vegetation. When in conflict, minimization of disturbance should normally be given priority. Exceptions would be on sites with high erosion potential, highly impacted sites, or sites with significant populations on non-native species.

Hand-broadcast of seed has the least negative impact of any artificial seeding technique, with the possible exception of aerial seeding. Disadvantages of hand broadcasting are that it is labor intensive and it may result in lower establishment rates than other methods. The later disadvantage can be partially overcome by raking or harrowing the soil surface after broadcasting to cover the seeds. Hand-broadcasting should be the technique of choice on small disturbed sites, unstable sites, rare or fragile sites, remote sites, and sites where there are significant amounts of mid-or late-seral species already established. Mechanical broadcasting can be used on larger disturbed sites when larger amounts of seed are available, provided the vehicle traffic does not result in disturbance to the surrounding vegetation.

Transplants provide a method of revegetation other than seeding. Transplants can be used to speed the rate of recovery and to revegetate sites where seedling establishment is particularly difficult. The major disadvantage in using transplants is increased cost. However, if it is difficult to establish a species from seed in the field, then cost may not be the criteria used to determine planting method. When using transplants, vegetation pattern should be considered. The transplants should be placed such that the natural pattern is mimicked as closely as possible with respect to spacing and species composition. It should be recognized that an early-seral pattern does not necessarily translate directly into a late-seral pattern. For example, much higher densities of young trees might be necessary to achieve the lower densities in a mature forest.

Sod-forming species or sod-based communities provide another alternative to seeding. Alpine tundra communities might be most effectively revegetated by use of a section of sod removed prior to disturbance or from adjacent established tundra communities. This technique might be used in other communities such as some grassland or riparian communities. If this technique is used, care should be taken that the removal of sod from established communities does not significantly impact these communities. Sod should be taken from as near the disturbed site as possible to maintain genetic integrity, although aesthetics should also be considered.

Removal of sod will result in the creation of small disturbances. Care must be taken to insure that these small patch disturbances revegetate properly. Small patches can be major invasion pathways and seedbank reservoirs for early-seral species. Patches of bare ground can also be slow to revegetate, especially in harsh environments such as alpine tundra. Plant cuttings may be used in lieu of sod cores if revegetation of the patch is a potential problem.

Additional information on seeding techniques is presented in the Appendix A.

4.8 Erosion Control Techniques

Some disturbed sites may have high erosion potential. This might be from water, wind, gravity, animal activity, or a combination of factors. If erosion is expected to be significant at a revegetation site, erosion control techniques are appropriate. These techniques may be vegetative or physical.

Vegetative erosion control techniques involve planting a short-lived cover crop before the seeding of the target species. The purposes of this technique are soil stabilization, micro-climate modification, slow invasion by non-native species, control nutrient availability levels, provide a more desirable belowground environment for redevelopment of the decomposer subsystem, and provide improved aesthetics during the initial stages of restoration. Conceptually, the technique should be valuable on some sites, especially harsh sites requiring soil stabilization (surface or belowground) or micro-climate modification. The major potentially negative factor is potential competition with establishing seedlings of more desirable species.

Physical techniques of erosion control can be separated into three categories: 1) barriers, 2) soil modification, and 3) surface applications. Barriers function as small dams or windbreaks and can be of many types. Natural materials such as logs, branches, and rocks should be used whenever possible. These should be arranged in a natural, random pattern rather then in a systematic pattern. Areas of extreme instability, such as steep road cuts or drainageways at high elevations, may require artificial barriers such as walls. These should be constructed to be as aesthetically pleasing as possible, using natural materials, incorporating plants as part of the design, and breaking the line of sight as much as possible.

Soil modification techniques involve altering the microtopography of the soil surface. The purpose of these techniques is to reduce the impact of the erosion agent. Examples include drain cuts along paths, pitting of the soil surface to allow increased water infiltration, construction of low mounds or ridges to form windbreaks or water catchment dams. When used, these techniques should be considered as temporary and should be integrated with the expected vegetation patterns. In cases involving compacted soils that restrict internal drainage, deeper tillage may alleviate the saturation and water flow problems observed on the soil surface.

Surface applications include various types of mulches applied to the soil surface to reduce wind and water erosion, modify micro-climate, or reduce invasion of undesirable species. Mulches may be either artificial or naturally-occurring materials. Artificial mulches, such as excelsior and plastic netting, have given mixed results and are generally visually unpleasing. These mulches can also prevent seed rain from adjacent native plants from becoming established for years until the mulch deteriorates sufficiently to allow seed to come in contact with soil. Therefore, mulches can at times inhibit natural succession if not carefully used. Therefore, their use should be minimized in RMNP. If excelsior mats are used, the netting material should be cotton rather than plastic because of the biodegradation problems associated with plastic netting. Natural mulches such as wood chips and straw are more aesthetically pleasing. The effectiveness of mulches is conceptually logical, since they modify micro-climate and add organic matter, but experimental results are not always consistent (Cotts et al 1991, Redente and McLendon 1993). Alone, or in combination with physical modifications such as logs, natural mulches might increase the success of revegetation efforts on some sites (e.g., long, steep slopes).

Additional information on mulching methods and materials is presented in the Appendix A.

4.9 Topsoil Issues

A potentially significant problem arises when erosion has occurred on disturbed sites in RMNP. The removal of topsoil by erosion creates a different environment, at least on the micro-site scale, than was present prior to disturbance (Cotts et al. 1991). This presents two alternatives: 1) accept the erosion-modified conditions, or 2) attempt to modify the effects of the erosion. Acceptance of the first alternative may result in a late-seral community developing on the site that is different from the pre-disturbance late-seral community, since the edaphic and physiographic environment is altered. The degree of divergence from the pre-disturbance community will depend on the type of vegetation and the degree of edaphic modification (McLendon and Redente 1990).

Acceptance of the second alternative presents the problem of how to restore the eroded soil. There are three possibilities: 1) import soil from another RMNP site, 2) import soil from outside RMNP, or 3) use a soil substitute. The first possibility is undesirable because it would result in the disturbance of a second site to attempt to restore the first site. The second possibility is generally undesirable because of the potential for importing plant, animal, or microbial materials into RMNP. However, there are examples within the Park (e.g. Hidden Valley) where imported topsoil has been used successfully. The use of a soil substitute is challenging because of the difficulty in acquiring the needed components and determining the ratios among materials that need to be mixed together to form a suitable soil. More work in this area is needed before it can be recommended.

Additional information on topsoil characteristics and topsoiling methodology is presented in the Appendix A.

4.10 Weed Control

A major problem often encountered in revegetation of disturbed sites is the invasion of undesirable species (i.e. noxious weeds, invasive species, and long-lasting exotics). These invasions are considered to be undesirable for one primary reason; the presence of these undesirable species may slow the rate of secondary succession. Therefore, weed control is often considered during the early stages of artificial revegetation.

Anthropic disturbances significantly increase the availability of sites favorable for dominance by undesirable species and, therefore, increase the abundance of these species over natural levels. High-use areas have an abnormally high frequency of disturbance and, therefore, are likely to have high levels of undesirable species.

If weed control programs are used in RMNP, care must be taken to minimize the effect on non-target species. Herbicide application is generally the least desirable method because of potential effects on associated native species and possible indirect effects on soil and water subsystems. Hand removal methods are the most desirable because of the high degree of selectivity possible with this method. However, hand methods are labor intensive and, therefore, expensive unless volunteer labor is used. Mechanical control methods are intermediate between chemical and hand methods, relative to ecological desirability. Care should be used in the use of mechanical control techniques so that the sites are not further disturbed by the equipment.

Other weed control methods are possible and may hold sufficient potential for consideration for use in RMNP where applicable. Biological control methods may be useful if the biological agent is native to RMNP or is sufficiently host-specific. Fire is a natural factor and could be used under limited and rigidly controlled conditions in some areas of RMNP. Modification of nutrient availability is another method that utilizes a natural factor to control the rate of secondary succession and may, therefore, have potential as an ecologically-friendly weed control method (McLendon and Redente 1992a, 1992b; Paschke et al. 2000).

For a more detailed discussion on weed control, the Invasive Exotic Plant Management Plan for RMNP (2003) should be used for management decisions.

4.11 Continued Maintenance

Induced revegetation programs involve modifications of the natural process of secondary succession. Many revegetation efforts are single event programs; i.e., the manipulations are carried out and no continued maintenance is required. Other revegetation efforts require additional activities that extend past the initial revegetation event. Examples include fertilization or weed control in years subsequent to an initial reseeding, replacement of decayed or displaced logs on a slope-stabilization project, and removal of brush or tree seedlings from a road shoulder.

Two basic questions related to continued maintenance are how much and how long? The answer to both questions is: sufficient to accomplish the task. The key, therefore, is to clearly define the task endpoint. For example, if the task endpoint is the reestablishment of a specific late-seral community on a disturbed site, the task is not completed until that late-seral community is established. If fertilization or weed control is necessary to accomplish the task, it should be continued until the task is completed. If fertilization or weed control is desirable but not necessary, then their use cannot be justified on the basis of the specified task endpoint; i.e., restoration of the specified late-seral community. Fertilization or weed control may, however, be justified on the basis of a related task endpoint; e.g., to maximize aesthetics during the early seral stages or to speed the rate of early secondary succession. In this later case, fertilization or weed control should be used to the degree, and for the period of time, that they are effective in accomplishing the tasks of improving aesthetics or speeding succession.

In general, continued maintenance should be minimized. Restoration efforts should be designed such that maintenance operations are either unnecessary or necessary for only a short time (e.g. supplemental watering of transplants for one year). If maintenance operations are required over a relatively long period of time, the system produced by the revegetation project is artificial and ecologically unstable. This may be necessary at some sites (e.g., road shoulders and firebreaks around buildings), but these management decisions should be made from the beginning of the restoration planning process and the continued maintenance should be considered vegetation management rather than maintenance of a restoration project.

4.12 Monitoring

The termination of restoration activities should not signify the completion of the restoration process. Each restored site should be monitored over time to document plant community development and to identify treatments that may be needed such as erosion control, replanting, or weed management. Monitoring programs may be as simple as establishing permanent photo points and taking photographs each year. If technical expertise and financial resources are available, monitoring should include plant sampling to quantify such parameters as cover and woody plant density. Sampling should be done at the species level to determine species composition. In addition, observations should be made as to the occurrence of soil erosion and the presence of weedy species that need specific control measures.

Restored sites that may be susceptible to human or wildlife impact should be fenced until plant established has occurred. These areas may include high use visitor areas, areas of high wildlife use, and riparian zones. Sensitive zones can be fenced to protect from wildlife or signed to inform public users to avoid disturbing the recovering zone.

Vegetative cover by species can be estimated by using a line-point transect method (Bonham 1989), with points read every 1.0 ft along a 100-ft transect. A minimum of five transects should be randomly sampled in disturbed sites within the boundaries of the disturbed area, as well as randomly within an equivalent area for adjacent reference sites. The total number of transects to be sampled should be based on the level of variation in cover according to the following equation for sample adequacy (Bonham 1989)

$$n = \frac{t^2 s^2}{\left(k \bar{X}\right)^2}$$

where n is the estimated number of observations needed to obtain an estimate of the difference between the sample mean ($\overline{X}$) and the true population average (μ) within a given probability (k). The value for t is taken from a table of the Student's t distribution. Its value is dependant on the number of observations used to estimate the sample mean ($\overline{X}$) and variance (s^2), as well as the confidence level desired for using $\overline{X}$ as an estimate of μ. The value used for k should be 0.1, and the confidence level should be 90%. Using these values, the calculation of sample adequacy allows for a detection of a 10% change in total live cover 90% of the time under repeated sampling.

Transplanted sites are disturbed areas in which containerized plant material is used, either from salvaged vegetation recovered prior to disturbance or from another site, or from hand collected seed that is propagated in the park's greenhouse until it is ready for transplanting. Some sites have been treated with a combination of seeding a nurse crop, seeding native perennial species, and transplanting. Five 2-m x 10-m belt transects should be randomly sampled within sites disturbed the previous year and revegetated by transplanting native grasses, forbs, or shrubs. All species with basal parts within the boundary of the belt transect should be counted to determine densities of individual species that have been transplanted.

5.0 SUMMARY AND RECOMMENDATIONS

5.1 Concepts

The following concepts should be used as the philosophical basis for restoration management decision-making in Rocky Mountain National Park.

1. The extent of anthropic disturbances should be minimized when appropriate.

2. The primary long-term endpoint of restoration efforts should be reestablishment of appropriate late-seral communities.
3. Short-term endpoints of restoration efforts are a) site stabilization, b) control of non-native species, c) improvement of site aesthetics, and d) increasing the rate of secondary succession.
4. Preservation of ecological and genetic integrity should be high-priority restoration considerations.
5. Anthropic disturbances should be the subject of restoration efforts.
6. Naturally-induced disturbances should not be the subject of restoration efforts, except when a) human activities significantly increase the severity of the natural factor, b) there is potential for significant damage to critical adjacent sites or human life and property, c) the disturbance vector is not native to RMNP, or d) rare or endangered species are threatened.
7. Secondary succession without human inputs is the restoration technique of choice, when it can be expected to provide acceptable results in acceptable periods of time.
8. Human-induced restoration is likely to be the technique of choice on a) erosion-prone areas, b) high-visibility disturbances, c) sites where rapid invasion of non-native species is likely, d) sties where the disturbance altered conditions sufficiently that the site would not return to pre-disturbance conditions, and e) sites lacking an adequate source of necessary biotic material (Class II and Class III areas).

9. Remote, pristine areas and sites supporting rare or endangered species or rare communities should receive maximum protection from anthropic disturbance, including artificial revegetation.

10. Vegetation management considerations in areas of high-use by humans should be made on the basis of a) human safety, b) erosion control, c) control of non-native species, and d) aesthetics.

11. All plant materials used in restoration in remote, rare, and fragile areas should come exclusively from RMNP sources, and should be collected as near the disturbed site as possible.

12. Plant materials used in restoration in high-use, heavily-impacted, and unstable areas should be of species native to RMNP and, when possible, should come from sources in RMNP.

13. Non-native plant materials can be used in revegetation of high-use, heavily-impacted, and unstable (Class III) areas if the species are short-lived (individual- and ecosystem-basis) and if appropriate native species are not available.

14. Topsoil may be imported into RMNP if the source is in close proximity to the park and is found to be clean of viable seed. Topsoil from an undisturbed site within the park should not be excavated to provide topsoil for another site from within the park.

15. Weed control should be minimized. If practiced, it should be confined to a) high-use areas, b) control of non-native species, or c) to speed the rate of secondary succession.

16. Restoration plans should be adequately funded and designed such that maintenance past the initial effort is minimized.
17. Long-term maintenance of restoration projects should be considered to be vegetation management projects rather than restoration projects.
18. Each restoration project should include performance measures and a quantitative monitoring program that is conducted throughout the lifetime of the project. To the extent possible, project-based monitoring should be coordinated with park-wide monitoring.

5.2 Techniques

1. Hand methods of vegetation restoration should be used in remote, pristine areas.
2. There should be no artificial introduction of biotic material into remote, pristine areas.
3. Restoration of bare sites, areas near significant populations of non-native species, and unstable sites should receive high priority.
4. Seed increase programs can be used to provide plant material used to restore high-use, heavily-impacted, or unstable (Class II and Class III) areas and to provide supplies of seed of rare RMNP plants.
5. Hand-broadcasting should be the artificial seeding technique of choice whenever possible, and should be the only technique used in pristine areas.
6. Vegetative erosion control techniques should be the erosion technique of choice.

7. Natural materials should be used whenever possible when barriers are required for erosion control.
8. Natural materials should be used if mulches are required.
9. Secondary succession should be the weed control method of choice.
10. Chemical weed control should be limited throughout RMNP and should not be used in areas supporting rare or endangered species.
11. Mechanical weed control should be limited to high-use and heavily-impacted areas.

5.3 Revision Procedure

This plan is considered a "living document" and should be revised over time to reflect changes in NPS policies, lessons learned in RMNP, and advances in the state-of-the-art of restoration ecology. This review and revision process should include RMNP personnel and outside experts to provided adequate depth and breadth to the review and revision process. This plan should be reviewed every five years and revised as needed to meet the needs of RMNP.

6.0 LITERATURE CITED

Bonham, C. D. 1989. Measurements for Terrestrial Vegetation. John Wiley & Sons. New York, NY.

Cotts, N.R., E.F. Redente, and R. Schiller. 1991. Restoration methods for abandoned roads at lower elevations in Grand Teton National Park. Wyoming. Arid Soil Research and Rehabilitation 5:235-249.

McLendon, T. and E.F. Redente. 1992a. Effects of nitrogen limitation on species replacement dynamics during early secondary succession. Oecologia 91:312-317.

McLendon, T. and E.F. Redente. 1992b. Role of nitrogen availability in the transition from annual-dominated to perennial-dominated seral communities. Proceedings of the Symposium on Ecology, Management, and Restoration of Intermountain Annual Rangeland. Intermountain Research Station. U.S. Forest Service. Ogden, Utah. Pp. 1-11.

Paschke, Mark W., Terry McLendon, and Edward F. Redente. 2000. Nitrogen availability and old-field succession in a shortgrass steppe. Ecosystems 3:144-158.

Redente, E.F. and T. McLendon. 1993. Hillside revegetation test plots for Bunker Hill Superfund Site. Annual progress report. Pintlar Corporation. Kellogg, Idaho.

Romme, W.H. and D.H. Knight. 1981. Fire frequency and subalpine forest succession along a topographic gradient in Wyoming. Ecology 62:319-326.

Tilman, D. 1990. Constraints and tradeoffs: toward a predictive theory of competition and succession. Oikos 58:3-15.

van Hulst, R. 1978. On the dynamics of vegetation: patterns of environmental and vegetational changes. Vegetatio 38:65075.

van Hulst, R. 1979. On the dynamics of vegetation: succession in model communities. Vegetatio 39:85-96.

Vitousek, P.M. and L.R. Walker. 1989. Biological invasion by *Myrica faya* in Hawaii: plant demography, nitrogen fixation, ecosystem effects. Ecological Monographs 59:247-265.

APPENDIX A

ADDITIONAL RESTORATION GUIDELINES

SITE PREPARATION

Site preparation activities initiate the restoration process and are essential to provide an environment that is conducive to plant establishment and plant community development. Site preparation can include both chemical and physical treatments that are a precursor to successful revegetation. The initial phase of preparation may include grading and shaping the disturbed area to restore topographical relationships, scarification to reduce compaction, topsoiling that renews the soil fertility status and initiates nutrient cycling processes, and the addition of amendments to improve soil physical and chemical properties.

Topographical Relationships

Restoration success in any disturbed setting will be dependent upon abiotic and biotic characteristics of the environment. The abiotic factors that can be readily influenced by restoration activities are soil and topographic conditions. Soil factors are important and should be considered because soil conditions will directly influence the rate and direction of plant community development. Topography interacts with macroclimate to produce the microclimate that influences both soil genesis and plant community development at any specific site.

Surface hydrologic characteristics are associated with macro and micro topographical variation. Disturbed sites are typically void of vegetation or dominated by unproductive stands of annual weeds. These sites are subject to overland flow and sediment transport, which often restricts vegetation development. On relatively level terrain, surface runoff is controlled by the infiltration rate of the soil surface. On steeper slopes and natural drainage ways, runoff is controlled by surface retention and depression storage characteristics of the soil surface.

Before planting on a disturbed site, preparations need to be made to create an environment suitable for plant establishment. Physical site preparation is often referred to as tillage. Tillage provides: 1) a favorable environment for germination and seedling growth, 2) weed control, 3) erosion control, and 4) soil water conservation. Tillage improves soil aeration, reduces runoff, increases infiltration, reduces compaction, and produces conditions for good seed contact with the soil.

There are primary and secondary tillage methods. Primary tillage methods affect the soil to a relatively deep depth and leave the surface rough. The two most common methods of primary tillage are ripping and chisel plowing. Secondary tillage methods affect the soil to a relatively shallow depth and are used to prepare the seedbed prior to planting. Secondary tillage reduces the roughness of the soil surface, removes weeds, and helps conserve water. The most common method of secondary tillage is dragging with a light weight disk or harrow.

Along with the tillage methods just described, site preparation can also include the manipulation of the soil surface to create small basins or depressions to reduce overland flow to control erosion and improve soil-water relationships for plant growth.

The grading associated with any construction activity results in uncontrolled water flow over bare areas. These areas are highly susceptible to soil loss resulting from erosional forces. It is imperative to minimize water flow over bare soil as the grading operations begin. Construction induced erosion can be reduced by increasing surface infiltration prior to plant establishment. Infiltration rate can be manipulated by grading slopes as flat as practical, using temporary mulches or soil binders, and by increasing surface roughness. Diverting water around the exposed site may be necessary to reduce soil erosion. Cut and fill slopes associated with road construction should be as shallow as possible because the potential for erosion is directly related to steepness and length of slopes.

Topsoil

Importance. Topsoil has been defined as the soil of the A and B horizons. Topsoil additions to disturbed lands usually provide plant propagules, soil microorganisms that are key to nutrient cycling and soil building processes, organic matter, and nutrients not usually present in subsoils.

Seedbed Relationships. Topsoil provides a seedbed that is generally more favorable for germination and plant growth especially when seeding operations will be used for propagule

introduction. A topsoiled area will usually enhance proper seed burial, ensure seed/soil contact, and ensure unrestricted root development, both physically and nutritionally.

Soil organic matter. Soil organic matter greatly influences the nutrient status and physical properties of most soils. Perhaps most importantly, organic matter serves as the carbon source supplying energy for microbial populations.

Disturbances can affect soil organic matter in several ways. The soil layer containing organic matter can be 1) removed by erosion, 2) buried by depositional processes or 3) become inactive by the removal of vegetation for an extended period of time. Reestablishing the organic matter layer thus becomes paramount in the restoration process. Topsoil additions supply soil organic matter which renews microbial activity and subsequently influences fertility and plant growth.

Soil organic matter enhances soil structure and subsequent infiltration of precipitation. The organic acids and stable humus substances act to bind soil particles into larger soil aggregates thereby creating more macropores which enhances water infiltration and percolation.

Microorganisms. Topsoil generally contains an important population of soil microorganisms. These microbes are responsible for decomposing plant and animal residues, supplying a source of CO_2 to plant roots, cycling nutrients from the atmosphere and soil organic matter, increasing moisture uptake, and influencing physical properties and development of the soil. Soils void of microorganisms tend to be unproductive and not capable of supporting a later successional plant community. Disturbance, in general, reduces microbiological activity and restoration practices which promote microbial recolonization will greatly enhance site recovery.

Mycorrhizal fungi are symbiotically associated with most plant species and they aid in the uptake of nutrients and water. It has been well documented that the absence of these fungi will restrict a plant community from progressing to a later successional stage. Disturbed areas which have been void of vegetation or dominated by certain early-seral species for long periods of time typically lose mycorrhizal populations. The fungi will eventually invade from surrounding intact communities, however this is dependent upon the size and intensity of the disturbance and the species composition of the surrounding community.

Topsoil can serve as a viable inoculum for mycorrhizal fungi, specifically and other microorganisms in general. A small application of topsoil (1-3 inches) to areas devoid of the essential microbes will have a great impact on the development of microbial populations and the subsequent development of plant communities that are self-sustaining.

Topsoil Manipulation. The potential benefits of topsoil reapplication depend on proper handling, storage, and reapplication of the topsoil. Topsoil removal and storage has received much attention due to its relative importance in the restoration process. Primary concern centers on the effect of these activities on microbial populations, viability of inherent seed propagules, and the impact on soil physical characteristics. Generally, topsoil removal and storage methods are based on the type of activity and the duration of the construction project. Immediate respreading of topsoil, or minimal storage time is desirable for any salvaged material. However, in cases where a longer storage time is required, methods have been developed to minimize adverse effects on the soil material.

The most conservative approach to topsoil handling and storage involves the windrow method. Topsoil windrowing can be used for relatively small disturbances occurring within restricted areas. The upper soil horizons (i.e topsoil versus subsoil) may be bladed or bulldozed into windrows in close proximity to the original disturbance. Soil handling is kept to a minimum and stored seed propagules are returned to the disturbed site, maintaining genetic integrity and ensuring a source of adapted plant materials to the disturbed site. The soil material can then be back-bladed over the disturbed area and prepared for seeding (if needed) following the completion of construction activities. If topsoil is properly saved and replaced after site preparation, often times, seeding or planting is not necessary except on steep slopes.

Immediate reapplication of topsoil to another prepared location is a second alternative. Large construction projects typically have various locations at different stages of completion. Removed topsoil can be reapplied directly to areas where construction activities have been completed. This method minimizes adverse impacts on microorganisms, inherent fertility, and soil physical characteristics. Every effort should be made to use soils from similar ecological conditions and avoid moving a soil from one ecological zone to another.

Surface mulching of existing vegetation prior to any method of topsoil removal can be an important process. A brush chopper can be used to incorporate vegetative and seed materials into the topsoil. This material serves as a potential source of nutrients as well as a source of plant propagules provided the vegetation was mulched at the appropriate time.

If salvaged topsoil is believed to contain a source of noxious weeds, it is critical that every effort be made to prevent the establishment of these plants. Although not enough is known about the potential negative effects of soil sterilization, if topsoil quantities infected with noxious weed propagules is small enough to sterilize, then the soil should be treated with a sterilization technique to kill the unwanted propagules. If this approach is not practical, the replaced topsoil should be managed for weed control by repeated cultivation, hand pulling, or using herbicides. The exact approach will depend upon the species of concern, restoration goals for the site, and Park policy relative to the use of chemicals.

In situations when topsoil must be stored, several techniques can be adopted to minimize the impact of disturbance. Topsoil stockpile depth should be minimized while retaining as much surface area as possible. Vegetation should be established to maintain microbial populations and associated nutrient cycles as well as organic matter levels where material will not be reapplied within twelve months. Vegetation establishment will also minimize erosional lose of soil material and nutrients. Upon reapplication, the active surface layer should be removed and applied as a source of inoculum. The soil material not occupied by roots and microbes should be placed beneath the active layer.

Soil Physical and Chemical Limitations

Soil Texture. Soil texture has a direct influence on such properties as infiltration, hydraulic conductivity, water-holding capacity, and cation exchange capacity. There is no optimum texture for all purposes and all plants because requirements vary greatly. But a growth medium with enough sand to allow for aeration and looseness to permit plant root growth and development and enough clay for adequate nutrient and water-holding capacity would be ideal for most situations.

Soils with a high percentage of clay size particles (less than 0.002 mm in diameter) have relatively high water-holding capacity and many available plant nutrients. These soils are harsh and hard when dry and sticky when wet. They are often poorly drained and aerated. In addition, some clay soils have a high shrink-swell potential that may be damaging to plant roots. Soils with a high percentage of sand size particles (0.5 to 2.0 mm) have relatively low water-holding capacity and limited plant available nutrients.

Restoring soils that are extreme in their texture is challenging because texture modification is not an easy task. Soil texture can be modified by mixing different textured materials together. This approach is not commonly used because of the problem of finding a suitable source of soil for mixing and the associated costs that are involved with transportation and mixing. Typically, the addition of an organic amendment to either sand, clay, or silt soils is effective in overcoming the physical limitations associated with texture. Organic matter additions to sandy soils will improve water-holding capacity, cation exchange capacity, and nutrient availability. Adding organic matter to clay soils will improve infiltration, drainage, and aeration and reduce the effect of crusting of the soil surface. Sources of organic matter include composted manure, leaves, weed free straw or hay, and saw dust or wood chips. The use of composted biosolids can also be considered if evaluated for presence of metals or other contaminants.

Soil Compaction. Soil compaction may be defined as the act of moving soil particles closer together by external forces. These forces range from natural ones, such as falling raindrops to unnatural forces such as motorized vehicle activity. A certain amount of compaction or firmness may be beneficial, such as to establish seed-soil contact for proper germination, but when compaction is excessive, it may result in deleterious effects to the soil and to the growth of plants.

The most common approach to alleviate problems associated with compaction is through physical manipulation of the soil by deep ripping, chiseling, or disking. Other approaches include the addition of amendments such as organic materials or chemical treatments such as gypsum. In RMNP, when restoring roads, or parking lots, reducing soil compaction to a depth of 24 inches has given the best results.

Aggregate Stability. Soil aggregates, composed of two or more cohering primary soil particles are the building blocks of soil structure. Both clay content and organic matter content are positively correlated with aggregation. A breakdown of aggregates by the disruptive forces of erosion, cultivation, and compaction results in the loss of structure, a reduction in infiltration, and crusting of the soil surface. If a soil has been compacted and also suffers from reduced aggregate stability, the use of ripping, chiseling, or disking may reduce bulk density but may not improve infiltration. The problem of reduced infiltration may need to be addressed by resolving the aggregate stability problem through the addition of organic matter or allow the problem to be resolved naturally through plant growth processes. As a plant community develops, root and shoot growth and decomposition will add organic matter to the soil and improve aggregate stability slowly over time.

Erosion. Erosion of disturbed lands, especially during the first few years following restoration can be a major factor limiting restoration success. There are two forms of erosion resulting from runoff. The first, sheet erosion, is a combination of raindrop dispersion and the movement of water in shallow layers more or less uniformly across the soil surface. The second is rill or gully erosion. It is the result of channelized flow of water into defined water courses. Factors that control erosion are soil physiochemical characteristics, vegetation cover, topography, and rainfall characteristics. The primary methods available to control erosion is through slope reduction, use of mulches during revegetation efforts, improving infiltration, and establishing an effective plant cover. Controlling erosion during the revegetation phase may be the most critical time for assuring restoration success.

Slope Angle and Exposure. The topography of a site, including slope angle, length of slope, and exposure may become a limiting factor to restoration success if these features are extreme. Steep slopes and long uninterrupted slopes are difficult to restore because of access, instability, and potential for erosion. In dry regions, slopes that are south and west facing are typically drier and more difficult to restore than north and east facing slopes because of lower soil water conditions and less soil development.

Where possible, slope angle and length of slope should be reduced as much as practicable when slopes exceed 33% and slope lengths exceed 100 feet. In RMNP, retaining walls and rock gabions have been used to successfully reduce the angle of repose on steep road shoulders allowing for successful revegetation projects.

Every effort should be made to conserve water on south and west exposures by improving infiltration and reducing evaporation. The use of mulches and physical manipulation of the soil surface to reduce runoff and concentrate water in depressions will aid in plant establishment.

Soil pH. The soil pH may influence nutrient absorption and plant growth in two ways: 1) through the direct effect of the hydrogen ion; or 2) indirectly, through its influence on nutrient availability and the presence of toxic ions. In most soils, the latter effect is of great significance. Although at extreme pH values the direct toxic effect of the hydrogen ion can be demonstrated, most plants are able to tolerate a wide range in the concentration of this ion so long as a proper balance of the other elements is maintained. Unfortunately, the availability of several of the essential nutrients is drastically affected by soil pH, as is the solubility of certain elements that are toxic to plant growth.

Several essential elements tend to become less available as the pH is raised from

5.0 to 8.0. Iron, manganese, and zinc are good examples. Molybdenum, on the other hand, is affected in the opposite way, being more available to plants at the higher pH levels. Phosphorus is never readily soluble in the soil, but it seems to be held with least tenacity in a pH range centering around 6.5. Phosphorus availability declines as pH increases from 7.0 to 8.5 and then increases at pH levels above 8.5. Generally, nitrogen availability is highest in soils with a pH in the 6 to 8 range and then decreases in the range of 8 to 9. Both nitrogen and phosphorus availability decrease at pH levels below 6.

At pH values below about 5.0, aluminum, iron, and manganese are often soluble in sufficient quantities to be toxic to the growth of some plants. At very high pH values, the bicarbonate ion is sometimes present in sufficient quantities to interfere with the normal uptake of other ions and thus is detrimental to optimum plant growth.

Microbial populations and processes are also influenced by pH. At soil pH values below 5.5, fungi are most active, but at pH values of 6.0 and higher, actinomycetes and bacteria are more prominent. The effect on populations of organisms in turn influences microbial processes that are important in nutrient cycling such as nitrification, mineralization, and nitrogen fixation.

An optimum pH range for plant reestablishment in RMNP is between 5.5 and 8.0. When soil pH falls below 5.5 or rises above 8.0 some investigation should be conducted to determine if soil amendments are needed to promote plant growth. Acidic soils can easily be treated with agricultural grade lime ($CaCO_3$) and alkaline soils can be effectively treated with elemental sulfur.

Soluble Salts. Saline soils are common features of arid and semiarid environments. These soils are associated with climates in which annual evapotranspiration greatly exceeds annual rainfall; therefore essentially no water percolates through the soil under normal conditions. The result is that, although the lack of water reduces the intensity of soil mineral weathering, the products of the weathering that do occur, for example, salts, tend to accumulate in the soil. Because water is the vector for salt, salt accumulation in soil commonly reflects the relief and geomorphological conditions of the area. Salt accumulation also results from high water tables, lack of drainage, or movement of water through saline geologic deposits.

A salinity hazard exists when there is sufficient soluble salt in a soil to interfere with the growth of desired vegetation (soil electrical conductivity (EC)$\geq$4.0 mmhos/cm). The major adverse effect of soil salinity is to reduce the availability of soil water to plants. Briefly, this is because the presence of salt in water increases the work that the plant must do to extract water from the soil solution. This work is referred to as the osmotic potential and is additive to the work required by the plant to extract water from a nonsaline soil solution (the matric potential). The sum of the two potentials, osmotic plus matric, is called the soil-water potential. Plant species have different abilities to make osmotic adjustments in the direction of maintaining a constant water potential gradient between the plant and the soil solution. Plants that are able to make the physiological changes associated with this adjustment and tolerate higher internal salt accumulations are plants considered to be salt tolerant.

Salinity-stressed plants exhibit no distinctive symptoms. The most common effect of salinity stress is a general reduction or stunting of plant growth. Under severe conditions, plant leaves may have a purple, dark-green color and a waxy appearance;

occasionally a white residue can be observed on the leaf surface. Salinity damage is most prevalent during germination and early seedling establishment.

At low to moderate salinity levels, fertilization can, to a limited degree, ameliorate the adverse effects of salinity. At the same time, some forms of fertilizer (e.g. most inorganic N fertilizers and chloride salts of K) have a relatively high salt index and may aggravate the salinity problem. The most common approaches to mitigating salinity problems are to add organic matter (e.g. straw or wood chips) to the soil to improve infiltration and natural leaching, irrigation to leach salts out of the root zone, and planting salt tolerant species.

Nutrient Limitations. Nitrogen (N) and phosphorus (P) deficiency on disturbed lands is generally one of the most limiting factors to restoration success. Nitrogen deficiencies result from either low levels of plant-available N created by a disturbance or a lack of microorganisms to convert various compounds to nitrogen forms used by plants. The reestablishment of an active biological cycle of N turnover is a key to restoration success on disturbed sites that have been severely impacted.

Phosphorus deficiencies occur primarily because of the insolubility of P and the fixation of P by clay minerals in the soil. When P is deficient, seedlings have a difficult time establishing because of a limited ability to access adequate amounts of P, due to restricted root development.

Nitrogen and phosphorus deficiencies can be overcome with inorganic or organic fertilizer. The primary concern is to limit the amount of N added because of the stimulation it causes in the growth of annuals, if annuals are a potential problem. Special attention needs to be given to formulating recommendations to fertilize with N. Soil tests should include analysis for total N, NO_3-N, and NH_4-N. The values from these results should be compared to soil N levels in undisturbed soils adjacent to the area to be restored. Nitrogen amendments should then be applied in very conservative amounts, if needed at all. Phosphorus is not known to stimulate weed growth and can be applied in more liberal amounts. Plant available P should be analyzed in the disturbed soil before making recommendations.

SEEDING RATES, PURE LIVE SEED, AND PLANTING METHODS

Seeding Rates. It is important to use enough seed to get a good stand, but not more than necessary. Too much seed may produce a stand of seedlings so thick that individual plants may compete with each other to the detriment of the majority of individuals. On the other hand, seeding rates that are too low will not provide adequate erosion control or competition against undesirable invading species.

The number of seeds placed in a unit area of soil is called the seeding rate. The total seeding rate is the sum of the individual species seeding rates. Seeding rates are normally expressed as the number of seeds per square foot or pounds per acre. Many different seeding rates for the same species can be found in the literature. The primary reason for these differences is that some rates are for monocultures and other rates are for diverse mixtures.

Seeding rates should be developed on the basis of number of seeds per unit area (e.g. number of seeds per square foot). Once this number is determined, then it can be converted to weight per unit area (e.g. pounds per acre). Since each species produces seed that weighs a different amount, the development of seeding rates based purely on weight per unit area will produce erroneous rates that will tend to over emphasize small seeded species and under-emphasize large seeded species. For example, blue grama seed is typically about 700,000 seeds per pound, while Indian ricegrass is 175,000 seeds per pound. If seeding rates were calculated simply on the basis of weight per unit area, without recognizing the fact that a pound of blue grama seed has four times the number of seeds per pound as Indian ricegrass, it would be very easy to over plant blue grama and under plant Indian ricegrass.

Seeding rate may be calculated from an expected field emergence for each species and the desired number of plants per unit area. For purposes of calculation, field emergence for small seeded grasses and forbs is assumed to be around 50% if germination is greater than 80%. Field emergence is assumed to be around 30% if germination is between 60 and 80%. The Natural Resource Conservation Service recommends a seeding rate of 20 to 30 pure live seeds per square foot as a minimum number of seeds when drill seeding in areas with an annual precipitation between 6 and 18 inches. Twenty pure live seeds per square foot, with an expected field emergence of 50% should produce an adequate number of plants on the seeded area to control erosion and suppress annual invasion. This seeding rate is primarily for favorable growing conditions such as a weed free seedbed, soils that are not extreme in texture, gentle slopes, north or east facing aspect, good moisture, and adequate soil nutrients. When conditions are less favorable or when the seed is broadcast (either by hand or hydroseeding), seeding rates should be increased up to a level that is two times the drill rate for favorable conditions. In areas receiving annual precipitation of 19 to 30 inches (typical for RMNP), the recommended drill seeding rate is 30 to 40 seeds per square foot (60 to 80 seeds per square foot if broadcast seeding) and 40 to 60 seeds per square foot (80 to 120 seeds per square foot if broadcast seeding) in areas receiving more than 30 inches of annual precipitation. The conventional thinking is that higher precipitation zones can support denser vegetation and should therefore be seeded at higher rates.

When determining the seeding rates of specific species in a mixture there are several factors that need to be considered. The first relates to the composition of the desired community. If the desired community is a shrubland or a shortgrass steppe dominated by warm season grasses, then the seeding rate needs to reflect this composition. Unfortunately, there are no simple recipes available to combine species to achieve a particular outcome. Most seeding rates for mixtures of plants are based on years of experience or specific experimentation with a specific set of species in a specific environment.

Pure Live Seed. Each State has a seed certifying agency and certification programs may be adopted by seed growers. Certification of a container of seed assures the customer that the seed is correctly identified and genetically pure. The State agency responsible for seed certification sets minimum standards for mechanical purity and germination for each species of seed. When certified, a container of seed must be labeled as to origin, germination percentage, date of the germination test, percentage of pure seed (by weight), other crop and weed seeds, and inert material. The certification is the consumer's best guarantee that the seed being purchased meets minimum standards and the quality specified.

When developing seed mixtures and when purchasing seed, the designation of <u>pure live seed</u> (PLS) must always be used. Percent pure live seed is expressed as follows:

$$\%PLS = \frac{\%\ Germination \times \%\ Purity}{100}$$

In the above equation, percent germination is the percent of the seeds in a unit weight that are viable (i.e. seed produces a shoot and root when tested) and purity is 100 minus the percent trash plus the percent weed seed.

Sample Problem

1. Seed a 50:50 mixture of Indian ricegrass and western wheatgrass at 20 PLS/square foot.

2. How many pounds per acre of each species would be required given the following information?

Species	Seeds/lb	%Germination	%Purity
Indian ricegrass	175,000	50	90
Western wheatgrass	250,000	70	85

Calculations:

Species	%PLS	Lbs PLS/A	Lbs Bulk Seed/A
Indian ricegrass	45	2.49	5.53
Western wheatgrass	60	1.74	2.90

$$\text{Lbs PLS/A} = \frac{(\text{\# seeds/square foot})(\text{square feet/A})}{\text{\# seeds/lb}}$$

$$\text{Lbs Bulk Seed/A} = \frac{1}{\text{PLS}} \times \frac{\text{lbs PLS}}{\text{acre}}$$

Seeding. The primary concern of seeding is to place the seed in the soil at the depth most favorable for its germination and establishment. The optimum depth of seed placement differs for each species, but in general, the smaller the seed the more shallow the placement in the soil and the larger the seed the deeper the placement. This general rule of thumb is directly linked to the amount of food reserves the seed contains to produce a coleoptile that is long enough to penetrate the soil surface. In addition, light stimulates germination of some species and darkness is needed for others. Because of the specific requirements that each species has, one planting depth or seeding technique may not be optimum for all the species being planted in a mixture.

Drill Seeding. Drill seeding uses an implement that places the seed at a specified depth in the soil. Since location of the seed in the soil profile should optimize its potential for contact with water, seeding depth will vary with soil water holding capacity, soil texture, site exposure, and other aspects that influence soil moisture. Drills should be set at deeper depths in light sandy soils or on southern exposures. On finer textured soils, high moisture conditions, or northern exposures, drills should be set at shallower depths.

Very small seed or seed with seed coats that are smooth will quickly move to the bottom of the seed box during the drilling operation. These kinds of seed should be placed in separate boxes to achieve a more uniform distribution. Fuzzy or hairy seeds or seeds with long awns will form large bunches that interfere with the movement of seed into the seed tubes. This problem can be overcome by adding a carrier to the seed mixture (e.g. rice hulls, ground corn cobs, or even sand) to improve the flow of seed from the seed box to the seed tubes. It is important to work with experienced applicators and to use equipment designed to properly apply native seed.

Broadcast Seeding. Any method of seed dispersal which drops seed upon the ground and does not place it in the soil is referred to as broadcast seeding. Broadcast seeding is the most commonly used seeding method in RMNP. Since the seed is deposited on the soil surface and not placed in the soil, some sort of device (e.g. harrow, chain) is pulled over the site after seeding to cover the seed with soil.

Centrifugal type broadcasters, also called end gate seeders, are commonly used for broadcast seeding. These broadcasters generally have an effective spreading width of about 20 to 40 feet.

Hydroseeding is a form of broadcast seeding in which the seed is dispersed in water under pressure. If this technique is used, seed should not be combined with hydromulch or any other type of tackifier because the seed will be suspended above the soil and will become desiccated as the mulch or tackifier dries. The only exception to this rule is in areas where precipitation is abundant and the probability of extended periods (2 to 3 weeks) of rainfall are high.

Aerial seeding is the dispersal of seed by fixed wing aircraft or helicopter. If properly conducted, this is a very efficient way to broadcast seed large areas, steep slopes, or areas inaccessible to ground transportation.

Seeding Nitrogen Fixing Species. Nitrogen fixing plant species (i.e. those plants living in a symbiotic relationship with either the bacteria *Rhizobium* [leguminous plants] or *Frankia* [actinorhizal plants]) are often included in seed mixtures to improve the nitrogen status of the soil and to add diversity to the plant community. Examples of native legumes that would potentially be used in RMNP include *Thermopsis divaricarpa*, *Astragalus adsurgens*, and *Astragalus flexuosus*; while native actinorhizal plants include species in the genera of *Purshia*, *Cercocarpus*, *Ceanothus*, and *Alnus*. These species need host specific bacteria present in order to establish a symbiotic relationship. When planting legumes, a commercial inoculum should be considered to ensure that the proper *Rhizobium* species is present. There are no commercial sources of *Frankia* or crushed nodules, so topsoil would be the only reliable source of this filamentous bacteria for potential inoclulation. Topsoil would also be a reliable source of *Rhizobia* when native legumes are being planted. When dry seeding, *Rhizobia* can be mixed with lightly moistened seed just before planting, if needed. Moistening the seed with sugar mixed with water helps bond the inoculum to the seed and extends the longevity of the *Rhizobia*. When seeding with a hydroseeder, the inoculant can be added to the slurry just before spreading. If fertilizer is added to the slurry there may be a concern with the generation of acid conditions in the slurry and potential mortality of the bacteria. The pH of the slurry should never be allowed to drop below 5.0 when *Rhizobium* is present. Inoculum should be stored in a cool location and should not be used if the expiration date on the package has passed.

Season of Seeding. The time of seeding or planting is influenced by such factors as climate and seasonal weather patterns, seasonal growth patterns and moisture requirements of the planted species. Usually the best times for planting precede or coincide with periods of precipitation that are of sufficient duration to allow the planted vegetation to become established.

Late fall seedings are common and are referred to as dormant fall seedings. Seed is placed in the ground as late in the season as possible. The seed undergoes vernalization in the soil and is ready to germinate when temperature and moisture conditions are optimum in the spring. In general, cool season species tend to perform better when planted in the fall and warm season species tend to do better when planted in the spring or summer, depending upon the region. This response is true because cool season species experience their greatest growth during the cool spring months and warm season species grow best during the warmer summer months. Weather conditions in the spring tend to be more unpredictable than in the fall for most areas and this adds some problems with respect to scheduling the seeding activity.

Planting Whole Plants. Whole plants or plant parts may be transplanted. Whole plants can be transplanted as bareroot stock, container grown stock, or as wildings (i.e. plants excavated from their natural setting and transplanted to the disturbed environment). Bareroot stock are grown in a protected or enclosed area. When the plants reach a predetermined size, they are hardened by reducing moisture, temperature, nutrients, and day length. During the hardening period, plants increase their carbohydrate reserves and go dormant. Once the plants are dormant, they are removed from the growth medium, stems and roots are trimmed, and the plants are packaged. These plants are then held in a cool, dark, moist environment until transplanted. The success of bareroot stock depends on keeping the plants inactive until planted and minimizing water stress when planted in the field. In addition, the success of bareroot material is dependent on root structure, carbohydrate reserves, and the presence of feeder (small) roots.

Containerized stock are grown in a greenhouse in some sort of container. These plants are encouraged to grow very rapidly and care should be exercised when growing plants in the Park's greenhouse or when purchasing these materials to make sure that good root development has occurred. Containerized stock are normally actively growing when purchased and transplanted so the season of planting is a primary concern to prevent frost damage. Containerized material can be hardened before transplanting to extend the planting season. There may be a risk when planting containerized or bareroot stock early or late season because of needle ice formation and heaving of plants out of the soil. If this problem is suspected to exist, it may be necessary to protect plant material with mats or insulated blankets when first planted to allow plant material to develop roots into adjacent soil. Care must be taken to keep the plants under the mats or blankets adequately watered to prevent desiccation.

Wildings are excavated from their natural setting and transplanted to the degraded site. Both trees and shrubs have been successfully moved by this technique and plants that sprout from roots or underground stems seem to do best with this approach. Above ground shoots should be pruned before transplanting to reduce transpiration and water stress on the plants. Wildings guarantee that genetic diversity is maintained and provide instant cover and food for wildlife species.

Planting Plant Parts. Cuttings, root pads, or sprigging are techniques for establishing grasses, shrubs, and trees. Cuttings consist of woody roots or pieces of stems that include nodes. Stem and root buds develop from the meristematic tissue in the root or at the plant nodes and grow into complete plants. It is common to treat the cuttings with a growth hormone to stimulate root development.

Root pads and sprigging are techniques for grass, forb, and shrub transplanting. Species that are root sprouting or rhizomatous are best suited for this approach. Equipment is available for lifting the root systems of plants following a close trimming of shoots to ground level. These sprigs are then spread over the site to be restored and covered with soil and lightly compacted. Root pads can be excavated with a dryland sodder that is described in the section under restoration equipment.

Materials established from cuttings and bareroot materials tend to be less tolerant of site-specific stress than are those established from container stock. Site conditions such as higher elevation (8,000 feet plus), salinity, alkalinity, high/low pH, etc. as well as high degrees of predation can negatively impact cutting-derived and bareroot materials due to the reduced degree of resiliency in comparison to container stock.

FERTILIZATION

Nutrients are found in the soil in different pools. Part of the total soil nutrient pool is readily available to plants. This available pool is found in soil solution. A second portion of the total nutrient content of a soil is complexed in one form or another and slowly becomes available to the plant. These nutrients may be in organic form or on cation exchange sites. The third, and usually the largest soil nutrient pool, is insoluble and not available to plants. Only as soil minerals weather does this insoluble portion of the soil nutrient supply move into one of the other pools. Fertilizers are usually added to soils as additions to the available pool or to that pool of nutrients that is slowly becoming available.

Nitrogen. Nitrogen (N) is typically the most limiting nutrient in disturbed soils. If plant available forms of N (NO_3-N and NH_4-N) are deficient, the effect on plant growth will be seen within the first couple weeks after a seedling has emerged. It is relatively easy to overcome N deficiency during the short term. Inorganic forms of N, such as ammonium nitrate, are readily available to plants and can be applied to the soil surface and allow natural leaching to move the nutrient into the root zone. However, because N is so highly mobile, it can be lost to the system by leaching below the root zone or may be lost through natural processes such as volatilization and denitrification. Nitrogen applied as inorganic fertilizer can be applied just prior to seeding or after initial emergence. In high precipitation regions, where the potential for leaching is great, nitrogen should be applied either just before or just after plant growth is to occur. If nitrogen is applied in an organic form or if applied with a wood waste product, the nitrogen should be mixed into the rooting zone prior to planting.

Providing a long-term source of N is more difficult and must include a source of organic matter. Using topsoil with organic matter and a healthy microbial population is the best method available for providing a long-term source of N. However, if topsoil is not available, the next best approach is to add composted manure or wood waste (e.g. wood chips) in combination with inorganic nitrogen. The soil microbial community will decompose the wood waste material and immobilize N from the fertilizer during the process. This N will then be released slowly through the process of mineralization. Approximately 10 lbs of N should be added for each ton of wood waste applied. The establishment of N fixing plants should also be considered as another source of N that will have long-term benefits. Another source of organic matter that would be a good source of nitrogen (and other nutrients) is the commercial product of Biosol®. This material has been used in RMNP and other parks with success.

Nitrogen fertilization has been shown to stimulate the establishment and growth of annual species. It has also been shown to reduce species diversity by favoring rapid growing early seral species which competitively displace slower growing late seral plants. Because of these effects, caution must be used when fertilizing with N.

Phosphorus. Phosphorus (P) is most likely the second most limiting nutrient on disturbed lands. If P is limiting, it will be very difficult for most perennial seedlings to establish because of limited root development. Phosphorus is a highly immobile element and does not leach in the soil. In order for a plant to access P, it must come into contact with labile forms of P through root growth or limited P diffusion. Since young seedlings have very limited root development, growth on P deficient soils will be difficult.

Phosphorus fertilizer is commonly applied in an inorganic form such as triple super phosphate (0-46-0). Because of its immobility, it must be incorporated into the root zone prior to planting, for maximum effectiveness. Phosphorus can be added to the soil in large amounts to provide a long-term source of P without fear of loss due to leaching. However, P will become fixed to clay particles over time or incorporated into organic matter, thus reducing its availability until the soil particle weathers or the organic material is mineralized.

Potassium. The final nutrient that will be discussed is potassium (K). Potassium tends to be limited on coarse textured soils but its deficiency is not as common as N or P. The mobility of K is less than N but greater than P. In most soils the loss of K to leaching is not a concern except in sandy soils or soils subject to flooding

One of the more common forms of K that can be commercially purchased is potassium chloride. This product is sold under the commercial term muriate of potash and contains about 60% K_2O. Potassium is most effective when incorporated into the root zone prior to seeding, but it will slowly move into the soil if surface applied after plant growth has begun.

Fertilizer Calculations. Of the three numbers printed on a fertilizer container, the first represents the percent N, the second is percent P_2O_5 (phosphorus pentoxide), and the third is percent K_2O (potassium oxide). A fertilizer bag with the formula "20-10-5" indicates that the mixture contains 20% nitrogen, 10% P_2O_5, and 5% K_2O. Nitrogen is calculated as a straight percentage. In other words, a 100 pound bag of 33-0-0 contains 33 pounds of N.

Phosphorus, however, is calculated differently. A 100 bag of 0-46-0 is 46 pounds of P_2O_5. The formula for calculating the percent P is $\%P_2O_5$ X 0.43. Therefore, the 100 pound bag of 0-46-0 contains 20 pounds of P (.46 X .43 = 20%; 20% of 100 = 20). A 100 pound bag of 0-0-35 contains 35 percent K_2O. Percent K is calculated by multiplying %K_2O times 0.83. Therefore, in this example, .35 X .83 = 29% K. This bag of fertilizer therefore has 29 lbs of K.

MULCHING

A mulch is non-living material placed or left on or near the soil surface for the purpose of protecting it from erosion or protecting plants from heat, cold, or drought. Mulches are used primarily to control wind and water erosion, facilitate infiltration, reduce evaporation, and moderate soil temperature. By fulfilling all of these objectives, the use of a mulch should improve overall germination and seedling establishment. One point that should be recognized is that the use of a mulch may not always be essential for controlling erosion or improving germination and establishment. There are many studies in the literature that report no differences in soil loss and plant establishment between treatments mulched and not mulched. Therefore, it is important that specific site conditions be examined before deciding on whether a mulch is needed. In general, if slopes are steep, if soils are highly erodible, if soil moisture is going to be limiting to plant establishment, if high winds are a common occurrence, if needle ice or soil crusting is a problem, then a mulch should be used. Selection of the appropriate mulch and application technique are critical to overall success.

Straw. Straw is one of the most common mulches used. It consists of stems of cereal grains such as wheat, barley, or oats. Application rates are normally about 2 tons/acre. It is critical that the stems be as long as possible (65% by weight should be 10 inches or longer) to increase its life expectancy as a mulch and to improve its effectiveness when crimped. Straw mulch may commonly contain seed of the parent crop or noxious weeds. Care should be exercised when selecting a mulch to make sure that seed content is minimal and the grain will not readily volunteer on the site. Colorado has a certified weed free hay program and only certified weed free straw is used in RMNP. However, it is important to note that even weed free straw may have exotic species (e.g. Timothy, red top, alfalfa) present and seed of these species may be introduced into the Park when using a certified mulch.

Straw can be spread by hand over small areas or with a pneumatic blower for large areas. The mulch must be secured in place to prevent loss due to high winds or overland flow of water. Straw mulch can be anchored to the soil by crimping. A crimper is a machine that pushes part of the straw into the soil and the remaining portion protrudes from the soil and acts like stubble. This stubble shades the ground, reduces wind velocity at the soil surface, and improves infiltration. Straw can also be secured in place with the use of tackifiers that are sprayed on top of the mulch or with plastic netting that is placed over the straw and secured in place with large metal staples.

Native Hay. Native hay is very similar to straw in its effectiveness, its application procedure, and in methods of anchoring the material in place. One advantage that native hay has over straw is that the stems of hay are usually longer and this results in longer mulch life and better results from crimping. Native hay will also contain large amounts of seed that may or may not be desirable depending upon the species composition of the hay and the presence of weedy species. If the species are desirable, then a native hay can result in an increased diversity of the established community.

Hydromulching. Hydromulching is the application of a wood fiber or paper mulch in a water slurry, using a specialized machine known as a hydromulcher or hydroseeder. This type of mulch is most effective on steep slopes were access is limited or where crimping straw or hay is not possible. Mulch that is manufactured from alder and aspen fibers is the best material for hydromulching because the longer fibers create an effective mat that adheres to the soil and is fairly resistant to wind and water erosion. Mulch that is manufactured from corrugated boxes or other recycled paper products is not as effective as wood fiber.

Hydromulch should be applied at a rate of approximately 1.5 tons/acre and a tackifier can be added to the mulch to improve its adherence to the soil. In addition, a hydromulcher/hydroseeder can be used to apply seed, fertilizer, and mulch separately or in any combination. Combining these materials into one operation is not recommended unless the probability of adequate precipitation is high. It is important that a Park employee remain on site with potential contractors to ensure that seeding and mulching occur as two separate steps. Applying fertilizer and seed is not recommended because fertilizer (especially N) can reduce the germination of seed by creating a salt effect and thus reducing water absorption by the seed.

Wood Residues. This category of mulch includes such things as wood chips, sawdust, or bark fragments. These products make an excellent mulch and are inexpensive if a local source can be found. The application rate for wood residues is usually about 2 to 6 times the application rate of straw or hay. These materials can be spread by hand over small areas or with pneumatic blowers over large areas. Wood residues are longer lasting than all other mulches except a gravel mulch. One limitation in using wood residues is that they are not effective on sloping terrain because they will wash off a site with any overland flow. Therefore their use should be restricted to flat or gently sloping areas. If wood residue is left on the soil surface there is little concern about nitrogen immobilization. However, if the mulch is incorporated into the soil then additional N should be added to compensate for the N that will be immobilized by microbial activity during decomposition. Approximately 10 pounds of N/acre should be added per 1 ton/acre of wood residue mixed into the soil.

Fabrics and Mats. There are many erosion control blankets available on the commercial market. The two most effective mulches in this category are jute netting and excelsior mat (a core of straw or wood fiber surrounded by two layers of plastic netting). Both are produced in large rolls that are simply rolled onto the site and secured in place with metal staples. During application of these mulches there are two general rules to follow: 1) there must be good contact between the mulch and the soil and 2) make every effort to secure the edges of the mulch to the soil to prevent strong winds from lifting the mat from the soil surface. Erosion control blankets are expensive and their use should be limited to sites with high erosion potential.

APPENDIX B

RMNP FORMS AND PROCEDURES

Revegetation Assessment
Rocky Mountain National Park

General Location:
Description of Activity:

___

Project Manager: ___
Size of Disturbed Area: ___
Time Schedule: (construction) ___
(revegetation) ___
UTM's: N- ___ **E-** ___

Native Species Present **Exotic Species Present**

Condition of Soil:
Depth of Top Soil

Revegetation Strategy:

Prepared By: ___ **Date:** ___

GO-NO-GO CHECKLIST
FOR DECIDING
PASSIVE VERSUS ACTIVE VEGETATION RESTORATION

Last Revised 11/05/2002

Disturbed site location ______________________________________

Date assessment was made ___________________________________

Person doing the assessment _________________________________

Square meters of disturbed area _______________________________

Include picture(s) of disturbed site

Based on current or expected conditions at the disturbed site:

1. Will or is the disturbed site ecologically appropriate for the area? ___

2. Does it or will it resemble an early seral, mid or late seral condition for an undisturbed community growing under similar environmental conditions? ___

3. Will the disturbed site preserve natural interactions between individuals growing both on the site and adjacent to the site, including genetic integrity? ____

4. Are there **no** exotics on the disturbed or nearby the disturbed site that could impede revegetation? ___

If you answer no, list the exotic species and highlight the ones that are on the park's species of special concern list.

_____________________ _____________________ _____________________

_____________________ _____________________ _____________________

_____________________ _____________________ _____________________

5. Is the disturbed area not adjacent or nearby (<50 m) a trail, destination area or backcountry campsite? ____

6. Are there **no** rare native plants in the vicinity that might be threatened by active vegetation restoration? _____

7. Can recreational use be controlled to allow adequate time for the site to restore to natural conditions? ______

8. Is the disturbed site **not** in a highly visual area? ______

9. Is topsoil, natural soil compaction and soil microbes still intact? _____

10. Is the site stable with no active unnatural soil erosion occurring? Unnatural is defined as any erosion caused by humans or animals due to human influences. ______

11. In your opinion, can the site restore itself naturally without active restoration? ______

If questions 4, 9, or 10 is answered no, in your opinion can corrections be made without active vegetation restoration? ____

If all questions have been answered "yes" passive vegetation restoration is recommended with the understanding that complete restoration may take 100 or more years.

If more than one question is **NO**, active restoration by developing and planting native vegetation maybe necessary with an emphasis on local genotypes.

Recommended Course of Action ____________________________________

__________________________________ ________________________
Project Coordinator Date

Will a ROMO Project Proposal Form (ROMO-178) be necessary? _______

If action is active vegetation restoration, list the species and recommend as follows: only seed collection (PLS needed), seed collection and germination for containerized plants (# of containerized plants), propagation (# of containerized plants).

__________________________________ __________________________________

__________________________________ __________________________________

__________________________________ __________________________________

__________________________________ __________________________________

__________________________________ __________________________________

__________________________________ __________________________________

Refer to Class I, II, or III area descriptions and genetic guideline document for further information.

CONSTRUCTION STIPULATIONS
for
NATURAL RESOURCE PRESERVATION
ROCKY MOUNTAIN NATIONAL PARK, COLORADO
(Revised May 7, 2003)

The undersigned NPS personnel, contractor or subcontractor agree to abide by the attached construction stipulations when working within the boundaries of Rocky Mountain National Park.

____

Project Title

______________________________ ________________

(Sub) Contractor Date

Project Approved:

______________________________ ________________

Natural Resources Specialist or Biologist Date

______________________________ ________________

Facilities Management Division Representative Date

Construction Stipulations Checklist
for
Natural Resource Preservation

Purpose

The enabling legislation for Rocky Mountain National Park and National Park Service (NPS) Management Policies require park managers to preserve natural conditions within the park. These construction stipulations have a threefold purpose:

- to protect the natural environment and preserve natural conditions
- to reduce the cost of restoration and revegetation once a project is completed
- to reduce the cost of invasive exotic plant control

These stipulations should be used as a guideline for minimizing impacts caused by ground-disturbing projects. Each project should be reviewed on an individual basis and stricter stipulations may be necessary in sensitive locations. Ground disturbing projects may require a vegetation restoration plan that identifies the type of restoration that will be done once construction is complete. The Division of Resources Management and Research in cooperation with other divisions usually writes the restoration plan.

Checklist

Check all items that apply to this project

Implementation

☐ The Contractor shall take every precaution and make every effort to protect the delicate environment of Rocky Mountain National Park.

☐ Construction stipulations will be incorporated in the contract documents.

☐ A performance bond will be required to cover all portions of the contract, including vegetation restoration.

☐ A one-year warranty will be required for all seeding or planting of vegetation.

☐ The project budget includes sufficient funds to cover the cost of all restoration work.

☐ To the degree possible, the project will be planned to maximize the survivability of salvaged trees and shrubs. Plant salvage will occur in early spring or late fall/early winter during dormancy.

☐ Ample lead time (as much as one year or more) will be provided for seed collection and propagation of plants for vegetation restoration.

- [ ] Reseeding will be scheduled in the fall or spring when soil temperature reaches 50 degrees.

Construction Limits:

- [ ] The construction area limits will be clearly defined, fenced, flagged or somehow delineated to keep ground disturbance to a minimum. Any deviation from the approved area of disturbance must be approved by the signatories to this document.

- [ ] Construction equipment will be kept within the construction limits to protect adjacent undisturbed vegetation. Under no circumstance will any vehicle be allowed outside the construction limits.

- [ ] Turning areas for hauling vehicles shall be approved by the Project Manager.

- [ ] Areas to be used for parking and stockpiling material are strictly controlled and will require approval of the Project Manager prior to their use by the Contractor.

Equipment

- [ ] Rubber-tired vehicles will be used unless specific approval for tracked vehicles has been granted by the Project Manager.

- [ ] Equipment will be refueled on an existing road or parking lot.

- [ ] Construction equipment not being used shall be parked out of the traveled way of roads and trails and within the construction limits.

- [ ] All earth-moving equipment (excluding hauling vehicles) shall be cleaned of mud, plant materials and weed seed prior to entering the National Park. Hauling vehicles shall meet the same requirement before their initial entrance into the park; subsequent entries will not require cleaning unless ordered by the Project Manager.

- [ ] Solvents used to clean pavers, tools, etc., shall be carefully used, completely contained at the work site, and satisfactorily cleaned up as may be required.

Clearing and Grubbing

- [ ] Selected snags 4 to 12 inches dbh shall be salvaged and stockpiled in designated storage areas for subsequent placement on the completed slopes. The trees and snags shall be cut into random lengths from 8 to 30 feet and shall be limbed on one side. Sound snags and dead trees are preferred over live trees.

- [ ] Surface boulders that will remain on the site following construction shall be carefully stockpiled to protect natural lichen growth. Boulders will be replaced in their natural position (i.e., partially buried with lichen facing up, etc.).

- [ ] Trees larger than 12 inches dbh and trees from 4 to 12 inches dbh not designated for salvaging and stockpiling shall become the property of the contractor and shall be removed from the park. Trees less than 4 inches dbh and over 3 feet in height shall be disposed of outside the park.

- [ ] Grubbing of stumps shall be accomplished in such a manner as to conserve topsoil material. Non-conventional methods will be required to remove stumps in order to conserve topsoil without contaminating the material with underlying inorganic soils. Pushing trees over with heavy equipment or performing grubbing operations shall not be permitted until topsoil is conserved.

- [ ] If stumps are to be left in place, trees should be flush cut to ground level. Designated trees and snags once cut shall be removed in such a manner as to minimize damage to adjacent trees and vegetation.

- [ ] Furrows created by dragging larger timber away for disposal shall be hand raked to blend with finished grade.

- [ ] Burning of debris within the park will not be permitted. All debris and left over construction materials shall be removed from the park and disposed of in accordance with applicable local, State, and Federal regulations.

Excavation

- [ ] If excavation and/or grading is required for ditches, foundations, road construction, etc., the topsoil shall be salvaged and stored in a separate location (refer to next section). Topsoil refers to the uppermost soil horizon, and natural humus bearing soils, duff, and vegetable matter. The depth of topsoil in the park varies and must be evaluated for each project to determine how much of the topsoil should be saved. As a rule, the depth of topsoil in the park is about the first six inches of soil.

- [ ] Trees and shrubs are to be avoided if possible during trenching or excavation.

- [ ] Any excavated boulders, subsoil or topsoil that will not be needed for the project are to be removed as soon as possible to minimize damage to underlying vegetation.

Topsoil Salvage

- [ ] Salvaged topsoil will be separated from the sub-soil and stored in piles no higher than three feet and three feet wide. If possible, the soil will be stockpiled in a disturbed area to minimize the impact to adjacent vegetation.

- [ ] If the topsoil is to be stockpiled for several months or longer, it should be planted in a cover crop as specified by the Biologist or Natural Resource Specialist.

- [ ] A minimum of 2 inches of material shall be conserved in all cases, and a depth of 12 inches of material is possible in some locations. Live vegetation less than 3 feet in height and limbs less than 1 inch in diameter may be incorporated as topsoil in the stockpiles. Conserved topsoil shall consist of natural humus bearing soils, duff, and vegetable mater obtained from the overlying portions of the roadway excavation and embankment areas.

- [ ] Due to the limited amount of material available for topsoil and the need to establish the best growing medium possible for revegetation, non-conventional methods will be required to excavate, stockpile, and place the conserved material. Equipment capable of excavating small, isolated pockets of soil; removing stumps as required; and placing material on slopes and in pockets on rock ledges will be required to perform the work.

Vegetation Salvage

- [ ] A representative from the Division of Resources Management and Research shall clearly identify all plant materials (trees, shrubs, grasses and forbs) to be salvaged prior to the start of construction.

- [ ] A representative from the Division of Resources Management and Research shall clearly identify all plant materials to be transplanted outside the zone of disturbance.

- [ ] Antelope bitterbrush is a plant species of special concern. If antelope bitterbrush is present at the project site, the goal of plant salvage and revegetation is no net loss of this shrub.

- [ ] When salvaging trees and shrubs, as much soil as possible shall be preserved around the roots. Root balls from salvaged trees and shrubs will either be placed in containers or wrapped in burlap. The plants must be watered to keep the soil moist until they are replanted.

- [ ] Trees, shrubs and other containerized plants will be watered during the first growing season.

☐ If sod will be salvaged at the project site, the sod can be stripped with a backhoe, sod cutter or spade. Ground disturbing projects in the alpine tundra should salvage all sod.

- ☐ If sod is to be replaced within five (5) days it can placed on canvas burlap and stored at the construction site. The sod should be watered and covered to prevent the vegetation from drying out. During hot, dry weather, the salvaged sod must be watered every day.

- ☐ Sod that cannot be replanted within five days must be placed into wooden flats lined with three inches of vermiculite and peat and watered daily. These flats would have to be watered daily.

Rough Grading

☐ A balance is to be achieved between these competing and equal considerations: (a) the creation of steep cuts and fills to minimize the amount of disturbance, and (b) the creation of flatter cuts and fills to minimize erosion and promote the reestablishment of vegetative cover.

☐ Subsoil is to be compacted to avoid settling.

Finish Grading

☐ Once construction is complete, the natural contour of the land is to be restored to the degree possible. Slopes shall simulate the irregularity of the existing terrain.

☐ Abrupt angles are to be avoided at the top, toe and ends of newly formed slopes. The top, toe and ends of the slope are to blend in with natural contours.

☐ All earth and rock slopes shall be left with a roughened surface as they are being constructed.

Cut Slopes

- ☐ Boulders firmly in place and protruding from cut slopes shall be left undisturbed.

- ☐ All cut slopes shall be sculpted to irregular surfaces preserving segments of large rock outcrops leaving staggered, irregular ledges, shelves, and outcrops with jagged edge appearance and planting pockets suitable for placement of topsoil and plants.

Fill Slopes

- [ ] Fill slopes shall be graded to provide an irregular surface with staggered ridges steeper than the nominal slope ratio, staggered ledges, planting pockets, and large boulders exposed above the nominal fill slope.

- [ ] Where shown on the plans or directed by park staff, additional material shall be incorporated into the fill slopes to obtain additional blending into the natural terrain and to develop areas for planting.

- [ ] Any soil that has been over-compacted by traffic or equipment, especially when wet, will be tilled to break up rooting restrictive layers, and then harrowed, rolled or packed to prepare the required firm seedbed.

Imported aggregate and soil

- [ ] All material sources used in the production of aggregates require archaeological clearance by a state or federal agency. The Contractor shall furnish written proof of archaeological clearance before transporting any aggregate into the park.

- [ ] All material sources require clearance for exotic plants. The Contractor shall notify the Project Manager of the sources(s) proposed for use at least 1 month before beginning operations. The source(s) will be investigated for exotic plants during the period. If exotics are present, the investigator will determine if the upper portion of the source is to be stripped or the exotics sprayed with an herbicide. When an herbicide is required, a licensed applicator shall apply the spray. An agronomist's certification that the source(s) is free from exotic plants may be substituted for the above requirements.

Placement of Topsoil

- [ ] Prior to placement of topsoil, prepare the areas as follows.
  (a) Slope ratios of 3:1 should be scarified to a nominal depth of 4 inches. Disking or scarification shall be done in a direction perpendicular to the natural flow of water.
  (b) Slopes steeper than 3:1 shall be prepared as directed by the Project Manager.

- [ ] Conserved topsoil shall be spread a minimum of 2 inches in depth, loose measurement, over all disturbed soil areas. Topsoil is to be replaced without compacting the soil.

- [ ] After spreading has been completed, large clods, loose stones larger than 12 inches, stumps, and large roots shall be removed and disposed of outside the park in accordance with local, county, State, and Federal regulations. Stones smaller than 12 inches which are firmly embedded in the topsoil may be left on the finished slopes

Erosion Control

☐ Temporary erosion control devices or methods shall be used to protect sensitive areas. Sensitive areas include but are not limited to lakes, stream corridors, drainages, riparian areas, wetlands, and aspen groves.

☐ In areas where slopes are greater than 2:1, soil erosion devices (including but not limited to weed-seed free straw bales, wattles and blankets) will be applied to the disturbed area. For larger disturbed areas, erosion control fencing must be installed. Areas requiring erosion control will be delineated and inspected by the park Biologist.

☐ Logs shall be placed on all erodible slopes. Logs shall be staggered and placed in a random fashion to prevent the appearance of a pattern. Logs will be measured by the linear foot, in place, completed and accepted.

☐ Logs should be staked to the slope by at least 1 inch by 2 inch by 2-1/2 foot hardwood stakes. Reinforcing steel (no. 5), 2-1/2 feet in length may be used in hard material where wood stakes cannot be driven. A minimum of three stakes shall be required to anchor logs up to 8 feet in length. An additional stake shall be required for each 2 feet of additional length over the 8 feet. A minimum of five stakes shall be used to anchor logs over 8 inches in diameter. Stakes shall be driven perpendicular to the ground line to a minimum depth of 18 inches. The top of the stake shall not extend above the log nor shall it protrude from the ground less than one-half the diameter of the log.

☐ Trees and snags shall be placed on slopes following the placement of topsoil..

Seeding

☐ Planted seed shall be covered with no more than 1/4 to 3/4 inch of soil.

Mulching

☐ Division of Resources Management and Research personnel will determine if a project requires the use of mulch. Nitrogen must be added to any wood product used on slopes to aid decomposition (this is not a fertilizer and should be applied directly to the wood). Wood products such as chips should be made about one year before use to allow time for the chips to cure, otherwise they may inhibit vegetation restoration.

Special Considerations

GENETIC GUIDELINES FOR RESTORATION PROJECTS

Rocky Mountain National Park has been actively involved in restoring human caused disturbances since the 1960's. In the late 1980's preserving genetic integrity in vegetation restoration projects became a priority issue. Following are guidelines adopted by the park:

1. Salvage as much plant material (e.g. whole plants, sometimes sod) and topsoil prior to the disturbance as possible.
2. Evaluate sites to determine if salvageable material and/or natural regeneration will provide sufficient plant cover to compete with weeds, retard erosion, and meet other management goals. (If natural regeneration is selected, it may be enhanced by activities such as watering and weeding).
3. When collection of additional plant material is necessary, whenever possible, plant material will be collected from either directly on or adjacent to the site to be revegetated. If parts of plants are collected for propagation, a minimum of fifty plants should be sampled to protect local genotypes
4. A plants material program is an appropriate technique when local plant material is needed for large-scale projects via a seed increase program. The nearest plants material center is in Meeker Colorado and the park has been involved in a seed increase program with Meeker for years. If seed is collected from shrubs, a minimum of fifty shrubs should be sampled from any one area to protect local genotypes and no more than 10% of the seed from any one shrub should be collected to leave an adequate amount of seed behind for natural plant germination and also as a food source for wildlife. If blue grama (*Bouteloua gracilis*) is to be used, the appropriate plant material center would be in Los Alamos, New Mexico.
5. If collection of plant material directly on site is not possible, material may be moved within the major drainages of the park. When possible match habitat type, aspect and elevation.
6. In special circumstances, material may be moved between the major drainages in the park, to be approved on a case by case basis.
7. To protect genetic integrity, no plant material will be moved across the Continental Divide.
8. No plant material will be planted higher or lower than 1,500 feet in elevation from their point of origin.
9. Nursery material grown from seed or propagules not collected in Rocky Mountain National Park or in immediately adjacent drainages will not be planted in the park unless approved on a case by case basis.
10. Transplanting plants from adjacent undisturbed sites may be suitable in some areas on a limited basis, particularly in the backcountry. However, transplanting is very expensive, frequently fails, and should be done very cautiously so as not to impact the undisturbed site.
11. Plant cultivars or other non-local native species only when absolutely necessary for competition with exotics or to retard erosion. This would usually only be allowed in developed areas of the park such as park housing or on severe sites where succession will go from grass/forb to dense forest.

In an area that would eventually become dense forest, the cultivars will eventually be shaded out. For example steep ski slopes being restored at Hidden Valley. All other revegetation alternatives including sterile cover crops, heavy mulch, and delaying planting until local material is available will be considered before cultivars are used. Only cultivars of species growing in Rocky Mountain National Park will be used and varieties will be chosen that originated as close to the park as possible.

12. Non-invasive exotic ornamentals may be planted in historical landscapes as mandated by the National Historic Preservation Act after a case by case review by the park's natural resources specialist, park archeologist, and/or designated historian. The park's natural resources specialist will ensure the exotic species are not on the state of Colorado's noxious weed list or show aggressive tendencies that could allow the plant to escape into natural areas of the park.
13. Exotic grasses may be planted to meet historical management goals in developed areas only, but only in association with National Register Sites or in some limited cases around park employee houses. However, Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermis*) timonthy (*Phleum commutatum*) and red top (*Agrotis gigantea*), which are commonly used in seed mixes are aggressive invaders into natural areas of the park and other native grasses should be seriously considered before these species are used. Seed mixes should also avoid using clovers such as White sweetclover (*Melilotus alba*) and yellow sweetclover (*Melilotus officcianalis*) due to their aggressive tendencies.

BEST MANAGEMENT PRACTICES
VEGETATION RESTORATION

ROCKY MOUNTAIN NATIONAL PARK

CLEARING AND GRUBBING

Selected snags 4 to 12 inches dbh shall be salvaged and stockpiled in designated storage areas for subsequent placement on the completed slopes. The trees and snags shall be cut into random lengths from 8 to 30 feet and shall be limbed on one side. Sound snags and dead trees are preferred over live trees, but if these are not available live trees are okay. Logs should be staked to the slope by at least 1 inch by 2 inch by 2-1/2 foot hardwood stakes. Reinforcing steel (no. 5), 2-1/2 feet in length may be used in hard material where wood stakes cannot be driven.

Logs shall be placed on all erodible slopes. Logs shall be staggered and placed in a random fashion to prevent the appearance of a pattern. Logs shall be oriented from parallel to centerline to perpendicular to centerline.

Trees and snags shall be placed upon completion of top soiling operations. A minimum of three stakes shall be required to anchor logs up to 8 feet in length. A minimum of five stakes shall be used to anchor logs over 8 inches in diameter. An additional stake shall be required for each 2 feet of length over the 8 feet minimum length.

Stakes shall be driven perpendicular to the ground line to a minimum depth of 18 inches. The top of the stake shall not extend above the log nor shall it protrude from the ground less than one-half the diameter of the log.

Logs will be measured by the linear foot, in place, completed and accepted.

Trees larger than 12 inches dbh and trees from 4 to 12 inches dbh not designated for salvaging and stockpiling shall become the property of the contractor and shall be removed from the park. Trees less than 4 inches dbh and over 3 feet in height shall be disposed of outside the park.

Grubbing of stumps shall be accomplished in such a manner as to conserve topsoil material. Nonconventional methods will be required to remove stumps in order to conserve topsoil without contaminating the material with underlying inorganic soils. Pushing trees over with heavy equipment or performing grubbing operations shall not be permitted until topsoil is conserved.

If stumps are to be left in place, trees should be flush cut to ground level and angled in such a way that they are not visible from the road. Designated trees and snags once cut shall be removed in such a manner as to minimize damage to adjacent trees and vegetation.

Furrows created by dragging larger timber away for disposal shall be hand raked and left in a roughed condition.

Burning of perishable debris within the park will not be permitted. All debris shall be removed from the park and disposed of in accordance with applicable local, State, and Federal regulations.

Excess material shall be disposed of outside the park in accordance with local, county, State, and Federal regulations.

All suitable soil, organic duff, and material capable of supporting vegetation encountered in the excavation and in areas of embankment foundations shall be removed to such extent and such depth as directed by the Engineer.

The conserved material shall be windrowed or stockpiled in a series of small stockpiles at the outer potion of the clearing limits or in areas designated by the Engineer. Windrows generally should not be any bigger than 3 feet high by 3 feet wide.

The depth of material conserved for topsoil will not be easy to determine. A minimum of 2 inches of material shall be conserved in all cases, and a depth of 12 inches of material is possible in some locations. Live vegetation less than 3 feet in height and limbs less than 1 inch in diameter may be incorporated as topsoil in the stockpiles. Conserved topsoil shall consist of natural humus bearing soils, duff, and vegetable mater obtained from the overlying portions of the roadway excavation and embankment areas.

Due to the limited amount of material available for topsoil and the need to establish the best growing medium possible to revegetate the roadside, nonconventional methods will be required to excavate, stockpile, and place the conserved material. Equipment capable of excavating small, isolated pockets of soil; removing stumps as required; and placing material on slopes and in pockets on rock ledges will be required to perform the work.

Additional material from prism excavation shall be incorporated into fill slopes to obtain varying, gently undulating contours; additional rounding at toes of fills; and to construct flatter slopes in selected areas to blend with existing landforms or promote revegetation.

Prior to placement of topsoil, prepare the areas as follows.

(c) Slope ratios of 3:1 should be scarified to a nominal depth of 4 inches. Disking or scarification shall be done in a direction perpendicular to the natural flow of water.
(d) Slopes steeper than 3:1 shall be prepared as directed by the Engineer.

Conserved topsoil shall be spread a minimum of 2 inches in depth, loose measurement, over all disturbed soil areas. If the conserved quantities of topsoil are not sufficient to obtain the designated depth, then the lower one-third of the embankment slopes are the least visible portions of the cut slopes shall be eliminated for topsoil requirements.

After spreading has been completed, large clods, loose stones larger than 12 inches, stumps, and large roots shall be removed and disposed of. Stones smaller than 12 inches which are firmly embedded in the topsoil may be left on the finished slopes, except that all stones protruding more than 4 inches that are within 6 feet of the subgrade shoulder shall be removed and disposed of outside the park in accordance with local, county, State, and Federal regulations.

The ends of all roadway cuts disturbed during the excavation operations shall be flared and cut slopes flattened to produce a smooth transition between the cut slope and the existing ground. The cut slope and treatment shall be as shown on the plans.

All earth and rock slopes shall be left with a roughened surface as they are being constructed. The slopes shall generally conform to the staked slope ratio but shall be steepened and flattened randomly and intermittently to simulate the irregularity of the existing terrain. Boulders firmly in place and protruding from the cut slopes shall be left undisturbed. All cut slopes shall be sculpted to irregular surfaces preserving segments of large rock outcrops leaving staggered, irregular ledges shelves, and outcrops with jagged edge appearance and planting pockets suitable for placement of topsoil and plants. Fill slopes shall be warped to provide an irregular surface with staggered ridges steeper than the nominal slope ratio, staggered ledges, planting pockets, and large boulders exposed above the nominal fill slope. Where shown on the plans or directed by the Engineer, additional material from the prism excavation shall be incorporated into the staked fill slopes to obtain additional warping and rounding and to develop landscaped areas for planting, topsoil, and seeding.

Individual boulders shall be buried in the cut and fill slope face.

Temporary erosion control devices or methods ordered by the Engineer shall be installed in sensitive areas. Sensitive areas include but are not limited to the Glacier Creek corridor when the creek is adjacent to the road, riparian areas, and aspen groves. Extra caution will occur in drainages that flow into the creek.

The use of hay or straw bales and brush for barriers is prohibited within the National Park unless approved by the Engineer and Park Service. Other temporary erosion control devices is preferred. If it is determined that hay or straw is the best material to prevent impacts to sensitive riparian environments only certified hay or straw is allowed.

CONTROL OF MATERIALS

All material sources used in the production of aggregates require archaeological clearance by a state or federal agency. The Contractor shall furnish the Engineer written proof of archaeological clearance before transporting any aggregate into the park.

All material sources shall also require clearance for exotic plants. The Contractor shall notify the Engineer of the sources(s) proposed for use at least 1 month before beginning operations or starting crushing. The source(s) will be investigated for exotic plants during the period. If exotics are present, the investigator will determine if the upper portion of the source is to be stripped or the exotics sprayed with a herbicide, preferably "Roundup" or an approved equal product. When spraying is required, a licensed operator in accordance with regulations from Colorado shall apply the spray. An agronomist's certification that the source(s) is free from exotic plants may be substituted for the above requirements.

The Contractor shall take every precaution and make every effort to protect the delicate environment of Rocky Mountain National Park. Asphaltic materials shall not be allowed to get on existing masonry rock structures, solvents used to clean pavers, tools, etc., shall be carefully used, completely contained at the work site, and satisfactorily cleaned up as may be required.

All earth-moving equipment (excluding hauling vehicles) shall be cleaned of mud and weed seed prior to entering the National Park. Hauling vehicles shall meet the same requirement before their initial entrance into the park; subsequent entries will not require cleaning unless ordered by the Engineer.

Construction equipment not being used shall be parked out of the traveled way and within the construction limits. No parking of equipment or vehicles will be permitted at picnic sites, Bierstadt Lake and Storm Pass trailhead parking lots, Glacier Gorge or the Bear Lake parking areas unless construction activities are underway in those specific areas.

Turning areas for hauling vehicles shall be approved by the Engineer. Under no circumstance will any vehicle (in part or whole) be allowed outside the construction limits.

Areas to be used for parking and stockpiling material are strictly controlled and will require approval of the Park Service prior to their use by the Contractor.

Camping will not be allowed within the park boundaries.

Work on weekends and holidays will be limited.

GENETIC GUIDELINES FOR VEGETATION RESTORATION PROJECTS

Highway projects, Wildland fires, and other ground disturbances requiring vegetation restoration

Last revised 9/13/2002

Rocky Mountain National Park has been actively involved in restoring human caused disturbances since the 1930's. In 1985 preserving genetic integrity in vegetation restoration projects became a priority issue of concern. Following are guidelines adopted by the park:

1. Salvage as much plant material (e.g. whole plants, sometimes sod) and topsoil prior to the disturbance as much as possible. In alpine tundra it is required to salvage all the plant material. Disturbance to alpine tundra should be minimized to the degree possible.
2. Evaluate sites to determine if salvageable material and/or natural regeneration will provide sufficient plant cover to compete with invasive exotic plants, retard erosion, and meet other management goals. (If natural regeneration is picked, it may be enhanced by activities such as watering and weeding). If salvageable material and/or natural restoration will not be sufficient, development of plant material in the park greenhouse/nursery, seed increase or use of a private contractor is warranted.
3. When collection of additional plant material is necessary, whenever possible, plant material appropriate for the expected plant community will be collected from either directly on or adjacent to the site to be revegetated. The priority should be to identify and collect early successional species. The important goal for any vegetation restoration is not to stop succession by what vegetation material was planted on site.
4. If parts of plants are collected for propagation, a minimum of fifty plants should be sampled from anyone area to protect local genotypes
5. A seed increase program is an appropriate technique when local plant material is needed for large-scale projects. The nearest plants material center is in Meeker, Colorado and the park has been involved in a seed increase program with Meeker for many years.
6. If seed is collected from shrubs, a minimum of fifty shrubs should be sampled from anyone area to protect local genotypes and no more than 10% of the seed from anyone shrub should be collected. It is important to leave an adequate amount of seed behind for natural plant germination and also for a food source for wildlife.
7. If blue grama (*Bouteloua gracilis*) is to be used, the appropriate plant material center would be the plants material center in southern Colorado.
8. If collection of plant material directly on or adjacent to the site is not possible, material may be collected from within the major drainages of the park. When possible match habitat type, aspect and elevation.
9. In special circumstances, material may be moved between the major drainages in the park, but only approved on a case by case basis.

10. To protect genetic integrity, no plant material will be moved from the east side to the west side of the park or the west side to the east side.
11. No plant material will be planted higher or lower than 1,500 feet in elevation from their point of origin.
12. Nursery material grown from seed or propagules not collected in Rocky Mountain National Park or in immediately adjacent drainages will not be planted in the park unless approved on a case by case basis.
13. Transplanting plants from adjacent undisturbed sites may be suitable in some areas on a limited basis, particularly in the backcountry. However, transplanting is very labor intensive, frequently fails unless supplementary watered until roots are well established and should be done very cautiously so as not to impact the undisturbed site.
14. Plant cultivars or other non-local native species are not to be used unless only when absolutely necessary for competition with exotics or to retard erosion. This will usually not be allowed in any recommended or designated wilderness unless the late seral site is something like a spruce/fir forest and eventually the non desirable plant material will be replaced and only if the non desirable plant material does not stop succession. This would usually only be allowed in developed areas of the park such as park housing or on severe sites where succession will go from grass/forb to eventually dense forest. In an area that would eventually become dense forest, it is believed the cultivars will eventually be shaded out. For example the ski slopes restoring at Hidden Valley. All other revegetation alternatives including sterile cover crops like sterile wheatgrass, heavy mulch, and delaying planting until local material is available will be considered before cultivars are used. Only cultivars of species growing in Rocky Mountain National Park will be used and varieties will be chosen that originated as close to the park as possible.
15. The revegetation protocol for recommended or designated wilderness should be natural restoration to the degree possible (i.e. allow succession to restore a site without any supplemental planting).
16. Non-invasive exotic ornamentals may be planted in historical landscapes as mandated by the National Historic Preservation Act after a case by case review by the park's natural resources specialist, park archeologist, and/or designated historian. The park's natural resources specialist will ensure the exotic species are not on the state of Colorado's noxious weed list or show aggressive tendencies that could allow the plant to escape into natural areas of the park.
17. Exotic grasses may be planted to meet historical management goals in developed areas only, but only in association with National Register Sites or in some limited cases around park employee houses. However, Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermis*) timonthy (*Phleum commutatum*) and red top (*Agrotis gigantea*), which are commonly used in seed mixes are aggressive invaders into natural areas of the park and other native grasses should be considered. The aggressive grasses should only be used as a last resort. Seed mixes should not have clovers such as White sweetclover (*Melilotus alba*) and yellow sweetclover (*Melilotus officcianalis*) due to their aggressive tendencies.

18. When collecting seed material in the park, it is important to determine if the seed material is mature. This can be checked by the hardness of the seed and if the interior is milky or hard. If milky the seed is usually not mature. Check seed heads or flowers to ensure seed has not already shattered before spending time in collecting. Timing of the seed collection is critical and seed from different species mature at different times. Germination tests maybe needed in certain situations.

A good database for propagation and germination techniques and protocols for native species:
www.nativeplantnetwork.org.

MINIMUM REQUIREMENT ANALYSIS WORKSHEET
ROCKY MOUNTAIN NATIONAL PARK

ROMO-180 (3/2000)

PROPOSED ACTION: ______________________ DATE: ____________

LEAD PERSON(S): ______________________ WORK UNIT(S): ______________________

PART A: Minimum Requirement *(should the action be done in wilderness)*

1 IS ACTION AN EMERGENCY?

Answer: ☐ Yes ☐ No
Explain:

YES → ACT ACCORDING TO APPROVED EMERGENCY MINIMUM TOOL CRITERIA

NO ↓

2 DOES ACTION CONFLICT WITH LEGISLATION, PLANNED WILDERNESS GOALS, OBJECTIVES OR FUTURE DESIRED CONDITIONS?

Answer: ☐ Yes ☐ No
Explain:

YES → DO NOT DO IT

NO ↓

3 IS ACTION PRE-APPROVED BY THE WILDERNESS AND BACKCOUNTRY OR OTHER PARK MANAGEMENT PLAN?

Answer: ☐ Yes ☐ No
Explain:

YES → DO ACCORDING TO APPROVED CRITERIA

NO ↓

4 CAN ACTION BE ACCOMPLISHED THROUGH A LESS INTRUSIVE ACTION THAT SHOULD BE TRIED FIRST? (Visitor Education…)

Answer: ☐ Yes ☐ No
Explain:

YES → DO IT

NO ↓

5 CAN ACTION BE ACCOMPLISHED OUTSIDE OF WILDERNESS AND STILL ACHIEVE ITS OBJECTIVES?

Answer: ☐ Yes ☐ No
Explain:

YES ↓ DO IT THERE

NO ↓ DO PART B

Page 1 of 2

PART B: Minimum Tool *(how the action should be done in wilderness)*

6 DESCRIBE, IN DETAIL, ALTERNATIVE WAYS TO ACCOMPLISH THE PROPOSED ACTION *
(These may include, primitive skill/tool, mechanized/ motorized, and/or combination alternatives)
(Use addition pages if necessary)

* Minimum questions to answer for each alternative:
- What is proposed?
- Where will the action take place?
- When will the action take place?
- What design and standards will apply?
- What methods and techniques will be used?
- How long will it take to complete the action?
- Why is it being proposed in this manner?
- What mitigation will take place to minimize action impacts?

GO TO NEXT STEP

7 EVALUATE WHICH ALTERNATIVE WOULD HAVE THE LEAST OVERALL IMPACT ON WILDERNESS RESOURCES, CHARACTER AND VISITOR EXPERIENCE **

** Minimum criteria used to evaluate each alternative:
- Biophysical effects
- Social/Recreational/Experiential effects
- Societal/Political effects
- Health/Safety concerns
- Economical/Timing considerations

GO TO NEXT STEP

8 SELECT AN APPROPRIATE, PREFERRED ALTERNATIVE

IF REQUIRED →

9 ATTACH TO APPROPRIATE PROJECT PROPOSAL/CLEARANCE FORM FOR REVIEW AND APPROVAL/DISAPPROVAL SIGNATURE

Alternative 1:

Alternative 2:

Alternative 3:

List preferred alternative and give justification:

Page 2 of 2

Minimum Requirement Analysis Worksheet and Instructions

The following are instructions for completing the Minimum Requirement Analysis Worksheet ROMO-180. Answer the questions asked on the worksheet in the spaces provided. Once completed and a decision is made, a copy of the worksheet will be kept on file with other action documents.

Proposed Action: List the proposed action.

Date: List month, day and year the worksheet is completed.

Lead Person(s): List the person or persons proposing and responsible for the action.

Work Unit(s): List the work unit or units who will be conducting the action.

Part A: Minimum Requirement *(should the action be done in wilderness)*

Step 1: Is action an Emergency?

A true emergency presents an immediate threat to human life, or natural or cultural resources and often requires a quick response beyond that available by primitive means.

Criteria for emergency actions are outlined in various operations plans (e.g. Emergency Operations Plan, Emergency Medical Services Plan and Fire Management Plan). If yes, act according to approved emergency minimum tool criteria in the appropriate plan. If no, go to Step 2.

Step 2: Does action conflict with legislation, planned wilderness goals, objectives or future desired conditions?

Park staff and managers must be familiar with the Wilderness Act, ROMO Wilderness recommendation/legislation, planned wilderness goals, objectives and future desired conditions. These can be found in the Wilderness/Backcountry Management Plan. If yes, then do not do the action. If no, go to Step 3.

Step 3: Is action pre-approved by the Wilderness/Backcountry or other park management plan?

Determine if the proposed action is programmatically pre-approved in an approved park management plan (e.g., Wilderness/Backcountry Management Plan, Fire Management Plan, General Management Plan, Resource Management Plan). If yes, the action has already been analyzed and determined to meet the minimum requirement. Do the action according to the approved criteria in the appropriate plan. If no, or if the action deviates at all from the pre-approval, go to Step 4.

Step 4: Can action be accomplished through a less intrusive action that should be tried first?

Explore less intrusive actions such as visitor education, staff training, signing, information media, regulations, use limits, law enforcement, area or trail closures, etc. If yes, implement other action using the appropriate process. If no, go to Step 5.

Step 5: Can action be accomplished outside wilderness and still achieve its objectives?

If yes, conduct action or place facilities determined "essential" (e.g., visitor orientation, information sign, radio repeater station, research) outside wilderness. If no, go to Part B.

<u>Part B: Minimum Tool</u> (how the action should be done in wilderness)

Step 6: Describe, in detail, alternative ways to accomplish the proposed action.

For the Minimum Requirement Concept to work, it is important to develop and seriously consider a range of realistic alternatives that in turn will help determine the appropriate minimum tool to be used to accomplish the action. This process involves a tiered analysis beginning with the least obtrusive, primitive/traditional skills alternatives, then proceeding to mechanized and/or motorized alternatives and finally on to a combination of the above alternatives.

Primitive skills involve the proficient use of tools and skills of the pre-motorized or pioneering era (e.g., the double-bit axe, the crosscut saw, the pack string). The working understanding of primitive skills is important to appropriately plan for their use. Managers must take the lead in demonstrating that tasks can be performed well by primitive or traditional, non-motorized methods. Field staff require adequate training in primitive-tool selection, use, and care to efficiently accomplish planned work. While agency staff should constantly stress the importance of using primitive skills in accomplishing management objectives, they should understand that minimum requirement analysis would not always lead to the use of a primitive tool.

The use of motorized equipment is prohibited when other reasonable alternatives are available to protect wilderness values. While Congress mandated a ban on motors and mechanized equipment, it also recognized that managers might occasionally need those sorts of tools. While this provision complicates the decision-making process, it remains an exception to be exercised very sparingly and only when it meets the test of being the minimum necessary for wilderness purposes (Worf 1987; Colorado State University 1991). If some compromise of wilderness resources or character is unavoidable, only those actions that have localized, short-term adverse impacts will be acceptable (NPS Reference Manual 41).

The minimum questions that should be answered for each alternative are:

What is proposed?
Where will the action take place?
When will the action take place?
What design and standards will apply?
What methods and techniques will be used?
How long will it take to complete the action?
Why is it being proposed in this manner?
What mitigation will take place to minimize action impacts?

Step 7: Evaluate which alternative would have the least overall impact on wilderness resources, character and visitor experience.

The manager must determine how to effectively and safely accomplish the action with the least impact on the wilderness resource and visitor experience. To assist with this determination, managers should use the following five criteria to evaluate each alternative. A brief statement about each should suffice.

1) Biophysical effects:

Describe the environmental resource issues that would be affected by the action.
Describe any effects this action will have on protecting natural or cultural resources.
Include both biological and physical effects.

2) Social/Recreational/Experiential effects:

Describe how the wilderness experience may be affected by the proposed action.
Include effects to recreation use and wilderness character.
Consider the effect the proposed action may have on the public and their opportunity for discovery, surprise and self-discovery.

3) Societal/Political effects

Describe any political considerations, such as MOU's, agency agreements, and local positions that may be affected by the proposed action.
Describe relationship of method to applicable laws.

4) Health/Safety concerns

Describe and consider any health and safety concerns associated with the proposed action. Consider types of tools used, training, certifications and other administrative needs to ensure a safe work environment for staff. Also consider the effect the proposed action may have on the health and safety of the public.

5) Economic/Timing considerations

Describe the costs and timing associated with implementing each alternative.
Assess the urgency and potential cumulative effect from this proposal and similar actions. The potential disruption of wilderness character and resources and applicable safety concerns will be considered before, and given significantly more weight than, economic efficiency.

Step 8: Select an appropriate preferred alternative.

Consult with appropriate park staff and/or the Wilderness Steering Committee as to which of the alternatives will cause the least overall impact to the wilderness resources and character while still accomplishing the action. Select that alternative, give the justification as to why this alternative was selected and list who was involved in the decision.

The net result of a minimum requirement analysis is a carefully weighed project or action that is found to be the most effective way of meeting wilderness objectives and the minimum necessary for Wilderness Act purposes.

Step 9: Attach to appropriate project proposal/clearance form for review and approval/disapproval signature.

If the scope of the action requires a higher level of approval, attach the Minimum Requirement Analysis Worksheet to the appropriate proposal/clearance form (e.g. Project Proposal/Clearance From (ROMO-178), Flight Request Form (ROMO-47) for review.