# General Considerations for Use in Revegetation

Regionally adapted native plant seed is likely to remain a valuable commodity in northern British Columbia for the foreseeable future, whether collected from the wild or grown in cultivation. Consequently, every effort must be made to optimize its use and to maximize its effectiveness for revegetation and restoration. While revegetation procedures will vary with local site conditions and project goals, some generalizations can be made. Foremost among these general rules are to:

- introduce seed to freshly loosened soil;
- match the species selected to local soil and site conditions;
- avoid or minimize the effects of weeds;
- remember that stand establishment will often take two growing seasons; and
- employ an adaptive management approach (testing different techniques and monitoring their effectiveness on an operational basis).

## ***Site Preparation***

It is important to prepare a receptive seedbed that will have good mineral soil exposure, good soil-seed contact, and will support unimpeded root growth. Many sites degraded by industrial activities such as road building, log loading, or overgrazing have very compacted soil. This first must be alleviated by deep cultivation, disking, or ripping. The rooting zone should be loosened (cultivated) to 10 or 15 cm if possible, and heavily compacted sites (such as former roads and landings) may need to be ripped or treated with a winged subsoiler to depths of 40 cm (Bulmer 1998). Simple raking or harrowing of the surface is insufficient to provide an optimal growing medium in most cases, but is better than no treatment at all. The removal or rearrangement of logs, brush, and stones is not necessary or desirable on most revegetation sites, as these features contribute to microsite diversity.

If the remnants of the pre-existing native plant community are already found on the site, one may not want to disrupt the vegetation, no matter how depauperate or degraded it might be. The existing vegetation can be directly "over-seeded," but provisions for inserting the seed into or onto the soil must be considered, and some degree of site preparation is still desirable. This may consist of mowing the existing vegetation to a short stubble, or raking/harrowing the soil surface to expose some bare soil. Manual removal of weeds or spot-spraying of weeds and other exotic plants with a broad-spectrum herbicide may be desirable. If the weeds are annuals, mowing or clipping them at the time of flowering (i.e., before they go to seed) can help shorten their hold on the site. When digging up perennial weeds such as bull thistle (*Cirsium vulgare*), the filled-in shovel holes left behind then consist of loose, bare soil that is well suited for immediate seeding with native plants.

When tillage or harrowing is conducted on sloping terrain, it is essential that furrows run parallel to the contours (perpendicular to the direction of slope) in order to minimize erosion. Very steep road cuts are difficult to revegetate unless they are terraced or re-sloped to the natural angle of repose for loose, unconsolidated material. A more common solution, employed for both agronomic and native species, is to use hydroseeding techniques in which commercial "tackifiers" can be added to a slurry of water, seed, fertilizer and mulch that is then applied to the site using a specialized pump and nozzle. The tackifier essentially glues the seed to steep slopes, so some seed will be in place to germinate and establish if weather conditions cooperate.

Optimal conditions for seeding disturbed lands exist immediately after soil disturbance or site preparation. If disturbed soil is left too long, weeds will have a chance to invade and establish. Weathering results in soil settling over time, and silt and clay particles will fill most soil cracks, resulting in a gradual recompaction of the soil.

***Soil Amendments and Mulches***

Sites degraded by industrial activities often consist of compacted soils, stripped of topsoil and plant nutrients. Consequently, some degree of soil improvement is often needed in order to support more than sparse plant growth, and to restore healthy ecosystem functioning. When the area to be revegetated is dominated by subsoil, bare parent material, or shattered lithic material, one challenge is to accelerate soil development. In addition to decompacting this material (as described above), it can also be useful to incorporate organic matter into the substrate to improve soil structure and to provide cation-exchange sites for the retention of nutrients and soil water (Bulmer 1998). Suitable amendments can include wood chips, sawdust, peat moss, straw, manure, or various waste treatment sludges (e.g., from pulp mills, fish farms, or municipal sewage treatment plants). Care must be taken to manage the carbon to nitrogen (C to N) ratio of these amendments. If material with a high cellulose content (e.g., wood chips, sawdust, or straw) is added to the soil, it will be decomposed by soil fungi and bacteria, but those fungi and bacteria will gobble up most of the available nitrogen in the soil, thereby depriving plants of adequate resources for growth. So any time amendments with high C:N ratios are used, supplemental fertilization with nitrogen-rich or low C:N materials must also be done. This fertilizer can be from commercial sources (e.g., ammonium nitrate formulations), or from organic sources (such as manures, or municipal sewage).

Soil amendments should be well incorporated into the rooting zone of the substrate, typically the top 10 to 20 cm, before seeding. This will usually require the use of farm machinery such as a disker, plow or cultivator, as part of site preparation procedures. If applied as a surface dressing or mulch, amendments are not as effective for soil improvement, but can be important for erosion control, especially on sloping sites. Surface mulches are generally applied after seeding, rather than before. Mulch should not be applied too thickly (generally less than 1-2 cm) or densely, (<70% cover), so that seedling emergence is not inhibited. Suitable mulches for revegetation and restoration activities include straw from annual cereal crops (i.e., wheat, oats, barley, rye), or the straw and screenings from native plant seed production fields. Care must be taken not to introduce weed seeds or other contaminants with the mulch. For example, hay bales from fields of domesticated smooth brome (*Bromus inermis*), timothy (*Phleum pratense*) and clover (*Trifolium* sp.) might contain viable seeds of those exotic agronomic species. So use of hay mulch is not recommended, as the exotic seeds might defeat the purpose and expense of introducing native plants in the seeding process.

Fertilizer is often applied when sowing a revegetation site, even if organic matter is not incorporated into the soil. This is because most degraded sites are nutritionally barren, with substrates often consisting of unmodified glacial till. Furthermore, the enhanced plant growth achieved through the use of fertilizer can stretch sparse supplies of native seed by generating more plant cover per plant and greater probability of seedling survival (Burton and Burton 2001a). Where no intact topsoil remains, a balanced, high-concentration fertilizer (e.g., 18-18-18 or 13-16-10 NPK) applied at a rate of 200 to 300 kg/ha is generally sufficient to promote vigorous plant growth. Supplemental fertilization may be beneficial in another three years or so, depending on the chemistry of the site, the effectiveness of plant establishment and the initiation of nutrient cycling above and below ground, and on the success of nitrogen-fixing species. Natural fertilizers such as manure, fish farm waste, or municipal sludge can be beneficial substitutes, since they also include organic matter. If possible, soil testing should be conducted to document the precise nutrient limitations, so that fertilizer prescriptions can be optimized. The heterogeneity of soil conditions on many revegetation and restoration sites often precludes accurate diagnostic soil testing. It is safe to generalize, however, that N will usually be more limiting than P, K, or other nutrients on degraded soils in northern B.C. Contrary to some recommendations, our research has shown that fertilization even benefits native plant establishment on sites dominated by agricultural weeds (Burton 2003).

## ***The Seeding Prescription***

Designing the mixture of species and the density at which they should be applied to a site constitute the fundamental elements of a revegetation prescription. To optimize the use of scarce seed, it is strongly recommended that sites be roughly mapped and categorized according to soil texture, topographic position, and/or vegetation goals, so that customized seed mixtures can be assigned to each site class. Gravelly soils in low-lying sites should receive a different mixture of species than gravelly sites on upper slopes and ridge crests, while fine-textured or loamy soils require yet a different suite of species. Site preferences and tolerances, where known, are provided below in the individual species accounts.

In formulating a seed mix, it is useful to employ a combination of 5 to 10 species, consisting of some graminoids (grasses, sedges, and rushes) of low and high stature, some species with rhizomes, some (usually legumes) with nitrogen-fixing ability, and some fast germinators. Care should be taken to ensure that the mix will not be dominated by a single aggressive species, and the mature stature of each species should be considered when deriving the ratio of seeds to use. That is, only a few individuals of large-statured species (e.g., *Lupinus polyphyllus*) are needed, while many individuals of smaller plants (e.g., *Festuca occidentalis*) are required to achieve the same proportional crown cover per unit area. Other considerations, such as the decision to include or exclude species highly palatable to livestock or wildlife, or the decision to include species resistant to trampling, will enter into the design of a mixture according to the land use goals for the land being revegetated. The soil texture, site drainage, and soil fertility of the site to be revegetated must also be considered and matched to the most suitable species. For example, many of the species covered in this manual can establish and grow well on gravelly soils, but *Dryas drummondii* and *Epilobium latifolium* are more demanding of coarse soils than other species, but still need good access to soil water, so are usually limited to lower slope positions. *Geum macrophyllum*, in contrast, is most suited to loamy soils with high nutrient levels.

It is worth considering the inclusion of a fast-germinating and fast-growing "cover crop" on steep bare sites where heavy precipitation or spring runoff is expected to generate a risk of soil erosion. Most native plants (with some exceptions) are relatively slow to establish and achieve full stature, so some non-native species would need to be used. The challenge is to find species that will quickly generate cover, but will not persist and compete with the native plants as they establish and grow. Suitable cover crops include fall rye (*Secale cereale*), Italian ryegrass (*Lolium multiflorum*), and sterile hybrids of slender wheatgrass and wheat (*Elymus trachycaulus* x *Triticum aestivum*, sometimes marketed under the trade name of Regreen™). When added to a native plant seed mixture, such cover crops should be added on top of the desired native plant seeding rate, and should not constitute more than 10 to 20% of the total seed mixture applied to the site.

All seeding ratios and densities should be formulated on the basis of the amount of pure live seed (PLS) per unit area, not the weight of seed or seed stocks. This is because plant species vary greatly in seed size and consequently in the number of seeds per kg, and individual seed lots also tend to vary in the number of viable seeds per unit weight (relative to other contaminants like dust and plant debris). Adjustments for PLS are required in order to refine the amount of seed to be weighed out and applied to a site. For example, if your seedlot is 90% pure mature seed (by weight), and those seeds exhibit 90% viability, then every 25 kg bag of seed only contains 0.9 x 0.9 x 25 = 20.25 kg or pure live seed. Combined with knowledge of the number of seeds per gram for a particular seedlot or species (as provided for each species below), this determination allows the inter-conversion of seeding densities in PLS/m$^2$ and in kg/ha. Prescriptions should be developed in PLS/m$^2$, but those prescriptions are usually implemented in the field in terms of kg/ha. Individual species treatments (below) include the mean and range of the number of seeds per gram, and the mean and range in germination capacity encountered in the Symbios research program; seed lot purity varies with every crop and every seed cleaning operation, however. Table 2 provides a sample worksheet for the preparation of a seeding prescription. Such a table can be easily transcribed to a computer spreadsheet program, in which the amount of seed of each species to be weighed out and the total application rate can then be calculated.

**Table 2.** Sample worksheet and worked example for preparing a seeding prescription and calculating the amount of seed (of each species) to be mixed and sown over a given area.

| Area to seed: __12,000_m$^2$ Plant Species | Plant Material Origins | | Seeds per gram | Seedlot | | Application Rate | | Notes |
|---|---|---|---|---|---|---|---|---|
| | Location Or Vendor | Year or Seedlot | | Purity, % of wt. | Viability, % germ. | desired PLS/m$^2$ | Total g or kg | |
| A. | B. | B. | C. | D. | D. | E. | F. | G. |
| 1. *Elymus glaucus* | Symbios | ET2001 | 228 | 93 | 80 | 300 | 2112g | |
| 2. *Festuca occidentalis* | Symbios | WM2001 | 2995 | 84 | 91 | 650 | 3407g | |
| 3. *Achillea millefolium* | Symbios | CFS2000 | 7560 | 71 | 90 | 500 | 1242g | |
| 4. *Lupinus polyphyllus* | wild:P.G. | 2000 | 117 | 95 | 77 | 50 | 7010g | add Rhizobium B |
| 5. | | | | | | | | |
| 6. | | | | | | | | |
| 7. | | | | | | | | |
| 8. | | | | | | | | |
| 9. | | | | | | | | |
| 10. | | | | | | | | |
| H. TOTAL: | | | | | | 1500 | 13771g | =11.48 kg/ha |

**Instructions:** A. Select species based on site attributes, management objectives, and seed availability.
B. Record plant material origins, making sure they are suitable for your location.
C. Insert seeds per gram from published averages (e.g., means reported as part of individual species treatments, below), or based on seedlot analysis.
D. Insert seedlot purity and viability on the basis of seedlot tests or certificates of analysis.
E. Specify the desired PLS/m$^2$, based on the stature and aggressiveness of each species, speed of germination, site attributes, and desired plant community structure, so that all individual species sum to the total PLS/m$^2$ desired.
F. Calculate the total number of grams of seedlot needed for each species as:
= area to seed (in m$^2$) x desired PLS/m$^2$ / (seeds/g x % purity x % viability);
record % purity and % viability as proportions (0 to 1) for use in this calculation; divide result by 1,000 to express large values in kg, if desired.
G. Record additional information as needed, such as price, checking off each species as weighed, etc.
H. sum individual species application rates to derive total seed mix application; divide total application rate in g by area to seed (in m$^2$) and multiple by 10 to give application rate in kg/ha, or divide total application rate in kg by area to seed in m$^2$ and multiply by 10,000 to give application rate in kg/ha.

The amount of PLS applied to a site will not result in an equivalent density of plants. Though all PLS should theoretically germinate, our experience indicates that only 10% to 20% of those seeds will successfully germinate, emerge, and establish as seedlings on degraded sites. This low success rate is due to a variety of suboptimal practices (e.g., surface sowing instead of drill seeding), harsh site conditions (e.g., infertile or compacted soil), and accidents of weather and herbivory (e.g., frost, drought, grazing by insects or small mammals). Recent research with plants native to northern B.C. indicates that adequate amounts of cover can be achieved across a broad range of sowing densities (375 to 6000 PLS/$m^2$), but full cover is attained faster at densities ranging from 750 to 1500 PLS/$m^2$ (Burton 2003). A broadly applicable and generally acceptable recommendation is for 1500 PLS/$m^2$ when broadcast-sown as a dry seed mix, with higher rates recommended on erosion-prone sites, where rapid green-up is desired, or where weeds populations are high. Lower densities are acceptable if seed is in short supply, if weeds are not a threat, and if establishing cover quickly is not a priority.

***<u>Sowing and Monitoring</u>***

Seed can be introduced to a site by drilling it into the soil using standard or modified agricultural machinery, broadcast using cyclone spreaders (mounted on a helicopter sling, on the back of a tractor, an ATV, or operated by hand), spread directly by hand, or as part of a slurry by hydroseeder. Drill seeding is most efficient in terms of ensuring that a large proportion of the seeds will have good contact with the soil and will successfully germinate and emerge; unfortunately, it is not suitable for rough or steep terrain, and is not currently the norm for most roadside seeding. Next efficient is dry broadcast seeding (Figure 12), so long as it is conducted quickly after soil disturbance or after soil loosening by raking or harrowing, and then is followed up by more raking or harrowing. Small areas can be sown by hand if care is taken to distribute seed evenly. Hydroseeding is least efficient in terms of the use of seed, but the presence of tackifier (an organic soil binder) can greatly enhance its effectiveness on steep slopes. Typically mounted on the back of a large truck along with a big mixing tank, hydroseeders can also be small enough to fit on a pickup truck. Simple substitutes can be built using some water pumps, so long as the pumping mechanism does not damage seeds and nozzle apertures are big enough for the seeds being applied. Hydroseeding is not currently recommended for most native plant seed application purposes (except for steep sites), because it uses approximately three times the amount of seed that is used in dry broadcast seeding applications. A large amount of hydroseeded seed ends up being applied to unsuitable microsites and obstacles, and much of the seed is found in the upper layers of the mulch where it dries out, rather than under the mulch where it is protected. So a recommendation of 1500 PLS/$m^2$ for dry seeding should be adjusted to 4500 PLS/$m^2$ when hydroseeding is used.

Domesticated legumes are routinely treated with bacterial inoculum before being sown. This may not be necessary for native legumes, for which natural inoculum seems to be widespread in the forest environment. However, for very sterile and isolated locations such as large mines, it may be prudent to coat legume seeds with commercial inoculum before sowing. Different strains of *Rhizobium* are needed for each legume genus, with each vendor using different names or labels for the strains applicable to *Lathyrus*, *Lupinus*, or *Vicia*. Inoculum can be mixed in a powdered milk slurry so it lightly coats the legume seeds before they are added to the seed mix.

**Figure 12.** Dry broadcast seeding along a newly built logging road, spreading a grass-legume seed mix using a cyclone seeder mounted on an all-terrain vehicle (ATV).

It is generally recommended that one weigh out and mix the different species in a seed mixture ahead of time (i.e., in the warehouse). When dry seeding, fertilizer and mulch (if used) are generally applied to the site in separate steps from the seed. It helps to weigh out bags or tubs of seed for each discrete stratum (e.g., moist sites, ridge crests, gravel patches, etc.) or fixed areas of uniform land (e.g., in 100 $m^2$, 900 $m^2$, or 2500 $m^2$ units). Then flag out the boundaries or corners of each unit of land on the revegetation site, so that the rate of seeding can be adjusted to make sure it uniformly covers the designated area. Until experience is acquired at judging the rate of application, it is better to seed sparsely at first and then do a supplemental application, rather than to run short of seed because original application rates were too generous. The site should be raked or harrowed to expose fresh, loose soil immediately before seeding (as mentioned above), and then raked, harrowed or dragged to cover the seeds somewhat after sowing too (Figure 13). In northern B.C., seeding can be done in the spring (any time before July) or in late summer, but late fall seeding is often best.

**Figure 13.** Raking or harrowing after broadcast seeding is recommended to promote seed germination and seedling establishment.

All revegetation and restoration prescriptions and subsequent seeding operations using native species should be considered experimental in nature. That is, they may represent your best effort at designing an appropriate mixture and density of seeds and associated amendments, but there is no *a priori* reason to expect this design to be the optimal solution to local site management challenges. It is therefore prudent to incorporate assorted modifications to the restoration prescription, apply them at multiple locations, keep careful records of what treatment was employed where and when, and to monitor the results. Monitoring might be as simple as the installation of permanent photo points, with photographs taken of each treatment area at the same time of year over a number of years. Or it might be as quantitative as a rigorous program utilizing line transects or randomly located quadrats to sample plant cover and density (Figure 14). A template for recording plant density and cover observations in three quadrats per treatment stratum is provided in Table 2. Note that it is usually worthwhile to record weed cover and evidence of soil erosion and the accumulation of organic matter as well as the abundance of each plant species. A more rapid form of monitoring can consist of recording plant cover in four broad groups: sown species, other native plants, agronomic grasses and legumes, and weeds. Whatever the nature and intensity of monitoring undertaken, it is important to adopt a philosophy of structured adaptive management, constantly improving one's expertise in restoring native vegetation.

**Figure 14.** Sampling the density and cover of native plants sown on an old log sort yard.

Revegetation success ultimately depends on the establishment of an adequate amount and composition of plant cover. Depending on the goals of the project, the vegetation may be expected to be a faithful re-creation of a natural plant community, and to dominate the site indefinitely. In other situations, it will be sufficient for the vegetation to reduce erosion, and to cover the soil for only a few years until tree and shrub species dominate the site. Mowing or weeding of exotic plants may be desired in some cases, and supplemental fertilization in two or three years may be appropriate, depending on the land use goals. But areas revegetated to native plants are generally expected to be self-maintaining.

The value of creating a plant assemblage that is pleasing to the eye (Figure 15) should not be underestimated, as public support for the wider use of native plants still needs to be nurtured. Coupled with a desire to promote biodiversity and to mimic the composition of natural meadows, such aesthetic considerations provide another incentive for including non-leguminous wildflowers in native plant seed mixtures.

**Table 3.** Sample data collection form for monitoring plant community development after revegetation. This form records plant count and cover observations from three quadrats (remember to record quadrat area, e.g., 0.25 $m^2$ or 1.0 $m^2$); x and y values denote random rectangular coordinates for each sample.

**Location:____________________________ Monitored by:________________ Date: __________**

**Stratum/Treatment:____________________________________________________________**

| | Sample 1 | | Sample 2 | | Sample 3 | |
|---|---|---|---|---|---|---|
| **Species or attribute** | x=_____m | y=_____m | x=_____m | y=_____m | x=_____m | y=_____m |
| **Seeded species** | density | Cover | density | cover | density | Cover |
| *Achillea millefolium* | | | | | | |
| *Carex aenea* | | | | | | |
| *Elymus glaucus* | | | | | | |
| *Festuca occidentalis* | | | | | | |
| *Geum macrophylum* | | | | | | |
| *Lupinus polyphyllus* | | | | | | |
| **Native invaders** | | | | | | |
| *Agrostis scabra* | | | | | | |
| *Aster sp.* | | | | | | |
| *Betula papyifera* | | | | | | |
| *Calamagrostis canadensis* | | | | | | |
| *Collinsia parviflora* | | | | | | |
| *Epilobium angustifolium* | | | | | | |
| *Epilobium ciliatum* | | | | | | |
| *Equisetum arvense* | | | | | | |
| *Hieracium albiflorum* | | | | | | |
| *Picea glauca x engelmanii* | | | | | | |
| *Populus trichocarpa* | | | | | | |
| *Rosa acicularis* | | | | | | |
| *Salix* sp. | | | | | | |
| | | | | | | |
| **Exotic Agronomics** | | | | | | |
| *Agrostis stolonifera* | | | | | | |
| *Dactylis glomerata* | | | | | | |
| *Festuca rubra* | | | | | | |
| *Phleum pratense* | | | | | | |
| *Poa pratensis* | | | | | | |
| *Trifolium sp.* | | | | | | |
| | | | | | | |
| **Exotic Weeds** | | | | | | |
| *Agropyron repens* | | | | | | |
| *Cerastium fontanum* | | | | | | |
| *Chrysanthemum leucocephalum* | | | | | | |
| *Cirsium vulgare* | | | | | | |
| *Galeopsis tetrahit* | | | | | | |
| *Sonchus arvensis* | | | | | | |
| *Taraxacum officinale* | | | | | | |
| | | | | | | |
| **Ground Cover / Physical features** | | | | | | |
| moss | | | | | | |
| stones/wood | | | | | | |
| erosional rills | | | | | | |
| litter (leaves, etc) | | | | | | |

**Figure 15.** A successfully established stand dominated by *Elymus glaucus*, *Festuca occidentalis*, and *Achillea millefolium*, with scattered *Bromus ciliatus*, *Lupinus arcticus*, *Geum* macrophyllum, *Carex* species and *Aster* species. This mixture was sown along recent ski trail improvements and along a forest access road in the Smithers Community Forest, with seeding done by volunteers from the local cross-country ski club. This photograph was taken two growing season after sowing.

## ***Some Examples of Native Plant Seeding Prescriptions***

As indicated above, it is desirable to devise a seed mixture and seeding rate to match the site conditions and objectives of every revegetation project undertaken. We here provide some examples of species mixtures designed to meet certain revegetation goals and site conditions, not to serve as a fixed set of "off the shelf" mixtures, so much as examples of the decision process by which species and seeding densities are chosen.

The first example describes a **general-purpose mixture** for seeding newly constructed roadsides and ditches where the glacial till substrate consists of bare, gravelly clay loam:

- *Festuca saximontana* 23%
- *Festuca occidentalis* 26%
- *Elymus glaucus* 18%
- *Achillea millefolium* 25%
- *Lupinus arcticus* 8%

Because erosion control and rapid cover production are priorities, the recommended application rate for this scenario is fairly high, approximately 2500 PLS/m$^2$. A short-lived, fast-growing cover crop of fall rye, Italian ryegrass, or Regreen$^{TM}$ could be added at rates of approximately 200 PLS/m$^2$. This mixture is dominated by three grass species: a tall one of medium longevity (*Elymus glaucus*);

a long-lived one of medium stature (*Festuca saximontana*); and a short-lived one with very rapid germination and short stature (*Festuca occidentalis*). The grasses are supplemented by a large amount of *Achillea millefolium*, which germinates rapidly, generates rosettes of low-lying foliage, and is rhizomatous, so provides valuable erosion control. Note that more *Festuca occidentalis* and *Achillea millefolium* seeds per $m^2$ are prescribed than *Elymus glaucus* and *Lupinus arcticus* seeds, because the latter two species are much larger when mature. *Lupinus arcticus* is included as a native nitrogen-fixer, but 300 kg/ha of 19-18-18 fertilizer is recommended for spreading at the time of seeding as well. Other native legumes, such as *Vicia americana*, could substitute for *Lupinus arcticus*, depending on seed availability and site conditions: if soils are "heavy" or clayey rather than gravelly, sandy or loamy, *Lupinus polyphyllus* would be a better choice. A variety of composites or other "wildflower" species could be added to the mixture to add a little colour and diversity, but these species should not constitute more than 10-15% of the total mix.

A second example describes a seed mixture recommended for a **lower slope position** that is either moisture-receiving, adjacent to a wetland or riparian area, or is characterized by seepage. Such sites might require revegetation in support of riparian restoration plantings of cottonwoods and willows, or they might be on the fringe of a reservoir subject to variable water levels, or in roadside ditches that tend to remain moist. Suggested species and proportions are:

- *Calamagrostis canadensis* 23%
- *Carex mertensii* 15%
- *Carex macloviana* 12%
- *Collinsia parviflora* 12%
- *Elymus glaucus* 10%
- *Achillea millefolium* 7%
- *Bromus ciliatus* 6%
- *Geum macrophyllum* 5%
- *Dryas drummondii* 5%
- *Arnica chamissonis* 3%
- *Lupinus polyphyllus* 2%

This mixture of 10 species includes a variety of moisture-loving species and some that are more tolerant of upland conditions. *Calamagrostis canadensis*, *Carex mertensii*, *Elymus glaucus*, and *Geum macrophyllum* are naturally abundant on moist sites, though all can tolerate upland conditions to a degree. *Carex macloviana* and *Bromus ciliatus* are included as short-statured and tall-statured upland graminoids, respectively. *Arnica chamissonis* and *Geum macrophyllum* are both known to prefer rich sites, and should provide good cover and contribute to vegetation diversity. *Achillea* is once again included as a fast germinator, and *Lupinus polyphyllus* as a nitrogen-fixer. *Dryas drummondii* should be included only if the substrate is sandy or gravelly, with water flowing through the site but not standing. It was recommended that this prescription could be sown at 1200 PLS/$m^2$, or at higher application rates on slopes of bare soil where erosion is a concern. Fertilizer is again recommended, though the rate of application does not need to be high (perhaps 150 to 200 kg/ha of 18-18-18) if some topsoil or subsoil is found on the site.

A third example describes the sort of seed mixture designed for a **high-elevation or high-latitude area** (such as the Engelmann Spruce – Subalpine Fir or Spruce-Willow-Birch biogeoclimatic zones) with rocky soils and a short growing season. Such a site might need to be reclaimed after mining or mineral exploration, or might consist of the sides of a new road, or disturbances associated with the expansion of a ski resort. A recommended mixture for this scenario is:

- *Festuca saximontana* 25%
- *Trisetum spicatum* 18%
- *Poa alpina* 18%
- *Achillea millefolium* 14%
- *Luzula parviflora* 10%
- *Epilobium latifolium* 10%
- *Lupinus arcticus* 5%

The backbone of this mixture consists of two medium-statured grasses, *Festuca saximontana* and *Trisetum spicatum*, supplemented by the shorter *Poa alpina*, all well-adapted northern, alpine and subalpine species. *Achillea millefolim* is again included for rapid germination and cover production, especially on steep sites where rapid erosion control is desired. *Luzula parviflora* is a graminoid that may provide low-lying ground cover too. *Lupinus arcticus* is included as a nitrogen-fixing legume, while *Epilobium latifolium* is a natural invader and useful cover-producer on well-drained (rocky) sites so long as moisture is available below the surface. Seeding of such sites is often best in fall, so that seeds will be in place well before access can be regained to such places in the spring. Light fertilization would be beneficial (50 to 150 kg/ha of 18-18-18), for such sites are nutrient-poor but plant growth tends to be more temperature-limited than nutrient-limited.

A final example describes the restoration of spot disturbances in a new nature reserve that includes a **sloping grassland** in the dry cool subzone of the Sub-Boreal Spruce biogeoclimatic zone (SBSdk) in the Bulkley Valley. These threatened ecosystems are classified as “Site Series 81, Saskatoon – Slender Wheatgrass Scrub/Steppe” (Banner et al. 1993). The natural vegetation of the site is largely intact around the disturbed areas, and is dominated by slender wheatgrass (*Elymus trachycaulus*) and Rocky Mountain juniper (*Juniperus scopularum*). Because this is a nature reserve, and the goal is **ecosystem restoration** (not just revegetation), priority is placed on the use of species documented to already occur in the project area; locally collected seed is used as much as possible. Soils are largely intact, fairly rich in level spots (which also had weed problems), but are shallow and dry on sloping areas. Existing plant cover makes erosion control a lower priority. Rather than digging up or herbiciding the exotic plants (especially *Chenopodium album* and *Cirsium arvense*) found on the site, these are manually cut or mulched with plastic ahead of time, and are then overseeded. The soil is manually raked before and after sowing. No fertilizer is used on the weedy areas; elsewhere, a light sprinkling of 13-10-10 fertilizer is applied at approximately 150 kg/ha. A light mulch consisting mostly of native *Elymus glaucus* straw and screenings is spread on areas with bare soil in order to partially shade new seedlings and help conserve moisture. The seed mixture and proportions (of PLS) devised for this project are as follows:

- *Elymus trachycaulus* 45%
- *Achillea millefolium* 18%
- *Collinsia parviflora* 13%
- *Bromus ciliatus* 7%
- *Elymus glaucus* 7%
- *Anaphalis margaritacea* 4%
- *Aster conspicuus* 2%
- *Polemonium pulcherrimum* 2%
- *Vicia americana* 2%

This mixture is to be applied at 1550 PLS/$m^2$ in early spring, soon after snow is gone from the site. All eight species are naturally found in the nature reserve. To restore the grassland, heavy emphasis is placed on introducing the dominant *Elymus trachycaulus*, with lesser amounts of *Bromus ciliatus* and *Elymus glaucus*, so that grasses (all tall in stature) should constitute 59% of the seedlings. Though few short-statured or rhizomatous native grasses are found in the local vegetation (at least none for which seed was available), *Achillea millefolium* was found on site. So *Achillea* is included at a fairly high density in order to provide a fast-germinating and low-lying ground cover. *Collinsia parviflora* is a native annual and may also provide rapid cover if germination conditions are favourable, but it can also persist in the seed bank and may be a useful contributor to the native plant community in the future. *Vicia americana* is included as a native nitrogen-fixer, and more would have been used if seed supplies had been available. The other three species in the mixture (*Anaphalis margaritacea*, *Aster conspicuus*, and *Polemonium pulcherrimum*) can be considered enriching elements of biodiversity, wildflower species found on the site which may be important for certain insects, for aesthetics, and to contribute diversity and resilience to the vegetation.