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Natural Vegetation Succession and Sustainable Reclamation at Yukon Mine and Mineral Exploration Sites

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Executive Summary

Increased interest in mining-related environmental issues in recent years has resulted in significant advances in the development of mine reclamation techniques. In the Yukon, the goal of most reclamation programs is to return disturbed lands as close to their original wild lands state as is feasible. The re-vegetation process, an integral component of reclamation, can be manipulated in ways to reflect this ultimate land use objective. This report reviews past Yukon reclamation practices and looks at how natural succession processes can be encouraged on lands disturbed by mining and mineral exploration practices.

By examining the factors that affect the succession patterns of re-vegetation on disturbed sites, and by noting the composition of plant communities that colonize these areas, the most appropriate pioneering shrub species can be selected for assisted re-vegetation programs. The species selected for re-vegetation must reflect each site's ecological variables, as well as the nature of the mining-related disturbances. The reclamation potential of Yukon native shrub species is discussed in this report, along with techniques for assisted re-vegetation, including the collection of plant materials and propagation methods.

The reclamation capabilities of 23 locally occurring shrub species is appended to this report. This information has been extracted primarily from re-vegetation experimentation in Alaska and northern Alberta. In order to determine whether these native shrubs are viable as species for reclamation work in the local environment, seeding and planting trials are recommended at Yukon mine and mineral exploration sites.

Non-technical Summary

This report looks at ways to help make plants grow on land that has been mined or explored for minerals. Plants help to keep the soil from washing away, and they also provide food and shelter for wildlife. Up until now, mostly grasses have been planted on old Yukon mine sites. We are now also trying to learn the best ways to get shrubs and trees to grow in these areas.

New mining regulations in the Yukon are reviewed in this report. We explain what mining companies must now do to repair damage to the land after they have finished mining or exploring for minerals.

We describe the different kinds of soils found at Yukon mines. Plants will not grow on soils that have too much or too little water, have too little nutrients, have too steep a slope, or are too cold. Some shrubs grow best in dry, windy areas, while others grow only in wet places. Shrubs that normally grow only where there is shade are not good for planting in areas where all the trees have been removed.

The best shrubs for planting on mine sites are the ones that can be found growing nearby. Some Yukon shrubs, especially willows, can easily be started by taking the stems or roots from willows in the late winter or early spring, and then planting these cuttings in the disturbed soil at the mine site. Others, such as birch or alders, are best started from seed collected in the fall and then planted the next spring.

Some Yukon trees and shrubs are easily grown on land that has been disturbed by mining. Others, normally found only in older forests, do not grow well in the open areas around mine sites. At the end of this report, we look at 23 different kinds of Yukon shrubs and discuss how useful they may be for planting at Yukon mine sites. We also describe how each of these shrubs is best started, either from seeds or from cuttings.

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Acknowledgments

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1.0 Background

Re-vegetation efforts in the north have largely focused on the rapid establishment of a green cover on disturbed areas, primarily by seeding graminoids and legumes. These measures generally meet the short-term expectations for aesthetic improvement and sometimes erosion control, but do not address the longer-sighted requirements for habitat restoration. It is been increasingly stressed by forest ecologists that the encouragement of a self-sustaining plant cover should be the goal of re-vegetation programs. The best strategy to achieve a stable plant cover on disturbed areas is to forget about the “instant green”, and focus on the longer term objective of returning these sites to their natural vegetative state by “kick-starting” the natural successional process. This approach may be less aesthetically pleasing at first but is more advantageous in the long run.

The establishment of a self-sustaining vegetation cover on drastically disturbed lands requires that the initial cover eventually give way to a cover of more permanent plant species. This process can be hastened by assisting in the early establishment of pioneering woody species, such as alder, willow, poplar and aspen. In this way, the successional stagnation, which has limited the success of many reclamation projects, can be avoided. These pioneering woody species, along with an initial vegetative cover of graminoids and legumes established on the site, modify the disturbed area in such a way as to encourage later seral stages of vegetation and eventually climax species.

Guidelines have been established by Kennedy (1993) and Hill *et al*. (1996) for determining the optimum mixtures of fertilizer and seeds (both agronomic and native varieties) for revegetating disturbed areas. Only limited study has been done in the Yukon, however, into ways to encourage later successional stages of vegetative growth. The natural re-vegetation of a few selected abandoned trenches and drill pads was observed by Mougeot (1996) and some experimental re-vegetation of abandoned mineral exploration sites was carried out by Craig *et al.* (1998). Although some ecological information can be obtained by directly observing natural and assisted re-vegetation practices in the Yukon, experience from other northern jurisdictions (particularly Alaska) could also be applicable to Yukon situations. In addition, there is a considerable amount of re-vegetation information that can be drawn from ecologically similar areas south of 60^0 N that could be applied to boreal and subarctic regions of the Yukon.

It is the objective of this project to determine the best approaches for encouraging the later successional patterns of vegetative establishment on disturbed lands on Yukon mine and mineral exploration sites and to recommend candidate native shrub species for field trials.

2.0 Yukon Mine Reclamation / Re-vegetation Practices

Reclamation and successful re-vegetation of areas disturbed by mining in the Yukon is only now being implemented on a major scale. In the past, legislative gaps and lack of environmental awareness of land use issues resulted in very little active reclamation. The situation now is very different, in that the mining community and regulators are actively pursuing practices that can restore lands disturbed by mining to their former level of utility.

2.1 Early Reclamation Initiatives

Very little in the way of deliberate reclamation or re-vegetation took place on Yukon mines sites prior to the late 1960s. Since that time there has been a steady increase in awareness of reclamation issues, culminating in changes to the Yukon mining legislation that require land use activities on mineral claims be taken into account.

During the 1970s, water licenses issued under the *Northern Inland Waters Act* began to take on some reclamation aspects as a result of requirements to stabilize slopes against erosive forces. This would have been the first regulated "reclamation" activity carried out on Yukon mineral properties. During the same time period, work was under way on developing guidelines for reclamation of the proposed Foothills gas pipeline. Research from that project had the affect of forming a basis for reclamation practices on mining disturbed lands in the Yukon.

During the past decade, significant efforts have been made to develop and implement reclamation / re-vegetation practices on sites disturbed by both quartz and placer mining. The Yukon Mining land Use Regulations (MLUR) were made possible by changes to *the Yukon Quartz Mining Act* and the *Yukon Placer Mining Act* . Prior to this time, the *Territorial Lands Act* section 3.3 prevented application of land use regulations to mineral exploration activities in the Yukon. The effect of this was that environmental assessment, including reclamation and re-vegetation rules, would apply only when a mining proposal included application for such permits as a water license or a surface land lease.

The development of the land use management system took many years of negotiations among the mining community, governments, First Nations, and other stakeholders. In 1984, environmental screening legislation was made law. This put the onus on the Department of Indian Affairs and Northern Development (DIAND) to ensure that activities under its jurisdiction were subject to environmental screening. In 1990, the Yukon Mining Advisory Committee (YMAC) was formed to make recommendations to the DIAND Minister as to how Yukon mining land use could be regulated in such a way to conform with environmental screening requirements. In 1992, YMAC submitted its report, which eventually led to the revision of the mining acts, passed by Parliament in 1996. The regulations finally came into effect in December 1998, and are only now being implemented under the Yukon mining land use management system administered by DIAND. Thus the MLUR now serve as the specific regulation that requires reclamation / re-vegetation to be included in mineral exploration and development projects.

2.2 MLUR Re-vegetation Requirements

The regulated requirement to revegetate areas disturbed by mining activity comes from Schedule 1 of the MLUR, known as the Operating Conditions. The Operating Conditions for re-establishment of the vegetative mat sates that "*All areas disturbed during an exploration program must be left by the operator in a condition conducive to* *successful re-vegetation by native plant species or other species adaptable to that environment".* This condition is directly related to the requirement for erosion control, which states that *"All areas disturbed during an exploration program must be re-sloped, contoured, or otherwise stabilized by the operator to prevent long term soil erosion, slumping, and subsidence* ***and to comply with the conditions for re-establishment of the vegetative mat"*** (emphasis added). Re-vegetation and erosion control measures are, therefore, regulated hand in hand. The approach being taken by the Chief of Mining Land Use has been to distribute guidelines on reclamation techniques in the Yukon, and to allow operators to apply and test a range of measures that can be shown to create successful re-vegetation at specific sites. A Certificate of Closure will not be issued unless and until the operator can demonstrate that the re-vegetation measures undertaken at the site are successful. This may take the form of test plots which can be observed over the period of the permit, allowing inspectors to verify that the re-vegetation methods being tested will be effective.

3.0 Revegetating Drastically Disturbed Lands

The successful re-vegetation of disturbed land depends on detailed information on the existing site conditions. Baseline information such as the area's slope, aspect, elevation, climate, drainage patterns and soil conditions is required. A knowledge of the vegetation patterns occurring on the site prior to the disturbance is also important. If this information is not available, an examination of the nearby vegetation would contribute to the understanding of the area's natural plant succession and assist in determining the most appropriate species for re-vegetation .

Before selecting the plant species that are best adapted to colonizing a disturbed site, the identification of the factors that limit the growth of vegetation and the amelioration of these limiting conditions are critical first steps in a re-vegetation program.

3.1 Factors Affecting Vegetation Growth

The following factors commonly limit the growth of vegetation on drastically disturbed mine sites:

- **soil nutrients** Essential nutrients are often lacking in drastically disturbed soils. The microbial community, which contributes significantly to nutrient recycling, is usually severely degraded in compacted soils that have had the humus and woody debris removed.

- **slope and aspect** Re-vegetation of steep slopes with unstable surface materials can be difficult. The aspect of the slope can also determine which plant species are suited for re-vegetation . Steep south facing slopes can result in exposed arid conditions, and north facing slopes are usually cold and often underlain with permafrost.

- **substrate texture** Soils that are too fine or too coarse textured result in the loss of moisture and nutrients. Soils most suitable for plant growth will have about 20% pass through a 200 mesh screen (Polster 1991). Soil porosity, which is often lost when substrate materials are moved or compacted, is also essential for the transfer of moisture, minerals and nutrients to plants.

- **microbial community** The availability of, and access to, soil nutrients and minerals is highly dependent on the complex symbiotic interactions between the plant's roots and the soil bacteria and fungi. Nitrogen-fixing bacteria and mycorrhizal fungi are usually destroyed or severely degraded when soils are moved or compacted.

- **substrate chemistry** Soils with adverse chemical properties (high concentrations of metals, high salinity, pH extremes, etc.) can severely limit plant growth. Some pioneering plant species are capable of tolerating these conditions.

- **soil temperature** The growth of many plant species is restricted when soil temperatures are extreme. The presence of permafrost often results in an acidic, nutrient-poor topsoil layer. The vegetative growth on the cold soils of north-facing slopes and narrow valley bottoms is often restricted to cold-tolerant, acid-tolerant species.

- **micro topography** Compacted surfaces, smoothly graded surfaces on slopes, and dry coarse grained surfaces are least likely to sustain growth. Successful re-vegetation requires the creation of micro sites for seed traps, accomplished by various means such as scarification of compacted surfaces parallel to the slope and leaving cleat marks or other small depressions.

Other problems imposed by the harsh northern climate on revegetating Yukon mine sites include the slower growth rate due to cooler temperatures, the shorter frost-free growing season, arid conditions, and the reduced number of appropriate species available (Brooks *et al*. 1989).

3.2 Categories of Disturbance on Mined Land

Prior to the commencement of any assisted re-vegetation program, it is important to know something about the condition of the disturbed land surface. An understanding of the fundamental types of mining waste materials is required before selecting plant species suitable for reclamation. Following are the basic kinds of disturbances and waste materials found at Yukon mine and mineral exploration sites:

- **soil disturbances** These disturbances are surface disruptions of the mineral soil and organic matter, along with drainage features and vegetation. They include access roads, drill pads, clearings for buildings, etc. These disturbances are the easiest to revegetate.

- **overburden disturbances** These are substantial disruptions below the mineral soil horizon. They usually include coarse textured material such as that found in waste rock piles, adit waste dumps, and material excavated from exploration trenches.

- **mill tailings** Tailings impoundments are usually lacking in organic materials and plant nutrients. They are rich in inorganic salts unsuitable for plant growth and are often acidic. Mill tailings can be difficult to revegetate. Some abandoned tailings impoundments in the Yukon have remained unvegetated for many years.

4.0 Encouraging Natural Succession

The theory of natural succession is based on the principle that individual plant species, once established on a site, modify soil and micro-climatic conditions until they are optimum for the next successional assemblage of species. These new species in turn alter their environment until new species are better adapted to the site conditions. This continuum of seral stages finally results in a cover of climax vegetation. The rate of this recovery process after a disturbance varies according to a number of climatic and edaphic factors. Natural succession takes an increasingly longer time as one progresses northward. Although there is little that can be done to hasten the slow rate of succession in subarctic regions, steps can be taken to ensure that pioneering woody plant species are allowed to establish on reclaimed sites and that the natural recovery process is initiated.

4.1 Establishment of Initial Ground Cover

If the objective of a reclamation program is to return the area as nearly as possible to its original wild state, the establishment of the initial ground cover of early successional species (grasses and legumes) must be developed in such a way as to allow space and protection for later successional species. Seed mixes should be balanced for species composition to provide the requirements for succeeding species to establish (Polster 1991). Seed mixes dominated by sod-forming species will inhibit the invasion of new species by competing for space, nutrients, sunlight and moisture. Seeding rates and the use of fertilizer must also be carefully regulated to prevent seeded species from becoming too firmly established (Kennedy 1985).

Several species of grasses recommended for use in Yukon re-vegetation programs (Kennedy 1992), including native species such as Red Fescue (*Festuca rubra*), Canada

Bluegrass (*Poa compressa*), Kentucky Bluegrass (*Poa pratensis* ssp. *pratensis*) and Northern Bluegrass (*Poa pratensis* ssp. *pratensis*) are sod-forming and may inhibit the invasion of pioneering woody species. Legumes such as Alsike Clover (*Trifolium hybridum*) may also impede the incursion of new species (Murray and Hill 1994).

4.2 Introducing Later Successional Species

The natural seral stages of succession usually progress from a cover of pioneering herbaceous species to one of pioneering woody species. In reclamation programs, the seeded cover of grasses and legumes serves as the pioneering herbaceous stage. The establishment of the woody species stage may be left to the natural invasion of locally occurring species or it may be assisted through direct seeding, transplanting seedlings, or the planting of stem and root cuttings.

The woody species selected for planting should fit the site edaphic conditions. Species that enhance the site's growing conditions, such as bacterial nitrogen-fixing alders, can hasten the successional process. Woody plants are best selected from those species that naturally colonize disturbed sites in the nearby area. They are best adapted to local site conditions. When choosing these species, particular attention must be given to such factors as the site's slope and aspect. Trembling aspen, for example, which is normally found on well-drained south-facing slopes, should not be planted on a cold ice-rich north-facing site.

Pioneering shrub species must be able to tolerate exposure. Shade-loving shrubs found only in the climax stage of forest succession are not good candidates for reclamation work that requires pioneering species. Trees and shrubs that are considered to be climax species, such as spruce in much of the Yukon, should not be introduced early in a re-vegetation program. They will invade naturally when the optimal conditions of that seral stage has been reached.

A notable characteristic of many pioneering shrub species is their ability to invade soils that are nutrient-poor and with severely altered or reduced microbial communities (invertebrates, bacteria and fungi). Shrubs such as alder and soapberry form actinorhizzal associations with the filamentous bacterium *Frankia*. This bacterium contains nitrogenase, the enzyme required for the fixation of atmospheric nitrogen (nitrogen is the most deficient nutrient in cold northern soils).

Reclaimed mine sites are also usually lacking in the mycorrhizal fungi that are so important in the nutrient transfer to many plant species. Ectomycorrhizae, in which the fungi surround but do not penerate the host plant's root cells, are characteristic of such shrubs as birch and alder. The mycorrhizae that occur on the roots of ericaceous shrubs, such as bearberry and Labrador tea, are particularly adept at enhancing nitrogen uptake, which is especailly important in the acidic, nitrogen-poor soils in which these plants grow. Moreover, they increase the tolerance of these plants to heavy metal poisoning. It has also been shown that the mycorrhizal fungus *Suillus* rapidly colonizes pine seedlings (Kranabetter *et al*. 1995), and this may help explain the ability of lodgepole pine to grow well on disturbed sites in ecosystems in the south-central Yukon.

Experimentation is required with introducing ectomycorrhizal inoculants when transplanting shrubs or planting stem and root cuttings. This usually only means transferring some of the organic soil from the area in which the shrubs or cuttings were collected.

4.2.1 Shrub Seeding

Ripe viable seed requires the careful timing of seed collection. The seed of most native Yukon shrub species should be collected in the fall (late August to September). The seeds of birch and alder (*Betula* and *Alnus* spp.) can also be collected throughout the winter. Willow and poplar seeds (*Salix* and *Populus* spp.), which disperse seed from May to early July, should be collected before the catkins open fully (Freeman *et al.* 1977). Most Yukon shrub seeds are dormant when collected (for exceptions see Appendix A) and require a period of storing (stratification) before planting. Seeds usually must be stored below freezing followed by a period of thawing. The length and temperature requirements of the stratification period varies according to species.

Many woody perennial species do not produce good seed crops every year. Seed crop periodicity varies with species. Alaska birch, for example, produces a good seed crop every 2 to 4 years, while trembling aspen has a relatively large seed crop every 4 or 5 years. Balsam poplar, on the other hand, produces seed in large quantity nearly every year (Zasada 1971).

The site preparation requirements for seeding woody plants depend on the edaphic limitations of each individual species. Shrubs should normally be seeded to a reclaimed mine site only after an initial open cover of grasses, legumes or other forb species has been established, in which case, most of the site preparation work will already have been completed. If they are seeded directly to mineral soil without the prior establishment of herbaceous plant material, fertilization with nutrients may be necessary.

Shrub seeding should be timed to take advantage of the higher soil moisture during spring snowmelt. Late fall or very early spring seeding is therefore preferable. Spot seeding, where seed is sown on randomly selected plots throughout the reclamation site, may be expedient where seed supplies are limited (for seed timing and spacing for candidate native Yukon shrub species, see Appendix A).

4.2.2 Shrub Planting

Natural seedlings from the local area can be directly transplanted during periods of dormancy. Fall transplanting of Yukon shrub seedlings is recommended unless a low insulating snow cover is anticipated, in which case an early spring transplanting is preferable.

Stem and root cuttings can be used to propagate many Yukon deciduous shrub species. As with seedlings, cuttings must be collected during dormancy. Cuttings are best collected in late winter or early spring (March or April), stored at freezing temperatures and planted in late spring when the soil has warmed. About 25 cm long stem cuttings should be placed in loosened soil with 10 cm left exposed above ground. Root cuttings should be buried in loosened soil with their proximal end pointing upward (Freeman *et al.* 1977).

Seedlings and cuttings must be heavily watered during planting. Watering of seedlings and cuttings may be required throughout the first summer. Fertilizer is not normally required if herbaceous plants have already been established (see Appendix A for planting information on native Yukon shrub species).

If the area to be reclaimed is too large for complete re-vegetation by woody species, shrubs can be established in clusters or 'islands'. Most shrubs grow best in lowlands, depressions or draws on slopes (Green *et al*. 1987). These topographic features may be selected for shrub planting if supplies of transplants or cuttings are limited.

5.0 Reclamation Potential of Yukon Native Shrub Species

A number of commonly found Yukon shrubs are potentially suitable as pioneering woody species for the reclamation of mined land, providing they are appropriately selected to meet site-specific conditions. 23 woody species are recommended here as candidates for re-vegetation trials on Yukon reclaimed mine and mineral exploration sites. The only conifer included here is lodgepole pine (*Pinus contorta*). All of these species should be considered as successional to an initial ground cover of established grasses and legumes. Their natural ranges and potential for reclamation work are shown in Appendix A. This is not intended as a comprehensive compilation of Yukon pioneering shrub and tree species. Most species of willow, for example, would be expected to be good candidate species for reclamation purposes. Little is known about the metal tolerances of most of these species.

<u>Low Shrubs (less than 1m)</u>

Arctostaphylos rubra	(Red Bearberry)
Arctostaphylos uva-ursi	(Kinnikinnick)
Ledum groenlandicum	(Labrador Tea)

Salix arctica	(Arctic Willow)

<u>Intermediate Shrubs (1 to 5 m)</u>

Alnus crispa	(Green Alder)
Betula glandulosum	(Dwarf Birch)
Potentilla fruticosa	(Shrubby Cinquefoil)
Rosa acicularis	(Prickly Rose)
Rubus idaeus	(Red Raspberry)
Salix alexensis	(Feltleaf Willow)
Salix glauca	(Blue-green Willow)
Salix planifolia	(Diamondleaf Willow)
Shepherdia canadensis	(Soapberry)
Spiraea beauverdiana	(Beauverd's Spiraea)
Viburnum edule	(Highbush Cranberry)

<u>Tall Shrubs or Trees (5m or more)</u>

Alnus incana	(Hoary Alder)
Betula neoalaskana	(Alaska Birch)
Pinus contorta	(Lodgepole Pine)
Populus balsamifera	(Balsam Poplar)
Populus tremuloides	(Trembling Aspen)
Salix arbusculoides	(Littletree Willow)
Salix bebbiana	(Bebb's Willow)
Salix scouleriana	(Scouler's Willow)

6.0 Recommendations

Although the pioneering woody perennials described here are commonly occurring Yukon species (Section 5.0), information on their reclamation capabilities has largely been taken from the results of field trials in other northern regions (primarily Alaska and northern Alberta). In order to more fully appreciate the reclamation potential of these species (as well as others) in local environments, field testing at Yukon mine and mineral exploration sites is required. The recommended stages of field experimentation are broadly outlined as follows:

1. **Site Selection** Shrub establishment trials should be carried out at Yukon mine and mineral exploration sites representing a range of ecological variables (latitude, elevation, slope, aspect, etc.). The test sites should also include the different types of mining-related disturbances (soil disturbance, overburden and bedrock disruptions, and mill tailings). As emphasized in Section 4.2, preferred sites for shrub establishment are those that already have an initial colonizing cover of grasses, legumes or other forb species.

2. **Baseline Data Collection** At each of the sites selected for shrub re-vegetation trials, the following background information should be noted where possible:

- topographical information (latitude, elevation, slope, aspect)
- site history (types of disturbance, etc.)
- climatic information (rainfall, snowpack, temperature, wind speed and direction)
- soil physical properties (texture, drainage, compaction, thermal regime)
- soil chemistry (pH, salinity, conductivity)
- soil nutrient status
- previous reclamation treatments (contouring, scarification, seeding, fertilization)
- existing vegetation

3. **Shrub Species Selection** At each re-vegetation trial site, an inventory should be taken of the pioneering shrub species that are naturally colonizing disturbed sites on nearby lands (the comparison site should be ecologically similar to the re-vegetation test site). This information on voluntary regeneration (along with the baseline biophysical data described above) can be used as a basis for determining the diversity and density of the species selected for seeding / planting in the test plots. It can also serve as a baseline standard for measuring the success of the re-vegetation trials. Permanent, monumented plots would be useful for long-term comparisons.

4. Shrub Seeding / Planting Test plots for the seeding and planting of shrub species should be established on each of the mining-related disturbances. A number of plots, each with different applied treatments (seeding rate, plant spacing, species diversity) would be desirable at each test site (see Section 4.2 and Appendix A for species-specific information on plant material collection, propagation methods, timing, etc.). Experimentation with the pre-inoculating of shrubs and cuttings with mycorrizal-rich soil is recommended. Nitrogen-fixing shrubs, such as alder and soapberry, could also be inoculated with bacterial microbes collected from the roots of these shrub species growing in nearby undisturbed zones. Test plots should be well marked in order to facilitate long-term monitoring.

5. Follow-up Monitoring After the criteria for determining the success of the re-vegetation trials is established, follow-up monitoring is required. Periodic site visits are necessary for documenting the survival and viability of each species. The diversity and density data collected during these surveys can be compared with the voluntary regeneration data compiled during observations of the permanent, off-site, comparison plots.

Annotated Bibliography

Although there are many published accounts on minesite reclamation practices, the following publications are particularly useful references for anyone interested in natural successional processes and the assisted re-vegetation of northern minesites.

Brooks, B.W., T.H. Peters and J.E. Winch. 1989**. Manual of methods used in re-vegetation of reactive sulphide tailings basins**. Canada Center for Energy Technology. Energy, Mines and Resources Canada. Ottawa, Canada.

This manual provides a comprehensive description of procedures for preparation, neutralization, fertilizing, seeding and follow-up maintenance for the re-vegetation of reactive sulphide tailings disposal sites. A discussion of the problems associated with re-vegetation of tailings north of 60^0 N is presented.

Freeman, T., J. Stroh, J. Zasada, A. Epps, and J. Smith, editors. 1977. **A revegetative guide for Alaska**. Alaska Rural Development Council. University of Alaska, Fairbanks, U.S.A.

This guide is a source of information on planting and management procedures for re-vegetation of disturbed sites in Alaska. It includes such topics as soils, seedbed preparation, seed specifications, seeding methods and maintenance. It discusses the reclamation potential of a number of northern native woody perennial species.

Green, J.E., R.E. Salter, and C.E. Fooks. 1987. **Reclamation of wildlife habitat in the Canadian prairie provinces, Volume 1: Techniques for the creation and enhancement of wildlife habitat.** Alberta Recreation, Parks and Wildlife Foundation, Canadian Wildlife Service, and Environmental Protection Service.

This report consists of a synthesis of existing technical information on methods for planning and implementing the reclamation of wildlife habitat. It also discusses the potential wildlife problems associated with reclamation projects.

Hardy, BBT Limited. 1987. **Reclamation guidelines for northern Canada.** Indian and Northern Affairs Canada. Ottawa.

This handbook incorporates information gained from reclamation programs in northern Canada since 1970. It concentrates on the reclamation of disturbed lands in climates with permafrost and short growing seasons.

Hardy, BBT Limited. 1989. **Manual of plant species suitability for reclamation in Alberta - 2nd edition**. Alberta Land Conservation and Reclamation Council Report No. RRTAC 89-4.

This manual discusses the reclamation potential, tolerances and propagation methods of a number of plant species, including many trees and shrubs that are commonly found in northern Canada. It rates each species by a series of reclamation suitability criteria in a combined performance chart.

Mougeot C. 1996. **Natural land reclamation for mineral exploration properties and placer mines in Yukon.** Mineral Resources Directorate, Indian and Northern Affairs Canada.

This study focuses on the natural reclamation that has occurred on sites disturbed by placer mining and mineral exploration in three different mining districts in the Yukon. It characterizes the effects of time on the soil and overburden conditions, vegetation, slope stability and permafrost at the three disturbed sites that date back as far as 1911.

Peterson, E.B. and N.M. Peterson. 1977. **Re-vegetation information applicable to mining sites in northern Canada.** Indian and Northern Affairs Canada. Environmental Studies No. 3.

This annotated bibliography summarizes published information on re-vegetation techniques that can be applied to reclamation of disturbed surfaces created by mining in the Yukon and Northwest Territories. It is a comprehensive reference source of northern reclamation information.

Polster, D.F. 1991. **Natural vegetation succession and sustainable reclamation.** Paper presented to the Canadian Land Reclamation Association / B.C. Technical Research Committee on Reclamation Meeting. Kamloops, B.C.

This paper presents a concept for land reclamation which is based on the use of successional processes. It identifies factors which preclude vegetation growth and offers solutions for overcoming theses growth limitations.

Polster, D.F. 1997. **Restoration of landslides and unstable slopes: considerations for bioengineering in interior locations.** Paper presented at 21st Annual B.C.. Mine Reclamation Symposium and the 22nd Annual Canadian Land Reclamation Association Meeting. Cranbrook, B.C.

Techniques are presented in this paper for the restoration of unstable slopes and landslides using bioengineering techniques. It discusses successional reclamation and soil bioengineering as means of providing self-sustaining vegetation. Examples are drawn from the author's experience.

Additional Literature Cited

Cody, W.J. 1996. **Flora of the Yukon Territory**. NRC Research Press Ottawa, Canada.

Craig, D.B., J. E. Craig, K. Pelletier, D. Emond and H. Copeland. 1998. **Reclamation practices and research on mineral exploration properties in the Yukon Territory.** Mineral Resources Directorate, Indian and Northern Affairs Canada.

Hill, T., C.E. Kennedy, and D. Murray, editors. 1996. **Guidelines for reclamation / re-vegetation in the Yukon: Volume Two.** Yukon Department of Renewable Resources.

Kennedy, A.J. 1985. **An evaluation of the influence of grassland mixtures on tree species at the Judy Creek test mine.** in: Proceedings of the Planning and Certification of Land Reclamation Conference. Edmonton, Alberta.

Kennedy, C.E., editor. 1992**. Guidelines for reclamation / re-vegetation in the Yukon.** Yukon Department of Renewable Resources.

Kranabetter, M., H.B. Massicotte and L. Tackaberry. 1995**. Mycorrhizal limitations of reclaimed soil: a trial using paper birch and soil inoculum.** B.C. Ministry of Forests.

Mining Land Use Division. 1999. **Handbook to reclamation techniques in the Yukon.** Department of Indian Affairs and Northern Development.

Mining Land Use Division. 1999. **Guide to land use regulations: policies and procedures.** Department of Indian Affairs and Northern Development.

Murray, D. and T. Hill. 1994. **Observations on the role of legumes in Shakwak highway re-vegetation program.** Yukon Department of Renewable Resources.

Zasada, J.C. 1971. **Natural regeneration of interior Alaska forests - seed, seedbed, and vegetative reproduction considerations.** in: Symposium Proceedings - Fire in a Northern Environment. Fairbanks, Alaska.

Appendix A Candidate Native Yukon Shrub Species

23 woody species are recommended here as candidates for re-vegetation trials on reclaimed Yukon mine sites. Species descriptions and distributions have been taken from Cody (1996). The information on tolerances, capabilities and propagation methods is primarily from Freeman *et al.* (1977) and Hardy BBT Ltd (1989). It should be stressed that, because the information presented here on reclamation potential has been extrapolated from data collected from other northern regions (particularly Alaska and northern Alberta), field experimentation with these species is required at Yukon mine and mineral exploration sites. Little is known about the metal tolerances of most of these species. They should be considered as successional species following the establishment of an initial ground cover of grasses and legumes.

Low Shrubs (less than 1 m)

Arctostaphylos rubra (Red Bearberry)

Red bearberry is found in open coniferous woodland, peaty soils, gravel floodplains and rocky tundra. It occurs throughout the Yukon north to the Arctic coast.

Adaptability

Red bearberry is adapted to a range of soil moisture conditions. It grows best on sandy loam or silty clay loam. A pioneering species in open woodlands, it is recommended for re-vegetation on disturbed sites in open black spruce forests and on alpine tundra.

Tolerances

shade:	low
acidity:	high
alkalinity:	moderate
salinity:	unknown
drought :	moderate
browsing:	moderate

Propagation

Red bearberry can be established from stem cuttings collected in the fall or winter and planted the following spring. Spacing should be about 0.3 m. Seeds from red bearberry, collected when ripe in the fall, have hard seedcoats and require stratification (25^0C for 60 to 120 days, followed by 5^0C for 60 to 90 days). They should be sown in the early spring.

Reclamation Potential

Red bearberry is a pioneering species on nutrient-poor soil. It spreads by stolons to form trailing mats. It has a slow cover rate, but can be a relatively aggressive competitor. It has no nitrogen-fixing capabilities. Red bearberry's high acid tolerance and its ability to grow on cold soils may make it a suitable re-vegetation species on areas underlain by permafrost. It reaches a height of about 0.2 m at maturity.

Arctostaphylos uva-ursi (Kinnikinnick)

Kinnikinnick is commonly found on exposed rocky sites and eskers, sandy plains, and eroding riverbanks. In the Yukon it occurs north to about the limit of trees.

Adaptability

Kinnikinnick is best adapted to well drained, nutrient-poor, coarse textured soils (particularly gravely or sandy loams). It is recommended for revegetating disturbed sites on dry south-facing slopes in the southern Yukon.

Tolerances

shade:	low
acidity:	unknown
alkalinity:	medium
salinity:	low
drought:	high
browsing:	medium

Propagation

Kinnikinnick is best established from evergreen cuttings collected in the fall and planted the following spring. Inoculation with ectomycorrhizal fungi may be beneficial. Spacing should be about 0.5 m. Propagation from seed is time consuming. Seeds collected in the fall must be warm stratified (25^0C for 60 to 120 days) followed by moist chilling (5^0C for 60 to 90 days)

Reclamation Potential

Kinnikinnick's high drought tolerance renders it suitable as a re-vegetation species for dry south-facing slopes and open coniferous forests. It is aggressive on open sites and spreads by stolons to form trailing mats. It may be useful for erosion control. Although kinnikinnick has root nodules, it is believed to have no nitrogen-fixing capabilities. Its height at maturity is about 0.2 m.

Ledum groenlandicum (Labrador Tea)

Labrador tea is found throughout the Yukon on peaty soils, bogs, and open meadows in coniferous forests.

Adaptability

Labrador tea is best adapted to wet, poorly drained soils. It is recommended for revegetating disturbed sites on north-facing slopes and valley bottoms underlain by permafrost.

Tolerances

shade:	moderate
acidity:	high
alkalinity:	low
salinity:	unknown
drought:	low
browsing:	moderate

Propagation

Labrador tea can be transplanted in the fall or in the early spring. Spacing should be about 1.2 m. It can also be propagated from seeds collected when ripe and sown the following spring.

Reclamation Potential

Not much is known about the potential of Labrador tea as a reclamation species. Its high acid tolerance and its tendency to form low thickets from spreading stolons may render it useful for stabilizing cold, nutrient-poor soils. It has no nitrogen-fixing potential. It has a moderate cover rate and reaches a height of about 0.8 m at maturity.

Salix arctica (Arctic Willow)

Arctic willow occurs in a variety of habitats from sedge meadows to dry sandy sites. In the Yukon, it is most commonly found on alpine tundra.

Adaptability

Arctic willow is best adapted to well-drained, nutrient-poor, sandy loam. It is a pioneering species recommended for revegetating disturbed sites in exposed subalpine areas and on alpine tundra.

Tolerances

shade:	low
acidity:	unknown
alkalinity:	moderate
salinity:	low
drought:	moderate
browsing:	moderate

Propagation

The tip cuttings (upper 30 to 45 cm of shoots) of arctic willow can be collected in late winter, stored at near freezing temperatures and planted in spring after the soil has warmed. Spacing should be about 0.5 m. Seeds should be collected when ripe and sown immediately.

Reclamation Potential

Arctic willow colonizes harsh growing sites but cannot compete with grasses under less severe conditions. This slow growing, trailing shrub provides little protection from soil erosion. It has no nitrogen-fixing capabilities. It spreads slowly but can form dense mats. It reaches a height of 0.3 m at maturity.

Intermediate Shrubs (1 to 5 m)

Alnus crispa (Green Alder)

Green alder (also known as mountain alder) is found throughout the Yukon north to the Arctic coast. It forms thickets on stream banks, mountain slopes, and tundra.

Adaptability

Green alder is adapted to a range of soil textures and soil moisture conditions. It is a good colonizing species in areas of spruce and mixed-wood forests. It is not recommended for areas of low precipitation or on slopes with steep south-facing aspect.

Tolerances

shade:	low
acidity:	moderate
alkalinity:	moderate
salinity:	low
drought:	low
browsing:	high

Propagation

Green alder is best propagated from seeds. Seed can be collected in the late fall or winter and sown in the early spring (requiring no stratification). Occasional lots of dormant seed require stratification at 1 to 5^0 C for 60 days or can be sown in the fall. Seedlings can be transplanted in the fall at a maximum spacing of 1.5 m.

Reclamation Potential

The atmospheric nitrogen-fixing potential of green alder renders it a useful pioneering species on nutrient deficient sites, particularly in subalpine areas. It has a shallow root system and has been shown to be effective in soil stabilization. It is also noted for its ability to colonize mine tailings. It is sensitive to soil copper concentrations. Green alder is aggressive and has a rapid spreading rate. Its spreads by seed or vegetatively from stump sprouts. Its height at maturity is about 3 m.

Betula glandulosa (Dwarf Birch)

Dwarf birch is found throughout the Yukon on low-arctic tundra, subalpine and alpine slopes, and muskeg.

Adaptability

Dwarf birch is most adaptable to poorly drained soils underlain by permafrost. It may be useful as a re-vegetation species on cold valley bottoms and in areas with open black spruce or subalpine fir forests.

Tolerances

shade:	low
acidity:	high
alkalinity:	unknown
salinity:	unknown
drought:	low
browsing:	high

Propagation

Dwarf birch is best propagated from seedlings transplanted in late fall. It can be also be propagated from seed collected in late summer while the strobiles are still green. Dried seed should be stratified for 2 months and sown in late fall or early spring. Spacing should be about 1.5 m. The survival rate of seeded or planted dwarf birch is often low.

Reclamation Potential

Little is known about the reclamation potential of dwarf birch. As a common upland species, it could be useful on cold acidic soils. It has no nitrogen-fixing capabilities. Dwarf birch spreads slowly by seed dispersal. It reaches heights of up to 2 m at maturity.

Potentilla fruticosa (Shrubby Cinquefoil)

Shrubby cinquefoil is common throughout the Yukon. It is found in open and partly wooded muskeg, in alpine tundra and north beyond the treeline.

Adaptability

Shrubby cinquefoil is adaptable to a wide range of soil conditions from well to poorly drained. It is recommended for re-vegetation on valley bottoms and subalpine slopes with white spruce / dwarf birch-willow communities.

Tolerances

shade:	low
acidity:	moderate
alkalinity:	moderate
salinity:	moderate
drought:	moderate
browsing:	moderate

Propagation

Shrubby cinquefoil is best established on disturbed lands by the field sowing of seed. Seed should be collected and sown as soon as it is ripened (seed ripening time is variable - usually late summer). Moist soil is needed for direct seeding. Wild plants transplant easily in the fall. Spacing should be about 1.2 m.

Reclamation Potential

Shrubby cinquefoil is moderately aggressive on disturbed areas, but fails when subjected to heavy competition from grasses. It has no nitrogen fixation capabilities. Shrubby cinquefoil has a fibrous root system and is moderately effective at soil stabilization and erosion control on slopes up to 30%. It will readily invade disturbed areas. It will grow on mine tailings if fertilized. Shrubby cinquefoil naturally reproduces from seed and rhizomes. Spreading rate is moderate. Height at maturity is 1.5m.

Rosa acicularis (Prickly Rose)

Prickly rose is common throughout the Yukon north to about 69^0 N. It is frequent on riverbanks and in woodland clearings and burns. It is recommended for re-vegetation on areas with mixed-wood forests of white spruce and trembling aspen.

Adaptability

Prickly rose is adapted to a range of soil textures and soil moisture conditions from well to poorly drained.

Tolerances

shade:	moderate
acidity:	high
alkalinity:	unknown
salinity:	low
drought:	moderate
browsing:	high

Propagation

Prickly rose can be propagated from seed collected in the late summer. It can either be sown in the late fall after warm stratification (60-90 days at about 25^0C) or in the spring after cold stratification (90-120 days at about 5^0C). Prickly rose can also be propagated from stem and root cuttings collected in late winter or early spring and planted after the soil has warmed. Bare stem cuttings which include top of the root are most effective. Spacing should be about 1.5 m.

Reclamation Potential

Prickly rose, with its tolerance to acidic soils, can be an asset to mine reclamation. It is quite effective in competing with grasses. It spreads rapidly by rhizomes and seed dispersal and grows to a height of about 1.2 m. It has been shown to survive well on mine tailings. Prickly rose has no nitrogen-fixing capabilities.

Rubus idaeus (Red Raspberry)

Red raspberry is found in woodland clearings in the Yukon as far north as the Porcupine River valley.

Adaptability

Red raspberry is best suited to sites with moderately well drained soils and with available moisture. It is recommended for re-vegetation on well drained, level to south-facing slopes in areas with mixed white spruce - trembling aspen forests.

Tolerances

shade:	low
acidity:	moderate
alkalinity:	unknown
salinity:	moderate
drought:	moderate
browsing:	moderate

Propagation

Red raspberry can be propagated from seeds extracted from fruit in mid-summer. Seed must be cold stratified for at least 3 months and is best sown in early spring. Seedlings can be transplanted in the fall. Stem and root cuttings, collected in late winter or early spring, can be planted after the soil has warmed. Spacing should be about 1.2 m.

Reclamation Potential

The drought tolerance of red raspberry and its ability to grow on infertile, bare mineral soil render it useful for erosion control. It has no nitrogen-fixing capabilities. Red raspberry spreads quickly by rhizomes, stolons and seed dispersal, but cannot compete with grasses. Its height at maturity is about 1.2 m.

Salix alexensis (Feltleaf Willow)

Feltleaf willow is a thicket forming species that is found on gravel bars, river terraces, glacial moraines and well drained alpine meadows. It occurs throughout the Yukon north to the arctic coast.

Adaptability

Feltleaf willow is best adapted to moist, but well drained, coarse soils. It is a pioneering species recommended for revegetating disturbed sites in well drained areas at all elevations.

Tolerances

shade:	low
acidity:	moderate
alkalinity:	unknown
salinity:	unknown
drought:	moderate
browsing:	high

Propagation

Feltleaf willow is best propagated from stem cuttings collected in late winter and planted in the spring after the soil has warmed. Spacing should be about 1.5 m. It can also be transplanted during the fall or early spring. Seeds collected when ripe in late spring should be sown immediately.

Reclamation Potential

Feltleaf willow spreads primarily by seed dispersal and has a rapid cover rate. It is a good colonizer of disturbed coarse textured soils. It has no nitrogen-fixing potential. It grows quickly to a height of about 4 m at maturity.

Salix glauca (Blue-green Willow)

Blue-green willow is commonly found throughout the Yukon north to the Arctic coast. It occurs on river floodplains, in white spruce woodlands, subalpine slopes and alpine tundra.

Adaptability

Blue-green willow is adaptable to a wide range of soil moisture and soil texture conditions, from well drained to waterlogged soils. It is a colonizing species and is recommended for re-vegetation on upland slopes and alpine areas throughout the Yukon.

Tolerances

shade:	low
acidity:	moderate
alkalinity:	unknown
salinity:	low
drought:	low
browsing:	high

Propagation

Blue-green willow is best propagated from stem cuttings collected in late winter and planted in late spring, or by transplanting seedlings in late fall or early spring. Unlike most willows, the seeds of blue-green willow require stratification. They can be collected in late summer and sown the following spring. Recommended spacing is 1 m.

Reclamation Potential

Blue-green willow is fairly aggressive with a moderate cover rate. It’s soil stabilizing abilities make it suitable for erosion control. It has no nitrogen fixing-capabilities. It has been known to colonize mine tailings and is moderately tolerant of zinc and copper. Height at maturity is about 1.2 m.

Salix planifolia (Diamondleaf Willow)

Diamondleaf willow forms thickets on sedge fens and black spruce bogs, in openings in white spruce forests and along the banks of lakes and streams. It occurs throughout the Yukon north to the Arctic coast.

Adaptability

Diamondleaf willow is best adapted to wet, poorly drained soils and areas underlain with permafrost. It is recommended as a re-vegetation species for acidic soils on north slopes, cold valley bottoms and boreal forest peat bogs.

Tolerances

shade:	low
acidity:	high
alkalinity:	low
salinity:	unknown
drought:	low
browsing:	high

Propagation

The propagation of diamondleaf willow is best done by stem cuttings collected in the winter and planted in late spring. It can also be transplanted in the fall or early spring. Spacing should be about 1.8 m. Seeds of diamondleaf willow can be collected when ripe and sown immediately.

Reclamation Potential

The adaptability of diamondleaf willow to cold, acidic soil makes it a suitable species for colonizing these harsh environments where other shrub species would fail. It spreads mostly through seed dispersal and has a moderate cover rate. It has no nitrogen-fixing capabilities. It grows to a height of about 2 m at maturity.

Shepherdia canadensis (Soapberry)

Soapberry is found throughout the Yukon north to the British Mountains. It occurs on riverbanks, in spruce woods clearings, and on alpine and subalpine slopes.

Adaptability

Soapberry is capable of growing on well to moderately drained, coarse textured soils (silty loam to sandy loam). It is recommended for re-vegetation in drier areas, particularly in forests of lodgepole pine or mixed forests of white spruce and trembling aspen.

Tolerances

shade:	moderate
acidity:	moderate
alkalinity:	moderate
salinity:	moderate
drought:	moderate
browsing:	moderate

Propagation

Soapberry is most easily propagated from seed. Seeds can be collected from late June to August. Field sowing should be done in the fall. Greenhouse sowing requires a cold stratification of 60 days. Propagation can also be done from root cuttings or suckers (maximum spacing 2 m), although the success rate is low to moderate.

Reclamation Potential

Soapberry is suitable for growing on dry, rocky sites where few other shrubs can survive. An atmospheric nitrogen-fixer, it is capable of growing on soils with low nutrient levels. Soapberry often forms dense thickets and can be useful for erosion control on dry, steep cutbanks. It reaches a height of about 1 m and is moderately aggressive due to its suckering ability.

Spiraea beauverdiana (Beauverd's Spiraea)

Beauverd's spiraea is common in the Yukon between 62^0 N and the Arctic coast. It occurs on the borders of muskegs, as well as on alpine and subalpine meadows and slopes.

Adaptability

Beauverd's spiraea is most adaptable to disturbed areas with moist loamy soils that are moderately to well drained. It is recommended for re-vegetation on upland slopes in the north-central Yukon.

Tolerances

shade:	low
acidity:	high
alkalinity:	unknown
salinity:	moderate
drought:	moderate
browsing:	moderate

Propagation

Beauverd's spiraea is best propagated by field seeding. Seed's have no dormancy so require no stratification. They can be collected in the late fall and sown immediately. Propagation can also be done from root cuttings collected in the early spring and planted after the soil has warmed. Spacing should be about 1.2 m.

Reclamation Potential

The extensive rhizome system of Beauverd's spiraea and its ability to colonize disturbed sites suggest it is a good candidate for soil building and erosion control, although it has no nitrogen-fixing capabilities. Its high acid tolerance could be an asset in mine site reclamation. Beauverd's spiraea spreads by rhizomes and seed dispersal, and reaches heights of up to 1 m at maturity.

Viburnum edule (Highbush Cranberry)

Highbush cranberry is found in woodland thickets in the Yukon north to the Porcupine River system.

Adaptability

Highbush cranberry is best adapted to moderate to well drained, fine sandy loam. It may be suitable for re-vegetation on valley bottoms and low-level woodland slopes dominated by white spruce.

Tolerances

shade:	moderate
acidity:	moderate
alkalinity:	unknown
salinity:	unknown
drought:	moderate
browsing:	moderate

Propagation

Highbush cranberry may be propagated from seed collected from fruit in the fall, and sown in late fall or early spring. Seedlings collected from nearby the reclaimed site can be transplanted in the fall. Stem cuttings can be collected in late winter and planted in the spring. Spacing should be about 1.2 m.

Reclamation Potential

Not much is known about the reclamation abilities of highbush cranberry. Its potential is probably limited on bare mineral soil. It spreads quickly by seed dispersal and reaches heights of up to 2 m at maturity.

Tall Shrubs (more than 5 m)

Alnus incana (Hoary Alder)

Hoary alder (also known as grey alder or river alder) is common on riverbanks and lakeshores. It occurs in the Yukon north to the Porcupine River.

Adaptability

Hoary alder is best adapted to alluvial and other moist soils. It can withstand flooding. It is recommended as a re-vegetation species on disturbed sites in wet but well drained depressions and on river bottom lands at lower elevations in the south-central Yukon.

Tolerances

shade:	low
acidity:	high
alkalinity:	low
salinity:	low
drought:	moderate
browsing:	moderate

Propagation

Hoary alder is best established from seeds collected in the late fall or winter, and sown in the spring (no stratification is normally required). It can also be transplanted in the late fall or early spring. Stem cuttings of hoary alder may be collected in the fall and planted immediately or in the following spring. Spacing should be about 1.5 m.

Reclamation Potential

Hoary alder's acid tolerance and its ability to fix atmospheric nitrogen makes it a useful mine reclamation species at lower elevations. Its ability to colonize streambanks makes it particularly effective for riparian restoration work. It has a rapid cover rate and grows quickly to a height of 6 m at maturity. It spreads primarily through seed dispersal.

Betula neoalaskana (Alaska Birch)

Alaska birch is found in peat bogs and north-facing slopes. In the Yukon, it occurs north to 68^0 N. Its close relative, paper birch (*Betula papyrifera*), less common in the Yukon, is found in open woodlands at lower altitudes north to the Klondike River area.

Adaptability

Alaska birch is adapted to moderately well drained, acidic, peaty soils. It may be useful as a reclamation species for disturbed sites on north-facing slopes underlain by permafrost, at lower to mid elevations throughout the Yukon.

Tolerances

shade:	low
acidity:	high
alkalinity:	unknown
salinity:	low
drought:	moderate
browsing:	moderate

Propagation

Alaska birch can be established from seed collected in late summer while the strobiles are still green and firm. Dried seed should be stratified at about 5^0 C for 2 months. It can be sown in the late fall or early spring. Although plenty of light is required for germination, seedlings require shade for 2 to 3 months in the first summer. Transplanting of seedlings or older shrubs is possible in the fall or early spring. Spacing should be about 2.5 m.

Reclamation Potential

The acid tolerance of Alaska birch may make it useful for revegetating acidic, nutrient-poor soils. It has no nitrogen-fixing capabilities. It has a slow cover rate through seed dispersal and by suckering, but grows rapidly to a height of about 15 m at maturity.

Pinus contorta (Lodgepole Pine)

Lodgepole pine is found on south-facing slopes and warm, well drained areas north to about 64^0 N in the central Yukon. A colonizing species, it is often found in dense, pure stands after fire.

Adaptability

Lodgepole pine is best adapted to well drained, sandy loam. It is recommended for reclamation on disturbed sites in well drained areas of low to mid elevations in the southern Yukon.

Tolerances

shade:	low
acidity:	high
alkalinity:	moderate
salinity:	low
drought:	high
browsing:	moderate

Propagation

Lodgepole pine can be established from seed. Seed cones should be dried immediately after collection. Seed can be sown directly in the fall, or in the spring after stratification at 5^0C for 30 to 50 days. Seedlings can be transplanted in the fall or early spring. Spacing should be about 3 m.

Reclamation Potential

The drought tolerance of lodgepole pine makes it a useful colonizing species on warm, well drained soils. It is a good soil stabilizer, although it is susceptible to wind throw. It can compete with light cover of grasses. Lodegepole pine has a slow cover rate and grows to a height of about 12 m at maturity. It has no nitrogen-fixing capabilities.

Populus balsamifera (Balsam Poplar)

Balsam poplar is a common floodplain tree species found in the Yukon as far north as the British Mountains.

Adaptability

Balsam poplar is best adapted to moist, well drained, low-lying ground. It is prolific colonizer of floodplain alluvium. It is recommended for revegetating disturbed sites in riparian zones and in floodplain white spruce forests.

Tolerances

shade:	low
acidity:	low
alkalinity:	moderate
salinity:	moderate
drought:	low
browsing:	high

Propagation

Balsam poplar can best be established from stem cuttings collected in late winter and planted when the soil has warmed in the spring. Alternatively, they can be collected in early spring and planted immediately. Spacing should be about 1.5 m. Catkins from balsam poplar can collected in late spring and allowed to dry. Seed from the catkins can then be sown on top of the soil. When watering, care must be taken not to wash the seedlings from the soil.

Reclamation Potential

Balsam poplar is an aggressive pioneering species and can compete well with grasses. It has a moderately high requirement for nutrients. It has a shallow root system and moderate cover rate. Balsam poplar grows rapidly, and in the Yukon reaches a height of about 12 m, although occasionally much higher. It has no nitrogen-fixing capabilities.

Populus tremuloides (Trembling Aspen)

Trembling aspen is a common species on dry, burnt-over slopes and south-facing ridges. It occurs in the Yukon north to the Porcupine River.

Adaptability

Trembling aspen is best adapted to well drained, sandy or gravely loams. It is recommended as a species for revegetating disturbed sites on south-facing slopes and upland ridges in the south-central Yukon.

Tolerances

shade:	low
acidity:	low
alkalinity:	moderate
salinity:	low
drought:	moderate
browsing:	moderate

Propagation

Trembling aspen are best propagated from seed. Catkins should be collected before dehiscence and dried. Catkins can be sown on the soil surface when dried (no stratification is required). Trembling aspen is not easily established from stem cuttings. Root or sucker cuttings, collected in the early spring, can be planted in moist soil. Spacing should be about 1.5 m.

Reclamation Potential

Trembling aspen is typically an early colonizer of disturbed sites. It spreads vigorously on disrupted soil by suckering. Its wide-spreading shallow root system makes it useful for soil stabilization on dry, nutrient-poor sites. It has no nitrogen-fixing capabilities. Trembling aspen does not compete well with sod-forming grasses. It is fast growing and reaches a height of about 12 m at maturity.

Salix arbusculoides (Littletree Willow)

Littletree willow is a common shrub or small tree found on stream banks, bogs and openings in white spruce-birch forests. It is a below-treeline species, occurring in the Yukon north to the edge of the arctic tundra.

Adaptability

Littletree willow is best adapted to wet, poorly drained sites. It is recommended for the re-vegetation of disturbed sites at lower elevations (below treeline) in the south-central Yukon.

Tolerances

shade:	low
acidity:	moderate
alkalinity:	unknown
salinity:	unknown
drought:	low
browsing:	high

Propagation

Littletree willow can be propagated from stem cuttings collected in winter and planted the following spring. It can also be transplanted in the fall or early spring. Spacing should be about 3 m. Seeds collected when ripe in late spring can be planted immediately.

Reclamation Potential

Not much is known about the reclamation potential of littletree willow. It spreads by seed dispersal and has a moderate cover rate. It has no nitrogen-fixing capabilities. Height at maturity is 5 m or more.

Salix bebbiana (Bebb's Willow)

Bebb's willow is a common understorey species in open white spruce woodlands on well-drained riverbanks and upland slopes. It occurs in the Yukon north to the Porcupine River.

Adaptability

Bebb's willow is best adapted to moist, well-drained sandy or gravely soils. It can withstand flooding. It is recommended for the re-vegetation of disturbed areas in white spruce or mixed spruce-aspen forests in the south-central Yukon.

Tolerances

shade:	low
acidity:	moderate
alkalinity:	moderate
salinity:	moderate
drought:	low
browsing:	high

Propagation

Bebb's willow is best propagated from stem cuttings collected in the fall or winter and planted the following spring; alternatively, cuttings can be collected in the early spring and planted immediately. Spacing should be about 1.5 m. The seed of Bebb's willow, which disperses in late spring, can be collected when ripe and sown immediately.

Reclamation Potential

Bebb's willow is moderately aggressive on suitable soils and has a moderate cover rate. It has a shallow, dense root system and is a relatively good soil stabilizer. It spreads primarily through seed dispersal. Like other willows, Bebb's willow has no nitrogen-fixing capabilities. It cannot withstand much competition from other ground cover. Height at maturity is about 6 m.

Salix scouleriana (Scouler's Willow)

Scouler's willow is found on not too densely wooded upland slopes in the Yukon north to about 64^0 30' N.

Adaptability

Scouler's willow is best adapted to moist, but well drained soils with a wide range of textures. It is recommended for the re-vegetation of disturbed sites on moderate to steep slopes in the subalpine zones of the south-central Yukon.

Tolerances

shade:	low
acidity:	high
alkalinity:	unknown
salinity:	moderate
drought:	low
browsing:	high

Propagation

Scouler's willow can readily be propagated from stem or root cuttings collected in late fall or winter and planted in the spring. It can also be transplanted in the fall or early spring. Spacing should be about 1.5 m. A very early flowering species, the seeds of Scouler's willow can be collected in June or early July and sown immediately. As with other willows, the seedbed must be moist for good seedling establishment.

Reclamation Potential

The aggressive nature of Scouler's willow and its moderate cover rate makes it a good candidate species for re-vegetation . It will shade out other species and act as a "nurse" species for shade tolerant conifers. It has no nitrogen-fixing potential. Its high acid tolerance may render it particularly useful for re-vegetation on some Yukon mine sites. It spreads primarily through seed dispersal and reaches a height of about 6 m at maturity.

Appendix B   Case History

Brewery Creek Mine Reclamation Program

Brewery Creek Mine Reclamation Program

1.0 Ecological Setting

The Brewery Creek Mine is located near the northern limit of the Yukon Plateau (North) Ecoregion as determined by the Ecological Stratification Working Group (1995).
In this ecoregion, northern boreal forests exist at elevations up to 1500 m asl. White spruce forms extensive open upland and riparian forests, whereas black spruce is commonly found on colder and poorly drained sites (discontinuous permafrost is extensive). Alpine fir occurs in higher subalpine areas. As naturally recurring fires are common, seral vegetation communities are prevalent.

Vegetation at the regional level has been described by Kennedy and Staniforth (1991) in the Klondike Valley Plan. The 1:40,000 scale map accompanying this unpublished report depicts 44 distinct vegetation communities in the region.

The Brewery Creek Mine property may be described as rolling hills with moderately incised drainage. Relief on the property is about 700 m, with the lowest and highest elevations approximately 600 m and 1,300 m, respectively.

The principal streams in the mine area are Lee Creek including its tributary Pacific Creek, Laura Creek including its tributary Carolyn Creek, and Golden Creeks including its tributary Lucky Creek. Lee, Laura and Golden Creeks are tributaries to the Klondike River.

2.0 Mining History

Exploration on the Brewery Creek property commenced in August of 1987 and was staked by Noranda Exploration Company Limited (NOREX) in October of 1987. In June 1990, Loki Gold Corporation entered into a joint venture agreement with Noranda and by August 1991 had a 49 percent equity interest in the property. In May 1991, Noranda transferred its interest in the property to Hemlo Gold Mines Inc. Exploration programs continued throughout 1990, 1991 and 1993. In June 1993, Loki Gold acquired Hemlo Gold's 51 percent share in the property, to hold 100 percent equity interest.

Exploration and mine infrastructure development by Loki Gold (Viceroy Minerals Corporation) continued through 1994 and 1995 when mining commenced. Gold production, utilizing heap leaching technology, began in November 1996.

The property, approximately 77 road km from Dawson City, comprises 788 contiguous mineral claims covering 16,135 ha in a roughly rectangular block 15 km east-west by 9 km north-south.

3.0 Nature and Extent of Land Disturbance

The land disturbances at the Brewery Creek Mine include those resulting from mineral exploration, such as access roads, drill pads and trenches, as well as those resulting from mining, such as open pits, waste rock storage areas and haul roads.

Mining to date has focused on the Canadian, Foster's, Kokanee, Golden and Blue Zones. The Lucky, Pacific, Moosehead, Bohemian and Big Rock Zones have yet to be developed. Of the ore zones that have been mined, the Canadian, Foster's, Kokanee and Golden Zones are intrusive hosted. They are dominantly oxidized quartz monzonite intercalated with argillaceous units. The Pacific Zone is sediment hosted with secondary amounts of quartz monzonite.

Waste rock has been backfilled into mined out pits and has been used to construct haul roads, ramps, leach pads, etc. Waste rock is segregated and stored according to four operational categories:

- "clean neutral", intrusive, non-leachable
- "dirty neutral", sediments, non-leachable

- "clean acid", intrusive, potentially leachable

- “dirty acid”, sediments, potentially leachable

Because of its low potential for leaching, “clean neutral” waste rock is the material used for external rock dump foundations and road construction near waterways. Waste rock storage areas and backfilled pits are being recontoured in zones where mining has been completed.

4.0 Reclamation Initiatives

Reclamation at the Brewery Creek Mine is an ongoing process that began with the commencement of mine development in 1994. Waste rock dumps and backfilled pits are recontoured and reseeded in each zone as soon as mining is completed. The final reclamation focus will result from the mine’s decommissioning plan, expected to be completed in 1999.

4.1 Objectives

The overall goal of the Brewery Creek Mine’s reclamation plan is to return the area as close to its former natural state as is feasible.

Specific objectives of the re-vegetation program include:

- to minimize erosion and increase the organic content of disturbances through the initial establishment of a vegetative cover
- to encourage natural vegetative succession on disturbed areas

4.2 Reclamation Research

Three re-vegetation trial plots were established on the Canadian Zone waste rock storage area in July 1996 for the purpose of determining the optimal rates of seeding and fertilizing on the mine’s waste rock dump areas. The three trial plots represented areas of exposed argillite waste rock on a moderate slope, partially silt-capped argillite waste rock on a low slope, and fully silt-capped argillite waste rock on a flat surface.

Each plot consisted of nine cells delineating a matrix of three seeding rates and three fertilizer rates including:

seeding rate (Klondike Valley Mix)	fertilizer rate (18-18-18)
50 kg/ha	200 kg/ha
75 kg/ha	350 kg/ha
100 kg/ha	500 kg/ha

Soil samples were collected from each of the three trial plots and from the Canadian Zone silt stockpile and analyzed for moisture content, grain size, organic content, nutrients and total metals.

By the late summer of 1996, the vegetative cover amounted to less than 1% at all three plots. This was probably a result of the late seeding of the plots.

Engmo Timothy was the dominant species on all of the cells at each of the trial plots by the late summer of 1997, with Kentucky Bluegrass, Common Bromegrass and Red Top Bentgrass in lesser abundance. Volunteer species, including Lupine and Lamb’s Quarters, were noted in a few cells. The success rate of the seeding trials appears to be most affected by the rate of fertilizer application. As expected, sites with organic capping material had a better cover than those with waste rock only.

The fertilizer application rate was also the most important factor affecting the degree of vegetative cover at each of the trial plots by the late summer of 1998. By this time (end of third growing season), however, the exposed argillite material had a vegetative cover comparable to the growth media-capped site. Timothy and Brome were consistently the dominant species, with Kentucky Bluegrass and Red Fescue in lesser abundance.

The trial reclamation plots will continue to be monitored in 1999.

In the spring of 1998, experimentation with the establishment of willows began at the Brewery Creek Mine. Willow cuttings (*Salix* spp.) were collected from the Dawson City area and planted in trial plots in the reclaimed Canadian Zone waste rock storage area by the grade 8 class from the Robert Service School.

101 willow cuttings were planted by the students in three trial plots, each measuring 2x10 ft, and representing a variety of soil conditions. After the plots were saturated with water, the cuttings were planted in 6 inch deep trenches, which were backfilled with bone meal to promote root development. Straw mulch was then placed on top to facilitate moisture retention. The willow cuttings were watered for two weeks following planting.

The rooting success rate of these willow cuttings will be monitored in the spring of 1999.

4.3 Seeding Program 1996 - 1999

Re-vegetation at the Brewery Creek Mine began in 1996. In June of that year, 4.6 ha of the Canadian Zone waste rock dump area and 1 ha of the Canadian Zone haul road right-of-way were prepared, seeded and fertilized. An agronomic (Klondike Valley) seed mix was applied at rate of 75 kg/ha. This mix consisted of:

25% Creeping Red Fescue
25% Common Bromegrass
15% Common Kentucky Bluegrass
10% Meadow Foxtail
10% Engmo Timothy
10% Alsike Clover
5% Red Top Bentgrass

An approximately 40% vegetative cover was observed on the right-of-way by mid-summer, while growth on the Canadian Zone waste rock dump was more sporadic. In

September, fireweed seed was collected from around the mine site and dispersed on the reclaimed Canadian Zone waste rock dump slope.

In September and October, another 3.5 ha adjacent to the Canadian Zone waste rock dump and about 3 ha below the leach pad were prepared, fertilized and seeded with the Klondike Valley seed mix.

In the spring of 1997, 11.5 ha of land were seeded with the same agronomic mix (Klondike Valley) used in 1996. The areas seeded included several small clearings around the waste rock dumps at the Canadian and Foster's Zones, along the Laura Creek right of-way, along the haul road and below the processing ponds.

A high vegetative cover on these areas was noted in mid-summer. An increase in the rate of fertilizer application (from 200 kg/ha in 1996 to 300 kg/ha in 1997) and abundant rainfall in June and July probably contributed to this higher success rate.

In the fall of 1997, an additional 8.5 ha of the Canadian Zone pit and waste rock dump were recontoured and seeded. In a move toward increasing the native species component of the seed mix, the Brewery Creek seed mix was developed and used on these areas. This mix included:

16% Dahurian Wild Rye
16% Sheep Fescue
12% Creeping Red Fescue
5% Rangelander Alfalfa
10% Climax Timothy
17% Fowl Bluegrass
16% Nugget Kentucky Bluegrass
8% Alsike Noducoat

Approximately 6 ha of disturbed areas around the mine site, leach pads and access roads were seeded in May 1998 with the Brewery Creek seed mix at a rate of 75 kg/ha. A high vegetative cover was noted by mid-summer.

In further efforts to increase the native species component of the seed mix, in the fall of 1998, modifications were made to the Brewery Creek seed mix. The new mix, to be used in the 1999 season, includes:

13% Slender Wheatgrass
35% Violet Wheatgrass
13% Sheep Fescue
10% Northern Fescue
16% Fowl Bluegrass
13% Alpine Bluegrass

4.4 Shrub Planting

The long-term re-vegetation plans at the Brewery Creek Mine include the re-establishment of shrub and tree species that naturally occur in the area. As part of the environmental surveys of the undeveloped Bohemian and Big Rock Zones, an inventory of species voluntarily revegetating disturbed sites (access roads, drill pads and trenches) was carried out in early September 1998. Also included in this survey was a compilation of shrub species occurring in undisturbed parts of the mine site that could be planted during future re-vegetation efforts.

Six distinct vegetation types were delineated during the survey. In each vegetation type, the following woody species were noted as potential candidates for reclamation planting:

Black Spruce Community

Alnus crispa

Betula glandulosa

Betula neoalaskana

Betula papyrifera

Ledum decumbens

Rosa acicularis

Rubus arcticus

Rubus chamaemorous

Rubus idaea

Salix spp.

Spiraea beauverdiana

Vaccinium uliginosum

Vaccinium vitus-idaea

Viburnum edule

Black Spruce - Paper Birch Community

Alnus crispa

Alnus incana

Betula papyrifera

Empetrum nigrum

Populus tremuloides

Ribes glandulosum

Rosa acicularis

Rubus idaea

Salix spp.

Vaccinium vitus-idaea

Vaccinium uliginosum

Black Spruce - Trembling Aspen Community

Betula glandulosa

Betula papyrifera

Empetrum nigrum

Ledum decumbens

Populus tremuloides

Rosa acicularis

Rubus idaea

Vaccinium vitus-idaea

White Spruce - Trembling Aspen Community

Arctostaphylos uva-ursi

Juniper communis

Linnaea boreale

Populus tremuloides

Rosa acicularis

Shepherdia canadensis

Vaccinium vitus-idaea

Shrub Birch Community

Betula glandulosa

Empetrum nigrum

Ledum decumbens

Vaccinium vitus-idaea

Willow Community

Alnus crispa

Alnus incana

Betula glandulosa

Ledum decumbens

Ledum groenlandicum

Populus balsamifera
Ribes sp.
Salix spp.
Spiraea beauverdiana
Vaccinium uliginosum

Experimentation with some of these shrub species for reclamation work at the Brewery Creek mine site is planned during the 1999 and 2000 field seasons. It is also planned to establish permanently monumented monitoring plots in undisturbed areas of the mine site in order to determine the abundance and relative frequency of naturally occurring species. These will provide a useful reference for determining the optimum density of species selected for re-vegetation , and serve as a standard for measuring the success of the re-vegetation trials.

References

Ecological Stratification Working Group. 1995. **A National Ecological Framework for Canada**. Agriculture and Agri-food Canada, Ecozone Analysis Branch, Ottawa, Canada.

Kennedy C. and J. Staniforth. 1991. **Klondike Valley Plan** maps and notes. Department of Renewable Resources, Government of Yukon. Unpublished.

Loki Gold Corporation. 1994. **Brewery Creek Project Initial Environmental Evaluation.**

Loki Gold Corporation. 1996. **Brewery Creek Mine 1995 Annual Water License Report**.

Steffen Robertson and Kirsten (Canada) Inc. 1994. **Brewery Creek Project Initial Environmental Evaluation.** Vancouver, B.C., Canada.

Viceroy Minerals Corporation. 1997. **Brewery Creek Mine 1996 Annual Water License Report.**

Viceroy Minerals Corporation. 1998. **Brewery Creek Mine 1997 Annual Water License Report.**

Viceroy Minerals Corporation. 1999. **Brewery Creek Mine 1998 Annual Water License Report.**